Part I

Status of Stock Assessment Knowledge Used to Manage Important Virginia Finfish Species

PREPARED BY
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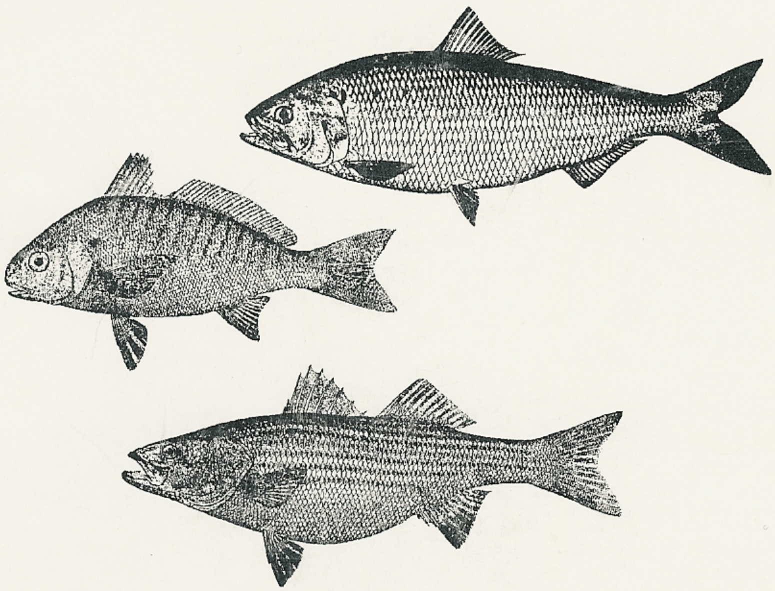

Including
Key Assessment Terms
Species Bibliographies

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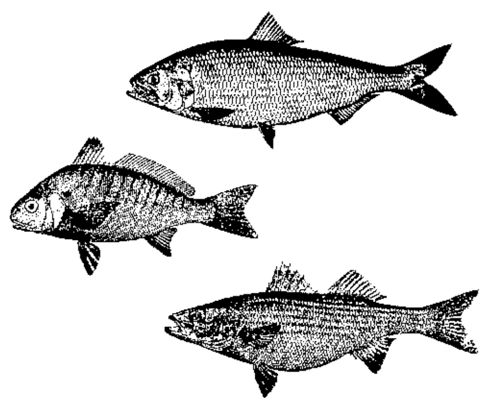
Table of Contents



This report is a collaborative effort prepared by the combined faculty and staff of the Virginia Institute of Marine Science/College of William and Mary (VIMS), Oceanography Department of Old dominion University (ODU, and the Virginia Marine Resources Commission (VMRC). It was conceived during a regular monthly VIMS-VMRC fisheries staff meeting.

The resources are dynamic, their abundances fluctuating annually; so too must the matrix and species write-ups. As such, updated editions will be prepared on a regular basis, as needed.

This report was compiled and published by the VIMS' Publications Center. Rob O'Reilly (VMRC) and Herb Austin (VIMS), editors.

Additional copies of this report may be obtained by contacting the VIMS' Library.

Introduction

History

Management of Virginia's finfish species has, during the last decade, become increasingly more structured and complex. In earlier years Virginia management of its finfish resources mainly involved reactive enforcement of the laws and several regulations. In recent years implementation of bi-state Chesapeake Bay, inter-state coastal, and regional federal fisheries management plans (FMP's) has been associated with rigorous conservation measures such as closed seasons, harvest quotas, gear restrictions and size limits. Management-scientific interaction has also evolved from a time when a science advisor attended Commission meetings, in case scientific council was sought, to an era when scientific input is provided for the development of the FMP's or directly to the Commission in response to data and information needs identified in the FMP.

Scientific information is, however, not always something that can simply be retrieved from the literature. Sometimes, the information available is not relative to Chesapeake Bay-Mid Atlantic Bight stocks or does not exist. As such, a one to three year lag between identified need and response is not uncommon. Efforts by the Chesapeake Bay scientific community to be responsive to the needs of management were focused in 1985 with the formation of the Chesapeake Bay Stock Assessment Committee, and its subsequent Status of Stocks Knowledge Subcommittee report in 1987 entitled, *Determine short- and long-term factors affecting mortality and recruitment of key commercial and recreational species, including fishing mortality and both natural and man-induced environmental impacts on mortality and recruitment.* That report followed the original approach to identification of scientific information needs set forth by Lionel Walford in 1946 in which he used a matrix to depict species and a status of assessment knowledge needs. The CBSAC 1987 report included a bibliography for each species, the citations being the documentation that "filled in" the species' stock assessment knowledge boxes.

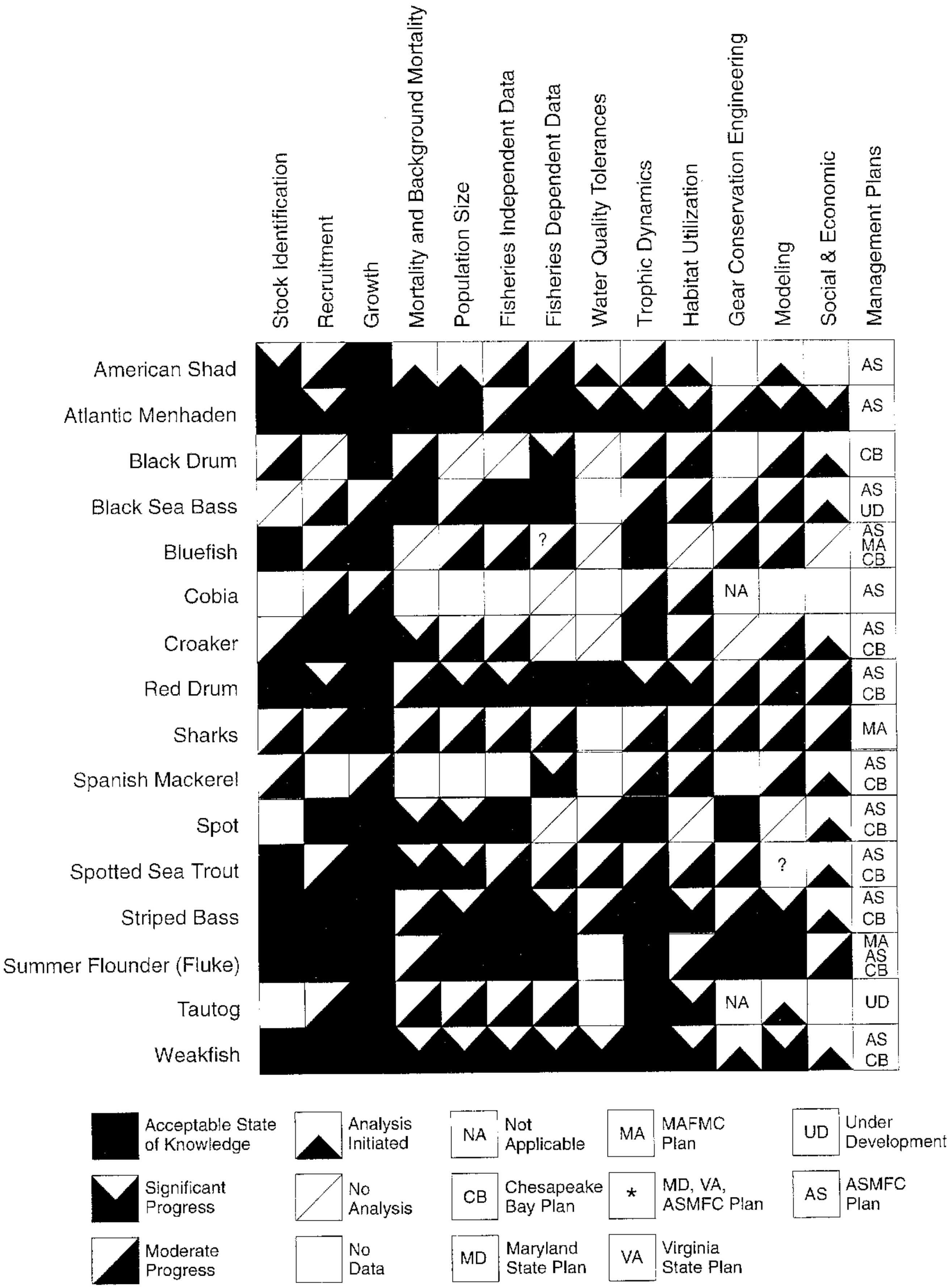
Scope and Format

This report consists of four parts. Following this introductory section is a matrix (similar to Walford's) which contains the status of assessment knowledge for important, currently managed Virginia finfish species. Assessment knowledge refers to key, mostly quantitative, data components used in stock assessment analyses and management of the listed finfish species. This matrix can be used to determine the strengths and weaknesses in assessment knowledge for any species, alone, or relative to other species in the matrix.

This matrix emphasizes management considerations. For example, an acceptable state of knowledge (a completely shaded block) about stock identification exists for many of the species listed. Some of these species (e.g. weakfish and summer flounder) are managed partially or fully by an Atlantic States Marine Fisheries Commission (ASMFC) management plan, and either the ASMFC has determined sufficient stock identification studies exist to manage these species as single Atlantic Coastal unit stocks, or a review of the literature has yielded publications with the needed information. Species, or information categories, that show an insufficient status of knowledge (empty boxes) are obvious candidates for study and offer guidance to scientist and management alike for developing priorities for research and research support.

At the same time, the matrix should not be viewed as a fixed determinant of assessment knowledge. Additional studies on any stock assessment or management component could prove useful, even if there exists an acceptable or lesser state of knowledge for the existing management plan. However, it should be the responsibility of the investigator to justify and explain the need for any study, regardless of the extant knowledge.

The remaining two sections of this report represent an expansion of the matrix. Each assessment or management term is explained, and practical examples of these stock assessment and management tools are provided. In addition, bibliographies of research reports and publications for all matrix species are provided, according to the assessment or management terms.


Stock Identification
Recruitment
Growth
Mortality and Background Mortality
Population Size
Fisheries Independent Data
Fisheries Dependent Data
Water Quality Tolerances
Trophic Dynamics
Habitat Utilization
Gear Conservation Engineering
Modeling
Social & Economic
Management Plans
American Shad
Atlantic Menhaden
Black Drum
Black Sea Bass
Bluefish
Cobia
Croaker
Red Drum
Sharks
Spanish Mackerel
Spot
Spotted Sea Trout
Striped Bass
Summer Flounder (Fluke)
Tautog
Weakfish
AS
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NA
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NA
Acceptable State of Knowledge
Significant Progress
Moderate Progress
Analysis Initiated
No Analysis
No Data
NA Not Applicable
CB Chesapeake Bay Plan
MD Maryland State Plan
MA MAFMC Plan
* MD, VA, ASMFC Plan
VA Virginia State Plan
UD Under Development
AS ASMFC Plan

Stock Identification

Stocks, or independent management units within a fishery, are typically defined on the basis of a lack of exchange between areas (revealed by tag and recapture studies) or a difference in genetic characters (morphological, life history, and genetic studies) between individuals from different areas. Analyses of movement provide information on direct fishery interaction, while genetic studies reveal instances where there has been historical (long-term) reproductive isolation. Genetic studies are not particularly useful for situations where there is considerable exchange between regions, as gene flow on the order of individuals per generation is sufficient to prevent the accumulation of significant genetic differences.

Recruitment

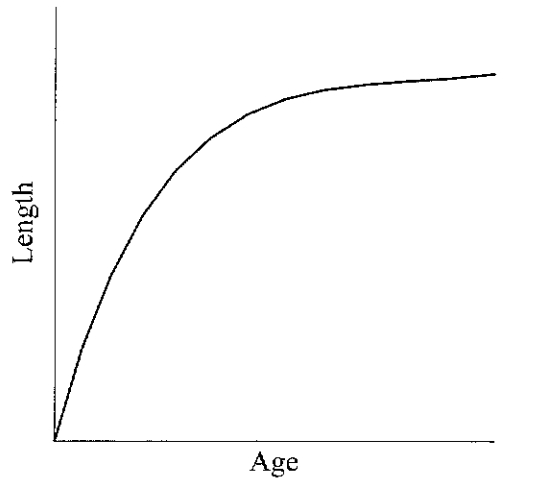
Recruitment is the measure of the weight or number of fish which enter a defined portion of a stock such as the fishable stock, spawning stock, or as young-of-the-year. In a broader context it includes the spawning season and grounds (where spawning actually occurs) and the nursery grounds (where the young-of-the-year spend their first season). In management it also includes analyses of fecundity (the capacity of a female to produce eggs), age at maturation, and indices of recruitment for spawner/recruit modeling.

One of the best examples of management use of recruitment data/information has been the development of the annual juvenile striped bass index in Maryland and Virginia (Figure 1). This index of the relative level of recruitment in the two states is used in the Interstate Fisheries Management Plan for Striped Bass as one "trigger" for more stringent or relaxed management action.

Growth

Growth is a fundamental property of population dynamics and one of the most important characteristics evaluated in fisheries stock assessments. Growth refers to an increase in size with time. It is usually measured in terms of length or weight. Growth in weight is the characteristic usually required in fisheries modeling, but it is usually measured through growth in length.

Quantification of growth starts with obtaining data to measure sizes at age in a sample of fish. These measurements are expressed using the following basic graph, a graph termed an age-length relationship (Graph A below).



Mathematical parameters of an age-length relationship are quantified using various growth equations. The growth equation most widely used in fisheries stock assessment is the von Bertalanffy equation.

For modeling, growth in weight must be estimated from the von Bertalanffy equation for growth in length. That is done by converting from length to weight using a length-weight relationship (Graph B below).

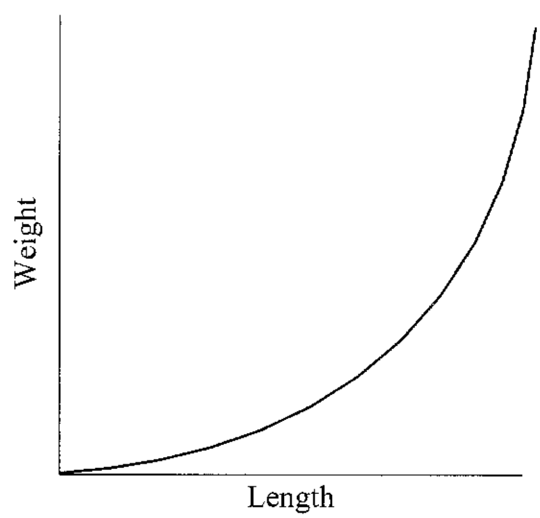
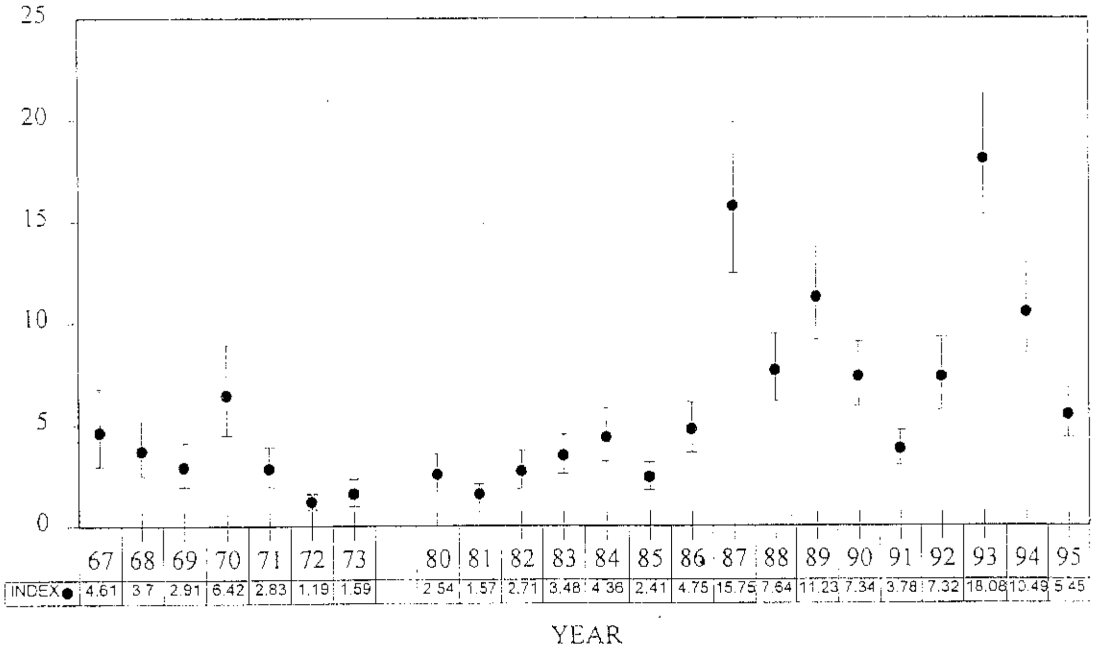


Figure 1. Annual Virginia Juvenile Striped Bass Index, 1967-1995.



Data for the length-weight relationship is obtained by measuring lengths and weights in a sample of fish.

Mortality

Mortality is usually expressed as a rate at which fish die. Mortality can be expressed as an annual percentage or instantaneous rate, where instantaneous rates account for mortality of a fraction of the stock over a short interval of time and are expressed logarithmically to facilitate ease in computation by fishery scientists.

Annual mortality (A) is the percentage of a fish stock which dies from all causes (natural and fishing), annually. The current A for weakfish is 79%.

Total instantaneous mortality (Z) is the combined effect of all sources of instantaneous mortality (generally fishing (F) and natural (M) mortality rates). Total F is the instantaneous rate at which fish in a stock die because of fishing activities and can be partitioned according to harvest and background (generally the fish are not harvested) mortality. Natural mortality (M) is the instantaneous rate at which fish die from causes other than fishing (e. g. predation, cannibalism). M can rarely be determined directly and is often derived from the difference between Z and F. From models, the current Z for weakfish is 1.55, F is 1.25, and M = 0.3. Table 1 shows the correspondence between various annual and instantaneous mortality rates.

The harvest or directed fishing mortality rate can be determined from tag (mark) and recapture studies. Background mortality usually arises from killed fish which are not subsequently harvested and includes hook-and-release mortality of angled fish, by-catch of fish in commercial fisheries targeting other species, poaching and discards of sub-legal fish from directed or by-catch fisheries. Precise estimates of background mortality rates are difficult to obtain and are usually incorporated by a total fishing mortality rate (F) estimate or represent the difference between total F

Table 1. Relationship among various mortality rates. Instantaneous total mortality rate (Z) = F (instantaneous fishing mortality rate) + M (natural instantaneous mortality rate).

Total instantaneous mortality (Z)	Annual mortality rate (A)	Annual percentage mortality (%)
0	0	0
0.10	0.10	10
0.20	0.18	18
0.30	0.26	26
0.40	0.33	33
0.50	0.39	39
0.60	0.45	45
0.70	0.50	50
0.80	0.55	55
0.90	0.59	59
1.00	0.63	63
1.50	0.78	78
2.00	0.86	86

and harvest-related, or directed, F. For example total F for Chesapeake striped bass in 1994 was 0.19, and background F was determined as 0.1, so directed (harvest-related) F was 0.09.

Population Abundance

Estimates of population abundance are of two types, absolute or relative. Regardless of the type, the information is important in of its self, and also for estimating other characteristics of a population, e.g., exploitation, mortality, and survival. The methodologies and models herein are but a few from a large body of possible inclusions. They were chosen for their simplicity or popularity, and it is not implied that they are the most appropriate for all situations.

Direct Enumeration

The simplest determination of a population's absolute abundance (N), or a portion of it (N_p) is by direct count. The method is inexpensive and relatively accurate. Its use, however, is restricted to populations in confined situations such as narrow and shallow, clear streams, or fishways where the fish can be seen, videotaped, or electronically counted, such as when the beam of a photoelectric cell is interrupted.

Mark-Recapture Data

Mark-recapture studies are conducted for various reasons in addition to estimating population size, e.g., appraisal of growth, mortality and survival rates, migratory routes, sites of exploitation, and fidelity to the location of release.

The Peterson method is a simple direct proportion model for estimating N from a single marking episode and a single recapture of marked fish. The equation is

$$\frac{N}{c} = \frac{m}{r}$$

where N is as before, and is the only unknown value, c is the number of fish in the sample, m is the number of fish marked and released, and r is the number of marked fish in c. The assumptions for this model are: 1) the marked fish are distributed randomly among the unmarked, or either the marking or recapture sample is random; 2) the probability of capture or death is not increased by marking; 3) there is no immigration; 4) marks are retained; and 5) all captures of marks are reported.

Methods that utilize single mark and single recapture episodes require a considerable proportion of the population must be tagged in order that marked individuals be recaptured. Other models, beginning with the Schnabel Method introduced in 1938, employ multiple marking and recapture episodes. The assumption of the Peterson model apply, in part or whole, to these methods, and, in addition, it is assumed that mortality is negligible during the time necessary to make the estimate. More complex models exist that employ multiple periods of marking and recapture, but are more flexible, e.g., some tolerate known mortality, others unknown mortality, emigration, and other considerations that affect estimates of population size. These models require a greater commitment of resources.

Depletion Methods

The concept behind depletion methods (also called catch-effort methods) is to assess how removal of individuals from a population affects estimates of relative abundance of the remaining individuals in the total stock. The assumptions are that the stock is closed (no immigration or emigration) and there is no natural mortality during the period of removal. The purpose is to estimate how large the cumulative catch would have to be to reduce the relative abundance estimate to zero. That prediction of cumulative catch is then an estimate of stock size before removal began.

The Leslie Method is a linear depletion model in which the initial population size N and the catchability coefficient q are estimate from

$$C_i/f_i = qN - qK_i$$

where C_i/f_i is catch-per-unit-effort, and K_i is the cumulative catch up to but not including the ith sampling period. The estimate of N is obtained from the average values of K and C/f_i, by,

$$N = \overline{K} + \overline{(C/f)}/q$$

can be visually estimated by extrapolating the regression line to the *X-axis*, at which point the *Y-axis* value (C/f_i) is zero and K_i is an estimate of N.

Virtual Population Analysis

Virtual Population Analysis (VPA) is one of several models utilizing catch-at-age-data. VPA is a recursive algorithm that calculates stock size based on catch data; recruitment is not a consideration because only a single year class is followed. The basic concept is that the number alive this year (N_i) is equal to the number alive at the beginning of next year (N_{i+1}) plus the catch this year (C_i) plus natural mortality this year (M). In addition to catch-at-age data, an estimate of fishing mortality (F) at the oldest age is needed. VPA proceeds from the age of the oldest individual caught (assuming gear selectivity does not exclude older individuals) back to the age at which recruitment occurs. Although not presented herein, the mathematical model is relatively straight forward when M and F occur in the same time period, but it is more complex when fishing occurs in a restricted period while M is, of course, unrestricted. In addition to estimating N at the time the cohort entered the fishery, the initial F progressively changes and has been said to converge on the "*true F*," this value, however, is not independent of the choice of M. The reader is referred to the references given for greater detail and examples.

Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) is a relative measure of abundance and may be related to population size. Measures of CPUE, however, must be used with caution, particularly when derived from commercial catch data. The CPUE may often remain high, even as abundance is declining due to fish aggregation and non-random fishing, and will not significantly decrease until the stock crashes. In contrast, if only a portion of the population is fished because it is readily accessible and productive, the CPUE will decrease rapidly while total abundance is relatively unaffected.

Surveys

The abundance of a population, in absolute or relative terms, may be estimated by some type of survey. It is important that surveys designed to monitor changes in abundance over time be repeated in as nearly identical form as possible. Surveys will be comparable if catches are adjusted to a standard sampling unit, such as area swept or volume of water filtered for active nets. With knowledge of area swept or volume of water filtered, old and new catch data are comparable, and old catch data can be adjusted to a new standard sampling unit when a change in gear or vessel occurs. Catches should be recorded as fish encounters with gear per time unit, for fishing lines and passive nets.

Juvenile indexes derived from survey catch data are frequently used to estimate the relative success of spawning. One indicator of the worth of an index is the strength of the correlation between its annual index values and recruitment of the respective year classes. A strong correlation indicates the index is attained after year-class strength is established. The juvenile index for river herring in the Mattaponi and Pamunkey rivers is an example; the correlations between the indexes and recruitment of the respective year classes are highly significant ($r = 0.87$ and 0.78 in the Mattaponi and Pamunkey rivers, respectively). Juvenile indexes may be used as a surrogate for actual recruitment in spawner-recruit models when the surveys have been made over a reasonably large range in population sizes.

Estimates of total abundance can be made from surveys of subunits of a total area. If a units are randomly chosen from A divisions of an entire area or time space occupied by a population, and for each a unit there is a count n_i, the estimate of the population is

$$N = \frac{A}{a}\sum_{i=1}^{a} n_i$$

There are statistical models for estimating N from counts along transect surveys from aircraft and vessels, or swim transects for sessile and slow moving organisms.

References

Cochran, W. G. 1977. Sampling techniques (3rd ed.). Wiley Series in Probability and Mathematical Statistics, John Wiley and Sons, New York.

Gulland, J. A. (Ed.) 1977. Fish population dynamics. John Wiley and Sons, New York.

Hilborn, R. And C. J. Walters. 1992. Quantitative fisheries stock assessment. Chapman and Hall, New York.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 191.

Rothschild, B. J. 1986. Dynamics of Marine Fish Populations. Harvard University Press, Massachusetts.

Fishery Independent Data

These are data and information collected by scientists and managers independently of commercial and/or recreational fishing activities. These data are collected directly by the scientist or manager which allows a degree of flexibility for design freedom. These data are free of bias inherent in a collection from a directed fishery. For example, abundance data collected from an area where the species is scarce, as opposed to data from the fishery which would only operate where fish was abundant enough to make a profit. It also allows collection of sizes and ages, for example young-of-the-year striped bass, that are not legal in the fishery. The long term collection of fishery independent data are not confused as management regimes are amended in response to a management plan that may change size or creel limits. Fishery independent data, while less biased than fishery dependent, is very personnel intensive and therefore expensive. Other examples are given in the section entitled **Surveys** on Page 5.

Fishery Dependent Data

This information is collected directly from both the commercial and recreational fisheries. Some examples are the VMRC Commercial Fishermen Mandatory Reports, and the VMRC Commercial Stock Assessments, Recreational Striped Bass Catch Reports, VMRC Commercial Pound Net Panel Study. Some problems with fishery dependent data are that the information could be biased by noncompliance in reporting harvest or by regulations on the gear or species fished. One use of fishery dependent data is to indirectly assess abundance of the fisheries from year to year or over a longer period of time.

Water Quality Tolerances

These tolerances refer to a species sensitivity to changing water characteristics such as salinity, turbidity, temperature, light, nutrients, toxicants, pH and dissolved oxygen. Usually each species has a unique range of values for each water characteristic, and values outside of this range may inhibit the growth or survival of the species. For example, a species with a narrow range in water quality tolerance would be adversely affected by changes in water quality, compared to a species with a broader water quality tolerance.

Trophic Dynamics

Trophic dynamics refers to the flow of energy through the complex food webs found in ecosystems, with reference to fishes that might be the target for management. It is important to understand how variations in primary production and/or the production of prey organisms might affect such processes as survivorship and recruitment of young-of-the-year, growth rates, age or size at maturity, and fecundity. In addition, knowledge of trophic dynamics can provide information about interspecific competition, and the effects of predation on natural mortality rates at various life history stages.

Habitat Utilization

Here, utilization indicates a species interaction with a particular habitat. The interaction is usually driven by a requirement such as growth, survival or reproduction. Some species occupy a particular habitat all their life, while other species move from one habitat to another based on the changing needs of that species. For example, striped bass spend the majority of their life in the ocean, but leave ocean waters for fresh water habitats in order to spawn. Knowledge of habitat utilization is important when considering applications for various permits, such as would be involved for aquaculture or fish farming.

Gear Conservation Engineering

Perhaps one of the least understood, but offering great promise to resource management, is the area of gear conservation and engineering. In an era in which management is becoming increasingly concerned with resolving the open-access, common-property problem, there is still considerable need to control the age at first capture and to mitigate or reduce the by-catch of protected marine mammals and turtles and other species of non-target finfish and shellfish. Gear conservation and engineering offers an opportunity to deal with these problems.

Overall, there does not appear to have been a significant amount of work on gear conservation and engineering in Virginia during the past 25 years. Other than mesh size requirements for nets, cull rings in the hard crab pot fishery are the first example of by-catch reduction devices required by regulation. Significant work has also been done on escape panels in pound nets, designed to allow undersized grey trout, as well as other fish, to escape the net unharmed. Testing of these escape panels has demonstrated their ability to retain grey trout of marketable size, while releasing smaller fish.

Modeling

Modeling applied to examining fisheries problems and issues is often terrifying to researchers and members of industry. In fact, one leader of the seafood industry once stated "when the scientists start modeling your fishery, it is time to find another job." Modelling, however, is an integral and necessary component of fisheries science. What are models? In general, a model is a quantitative--mathematical or statistical--description of the relationships between variables. For example, the traditional model of M.B. Schaefer (1957) which relates long-run equilibrium catch to effort has been widely used to estimate maximum sustainable yield or the maximum average annual harvest that can be sustained.

Some models are qualitative. That is, we do not have a fixed mathematical or statistical relationship between variables. We instead have an idea about the possible relationship. For example, we believe that as current stock size increases, future recruitment will increase; we do not know the actual relationship. Alternatively, we conceptualize that as water quality improves, stock abundance and resource conditions will improve. Many qualitative models, however, are also quantitative models. For example, we might only know that resource levels will increase, remain unchanged, or decrease given different environmental conditions. Using special modelling methods, we may model the qualitative response.

In examining resource conditions, fisheries management, and regulation, numerous disciplines employ many quantitative and qualitative models. Foremost among modeling activities is the set of models used to assess resource conditions. These are the models which explain and predict the dynamics of fish populations or changes in resource conditions over time (e.g., growth over time, the relationship between weight and length, or the relationship between fishing mortality and fishing effort). Economic modelling is also important for resource management. Economic modelling focuses on the relationships between economic variables. For example, how much will the catch of a particular species change if the ex-vessel price for that species increases five percent? An increasing area of modelling is ecosystem modelling which more completely focuses on the entire biotic and abiotic system.

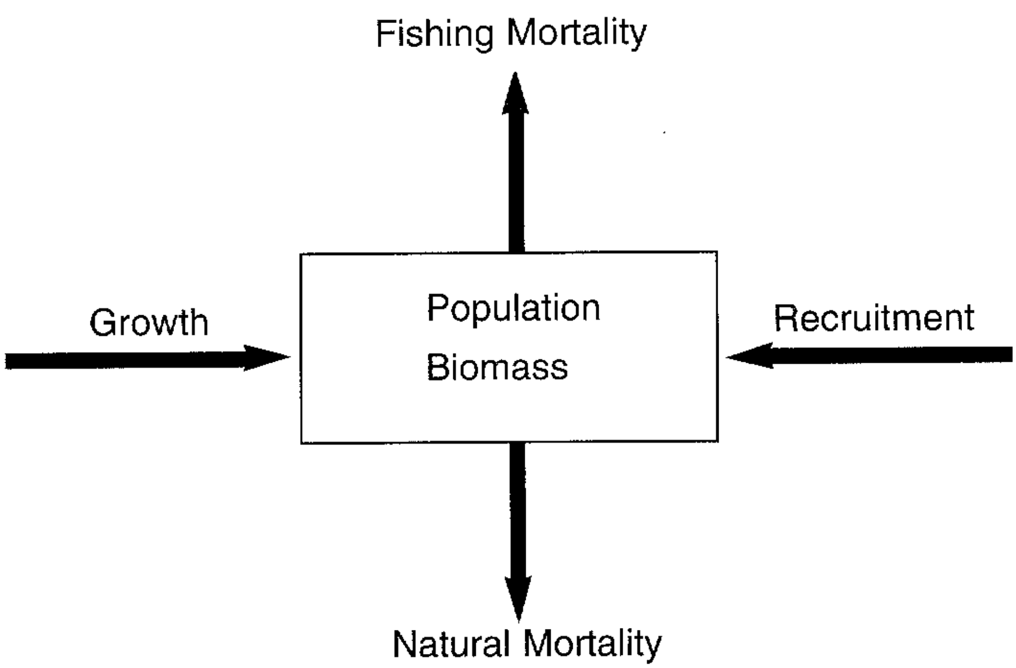
In the simplest case of a fisheries model, production by a population is considered. The static and nonstochastic input-output model of F.S. Russell (1931) "Some theoretical considerations on the overfishing problem" (J. Cons. Perm. Int. Explot. Mer 6:3-27) offers a convenient framework for understanding the modelling of the underlying population dynamics (Figure 4). The model restricts attention to five basic components: (1) growth, (2) recruitment, (3) natural mortality, (4) population biomass, and (5) fishing mortality.

Any of the components, however, may be modified to better reflect environmental, ecological, and economic conditions and the underlying dynamics. For example, we might have population biomass affecting recruitment and recruitment affecting population biomass. We might expand on growth, biomass, and mortality to reflect age/size/sex composition. The same could be done for growth and mortality. What are some of the basic conceptual models for examining stock? Although production by an individual fish is the most basic model, there appear to be few models used for fisheries management that actually attempt to estimate energy change among the various trophic levels.

Fishing mortality is perhaps the information of greatest concern to resource managers. Fishing mortality may be assessed via several methods and models but is most useful when related to fishing effort. The basic framework relates fishing mortality (F) to fishing effort (f) through a catchability coefficient (q): $F = q f$. By knowing q and f, resource managers may assess changes in fishing mortality associated with regulatory strategies. There is a wide array of models used by assessment scientists to determine resource conditions.

Possibly one of the most contentious (but widely used) models of fisheries science is the stock-recruitment relationship. There are numerous formulations; but attention to the simple functional model $R = f(P)$, where R is number of recruits and P is size of parental stock which may be measured in numbers, weight, or egg production. The stock-recruitment relation-

Figure 4. Input-output Model of Fish Population



ship may take many forms, but, usually it assumes that the number of progeny increase, as the number of spawners increase, reaches a maximum, and then declines.

Yield per recruit models are also widely used in stock assessments and to examine fishery regulations. In simple terms, the yield per recruit is the per unit weight of recruits or additions to the vulnerable stock because of from growth. For example, small fish may not be harvested by a given gear, but because of growth, they are eventually vulnerable to being harvested by the gear). Yield per recruit (YPR) models widely vary in functional form and with respect to the number of variables thought to affect recruitment. In general form, YPR is a function of the growth rate, the natural mortality rate, and the exploitation pattern of a particular fishery on a stock. For example, YPR might be expressed as a function of the fishing mortality rate. Alternatively, we might model the spawning stock biomass per recruit (SSB/R) and relate that to fishing mortality.

Modeling is thus an essential component of fishery management plans and regulations. Stocks and associated resource conditions must be determined. Only through modeling is it possible to even crudely assess whether or not regulatory strategies will achieve stated objectives. Moreover, economic modeling is essential for detemining the social and economic ramifications of resource management. It must be remembered, however, that models and data give inaccurate results; results of models are only as good as the models and the data.

Management and Social and Economic Concerns

Although management and regulation of fisheries are typically ensconced in the population dynamics or biology of the resource, economic and social concerns typically drive resource management. That is, resource managers not only usually have an obligation but also are typically mandated by law to ensure that fisheries management offers maximum benefits to society. Moreover, management is concerned with maintaining or enhancing economic activities from resource exploitation. Most recently, managers have also become concerned with maintaining the social and cultural traditions of fishing communities.

Why not just manage all fisheries to achieve maximum sustainable yield (MSY)? MSY-based management would at least allow fishers the opportunity to harvest the maximum average annual harvest possible, and conceivably, could allow the largest sustainable number of fishermen. MSY-based management, however, is fraught with difficulties. Under such a strategy, benefits and economic opportunities are not maximized. Without additional regulations, profits to the fishery and usually to individual fishermen are driven to zero. There are few winners with an MSY-based strategy. Fishermen are also typically forced to "race" to harvest the resource which further exacerbates social and economic problems. A "race to fish" may well disrupt social and community structure.

Management of Virginia's marine resources, however, must also include recreational fisheries. The social and economic aspects of recreational fisheries have actually been accorded more attention than given to commercial fisheries. The National Marine Fisheries Service obtained social and economic data in 1994 which permits an assessment of the social benefits of recreational fishing. The Virginia Institute of Marine Science is updating the NMFS study for 1995 and developing a socio-economic impact assessment framework which will permit assessment of the economic impacts of recreational fishing and changes in fishing patterns.

Economic and social concerns, to a large degree, focus on product flow. Relative to commercial fisheries, the emphasis is on the linkages between the biological environment, ex-vessel or harvesting sector, processing/wholesaling sector, retail sector, and consumer or final users. For recreational fisheries, the emphasis is on the linkages between the biological environment, marinas and support services, expenditure patterns, and preferences of the recreational angler.

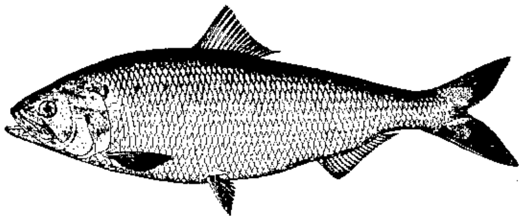
The most difficult area of social and economic research will be assessing the trade-offs between equity, fairness, and allocation of resource among competing user groups. When decisions about resource allocation are made, they should be partly based, at least, on how the allocation schemes enhance the economies of the Commonwealth and distribute benefits to the citizens. At least, the state should know how different resource allocations affect the economies of coastal communities.

Management Plans

Fishery management plans (FMP's) provide a framework for coordinated conservation, allocation, and utilization of fishery resources. Plans consist of pertinent background information (biological, economic, and social aspects of the resource and its fishery), descriptions of problems with the status of the resource or its fishery, and potential solutions or management strategies.

The Virginia Marine Resources Commission (VMRC), Atlantic States Marine Fisheries Commission (ASMFC), and Mid-Atlantic Fishery Management Council (MAFMC) each prepare fishery management plans. Plans of the VMRC generally are drafted as Chesapeake Bay management plans in coordination with the State of Maryland and are implemented by state regulation. These plans often mirror those of the ASMFC. ASMFC management plans usually pertain to coastal migratory species such as bluefish, summer flounder, and weakfish. Compliance with these plans is mandated by federal law (Atlantic Coastal Fisheries Cooperative Management Act). Plans of the MAFMC generally pertain to species harvested predominantly in the Exclusive Economic Zone (3-200 mile zone). These plans are implemented by federal regulation. Occasionally, the above mentioned organizations prepare joint management plans to ensure that a species is managed throughout its range.

In addition to providing for the management of a particular species, FMP's often cite research needs for that species. These sections of the management plan should serve as another valuable guide in setting research priorities.



American Shad

Alosa sapidissima

American shad in Atlantic coastal waters range from Florida to the Gulf of St. Lawrence, but they are most abundant from Connecticut to North Carolina (Mansueti and Kolb 1953); the extreme extent of their northern range is Labrador (Dempson et al. 1983). During an average life span of 5 years at sea, shad may migrate over 20,000 km (Dadswell et al. 1987). The major fisheries for shad occur from North Carolina to the Gulf of Maine. Shad, like its close relatives, the alewife, blueback herring, and hickory shad (*A. pseudoharengus, A. aestivalis, and A. mediocris*, respectively) are anadromous and, therefore, they must migrate from the ocean to spawn in freshwater. The time of the spawning is related to water temperature, with the peak movement when temperatures are about 55 to 61° F (Walburg and Nichols 1967). In Virginia, spawning is generally between mid- to late March and early June. Juvenile (young-of-the-year) shad in the Chesapeake region spend their first summer in the tidal freshwater and the estuary. Although a few juveniles winter over, most migrate to sea in the late fall and do not return to spawn until age 4 or 5.

Accounts in colonial times of fishes in the estuaries and open freshwater systems of the east coast are replete with statements about the great abundance and desirability of American shad and river herring (alewife and blueback herring). Much of the information regarding Virginia's anadromous fishes in colonial days was published by the Virginia Commission of Fisheries (VCF) in 1875, the first year of the Commission's existence. Before the colonists came to Virginia, Native Americans caught large quantities of shad in the rivers and streams with crude seines made of bushes (Walburg and Nichols 1967). Shad were so plentiful that they were easily speared with pointed sticks as they swam on the flats (VCF 1875). The early settlers utilized river herring and shad as a major food supply, and their ability to keep well when salted added to their value (VCF 1875; Walburg and Nichols 1967). Many of those involved in the early shad fisheries were large plantation owners. Thomas Jefferson brought shad to Monticello, and George Washington ran a shad fishing business, and leased fishing rights and privileges on his land on the Potomac River. There was a general pattern throughout the coastal colonies regarding the abundance of anadromous fish stocks. A plethora of fishes, then construction of dams to harness water power for mills, and, subsequently, a great reduction or extirpation of the anadromous runs. Concern about the plight of the anadromous stocks led to legislation requiring fish passage facilities. In 1623 the first fishery law in the Colonies (known as the Plymouth Colony Fish Law) was passed for the protection of alewives. In 1680, the first law in Virginia protecting fish was passed by the House of Burgesses. There were numerous laws enacted in Virginia for the protection of anadromous fish stocks since the colonial period, but enforcement of the laws was most often lax or absent. The loss of ancestral spawning grounds due to dams and other obstructions gained ardent attention only when a serious depletion of the striped bass (*Morone saxatilis*) stocks in Chesapeake Bay was recognized in the late 1970's.

Total landings of American shad along the Atlantic coast have sharply declined since the late 1800s. The landings in 1896 exceeded 22,000 metric tons (mt), averaged 1,000 mt in the 1980s , and declined to only 700 mt in 1992 and 1993 (Shepherd 1995). Shad landings in Chesapeake Bay followed the same pattern as collectively exhibited along the Atlantic seaboard. The shad fishery of Chesapeake Bay gained importance about 1869, and developed rapidly in the ensuing years. Due to decreased landings, an artificial hatching program was begun in 1875 by the U.S. Fish Commission and the Virginia Commission of Fisheries. In 1879 the fishery began to improve, and this increase led biologists to believe that the shad fishery was largely dependent upon artificial propagation. The hatchery program was expanded, but later studies showed that the upsurge could not be correlated with the output from artificial stocking (Mansueti and Kolb 1953). In 1880 the tributaries of the Chesapeake Bay yielded more than 2,268 mt of shad. Virginia ranked second to New Jersey in shad landings in 1896 with 4,990 mt. In 1908, Virginia's catch of 3,311 mt of shad made it the most important fish caught in Virginia and comprised about one fourth of all shad taken in the United States. In the early 1900s a decline began in the numbers of shad harvested despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953). Heavy fishing pressure and the reduction in spawning grounds possibly offset the potential gains of the hatchery operations, or there was poor survival of the shad fry. The total landings in Virginia were 442 mt in 1980, and only 180 mt in 1990. The Virginia Marine Resources Commission imposed season limits in the bay-side (bay and rivers) shad fisheries in 1991, 1992, and 1993, and the fisheries were closed in 1994 and 1995 (VMRC Regulation 450-01-0069). Although the shad and river herring fishery management plan calls for the enhancement of the traditional (bay-side) Alosa fisheries, the ocean fishery was excluded from the recent management strategies. The bay-side fisheries accounted for 90% of the shad landed in Virginia and the ocean-side intercept fishery 10% in 1980, by 1992, however, 90% of the landings were from the ocean fishery.

Stock Identification

Brown, B. L. and J. M. Epifanio. 1994. Mixed-stock analysis of American shad in Virginia's and Maryland's coastal intercept fisheries. Report to the Virginia Marine Resources Commission, Sport Fish Restoriation Project No. F-110-R. Ecological Genetics Laboratory, Virginia Commonwealth University, Richmond, Virginia.

Brown, B. L. and R. W. Chapman. 1991. Genetic analysis of American shad entering Chesapeake Bay. Report to the Chesapeake Bay Commission, Annapolis, Maryland.Dadswell, M. J., G. D. Melvin, P. J. Williams, and D. E. Themelis. 1987. Influences of origin, life history, and chance on the Atlantic coast migration of American shad. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

Recruitment

Lorda, E. and V. A. Crecco. 1987. Stock-recruitment relationship and compensatory mortality of American shad in the Connecticut River. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond, Virginia. 38 pp.

Growth

Cating, J. P. 1953. Determining age of Atlantic shad from their scales. U.S. Fish and Wildlife Service Fishery Bulletin 54:187-199.

Mortality

Chittenden, M. E., Jr. 1976. Weight loss, mortality, feeding, and duration of resident adult American shad, *Alos sapidissima*, in fresh water. Fishery Bulletin (U.S.) *74*:151-157.

Lorda, E. and V. A. Crecco. 1987. Stock-recruitment relationship and compensatory mortality of American shad in the Connecticut River. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

Population Size

Chittenden, M. E., Jr. 1974. Trends in abundance of American shad, *Alosa sapidissima* in the Delaware River Basin. Chesapeake Science *15*:96-103.

Gibson, M., V. Crecco, and D. Stang. 1988. Stock assessment of American shad from selected Atlantic coast rivers. Special Report No. 15 of the Atlantic States Marine Fisheries Commission, Washington, D.C.

Fisheries Independent Data

Lorda, E. and V. A. Crecco. 1987. Stock-recruitment relationship and compensatory mortality of American shad in the Connecticut River. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond, Virginia. 38 pp.

Fisheries Dependent Data

McDonald, M. 1884. The shad and alewife. *In* The fisheries and fishery industries of the United States, pp. 594-607; G. B. Goode and 20 associate author. U.S. 47th Congress, 1st Session, Senate Miscellaneous Document 124, Washing, D.C.

Shepherd, G. 1995. American shad. *In* Status of the Northeastern United States for 1994, pp. 128-129. NOAA Technical Memo NMFS-NE-108.

Trophic Dynamics

Crecco, V. A., and M. M. Blake. 1983. Feeding ecology of coexisting larvae of American shad and blueback herring in the Connecticut River. Transactions of the American Fisheries Society 112:498-507.

Domermuth, R. B., and R. J. Reed. 1980. Food of juvenile American shad, *Alosa sapidissima*, juvenile blueback herring, *A. aestivalis*, and pumpkinseed, *Lepomis gibbosus*, in the Connecticut River below Holyoke Dam, Massachusetts. Estuaries 3:65-68.

Levesque, R. C., and R. J. Reed. 1972. Food availability and consumption by young Connecticut River shad *Alosa sapidissima*. Journal of the Fisheries Research Board of Canada 29:1495-1499.

Habitat Utilization and Water Quality

Chittenden, M. E., Jr. 1972. Responses of young American shad, *Alosa sapidissima*, to low temperature. Trans. Amer. Fish. Soc. 101:680-685.

Chittenden, M. E., Jr. 1973. Effects of handling on oxygen requirements of American shad, *Alosa sapidissima*. J. Fish Res. Bd. Canada 30:105-110.

Chittenden, M. E., Jr. 1975. Dynamics of American shad, *Alosa sapidissima*, runs in the Delaware River. Fishery Bulletin (U.S.) *73*:487-494.

Chittenden, M. E., Jr. 1976. Present and historical spawning grounds and nurseries of American shad, *Alosa sapidissima*, in the Delaware River. Fishery Bulletin (U.S.) *74*:343-352.

Dadswell, M. J., G. D. Melvin, and P. J. Williams. 1983. Effect of turbidity on the temporal and spatial utilization of the inner bay of Fundy by American shad (*Alosa sapidissima*) (Pices: Clupeidae) and its relationship to local fisheries. Canadian Journal of Fisheries and Aquatic Sciences *40*:322-330.

Dadswell, M. J., G. D. Melvin, P. J. Williams, and D. E. Themelis. 1987. Influences of origin, life history, and chance on the Atlantic coast migration of American shad. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

Dempson, J. B., L. J. LeDrew, and G. Furey. 1983. Occurrence of American shad (*Alosa sapidissima*) in northern Labrador waters. Naturaliste canadien (Quebéc) 110:217-221.

Dodson, J. J. And L.A. Dohse. 1984. A model of olfactory-mediated conditioning of directional bias in fish migrating in reversing tidal currents based on the homing migration of American shad *Alosa sapidissima*. *In*: Mechanisms of migration in fishes, pp 263-282; J. D. McCleave, G. P. Arnold, J. J. Dodson, and W. H. Neill ,editors. Plenum, New York, New York.

Jesien, R. And C. Hocutt. 1991. Movement of American shad in the Chesapeake Bay. Progress Report to the Maryland Department of Natural Resources, Annapolis, Maryland.

Leggett, W. C. 1976. The American shad (*Alosa sapidissima*), with special reference to its migration and population dynamics in the Connecticut River. The Connecticut River Ecological Study; the Impact of a Nuclear Power Plant. American Fisheries Society Monograph No. 1:169-225.

Leggett, W. C. And R. R. Whitney. 1972. Water temperature and the migration of American shad. Fishery Bulletin (US) *70*:659-670.

Marcy, B. C., Jr. 1976. Early life history studies of American shad in the lower Connecticut River and the effects of the Connecticut Yankee plant. American Fisheries Society Monograph 1:141-168.

Massmann, W. H. 1963. Summer food of juvenile American shad in Virginia waters. Chesapeake Science 4:167-171.

Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. Maryland Department of Research and Education, Publication No. 97. 293 pp.

Melvin, G. D., J. D. Michael, and J. D. Martin. 1985. Fidelity of American shad, *Alosa sapidissima*, (Osteichthyes: Clupeidae) to its river of previous spawning. Canadian Journal of Fisheries and Aquatic Sciences 42:1-19.

Moffitt, C. M., B. Kynard, and S. G. Rideout. 1982. Fish passage facilities and anadromous fish restoration in the Connecticut River Basin. Fisheries (Bethesda) *7*(6):2-11.

Talbert, G. B. And J. E. Sykes. 1958. Atlantic coast migrations of American shad. Fishery Bulletin (U.S.) *58*:473-490.

Modeling

Dodson, J. J. And L.A. Dohse. 1984. A model of olfactory-mediated conditioning of directional bias in fish migrating in reversing tidal currents based on the homing migration of American shad *Alosa sapidissima*. *In*: Mechanisms of migration in fishes, pp 263-282; J. D. McCleave, G. P. Arnold, J. J. Dodson, and W. H. Neill ,editors. Plenum, New York, New York.

Lorda, E. and V. A. Crecco. 1987. Stock-recruitment relationship and compensatory mortality of American shad in the Connecticut River. *In* American Fisheries Society Symposium 1: Common strategies of anadromous and catadromous fishes, pp 313-330; M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. R. Rulifson, and J. E. Cooper, editors. American Fisheries Society, Bethesda, Maryland.

Social and Economic

Atran, S. M., J. G. Loesch, W. H. Kriete, Jr., and B. Rizzo. 1983. Feasibility study of fish passage facilities in the James River, Richmond, Virginia. Virginia Institute of Marine Science report prepared for Virginia Commission of Game and Inland Fisheries. Special Report No. 269 in Applied Marine Science and Ocean Engineering. 109 p. + appendix.

Dadswell, M. J., G. D. Melvin, and P. J. Williams. 1983. Effect of turbidity on the temporal and spatial utilization of the inner bay of Fundy by American shad (*Alosa sapidissima*) (Pices: Clupeidae) and its relationship to local fisheries. Canadian Journal of Fisheries and Aquatic Sciences *40*:322-330.

Loesch, J. G. and S. M. Atran. 1994. History of *Alosa* management: Virginia, a case example. *In* Proceedings of the Anadromous *Alosa* Symposium, pp. 1-6; J. E. Cooper, R. T. Eades, R. J. Klauda, and J. G. Loesch, editors Tidewater Chapter, American Fisheries Society, Bethesda, Maryland.

Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. Maryland Department of Research and Education, Publication No. 97. 293 pp.

Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. Maryland Department of Research and Education, Publication No. 97. 293 pp.

VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond, Virginia. 38 pp.

Fishery Management Plans

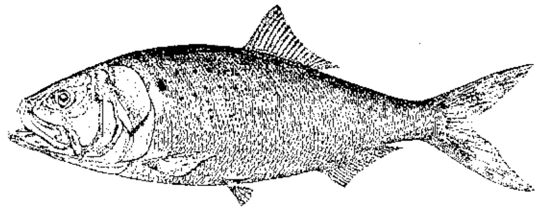
ACMFC. 1988. 1988 Supplement to American shad and river herring fishery management plan. Fisheries management Report No. 12 of the Atlantic States Marine Fisheries Commission, Washington, D.C.

Chesapeake Executive Council. 1989. Chesapeake Bay alosid management plan.

Flagg, L. 1990. Review of Atlantic States Marine Fisheries Commission Fishry Management Plan for American shad and river herring. *In*: Atlantic States Marine Fisheries Commission 1990 shad and river herring workshop report. October 16-17, 1990, Nags Head, NC.

Loesch, J. G. and S. M. Atran. 1994. History of *Alosa* management: Virginia, a case example. *In* Proceedings of the Anadromous *Alosa* Symposium, pp. 1-6; J. E. Cooper, R. T. Eades, R. J. Klauda, and J. G. Loesch, editors Tidewater Chapter, American Fisheries Society, Bethesda, Maryland.

Walburg, C. H. and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 550. 105 pp.



Atlantic Menhaden

Brevoortia tyrannus

Atlantic menhaden (*Brevoortia tyrannus*) are distributed from northern Florida to Nova Scotia in estuarine and coastal waters. Adult and juvenile menhaden feed by straining plankton from the water. They, in turn, serve as prey for many fish and sea birds.

Sexual maturity begins just before age 3, with major spawning areas from the Carolinas to New Jersey; spawning occurs primarily offshore (20-30 miles) during winter. Buoyant eggs hatch at sea, and larvae are carried into estuarine nursery areas by ocean currents. Larvae change into juveniles in estuaries where they spend most of their first year of life; then migrate to the ocean in late fall. Adult and juvenile menhaden migrate south from fall to winter, and adult menhaden migrate north in spring. Adult and juvenile menhaden form large, near-surface schools, primarily in estuaries and near-shore ocean waters, from early spring through early winter. By summer menhaden schools stratify by size and age along the coast, with older and larger menhaden found farther north. During fall and early winter menhaden of all sizes and ages migrate south around the North Carolina capes.

The menhaden fishery is one of the most important and productive fisheries on the Atlantic coast. The overwhelming majority of menhaden catches come from estuaries and the nearshore coastal waters, often within a mile of the ocean shore. In 1993 about 40 percent of U.S. Atlantic coast commercial fisheries landings, by weight, were Atlantic menhaden. Landings have remained fairly consistent, ranging from 300,000 to 400,000 metric tons since the mid-1970s. The purse-seine fishery is the primary fishery and it provides catch for reduction which is processed into fish meal, fish oil and fish solubles. Landings of menhaden for bait by fisheries (such as pound net and snapper rig) are thought to comprise about 11 percent of the total Atlantic menhaden catch.

A major study during the 1992 season reaffirmed previous findings that the menhaden purse-seine fishery is an extremely "clean" fishery; that is, there is a negligible incidental catch of other species in the menhaden purse-seine fishery (less than one tenth of one percent) (Austin et al. 1994).

There have been significant changes in the Atlantic menhaden stock and fishery since the Atlantic States Marine Fisheries Commission's 1981 Atlantic Menhaden Fishery Management Plan was adopted. Different fishing areas are being targetted (most fishing is now in the Chesapeake Bay rather than the mid-Atlantic); the number of vessels in the reduction fishery has declined (from 150 in 1955 to 31 in 1993) as has the number of shore-side reduction facilities (from 23 in 1955 to 5 in 1993); regulatory restrictions have increased and menhaden have smaller mean weight-at-age since the mid-1970s.

The menhaden stock is healthy, with total stock size and recruitment comparable to levels recorded during the late 1950s - early 1960s. The most recent estimates of maximum sustainable yield are about 480,000 metric tons. Research indicates that undefined environmental conditions probably are more important in determining reproductive success than spawning stock size, although there is a weak spawner-recruit relationship.

Stock Identification

Dryfoos, R.L., R.P. Cheek and R.L. Kroger. 1973. Preliminary analyses of Atlantic menhaden, *Brevoortia tyrannus*, migrations, population structure, survival and exploitation rates and availability as indicated from tag returns. Fish. Bull. 71: 719-734.

Hettler, W.F. 1984. Description of eggs, larvae and early juveniles of gulf menhaden, *Brevoortia patronus*, and comparisons with Atlantic menhaden, *B. tyrannus*, and yellowfin menhaden, *B. smithi*. Fish. Bull. 82: 85-95.

Nicholson, W.R. 1978. Movements and population structure of Atlantic menhaden indicated by tag returns. Estuaries 1: 141-150.

Recruitment

Ahrenholz, D.W., W.R Nelson, and S.P. Epperly. 1987. Population and fishery characteristics of Atlantic menhaden, *Brevoortis tyrannus*. Fish. Bull. 85: 569-600.

Checkley, D.M., Jr., S. Raman, G.L. Maillet and K.M. Mason. 1988. Winter storm effects on the spawning and larval drift of a pelagic fish. Nature 335(6188): 346-348.

Gabriel, W.L., M.P. Sissenwine and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: An example for Georges Bank haddock. No. Amer. J. Fish. Mgmt. 9: 383-391.

Lewis, R.M., D.W. Ahrenholz and S.P. Epperly. 1987. Fecundity of Atlantic menhaden, *Brevoortia tyrannus*. Estuaries 10(4): 347-350.

Nelson, W.R., M.C. Ingham and W.E. Schaaf. 1977. Larval transport and year-class strength of Atlantic menhaden, *Brevoortia tyrannus*. Fish. bull. 75: 23-41.

Reish, R.L., R.B. Deriso, D. Ruppert and R.J. Carroll. 1985. An investigation of the population dynamics of Atlantic menhaden (*Brevoortia tyrannus*). Can. J. Fish. Aquat. Sci. 42(Suppl.1): 147-157.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191, 382 p.

Vaughan, D.S., J.V. Merriner, D.W. Ahrenholz and R.B. Chapoton. 1986. Stock assessment of menhaden and coastal herrings. NOAA Tech. Memo. NMFS-SEFC-178, 46 p.

Vaughan, D.S. and J.W. Smith. 1988. A stock assessment of the Atlantic menhaden, *Brevoortia tyrannus*, fishery. NOAA Tech. Rep. NMFS 63, 18 p.

Growth

Kroger, R.L., J.F. Guthrie and M.H. Judy. 1974. Growth and first annulus formation of tagged and untagged Atlantic menhaden. Trans. Am. Fish. Soc. 103: 292-296.

Nicholson, W.R. 1978. Movements and population structure of Atlantic menhaden indicated by tag returns. Estuaries 1: 141-150.

Reintjes, J.W. 1969. Synopsis of biological data on the Atlantic menhaden, *Brevoortia tyrannus*. FAO Species Synopsis 42. 30 p.

Reish, R.L., R.B. Deriso, D. Ruppert and R.J. Carroll. 1985. An investigation of the population dynamics of Atlantic menhaden (*Brevoortia tyrannus*). Can. J. Fish. Aquat. Sci. 42(Suppl. 1): 147-157.

Vaughan, D.S. and J.W. Smith. 1988. A stock assessment of the Atlantic menhaden, *Brevoortia tyrannus*, fishery. NOAA Tech. Rep. NMFS 63, 18 p.

Mortality

Ahrenholz, D.W., W.R. Nelson and S.P Epperly. 1987a. Population and fishery characteristics of Atlantic menhaden, *Brevoortia tyrannus*. Fish. Bull. 85: 569-600.

Ahrenholz, D.W., J.F. Guthrie and R.M. Clayton. 1987b. Observations of ulcerative mycosis infections on Atlantic menhaden (*Brevoortia tyrannus*). U.S. Natl. Mar. Fish. Serv. Tech. Mem. NMFS-SEFC 196, 28 p.

Burton, D.T., L.B. Richardson and C.J. Moore. 1980. Effect of oxygen reduction rate and constant low dissolved oxygen concentrations on two estuarine fish. Trans. Am. Fish. Soc. 109: 552-557.

Smayda, T.J. 1989. Primary production and the global epidemics of phytoplankton blooms in the sea: a linkage?, p. 449-484 In E. M. Cosper, V.M. Bricelj and E.J. Carpenter (eds). Novel phytoplankton blooms. Coastal and Estuarine Studies 35. Springer-Verlag. New York, N.Y., 799 p.

Vaughan, D.S. 1990. Assessment of the status of the Atlantic menhaden stock with reference to internal waters processing. NOAA Tech. Memo. NMFS-SEFC-262, 28 p.

Population Size

Ahrenholz, D.W, W.R. Nelson and S.P. Epperly. 1987. Population and fishery characteristics of Atlantic menhaden, *Brevoortia tyrannus*. Fish. Bull. 85: 569-600.

Powers,.J.E. 1983. Report of the Southeast Fisheries Center Stock Assessment Workshop, August 3-6, 1982. NOAA Tech. Memo. NMFS-SEFC-127, 229 p.

Reish, R.L., R.B. Deriso, D. Ruppert and R.J. Carroll. 1985. An investigation of the population dynamics of Atlantic menhaden (*Brevoortia tyrannus*). Can. J. Fish. Aquat. Sci. 42(Suppl. 1): 147-157.

Vaughan, D.S. 1990. Assessment of the status of the Atlantic menhaden stock with reference to internal waters processing. NOAA Tech. Memo. NMFS-SEFC-262, 28 p.

Vaughan, D.S., J.V. Merriner, D.W. Ahrenholz and R.B. Chapoton. 1986. Stock assessment of menhaden and coastal herrings. NOAA Tech. Memo. NMFS-SEFC-178, 46 p.

Vaughan, D.S. and J.W. Smith. 1988. A stock assessment of the Atlantic menhaden, *Brevoortia tyrannus*, fishery. NOAA Tech. Rep. NMFS 63, 18 p.

Fisheries Independent Data

Judy, M.H. and R.M. Lewis. 1983. Distribution of eggs and larvae of Atlantic menhaden, *Brevoortia tyrannus*, along the Atlantic coast of the United States. U.S. Natl. Mar. Fish. Serv. Spec. Sci. Rep. Fish. 774, 23 p.

Kroger, R.L. and J.F. Guthrie. 1973. Migrations of tagged juvenile Atlantic menhaden. Trans. Amer. Fish. Soc. 102: 417-422.

Lewis, R.M. and W.C. Mann. 1971. Occurrence and abundance of larval Atlantic menhaden, *Brevoortia tyrannus*, at two North Carolina inlets with notes on associated species. Trans. Am. Fish. Soc. 100: 296-301.

Fisheries Dependent Data

Ahrenholz, D.W., W.R. Nelson and S.P. Epperly. 1987. Population and fishery characteristics of Atlantic menhaden, *Brevoortia tyrannus*. Fish. Bull. 85: 569-600.

Atlantic Menhaden Management Board (AMMB). 1981. Fishery management plan for Atlantic menhaden, *Brevoortia tyrannus* (Latrobe). Atlantic States Marine Fisheries Commission, Washington, D.C., Fish. Mgmt. Rep. No. 2, 134 p.

Chester, A.J. 1984. Sampling statistics in the Atlantic menhaden fishery. NOAA Tech. Rep., NMFS 9, 16 p.

Nicholson, W.R. 1971. Coastal movements of Atlantic menhaden as inferred from changes in age and length distributions. Trans. Am. Fish. Soc. 100: 708-716.

__________ 1972. Population structure and movements of Atlantic menhaden, *Brevoortia tyrannus*, as inferred from back-calculated length frequencies. Chesapeake Sci. 13: 161-174.

Schaaf, W.E. 1975. Status of the gulf and Atlantic menhaden fisheries and implications for resource management. Mar. Fish. Rev. 37: 1-9.

__________ 1979. An analysis of the dynamic population response of Atlantic menhaden, *Brevoortia tyrannus*, to an intensive fishery. Rapp. P.-V. Reun. Cons. int. Explor. Mer. 177: 243-251.

Schaaf, W.E. and G.R. Huntsman. 1972. Effects of fishing on the Atlantic menhaden stock: 1955-1969. Trans. Amer. Fish. Soc. 101:290-297.

Smith, J.W., W.R. Nicholson, D.S. Vaughan, D.L. Dudley and E.A. Hall. 1987. Atlantic menhaden, *Brevoortia tyrannus*, purse seine fishery, 1972-84, with a brief discussion of age and size composition of the landings. NOAA Tech. Rep. NMFS-59, 23 p.

Vaughan, D.S. 1990. Assessment of the status of the Atlantic menhaden stock with reference to internal waters processing. NOAA Tech. Memo. NMFS-SEFC-262, 28 p.

Trophic Dynamics

Atlantic Menhaden Management Board (AMMB). 1981. Fishery management plan for Atlantic menhaden, *Brevoortia tyrannus* (Latrobe). Atlantic States Marine Fisheries Commission, Washington, D.C., Fish. Mgmt. Rep. No. 2, 134 p.

Durbin, E.G. and A.G. Durbin. 1981. Assimilation efficiency and nitrogen excretion of a filter-feeding planktivore, the Atlantic menhaden, Brevoortia tyrannus (Pisces: Clupeidae). Fish. Bull. 79: 601-616.

Friedland, K.D., L.W. Haas and J.V. Merriner. 1984. Filtering rates of the juvenile Atlantic menhaden *Brevoortia tyrannus* (Pisces: Clupeidae), with consideration of the effects of detritus and swimming speed. Mar. Biol. (Berl.) 84:109-117.

Hettler, W.F. 1976. Influence of temperature and salinity on routine metabolic rate and growth of young Atlantic menhaden. J. Fish. Biol. 8: 55-65.

Jeffries, H.P. 1975. Diets of juvenile Atlantic menhaden (*Brevoortia tyrannus*) in three estuarine habitats asdetermined from fatty acid composition of gut contents. J. Fish. Res. Bd. Can. 32: 587-592.

June, F.C. and F.T. Carlson. 1971. Food of young Atlantic menhaden, *Brevoortia tyrannus*, in relation to metamorphosis. Fish. Bull. 68: 493-512.

Kjelson, M.A., D.S. Peters, G.W. Thayer and G.N. Johnson. 1975. The general feeding ecology of postlarval fishes in the Newport River Estuary. Fish. Bull. 73: 137-144.

Lewis, V.P. and D.S. Peters. 1984. Menhaden - a single step from vascular plant to fishery harvest. J. Exp. Mar. Biol. Ecol. 84: 95-100.

Peters, D.S. and W.E. Schaaf. 1981. Food requirements and sources for juvenile Atlantic menhaden. Trans. Am. Fish. Soc. 110: 317-324.

Habitat

Cross, F.A., D.S. Peters and W.E. Schaaf. 1985. Implications of waste disposal in coastal waters on fish populations, p.383-399 In Cardwell, R.D., R. Purdy and R.C. Bahner (eds). Aquatic toxicology and hazard assessment: Seventh Symposium. ASTM STP854. Amer. Soc. for Testing and Materials, Philadelphia.

Hettler, W.F. 1976. Influence of temperature and salinity on routine metabolic rate and growth of young Atlantic menhaden. J. Fish. Biol. 8: 55-65.

Judy, M.H. and R.M. Lewis. 1983. Distribution of eggs and larvae of Atlantic menhaden, *Brevoortia tyrannus,* along the Atlantic coast of the United States. U.S. Natl. Mar. Fish. Serv. Spec. Sci. Rep. Fish. 774, 23 p.

Rogers, S.G., T.E. Targett and S.B. VanSant. 1984. Fish-nursery use in Georgia salt-marsh estuaries: the influence of springtime fresh-water conditions. Trans. Am. Fish. Soc. 113: 595-606.

Stout, V.F., C.R. Houle and F.L. Beezhold. 1981. A survey of chlorinated hydrocarbon residues in menhaden fishery products. Mar. Fish. Rev. 43(3): 1-13.

Warlen, S.M., D.A. Wolfe, C.W. Lewis and D.R. Colby. 1977. Accumulation and retention of dietary 14C-DDT by Atlantic menhaden. Trans. Am. Fish. Soc. 106: 95-104.

Weinstein, M.P., S.L. Weiss and M.F. Walters. 1980. Multiple determinants of community structure in shallow marsh habitats, Cape Fear River estuary, North Carolina, USA. Mar. Biol. (Berl.) 58: 227-243.

Modeling

Ahrenholz, D.W., W.R. Nelson and S.P. Epperly. 1987. Population and fishery characteristics of Atlantic menhaden, *Brevoortia tyrannus.* Fish. Bull. 85: 569-600.

Fogarty, M.J., F.P. Almeida, J. Chenoweth and J.S. Idoine. 1989. Population dynamics of Atlantic herring in the Gulf of Mexico. Natl. Mar. Fish. Serv., N.E. Fish. Ctr. SAW-9 Working Paper 7, 12 p.

Gabriel, W.L., M.P. Sissenwine and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: An example for Georges Bank haddock. No. Amer. J. Fish. Mgmt. 9: 383-391.

Nelson, W.R., M.C. Ingham and W.E. Schaaf. 1977. Larval transport and year-class strength of Atlantic menhaden, *Brevoortia tyrannus.* Fish. Bull. 75: 23-41.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull Fish. Res. Bd. Can. 191, 382 p.

Schaaf, W.E. 1975. Status of the gulf and Atlantic menhaden fisheries and implications for resource management. Mar. Fish. Rev. 37: 1-9.

__________ 1979. An analysis of the dynamic population response of Atlantic menhaden, *Brevoortia tyrannus,* to an intensive fishery. Rapp. P.-V. Reun. Cons. int. Explor. Mer. 177: 243-251.

Gear Conservation Engineering

Austin, H., J. Kirkley and J. Lucy. 1994. By-catch and the fishery for Atlantic menhaden in the Mid-Atlantic Bight. Va. Sea Grant Mar. Res. Adv. No. 53, VSG 94-06: 39.

Rulifson, R.A., J.D. Murray and J.J. Bahen. 1992. Finfish catch reduction in south Atlantic shrimp trawls using three designs of by-catch reduction devices. Fisheries 17(1):9-20.

Social and Economic

American Fisheries Society. 1982. Monetary values of freshwater fish and fish-kill counting guidelines. Amer. Fish. Soc., Bethesda, MD, Spec. Publ. 13, 40 p.

Bimbo, A.P. 1989. Recent advances in upgrading industrial fish to value-added products. Proc. AOCS Symposium: Value-added feed products from protein and co-products: Changing resources and needs. May 1989. Cincinnati, OH.

Frye, J. 1978. The men all singing. The story of menhaden fishing. Donning Co., Virginia Beach, VA., 242 p.

Garrity-Blake, B. 1991. The meaning of work for black and white fishworkers of the U.S. menhaden fish meal and oil industry. Ph.D. Diss. Univ. of Virginia, Charlottesville, 251 p.Ligouri, V.A. 1967. Stability and change in the social structure of Atlantic coast commercial fisheries. Ph.D. Diss. Princeton Univ., Princeton, NJ.

Maiolo, J.R. 1991. Atlantic menhaden socio-economic study. Rep. to the Atlantic States Marine Fisheries Commission. Unpubl.

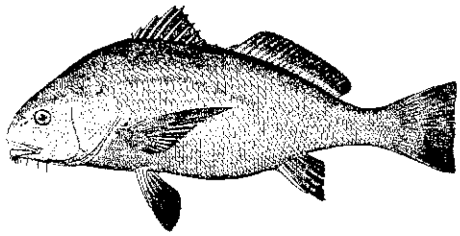
Waters, J. 1992. Report to the Atlantic Menhaden Advisory Committee on the Atlantic menhaden economic survey. Unpubl. Rep., Nat. Mar. Fish. Serv., Beaufort, NC Lab.

Management Plans

Atlantic Menhaden Management Board (AMMB). 1981. Fishery management plan for Atlantic menhaden, *Brevoortia tyrannus* (Latrobe). Atlantic States Marine Fisheries Commission, Washington, D.C., Fish. Mgmt. Rep. No. 2, 134 p.

__________ 1986 Supplement to Atlantic Menhaden Fishery Mangement Plan. ASMFC, Washington, D.C., Fish. Mgmt. Rep. No. 8, 61 p.

Atlantic Menhaden Advisory Committee (AMAC). 1992. Fishery Management Plan for Atlantic Menhaden 1992 Revision. ASMFC, Washington, D.C., Fish. Mgmt. Rep. No. 22, 159 p.



Black Drum

Pogonias cromis

The black drum, *Pogonias cromis*, is the largest member of the family *Sciaenidae*. Black drum are a warm-temperate species whose range in U.S. waters is from New England south through Florida and across the northern Gulf of Mexico, with Chesapeake Bay near the northern end of the breeding range. Fish enter Chesapeake Bay in April to spawn through May, disperse throughout the bay afterwards and leave in the fall. This species supports an important commercial and recreational fishery on the Eastern Shore of Virginia. At least two stocks exist, one on the eastern coast of the U.S., and one across the northern Gulf of Mexico. The boundary between these two stocks is undefined at present.

Black drum have been occasionally abundant in the bay as indicated by commercial landings and recreational citations. The catch in Virginia waters is dominated by older, larger fish (averaging 26 years and 50 pounds). Typically in a long-lived fish, a few dominant years classes drive the fishery and this appears to be true for black drum. This species is currently managed by the Gulf of Mexico and South Atlantic Fishery Management Councils, as well as various states.

Some work has been done on black drum. Nearly all of the work on adult black drum has been done off Florida and in the Gulf of Mexico. The work in the Chesapeake Bay region has mostly concentrated on early life stages. The adult studies that have been done have been based on ageing with scales, which underestimate ages beyond 10 years. Other recent work (Jones et al. and Wells et al., both submitted for publication) has been directed to estimates of biological characteristics on otolith ageing and includes yield modeling.

The materials that follow include a listing of the most recent studies, and then the historic studies for the entire range of this species.

Recent studies on black drum in the Chesapeake Region

Jones, C. M., M. E. Chittenden, Jr., and B. K. Wells. In Review. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Submitted to Fisheries Bulletin.

Stock Identification

Daniel, L. B., and J. E. Graves. 1994. Morphometric and genetic identification of eggs of spring-spawning sciaenids in lower Chesapeake Bay. Fish. Bull. 92: 254-261.

Jones, C. M., M. E. Chittenden, Jr., and B. K. Wella. In Review. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Submitted to Fisheries Bulletin.

Recruitment

Cowan, J. H. Jr., and R. S. Birdsong. 1985. Seasonal occurrence of larval and juvenile fishes in a Virginia Atlantic coast estuary with emphasis on drums (Family Sciaenidae). Estuaries 8: 48-59.

Cowan, J. H. Jr., R. S. Birdsong, E. D. Houde, J. S. Proest, W. C. Sharp, and G. B. Mateja. 1992. Enclosure experiments on survival and growth of black drum eggs and larvae in lower Chesapeake Bay. Estuaries 15: 392-402.

Daniel, L. B., and J. E. Graves. 1994. Morphometric and genetic identification of eggs of spring-spawning sciaenids in lower Chesapeake Bay. Fish. Bull. 92: 254-261.

Ditty, J. G. 1986. Ichthyoplankton in neritic waters of the northern Gulf of Mexico off Louisiana: composition, relative abundance, and seasonality. Fish. Bull. 84: 935-946.

Fitzhugh, G. R., and D. W. Beckman. 1987. Age, growth and reproductive biology of black drum in Louisiana waters. Coastal Fisheries Institute, Center for Wetland Resources, Louisiana State University, Final Report of Funded projects FY 1986-1987. 89 p.

Frisbie, C. M. 1961. Young black drum, *Pogonias cromis*, in tidal fresh and brackish waters, especially in the Chesapeake and Delaware Bay area. Ches. Sci. 2: 94-100.

Holt, G. J., S. A. Holt, and C. R. Arnold. 1985. Diel periodicity of spawning in sciaenids. Mar. Ecol. Prog. Ser. 27: 1-7.

Jannke, T. E. 1971. Abundance of young sciaenid fishes in Everglades National Park, Florida, in relation to season and other variables. Univ. Miami Sea Grant Program. Sea Grant Fish Bull. No. 11.

Joseph, E. B., W. H. Massmann, and J. J. Norcross. 1964. The pelagic eggs and early larval stages of the black drum from Chesapeake Bay. Copeia 2: 425-434.

Murphy, M. D., and R. G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Sci. 10: 127-137.

Richards, W. E. 1973. Age, growth and distribution of black drum (*Pogonias cromis*) in Virginia. Trans. Am. Fish. Soc. 102: 584-590.

Richards, C. E., and M. Castagna. 1970. Marine fishes of Virginia's Eastern Shore (inlet and marsh, seaside waters). Ches. Sci. 11: 235-248.

Thomas, D. L., and B. A. Smith. 1973. Studies of young of the black drum, *Pogonias cromis*, in low salinity waters of the Delaware Estuary. Ches. Sci. 14: 124-130.

Wells, B. K. 1994. Reproductive biology of Chesapeake Bay black drum, *Pogonias cromis*, with an assessment of fixatives and stains for histological examination of teleost ovaries. MS. Thesis. Old Dominion Univ., Norfolk, VA. 67 p.

Growth

Beckman, D. W., C. A. Wilson, and A.L. Stanley. 1990. Age and growth of black drum in Louisiana waters of the Gulf of Mexico. Trans. Am. Fish. Soc. 19: 537-544.

Bobko, S. 1991. Age, growth, and reproduction of black drum, *Pogonias cromis*, in Virginia. MS. Thesis. Old Dominion Univ., Norfolk, VA. 66 p.

Desfosse, J. C. 1987. Preliminary analysis of Virginia's black drum (*Pogonias cromis*) recreational and commercial fisheries. Virginia Marine Resources Commission Report 87-7. Newport News, VA. 27 p.

Fitzhugh, G. R., and D. W. Beckman. 1987. Age, growth and reproductive biology of black drum in Louisiana waters. Coastal Fisheries Institute, Center for Wetland Resources, Louisiana State University, Final Report of Funded projects FY 1986-1987. 89 p.

Jones, C. M., M. E. Chittenden, Jr., and B. K. Wells. In Review. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Submitted to Fisheries Bulletin.

Murphy, M. D., and R.G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Sci. 10: 127-137.

Richards, W. E. 1973. Age, growth and distribution of black drum (*Pogonias cromis*) in Virginia. Trans. Am. Fish. Soc. 102: 584-590.

Mortality

Bobko, S. 1991. Age, growth, and reproduction of black drum, *Pogonias cromis*, in Virginia. MS. Thesis. Old Dominion Univ., Norfolk, VA. 66 p.

Cowan, J. H., JR., R. S. Birdsong, E. D. Houde, J. S. Priest, W. C. Sharp, and G. B. Mateja. 1992. Enclosure experiments on survival and growth of black drum eggs and larvae in lower Chesapeake Bay. Estuaries 15: 392-402.

Jones, C. M., M.E. Chittenden, Jr., and B. K. Wells. In Review. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Submitted to Fisheries Bulletin.

Population size

None.

Fisheries Independent Data

Cowan, J. H., Jr., and R. S. Birdsong. 1985. Seasonal occurrence of larval and juvenile fishes in a Virginia Atlantic coast estuary with emphasis on drums (Family Sciaenidae). Estuaries 8: 48-59.

Frisbie, C. M. 1961. Young black drum, *Pogonias cromis*, in tidal fresh and brackish waters, especially in the Chesapeake and Delaware Bay area. Ches. Sci. 2: 94-100.

Joseph, E. B., W. H. Massmann, and J. J. Norcross. 1964. The pelagic eggs and early larval stages of the black drum from Chesapeake Bay. Copeia 2: 425-434.

Thomas, D. L., and B. A. Smith. 1973. Studies of young of the black drum, *Pogonias cromis*, in low salinity waters of the Delaware Estuary. Ches. Sci. 14: 124-130.

Fisheries Dependent Data

Anonymous. 1994. Marine recreational fishery statistics survey, Atlantic and Gulf coasts. U.S. NMFS. Curr. Stat. Rept.

Cody, T. J., K. W. Rice, and C. E. Bryan. 1978. Commercial shrimp and panaeid shrimp studies, northwestern Gulf of Mexico. Texas Parks and Wildlife Dept. Coast. Fish. Proj. Report 2-276-R.

Desfosse, J. C. 1987. Preliminary analysis of Virginia's black drum (Pogonias cromis) recreational and commercial fisheries. Virginia Marine Resources Commission Report 87-7. Newport News, VA. 27 p.

Hildebrand, S. F., and W. C. Schroeder. 1928. The fishes of Chesapeake Bay. Bull. U.S. Bur. Fish. 43:1-388.

Hutchinson, R., and C. Rogers. 1969. Salt water fishing in Virginia. Dept. Conserv. and Econ. Devel., Richmond, VA. 41 p.

Jones, C. M., M. E. Chittenden, Jr., and B. K. Wells. In Review. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Submitted to Fisheries Bulletin.

Jones, C.M., K.H. Pollock, A. Ehtsham, and W. Hinkle. 1990. Assessment of the black drum recreational fishery, 1989, in Virginia. Old Dominion Univ. Res. Found. Tech. Rep. No. 90-2. Norfolk, VA. 100 p.

Murphy, M. D., and R. G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Sci. 10: 127-137.

Music, J. F., and J. M. Pafford. 1984. Population dynamics and life history aspects of major marine sportfishes in

Pearson, J. C. 1929. Natural history and conservation of redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 44: 129-214.

Richards, W. E. 1973. Age, growth and distribution of black drum (*Pogonias cromis*) in Virginia. Trans. Am. Fish. Soc. 102: 584-590.

Richards, C. E., and M. Castagna. 1970. Marine fishes of Virginia's Eastern Shore (inlet and marsh, seaside waters). Ches. Sci. 11: 235-248.

Silverman, M. J. 1979. Biological and fisheries data on black drum, *Pogonias cromis* (Linnaeus). NOAA, Natl. Mar. Fish. Serv. Tech. Rep. No. 22. Sandy Hook Laboratory, Northeast Fisheries Center. Highlands, NJ.

Wells, B. K. 1994. Reproductive biology of Chesapeake Bay black drum, *Pogonias cromis*, with an assessment of fixatives and stains for histological examination of teleost ovaries. MS. Thesis. Old Dominion Univ., Norfolk, VA. 67 p.

Welsh, W. W., and C. M. Breder, Jr. 1923. Contributions to the life histories of Sciaenidae of the eastern United States coast. Bull. U.S. Bur. Fish. 39: 141-201.

Water Quality Tolerances

None.

Trophic Dynamics

Chao, L. and J. Musick. 1977. Life history, feeding habits, and functional morphology of juvenile sciaenid fishes in York River estuary, Virginia. Fish. Bull. 75: 675-702.

Habitat Utilization

Jannke, T. E. 1971. Abundance of young sciaenid fishes in Everglades National Park, Florida, in relation to season and other variables. Univ. Miami Sea Grant Program, Sea Grant Fish. Bull. No. 11.

Osburn, H. R., and G. C. Matlock. 1984. Black drum movement in Texas Bays. N. Amer. J. Fish. Management 4: 523-530

Pearson, J. C. 1929. Natural history and conservation of redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 44: 129-214.

Richards, W. E. 1973. Age, growth and distribution of black drum (*Pogonias cromis*) in Virginia. Trans. Am. Fish. Soc. 102: 584-590.

Richards, C. E., and M. Castagna. 1970. Marine fishes of Virginia's Eastern Shore (inlet and marsh, seaside waters). Ches. Sci. 11: 235-248.

Welsh, W. W., and C.M. Breder, Jr., 1923. Contributions to the life histories of Sciaenidae of the eastern United States coast. Bull. U.S. Bur. Fish. 39: 141-201.

Gear Conservation Engineering

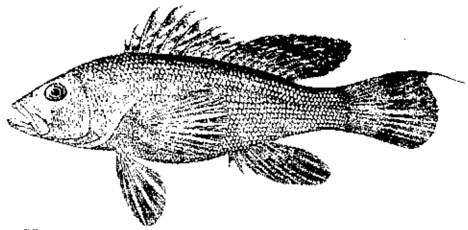
None.

Modeling

Murphy, M. D., and R. G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. Northeast Gulf Sci. 10: 127-137.

Social and Economic

Jones, C. M., K. H. Pollock, A. Ehtisham, and W. Hinkle. 1990. Assessment of the black drum recreational fishery, 1989, in Virginia. Old Dominion Univ. Res. Found. Tech. Rep. No. 90-2. Norfolk, VA. 100 p.



Black Sea Bass

Centropristis striata

The black sea bass range from Cape Cod, MA to south Florida, primarily inhabiting the continental shelf. There are two stocks, one north and one south of Cape Hatteras, NC. While the southern stock is quite residential, the northern stock migrates seasonally from the southern offshore edge of the shelf during winter to northern inshore areas during spring and summer. Juveniles of the northern stock are found in coastal and estuarine areas, and as they grow join the seasonal migration.

Sea bass are protogynous hermaphrodites, that is to say, they transform from females to males when two to five years of age. They reach sexual maturity when age two, and males may grow to 15 years and reach a length of two feet.

The commercial fishery for black sea bass is primarily pursued in the EEZ (the 200 mile Exclusive Economic Zone, or the "200-mile limit") and is composed of otter trawl and pots. Hand lines, lobster pots, pound nets (inshore) and traps account for the balance of the catch. Most are landed in New Jersey and Virginia. Although the bulk of the catch is taken by otter trawl, it is as a winter by-catch for summer flounder and squid at the edge of the continental shelf.

Management is by a plan under the Mid-Atlantic Fisheries Management Council, and was to be part of a multi-species plan with summer flounder and scup. This has not worked out as summer flounder have been actively managed since the 1980's and the sea bass plan not written until 1993. The plan which calls for management by control of the minimum size in the commercial and recreational fishery and a recreational bag limit is currently in the process of implementation.

Stock analysis, using a virtual population analysis, indicate that the northern stock is over fished.

Stock Identification

Kendall, A. W., Jr. and L.P. Mercer. 1982. Black sea *bass, Centropristis striata.* In: M. D. Grosslein and T. R. Azarovitz (eds.) Fish Distribution MESA atlas moncraph 15, p 82-83. N.Y. Sea Grant Institute, Albany, NY.

Shepherd, G. R. 1991. Meristic and morphometric variation in black sea bass north of Cape Hatteras, North Carolina. N.Am. J. Fish. Manage. 11: 139-148.

Recruitment

Able, K. W., M. P. Fahay and G.R. Shepherd. 1995. Early life history of black sea bass, *Centropristis striata,* in the mid-Atlantic Bight and a New Jersey estuary. Fish Bull. 93(3): 429-445.

Caruso, P. G. 1995. The biology and fisheries of black sea bass *Centropristis striate, in* tviassachusetts waters. MS. Thesis, Univ. RI.

Lavanda, N. 1949. Sexual differences and normal protogynous hermapliroditism in [i.e., Atlantic sea bass, *Centropristis striata.Copeia* 1949:185-194.

Mercer, L. P. 1978. The reproductive biology and population dynamics of black sea bass, *Centropristis striata.* Ph.D. diss, VA.Inst. Mar. Sci., College of William and Mary, Gloucester, VA.

O'Brien, L. J. Burnett, and R.K. Mayo. 1993. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990. NOAA Tech. Rpt. NMFS 113. 66 p.

Growth

Caruso, P. G. 1995. The biology and fisheries of black sea bass *Centropristis striata, in* tviassachusetts waters. MS. Thesis, Univ. RI.

O'Brien, L. J. Burnett, and R.K. Mayo. 1993. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990. NOAA Tech. Rpt. NMFS 113. 66 p.

Pope, J. and J. Shepherd. 1982. A simpte method for the consistent interpretation of catch at age data. ICES J. Cons. Mar. Sci. J. Cons. int. Explor. Mer, 40:184-186.

Mortality

Alexander, M. S. 1981. Population response of the sequential hermaphrodite black sea bass. *Centropristis striata,* to fishing. MS thesis, State Univ. of New York, Stony Brook. 104 p.

Population Size

Musick, J. A. and L. P. Mercer. 1977. Seasonal distribution of Northern black sea bass *Centropristis striata* (Pisces: Serranidae) in the mid-Atlantic Bight with comments on the fisheries and ecology of the species. Trans. Amer. Fish. Soc. 106:12-26.

Northeast Fisheries Science Center. 1989. Report of the fall 1989 NEFC stock assessment workshop (Ninth SAW). NEFSC Ref. Doc. No. 89-08.

Shepherd, G.R. and M. Terceiro. 1994. The summer flounder, scup and black sea bass fisherv of the Middle Atlantic Bight and Southern New England waters. NOAA Tech. Report NMFS 122. 13 p.

Vaughn.D. S., M. R. Collins, and D. J. Schmidt. 1995. Population characteristics of the black, sea bass *Centropristis striata* from the southeastern U.S. Bull. of Marine Scl. 56(l):250-267.

Fishery Dependent Data

Bugley, K. and G. Shepherd. 1991. Effect of catch-and-release angling on the survival of black sea bass. N.Am. J. Fish. Manage. 11:468-471.

Clark, S. H. t978. Application of botom-trawl survey data to fish stock assessments. NOAA NMFS, Woods Hole Lab. Ref. Doc. 78-21. 13 p.

Eklund, A. and T. E. Targett. 1991. Seasonality of fish catch rates and species composition from the hard bottom trap fishery in the Middle Atlantic Bight (US east coast). Fish. Res. 12(1991)1-22.

Shepherd, G.R. and M. Terceiro. 1994. The summer flounder, scup and black sea bass fisherv of the Middle Atlantic Bight and Southern New England waters. NOAA Tech. Report NMFS 122. 13 p.

Habitat Utilization

Kendall, A. W., Jr. and L.P. Mercer. 1982. Black sea *bass, Centropristis striata.* In: M. D. Grosslein and T. R. Azarovitz (eds.) Fish Distribution MESA atlas monograph 15, p 82-83. N.Y. Sea Grant Institute, Albany, NY.

Modeling

Conser, R. J. and J. E. Powers. 1990. Extensions of the ADAPT VPA tuning method designed to facilitate assessment work on tuna and swordfish stocks. Collect. Vol. Scl. Pap. ICCAT, 32:461-467.

Gavaris, S. MS 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doe. No. 29, 12 P.

Mercer, L. P. 1978. The reproductive biology and population dynamics of black sea bass, *Centropristis striate.* Ph.D. diss, VA.Inst. Mar. Sci., College of William and Mary, Gloucester, VA.

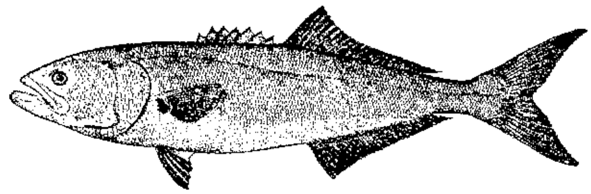
Musick, J. A. and L. P. Mercer. 1977. Seasonal distribution of Northern black sea bass *Centropristis striate* (Pisces: Serranidae) in the mid-Atlantic Bight with comments on the fisheries and ecology of the species. Trans. Amer. Fish. Soc. 106:12-26.

Northeast Fisheries Science Center. 1989. Report of the fall 1989 NEFC stock assessment workshop (Ninth SAW). NEFSC Ref. Doc. No. 89-08.

Shepherd, G. R. and J. S. Idoine. 1993. Length-based analyses of yield and spawning biomass per recruit from black sea bass, *Centropristis striata,* a protogynous hermaphrodite. Fish Bull. 91:328-337.

Thompson, W. F. and F. H. Bell. 1934. Biological statistics of the Pacific halibut fishery 2. Effect of changes in Intensity upon total yield and yield per unit of gear. Rep. In Fish. (Pacific halibut) Comm. 8:49 p.

Vaughn, D. S., M. R. Collins, and D. J. Schmidt. 1995. Population characteristics of the black, sea bass *Centropristis striata* from the southeastern U.S. Bull. of Marine Sci. 56(l):250-267.



Bluefish

Pomatomus saltatrix

The bluefish, *Pomatomus saltatrix*, is a pelagic coastal species that seasonally migrates from south of Hatteras to north of Cape Cod. The main body of bluefish entering Virginia's waters appear each spring along the coast during their annual northern migration, entering the Chesapeake Bay to feed before moving north. Its aggressive feeding habits and strong spirited fight make it a popular sportfish in the mid-Atlantic Bight. Spawning occurs south of Hatteras each spring, and again during summer off Block Island on the continental shelf. Whether they spawn during two distinct periods, or a continuous wave with only first and last spawned young surviving, remains to be determined.

Although the two spawnings can be separated morphometrically they are of one genetic spawning stock.

The fishery for bluefish is partitioned roughly 80:20 with the 80% historically going to the recreational fishermen. Combined landings peaked in 1980 at just over 75,000 mt and has declined steadily ever since. The landings in 1993 were 18.8 mt. During this same period the spawning stock biomass declined from over 300,000 mt to less than 100,000 mt by 1993.

Management of the mid-Atlantic stock is provided by separate management plans prepared by the ASMFC and MAFMC. Fishing mortality (F) has increased from 0.20 in 1980 to over 0.45 in 1993. The current plan specifies an $F_{0.1}$= 0.20 and an F_{max}=0.30. The 1994 Status of Fishery Resources of the Northeastern United States cites the stock as overharvested.

Stock Identification

Austin, H., D. Scoles, and A. Abell. MS. Stock Identification of Mid-Atlantic bluefish, *Pomatomus saltatrix*, using discriminant function Analysis. 26 p. + 6 Fig.

Graves, J., J. McDowell, A. Beardsley, and D. Scoles. 1992. Population genetic structure of the bluefish, , in Atlantic coastal waters., Fish. Bull., 90:469-475.

Sullivan, J. 1986. Stock identification of Atlantic croaker and bluefish using biochemical methods, *In* Ross, J. et al. Assessment of N.C. Commercial finfish. NC Dept. Nat. Res. Commercial Dev. Div., Mar. Fish., Proj 2-386-R.

Recruitment

Chiarella, L. A. and D. O. Conover. 1990. Spawning season and first-year growth of adult bluefish from the New York Bight. Trans. Amer. Fish. Soc., 119:455-462.

Cowen, R. K., J. A. Hare, and M. P. Fahay. 1993. Beyond hydrography: Can physical processes explain larval fish assemblages within the Middle Atlantic Bight? Bull. Mar. Sci.,53(2):567-587.

Hare, J. A., and R. K. Cowen. 1993. Ecological and evolutionary implications of the larval transport and reproductive strategy of bluefish *Pomatomus saltatrix.* Mar. Ecol. Prog. Ser. 98:1-16.

McBride, R. S., and D. O. Conover. 1991. Recruitment of young-of-the-year bluefish, *Pomatomus saltatrix*, to the New York Bight: variation in abundance and growth of spring- and summer-spawned cohorts. Mar. Ecol. Prog. Ser. 78:205-216.

Nyman, R. M. and D. O. Conover. 1988. The relation between spawning season and the recruitment of young-of-the-year bluefish, *Pomatomus saltatrix*, to New York, Fish. Bull. 86(2):237-250.

Shima, M. 1989. Oceanic transport of the early life history stages of bluefish (*Pomatomus saltatrix*,) from Cape Hatteras to the mid-Atlantic Bight. MS Thesis, SUNY, Stony Brook, Dec. 1989, 69 pages.

Smith, W., P. Berrien and T. Potthoff. 1994. Spawning patterns of bluefish, *Pomatomus saltatrix*, in the northeast continental shelf ecosystem. Bull. Mar. Sci., 54(1):8-16.

Growth

Barger, L. E. 1990. Age and growth of bluefish, *Pomatomus saltatrix.*, from the Northern Gulf of Mexico and U.S. South Atlantic Coast. Fish. Bull. 88:805-809.

Terceiro, M. and J. Ross. 1993. A comparison of alternative methods for the estimation of age from length data for Atlantic coast bluefish (*Pomatomus saltatrix*). Fish. Bull. 91:534-549.

Mortality

Austin, H., J. Kirkley, and J. Lucy. 1994. Bycatch and the fishery for Atlantic menhaden, *Brevoortia tyrannus* in the Mid-Atlantic Bight: An assessment of the nature and extent of bycatch. VaSeaGrant Mar. Res. Advisory No. 53 (VSG 94-06), 39 pp.

Population Size

Conservation and Utilization Div., NEFC/NMFS. 1991. Report of the Twelfth Northeast regional stock assessment Workshop (12th SAW), spring 1991. NEFC Ref Doc. 91-03: 187 p.

Simpson, D., P. Howell, and M. Johnson. 1990. Assessment of bluefish in Long Island Sound with reference to the coastwide stock, Section 2, Job 6., A study of marine recreational fisheries in Connecticut., pp 83-104.

Fishery Independent Data

Austin, H. and D. Seever. 1995. Monitor juvenile recreational fishes on the Ocean beaches of Virginia, including the Eastern Shore with special focus on developing a bluefish young-of-the-year index in Virginia. First Ann. Rept. VMRC Vir. Rec. Fish. Adv. Brd., Cont. No. 576601.

Bonzek, C., Geer, P. and H. Austin. 1995. VIMS juvenile fish trawl survey, Juvenile indices 1979-1994. 15 p.

Geer, P., and H. Austin. 1994. Estimation of relative abundance of recreationally important finfish in the Virginia portion of Chesapeake Bay. U.S.F&WS Sportfish Rest. Proj. F104R2, 85 p.

Fishery Dependent Data

Chang, S. 1990. Seasonal distribution patterns of commercial landings of 45 species off the northeastern United States during 1977-1988. NOAA Tech. Memo. NMFS/NEC-78, 130 p.

Conservation and Utilization Div., NEFC/NMFS. 1993. Status of the fishery resources off the northeastern United States for 1993. NOAA Tech. Memo., NMFS/NEFC-101, 140 p.

Kline, L. 1993. Report of the marine recreational fisheries statistics committee. Spec. Rept. No. 23, ASMFC. 71 p.

Kline, L., C. Moore, and D. Keifer. 1994. Report on status of stock and bluefish fishery management. ASMFC Spec. Rept. No. 40, 41 p. + Appendx.

MacKenzie, C. 1991. History of the fisheries of Raritan Bay, N.Y. and N.J. Mar. Fish. Rev. 52(4):1-45.

Marshall, A. and J. Lucy. 1981. Virginia's charter and head boat fishery: analysis of catch and socioeconomic impacts. VIMS Spec. Rept. Appl. Mar. Sci. & Ocn Engineering. No. 253.

Water Quality Tolerances

Austin, H. In Press. Impacts of contaminants on marine coastal ecosystems, 26 pp. + 2 fig., *In* Environmental Contaminants and Health, PA Acad. of Sci. *Editors:* Majumdar, S. and F. Brenner.

Freeman, B. and S. Turner. 1977. The effects of anoxic water on the bluefish, an actively swimming fish. NMFS, NEFC Sandy Hook Lab. Tech. Ser. Rept. No. 3:431-450.

Funderburk, S., Mihursky, J., Jordan, S., and Riley, D. 1991. Habitat requirements for Chesapeake Bay living resources. CRC, 23 chapt., 47 maps.

Klauda, R. and M. Bender. 1987. Contaminant effects on Chesapeake Bay finfishes. Chapter 15, pp321-372, *In* Contaminant Problems and Management of Living Chesapeake Bay Resources, *Editors*, Majumdar, S., Hall, L., and H. Austin, 573 p.

Mahoney, J. F. Midlige, and D. Duel. 1973. A fin rot disease of marine and euryhaline fishes in New York Bight. Trans. Am. Fish. Soc., 102(3):596-605.

Trophic Dynamics

Kohler, N. and C. Stillwell. 1981. Food habits of the blue shark in the northwest Atlantic., Int. Council Explor. Sea, Pelagic Fish. Comm., C.M. 1981/H:61.

Mahoney, J. 1972. Predation by bluefish on flatfishes. Mar. Fish. Rev. 34(7-8): 30-35.

Naughton, S. and C. Saloman. 1984. Food of bluefish from the US south Atlantic and Gulf of Mexico. NOAA Tech. Mem. NMFS-SEFC-50.

Stillwell, C. and N. Kohler. 1985. Food and feeding ecology of the swordfish in the western North Atlantic Ocean with estimates of daily ration. Mar. Ecol. Prog. Ser. 22(3):239-247.

Habitat Utilization

Funderburk, S., Mihursky, J., Jordan, S., and Riley, D. 1991. Habitat requirements for Chesapeake Bay living resources. CRC, 23 chapt., 47 maps.

Gear Conservation Engineering

Nothing found

Modeling

Richkus, W., Nelson, S. and H. Austin. 1993. Fisheries assessment and management synthesis: Lessons for Chesapeake Bay. CRC

Social & Economic

Agnello, R. 1989. The economic value of fishing success: an application of socio-economic survey data. Fish. Bull. 87(1):223-232. (From MAFMC FMP).

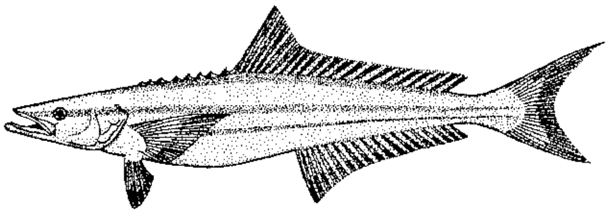
Marshall, A. and J. Lucy. 1981. Virginia's charter and head boat fishery: analysis of catch and socioeconomic impacts. VIMS Spec. Rept. Appl. Mar. Sci. & Ocn Engineering. No. 253.

Management Plans

MAFMC. 1989. Fishery management plan for the bluefish fishery. (Prepared in cooperation with the ASMFC Bluefish Management Board.) 81p. + 7 Appendx.

CEC. Chesapeake Bay Management Plan for Bluefish.

Kline, L., C. Moore, and D. Keifer. 1994. Report on status of stock and bluefish fishery management. ASMFC Spec. Rept. No. 40, 41 p. + Appendx.



Cobia

Rachycentron canadum

Cobia is widely distributed from Atlantic to Indo-Pacific localities, and is highly prized by sportsman because of its habit of hard fighting, its large size (up to and rarely exceeding 100 lbs), and its highly palatable flesh. The species is closely related to the oceanic dolphinfishes (*Coryphaena* spp.), but usually prefers coastal, estuarine or reef habitats throughout its distribution. Cobia eat both fish and invertebrates (primarily shrimps and crabs), and are often found in association with larger fish, floating debris, or structures such as bouys and pilings.

A coastal migrant, cobia are generally caught in summer months in the Chesapeake Bay, and their appearance constitutes one of the few exclusively recreational fisheries in Virginia's waters. A few fishes are taken every year in pound nets, but landing records suggest that the recreational catch usually is far greater than commercial activity for this species. Cobia are captured by trolling, casting and fishing cut or live baitfish in chum slicks. Most fishes are caught in Virginia's portion of the lower bay and along the eastern shore and bay entrance. Elsewhere, cobia are captured in both commercial and recreational fisheries along the south Atlantic and Gulf of Mexico coasts. During each year in the period 1981-1986, commercial harvests exceeded recreational catch in these regions.

Running ripe male and female cobia are usually captured each year, and it is generally believed that a reproductively active population exists during summer months in Chesapeake Bay. Eggs presumed to be those of the cobia have been captured in plankton nets at the Chesapeake Bay entrance, and new recruits are frequently observed in late summer in Chesapeake Bay waters.

Cobia is currently included in a 1990 Fishery Management Plan (FMP) developed by the South Atlantic Fishery Management Council (SAFMC) and the Gulf of Mexico Fishery Management Council (GMFMC). The multispecies FMP includes spanish mackerel. The plan limits catch to two fish (minimum size, 37" total length) per angler per day, and has been adopted by Virginia. This management scheme probably restricts the taking of fishes <5 y-old. Age at maturity and seasonal patterns of gonadal development in Chesapeake Bay are poorly known, but available data suggest that individuals of both sexes may mature at 20-27" fork length.

Stock Identification

no information

Recruitment

Biesiot, P.M., R.E. Caylor, and J.S. Franks. 1994. Biochemical and histological changes during ovarian development of cobia, *Rachycentron canadum*, from the northern Gulf of Mexico. Fishery Bulletin 92: 686-696.

Caylor, R.E., P.M. Biesot, and J.S. Franks. In press. Culture of cobia *Rachycentron canadum:* cryopreservation of sperm and induced spawning. Aquaculture

Dawson, C.E. 1971. Occurrence and description of prejuvenile and early juvenile Gulf of mexico cobia, *Rachycentron canadum*. Copeia 1971(1): 65-71.

Ditty and Shaw. 1992. Larval development. distribution, and ecology of cobia, *Rachycentron canadum* (Family: Rachycentridae), in the northern Gulf of Mexico. Fishery Bulletin 90: 668-677.

Hassler, W.W. and R.P. Rainville. 1975. Techniques of hatching and rearing cobia, *Rachycentron canadum*, through larva and juvenile stages. Univ. North Carolina Sea Grant Coll. Prog., UNC-SG-75-30, Raleigh, 26 pp.

Joseph, E.B., J.J. Norcross, and Wm. H. Massman 1964. Spawning of the cobia, *Rachycentron canadum*, in the Chesapeake Bay area, with observations of juvenile specimens. Chesapeake Science 5(1-2): 67-71.

Growth

Richards, C.E. 1967. Age, growth and fecundity of the cobia, *Rachycentron canadum*, from the Chesapeake Bay and adjacent Mid-Atlantic waters. Transactions of the American Fisheries Society 96(3): 343-350.

Richards, C.E. 1977. Cobia (*Rachycentron canadum*) tagging within Chesapeake Bay and updating of growth equations. Chesapeake Science 18: 310-311.

Thompson, B.A., C.A. Wilson, J.H. Render, and M. Beasley. 1991. Age, growth, and reproductive biology of greater amberjack and cobia from Louisian waters. Year 1, Report to U.S. Dept. Commerce, NOAA, NMFS, MARFIN Program, Louisian State Univ., 55 p.

Mortality

no information

Population Size

no information

Fishery Independent Data

no information

Fishery Dependent Data

Virginia Salt Water Fishing Tournament Records

Water Quality Tolerances

no information

Trophic Dynamics

Boehlke, J.E. and C.C.G. Chaplin. 1968. Fishes of the Bahamas and adjacent tropical waters. Second Edition, Univ. Texas at Austin, 771 pp.

Habitat Utilization

Shaffer, R.V. and E.L. Nakamura. 1989. Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Tech. Rept. NMFS 82, 21 p.

Modeling

no information

Social and Economic

no information

Management Plans

GMFMC and SAFMC. 1990. Amendment Number 5 to the Fishery Management Plan for the coastal migratory pelagic resources (mackerels). March 1990, 33pp + 9 appendix pp.

Continue with Part II