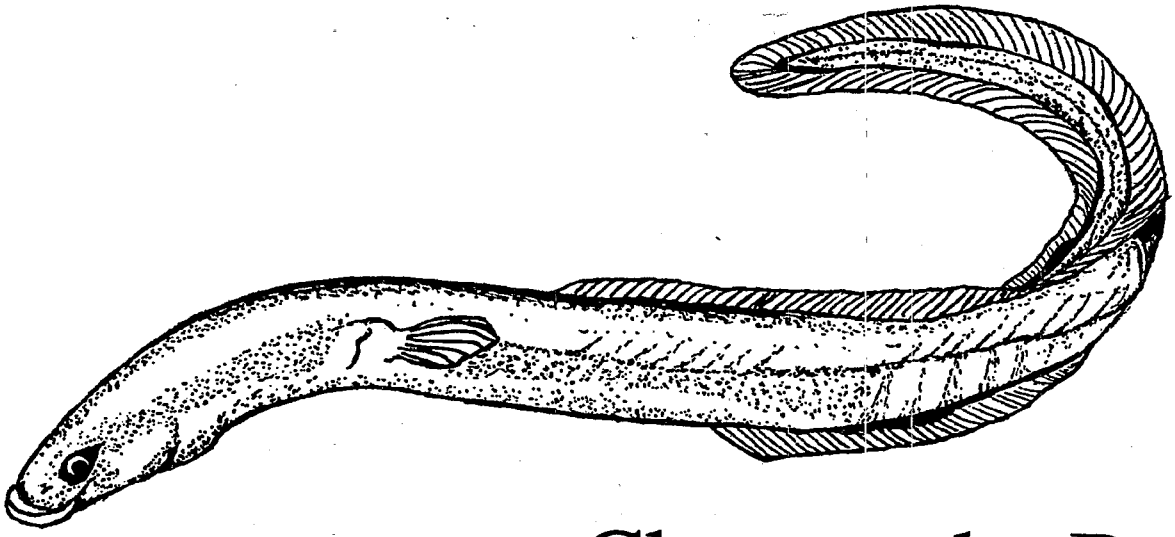
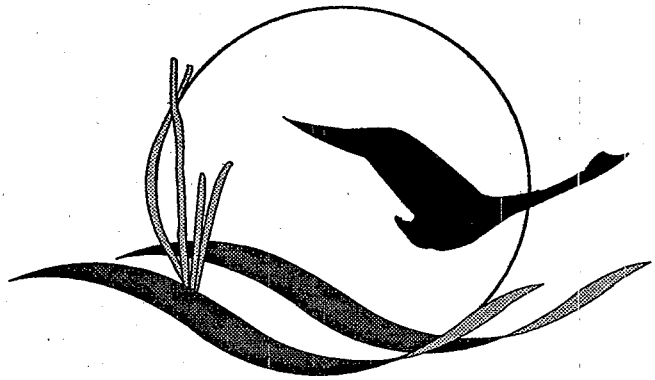


Chesapeake Bay American Eel Fishery Management Plan

Agreement Commitment Report 1991



Chesapeake Bay Program

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Chesapeake Bay American Eel Fishery Management Plan

Chesapeake Bay Program

Agreement Commitment Report 1991

Produced under contract to the U.S. Environmental Protection Agency
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ADOPTION STATEMENT

We, the undersigned, adopt the Chesapeake Bay American Eel Fishery Management Plan in partial fulfillment of Living Resources Commitment Number 4 of the 1987 Chesapeake Bay Agreement:

> *". . . by July to develop, adopt, and begin to implement a Baywide management plan of oysters, blue crabs, and American Shad. Plans for the other major commercially, recreationally and ecologically valuable species should be initiated by 1990."*

The American Eel was designated a valuable species in the Schedule for Developing Baywide Resource Management Strategies. In 1991, the American Eel plan was completed.

We agree to accept the plan as a guide to managing the American Eel stock in the Chesapeake Bay and its tributaries for optimum ecological, social and economic benefits. We further agree to work together to implement, by the dates set forth in the plan, management actions recommended to monitor the status of the stocks, obtain catch and effort information from the bait fishery, address research and monitoring needs, and develop the habitat and water quality criteria necessary for healthy American Eel populations.

We recognize the need to commit long-term, stable, financial support and human resources to the task of managing the American Eel stock. In addition, we direct the Living Resources Subcommittee to periodically review and update the plan and report on progress made in achieving the plan's management recommendations.

Date December 18, 1992

For the Commonwealth of Virginia Lawrence Douglas Wilder

For the State of Maryland William Donald Schaefer

For the Commonwealth of Pennsylvania Robert P. Casey

For the United States of America William K. Reilly

For the District of Columbia Sharon Pratt Kelly

For the Chesapeake Bay Commission Bruce Jenkins

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Members of the Fisheries Management Workgroup were:

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Mr. K.A. Carpenter, Potomac River Fisheries Commission
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Mr. William Goldsborough, Chesapeake Bay Foundation
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Mr. Jack Travelstead, Virginia Marine Resources Commission
Ms. Mary Roe Walkup, Citizen's Advisory Committee

EXECUTIVE SUMMARY

Introduction

One of the strategies for implementing the Living Resources Commitments of the 1987 Chesapeake Bay Agreement is to develop and adopt a series of baywide fishery management plans (FMPs) for commercially, recreationally, and selected ecologically valuable species. The FMPs are to be implemented by the Commonwealth of Pennsylvania, Commonwealth of Virginia, District of Columbia, Potomac River Fisheries Commission, and State of Maryland as appropriate. Under a timetable adopted for completing management plans for several important species, the American eel FMP was scheduled for completion in December 1991.

A comprehensive approach to managing Chesapeake Bay fisheries is needed because biological, physical, economic, and social aspects of the fisheries are shared among the Bay's jurisdictions. The Chesapeake Bay Program's Living Resources Subcommittee formed a Fisheries Management Workgroup to address the commitment in the Bay Agreement for comprehensive, baywide fishery management plans. The workgroup is composed of members from government agencies, the academic community, the fishing industry, and public interest groups representing the District of Columbia, Maryland, Pennsylvania, Virginia, and the federal government.

Development of Fishery Management Plans

An FMP prepared under the 1987 Chesapeake Bay Agreement serves as a framework for conserving and wisely using a fishery resource of the Bay. Each management plan contains a summary of the fishery under consideration, a discussion of problems and issues that have arisen, and recommended management actions. An implementation plan is included at the end of the FMP to provide additional details on the actions that participating jurisdictions will take and the mechanisms for taking these actions.

Development of a fishery management plan is a dynamic process. The process starts with initial input by the Fishery Management Workgroup, is followed by public and scientific review of the management proposals, and then by endorsement by the appropriate Chesapeake Bay Program committees. A management plan is adopted when it is signed by the Chesapeake Bay Program's Executive Committee. In some cases, regulatory and legislative action will have to be initiated, while in others, additional funding and staffing may be required to fully implement a management action. A periodic review of each FMP is conducted under the auspices of the Bay Program's Living Resources Subcommittee, to incorporate new information and to update management strategies as needed.

Goal of the American Eel Management Plan

The goal of the Chesapeake Bay American Eel Management Plan is to manage the American eel harvest in the Chesapeake Bay and its tributaries so that harvest does not exceed the reproductive capacity of the population to maintain its size from year to year. With this goal, optimum biological, economic, and social benefits will be attained.

In order to meet this goal, a number of objectives must be met. These objectives are incorporated into the problem areas and management strategies discussed below.

Problem Areas and Management Strategies

Problem 1: Stock Status. The status of the American eel stock in the Chesapeake Bay is unclear. Local watermen have reported catching smaller eels and a decrease in the number of eels. Biological data to characterize the stock is not current. There is the potential to harvest large quantities of elvers which could impact the local eel fishery.

Strategy 1: Stock Status. The jurisdictions will adopt a conservative approach to managing American eels in the Bay until stock assessment analyses have been completed. A minimum size of 6 inches will be adopted to protect elvers. A baywide minimum mesh size for eel pots will be implemented.

Problem 2: American Eel Bait Fishery. The use of eels for crab bait, especially in the Maryland portion of the Chesapeake Bay, places additional fishing pressure on the population. The quantity of "pencil eels" (eels larger than 6" and less than 10") used for finfish bait by recreatioanl fishermen is unknown but has the potential to increase. The harvest of eels for bait has not been completely recorded in catch statistics. Accurate catch statistics are necessary for assessing the status of eels in the Bay.

Strategy 2: American Eel Bait Fishery. Catch and effort information from the American eel bait fishery is important for developing management measures. Catch and effort statistics will be improved by adding questions about the use of eel bait to the crab survey.

Problem 3: Research Needs. Basic stock assessment data is lacking for American eels in the Chesapeake Bay. There is a limited amount of fishery dependent data and fishery independent data. Very little is known about the economic value of the bait eel fishery and how it affects harvest practices. Lack of biological and socioeconomic information hinders effective management practices.

Strategy 3: Research Needs. In order to increase the knowledge and understanding of the American eel resource in the Chesapeake Bay, research projects will be promoted to address the deficiencies in biological and socioeconomic data.

Problem 4: Habitat and Water Quality Issues. American eels prefer well-oxygenated areas and anoxic water probably affects distribution and inhibits growth. The condition of bottom sediments and substrates is also important since eels are bottom dwellers. Long-term exposure to pollutants and toxic substances can interfere with metabolic processes. American eel habitat is currently blocked by dams and other obstructions.

Strategy 4 Habitat and Water Quality Issues: The Bay jurisdictions will continue to set specific objectives for water quality goals and review management programs established under the 1987 Chesapeake Bay Agreement. Efforts include identifying and controlling nutrients, toxic materials, conventional pollutants, and atmospheric inputs; protecting wetlands and submerged aquatic vegetation; and managing population growth. In addition, the jurisdictions have committed to providing upstream access for migratory fishes.

INTRODUCTION

MANAGEMENT PLAN BACKGROUND

As part of the 1987 Chesapeake Bay Agreement's commitment to protect and manage the natural resources of the Chesapeake Bay, the Bay jurisdictions are developing a series of fishery management plans covering commercially, recreationally, and selected ecologically valuable species. Under the agreement's Schedule for Developing Baywide Resource Management Strategies, a list of priority species was formulated, with a timetable for completing fishery management plans as follows:

- oysters, blue crabs and American shad by July 1989;
- striped bass, bluefish, weakfish and spotted seatrout by 1990;
- croaker, spot, summer flounder and American eel by 1991;
- red and black drum by 1992; and
- Spanish and king mackerel, tautog, black sea bass and freshwater catfish by 1993.

A comprehensive and coordinated approach by the various local, state and federal groups in the Chesapeake Bay watershed is central to successful fishery management. Bay fisheries are traditionally managed separately by Pennsylvania, Maryland, Virginia, the District of Columbia, and the Potomac River Fisheries Commission. There is also a federal Mid-Atlantic Fishery Management Council, which has management jurisdiction for offshore fisheries (3-200 miles), and a coastwide organization, the Atlantic States Marine Fisheries Commission (ASMFC), which coordinates the management of migratory species in state waters (internal waters to 3 miles offshore) from Maine to Florida. The state/federal Chesapeake Bay Stock Assessment Committee (CBSAC) is responsible for developing a Baywide Stock Assessment Plan, which includes collection and analysis of fisheries information, but does not include the development of fishery management plans.

Consequently, a Fisheries Management Workgroup, under the auspices of the Chesapeake Bay Program's Living Resources Subcommittee, was formed to address the commitment in the Bay Agreement for baywide fishery management plans. The Fisheries Management Workgroup is responsible for developing fishery management plans with a broad-based view. The workgroup's members represent fishery management agencies from the District of Columbia, Maryland, Pennsylvania, the Potomac River Fisheries Commission, Virginia, and the federal government; the Bay area academic community; the fishing industry; conservation groups; and interested citizens. Establishing Chesapeake Bay FMPs, in addition to coastal FMPs, creates a forum to specifically address problems that are unique to the Chesapeake Bay. They also serve as the basis for implementing regulations in the Bay jurisdictions.

WHAT IS A FISHERY MANAGEMENT PLAN?

A Chesapeake Bay fishery management plan provides a framework for the Bay jurisdictions to take compatible, coordinated management measures to conserve and utilize a fishery resource. A management plan includes pertinent background information, lists management actions that need to be taken, the jurisdictions responsible for implementation, and an implementation timetable.

A fishery management plan is not an endpoint in the management of a fishery; rather, it is part of a dynamic, ongoing process consisting of several steps. The first step consists of analyzing the complex biological, economic and social aspects of a particular finfish or shellfish fishery. The second step includes defining a fishery's problems, identifying potential solutions, and choosing appropriate management strategies. Next, the chosen management strategies are put into action or implemented. Finally, a plan must be regularly reviewed and updated in order to respond to the most current information on the fishery; this requires that a management plan be adaptive and flexible.

GOALS AND OBJECTIVES FOR FISHERY MANAGEMENT PLANS

The goal of fisheries management is to protect the reproductive capability of the resource while providing for its optimal use by man. Fisheries management must include biological, economic and social considerations in order to be effective. Three simply stated objectives to achieve this goal are:

- quantify biologically appropriate levels of harvest;
- monitor current and future resource status to ensure harvest levels are conserving the species while maintaining an economically viable fishery; and
- adjust resource use and other factors affecting resource status, as needed, through management efforts.

These general objectives are incorporated with information on a particular resource and the current status of management for that resource, into specific objectives for a fishery management plan.

MANAGEMENT PLAN FORMAT

The background section of this management plan summarizes:

- natural history and biological profile of the American eel;
- American eel fishery and fishery parameters;
- economic perspective;

- resource status;
- habitat issues;
- FMP status and management unit;
- current laws and regulations in the Chesapeake Bay; and
- data and analytical needs.

The background information is partially derived from the document entitled, Chesapeake Bay Fisheries: Status, Trends, Priorities and Data Needs and is supplemented with additional data. Inclusion of this section as part of the management plan provides historical background and basic biological information for each of the species.

The management section of the plan, which follows the background, defines:

- the goal and objectives for management of the species;
- problem areas;
- management strategies to address each problem area; and
- action items, with a schedule for implementation, by the appropriate management agency.

THE CHESAPEAKE BAY PROGRAM'S FISHERY MANAGEMENT PLANNING PROCESS

The planning process starts with initial input by the Fisheries Management Workgroup and development of a draft plan. This is followed by a review of the management proposals by Bay Program committees, other scientists and resource managers, and the public. After a revised draft management plan is prepared, it must be endorsed by the Chesapeake Bay Program's Living Resources Subcommittee and Implementation and Principal Staff committees. The plan is then sent to the Executive Committee for adoption.

Upon adoption by the Executive Committee, the appropriate management agencies implement the plan. In 1990, the Maryland legislature approved §4-215 of the Natural Resource Article giving the Maryland Department of Natural Resources authority to regulate a fishery once a FMP has been adopted by regulation. In Virginia, FMP recommendations are pursued either by legislative changes or through a public regulatory process conducted by the Commission. A periodic review of each FMP is conducted by the Fisheries Management Workgroup to incorporate new information and to update management strategies as needed.

Section 1. Biological Background

Life History

The American eel (Anguilla rostrata), also known as the common or freshwater eel, can be found in a variety of habitats across an extensive geographic range. It probably has the broadest diversity of habitats of any fish species in the world (Helfman et al. 1987). American eels occur in freshwater rivers and lakes, estuaries, coastal areas, and open ocean from the southern tip of Greenland, along the entire coast of North America, into the Gulf of Mexico, and southward to the northeastern portion of South America (Van Den Avyle 1984). In the Chesapeake Bay, American eels can be found in the mainstem and all tributaries and streams (Hildebrand and Schroeder 1927).

The general life history pattern of the American eel is complex and not fully understood. It is a catadromous species, that spends most of its life in rivers, lakes and estuaries, but migrates to the ocean to spawn. Prior to beginning a fall migration, maturing eels undergo a metamorphosis which includes a change in color, fattening of the body and thickening of the skin, enlargement of the eyes, and degeneration of the digestive tract (Van Den Avyle 1984). Migrating adult eels are referred to as silver eels and details of their migration are not well known (Helfman et al. 1987). Spawning has never been directly observed, but based on larval distribution, it is believed to occur during winter and spring in the Sargasso Sea (east of the Bahamas and south of Bermuda) at temperatures between 22 and 25°C (72-77°F) (McCleave et al. 1987). Fecundity, the number of eggs per female, is between 10 and 20 million (Fahay 1978). Current evidence suggests that American eels spawn only once and then die. Results from genetic studies indicate very little variation in eel populations throughout their geographic range and support the concept of a single, randomly breeding population (Helfman 1987).

The larval form or leptocephalus stage of the eel is so different from the adult that it took over forty years to discover the connection between it and the adult form. The leptocephalus stage (characterized by a ribbon-like transparent body form) usually lasts for one year but may be longer depending on latitude. During this time, growth occurs and the larvae are dispersed by ocean currents. Once they reach a certain size and physiological state, they begin to metamorphose. The modifications in body form include a reduction in size and weight, changes in the shape of the head and jaw, and accelerated development of the digestive system (Van Den Avyle 1984). After these changes occur, the larvae would be recognized as a "typical" eel except that it is unpigmented and more or less transparent. Eels at this stage are called "glass eels" and migrate toward freshwater. The mechanisms that trigger migration towards land and freshwater are not well understood. Migration may involve active swimming, selective tidal-stream

transport, and transport by Gulf Stream intrusions and long-shore currents (Kleckner and McCleave 1985; Williams and Koehn 1984). As glass eels move into coastal areas, pigmentation develops and the body becomes uniformly dark brown. At this point, metamorphosis is complete and the eel is now called an elver (Van Den Avyle 1984).

Elvers generally move into estuarine and freshwater habitats in late winter and early spring. They usually appear in the Bay area during April and the run can last a few days or a month (Schwartz 1961 as cited by Mowrer 1979). Young eels assume a nocturnal lifestyle, active at night and resting in deep water during the day. Typically, elvers are smaller and arrive earlier in southern areas along the coast. Movement upstream appears to be affected by tidal action and currents (Fahay 1978). Elvers can range in size from 46 mm (1.8") to 127 mm (5") (Bigelow and Schroeder 1953). In the Chesapeake Bay, an eel less than 152 mm (6") is generally referred to as an elver. When elvers stop migrating, they undergo a period of growth and differentiation and are then known as yellow eels.

The yellow eel stage (also referred to as the juvenile or subadult stage) can last from 8 to 24 years. Growth rates during this time are highly variable and there is considerable overlap in length, weight, and age. Predicting age from size is, therefore, not reliable (Van Den Avyle 1984). Growth rates for eels in the upper Chesapeake Bay appear to differ by sex and age. Estimates of eel growth rates from the South Altahama River, Georgia, based on seasonal and long-term recapture methodology, were 57 and 62 mm/yr (Helfman et al. 1984). The yellow eel stage is highly mobile which accounts for their widespread distribution (Williams and Koehn 1984). Studies suggest that eels living in river and lake habitats have long distant seasonal movements and relatively large home ranges (Gunning and Shoop 1962). Estuarine eels are more sedentary with little evidence of seasonal movements and smaller home ranges (Helfman et al. 1983). Tag return data from the upper Chesapeake Bay support the concept of limited movement and discrete eel sub-populations within tributaries (Foster and Brody 1981). There have been conflicting reports on habitat preference by sex with females preferring freshwater and males preferring brackish water. Foster and Brody (1982) found female eels in estuarine areas in the Bay and male eels in freshwater.

Prior to migrating to the sea, the yellow eel changes to a silver or bronze eel, the final stage in its life history. This stage generally lasts for one year and sexual maturity is reached during this time. Since sexual maturity depends to some extent on size, the variation in maximum and minimum lengths makes it difficult to state the age or length at which an eel will mature (Moriarty 1987). However, there appears to be a general trend in age and size at maturity with location. Eels are older and reach a larger size at maturity in northern locations. Age at maturity for female eels from the Chesapeake Bay has been estimated at 10 to

12 years at a minimum size of 470 mm (18.5") (Foster and Brody 1982).

The American eel feeds mostly at night. In the Chesapeake Bay, crustaceans, bivalves and polychaetes make up the majority of their diet. Food analyses suggest that the eel may be a significant predator on blue crabs (Wenner and Musick 1975). Anguillid eels are considered dietary generalists, eating a broad diversity of food items, limited only by the availability of a particular food item (Tesch 1977). Leptocephali, glass eels, elvers, and small yellow eels are consumed by a variety of predatory fish. Larger eels are eaten by other species of eels and a number of bird species (Sinha and Jones 1967).

Biological Profile

Natural mortality rate:	Currently unknown.
Fecundity:	10 to 20 million eggs per female
Longevity:	Up to 25 years.

Spawning and Larval Development

Spawning season:	Not known with certainty, probably winter and spring.
Spawning area:	Warm side of a thermal front in the Sargasso Sea (23-26°N, 69-74°W).
Spawning location:	Spawning probably takes place above the thermocline at depths of less than 350 m. Leptocephali occur in ocean waters. Glass eels occur in offshore and coastal waters.
Salinity:	35 ppt.
Temperature:	22-25°C (72-77°F).

Elvers

Location:	At sizes less than 150 mm (6") in length, generally in shallow, near-shore waters; larger individuals in deeper waters.
Salinity:	0 - 35 ppt.
Dissolved Oxygen:	Greater than 2.5 ppm.

Juveniles

Location:	Fresh, estuarine and marine waters. Apparently prefer vegetated areas.
Salinity:	0 - 35 ppt.
Dissolved oxygen:	Greater than 2.5 ppm.

Adults

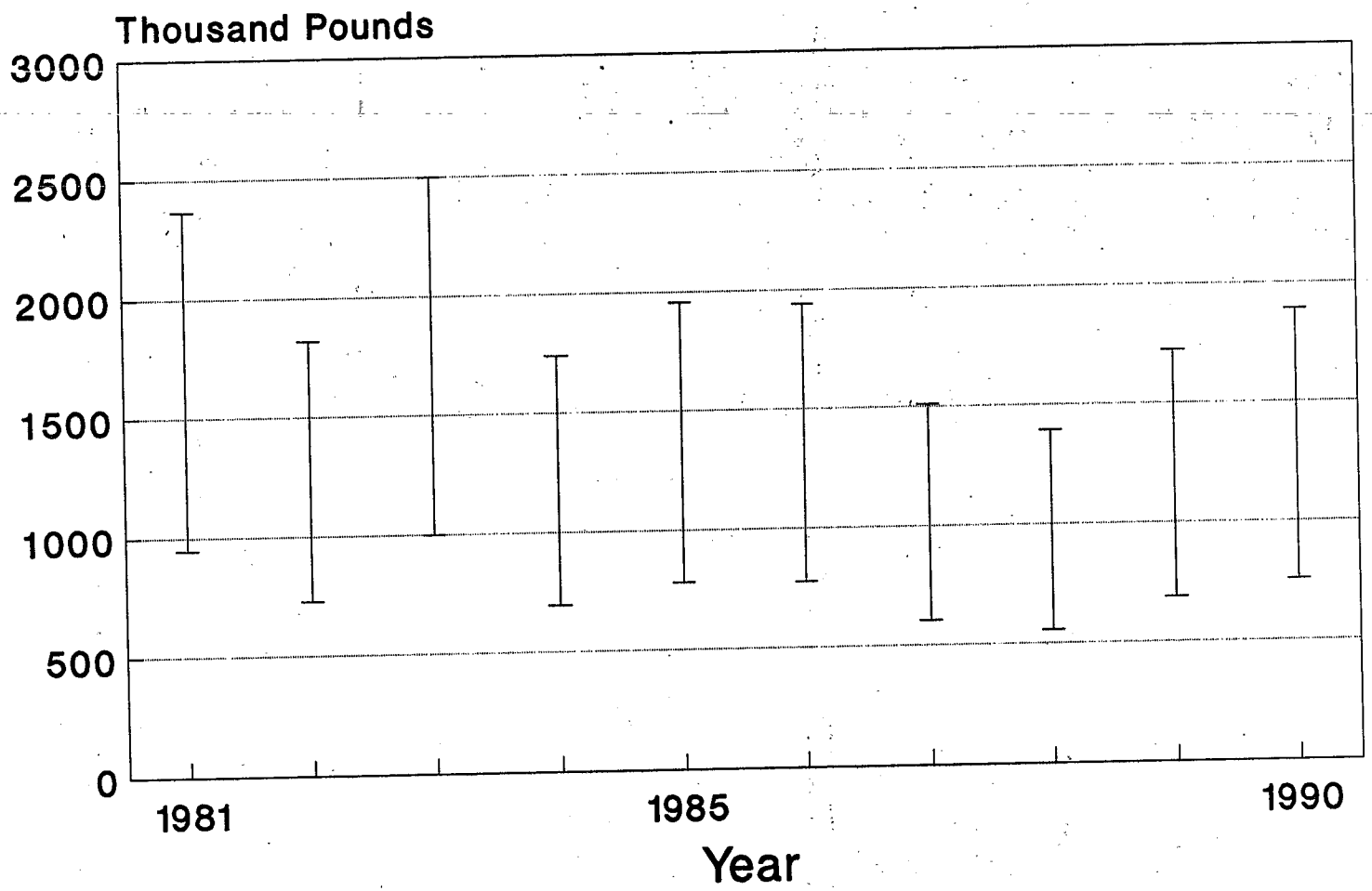
Location:	Initially in fresh, estuarine or marine waters; as sexual maturity progresses, migratory activity to offshore spawning waters begins.
Salinity:	0-35 ppt.
Dissolved Oxygen:	Greater than 2.5 ppm.

The Fishery

There are two distinct industries for eel, the crab trotline bait market in which 0.5 - 1.0" (1.3 - 2.5 cm) diameter eels of approximately 10 - 14" (25.5 -35.5 cm) lengths are used, and the live-eel market where eels of at least 13" (33 cm) length are preferred for export. Traditionally in the Chesapeake Bay region, smaller eels were salted for crab trotline bait and, secondarily, marketed for local consumption (Foster and Brody 1981). Presently, the use of eels for crab trotline bait widely occurs in Maryland waters. In Virginia, the number of eels used for crab bait is small and mostly used by the recreational crabber. The number of eels harvested for crab bait in the Chesapeake Bay is unknown and generally goes unreported. An attempt has been made to calculate the harvest of eels used for bait from the Maryland portion of the Bay (Krauthamer, unpubl. manuscript). Estimates of annual eel harvest were based on the ratio of eel bait to trotline crab catch and multiplied by the total annual commercial trotline crab harvest (Figure 1). Ratios of 1:10 (1 pound of eel bait to 10 pounds of crabs harvested, the high value) and 1:17 (mid-value) were determined from information gathered from crab fishermen (Krauthamer, unpubl. manuscript). Since the price of eel bait has increased and the price of other baits decreased, crab fishermen have become more conservative with their bait usage. A lower ratio of 1:25 appears more reasonable for the 80's (Jim Casey-MDNR, per comm.). Values from the ratio method of estimation increased total eel harvest between 0.6 and 2.4 million pounds, depending on the specific year in question (Figure 2).

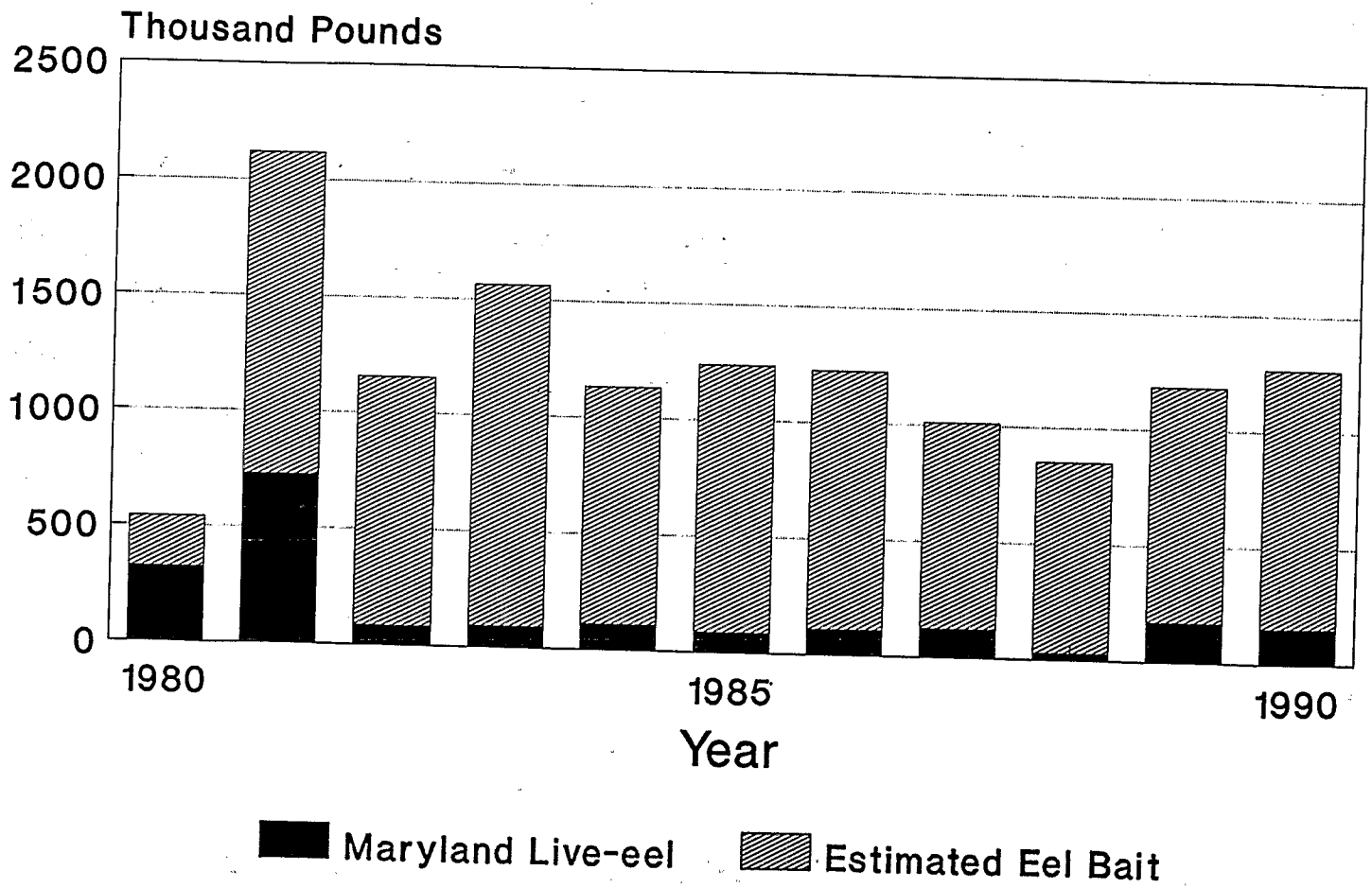
Beginning in the mid 60's, the live-market industry developed when air freight transportation made it possible to export live

Figure 1. Estimated range of eel harvest used for bait by Maryland trotliners



Estimates based on ratios cited in text

Figure 2. Estimated total eel harvest from Maryland



Bait estimates based on 1:17 ratio

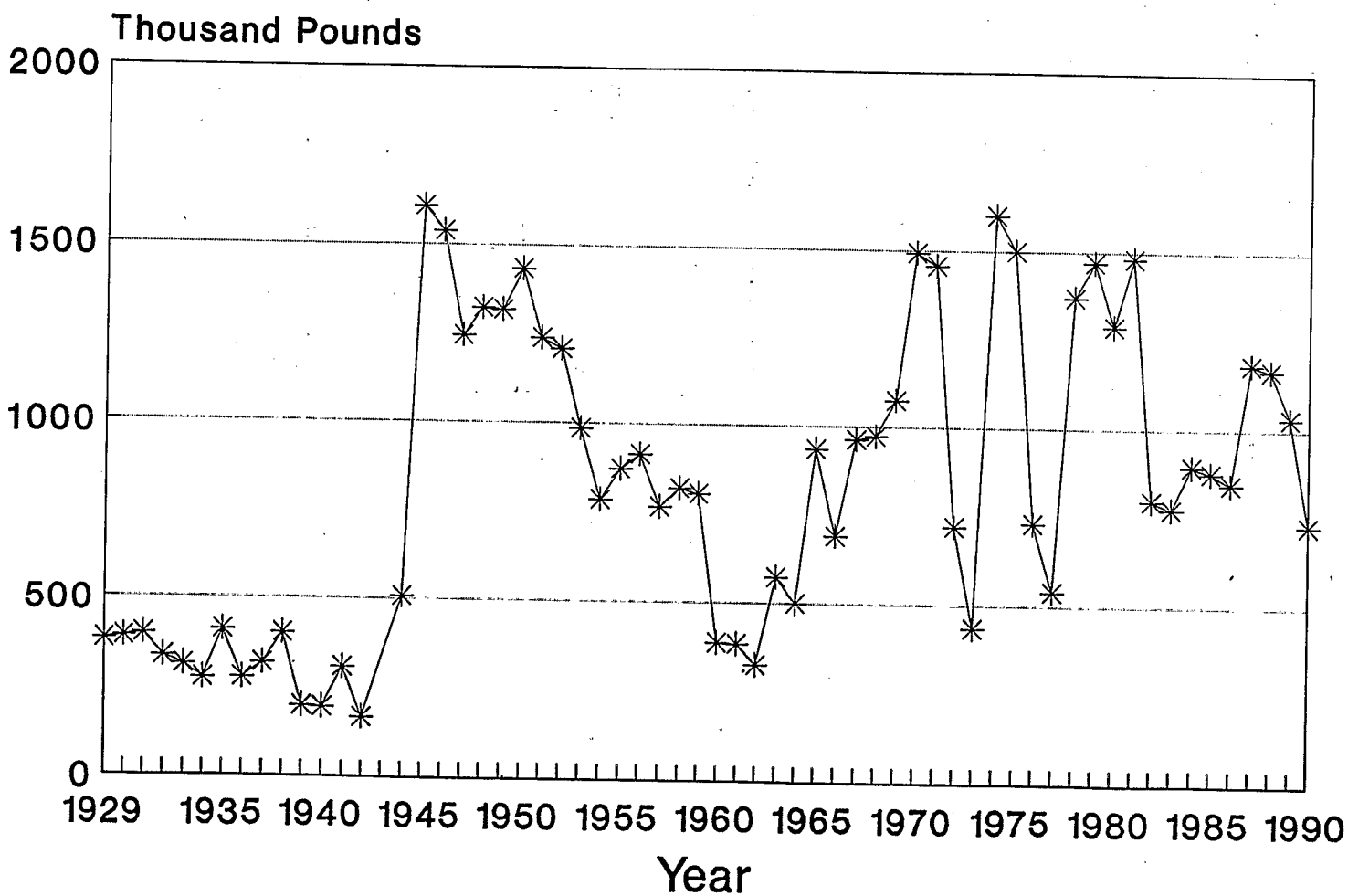
eels to the European market. Since then, the live-eel market has grown and it is from this industry that harvest statistics are obtained. In 1990, 730,000 pounds were harvested from the Chesapeake Bay, of which 577,000 pounds were landed in Virginia. These values do not include eels harvested by the crab trotline bait fishermen who are not required to report. The Potomac River Fisheries Commission (PRFC) requires the reporting of all eels caught from the Potomac River. The reported commercial eel harvest from the Chesapeake Bay has been highly variable (Figure 3). The difference in reported and estimated catch can be illustrated by Foster and Brody's investigation of the eel fishery. In 1980, Maryland DNR estimated total eel catch in Maryland at approximately 1.2 million pounds, yet the reported catch from Maryland was only 322,000 pounds.

Historically, the American eel populated the Susquehanna River Basin from the mouth of the river to its headwaters. Although the size of the historic population cannot be determined, the Pennsylvania Fish Commission (PFC) estimates that over 900,000 pounds per year were taken for commercial resale and home consumption at the turn-of-the-century. Although eels still exist (PFC stocking program) in limited numbers in many basin tributaries and the mainstem, construction of four hydropower dams on the lower river in the early 1900s has blocked nearly 350 miles of river habitat. Under the Fish Passage Workgroup, a plan has been adopted to provide fish passage at dams and to remove stream blockages wherever necessary. This strategic plan for reestablishing American eels throughout their historic range, especially in the Susquehanna River basin, is currently in progress.

Reported harvests from the Chesapeake Bay up until 1980, were based on National Marine Fisheries Service (NMFS) statistical surveys which relied on interviews from fishhouse managers only. This method of collecting data probably contributes to the variability in yearly harvests. Since 1980, harvests in Virginia have been collected directly from live-market eel buyers and other seafood buyers, which accounts for the majority of Virginia's eel landings.

In 1990, Maryland DNR began including the catch of eels on their mandatory finfish reporting forms. The harvest record should be more accurate with this improvement in reporting, however, obtaining accurate catch information on eels used for bait is still a problem and will continue to hinder stock assessments of the eel resource in the Chesapeake Bay. Crab licensees are allowed to use up to 50 eel pots for personal use and are not required to report their bait eel catch. The Potomac River Fisheries Commission (PRFC) has had mandatory catch reporting for eels since 1964. The reports indicate eels are sold for both the live and bait markets. Eel landings from the Potomac have averaged over 300,000 pounds per year and have ranged from 126,000 to 650,000 pounds. Approximately 80% of the Potomac harvest is landed in Virginia.

Figure 3. Reported Commercial Landings of American Eel from the Chesapeake Bay



In the Chesapeake Bay, the eel pot is the major gear type for capturing eels and has been responsible for between 80 and 98% of the reported commercial harvest since 1929. Eel pots are baited with a variety of fresh and frozen baits (soft clams, female herring, carp roe, female horseshoe crabs, menhaden and small female crabs) (Foster and Brody 1981). The traditional upper Bay eel pot is cylindrical (8 to 12" in diameter, 24-36" long) with two fabric funnels in one end and a closed, opposite end. It is constructed of wire mesh with 1/3 X 1/3", 1/2 X 1/2", or 1/2 X 1" size meshes. The minimum size eel retained by each mesh size is 230 mm (9"), 260 mm (10.2") and 320 mm (12.6"), respectively (Foster and Brody 1982). In Maryland, 1/3 X 1/3" mesh size is used in approximately 15 to 20% of the eel pots with the two other mesh sizes evenly divided across the remaining eel pots (Foster and Brody 1982). In Virginia, a square or rectangular pot (12-16" high, 18-24" long) with 1/2 X 1/2" or 1/2 X 1" wire mesh is more widely used since the major portion of the catch is for live market eels. Virginia currently has a 1/2 X 1/2" minimum mesh size limit and requires two escape panels of 1/2 X 1" mesh in 1/2 X 1/2" mesh pots. Pound and fyke nets are of minor importance in the fall, catching silver eels as they migrate out of the Chesapeake Bay (Foster and Brody 1981).

In Virginia, the eel pot fishery has historically been a transitional type of fishery. Commercial watermen would generally fish a few eel pots in between other fishing seasons, particularly in the spring and fall. During the last few years with the decline of the oyster, shad, and striped bass fisheries, more fishing pressure has been exerted on the eel resource. There has been an increase in the number of fishermen targeting eels and an increase in the number of pots being fished per man. Over the last 10 years, dockside price for eels to the fishermen has increased at a rate greater than that for other finfish.

There is evidence that hook and line, or recreational fishing for eels existed throughout the Susquehanna River basin. Presently, rod and reel fishing occurs in the basin on eels remaining from eel stocking above Conowingo Dam. Other active fisheries are on the Octoraro and Elk Creeks in Lancaster and Delaware Counties. These fisheries are not well documented.

Due to the vulnerability of elvers to overharvest, a prohibition on the taking of elvers was established by Virginia in 1977. Waves of elvers (eels less than 6" long) enter the Bay and its tributaries in the spring, converging at outfalls, as they migrate toward freshwater. These large concentrations are easily harvested. In addition to the overharvest potential at outfalls, there is the potential to harvest elvers for the foreign eel culture market. Harvesting large numbers of elvers could negatively impact the Chesapeake Bay American eel stock.

Small to medium sized eels are used as live bait by hook and line fishermen targeting striped bass and cobia. When striped bass stocks declined, this usage of eels diminished. Now that striped bass stocks are recovering and limited fishing is allowed live eel bait is preferred. In addition, cobia have been abundant in the Bay. Consequently, a live-bait market for the recreational hook and line finfish fishery has been reestablished.

Fishery Parameters

Status of exploitation:	Unknown.
Long term potential catch:	Currently unknown.
Importance of recreational fishery:	Insignificant.
Importance of commercial fishery:	Significant, becoming increasingly important.
Fishing mortality rates:	Currently unknown.

Economic Perspective

Since commercial landings from the Chesapeake Bay are probably under-reported, only a limited economic perspective can be discerned based on dockside value. Based on the Maryland American eel market, price per pound decreased from $0.85 in 1980 to $0.35 in 1983, and for Virginia, decreased from $0.94 to $0.46 during the same time period. Since then, there has been a gradual increase in price per pound (Figure 4 and 5). In Maryland, American eel sold for its highest price ($1.72 per pound) in 1990 and ranked 4th compared to other finfish species. In 1988, Virginia eels sold for $1.72 per pound, its highest value since 1980. The average wholesale price for eel during 1990 was $1.53 per pound and ranked third compared to other finfish species. Almost all of the eels bought for the live-market trade are exported to Europe, where there is a high consumer demand for eels.

Resource Status

In the late 70's there was some concern about the eel fishery in Maryland. Anecdotal comments suggested that eels were becoming less abundant. In 1980, a study was conducted to characterize Maryland's eel fishery. A number of eel fishermen and marketers were interviewed to help define problems in the fishery. The main problems expressed by the fishermen were that the average size eel was decreasing, there were too many part-time eelers, too many elvers and small eels were being harvested, cost of bait was increasing, and there was a high rate of pot loss. Suggestions for

Figure 4. Maryland Commercial Landings and Dockside Value of American Eels

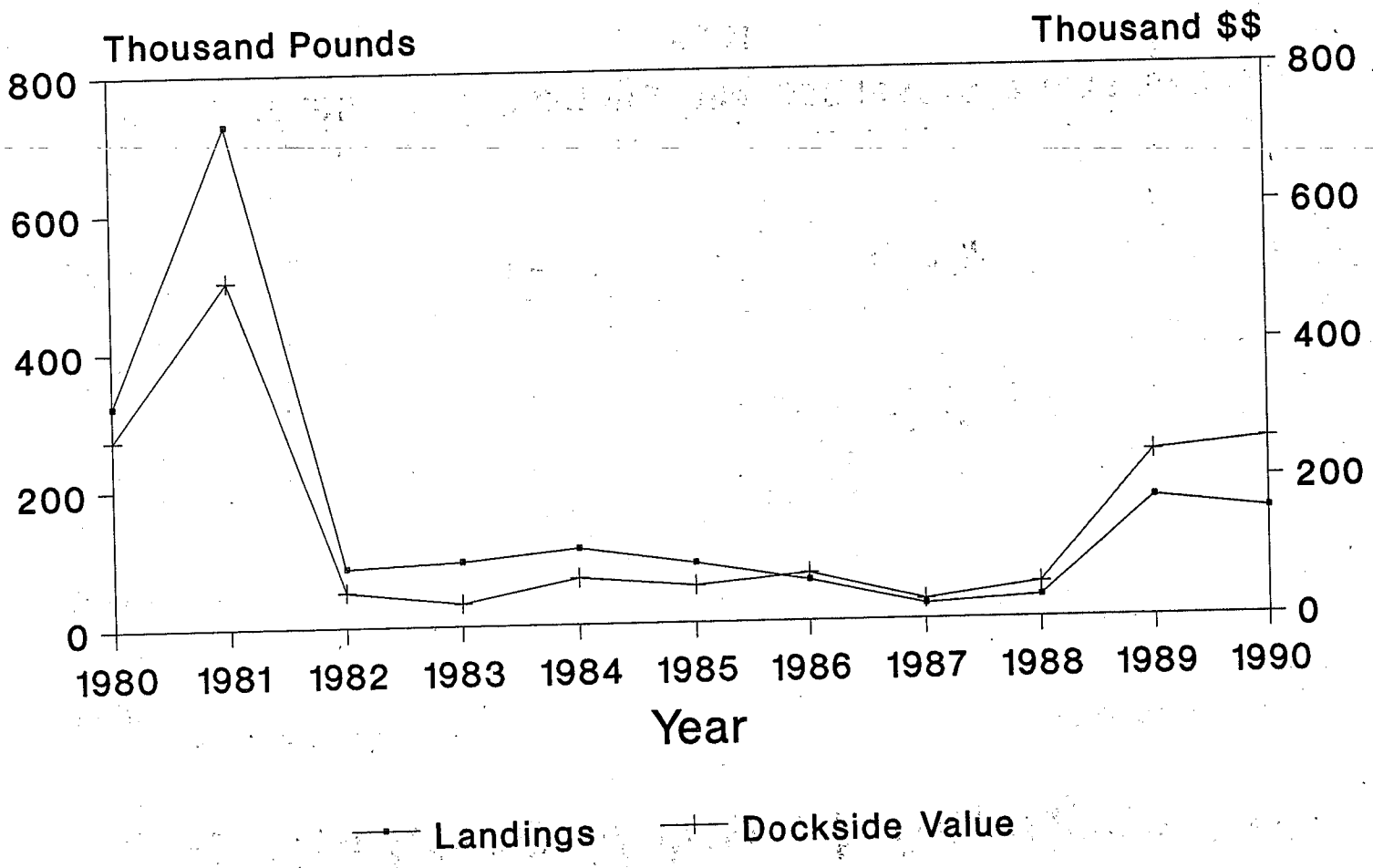
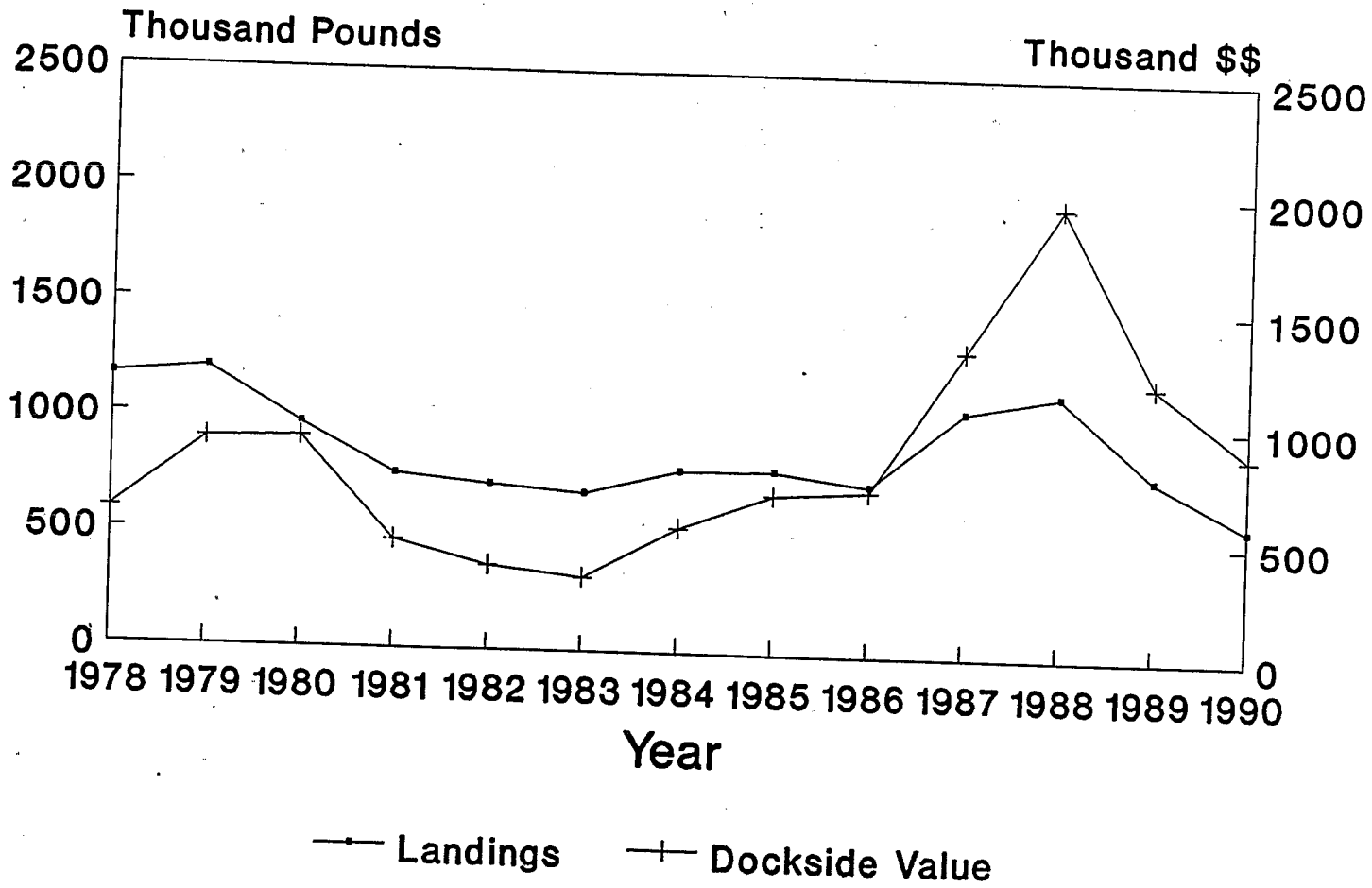


Figure 5. Virginia Commercial Landings and Dockside Value of American Eels



improvement included the adoption of a commercial eel fishing license, a minimum 6" size limit, and a minimum mesh size restriction for eel pots (Foster and Brody 1982). The study also analyzed eel catch by pot mesh size in the upper Chesapeake Bay. With the smallest mesh size (1/3 X 1/3"), 80% of the eels were too small for the live market fishery. There is a potential conflict over optimum mesh size for the live market and the bait fishery since each targets a different size eel. Presently, it is unknown if restricting the harvest of small eels will benefit the harvest of eels in following years.

Overfishing for eels and decreasing size of eels have also been concerns for the Virginia eel industry. As a result of pressure from Virginia eel fishermen and processors, a study on optimum mesh size for eel pots was conducted in 1981. Results of this study indicated that 61% of the eels caught in pots of 1/2 X 1/2" mesh were below the minimum live market size (13 - 14" length), and on average, caught an eel 1.8" shorter and 1.7 ounces lighter than the 1/2 X 1" mesh pots. In 1990, after a series of meetings with eel industry representatives, Virginia passed a regulation which established a 1/2 X 1/2" minimum mesh size for eel pots and which required 1/2 X 1" mesh escape panels in 1/2 X 1/2" mesh pots. The purpose of this regulation is to conserve the Chesapeake Bay eel stock, to reduce the possibility of growth overfishing, and to prevent the wastage of small eels. A similar law was passed in North Carolina that same year. Virginia also passed a regulation in 1990 which established procedures for the setting, fishing, and marking of eel pots.

In 1983, the Potomac River Fishery Commission required a 1/2 X 1/2" minimum mesh size for eel pots. In 1985, the PRFC adopted a 1/2 X 1" minimum mesh size to become effective in 1987. However, it was repealed before 1987, thereby, returning the 1/2 X 1/2" minimum mesh size requirement. This illustrates the difficulty in changing traditional methods and gear types. An investigation of the Potomac River eel fishery was conducted in the fall of 1989. Again, the perception of decreasing catch and smaller available eels, prompted the investigation. The results indicated a significant increase in fishing pressure during the previous five-year period, both in the number of fishermen catching eels and the average number of eel pots being fished. The average size of eels has declined which could be an indication of growth overfishing (Smoller 1989). In growth overfishing, fish are caught at too small a size to allow realization of growth and yield potential.

American eel populations along the Atlantic coast appear variable depending on the estuary or river in question. Even two closely related systems may differ considerably in abundance and biological characteristics. Computer simulations of larval drift indicate a broad, uniform distribution of eels along the coast (Helfman et al. 1987). In many ocean spawning fish species, environmental factors are far more important in determining

survival of eggs and young than are the number of parents. Whether there is a relationship between number of adult eel spawners and eventual number of elvers that enter Atlantic and Gulf Coast streams is unknown. The spawning aggregation of eels in the Atlantic is composed of eels from Greenland to South America. Even if one or several river specific populations within the range were subjected to intense fishing pressure, it is unlikely that reproduction would be negatively affected (recruitment overfishing) if the remainder of the habitats experienced only moderate fishing pressure. There is some evidence that total American eel harvest from the Canadian maritime provinces has declined due to local growth overfishing. This situation has resulted in the development and consideration of new management policies. These policies include restrictions on the number of eel licenses, gear and area restrictions, and a closed season (Jessop 1982). Other regions, including the Chesapeake, have also exhibited signs of growth overfishing and should be investigated further.

Habitat Issues

American eels are numerically dominant in a broad array of habitats which includes small clear streams; large, turbid rivers; blackwater swamps; springs and caves; clear and turbid, deep and shallow, vegetated and barren lakes and ponds; and fresh, brackish, and saltwater marshes (Helfman et al. 1987). Given this diversity of habitats, the eel has relatively broad environmental tolerances. Eels are considered a "hardy" species. From the available literature, it appears that eels generally prefer well-oxygenated areas (Hill 1969). Anoxic water in the Chesapeake Bay probably affects eel distribution and may contribute to slow growth rates. Since eels are essentially bottom dwellers, the condition of bottom sediments and substrates is important. Migrating elvers seek shelter in bottom areas and adult and subadult eels, especially in northern areas, use the bottom mud during winter (Van Den Avyle 1984). It would follow that disturbances to the bottom habitat, such as physical alteration, chemical and metal pollution, would affect American eels in the Bay.

The effects of pollutants on American eels have not been extensively researched. High levels of chlordane have been found in eels tested from Back River and Baltimore Harbor. These tests resulted in a health advisory to limit the consumption of eels caught in these two areas. Toxicity of aquaculture chemicals has been investigated by Hinton and Eversole (1979) and results suggest that tolerance increases with size and age. Permanent damage from pollution occurs only if the pollutants produce long-term metabolic effects (Tesch 1977). Sewage probably has an adverse effect on elvers migrating upriver (Tesch 1977).

Upstream habitat in many areas of the Bay is inaccessible to migrating eels. In particular, young eels are impeded by structures such as weirs and dams. Eel populations could be improved by facilitating upstream passage (Tesch 1977).

FMP Status and Management Unit

There is no coastal management plan for American eels. The 1987 Chesapeake Bay Agreement contains a commitment to develop, adopt, and begin to implement this baywide FMP for American eels by December 1991.

The management unit is defined as all American eels (Anguilla rostrata) in Chesapeake Bay waters.

Laws and Regulations

Limited entry:	Maryland's Delay of Application Process, which went into effect September 1, 1989, requires previously unlicensed applicants to wait two years after registering with MDNR before a license to harvest finfish with commercial fishing gears will be issued. Limited or delayed entry is not in effect for Pennsylvania, the Potomac River or Virginia.
Minimum size limit:	None in Maryland, Pennsylvania, or the Potomac River. In Virginia the taking or catching of elvers is prohibited.
Creel limit:	50 per person per day in Pennsylvania. Not in effect in Maryland, Potomac River or Virginia.
Harvest quotas:	Not in effect in Maryland, Pennsylvania, Potomac River or Virginia.
By-catch restrictions:	Not in effect in Maryland, Pennsylvania, Potomac River or Virginia.
Season:	No closed season.
Gear/Area restrictions:	**Maryland** - No restrictions on eel pots. **Pennsylvania** - No gear restrictions. **Potomac River** - The use of spears, gig, gig irons or dynamite are prohibited. Minimum mesh size restrictions: pound and

fyke nets - 1-1/2"; eel pots - 1/2 X 1/2"; bait pots - 1"; fish pots - 2"; fyke net -1.5". Length limitations on fish pots - 10'; bait pots -2' cube. Seasonal restrictions: pound nets - Feb. 15 through Dec. 15.

Virginia - Eel pots: 1/2 X 1/2" minimum mesh size; rectangular or square pots of 1/2 X 1/2" mesh required to have two unrestricted 1/2 X 1" mesh escape panels; cylindrical pots of 1/2 X 1/2" mesh required to have one unrestricted 1/2 X 1" mesh escape panel. Each single pot must be marked with a buoy; for multiple pots on a line, the eel pot line may not exceed 1200' and must be buoyed at each end; unlawful to set pots in a navigable channel. It is unlawful to set, place or fish a fixed fishing device within 300 yards of the Chesapeake Bay Bridge Tunnel. Minimum stretch mesh size restrictions: pound net 2", haul seine 3" (nets over 200 yards long). No haul seine can be longer than 1000 yards or deeper than 40 meshes. Also, Sections 28.1-52 and 28.1-53 of the Code of Virginia outline placement, total length and distance requirements for fishing structures.

Other prohibitions: Obstructing passage of fish and dynamiting streams.

Status of Traditional Fishery Management Approaches

The following definitions have been adapted from the document, "Status of the Fishery Resources Off the Northeastern United States for 1989" (NOAA Technical Memorandum NMFS-F/NEC-72). For a more thorough review of fisheries terminology, refer to this document under the section "Definition of Technical Terms."

Catch-Effort or (Catch per unit of effort)- Defined as the number or weight of fish caught during a specific unit of fishing time and considered a basic measure of abundance or stock density: Only limited catch data exists for eels.

Estimates of mortality based on abundance- Instantaneous mortality is defined as the rate at which fish are removed from a population by death (Z). It can be represented mathematically by the natural logarithm of a ratio of the number of fish alive at the end of a unit of time, to the number alive at the beginning of the unit of

time. It can also be expressed as a percentage of the population: None available for eels in the Chesapeake Bay.

Yield-per-Recruit- A mathematical calculation of the theoretical yield that would be obtained from a group of fish of one age if they were harvested according to a certain exploitation pattern over the life span of the fish: Unknown for eels.

Spawning Stock Biomass- The total weight of all sexually mature fish in the population. This changes depending on the size of new year classes, the growth rate of young fish, the age at sexual maturity, the growth and natural mortality of older fish, and the fishing mortality rate: Unknown for eels.

Spawning Stock Biomass Per Recruit (SSBR)- The spawning stock biomass divided by the number of fish recruited to the stock at age 2. This number is in units of weight and measures the average or expected contribution of any one young fish to the spawning stock biomass over its lifetime: Unknown for eels

Stock-Recruitment- The relationship between the adult stock size and subsequent recruitment (fish that reach a certain size or age in a specific year). Unknown for eels.

Maximum Sustainable Yield- The number or weight of fish in a stock that can be taken by fishing without reducing the stock's biomass from year to year, assuming that environmental conditions remain the same: Unknown for eels.

Virtual Population Analysis- Defined as an analysis of fish catches from a given year class over its life in the fishery: Has not been carried out for eels - no information on age specific catch of eels.

Data and Analytical Needs

1. Collect biological information on the distribution, size, age and sex composition of the catch in fresh, brackish, estuarine and marine waters of Maryland and Virginia.

2. Collect data for estimating catch-per-unit-effort in the eel pot fishery.

3. Improve annual estimates of total landings including eels harvested for crab bait.

4. Determine the optimum minimum size for harvesting eels.

5. Determine natural and fishing mortality rates.

6. Determine economic characterizations of each major component of the fishery.

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Section 2. American Eel Management

Source documents for this plan (Foster and Brody 1982; Van Den Avyle 1984; and Stagg 1986) discuss various aspects of the American eel life history, fishing exploitation, and potential problems associated with the fishery.

A. GOAL AND OBJECTIVES

The goal of this plan is to manage the American eel population in the Chesapeake Bay and its tributaries so that harvest does not exceed the natural capacity of the population to maintain its size from year to year. With this goal, optimum biological, economic, and social benefits will be attained.

In order to achieve this goal, the following objectives must be pursued:

1) Promote protection of the resource by maintaining a clear distinction between conservation goals and harvest regulations.

2) Restore self-sustaining populations of American eels to their historical ranges.

3) Implement appropriate monitoring programs necessary for collecting stock assessment data.

4) Provide for fair allocation of allowable harvest, consistent with traditional uses, among the various components of the fishery.

5) Promote studies to improve the understanding of economic, social, and biological aspects of the fishery.

6) Continue to pursue and enforce standards of environmental quality and habitat protection necessary to protect the American eel population within the Bay and its tributaries.

B. PROBLEM AREAS AND MANAGEMENT STRATEGIES

Problem 1 - Stock Status: The current status of the American eel stock in the Chesapeake Bay is unclear. It has been suggested (Helfman) that the eel's long stay in freshwater may make it more vulnerable to local exploitation. There is some anecdotal information that eels in the Bay are smaller and less abundant than in the past, but commercial landing statistics do not indicate any stock trends. Biological data to characterize the stock is not current. Harvesting large quantities of elvers when they enter the Bay in dense numbers and foreign interests looking to obtain elvers for culture could negatively impact the Chesapeake Bay American eel

stock. American eel habitat is currently blocked by dams and other obstructions which potentially limits stock abundance. Annual recruitment of elvers is more affected by environmental factors (offshore winds, currents) then abundance of spawning stock from any one region.

Strategy 1 - Stock Status: Until stock assessment analyses are available, the jurisdictions will adopt a conservative approach to managing the eel stock in the Bay by reducing the possibility of growth overfishing and by preventing the wastage of small eels.

Problem 1.1
The current status of the American eel stock in the Bay is unclear and stock assessment data is unavailable. The harvest of elvers has the potential to impact the Chesapeake Bay eel fishery. Elver migration in the spring is blocked by dams and other obstructions.

Strategy 1.1
The jurisdictions will adopt a conservative management approach until stock assessment analyses have been completed for American eels in the Bay.

Action 1.1
A) Maryland and the Potomac River Fisheries Commission will adopt a minimum size limit of 6 inches for American eels in the Bay.
B) Virginia will continue its prohibition on the taking of elvers and will adjust its definition to correspond to a 6" minimum size limit.

Implementation 1.1
A) 1992 B) 1992

Action 1.2
A) Maryland will implement a 1/2 x 1/2" minimum mesh size for eel pots.
B) Virginia and the Potomac River Fisheries Commission will continue to enforce a 1/2 X 1/2" minimum mesh size for eel pots. Virginia will continue to enforce the escape panel requirements in 1/2 X 1/2" mesh pots.

Implementation 1.2
A) 1992 B) Continue

Action 1.3
Upon restoration of American eels to the Susquehanna River basin, the Pennsylvania Fish Commission (PFC) will adopt regulations to prevent the overharvest of small eels.

Implementation 1.3
Dependent on restoration.

Problem 2 - American Eel Bait Fishery: In the Maryland portion of the Chesapeake Bay, the use of eels for crab bait is a major source of fishing pressure on the population. The harvest of American eels for crab bait has not been completely recorded in catch statistics. Estimates of eels harvested for bait and used by commercial crab trotliners range between 700,000 and 1,700,000 pounds per year. The quantity of "pencil eels" (eels larger than 6" and less than 10") used for finfish bait by recreational fishermen is unknown but has the potential to increase. Accurate catch statistics are necessary for assessing the status of eels in the Chesapeake Bay.

Strategy 2 - American Eel Bait Fishery: Catch and effort information from the American eel bait fishery is important for the development of management measures for the eel stock in the Bay. The jurisdictions will monitor the crab bait fishery to obtain catch and effort data.

Problem 2.1
The American eel crab bait fishery in Maryland has been estimated at three to five times that of the reported eel harvest for the live-eel fishery but is not completely reported in the catch statistics.

Strategy 2.1
Catch and effort statistics for the American eel crab bait fishery will be obtained.

Action 2.1
Maryland will require the reporting of American eels used for the crab bait fishery on their mandatory finfish reporting forms.

Implementation 2.1
1992

Problem 3 - Research Needs: Basic stock assessment data is lacking for American eels in the Chesapeake Bay. Size and age composition, maturity, growth rates, mortality rates, and estimates of abundance are not available. Currently, there is a limited amount of fishery dependent and fishery independent data. The price of eels used for bait has increased over the past few years, however, very little is known about the economic value of the bait eel fishery and how it affects harvest practices. Lack of biological and socioeconomic information complicates effective management.

Strategy 3 - Research Needs: In order to better understand the American eel resource in the Chesapeake Bay, research projects will be promoted to address the deficiencies in biological and socioeconomic data.

Problem 3.1
There is a lack of basic biological and fisheries data necessary for effective management of the American eel resource in the Chesapeake Bay.

Strategy 3.1
The jurisdictions will increase their understanding of the American eel resource in the Chesapeake Bay. Important research topics include but are not limited to the following: fishery independent estimates of abundance; mortality rates; the effects of fishing exploitation on growth; the factors that influence recruitment in the Bay; and how economic aspects affect the eel fishery.

Action 3.1
A) Maryland and Virginia will continue to collect catch and effort data from the live-eel fishery and begin monitoring the bait eel fishery.
B) PRFC will continue to collect catch and effort data from their commercial fishery.

Implementation 3.1
A) Continue B) Continue

Action 3.2
Maryland, the Potomac River Fisheries Commission, and Virginia will encourage research to collect basic biological and socioeconomic information.

Implementation 3.2
1992

Problem 4 - Habitat and Water Quality Issues: American eels are generally considered a "hardy" species since they inhabit a broad array of habitats and occur over a wide range. Upstream habitat in many areas of the Chesapeake Bay system is inaccessible to migrating eels because of dams and other blockages. Eels prefer well-oxygenated areas and are essentially bottom dwellers. Anoxic water probably affects distribution and inhibits growth. The condition of bottom sediments and substrates is important. Disturbances to the bottom habitat will also affect eel distribution. Tolerance to pollutants varies with different life stages. Long-term exposure to pollutants and toxic substances can interfere with metabolic processes.

Strategy 4 - Habitat and Water Quality Issues: The jurisdictions will continue their efforts to improve water quality, habitat, and provide fish passage for living resources in the Bay.

Problem 4.1
Water quality and stream impediments impact the distribution and abundance of finfish species in the Chesapeake Bay.

Strategy 4.1
The District of Columbia, Environmental Protection Agency, Maryland, Pennsylvania, the Potomac River Fisheries Commission, and Virginia will continue to promote the commitments of the 1987 Chesapeake Bay Agreement. The achievement of the Bay commitments will lead to improved water quality and enhanced biological production. In addition, the jurisdictions have committed to providing upstream passage for migratory fishes.

Action 4.1
The jurisdictions will continue to provide for fish passage at dams, and to remove stream blockages wherever necessary.

Implementation 4.1
Continue

Action 4.2
The jurisdictions will continue to set specific objectives for water quality goals and review management programs established under the 1987 Chesapeake Bay Agreement. The Agreement and documents developed pursuant to the Agreement call for:

A) Developing habitat requirements and water quality goals for various finfish species.
B) Developing and adopting basinwide nutrient reduction strategies.
C) Developing and adopting basinwide plans for the reduction and control of toxic substances.
D) Developing and adopting basinwide management measures for conventional pollutants entering the Bay from point and nonpoint sources.
E) Quantifying the impacts and identifying the sources of atmospheric inputs on the Bay system.
F) Developing management strategies to protect and restore wetlands and submerged aquatic vegetation.

G) Managing population growth to minimize adverse impacts to the Bay environment.

Implementation 4.1
Continue

CHESAPEAKE BAY
AMERICAN EEL MANAGEMENT PLAN IMPLEMENTATION

PROBLEM AREA	ACTION	DATE	RESPONSIBLE AGENCY & METHOD	ADD. STAF or $$	COMMENTS/NOTES
1. Stock status	1.1 MD & PRFC will adopt a 6" minimum size limit. VA will continue to prohibit the taking of elvers and adjust definition to correspond to a 6" minimum size limit.	1992	MDNR - A,R PRFC - A,R VMRC - A,R		Until information is available on optimizing yield per recruit, the 6" minimum size will prevent the development of an elver fishery.
	1.2 MD will implement a 1/2 x 1/2" mesh size for eel pots. VA & PRFC will continue to enforce their 1/2 X 1/2" mesh. VA will continue to enforce escape panels in 1/2 X 1/2" mesh pots.	1992 Continue	MDNR - A,R PRFC - R VMRC - R		There will be reluctance in accepting a minimum mesh size by the bait eel harvesters.
	1.3 Upon restoration of eels to the Susquehanna River basin PFC will adopt regulations to prevent overfishing of small eels.		MDNR - A PFC - A,R PRFC - A VMRC - A		Providing fish passage will make American eel habitat more accessible and benefit the Bay population.
2. Bait fishery	2.1 MD will require the reporting of eels used for crab bait on reporting forms.	1992	MDNR - A		This is an improvement in reporting. However, crabbers catching and using eels for their personal use still are not required to report.
3. Research needs	3.1 Continue to collect catch and effort data from live-eel fishery and begin monitoring crab bait fishery.	Continue	MDNR - A PRFC - A VMRC - A	$100K	Will need to develop a monitoring approach for the bait eel fishery. Basic stock assessment & biological monitoring is needed.
	3.2 Encourage research to collect basic biological and socioeconomic information.	1992	MDNR - A PRFC - A VMRC - A		Requires coordination with other agencies and universities.

American Eel Management Plan Implementation (cont'd)

PROBLEM AREA	ACTION	DATE	RESPONSIBLE AGENCY & METHOD	ADD. STAF or $$	COMMENTS/NOTES
4. Habitat and water quality issues	4.1 Continue to provide streamset passage. 4.2 Continue to set specific objectives for water quality goals and habitat requirements	Continue	DCFM - A MDNR - A PFC - A PRFC - A VMRC - A		Requires coordination among agencies.

Legend:
DCFM = District of Columbia, Fisheries Management
MDNR = Maryland Department of Natural Resources
PFC = Pennsylvania Fish Commission
PRFC = Potomac River Fisheries Commission
VMRC = Virginia Marine Resources Commission

A = Administrative action
R = Regulation
L = Legislation
K = $1,000