Chesapeake Executive Council

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Stock Assessment Plan

Chesapeake Bay Program

Agreement Commitment Report

July 1988

Stock Assessment Plan

An Agreement Commitment Report from the Chesapeake Executive Council

Annapolis, Maryland
July 1988

ADOPTION STATEMENT

We, the undersigned, adopt the **Chesapeake Bay Stock Assessment Plan**, as developed by the Chesapeake Bay Stock Assessment Committee, in fulfillment of Living Resources Commitment Number 2 of the 1987 Chesapeake Bay Agreement:

> *"...by July, 1988, to develop, adopt and begin to implement a Bay-wide plan for the assessment of commercially, recreationally and selected ecologically valuable species."*

The Plan proposes improved means of assessing stocks of finfish and shellfish in the Chesapeake Bay. It identifies outstanding data needs for stock assessment models for Bay fisheries. Recommendations include improved ways to collect catch, effort, and biological data from commercial and recreational landings, in addition to long- term surveys for estimating relative abundance of important species in all regions of the Bay and its tributaries. There are recommendations in the Plan for studies of early life stages designed to examine natural and human-caused sources of mortality and to investigate biological effects of pollution, habitat loss, and disease.

The data collected in the recommended trawl and seine surveys will be used by the stock assessment groups to develop short-term management related information and by monitoring groups to track long-term trends. These stock assessments will be used in the development of fisheries management plans due for thirteen species between July 1989 and 1992.

We agree to support the Plan's recommendations for new efforts to collect basic, short- and long-term data, consistent Bay-wide, that are essential for stock assessment and monitoring. We recognize the need to commit financial and human resources to the task of developing and implementing the recommendations of the plan. Finally, we direct the Chesapeake Bay Stock Assessment Committee to prepare annual reports detailing the progress made in implementing the Plan's recommendations.

For the Commonwealth of Virginia

For the State of Maryland

For the Commonwealth of Pennsylvania

For the United States of America

For the District of Columbia

For the Chesapeake Bay Commission

FOREWORD

We, the undersigned, adopt the Chesapeake Bay Stock Assessment Plan, as developed by the Chesapeake Bay Stock Assessment Committee, in fulfillment of the living resources commitment:

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The data collected in the recommended trawl and seine surveys will be used by the stock assessment groups to develop short-term management related information and by monitoring groups to track long-term trends. Stock assessment information will also be used in the development of fisheries management plans, scheduled for completion for 13 species between July 1989 and 1992.

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ACKNOWLEDGEMENTS

The development of this plan has been a cooperative effort of the Chesapeake Bay Stock Assessment Committee (CBSAC) and its coopted experts. The following scientists authored sections of the Plan: Herb Austin, Erik Barth, Chris Bonzek, John Boreman, Bess Gillelan, Dick Hennemuth, Marta Nammack, Mike Prager, Louis Rugolo, and Cluney Stagg. Chapter 2 is an edited version of the soon to be released Status of Stock Knowledge report which was edited by Herb Austin and authored by members of the CBSAC SOSK working group. The Plan was edited by Erik Barth. Special thanks are due to Dick Hennemuth, Bess Gillelan, and Verna Harrison for guiding the Plan through the development and adoption process. The remainder of the Committee assisted substantially through their review and comment on the Plan. The membership of the committee is as follows:

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Bess Gillelan, NOAA EPO	--
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EXECUTIVE SUMMARY

In recognition of the important values - economic, recreational, ecological, aesthetic, symbolic - that are attributed to Chesapeake Bay living resources, the 1987 Chesapeake Bay Agreement contains an entire category of commitments related to restoring and protecting the Bay's living resources. The Chesapeake Bay Stock Assessment Plan responds to one of these commitments:

By July 1988, develop, adopt, and begin to implement a Baywide plan for the assessment of commercially, recreationally, and selected ecologically important species.

The Plan was developed by the Chesapeake Bay Stock Assessment Committee, a federal/state committee sponsored by the National Oceanic and Atmospheric Administration (NOAA). Membership includes scientists and resource managers from Maryland, Virginia, Pennsylvania, the District of Columbia, NOAA National Marine Fisheries Service and Estuarine Programs Office, and the US Fish and Wildlife Service.

This summary highlights the conclusions and recommendations of the Stock Assessment Plan.

BACKGROUND

Stock assessment is the interpretation of fish population data for describing the status of fish stocks and for predicting the results of fishery management options. Stock assessment analyses take population characteristics such as growth, mortality, and reproduction and relate them to controlling factors which include fishing pressure and environmental distress such as climatic fluctuations, pollution, and habitat degradation.

Maryland, Virginia, and the District of Columbia have all been conducting stock assessments on selected species, but many of the ongoing programs are limited in terms of geographic coverage and range of species. The Plan concludes that existing programs do not constitute a comprehensive stock assessment program for the Bay and its tributaries. In response, the Plan recommends the cooperative development of routine, systematic assessments in conjunction with cooperative, long-term data collection programs for the Bay's fishery species.

WHAT DO WE KNOW ?

Chapter 2 of the Plan describes present knowledge of several representative Chesapeake Bay finfish and shellfish species. For some species, such as menhaden, there is adequate information upon which to make informed management decisions. Other species, such as the oyster, have not received the level of attention their importance would seem to warrant.

For the most part, the programs in the Plan have not been described in a species specific manner, since it was felt that this would be the most effective means of depicting the needs of stock assessment. Specific requirements for individual species will be reviewed in a document entitled, Status, Trends, Priorities, and Data Needs for Chesapeake Bay Fisheries, to be produced during the summer of 1988.

DATA NEEDS

In general, there is sufficient basic biological information for many species, but little reliable catch, effort, and recruitment data is available. This deficiency is significant because these data are the major types of information required for stock assessment analyses.

Stock assessment data needs include improved catch data, fishing effort data, and biological data (length, age, weight, sex) from commercial and recreational fisheries. These three categories are called "fishery dependent" data.

"Fishery independent" data are also necessary so that unbiased information essential for stock assessments is collected on juveniles and adults. Fishery independent sampling does not rely on commercial or recreational fishermen for collecting fish and is conducted through standardized surveys, such as the Maryland beach seine survey which is used to estimate a juvenile index for striped bass.

Short-term intensive research is also needed to understand the environmental and biological processes that affect growth, mortality, and reproduction within fishery stocks.

The Plan calls for baseline fisheries data that are 1) collected with standard methods Baywide, 2) precise and accurate, 3) representative of the distribution and abundance of Bay species, 4) inclusive of all major species and their critical life stages, and 5) long-term in scope.

PROPOSED PROCESS FOR IMPLEMENTATION

Approximately 100 people are currently working on some aspect of stock assessment in the Bay region at over twenty organizations. Research, monitoring, and management programs that contribute to stock assessment spend about three million dollars per year; most of these funds ($2.5 million) are administered by federal agencies, in particular NOAA and the Fish and Wildlife Service. Coordination of personnel and financial resources will be a key goal for implementing the proposed Baywide data collection program and for conducting stock assessment analyses.

The Chesapeake Bay Stock Assessment Committee (CBSAC) was formed in 1985 to improve the coordination of technical stock assessment problems. The plan recommends that the Committee continue its coordination role and begin to oversee the active development of baywide stock assessments.

The major features of a Baywide stock assessment program and recommended dates of implementation are summarized as follows.

Fishery Dependent Programs: July 1989

Initiate a Baywide fishery statistics program to provide improved estimates of catch and fishing effort for each type of fishing gear and area of the Bay.

Outline procedures for collecting such data, to include the implementation of a trip-ticket system for commercial fishermen and more extensive recreational fisheries surveys.

Institute a program for obtaining species and age composition, as well as other biological characteristics of commercial and recreational catch.

Fishery Independent Programs: Spring 1989

Complete final design for a Baywide trawl survey to obtain fishery independent estimates of abundance and distribution.

Augment trawl survey with other sampling methodologies to obtain abundance indices for species and life stages not captured by the trawl survey, such as the ongoing beach seine surveys in Maryland and Virginia.

Develop research program to investigate the effects of the environment on juvenile fish and shellfish populations.

Coordinate these surveys and studies with the Chesapeake Bay Program Baywide Monitoring Program.

Stock Assessment Implementation: July 1988

Chesapeake Bay Stock Assessment Committee (CBSAC) will have oversight responsibilities for Baywide Stock Assessment.

Maintain CBSAC working group roles for reporting on status of Bay stocks, investigating analytical techniques, and data management.

Establish new stock assessment working groups on finfish, oysters, and blue crab to begin immediately with the evaluation of available data and proposed sampling programs.

Produce annual reports on the status of stocks, fishery statistics, and periodic Baywide stock assessment reports.

CHAPTER I. INTRODUCTION

BACKGROUND

Maryland and Virginia fisheries managers and scientists began meeting informally in 1979 to discuss ways of coordinating the collection of fisheries data information, prior to even the "Chaffee Amendment" of P.L. 89-304. Striped bass, shad and blue crab were targeted at that time as the most important species. From these informal meetings, a Planning Committee was appointed to formalize future efforts. Consequently, shortcomings in catch statistics, recruitment surveys, and data archiving were discussed, and recommendations for achieving appropriate Baywide statistical programs. A document, entitled Report of a Workshop on Chesapeake Bay Fisheries Statistics was generated, and the recommendations forwarded to the Bi-State Working Committee, chaired jointly by the Natural Resource Secretaries of the states of Maryland and Virginia, of the Chesapeake Bay Commission. These recommendations were later contained in a 1983 report entitled, Implementation of Recommendations on Chesapeake Bay Fisheries Statistics, and cited several needs and recommendations, relevant to the current NOAA Chesapeake Bay Stock Assessment Program, and included:

- That Maryland and Virginia develop adequate, quantitative, and coordinated fisheries data and information systems.

- That Maryland and Virginia design and implement a coordinated program of juvenile and adult monitoring and biological sampling.

- That Maryland and Virginia develop a compatible automated data base management system for catch, effort, and size distribution.

In 1983, the EPA Bay Report reiterated the importance of stock assessment as a means of providing information on living resources for water quality, as well as fisheries management. The EPA Report, Governors' Conference, and Bi-State Chesapeake Bay Commission recommendations made clear the need for Baywide fisheries stock assessment. Action on the part of the General Assemblies of Maryland and Virginia, stemming in part from the 1982 workshop recommendations, gave mandate to the regulatory and research agencies to develop such programs. In 1984, action by the Congressional delegations of Maryland, Virginia, and Pennsylvania resulted in the inclusion of $1.5 million for Chesapeake Bay resource assessments, oxygen depletion studies and fisheries statistics in the FY85 NOAA appropriation law, P. L. 98-411. As a result, NOAA generated its Chesapeake Bay Study Plan, and at the same time coordinated the formation of the

Chesapeake Bay Stock Assessment Committee (CBSAC). The committee is composed of scientists and managers from Maryland, Virginia, Pennsylvania, the District of Columbia, and the Federal Government (NOAA NMFS, NOAA EPO, and FWS). The membership of the Committee reflects the recognition that many of the Bay's fishery stocks cross jurisdictional lines within and beyond the Bay, and that appropriate assessment can only occur if the respective jurisdictions work cooperatively.

The CBSAC Terms of Reference state that it will undertake a program for the Baywide assessment of fishery resources which will partition the effects of fishing mortality, natural mortality, and contaminants on variation and trends in abundance. Specifically,the Committee will:

- identify and describe state and federal stock assessment programs;
- identify and describe additional data collection systems needed to characterize the future status of the stocks and explain their fluctuations;
- review fishery statistics needs and recommend programs to improve the current fishery statistics collection program;
- plan and integrate biological effects studies with stock assessments;
- recommend research projects; and
- provide guidance to Sea Grant to insure that low D.O. and other biological effects studies on fish and shellfish are supportive of stock assessment studies.

As of 1987, thirty research projects with total funding over 2.7 million dollars have been supported. The emphasis in 1985 and 1986 was on statistical interpretation of historical data and on the evaluation of various stock assessment sampling methods. The emphasis in 1987 was on fishery independent sampling throughout the bay, utilizing trawling.

The Stock Assessment Plan presents CBSAC's guidance for the development of a Chesapeake Bay stock assessment program. Many of the general recommendations of the Plan have been presented in the past. Although positive steps have been taken on past recommendations, progress has been slow towards the development of cohesive inter- and intra-state stock assessment programs. It is hoped that the completion of the plan and the continuation of the Chesapeake Bay Stock Assessment Committee will be the catalysts required to build a cooperative program.

The urgent need for baywide stock assessment is also acknowledged in the 1987 Chesapeake Bay Agreement through a commitment by the Bay's jurisdictions which reads:

"by July 1988, to develop, adopt, and begin to implement a baywide plan for the assessment of commercially, recreationally, and selected ecologically important species."

This agreement commitment reaffirms the need to develop a quantitative understanding of the relationships between environment and fisheries in order to understand how to appropriately rehabilitate the Bay.

GOALS AND OBJECTIVES FOR STOCK ASSESSMENT

Man's primary benefit from healthy fish, crab, clam, and oyster stocks is the continued capability of harvest for enjoyment, consumption, or profit. From this perspective, it is the fisheries manager's goal to assure sustained harvests. Likewise, one of the goals of environmental management is to provide adequate habitat quality to support living resources, which, in turn, would provide sustained harvests. In fisheries management the optimum level of sustainable harvest is determined through consideration of biological and socio-economic factors. Three simply stated objectives for meeting the goal of sustained harvest are (1) quantify biologically appropriate levels of harvest, (2) monitor current and future resource status for comparison to harvest objectives, and (3) adjust resource status if necessary and if possible through management. Stock assessment is a process that will contribute to all three management objectives.

In the Chesapeake Bay, the ability to accomplish any of the three objectives for meeting the goal of sustained harvest is limited by inadequate knowledge of the size of the stocks, their variability, and the effects of fishing and pollution on productivity and the recruitment of young fish. A major constraint with regard to materially improving the status of stocks is a lack of basic data usually available for fisheries as valuable as those of Chesapeake Bay. To rectify this problem it is necessary to define stock assessment programs both within and among the states that obtain required data and specifically address questions which must be answered to achieve better fishery and habitat management decisions.

WHAT IS STOCK ASSESSMENT ?

Fishery stock assessment refers to the process of compiling and interpreting available and relevant information on the fish stock in question. The objective of this process is to produce an accurate statement detailing the status of the stock (so far as the data allow), to inform the decisionmaker of options for management and to predict possible consequences of resource management strategies. Consideration is given to the population dynamics of the stock, particularly growth, mortality, and recruitment processes, and how fishing (or other anthropogenic activities) affects any or all of these. Principal points to note about stock assessments are the following: (1) they are an attempt to describe the status of a fish stock and the associated fishery; (2) they range from accurate measures of the status of a stock to subjective estimates, and (3) they require fishery, biological and sometimes economic data, often long time series, to provide the knowledge base necessary for fishery management decisions.

Using a liberal definition of stock assessment, Maryland, Virginia and the District of Columbia have been conducting stock assessments on a number of important species. Many ongoing programs are limited in scope in terms of species and geographic coverage and are primarily geared toward collection of data rather than analysis. With these shortcomings it can be argued that existing programs do not constitute a comprehensive stock assessment program for the Chesapeake Bay and its tributaries, neither in individual jurisdictions nor in a Baywide context. A program suggests routine, systematic assessments based on precise and timely data. At the very least, these data must include catch and effort from each component of fishing, and biological data to include length-frequency (or age-frequency) and sex ratio observations. For the most critical species, fishery independent (scientific survey) information on abundance and other stock parameters will be necessary.

A commitment to a long term, coordinated program for the collection of these data is a necessary part of any stock assessment program. While the objective of such a commitment may be more closely aligned with the implementation (or potential implementation) of management regulations, the activity still constitutes biological monitoring. Depending on the management issues and biological events involved, information from an environmental monitoring program may also be useful in stock assessment; as such close coordination of the stock assessment and monitoring programs in the Chesapeake Bay is important. If anything the coordination will avoid duplication of effort and inefficiency, and enable the collection of data that would be better suited for analyses. Close coordination will also enable the collection of a broader range of information than would be possible by each program individually. For these reasons this plan is coordinated with the activities of the Chesapeake Bay Program. Furthermore, the recommendations of this plan concerning fishery independent and fishery dependent data collection serve as the basis for the component of the Chesapeake Bay Biological Monitoring Plan for bay finfish and shellfish species.

CHAPTER II. CHARACTERISTICS OF SELECTED BAY FISHERY SPECIES

Chesapeake Bay fishery resources may be categorized several ways according to their life cycle, fishery, or management protocol. Further, finfish and shellfish are separated in a similar fashion. Of significance for management and fisheries alike, is the fact that there are few finfish fishery species that are year-round Bay inhabitants. Even the Chesapeake Bay striped bass, after reaching sexual maturity, is a seasonal visitor. Most commercial and recreational finfisheries harvest seasonal transients that migrate across coastal states' boundaries into varying management regimes. Managing and assessing such transients is far more complex than the management and assessment of a year-round resident.

Some representative categorizations are as follows:

- Anadromous spawners vs ocean spawners vs bay spawners
- Grazers vs apex predators
- Commercial vs recreational vs ecological importance
- Fishery (pound net, hook and line, hand tongs)
- Natural recruitment vs human-aided recruitment (hatchery releases, seed transplants)
- Mobile (crabs) vs sessile (oysters)

Generally management and often assessments, are species specific. The joint gubernatorial directive to develop Baywide FMP's is on a species by species basis. This approach to management is pragmatic and logistic and is probably the best current system to use. Attention should also be directed to the possibility of developing management plans for multi-species fisheries by gear such as the pound net. Further, the non-harvested stocks of ecological importance such as the bay anchovy, silverside, killifish, opossum shrimp (mysid), and grass shrimp should be candidates for management. The Bay Program has focused, since its inception, on the habitat; and while the fishery managers need to concentrate their energy on control of the harvest to effect management, they must not lose sight of the importance of the habitat. Clearly in an estuarine system resource management by habitat-resource characterization is also a viable alternative.

The CBSAC stock assessment plan is a combination of fishery dependent and independent assessment programs directed toward providing data and information in support of management. Non-species specific trawl surveys and commercial/recreational catch sampling provide data for assessment models and FMP's. While stock assessments are needed for these broad species groups, (e.g. the ocean vs bay spawners, pound net catches, or commercial vs recreational harvest), in the final analysis, questions are directed to the status of stocks for individual species.

The 1983 EPA Bay Report described stock fluctuations in anadromous and ocean spawners in an initial attempt to look at cause and effect of the trends in these two "groups". The concept of grouping these stocks ecologically according to spawning areas is sound, and has a rationale that supports management. Ocean spawned fish may prove harder to manage than the Bay or river spawned species, as their recruitment and harvest are more strongly influenced by events outside of the Bay. Riverine species, on the other hand, spawn where Bay state managers have the potential to control both the environmental quality and harvest pressure.

Habitat requirements are a neglected categorization of fishery resources. Recruitment processes described above are different even though anadromous and ocean species are taken in the same nets at the same time. Anadromous spawners are influenced by river flow and rooted plant detritus forms the basis for their food chain. Abundance of ocean spawners, on the other hand, is influenced by offshore shelf wind shifts and these spawners derive their energy from the pelagic phytoplankton.

The Chesapeake Bay Program Living Resources Task Force developed a habitat characterization report in 1987 that identified our status of knowledge on resource habitats. The identified gaps were many and should provide the rationale for future research efforts on habitat-resource requirements. A concurrent effort by the CBSAC Status of Stocks Knowledge Work Group identified the types and sufficiency of our knowledge about the biology and population dynamics of the Bay species. The body of this report is contained in a species matrix (Figure 1) and a bibliography.

An examination of the matrix shows that for some species (e.g. menhaden) there is adequate information upon which to base informed management decisions. Other species such as the oyster have not received the level of attention their importance would seem to warrant. Further, the matrix shows that for most other species we have sufficient basic biological information, but that in the area of population dynamics and catch/effort data little is available. This is a significant omission as they are the parameters in the various dynamic population models needed for the management decisions. Indeed, it would appear that another way of characterizing or categorizing species would be by our lack of knowledge.

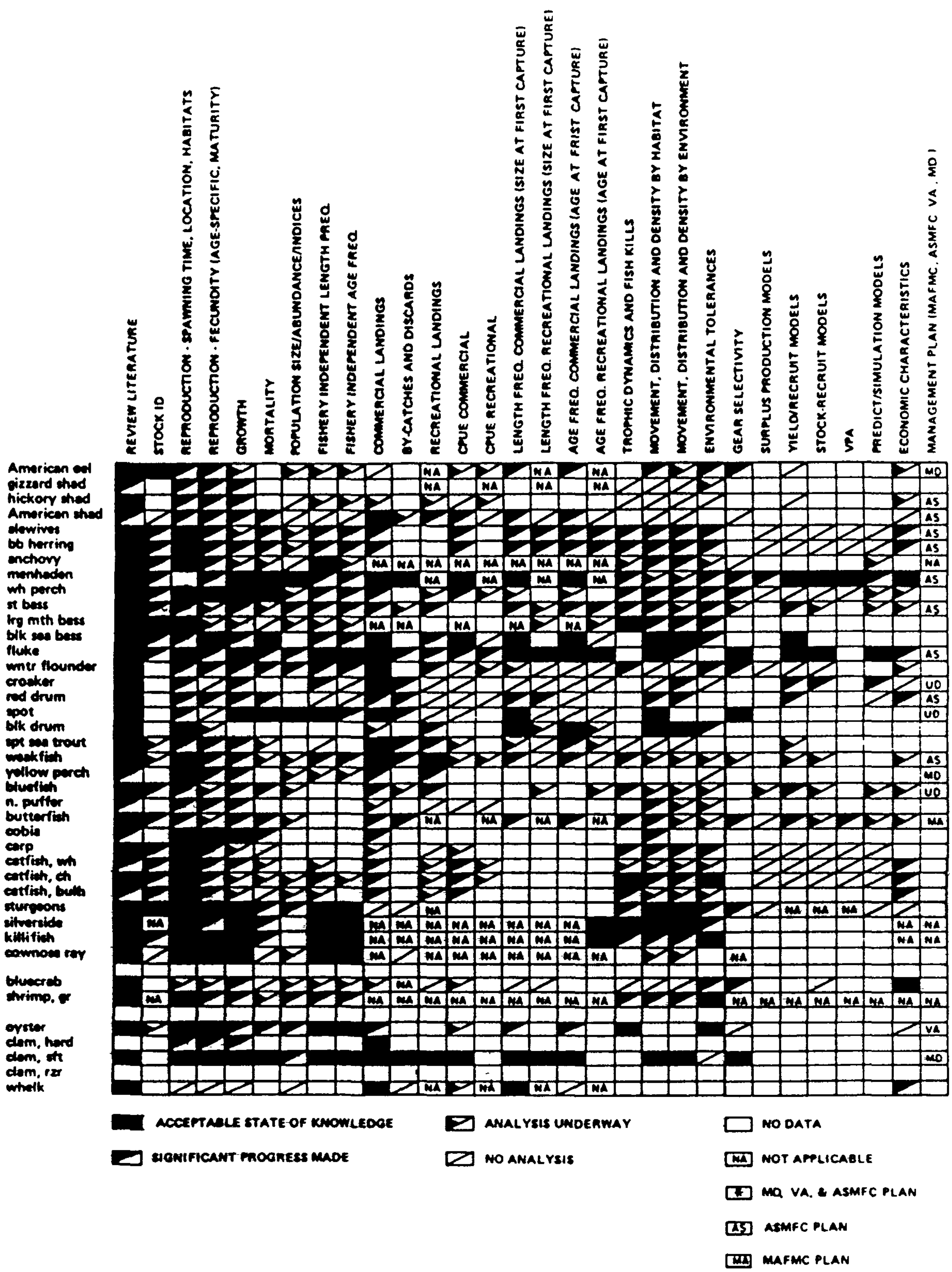


FIGURE 1. STATUS OF STOCK KNOWLEDGE (CBSAC SOSK WORKING GROUP, JAN 1988)

An annual assessment of the status of the Bay stocks is an objective of CBSAC. This will be contained in an annual Status of Stocks (SOS) report patterned after the NEFC Status of Stocks Report produced since 1976. The SOS report will include both a biological status of the stocks, an analysis of the fishery during the previous year, and a report on the status of our knowledge. The status descriptions for several important species that are contained in the SOS report follow on the next several pages.

AMERICAN SHAD, *Alosa sapidissima*

The American shad (*Alosa sapidissima* Wilson) is an anadromous member of the herring family which ranges from southern Labrador to northern Florida on the Atlantic coast. Its spawning and nursery grounds are located in estuaries and rivers. Shad rear in their river of birth for their first summer, then migrate to the ocean, and eventually return to their natal rivers to spawn about three years later.

The American shad has been a popular and heavily fished species valued for its flesh and roe for at least the past two centuries in Atlantic coastal areas. Shad catches peaked in Maryland in 1890, then declined until 1942. A period of relative recovery in the 1950's followed, especially in Maryland. However, by 1980 stocks in Maryland were so low the fishery in Maryland was closed indefinitely, with reported harvests having decreased from 184,221 pounds in 1971 to 14,319 pounds in 1979. While such a catastrophic reduction in catch (and presumably abundance) has not yet occurred in Virginia, the trend in catch over the last ten years has been downward. From NMFS surveys the recreational landings were 61 and 65 percent by weight of the commercial catch on the Atlantic coast in 1965 and 1970 respectively. If the 1965 and 1970 surveys are approximately representative, it is obvious that sportfishing for American shad has been significant.

There are no reported results of standard production, yield-per-recruit or stock-recruitment models for American shad for the Chesapeake Bay. To be meaningful, these models require data that currently does not exist for Chesapeake Bay.

BLACK DRUM, *Pogonias cromis*

The black drum, *Pogonias cromis* (Linnaeus), ranges from Nova Scotia south through the Gulf of Mexico to Argentina. It is most abundant along Texas, but is common along the Atlantic coast from Chesapeake Bay to Florida. The black drum is the largest member of the family Sciaenidae along the Atlantic coast, attaining a maximum weight of 66.28 kg (146 lbs).

Black drum enter coastal waters of Virginia during early to mid-April, presumably migrating from offshore areas south of Chesapeake Bay. Recreational fishermen begin to catch black drum during early to mid-May in the lower portion of the Bay and throughout the Bay as the season progresses. Adults migrate southward and offshore by late fall.

Larval black drum utilize tidal currents to enter nursery areas located in the mid to upper marsh areas throughout Chesapeake Bay. Juvenile black drum have been reported to enter Chesapeake Bay following the adults and disperse throughout the Bay.

A question still exists as to whether black drum spawn in Chesapeake Bay. A 1961 paper stated that spawning did not take place in Chesapeake Bay because no larval black drum were found. A later study identified black drum eggs obtained from Chesapeake Bay near Cape Charles City, but failed to delimit the area of spawning. They concluded that spawning occurred along the seaside of Virginia's Eastern Shore and the mouth of Chesapeake Bay. Ripe males and partially spent females were observed in Virginia waters during spring and early summer. This led to the conclusion that spawning probably took place near the mouth of the Chesapeake Bay. Spawning apparently occurs from early April through mid-June, when water temperature is about 17.5^{o}C (63.5^{o}F).

Black drum from the Gulf of Mexico reach maturity by the end of their second year, at standard lengths (SL) of 285-330 mm (11.2-13.0 in). Age at maturity of black drum is unknown from along the Atlantic coast. Fecundity data for this species is lacking as well; however, a 1929 study estimated that a ripe female 1.1 m (43.3 in) in total length (TL) from the Gulf of Mexico contained approximately 6,000,000 eggs.

Commercial landings of black drum in Virginia have averaged approximately 30,000 pounds for the past fourteen years. Prior 1972, landings for the Chesapeake Bay area ranged from 60-481,000 pounds.

The increased popularity of black drum as both a food and game fish has brought this species to the attention of various regulatory agencies. A minimum size limit for black drum has been set by the VMRC at 16 inches TL. Commercial harvesters and buyers are required to submit daily harvest information to the VMRC, and anyone buying, or catching and selling black drum are required to obtain a Commercial Harvest Permit.

BLUEFISH, (Pomatomus saltatrix)

The bluefish (Pomatomus saltatrix Linnaeus) is a migratory, pelagic species which is distributed worldwide in the shelf waters of temperate and warm-temperate latitudes. In the western Atlantic it is found from Nova Scotia to the Gulf of Mexico, and is particularly common in the Middle Atlantic Bight especially from spring to fall. Bluefish are ravenous carnivores that prey on a wide variety of invertebrates and vertebrates throughout the water column.

Most bluefish mature by two years of age; males perhaps at a smaller comparative weight. Sex ratios of spawning stocks are approximately equal, as they appear to be at all other life phases. Evidence suggests that two principal spawning populations of bluefish exist along the Atlantic coast. Spawning occurs over the "open shelf" and larvae develop in surface waters. Major bluefish spawning sites in the Chesapeake Bight are located offshore over the outer half of the continental shelf, where water temperatures are 22^{o} C (72^{o}F) or greater and salinities are 31 ppt or greater. Initiation of spawning, as well as daily activity and swimming speed are determined in part by temperature and photoperiod. Year class success is postulated to be dependent on the circulation of the continental shelf waters; vertical or geographic position in the water column determine when and where eggs and larvae are transported.

Bluefish exhibit complex migratory patterns which are not well understood; apparently major differences between the migratory routes of the two principal spawning stocks do exist but further knowledge on migratory patterns is limited. Reported commercial catch of bluefish along the Atlantic coast dates to 1880. The peak reported commercial catch for the Atlantic coast was about 21 million pounds in 1897 which was followed by a period of low harvests. A trend of increased catches that began in 1960 was succeeded by significant increases in the mid-1970's, but reported harvests have since stabilized or declined slightly. From 1970-1982, reported Maryland commercial catches ranged from 1-6 percent of the reported Atlantic coast total of 4,715 tons (annual average); Virginia catches ranged from 10-40 percent.

Historically, the recreational catch of bluefish has been many times larger than the commercial catch; since 1960, the average distribution of removals along the whole Atlantic coast is estimated to have been 12 percent commercial and 88 percent recreational, based on reported commercial and estimated recreational catch. From 1979-1982, the estimated Chesapeake Bay recreational catch was 36 percent of the estimated mid-Atlantic bight recreational catch, which was in turn 52 percent of the estimated total Atlantic coast recreational bluefish catch of 59,421 tons (annual average).

During the 1970's, a small quantity of bluefish was taken annually by foreign fishing vessels (472,000 pounds maximum). Currently, bluefish may not be retained by foreign fishing boats. The Atlantic bluefish stock(s) seems to have increased in abundance in the past ten years. Evidence for an increase is based on the large increases in both reported commercial and estimated recreational catch, and on the results of Northeast Fisheries Center (NEFC) surveys, in which abundance indices (number of fish per tow) have generally increased during the same time period.

Since 1979, the MAFMC has been developing a bluefish management plan for the Atlantic coast stock(s), and since 1985 the ASMFC has been working on one for their interstate management. The plan allocates 20 percent of the total projected bluefish catch for a given year to the commercial fishery, 10 percent of which will be allocated to the New England area, 50 percent to mid-Atlantic area, and 40 percent to the south Atlantic area.

BLUE CRAB, *Callinectes sapidus*

The blue crab is a common inhabitant of near-shore waters of the Atlantic coast from New Jersey to Florida and along the Gulf Coast. The Chesapeake Bay is the center of abundance and produced 82.9 million pounds of hard crab, and 2.7 million pounds of peeler and soft crab with a total value of $31.2 million in 1986. This compares with total average annual Bay hard crab landings of 75 million pounds at $5.9 million from 1960 to 1970. Not only do these numbers account for over half the total landings for the entire east coast, but the Bay also provides almost all the United States supply of soft crabs.

Blue crabs mate in brackish water, generally mid-spring through summer, during which time they are called "doublers". After mating, the females make their way down the Bay to the higher salinity waters near the mouth of the Bay where they overwinter. The males remain year-round in the lower salinity waters further up estuary. During winter when temperatures are below 8° C (47° F), blue crabs bury in the mud or sandy bottom. It is at this time that the females in the lower Bay are taken by the winter dredge fisheries. Females carrying eggs are called "sponge crabs", and the eggs are extruded and hatch from mid-Spring through summer. At first the larvae swim feebly in the near-surface waters, but later descend to near-bottom waters. In the surface waters they are susceptible to being swept out of the Bay, but once in the bottom waters are transported up-Bay in the estuarine circulation of the "salt wedge".

The blue crab may live three years, but most only survive two years. Females mate when one year old during their terminal molt, and after spawning they neither molt nor grow. From May through September in their second summer they are captured and sold as peelers. Late in their second summer both males and females generally reach 5 inches carapace width, the legal minimum size in Virginia. Sponge crabs are protected when they enter the 130 square mile "crab sanctuary" at the mouth of the Bay from 1 June - 15 September, but may be harvested outside the sanctuary.

Prior to the 1940's baited trotlines were the main fishery in the Bay. Since then almost all hard crabs have been taken in baited crab pots, with the exception of the winter dredge fishery in Virginia that comprises some 15% of the Bay catch. The recreational catch is undocumented but is believed to be large. Peelers are captured by scrape, "peeler pots", or a staked net called a "peeler pound". Peelers are sold as bait for recreational fishing or held in floating cages until they molt and become soft crabs.

Management of blue crabs, whether by state or bistate regulation will be difficult, as the natural environment, more so than the spawning adult population size, plays the dominant role in establishing year class success. Consequently, with the primary factors regulating stock size not under the control of fisheries managers, effective fisheries management may be difficult.

ATLANTIC CROAKER, _Micropogonias undulatus_

The Atlantic croaker is a medium-sized member of the Sciaenidae family and ranges from Massachusetts to Mexico on the North American coast and from Surinam to Argentina on the South American coast. The species is most abundant, however, along the southeast coast of the United States and in the northern Gulf of Mexico. The Atlantic croaker is iridescent overall, greenish silver above and silvery white below. Numerous brassy or brownish spots form oblique wavy lines on the upper sides and back.

Adult croaker tolerate a wide range of temperatures, 2-30^{o} C (35-86^{o} F) and salinities (0-35 ppt), but the juveniles

prefer the lower salinity and oligohaline environment of the estuaries which serve as nursery grounds. Adult croaker, like other sciaenids, spawn in the waters of the continental shelf during the late summer and fall of their second year, but return to the estuaries during the following spring. Spawning occurs from August through December off the Chesapeake Bay and south to Cape Hatteras.
Although estimates vary, reported size and age at maturity suggests that Atlantic coast croaker are sexually mature when 3-4 years old. The smallest reported mature male and female were 24 cm (9.5 in) TL and 27.5 cm (11 in) TL, respectively. Eggs and larvae drift toward land until they are able to actively swim towards land and estuarine nursery areas where they remain until the following fall.

Atlantic croaker are believed to reach a maximum age of 7-8 years when they are >500 mm (20 in) TL. The species feeds on polychaetes, mollusks, mysids, decapods, other invertebrates, and occasional small fish.

The croaker is one of the most frequently caught species in estuarine and nearshore waters, particularly from March to October. Maryland and Virginia have generally accounted for the majority of the Atlantic coast croaker harvest. The Virginia catch has varied from a high of 25,000 mt in 1945 to a low of 3 mt in 1968, peaking again in 1977 with a catch of 3,900 mt before dropping once again. The 1986 harvest totaled only 1,034 mt.

Maryland's landings show a similar trend, but the relative catch was much smaller, the largest catch being 2,260 mt in 1944. The 1984 harvest totaled only 12 metric tons. Maryland currently imposes a 10 inch minimum size for the species. The Mid-Atlantic recreational catch, recorded since 1979, declined between 1979-1980, but has since steadily increased to 3,426 mt in 1984.

The abundance of Atlantic croaker seems to be closely related to climatic trends and fishing pressure. Warmer temperatures appear to favor the species as evidenced by increases in landings during the first part of the 20th century. Between 1958 and 1971, increased fishing pressure and cold winters reduced the Atlantic catch to <3,000 mt from 1961-1973. Subsequent increases and decreases in catch after 1973 seem to be correlated with fluctuations in the fishing effort and general temperature trends during that period.

AMERICAN EEL, Anguilla rostrata

The American eel, Anguilla rostrata (Lesueur) is a diadromous species found in coastal waters from Greenland and Northern Canada to the Gulf of Mexico and the West Indies. The species is also widely distributed in inland waters, including the Great Lakes, the Mississippi drainage as far as South Dakota and west to the Rocky Mountains.

American eels are believed to spawn between Bermuda and the West Indies, in the vicinity of the Sargasso Sea. Spawning occurs from February through June. The larval stage eel is called a leptocephalus. During the leptocephalus stage, which lasts one or two years, currents distribute the larvae in an apparently random manner along the Western Atlantic Coast. Transformation from the leptocephalus to the glass eel stage is complete by the time eels reach the coast. After arriving in coastal regions they gain pigmentation and are then called elvers. Within a few months elvers enter the yellow eel stage which lasts until sexual maturity is reached 5 to possibly 18 years later.

At the present time, eels are not a desirable recreational species, but commercial fisheries are carried out for both elver and yellow eel stages. In many areas, elvers are trapped and used for stocking lakes and reservoirs. Yellow eels are widely used as bait in the blue crab trotline fishery in Chesapeake Bay, and in recent years a live eel export fishery has developed. Although the American eel is an important commercial species, catch statistics are probably not a reasonable indicator of actual harvest levels because of a lack of reporting requirements and because of the nature of the fishery itself. For example, statistics for the elver fishery are not available, and only crude estimates of the yellow eel harvest used as bait in the blue crab fishery exist.

ATLANTIC MENHADEN, _Brevoortia tyrannus_

Atlantic menhaden, or bunker, is a member of the Clupeidae, or herring family. Although very similar to the alewife and shad in appearance, menhaden are distinguished by a mouth lacking teeth, and a dorsal fin located between the anal and pelvic fins. The body is bluish above and the sides are silvery with a reddish tint. A dark spot followed by several smaller spots is present on the shoulder.

Atlantic menhaden are a euryhaline species inhabiting bays, sounds and estuaries from Nova Scotia, Canada to West Palm Beach, Florida. The species travels in dense schools of 50-200,000 fish and makes extensive north-south coastal migrations. In the spring, menhaden travel north with larger, older individuals moving further north than the younger, smaller fish. During the autumn, Atlantic menhaden migrate southward where they are usually intercepted by fishing fleets off North Carolina.

Spawning occurs in different locations throughout the year. Menhaden become sexually mature usually between age 1 (8 inches) and age 2 (10 inches) with all capable of spawning by the third year. Fecundity estimates range from 38 to 631 thousand eggs for each female. The eggs float freely and hatch at sea, and wind and currents carry the larvae into sounds and estuaries where the young spend their first year. Phytoplankton and zooplankton serve as the major food source. Menhaden are an important forage for mackerels, Atlantic bonito, bluefish, striped bass, and weakfish.

Although not a desirable recreational catch, menhaden have been caught by commercial fishermen since the mid-1800's, and reports of their importance to the earliest colonists are frequent. The stock is concentrated in different areas along the Atlantic coast at different times of the year, and the fishing fleets follow them as they move.

Menhaden are caught by pound nets and gill nets year-round in the Chesapeake Bay. The use of purse seines is restricted. No purse seines are allowed in Maryland; while Virginia allows them, but only between the third Monday in May and the third Friday in November. Each year commercial fishermen land more Atlantic menhaden than any other fish in the United States. Since 1969, landings in the Chesapeake Bay - Mid-Atlantic region have varied from 150,000 metric tons (mt) in 1975 to 283,000 mt in 1980 when purse seine landings in this region represented 70% of the total Atlantic menhaden harvest. Since 1980, the Chesapeake Bay - Mid-Atlantic catch has averaged 240,000 mt.

Stock assessments in the Bay are conducted by NMFS-Beaufort.

AMERICAN OYSTER, Crassostrea virginica

The American or eastern oyster, Crassostrea virginica, builds intertidal reefs in higher salinity waters along the entire east coast of North America from the Gulf of St. Lawrence to the Yucatan and West Indies. In estuarine locations, where lower salinity water provides some refuge from predation, deeper subtidal reefs or "rocks" are common. Such oyster rocks are present throughout the shallow portions of the Chesapeake Bay and its subestuaries. The genus Crassostrea is notable for its tolerance to wide ranges of salinity, temperature, turbidity and oxygen tension.

Oysters are characterized by lateral compression of the body and the division of the shell into two halves (valves - hence the term bivalve) separated by a non-calcareous ligament. The valves are unequal and have no hinge teeth (except in the larval stage). The typically bivalve foot, byssus, and anterior adductor muscle are either much reduced or missing. Only the posterior adductor muscle remains in the sessile, attached adult form.

The genus Crassostrea is characterized by variably shaped (ecomorphic) shells. The adult usually rests in the left (cupped) valve; however, in dense reefs, oysters often orient vertically with both valves pointed upward. Internally, the mantle extends to the margins of the shell.

Ecological and physiological data suggest the presence of several physiological "races" of Crassostrea virginica along the eastern coastline of North America. Such "races" have, however, been actively mixed through fishery-related transplanting for at least a century -- especially so in the Chesapeake Bay. In experimental culture, C. virginica has been shown to hybridize with C. rhizophorae, the mangrove oyster, and C. gigas, the Pacific oyster.

The oyster is dioecious (separate sexes) but also exhibits protandry and protogyny (ability to change sex, male to female and female to male, respectively). Oysters can mature sexually at 2 to 3 months of age, usually in response to increased temperature and availability of food. Spawning is stimulated above a temperature which characterizes the aforementioned "race"of origin. This temperature may vary from 17 to 25^{o} C (63-77^{o} F) and increase progressively for more southerly "races."

Fertilization is external. The planktonic larvae are typically bivalve, filter feed predominantly on phytoplankton, and remain in the water column for 2-3 weeks depending upon salinity, temperature and food conditions. Larval behavior is complex and suspected to play an important role in retention in estuarine and coastal waters and selection of substrate for settlement and metamorphosis. Larvae exhibit gregarious settlement and specificity to hard substrate. These behavioral traits are central to the maintenance of oyster reefs or "rocks" as distinct biological and geological features.

Adult filter feeding activity is influenced by temperature, salinity and sediment load. A large oyster can filter several liters of water per hour. Consequently, oyster reefs or "rocks" are major components of sedimentary processes in estuarine and coastal systems.

Historically, the oyster reefs of the Chesapeake were much more extensive than present day. Inadequately controlled exploitation followed by decimation and essential elimination of significant Chesapeake Bay oyster stocks in higher (> 20 ppt) salinity seawater by MSX (a haplosporidium, Minchinia nelsoni) after 1960 has left a resource that is only a fraction of its original size. Continued intense disease and fishing pressure present little hope for expansion of the resource in the near future.

The market oyster season in Virginia and Maryland runs from 1 October through 31 March. A market oyster in Virginia and Maryland is 3" long.

Both Maryland and Virginia have extensive monitoring and research programs directed at understanding oyster biology. In spite of these efforts, little is known about the population dynamics of the stocks as they relate to management. While oyster biology shows a degree of similarity Baywide, there are many differences even between river systems. To be effective, management will have to be on a river-by-river basis.

ALEWIFE, Alosa pseudoharengus
BLUEBACK HERRING, A. aestivalis

The alewife, Alosa pseudoharengus, and the blueback herring, A. aestivalis, are anadromous members of the family Clupeidae, and collectively are referred to as alewife or gaspereau in Canada and as river herring in the United States. In both countries the commercial landings are reported as alewife. Collective reference to the two species stems from similarities in their appearance, times of spawning, methods of capture, and the juxtaposition of spawning grounds. The commercial catches are used primarily for bait, pet food, fish meal, and in Canada, a substantial portion of the catch is salted and exported for human consumption. Small, local markets exist for smoked river herring and fresh or canned roe.

The alewife and the blueback herring have a largely sympatric distribution. Alewives occur from Labrador and Newfoundland to South Carolina, while blueback herring range from Nova Scotia and northeastern New Brunswick to Florida. Adults are generally distinguished at capture on the basis of eye diameter, body depth, and peritoneum color. The diameter of the alewife eye is larger than the distance between the tip of the snout to the forward edge of the eye, but the two measurements are about equal in blueback herring. The alewife body tends to be deeper, and its peritoneum is pale (pearl-grey to pinkish white), sometimes with dusky spots (melanophores); in contrast, the blueback herring peritoneum is black but sometimes soot-grey with darker spots.

The onset of river herring spawning is related to water temperature; thus, it varies with latitude, and it may vary annually by 3 to 4 weeks in a given locality. There is considerable overlap in the spawning seasons of the two species. Spawning for alewife generally begins between 5 to 10° C and for blueback herring, between 10 to 15° C. Alewives begin to spawn 3 to 4 weeks earlier than blueback herring, but their peaks of spawning differ by only 2 to 3 weeks. In the Chesapeake Bay region the onset of spawning is about mid-March in Virginia streams and the last of March in Maryland streams. Both species return to sea shortly after spawning.

When spawned in flowing streams, river herring eggs (after the loss of adhesiveness) and larvae are transported downstream. In Chesapeake bay tributaries, juveniles (young-of-the-year) are distributed widely throughout tidal freshwater nursery areas in spring and early summer, but subsequently move upstream in summer with the encroachment of saline water. With decreasing water temperatures in the fall or early winter, the juveniles move downstream as a first stage of their seaward migration. Some juvenile Alosa will remain in deep estuarine waters through the winter.

First spawning by river herring occurs from ages 3 to 6, with the composition of virgin spawners strongly dominated by age 4 fish. In general, spawning stocks of river herring are comprised of ages 3 to 8. Males tend to dominate age classes 3 to 5, while females live longer and, thus, dominate the older age classes.

The male to female ratio throughout a season tends to favor males, about 2:1. Male domination of the sex ratio is probably due to a greater proportion of males maturing at ages 3 and 4. Males tend to dominate in the early runs, but the proportion of females increases (sometimes significantly) in the later runs.

There is considerable variation in the mean lengths at age reported for river herring. Part of the variation is undoubtedly natural, but part is due to different methods of back calculating lengths at age. In general, females of both species are larger than males, and alewives are somewhat larger than blueback herring. Most reported maximum total lengths range from 12.1-13.7 in (310 to 350 mm).

Very positive contributions to freshwater ecosystems can result from the presence of river herring. All life stages of both anadromous and landlocked river herring are important forage for many freshwater and marine fishes and, in addition, birds, amphibians, reptiles and mammals have also been documented as predators. Due to mortality on the spawning grounds, anadromous alewives were shown to be a nutrient source to a system rather than just a mechanism for nutrient regeneration.

RED DRUM, Sciaenops ocellatus

The red drum, Sciaenops ocellatus, is one of the 22 members of the drum family known for the drumming or croaking sounds produced by vibrating their swim bladders. The species is also known as channel bass, puppy drum (juveniles), spottail bass, and redfish. They are silvery-gray overall with a coppery cast. One or more black spots are present at the base of the caudal fin. The species is also recognized for the subterminal mouth and the lack of barbels on the chin.

Red drum range from Massachusetts to Key West, Florida, on the Atlantic coast but are not common north of New Jersey. They also inhabit the Gulf of Mexico from the southwest tip of Florida to Vera Cruz, Mexico.

Spawning takes place in nearshore ocean waters near passes and inlets. On the Atlantic coast spawning may begin as early as July and continue through December, or possibly as late as mid-February, peaking in late September or October. Sexually mature males are 18-20 in. (age 1+, 470-530mm FL). Females mature at ages II and III or 23-30 inches FL (575-760mm FL).

Problems with age determination techniques have prevented documentation of the maximum age for red drum. An estimate based on banding patterns on otoliths, however, suggested a maximum age of 33 years.

Crabs, shrimp, fish such as striped mullet, spot, pinfish, and pigfish compose the majority of the diet of adult red drum. Smaller individuals less than 3 in (75 mm) SL feed mainly on small bottom invertebrates and other juvenile fish.

Maryland-Virginia red drum are commercially harvested in estuaries and ocean water in a mixed species fishery by several gear types. These include haul seines, fish trawls, pound nets, gill nets, hand lines and trammel nets. Pound nets and fish trawls have claimed the majority of red drum caught in Virginia since 1977. Most of the fish are landed between May and October in Virginia and year-round from

North Carolina to Florida. The recreational fishing season in the Chesapeake Bay lasts from late April to November. In Virginia, recreational landings exceed the commercial. Current regulations in this state prohibit the possession of more than two red drum greater than 32 inches total length or any less than 14 inches TL.

Data on commercial landings of red drum have been collected since 1880 with Atlantic coast landings being consistently lower than those of the Gulf of Mexico. Red drum landings reached 83 mt in 1950. With the exception of 2 years, 1965 and 1983, Virginia landings have not exceeded 9 mt over the past 20 years.

SPOT, Leiostomus xanthurus

The spot is a member of the Sciaenidae, or drum family, which inhabits estuaries and coastal waters from Massachusetts to Mexico. They are distinguished from other sciaenids by the lack of chin barbels and by their silvery-gray body and 12-15 dark lines extending from the dorsal fin to the lateral line. A prominent black spot about the size of the eye is located behind the gill cover.

During the summer, spot are found in shallower waters from Delaware to Georgia. Later in the year they tend to move offshore onto the shelf edge from Cape Hatteras to central Florida where they remain throughout the winter. Spot generally tolerate a wide range of salinities (fresh to 37 ppt) and temperatures 2-35 C (35-95 F); however, long cold spells are known to cause extensive mortalities.

Spot spawn at sea in the fall and winter when water temperatures are between 59-79 F, although the spawning season is extended from September through November off the Chesapeake Bay. Most individuals on the Atlantic coast are sexually mature by the end of their second year or the beginning of the third year when they are 186-214 mm (7.0-8.5 in) TL. Data on fecundity are scarce, but fecundity estimates for spot 158-187 mm (6.0-7.5 in) SL range from 77,730-83,900. The estuaries serve as nursery grounds for the larvae. As they mature, the juveniles move up into less saline or fresh water where they remain throughout their first winter.

Spot grow rapidly during the first year attaining a length of 132 mm. Their reported maximum age is IV in the Chesapeake Bay and V near North Carolina. They feed on a variety of foods such as crustaceans, polychaetes, detritus, and small fish.

The spot is a popular catch for both recreational and commercial fishermen. A migratory species which travels in large schools, the spot is especially accessible to pound net harvest by commercial fishermen. Landing statistics since 1930 reflect great fluctuations in the harvest. In 1952, landings of spot reached a high of 14.5 million lbs. but have since varied between 3.9 million and 12.7 million lbs. The greatest proportion of the commercial catch comes from the Chesapeake Bay and South Atlantic regions, although since 1960 the South Atlantic states have dominated the fishery.

In 1949, the Chesapeake landings reached 8.7 million lbs., fell sharply in the 1960's, and peaked at 6.4 million lbs. in 1970. Maryland and Virginia landings in 1985 totaled 44,000 lbs. and 737,000 lbs., respectively. The estimated recreational catch along the entire Atlantic coast ranged from 13.3 million lbs. in 1980 to 4.1 million lbs. in 1984. Spot are one of the species that can be adequately sampled by a trawl survey.

There is no minimum size limit for spot in Virginia or Maryland.

STRIPED BASS, Morone saxatilis

The striped bass (Morone saxatilis Walbaum) or rockfish as it is commonly called in the Chesapeake Bay region is an anadromous species which ranges from the St. Lawrence River, Canada to the St. John's River, Florida on the Atlantic coast. Striped bass spawning in Chesapeake Bay occurs from April to June at (or near) the surface in fresh or slightly brackish water. Peak spawning activity is observed between 15^{o} C and 20^{o} C; however, salinity, turbidity, and temperature, as well as other factors affect egg and larval survival. Rockfish assemble in small groups before age two and thereafter generally travel in schools.

Little migration out of the bay occurs in striped bass before 3 years of age. Tagging studies and age composition data from the coastal fisheries indicate that most female striped bass migrate out of the Chesapeake Bay at about age 3; conversely, in Maryland, relatively few males ever migrate out of the region. The coastal migratory stock, believed to be typically dominated by rockfish of Chesapeake Bay origin, apparently moves along the Atlantic coast from New England to North Carolina. Movement is generally seasonal: north in spring, south in autumn.

The coastal migratory stock of striped bass has been characterized by the periodic entrance of a dominant year

class into the fishery. The last such year class in Chesapeake Bay occurred in 1970 and resulted in peak commercial landings in the coastal states in 1973. The reported commercial and recreational catch data, CPUE and the Maryland juvenile index all indicate that striped bass abundance in the Chesapeake Bay has suffered a continuous decline since 1973. The decline in landings since 1973 is probably attributed to a combination of three primary factors: (1) natural fluctuations, (2) overfishing, and (3) degraded water quality, including pollution and loss of spawning habitat. Maryland juvenile index data indicates that mortality in the fishable stock may have increased since the early 1970's, which may explain the observed shift in landings from 4 and 5 year olds to 2 and 3 year olds.
A coastwide management plan for striped bass was adopted by the Atlantic States Marine Fisheries Commission (ASMFC) in 1982. The ASMFC suggested that states enforce a 14 inch total length minimum size limit on striped bass in inland waters, and a 24 inch total length minimum size limit on the coastal fisheries. The plan further urged that major spawning areas or rivers be closed during the spawning season.

By 1987 the amendments to the plan called for a 95% reduction in mortality of 1982 year class females and subsequent year classes until such time as 95% of the females spawned. This resulted in a 24" Bay/31" ocean size limit in Virginia, and a 6 month closure to fishing (June - November). In 1984, based largely on the relentless decline in catch, reduced abundance of spawning females, and eleven years of below average reproduction, Maryland initiated a striped bass moratorium effective the beginning of 1985.

Currently, there are several positive signs of stock recovery. In Maryland, the number of 4 year old female spawners (1982 year class) sampled on the spawning grounds in 1986 was greater than any year since sampling began in 1982. However, indices of egg deposition exhibited only a slight upward trend in 1986, and the number of older females was found to be decreasing. A larger percentage of the 1982 year class will be mature in the spring of 1988 and will be joined by spawners of other year classes which have been protected.

The Maryland juvenile striped bass index of 4.8 improved slightly in 1987, but was still less than the long term historic average of 8.8 (the Interstate Fisheries Management Plan established a 3 year running average of 8.0 as one of the criteria that signals reproductive recovery). According to the Maryland Striped Bass Annual Report, a continuation of the Maryland striped bass moratorium will afford the current female spawning stock, and those that will eventually become mature, the protection from fishing mortality which they require. In Virginia the juvenile index continued to show an upward trend since reaching a low in 1980.

Adult striped bass are assessed when on the spawning rounds in Maryland using gillnets, and in Virginia from poundnet catches. Juvenile abundance is estimated each summer during directed young-of-the-year seine surveys in each state.

SUMMER FLOUNDER, Paralichthys dentatus

The summer flounder is a commercially important flatfish species that generally ranges from Cape Cod to northern Florida, with occasional capture north of Cape Cod. During the late spring to early fall, adults are found in coastal and estuarine waters, to as shallow as 1 m. Decreasing water temperatures and changes in photoperiod cue the annual fall migration of fish north of Chesapeake Bay to offshore spawning and wintering grounds on the middle and outer portions of the continental shelf respectively. Fish south of Chesapeake Bay spawn and overwinter on the inner/middle continental shelf.

Reproductive data from specimens collected on 1974-1979 NMFS bottom trawl surveys between Cape Cod and Cape Lookout indicate that most spawning occurs between October and February. Fish north of Chesapeake Bay spawn from September to December, whereas fish south of Chesapeake Bay spawn from November to February.

Eggs rise to the surface and are presumably transported by wind driven surface currents. Winds from the NW to NE are believed to cause the successful transport of larvae to estuarine nursery habitats. It has been suggested that the major nursery areas are in Virginia and North Carolina. Juveniles seem to prefer mesohaline/polyhaline nursery areas, where maximum growth rates occur. Juvenile summer flounder remain in estuarine and coastal waters until ages 2-3.

Summer flounder are fully recruited to the commercial fishery at ages 2-3. The optimal age at entry to the fishery is 5-7 years for females and 4-5 years for males.

Commercial landings in Virginia increased significantly in 1973 and have remained at a relatively constant level since then. The increase in landings may have been due to increases in fishing effort and fishing power in the offshore trawl fishery. Commercial landings in Maryland also increased in 1973 and remained at a higher level through 1979. Landings decreased substantially between 1981 and 1986. Recreational catch data, though not as extensive as commercial catch data, indicates that 45-70% of total U.S. summer flounder landings can be attributed to the recreational fishery. The recreational fishery has the potential to significantly impact the commercial fishery (coastal and offshore) because it catches younger fish prior to their recruitment to the commercial fishery. The minimum size limit in Virginia and Maryland is 12 in (30.5 cm).

Young flounder are first sampled in trawl surveys during their second year. Young-of-the-year which inhabit shallow vegetated areas are not susceptible to trawling gear.

WEAKFISH, *Cynoscion regalis*

The weakfish, *Cynoscion regalis*, also known as the gray trout or squeteague, is a member of the drum family, Sciaenidae, so named for the drumming sounds created by vibrating the swim bladder. The body is elongate and moderately compressed, olive above and silvery on the sides and underside. Dark blotches mark the upper body in oblique wavy lines. The dorsal and caudal fins are dusky, while the ventral, anal, and margin of the caudal fin are bright yellow. Two large recurved teeth are present in the upper jaw.

Weakfish are found in coastal waters from southern Florida to Cape Cod, Massachusetts, but are most abundant from New York to North Carolina. With rising water temperatures during the spring, weakfish migrate northerly and inshore into bays, sounds, and estuaries. During the fall and winter, the younger weakfish less than 4 years old move offshore and south, often as far south as Florida, while older fish move further offshore and only as far south as North Carolina.

Spawning, hatching, and larval development occur in nearshore and estuarine waters between March and October with peak production between late April and June. The mouth of the Chesapeake Bay is the major Virginia-Maryland spawning ground. Weakfish grow rapidly and are reported to reach a maximum age of 11 years old (approximately 11.6 pounds). Males reach sexual maturity when approximately 1 year old or 5-6 inches (130-150mm) SL, while females are slightly larger (145-190mm SL or 5.7-7.4 in) before attaining sexual maturity. The species is also highly fecund: a female 500mm (19.7 in) TL may produce over two million eggs at one time. Young gray trout feed primarily above the bottom on mysid shrimp and anchovies, while older individuals feed throughout the water column mostly on herrings, anchovies, silversides, other fish, and blue crabs.

Weakfish are a valuable commercial and recreational sport fish found along the United States east coast. Commercial catch statistics indicate that weakfish landings have fluctuated widely, increasing from a recent low of 1,397 mt in 1967 to 16,293 mt in 1980. Recreational landings also peaked in 1980 at 21,064 mt. In Virginia the commercial catch dropped from 6.2 million pounds in 1980 to 2.0 million pounds in 1986. The Maryland landings suffered a similar decline from 568,000 pounds in 1980 to 173,000 pounds in 1986.

Results of a weakfish stock assessment indicate that weakfish from Maryland to North Carolina may have experienced both growth and recruitment overfishing in recent years: however, these conclusions are uncertain due to weaknesses in the data set used in the analyses and lack of knowledge of weakfish stock structure.

WHITE PERCH, Morone americana

The white perch (Morone americana Gmelin) is a semi-anadromous schooling species found primarily in shallow, brackish waters, and ranging from Nova Scotia to South Carolina. It is most abundant from the Hudson River to the Chesapeake Bay. This species is both adaptable and broadly tolerant and hence is capable of dominating fish communities in both fresh and estuarine waters.

White perch migrate upriver to areas of low salinity for spawning after overwintering in deep, saline waters. Spawning occurs from late March through June, and has been found to peak at temperatures around 10 C in Chesapeake Bay. Following spawning, adults move downstream to brackish waters in the middle and lower estuary. Within the Chesapeake Bay, young white perch move progressively downriver as they develop from egg through juvenile stages. Evidence suggests that environmental factors including temperature, fresh water flow, dissolved oxygen, competition, and predation are related to survival of white perch larvae and early juveniles and subsequent establishment of year-class strength. The young grow rapidly during their first year, often reaching 40% or more of their maximum size. This rapid growth of white perch combined with production of large numbers of offspring and a wide environmental tolerance range has allowed the species to rapidly colonize new environments.

Historically, the white perch has been an important food fish in the Chesapeake Bay region. Annual landings are perpetually variable apparently due largely to climatic conditions.

YELLOW PERCH, Perca flavescens

The yellow perch, Perca flavescens, inhabit cool water lakes and reservoirs, coastal rivers, streams and low salinity estuaries from Canada to South Carolina. They have 6 or seven vertical black bands extending across the back and yellow to bright red pelvic and anal fins.

Males are sexually mature at 2 years of age, or about 5 in (12.7 mm) long, and females at 3 years or 6 in (15.2 mm). Spawning occurs in shallow water between March and April. A female may release from 3 thousand to 150 thousand eggs at a time. The eggs are deposited in a gelatinous strand which is left among vegetation and submerged branches.

Yellow perch may live up to 13 years and attain a weight of 4 pounds, but most are small and only 5-8 in (13-20 cm) long. Their diet is largely composed of benthic insect larvae, leeches, amphipods, crayfish, and small fish.

The yellow perch is a valuable sport and commercial species which is primarily encountered on its spring spawning run. The commercial fishery is centered in the upper Maryland Bay and freshwater reaches of the main-Bay tributaries. Commercial landings have undergone a dramatic decline since the 1880's when Maryland landings were estimated at over 1 million pounds. In 1985 Maryland landings had dropped to only 43,000 pounds. There are no minimum or maximum size limits in Maryland or Virginia at this time.

BAY ANCHOVY, Anchoa mitchilli

The bay anchovy (Anchoa mitchilli Valenciennes) is a widely distributed engraulid, found in coastal, estuarine and freshwater habitats along the Atlantic seaboard from Cape Cod to Yucatan, Mexico. Bay anchovy is one of the most abundant fish species in its range and probably is the single most abundant fish in Chesapeake Bay. It is a small species with a maximum size not exceeding 110 mm (4.33 in), and individuals larger than 90mm (3.54 in) are uncommon.

There is no commercial or recreational fishery for bay anchovy. Its small size and habit of aggregating in small schools make it an unlikely target for future fisheries. However, bay anchovy is an important forage species for predator fishes throughout its range. Predators include striped bass, bluefish, weakfish and summer flounder. Bay anchovy primarily feed on zooplankton and thus are an important link between primary producers and harvested predator species in many ecosystems, including the Chesapeake Bay.

Male and female bay anchovy mature at age 0+ when 35-40mm (1.4-1.6 in) in length. Spawning season varies with latitude, being more protracted in the southern part of its range. Most spawning in the Chesapeake region occurs from mid-May through mid-September. Spawning occurs over a wide range of salinities and temperatures (15-30 C). Eggs and larvae are abundant in both shelf and estuarine waters. They are the most common component of the Chesapeake Bay ichthyoplankton in summer months. Larvae hatched in May probably mature and spawn by mid-August, based on reported larval growth rates. Larvae that occur in Chesapeake Bay tributaries tend to be transported upriver. Entrainment and impingement of young bay anchovy in power plant intakes is a problem in the Chesapeake and other estuaries.

Causes for interannual variability in abundance and recruitment are little known, primarily because bay anchovy is not exploited. Long-term trawling surveys in the Virginia part of the Chesapeake Bay and egg and larvae abundances indices in Maryland have suggested major fluctuations in yearly abundance. Unlike more northern estuaries where bay anchovy migrate offshore in winter and have variable return rates the following spring, Chesapeake Bay populations overwinter in the Bay. Abundance of mature individuals in the Chesapeake region apparently is highest in late summer (August-September) when new recruits predominate.

The population dynamics are relatively little understood. Bay anchovy is short-lived; length-frequency and otolith (ear bone) analyses indicate that maximum age probably does not exceed 3+ years. Few individuals attain two years of age. Adult mortality rates seldom have been estimated. In the Delaware Bay during 1983, annual mortality was estimated to average 80.2%, based on mean daily rates. Fishery assessment models have not been applied because the species is not exploited. Considerable literature, both in published form and reports, is available on the dynamics of bay anchovy populations exposed to power plant entrainment and impingement effects.

KILLIFISHES, Fundulus sp.

The killifishes, principally the common killifish, F. heteroclitus, and the striped killifish, F. majalis, are common marsh and tidal creek nearshore species in the Bay and its tributaries. They inhabit areas that are often oxygen deficient in summer and exhibit large seasonal temperature extremes. During winter they bury in the mud. Spawning occurs during the spring on the spring tide. Eggs are deposited above the normal high tide where they develop and hatch the next month on the high spring tide. Killifish are omnivorous and are one of the most common forage for the blue, crested night, and green herons.

ATLANTIC SILVERSIDE, *Menidia menidia*

The Atlantic silverside, and its cousin, the Tidewater silverside, *M. berelina*, are common species along the entire Mid-Atlantic coast. The Atlantic silverside is common in higher salinities, and the Tidewater silverside in lower salinities; below 5 ppt only the Tidewater silverside is taken. In the Chesapeake Bay these two species are important forage for bluefish, striped bass and weakfish. They support no commercial fishery but are one of the most important ecological species in the Bay. The silverside spawn in the spring, laying demersal eggs that are attached to shoreline grasses. They grow rapidly reaching 60-80 mm (2.5-3 in) by the end of the first summer, and after spawning the following spring (April-May) reach 100 mm (4 in) before they die at 14-16 months of age.

In spite of their ecological importance they have not been studied as extensively as many other Bay species.

CHAPTER III. APPROACH TO STOCK ASSESSMENT

Chapter I describes general data needs for stock assessment; Figure 1, a summary of present knowledge, accentuates the many shortcomings in present data collection in the Bay and tributaries. To, remedy these shortcomings, CBSAC has devised a Baywide data collection program for fishery assessment and management (Chapter IV). In that program, long-term monitoring programs are supplemented with shorter-term surveys and special studies when needed to clarify stock characteristics. Data collection and analysis provide the basis for regular assessments of the status of each fishery. The assessments, in turn, help define the data that must be collected.

THE NEED FOR VALID LONG-TERM DATA

The most basic data needs of stock assessment (Figure 1) include (1) knowledge of stock identity in a biological sense; (2) estimates of growth and mortality rates; and (3) catch and effort statistics by age and area. For valuable species (especially short-lived species such as blue crab, to which some stock assessment models are less applicable), fishery independent indices of recruitment and spawning stock size are also essential.

Necessary characteristics of data for management include: (1) regularity--timely, periodic, and continuous data collection using standard equipment and procedures; (2) precision and accuracy in sampling and recording; (3) representativeness of the data, usually obtained through control of sampling regimes; (4) inclusiveness of the range of stocks throughout the Bay and tributaries, and (5) temporal continuity, the collection of long series of regular data over many years.

The pressing need for temporal continuity in the data arises from the life histories of the resource organisms. Most exploited species in Chesapeake Bay take two to ten years to reach sexual maturity, and then produce only one new generation each year. (Hence the expression "yearclass" refers to a generation.) Lengthy life cycles mean that detailed insight into population dynamics (of which an important component is variation in yearclass strength) can come only from analysis of data collected over years and decades.

PERSPECTIVES ON MANAGEMENT

Fishery assessment and management in Chesapeake Bay have often been directed at single stocks; however, several species (and therefore several stocks) are often taken in a fishery, even when only one species is targeted. Assessment of multistock fisheries generally begins, but should not end, with a thorough understanding of each component stock. Sufficient progress has been made in multistock assessment techniques to make them useful in management. Use of these approaches appears to be a logical step for contemporary fishery management in Chesapeake Bay.

Ideally, fishery managers regulate fishing to obtain the optimum sustainable benefit from the fishery. This optimum necessarily considers both biological and socioeconomic factors. However, the history of fishery management includes numerous cases of stock collapses when socioeconomic considerations were allowed to overrule sound biological advice. The collapse of the California sardine, the striped bass and American shad stocks of Chesapeake Bay, the Georges Bank herring, the Pacific mackerel, and the Atlantic salmon should speak clearly to us.

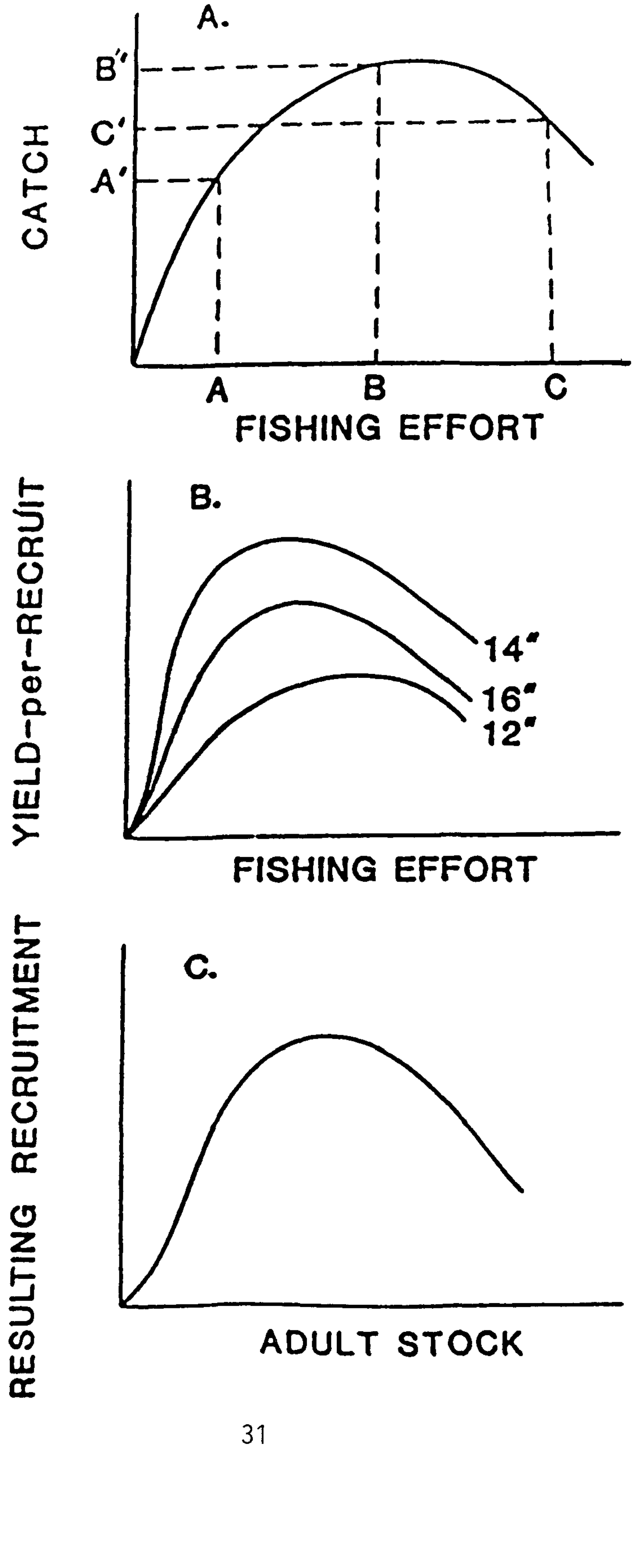
TYPICAL MODELS OF POPULATION DYNAMICS

In formulating scientific advice for management, fishery scientists often employ mathematical models of fish stocks. Although any model can only approximate the dynamics of a living stock, the models described below contribute greatly to our ability to understand population dynamics, formulate objectives, and estimate the risks and benefits of management strategies.

Surplus Production Models

The goal of surplus production models is to determine the maximum sustainable yield (MSY) obtainable from a stock or group of stocks. The model is based on a dome-shaped relationship between equilibrium yield (the amount of harvest that can be balanced by growth and recruitment) and fishing effort or stock size. The model's results are used to regulate effort or harvest. In the example shown (Figure 2A), fishing effort at point A results in equilibrium yield (labeled "catch") of A'. To maximize yield, the fishing effort is set at B, since any other effort level results in lower equilibrium yield. Overfishing occurs at point C, where increased effort results in lower yield. In an unmanaged fishery, fishing effort tends toward excess; in this example, effort in an unmanaged fishery might be at C, and the quantity B' - C' would represent lost potential yield.

FIGURE 2. CONCEPTUAL RELATIONSHIPS BETWEEN (A) CATCH AND EFFORT, (B) EFFORT AND YIELD-PER-RECRUIT, AND (C) STOCK AND RECRUITMENT (FROM ROTHSCHILD ET AL, AN ACTION PROGRAM TO DEVELOP A MANAGEMENT SYSTEM FOR CHESAPEAKE BAY FISHERIES, UMCEES-CBL-84-7)



Problems with surplus production models include the difficulty of knowing whether one is above or below MSY, the need for long series of data (preferably over 10 years and including years of sharply different population sizes), and statistical difficulties due to variability in the data.

Surplus production models require, at the least, time series of catch and effort data. In addition, time series of abundance can be used to improve their reliability. Although catch statistics are recorded for many species, neither effort nor abundance is regularly measured for most Bay species.

Dynamic Pool Models

Since recruitment fluctuates unpredictably from year to year, a common management tactic is to maximize yield per recruit; ie., to obtain the maximum yield in weight from any level of recruitment. With knowledge of a stock's growth and mortality characteristics, maximum yield per recruit can be obtained by regulating fishing mortality and the minimum age (or size) at capture. In Figure 2B, a minimum size of 14" gives the maximum yield per recruit; either a 12" or a 16" minimum reduces the yield. The optimal fishing effort for a chosen minimum size is also obtained. Regulating a fishery for maximum yield per recruit (or its variants) can increase yield substantially, especially for relatively long-lived species. However, since the model does not control the level of recruitment, the stock can become overexploited, even at optimum yield per recruit. The solution to this dilemma is to employ the dynamic pool model together with methods (or extensions of the basic method) to monitor and control stock size. Another difficulty is that the minimum size that provides optimum yield per recruit may be unacceptable for socioeconomic reasons.

Dynamic pool models require timely estimates of growth and mortality rates. These elementary data are not well known for most species in the Bay (Figure 1).

Virtual Population Analysis

Virtual population analysis (VPA) allows the scientist to retrospectively estimate recruitment and population size by analyzing age-specific catch data from preceding years. VPA can provide relatively accurate and precise estimates of population size. These, in turn, can be used as input to other models and to clarify the interpretation of such other models. VPA requires a medium to long-term series of catch-at-age data. Unfortunately, age-structured catch data have been collected for only one or two species in the Bay (Figure 1).

Models of Stock and Recruitment

Although tremendous variability tends to obscure the relationship, each year's recruitment is influenced by the spawning stock size; i.e., the number of parents. A simplified model of such a relationship is shown in Figure 2C. In management, it is crucial to conserve sufficient spawning stock to ensure the stock's persistence; this is best done through knowledge of the stock-recruitment relationship. Stock-recruitment models can also provide a framework for evaluating the effects of external factors, such as climate or habitat quality, on fish stocks. These models require medium- to long-term sets of stock size and recruitment estimates, which are not now available for most Bay species.

Other Models

CBSAC has instituted several retrospective analyses of Chesapeake Bay fishery data. Preliminary conclusions indicate that statistical techniques such as Box-Jenkins times series analysis and categorical regression may be useful, especially as they can easily include environmental factors that may affect stock dynamics. In addition, fishery scientists are constantly refining and adding to their collection of population dynamics models. However, the usefulness all models depends on the type and quality of data available.

CONCLUSIONS

It is clear from the above discussion that (1) fishery scientists have developed a respectable repertoire of tools (models) for the provision of scientific advice to managers, (2) the data needs of these models are quite well understood, and (3) any model requires regular and prolonged sampling to produce useful results. It is also clear that past data collection in the Chesapeake Bay region has often lacked the qualities needed: regularity, precision and accuracy, representativeness, inclusiveness, and temporal continuity. The sampling plans described in Chapter IV of this document represent attempts to improve this situation.

Since most models require several years' worth of data, it will be a number of years after the initiation of appropriate data collection programs before a complete, analytical stock assessment can be achieved. In the interim, stock assessments will rely primarily on historical information. As new information is added and modeling tools developed, the reliability of assessments will increase. During this phase of assessment development, the data that have been collected in Chesapeake Bay over past decades should be made available for the best possible analysis by the fishery science community as a whole. Although these data may have many shortcomings, their analysis is necessary to provide insight into the dynamics of our valuable living marine resources. Finally, it is important to emphasize that data collection and stock assessment activities are best partitioned by biogeographic, rather than political, boundaries. Fish stocks are not restrained by state lines; stock assessments can provide the best information if their data and analyses are similarly extensive.

CHAPTER IV. DATA COLLECTION PROGRAMS

The previous section emphasized the importance of appropriate data collection to the process of stock assessment. Many of the problems associated with our present assessment capabilities are caused by inadequate data. The following three sections on fishery dependent programs, fishery independent programs, and recruitment process studies will detail the type of improvements in data collection programs that are necessary for stock assessment.

Fishery dependent programs rely on the monitoring of commercial and recreational fisheries to determine trends in abundance, as well as describe the characteristics of fisheries. Fishery independent programs utilize statistically designed surveys to collect the data used for studying the dynamics of fishery stocks. Investigation of recruitment processes is accomplished through short term research projects and is intended to improve the interpretation of statistics collected by longer term programs. As such, all three programs should be viewed as a complementary and comprehensive means of monitoring fishery resources of the bay.

For these data collection programs a discussion of techniques is presented. It is important to emphasize that data collection programs will only be successful if they are supported by appropriate data management and analysis. The implementation chapter of this plan (Chapter 5) will discuss the integration of data collection, management, analysis, and documentation.

FISHERY DEPENDENT DATA COLLECTION

For the purposes of discussion, fishery dependent programs for commercial and recreational fisheries will be treated separately. Although data needs for both types of fisheries are essentially the same, the techniques for data collection are dramatically different due to the difference in number of commercial and recreational fishermen. (There are on the order of 10,000 commercial fisherman and 1,500,000 recreational fishermen fishing the bay each year.) This difference, as well as other reasons, requires different approaches to collection of statistics for commercial and recreational fisheries.

Commercial Fishery Statistics

Commercial fishery statistic programs involve the collection of the following four types of data:

- Catch; meaning the amount of fish caught, including fish killed and discarded during capture.
- Effort; meaning a measure of the amount of time and gear used to catch the fish.
- Biological parameters; meaning measures of length, weight, age and sex of harvested fish.
- Dockside value; meaning the amount of money paid to the fisherman for his catch.

Catch, effort, and biological data are among the primary inputs for most stock assessment models. Catch, effort, and value data are the primary basis for making many management decisions.

For both stock assessment and management the yearly statewide or regionwide estimates must be disaggregated by gear type, time (month or day) and water area. Many classical stock assessment models do not require disaggregated estimates of catch and effort. However, the ability to describe distribution is a necessary component of predictive and simulation models. For management, disaggregated estimates are absolutely necessary for evaluation of social and economic effects of proposed regulations.

Within the limits which allow for collection of necessary information, a commercial fishery statistics program should impose as little burden on the industry as possible. An unobtrusive system will have the best compliance and least possible economic impact. Compliance will also be increased by using a system which becomes a routine part of the industry's practices.

Implementation of an adequate statistics program is dependent on the appropriate legal, regulatory, and licensing structures. Management agencies must have the authority to collect the required information, to keep it confidential, and to provide penalties when data is not supplied. Without an adequate licensing system, it would be next to impossible to organize a good fishery statistics system. An ideal licensing system would require that each gear type to be licensed and each individual would be licensed separately for each gear type fished. For the bay region, adequate authority and licensing structures exist, however compliance and enforcement still pose difficult problems that must be faced. The implementation of revised harvest reporting procedures will offer a good opportunity for emphasizing improved compliance with reporting and licensing laws.

Estimation of numerous variables in an accurate, precise and timely manner, by species, year, month, day, water area and gear type involves tradeoffs among some desirable characteristics. For example, a system which estimates landings nearly in "real time" (as is necessary when quotas are involved) will not be as accurate or precise as other systems; or a system which produces disaggregated estimates will be more expensive than one which produces only a yearly estimate. For Chesapeake Bay fisheries, the highest priority for stock assessment and management is to design a program which will accomplish the following:

- Estimate landings and effort by species, year, month, gear type and river system.
- Estimate economic value by species, year, month, gear type and river system.
- Estimate length composition of the catch by year and month.

Additionally, it may be necessary to develop capabilities to develop more timely estimates. For some fisheries, year-end estimates are probably sufficient; for others, month-end are required; and for fisheries under a strict seasonal quota, estimates at the end of each week or even day would be necessary.

Measurement of Commercial Catch, Effort, and Biological Data

This section describes the units in which each of the data types should be collected. In some cases, the units are apparent (such as dollars for dockside value) while others may be less so. In some cases, the best units may change over time and space. Effort data is the most complex, with several different measures of effort being possible for each of several gear types.

Landings Estimates

These data are typically collected in units of weight (pounds) or volume (bushels) for commercial fisheries and numbers for recreational fisheries. Annual conversion factors between weight and numbers should be established from biological sampling of the catch.

Effort Estimates

For the most part, the required units are specific to each gear type. For some fisheries and some analyses, labor units such as man-days or boat-hours may be sufficient, but not ideal. The suggested "best" units for each gear type are as follows.

- Gill nets - net type (anchor, drift, stake), length, depth, thread size and time fished, by mesh size, for each day.
- Pound nets - mesh size of lead and pound, length of lead, and number of hours between catches.
- Fyke nets, fish pots, crab pots - mesh size and number of hours between catches.
- Haul seines - length and depth of net, smallest mesh size, number of hours fished and number of hauls per day.
- Dredges (oyster, crab, clam), scrapes - size/weight of gear and hours fished per day.
- Hand tongs, patent tongs, rakes - number of gear and hours fished per day.
- Divers, by hand - number of hours.
- Trotlines and long lines - length of line, number of baits, hours fished per day.
- Purse seines - vessel size, length of nets.
- Otter trawls - width of mouth, cod end mesh size, tow duration and tow speed.
- Hook & line - number of trips, hours per trip and number of lines fished

Estimates of Biological Statistics

Individual organisms in the biological sample are weighed and measured. In cases where accurate length/weight relationships are established, only lengths may be taken. If required, subsamples are taken to determine sex, collect hard parts (scales, otoliths, fin rays, etc.) for laboratory age determination and to collect gonads to develop maturity and fecundity schedules. All sample sizes must be sufficient to allow accurate characterization of the harvests.

Biological statistics must also be coupled with the type of gear used for harvest in order to determine the selectivity of the gear and the representativeness of the sample. This can be achieved either by taking samples at fish processing points which can be associated with gear by interview, or by sampling directly on board commercial boats. The latter will eliminate the uncertainty that may occur with dockside samples, and also will provide useful information on catch per unit effort (CPUE).

Techniques for Estimation of Commercial Catch, Effort, and Value

A myriad of possible methods exist for estimation of fisheries statistics. The following descriptions of many possible alternatives is not all inclusive. All of the methods described are in use or have been used in the Chesapeake region.

Comparative Adjustment

Another cost efficient method, apparently still in use for some fisheries in some areas, is for statistics agents to visit a selection of fish dealers for information (usually verbal) on the relative magnitude of recent catches. A factor is calculated to adjust previous figures. For example, if a consensus is developed that the harvest of species X is down 10% from the previous year, last year's figures are decreased 10% to calculate this year's harvest.

Advantages are in the area of cost and unobtrusiveness. Disadvantages are inaccuracy, imprecision, no disaggregation of estimates, no effort data.

Dealer Censuses

This is one of the most common methods of collecting fisheries statistics throughout the world. Periodically each licensed fish buyer is visited. The agent either reviews the buyer's records or obtains a verbal or written report on recent activities. Advantages of this system include: relative unobtrusiveness; relatively low cost; when no basket trade is involved, landings and value data can be quite good; it maintains a direct agency contact with the industry. Disadvantages include: lack of fishing effort data; underestimates of landings when dealers don't cooperate or in fisheries with large basket trades; disaggregated data is more difficult to obtain than in a system dependent on harvester reporting; daily estimates of catch are not usually available.

Harvester Censuses

In this type of system, each licensed harvester is required to send in a report on some periodic basis. Advantages include: complete coverage of all licensed fisheries, i.e. basket trade should be included in harvest estimates; disaggregation of estimates can be accomplished on the reporting form; effort data can be reported directly by the harvester. Disadvantages include: this type of system is very intrusive and quite costly; recall and truthfulness are questionable if there is no cross-checking audit system; due to late submission of reports, the system will not be timely; any failure to complete the census means an automatic under-estimate of catch; separate systems would usually have to be constructed for dockside value data.

Harvester Sample Surveys
In this type of ,system, only a sample of fishermen are periodically required to report their catch. From the sample, an average catch per license is calculated and this figure multiplied by total number of licenses to estimate total catch. Advantages include: lower cost and less intrusiveness than with a census; defined allowable error ranges can be designed into the system; non-reporting is less of a problem than in a census system; basket trade should be included in harvest estimates; effort data is obtainable directly from the harvester reports. Disadvantages include: disaggregation requires wider confidence limits or larger sample sizes; recall and truthfulness can be questionable.

Trip (Transaction) Ticket Censuses
This type of system requires that each day's fishing activity is recorded on a transaction ticket, with a copy sent to the management agency. The system can depend on either the dealers or the harvesters to be responsible for submission of the ticket. If dealers are to be responsible then a requirement needs to included for harvesters to report when their catch is not sold to a licensed dealer. Advantages of this type of system include: every required level of detail can be included; catch, effort and value can all be collected in one system; completion of the trip ticket should become routine and copies can be used for records purposes for both harvesters and dealers; recall is not a concern. Disadvantages include; the system is relatively intrusive; agency cost is relatively high; the system cannot be as timely as may be required for some fisheries.

A Framework for Commercial Fishery Statistics Collection

The preceding section detailed the data requirements and techniques for collection of data from commercial fisheries. Current programs use these techniques, but in an inconsistent manner. A satisfactory, baywide statistics program is essential for stock assessment. The following description is a proposal for developing an integrated program. Over the next year, this proposal should be critically reviewed for feasibility of implementation.

The foundation of the proposal is a mandatory commercial harvest reporting program. A transaction ticket system is the suggested method of censusing commercial fishermen and dealers. This method allows collection of information on catch, effort, and dockside value at a high resolution of time and area. Because of data processing backlogs, the reporting system may need to be supplemented by informal dealer surveys to determine estimates of catch during short season, intense fisheries (striped bass, shad, black drum). It is also likely that effort information from the harvest reporting forms will need to be verified by field surveys of effort. Finally, catch estimates must be partitioned by age (size), and sex for stock assessment, which will require a comprehensive biological statistics program. A more detailed accounting of these programs follow.

Trip Ticket System

Figure 3 shows a draft of a trip ticket which would be completed by each fisherman at the end of a fishing day. Such tickets would be provided to each fisherman in a three part receipt book format similar to those used in restaurants and other cash businesses. One copy would go to the management agency, one to the buyer and one to the fisherman. Copies would be sent by the licensed fishermen to the management agency weekly.

Figures 4 and 5 show samples of the coding systems which would be provided with each booklet of trip tickets. These would be printed on the inside and outside covers of the booklet.

Careful record keeping would be necessary to insure that every person was sending in reports in a timely manner. Penalties must be assessed for those individuals who do not comply. Fishermen must have an incentive for compliance; that is, they must be shown that it is in their self interest to provide the information.

A drawback to this system is that no census can ever be complete; some fishermen will not comply, some paper will be lost, etc. One possible way around this would be to treat the entire trip ticket census as a large "sample" and expand up to the total license count. The effects and validity of this idea should be studied using existing data.

A transaction ticket system would generate large amounts of paper. The only way to tabulate large amounts of paper in a timely way is through automation. Computer machinery now exists which is capable of reading human hand printed figures with low error rates. Such machinery may well be a cost effective alternative to key punching of data.

Randomized Dealer Telephone Survey

For those fisheries in which timeliness is a paramount concern and in which a constant or known fraction of the catch is sold to dealers, rough estimates of total catch can be estimated with a daily or weekly telephone survey of seafood buyers. Once good mathematical relationships are established between this system and the harvest reporting system, it could be used to manage quota regulated fisheries.

<u>Surveys for Cross Checking Effort Data</u>
For some fisheries, a system of vessel or net counts would provide a good cross-check on participation levels. Such fisheries would be those in which vessels and gear are easily distinguishable.

<u>Biological Data for Commercial Fisheries</u>
Collection of biological data from commercial harvests is a critical element of the fishery dependent programs. The intercept point for biological sampling can either be on board commercial boats or at dockside. For the latter, landing sites are regularly visited and fish measured either as they come off the boats or after they have been sold to a dealer. For species in which length-at-age and length-weight relationships have been established, length frequency data would be sufficient, thus fish would not have to be purchased. Purchase of some fish is probably unavoidable since they would have to be dissected for sex determination or other types of tissue samples. Recommendations for biological sampling techniques for commercial pound nets has been prepared by Chittenden (VIMS) under funding by CBSAC.

For sampling on commercial boats, CPUE data, in addition to the data described above are, collected with little uncertainty as to origin, gear type, and level of effort. Recommendations for this type of program have been prepared by Rothschild (CBL) for commercial blue crab fisheries in the Bay.

FIGURE 3. SAMPLE FISH TICKET

DAILY SEAFOOD CATCH TICKET 000001

1.a. FISHERMAN'S LICENSE NUMBER/

b. CAPTAIN'S LICENSE NUMBER (if different)

2. DATE

month	day	year

3. GEAR TYPE USED (see front cover for codes)

4. TOTAL NUMBER OF PERSONS FISHING ON BOAT

5. a. AMOUNT OF GEAR (see front cover for units)

   b. use as necessary and as directed on front cover

6. MESH SIZE (if appropriate)

7. HOURS FISHED TODAY

8. HOURS SINCE GEAR LAST FISHED (if gear left set in water)

9. HARVEST AREA (see front flap for codes)

10. COUNTY LANDED

11. CATCH INFORMATION (see back flap for species unit codes)

   a. PRIMARY SPECIES SOUGHT

   b. CATCH AND PRICE

SPECIES CODE	AMOUNT	UNT	TOTAL PRICE

12. FISHERMAN'S SIGNATURE ______________________________

13. BUYER LICENSE NUMBER (if appropriate)

FIGURE 4. SAMPLE GEAR AND AREA CODING SCHEME FOR FISH TICKET BOOKLETS

GEAR CODES &	AMOUNT OF GEAR UNITS a.	b.
FINFISH		
425 GILL NET, ANCHOR	NET LENGTH (YARDS)	NET DEPTH (YARDS)
470 GILL NET, DRIFT	NET LENGTH (YARDS)	NET DEPTH (YARDS)
480 GILL NET, STAKE	NET LENGTH (YARDS)	NET DEPTH (YARDS)
275 POUND NET, FINFISH	NUMBER OF NETS	LENGTH OF LEAD
020 HAUL SEINE	NET LENGTH (YARDS)	NUMBER OF HAULS
310 FYKE NET	NUMBER OF NETS	leave blank
345 FISH POTS	NUMBER OF POTS	leave blank
210 OTTER TRAWL	WIDTH OF MOUTH	LENGTH OF TOW (HOURS)
125 PURSE SEINE	???	???
CRABS		
330 CRAB POTS	NUMBER OF POTS	leave blank
680 TROTLINES	LENGTH OF LINE	NUMBER OF BAITS
770 SCRAPES	NUMBER OF SCRAPES	????
280 POUND NET, CRAB	NUMBER OF NETS	LENGTH OF LEAD
390 BANK TRAP	NUMBER OF NETS	LENGTH OF LEAD
XXX COLLAPSIBLE TRAP	NUMBER OF TRAPS	leave blank
703 DIP NETS	NUMBER OF NETS	leave blank
805 DREDGE	NUMBER OF DREDGES	???
OYSTERS		
840 HAND TONG	NUMBER OF TONGS	leave blank
841 PATENT TONG	NUMBER OF TONGS	leave blank
943 DIVING	????	
815 DREDGE	NUMBER OF DREDGES	???
CLAMS		
803 DREDGE	NUMBER OF DREDGES	???
855 RAKE	NUMBER OF RAKES	???

HARVEST AREAS

412 ASSAWOMAN BAY .
012 ATLANTIC OCEAN .
005 BIG ANNEMESSEX RIVER .
537 BROAD CREEK .
013 CHES. BAY - N. OF WORTON PT. .
025 CHES. BAY - N. OF BRIDGE &
S. OR WORTON PT. .
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. .
262 NANTICOKE RIVER - ABOVE XXXXX .
continued .

FIGURE 5. SAMPLE SPECIES CODING SCHEME FOR FISH TICKET BOOKLET

SPECIES CODES

FINFISH	
0010 ALEWIVES	5170 YELLOW PERCH
0230 BLUEFISH	.
.	.
.	5290 UNCLASSIFIED BAIT FISH
.	CRABS
.	7000 BLUE CRABS, HARD
.	7028 BLUE CRABS, SOFT
.	7029 BLUE CRABS, PEELER
.	7100 RED CRABS
.	7110 JONAH CRABS
.	.
.	CLAMS
.	7480 HARD CLAMS, PUBLIC
.	7510 HARD CLAMS, PRIVATE
.	7540 OCEAN QUAHOG
.	7630 SOFT CLAMS
.	7690 SURF CLAMS
.	CONCHES
.	7750 CONCHES
.	OYSTERS
.	.
.	OTHER SHELLFISH
.	8081 TERRAPIN
.	.
.	UNITS
.	P POUNDS
.	B BUSHELS
.	D DOZEN
.	E EACH
4180 STRIPED BASS	

Recreational Fishery Statistics

Fisheries in Chesapeake Bay also have a very active recreational component. The effort, landings and economic value have been reported for the commercial sector for many years. However, until 1979, with the advent of the National Marine Fisheries Service Marine Recreational Fishery Statistics Survey (MRFSS), there was little data collected from marine recreational fisheries. MRFSS was established to meet the goals of the Magnuson Fishery Conservation and Management Act of 1976, which required management of both the commercial and recreational components of fisheries within the 3-200 mile coastal zone. Prior to this there were few and mostly localized surveys of the recreational fisheries in Chesapeake Bay.

Management of the combined recreational and commercial fisheries of Chesapeake Bay will rely on accurate estimates of fishing pressure, catch, and biological parameters, such as size-fecundity schedules and age and growth. Since, in some fisheries the recreational harvest is thought to equal or exceed the commercial catch, reliable estimates of effort and harvest are of utmost importance for management of Baywide fisheries. Equally important for the equitable allocation of increasingly scarce resources is the knowledge of the size and economic importance of the angling community.

The recreational fisheries of Chesapeake Bay target species which are seasonal or year round residents in the Bay (spot, white perch, and flounder for example) and species that have extensive coastal migration and are resident in the Bay as adults for brief periods only (river herring, shad, and black drum for example). The type of statistical survey sampling used to obtain information on catch and biological parameters can be quite different for these two types of target species. The first type can be assessed with a broad temporal and geographical design, while the second type may require surveys specifically designed for short and intense fisheries.

Several methods exist for assessing recreational fishing effort and harvest. Effort can be estimated from telephone or mail surveys, or from contact interviews. The advantage of obtaining effort information from telephone or mail surveys is the reasonable cost of such surveys. They are most efficient when a recreational fishing license list is available to define the sampling frame for the study. Such lists exist, of course, only in states that have mandated licenses. The disadvantage of this method is that the accuracy of the data is dependent on the anglers' memory recall, which declines substantially within months of the latest fishing trip.

Effort can also be measured through aerial surveys or from direct contact angler surveys. Aerial surveys are a cost-efficient method for collecting effort estimates. They work best for fisheries which can be discerned readily from other recreational usage. Direct contact angler surveys can provide information on both effort and catch. Their advantage is the accuracy of information that is obtained. Their disadvantage is relatively high cost and. Catch and biological data are- also obtained through contact angler surveys, where agents can actually identify, measure, and weigh the fish. Contact surveys are used in conjunction with telephone mail questionnaires and aerial surveys to provide accurate catch data.

The most extensive survey currently being conducted in Chesapeake Bay is the MRFSS. It is a dual-frame survey. Effort is expanded from information obtained through telephone interviews of coastal residents. The ratio of fishing households to the total of households called is used, in combination with U.S. Census data to estimate the total number of fishing trips. Access intercept interviews, where anglers are contacted at fishing access points, are used to estimate fishing success rate, catch and biological parameters. Additionally, the intercept interviews serve to determine the effort for angling parties who live outside the regional coastal area addressed through telephone interviews.

Although the MRFSS is based on sound statistical design, the intent of the survey is to give estimates of recreational harvest and effort for broad geographic areas. For the purposes of stock assessment and fisheries management in the Bay it may be necessary to have better refined estimates. In 1989, CBSAC will fund a study which will detail the sampling requirements necessary to provide satisfactory recreational fishing statistics for stock assessment. The adequacy of the MRFSS and other survey designs for meeting the requirements will be explored.

FISHERY INDEPENDENT DATA COLLECTION

Fishery independent monitoring is the collection of data on abundance, distribution, and biological characteristics of fisheries stocks through the use of statistically designed survey methods. The surveys are intended to complement and supplement information produced by fishery dependent monitoring of commercial and recreational fisheries. Thus, the term 'independent' refers to the fact that data collection is not dependent on harvests as a source of biological statistics. The primary objectives of baywide fishery independent surveys are as follows:

- Collect data necessary to derive estimates of relative or absolute, age-specific abundance for the tributaries and mainstem bay. Highest priority life stages will likely be pre-recruits (juveniles) and adult spawners.

- Collect other data useful in stock assessments to determine age specific patterns of distribution, growth, mortality, fecundity, sex and maturity.

Current methods for fishery independent sampling of marine organisms have ranged from the conventional, eg. beach seines for striped bass juvenile fish, to the unconventional, air conditioner filters for blue crab megalopae. A review of current methods can be found in the Chesapeake Bay Program Biological Monitoring Atlas. A few of the more common methods are found in Table 1.

It is not within the scope of this plan to specify all aspects of survey designs that are required to provide the fishery independent information necessary for stock assessment. Nor is it likely that it could be done. Uncoordinated surveys employing many if not all of the gears listed in Table 1 are undertaken in the various jurisdictions of the Bay every year. Some are long term programs, others are shorter term experimental projects. However, all have advantages and disadvantages. The task of evaluating these programs is not simple and requires thorough analysis to determine which programs should be further developed for assessment purposes. This process should occur during the course of individual stock assessments. However, it is possible, and it will be the purpose of this section, to review the primary alternatives for development of a baywide core program for fishery independent data collection.

In 1985, CBSAC began the process of reviewing existing programs by funding projects concerning the juvenile finfish trawl program in Virginia and the beach seine surveys used in Maryland, Virginia, and the District of Columbia.

Table 1. Representative gears for fishery independent sampling.

LIFE STAGE	GEAR OR METHOD USED FOR ENUMERATION
Meroplankton (eggs & larvae)	lined trawls plankton nets pumps/filters
Juveniles	
fish/crabs	trawls (lined/unlined) beach seines
shellfish	substrate samplers 'spat' collectors
Adults	
fish/crabs	trawls, gillnets, and other commercial gears
shellfish	scrapes dredges bottom grabs

Beach seine surveys are an integral part of striped bass research and management in Virginia, Maryland, and the District of Columbia and from that respect will continue for the foreseeable future. Due to the recent investigation of the survey, methodologies in all three jurisdictions have been standardized.

Deliberations on a trawl program for the Bay continue. The committee sponsored baywide trawl projects in 1988; it plans to hold a workshop in Fall of 1988 to complete a final design for a baywide trawl program. It is the collective decision of the committee that a unified, consistent trawl program should be one of the primary monitoring tools for finfish and crab stock assessment.

The following outlines describe the recommended approaches to fishery independent monitoring of finfish, crabs, and shellfish.

Finfish Monitoring - trawl, beach seine, and other gears

The Bay Trawl Study

Objectives:

- Collect information necessary to derive estimates of abundance for juvenile and/or adult fish and crustaceans.
- Spacial and temporal coverage of the survey will allow documentation of habitat utilization by the species sampled. Samples will be taken in all major tributaries up to tidal freshwater, and in the main bay.
- Survey will provide biological samples for life history studies and other concurrent scientific investigations.
- Survey will be coordinated among jurisdictions to provide long term, consistent estimates of abundance for the bay and its tributaries.

Sampling Design: Stratified, randomized block design, bay area will be broken into large geographic segments roughly based on salinity and habitat characteristics. Within each segment, random sampling will be stratified by depth.

Gear: Gear configuration is undecided. Current tests have involved a 30' trawl and larger vessels (>40'). Smaller trawls may also be needed to work in the upper tributaries and shallow water areas. Gear will be selected within one year and will be consistent among jurisdictions in sampling areas with similar characteristics.

Temporal Resolution: Sampling will occur at least monthly. As the survey develops sampling frequency may be increased or decreased, dependent on abundance, during certain time segments to improve the precision of estimates and the efficiency of the survey.

Spatial Resolution: In Virginia plans are being made to develop the survey initially in the tributaries with expansion to the main bay. Depth ranges under consideration are: 3'-12' unsampled unless by smaller trawl; 12'-30', 30'-42', >42'sampled by large trawls. In Maryland a similar strategy is being developed. The District of Columbia will use a smaller trawl.

Species: Weakfish, striped bass, croaker, spot, spotted hake, white perch, silver perch, anchovy, hogchoker, menhaden, eel, channel catfish, white catfish, toadfish, silversides, alewife, blueback herring, blue crab

Implementation: Maryland has proposed a five year trawl project at CBL through W/B funds. Virginia plans to upgrade the VIMS juvenile trawl survey through additional state funding that was approved in the 1988 General Assembly. Both projects will be in a developmental phase into 1989. CBSAC proposes to hold a technical workshop beginning in Fall of 1988 to aid in the development of the survey design.

Beach Seine Survey

Objectives:

- Collect data to derive estimates of abundance for young of the year striped bass, and secondarily for other fish using the near shore zone.
- Document habitat utilization of striped bass, and other species, in the important striped bass nursery areas.
- Collect biological samples for life history studies.
- Maintain a long term, consistent, cooperative survey for striped bass assessment and management.

Sampling Design: Systematic sampling - fixed stations and times

Gear: 100' x 4' beach seine, 1/4 inch mesh

Temporal Resolution: Samples are taken approximately once a month from July through September (2 seine hauls per station).

Spatial Resolution: 22 stations in Maryland in the upper bay, Choptank, Nanticoke, and Potomac Rivers. 18 stations in Virginia in the James, York, and Rappahannock Rivers. 5 stations in the District of Columbia in the Potomac River. Stations are limited to favorable seining sites in the nearshore zone (0-3').

Species: Striped bass, white perch. Other species are captured; Virginia's survey has recorded over 50 different species. All are not representatively sampled.

Implementation: Beach seine surveys will continue as in the past. Review of the survey and the associated historical data base will occur during the course of baywide stock assessment of striped bass. Additional work should be funded to investigate the utility of the survey for other species.

Other Fishery Independent Finfish Surveys

Objectives: The objectives of other types of fishery independent surveys would be the same as those listed for the trawl and beach seine surveys. The primary objective of alternate surveys is to collect information on finfish species or life stages not obtained from the trawl or beach seine surveys, or from fishery dependent programs.

Sampling Design: Will be dependent on specific objectives of the survey. Statistical properties of proposed surveys to be considered during planning.

Gear: Commercial gears employed with a statistical design - gillnets, pound nets, fyke nets, trawls. Specialized sampling devices - designed traps, electrofishing, hydroacoustics, pop nets.

Temporal/Spacial Resolution: Dependent on survey objectives.

Species: Dependent on perceived needs for management and assessment.

Implementation: Of immediate concern, is the establishment of a consistent survey for juvenile shad and herrings. The gear of choice appears to be a boat mounted push net. However, sampling difficulties and funding have thwarted a consistent survey. It is recommended that a survey be instituted in Maryland, Virginia, and the District of Columbia.

Shellfish and Crab Monitoring

Blue Crab

Objectives:

- Collect post larval and juvenile blue crab data as an index of potential recruitment.
- Survey yearling and adult crabs as an index of abundance and distribution.
- Document and quantify habitat use (non-vegetated and SAV beds) by life stages.

Sampling Design: Post larval stages can be collected and abundance quantified in planktonic samples near the Bay mouth and in marsh areas on megalopae collectors. Juveniles and adults are taken by finfish trawls. Shallow SAV beds require specialized sampling.

Gear: Plankton nets, "megalopae screens", otter trawl, SAV push or pop nets.

Temporal Resolution: Planktonic collections should be made weekly during the "spawning" season; megalopae can be collected daily during a 10-day period bracketing the full moon; and juveniles and adults should be enumerated from finfish trawling surveys on a monthly basis.

Spatial Resolution: Plankton collections can be made along a transect across the Bay mouth. Stations should be spaced to include inflow and outflow waters. Megalopae collectors should be placed in representative marsh sites. Juvenile and adult samples are collected from the stratified, randomized finfish trawling.

Species: Blue crab

Implementation: Maryland and Virginia must continue their commitment to the trawl surveys. Other juvenile sampling, whether planktonic or post settlement, should be evaluated as a part of a long term monitoring program. If these additional programs are appropriate they should become part of the core monitoring programs.

Oysters

Objectives:

- Collect data on annual initial (summer) and surviving (fall) spatfall on public oyster bars to derive an index of recruitment.

- Survey spring and fall abundance of seed, small, and market oyster, and predators (drills, mud crab, flatworm) and fouling organisms on public oyster bars.

- Survey incidence of MSX and Dermo on selected public bars to maintain an index of infestation.

- Measure condition index (CI) of oyster on selected bars as an index of health and spawning condition.

Sample Design: Systematic sampling of public oyster bars in the mainstem Bay and tributaries. Repetitive samples should be collected.

Gear: Hand tongs, patent tongs, dredge.

Temporal Resolution: Spatfall data should be collected weekly from June through September; fall and spring survey counts need only be sampled twice a year; disease incidence

should be monitored weekly throughout the active infestation periods; and CI needs to be measured monthly at representative stations.
Spatial Resolution: Public oyster bars

Species: oyster, MSX, Dermo, tunicates, bryozoans, oyster drill, pea crabs.

Implementation: Maryland and Virginia have monitoring programs for spatfall and disease. Methodology should be standardized and augmented as indicated by the objectives. All oyster monitoring programs need to be infused with additional funds.

Clams (hard and soft)

Objectives: Establish an annual survey of clams to determine recruitment, abundance, distribution, and growth.

Sample Design: Stratified by depth, substrate, and salinity, and randomized sampling on known or historic clam beds.

Gear: Patent tong, dredge and hydraulic escalator dredge.

Temporal Resolution: Twice-annual sampling, weekly during periods of recruitment.

Spatial Resolution: Baywide

Species: Hard clam, soft clam

Implementation: Neither Maryland nor Virginia have a monitoring program to survey stocks of juvenile or adult clams, nor are any programs under development to obtain an index of recruitment. Because of the economic importance of clams, these programs should be initiated.

RECRUITMENT PROCESS STUDIES

The process of adding members to the exploitable stock is termed the recruitment process. It covers the period in the life history beginning at the egg stage and ending at the onset of fishing mortality. In terms of population dynamics, the period encompassing the recruitment process is usually characterized by high mortality rates and large year to year fluctuations in abundance. Environmental variables, natural and man induced, play the most important role in governing survival during these life stages. Although predation, competition, cannabolism, and spawning stock conditions will also influence survival to a greater or lesser degree in some species. As such, recruitment process research usually serves as the basis for determining critical habitat requirements.

Generally, the effect of factors that determine the degree of contribution of a given year's spawn to the exploitable stock (termed yearclass strength) occurs in the first year of life. These factors may be related to the abundance of spawners that produced the yearclass or the abundance of members of the yearclass themselves (density dependent factors), or related to biological and habitat events unrelated to their abundance or the abundance of their parents (density independent factors). The objective of recruitment process studies is to examine the extent to which density dependent and density independent factors influence the establishment of yearclass strength. As such this type of research in part will seek to quantify the effects of environment on resource production.

Approach

It is necessary to determine the pattern of survival during the period of the recruitment process, and to relate this pattern to trends in biotic and abiotic variables. The relationship can be inferred from analysis of stock and environmental monitoring data, or can be tested directly through controlled laboratory and field studies. Recruitment process research yields best results when it is a combination of the two. Inferences drawn from analysis of historical data sets can be used to formulate hypotheses for laboratory and field testing.

Given the adequacy of available data sets, it is possible to determine the potential influence of biotic and abiotic factors on the recruitment process by examining the historical relationships between stock size, fishing mortality, environmental variables, pollutant loadings, and habitat loss. This type of analysis, termed time series analysis, requires a series of continuous measurements over a considerable length of time, since stock abundance varies on annual cycles. Missing data, imperfect sampling, spatial incongruities in measurements, and data sets with too few observations are several of the major factors that inhibit time series analysis. Some of these inhibiting factors may be overcome by data interpolation, use of alternative (proxy) data sets, and adjustment of the level of resolution to a broader scale. An example of such an exercise, which involves the white perch populations in the Choptank and York rivers, has been documented by the CBSAC Data Set Identification and Interpretation Working Group (see Related Readings).

Data Needs

While retrospective analyses furnish important information for understanding the factors that are important in the recruitment process, they should not hinder efforts to move forward with the collection of new, better suited data. There often exists a tendency to conduct retrospective analyses first, then design a sampling program to accomplish what could not be accomplished using historical data sets, leading to further and further delays in getting on with the task. Based on the retrospective analyses performed to date, scientists have gained a appreciation for the types of data sets that would be most useful, given available methodologies and techniques for time series analysis. These generic criteria are summarized as follows:

- Observations should be taken often enough to include short term (seasonal) variability.
- Enough locations should be sampled to cover spatial variability.
- A long enough time series is necessary to show potential long term changes or trends.
- Observations need to be taken in a consistent manner. The same techniques and gear should be used throughout the time series.
- The observations must be on a variable that is related in a consistent manner to the parameter being estimated.
- Choice of environmental variables to measure must make good biological sense.

Usually one or more of these general criteria are not met. Sampling programs focused on early life stages are typically limited to certain habitat types (e.g., beach seines are limited to beaches), have sampling frequencies that exceed life stage durations, and do not coincide well with environmental monitoring programs in terms or spatial and temporal resolution. These limitations result in failure to detect causative relationships with any degree of statistical confidence. With these problems in mind, it is recommended that CBSAC continue to work with the Monitoring Subcommittee of the Chesapeake Bay Program to ensure that, where possible monitoring data sets include environmental variables important to assessment and are established on temporal and spatial resolutions compatible with assessment. Furthermore, where possible, programs designed to collect data related to stock parameters (abundance, growth, distribution, and mortality) should also collect relevant environmental data.

Basic data needs relative to the study of recruitment processes include life stage specific estimates of abundance and development (growth) rates. To approximate the pattern of survival through the life stages involved in the recruitment process, age specific estimates for daily or weekly cohorts within a life stage should be determined. This will allow analysis of the age structure within a given life stage (which may last from one day to several months), and will enable comparison of survival rates to growth rates.

Age specific estimates within the early life stages will also enable determination of the approximate date of spawning and allow comparison of the survivability of the offspring to the condition of the parents. A significant part of the recruitment process is related to the adult population itself. Such factors as behavior, adult stock structure (age, size, and sex ratio), genetic variability in egg quality, and fecundity, influence the survivorship and development of the offspring.

Selection of Species

Research on the recruitment process will involve dedication of a significant amount of scientific resources because of the type of information that needs to be retrieved. Initial research efforts should focus on species considered important in fisheries management. Commercial and recreational finfishes of interest include striped bass, American shad, river herring, yellow perch, white perch, spot, croaker, and seatrout. Shellfish of interest include blue crab and oyster, for which physical and environmental factors have been suggested as the most important in controlling the recruitment process.

Second priority should go to those species that appear to be a significant factor in controlling the year class success of commercial and recreational species. These ecologically valuable species include potential predators, competitors, and prey, as well as plant species that are significant components of critical habitats.

Conclusions

Research on the recruitment process is valuable to fisheries management in that it supplies:

- Information on critical habitat requirements for important species.
- Estimates of potential strength of age classes that will be entering the fishery.
- Information on the trend in the abundance of a species as it relates to trends in the ecosystem.
- A basis for evaluating habitat condition and alteration of the environment.
- An improved understanding of the relationship between stock size and recruitment.

Approaches to recruitment research have been developing rapidly over the last several years. There are many sampling and measurement difficulties inherent to the type of work described. CBSAC recommends that any work undertaken to investigate recruitment dynamics be carefully planned before implementation. The Committee also proposes to review project results in the Bay region and key projects undertaken in other parts of the world to help better define appropriate objectives and techniques for future research.

CHAPTER V. IMPLEMENTATION

The stock assessment plan is oriented primarily to meet the needs of state management bodies for information on the status of the fishery resources. Assessments traditionally relate status to the effects of fishing, and provide some basis for evaluating expected future yields and population changes resulting from postulated fishing levels. This usually applies to individual stocks defined by population distribution and, to some necessary extent, by practical fishery management considerations.

It is apparent that human development has resulted in significant effects on the resources supporting the fisheries. These effects must now be included in assessments. Furthermore, alternative conservation and management practices need to take into account implications of the multispecies fisheries and ecosystem-related aspects of natural factors of environment and species interactions.

These additional considerations require the collection of more data, and the development and application of new methodology. Achieving this increased sophistication in assessments will take time, and requires that the first steps be started immediately.

Although a rigorous accounting has not been made, there are at least one hundred persons actively working on some aspect of stock assessment in the Bay region. This tally would include fisheries biologists, technical staff, academic faculty, graduate research students and others working at over twenty organizations in the Bay area. About three million dollars per year are spent on research, monitoring, and management programs that contribute to stock assessment. A majority of these costs are covered by federal funds (currently, approximately $2.5 million per year). An obvious challenge for development of a baywide stock assessment program is the coordination of these human and monetary resources.

Implementation will be the shared responsibility of the jurisdictions whose fishermen and other citizens benefit from utilization of the resources and the Bay, and the federal government. Implementation is obviously a cooperative endeavor; the speed and effectiveness with which it is carried out will be governed by factors outside the scope of this plan. This section only offers advice on the relative importance, need, and mechanisms to achieve the objectives of stock assessment.

A PROPOSED PROCESS

Figure 6 displays a basic flow of organizational responsibilities and activities involving fishery stock assessment in the Bay. To an extent, current assessment practices follow this pattern, but they must be supplemented and better coordinated to truly create an effective Chesapeake Bay stock assessment process.

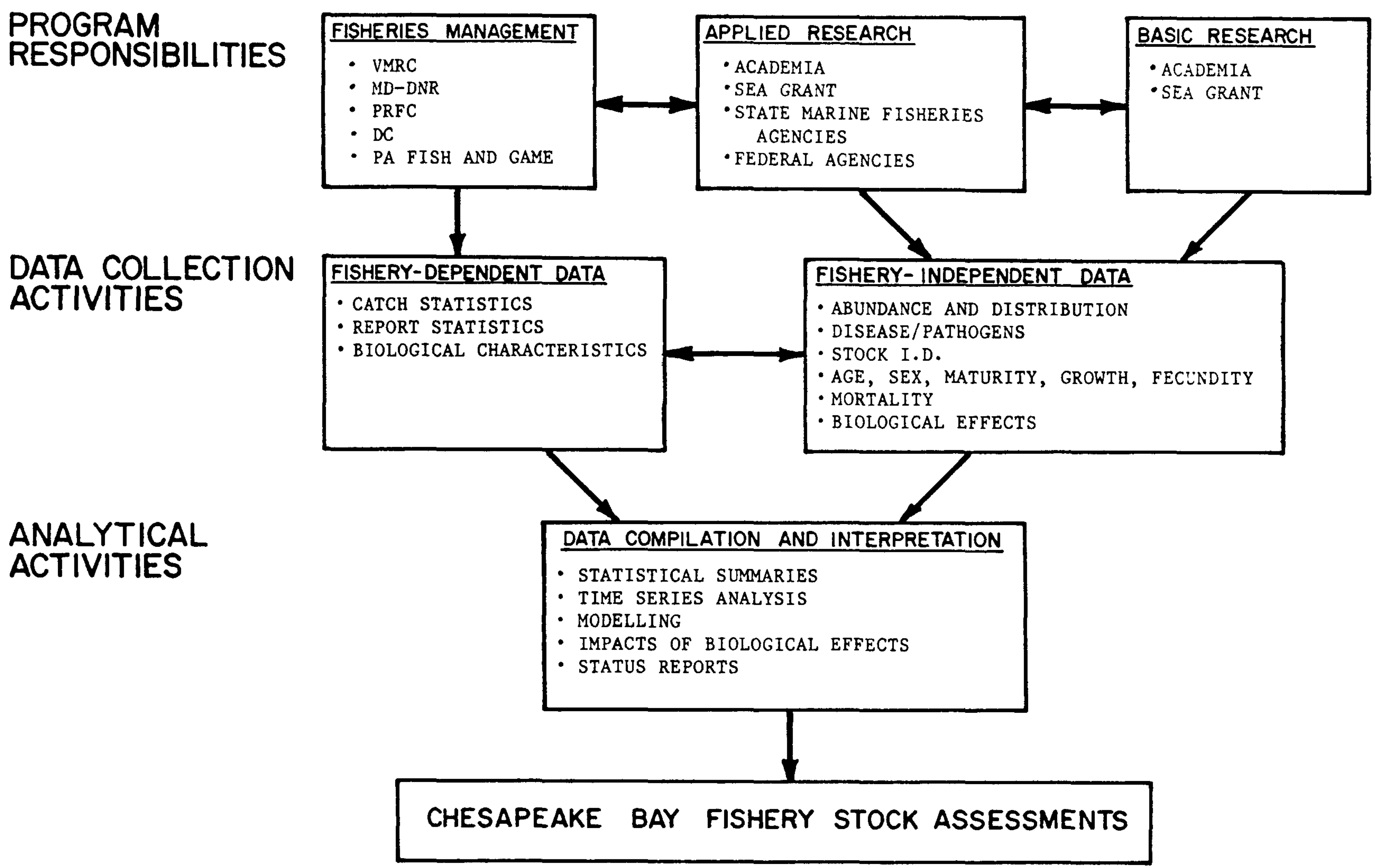
A noticeable feature of Figure 6 is the division of responsibility between research and management organizations in all jurisdictions. While there is no single authority by which stock assessment is controlled, the formation of CBSAC in 1985 was intended to solve the coordination problem for assessment activities. The committee has the appropriate membership, with the assistance of its work groups, to solve technical stock assessment problems and it is a recommendation of this plan to continue the committee with further direction to begin a more active role in the oversight of fisheries stock assessment activities in the Bay.

The most effective way to integrate assessment activities will be to encourage as much interaction as possible between representatives from all jurisdictions on technical stock assessment problems. During the first several years of CBSAC this has been achieved through the activities of the committee's workgroups. Their responsibilities have been to review and analyze data sets for the purpose of better understanding shortcomings in available data in order to improve their utility and to suggest improvements for data collection programs.

A stronger role by the working groups is needed to implement the programs proposed herein. These groups would serve to focus and coordinate among the large number of individuals contributing to stock assessment. In addition to the present workgroups, Status of Stock Knowledge (SOSK), Data Set Identification & Interpretation (I & I), and the Data Base Coordination (DBC), new workgroups will be initiated for finfish, oysters and blue crab. For this approach to succeed, it is essential that the jurisdictions contribute adequate staff time for preparation of technical documents. For an interim period, it may be wise to have each workgroup have one full time staff person.

The foregoing discussion generally describes some of the organizational ideas that will be useful to build a stock assessment process for the Chesapeake Bay. The most important point is the continuation of CBSAC as a cooperative means of overseeing stock assessment in the Bay.

FIGURE 6 FLOW OF ACTIVITIES AND RESPONSIBILITIES FOR THE CHESAPEAKE BAY STOCK ASSESSMENT PROCESS.



A revised terms of reference for the committee would be as follows:

- o Coordination, review, and oversight of data collection, processing, archiving, and analysis.
- o Preparation of annual Fishery Statistics and Status of Stocks Reports, and periodic Status of Stock Knowledge Report.
- o Organize working groups and conduct workshops to complete needed analytical assessments.
- o Recommend research projects to provide information needed for assessments.

A summary of the major features of a baywide stock assessment program and recommended dates of implementation follows.

Fishery Stock Assessment

Stock assessments will be overseen by CBSAC. Baywide working groups for finfish, crabs, and oysters will be established to coordinate and focus the multitude of stock assessment scientists. The present working groups (SOSK, I&I, DBC) will continue with the respective tasks of reporting on status of Chesapeake Bay stocks, investigating analytical techniques, and coordinating data management. **Annual cooperative reports documenting status of stocks and fishery statistics, and periodic reports detailing assessments will be produced.** Assessments should begin as soon as workgroups are established by CBSAC. Initial work will depend on analysis of historical data. Special attention should be directed in these initial assessments towards critically evaluating all current and proposed monitoring programs.

Commercial Fishery Statistics

The jurisdictions will improve existing statistics programs to build a baywide fishery statistics program to obtain and document annual, unbiased estimates of catch, landings, and fishing effort. At a minimum the estimates will be broken out by species for each type of gear, for each month of catch, and for each water area. Actual procedures for improved harvest reporting, fishing effort estimation, and data management should be finalized within one year of the approval of this plan and should strongly consider the framework proposed in Chapter IV (particularly a mandatory commercial tripticket system).

Recreational Fishery Statistics

Investigate the utility of statistics generated by the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for Bay stock assessment. Augmentation of that survey with state and federal funds may be all that is necessary to provide unbiased, annual estimates of recreational catch and effort at a comparable resolution to commercial harvest data. **Review of the MRFSS survey and a plan for recreational statistics collection should be completed by December 1989.**

Biological Characteristics of Harvest

One of the poorest aspects of current stock assessment information is the lack of knowledge of age composition of harvests. **Biological samples must be collected annually from both recreational and commercial harvests to obtain the necessary data on species composition and age composition.** Improvements in age determination capabilities will be a necessity for this program. Virginia plans a pilot program for biological sampling of commercial harvests for July 1988; funding and staff have been approved. Maryland will also begin a broader scale program after the initiation of new harvest reporting procedures.

Fishery Data Management

An emphasis must be made on data sharing, particularly for time series of routine harvest, effort, and recruitment data. Non-confidential data bases for each of the routine data sets should be available for stock assessment within six months of the end of each calendar year. Common data files should be maintained for harvest, effort, and recruitment data. Annual or biannual fishery statistic reports should be used to document and disseminate this information. Guidelines that increase access to research data while protecting the obvious rights of individual investigators should be developed. All pertinent data sets will be properly documented and stored in a central data center.

Fishery Independent Surveys

Recommendation is to adopt a long term, baywide trawl program to obtain fishery independent estimates of abundance and distribution of many of the important fish species and crabs. The cooperative trawl project would be augmented as necessary by other sampling methodologies to obtain abundance estimates for species and life stages not captured by the trawl. At least one important alternative method will be beach seine surveys for anadromous fish. Pilot projects for a trawl program were begun in 1988.

Implementation of the program should begin by spring of 1989. **In addition, analyses of existing fishery independent survey data should be improved. This will occur to some extent through the development of baywide assessment work groups, but will also require the addition of staff to some state programs (see Table 2).**

Recruitment Process Studies

A variety of research projects to investigate recruitment processes have been undertaken in the Bay region. Key species have been striped bass, oyster, blue crab, spot, croaker, and flounder. **A review of Bay recruitment projects and similar projects worldwide should occur in order to better define research objectives and sampling designs that would best determine the relative effects of environment and fishing.**

Biological Monitoring

The fishery dependent and independent data collection techniques described in Chapter 4 serve as the basis for the monitoring of fishery species, as well as other ecologically important finfish, of the Chesapeake Bay. Assessments will seek to use both long term monitoring information and short term research information to understand the dynamics of these living resources. Stock assessment data collection programs will be coordinated with Bay monitoring programs for water quality, and benthic and plankton communities. An initial medium for reporting these data that will lead to a description of the relationships between the environment and fishery resources will be the biannual State of the Bay Report.

Funding Considerations

The following table gives a rough accounting of staff and budget needs to meet the recommendations within the plan (Table 2). Also included in the table are potential funding sources for the various activities. Notice that required funding increases are not great, and that there are a number of potential federal funding sources. **Three actions that would aid program development are (1) ensure a long term funding base such as the CBSAC NOAA appropriation, (2) give state agencies permission to use federally funded FTE's, and (3) ensure adequate state funding for facilities, and for staff when federal funds are not available.** It is recommended that individual jurisdictions develop thorough program requests through their normal administrative processes. **The program changes and additional work required to create a cooperative stock assessment program in the time frames indicated will require the addition of the staff positions shown in Table 2 by July 1989.**

TABLE 2. ESTIMATES OF ADDITIONAL FUNDS REQUIRED TO FULFILL STOCK ASSESSMENT PROGRAM RECOMMENDATIONS. CURRENT PROGRAM COSTS AND STAFFING ARE ALSO SHOWN (IN PARENTHESES). THE ADDITIONAL STAFF AND BUDGET NEEDS PRESENTED TOTAL 30 FTE'S AND $1,156,000. CBSAC AND LRS HAVE OVERSIGHT RESPONSIBILITY.

	VA		MD		DC		POTENTIAL FUNDING	IMPLEMENTATION		INITIAL
ACTIVITY	FTE's	$ (1000's)	FTE's	$ (1000's)	FTE's	$ (1000's)	SOURCES (1)	ORG	DATE	TASKS
Fishery Dependent Programs (2)								VMRC MDDNR DCRA		
Cooperative Stock Assessment	3 (0)	100 (0)	3 (0)	100 (0)	0 (1)	0 (35)	GF,IJA		12/88	Assessment review for baywide FMP's
Commercial Fishery Statistics	1 (4)	30 (130)	1 (2)	35 (150)	0 (0)	0 (0)	IJA,GF		12/89	Annual fish statistics series
Recreational Fishery Statistics	1 (0)	30 (0)	0 (1)	0 (35)	0.5 (0)	14 (0)	W/B,GF		12/89	Annual fish statistics series
Bio-characteristics of Harvest	0 (4)	0 (130)	2 (1)	70 (35)	1 (0)	15 (0)	IJA,GF		12/89	Annual fish statistics series
Data Management	1 (0)	30 (0)	1 (0)	30 (0)	1.5 (0)	29 (0)	GF		4/89	Plan data mgmt procedures
Fishery Independent Programs (3)					5 (2)	104 (70)	GF,W/B	VIMS CBL		
Trawl Survey	0 (5)	0 (328)	0 (5)	0 (330)	-	-	GF,W/B	MDDNR	4/89	Baywide trawl survey design
Seine Survey	1.5 (1.5)	55 (65)	1 (1)	39 (39)	-	-	W/B,IJA,GF	DCRA	90	Survey use for other species?
Alosid Survey	2 (4)	75 (200)	0 (5)	0 (200)	-	-	AFCA,IJA,W/B,GF		90	Reinstitute alosid juv survey
Blue Crabs	1.5 (2)	45 (75)	0 (3)	0 (100)	-	-	GF		90	Compile crab historical data
Shellfish	2 (6)	85 (145)	0 (3)	20 (100)	-	-	GF		90	Review/compile oyster data; Design clam surveys
Developmental Recruitment Process Studies	0 (4)	125 (200)	2 (5)	125 (400)	0 (0)	0 (0)	CBSAC,GF		89	Review existing projects; Determine research design
TOTALS	13 (31)	575 (1,273)	9 (27)	419 (1,389)	8 (3)	162 (105)				

(1) GF-State Funds, IJA-Interjurisdictional Fisheries Act, W/B-Sport Fish Restoration Act, AFCA-Anadromous Fish Conservation Act
(2) Fishery dependent programs are not included in the budget tables in the Living Resources Monitoring Plan (LRMP).
(3) Costs for fishery independent programs agree approximately with those in the LRMP, except that blue crab and alosid program costs recommended here are not included in the LRMP.

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