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CHESAPEAKE BAY FISHERIES ECOSYSTEM PLAN:PATTERNS IN TOTAL REMOVALS

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Submitted by: Thomas J. Miller
Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science
Solomons, MD 20688-0038

I. INTRODUCTION

Fisheries ecosystems have limits to their production. There are many well documented examples from the earliest days to the most recent times of overharvesting of individual species that lead to declines in fisheries (Smith, 1994; Myers and Hutchings Starkey et al. 2000). In addition, there is evidence that the undesirable impacts brought about by the overharvest of individual species may either not be reversible, or may take a considerable time (Hutchings 2000). Defining the limits to exploitation of a single species is not a simple task, given the statistical variability in available data, the biological variability in populations, and the economic variability in the markets. However, both empirical and theoretical approaches are available (Quinn and Deriso 199x). For example, the blue crab (*Callinectes sapidus*) in Chesapeake Bay is currently managed under an empirically defined abundance threshold (Miller 2001). Despite the difficulty in defining abundance thresholds, it is clear that fisheries management policies must identify and stay within thresholds for exploitation (Caddy and Mahon 1995).

Concerns over the perceived shortcomings of traditional fisheries management which is dominated by a single-species approach lead to the development of multispecies alternatives (Miller et al. 1996). Mutispecies management seeks to balance the fishery catch, predation mortality and natural mortality of all exploited species in the ecosystem. However, even here it is important to recognize that there are limits to exploitation that when exceeded cause susbstantial and perhaps irreversible changes in the ecosystem. Thus it is as important to define limits to the level of total removals in a fishery managed using multispecies approaches as it is for single species fisheries.

Establishing thresholds for removals in the Chesapeake Bay is particularly challenging. Fishing activity in Chesapeake Bay is diverse: there are important recreational, charter boat and commercial fisheries for a large number of species. Any attempt to set a limit for the total removals must account for all sectors in the fishery. Moreover, the major of the species targeted in the different sectors are not wholly resident in the Chesapeake Bay. It is possible to recognize three categories of life history in the exploited species of Chesapeake Bay. One can define the standing stocks of a single species or of the entire community being comprised of three components (Fig. 1). There is a portion of the standing stock that resides within the Chesapeake Bay (S_{CB}), a portion that resides in the coastal waters outside of the Bay (S_{CSTt}), and a portion that may reside in other estuaries along the mid Atlantic seaboard (S_{EST}). Not all species will exhibit all three components of population structure. For example, resident species will only occur in the Chesapeake Bay standing stock component (Fig 2A). Other species will require only two components to describe their population structure (Fig 2B), while some will require all three (Fig 2C). The three standing stocks may be considered to be separated in time, such that the estuarine stocks represent different life history stages than the coastal stock. Examples of species that could be described in this way are blue crab, menhaden and striped bass. Alternatively, the three standing stocks may be considered to be separated in space, with the bulk of the life history occurring in all three regions. Examples of such species may include bluefish, and winter flounder.

The abundance of each standing stock component, S_{CB}, S_{CST}, and S_{EST} , is governed by the same seven processes. There are five processes which decrease standing stocks. Each standing stock is subjected to three sources of fishing mortality: reported catch, unreported catch and discard mortality. The level and importance of the three sources will be species or community specific. Each standing stock also experiences natural mortality. These four loss terms are intrinsic to the species or community. Finally for species that exist in more than one component, there is an emigration loss representing the movement of individuals from the stock to either or one of the other components of the population. This loss term is extrinsic to the species or community. There are two processes that result in gains to the standing stock. Components may produce new individuals, or may experience growth of individuals leading to increases in the total stock biomass. This is an intrinsic gain. Secondly, new individuals may immigrate into the stock from one or both of the other components. This is an extrinsic gain. Two prerequisites must be satisfied if one wished to develop removal thresholds within fully ecosystem-based management. One would need estimates of all vital rates in all components of all populations to estimated the threshold for total removals. Moreover, one would need management jurisdiction over all components to be able to regulate the pattern fishing to stay within identified thresholds.

For the immediate future, it is unlikely that we will meet such goals. However, this should not prevent progress on estimation of the thresholds for total removals in the Chesapeake Bay, the region for which coordinated jurisdictions exist. Two analyses are required to achieve progress. We must identify and categorize all species deemed important to fisheries management into the three life history patterns in order to determine the extent of potential control. We must determine the patterns in the total removals within the Chesapeake Bay, which up to now has been sustainable to determine the potential limits on removals.

II QUANTIFYING TOTAL REMOVALS

II. A. Utility of total removals in other systems.

Many industrialized countries estimate the level of removals form their fishery ecosystems as a routine part of stock assessments conducted on individual species. However, the use to which these estimates are put varies considerably.

The most common use of estimates of total removals is in determining allocations among competiting stakeholder groups. Typically this objective is acheived by estimating a level of sage harvest in the upcoming fishing season based on scientific advice. These are often termed Total Allowable Catches of TACs. For example, the EU relies on scientific advice from ICES and individual member states to estimate the TAC for the principal fisheries under its jurisdiction. Each TAC is then allocated to member states under the principle of "relative stability" enshrined in the EU's Common Fishery Policy. A similar policy is followed in both Canada, Australia and New Zealand. The governments of these nations estimate annual TACs for their principal fisheries. Each TAC then forms the basis for allocation among indigenous, recreational and commercial exploitation. However, in these cases there is no restriction or cap on the mangitude of combined TAC's that would limit fisheries activity. Thus the overall fishery acitivity is simply the sum of the combined TACs

In a few circumstances the magnitude of total removals has been or is used as a management tool in itself. From 1949 - 1982, fishing activity on the Northwest Atlantic was regulated by International Commission for Northwest Atlantic Fisheries (INCNAF). INCNAF managed the commercial fisheries under a two-tier system from 1974 - 1982. Maximum sustainable yields were calculated for individual fish stocks. Subsequently, a second tier or a combined maximum sustainable yield was established for the INCNAF area that was less than the sum of the individual MSYs. This upper tier restricted fishing on the individual stocks by implicitly recognizing the potential for biological and technical interactions (Fogarty and Murawski 1998). However, after the establishment of the New England Fishery Management Council in 1982 this two-tiered management strategy was abandoned. A similar approach was established and is still pursued by the North Pacific Management Council (Witherell et al. 199_).
The NPFMC regulates total removals of ground fish for each stock. Three levels of harvest are established, corresponding to overfishing (OFL), the acceptable biological catch (ABC) and the total allowable catch (TAC) from which actual catches are determined. These three levels are set such that the OFL > ABC > TAC. Moreover the TAC is set intentionally much lower than the ABC to ensure adequate resilience is maintained. However, a second level of threshold is also maintained. The sum of all TACs must be less than 2 million MT per year, which has been determined to be less than the aggregate acceptable biological catch in the system. Two additional examples of two-tiered management can be found in the southern oceans. The Southeast Australian trawl fishery is managed in a two-tiered system that attempts to account for the multispecies nature of many of its fisheries (AFMA 2001). Finally, the krill fishery in the Antarctic Ocean is managed on the basis of a level of total removals. However, the total removals are partitioned into those removed by capture fisheries and those removed by natural predators. Thus, the commercial catch of krill is set at that level that ensures sufficient biomass remains to provide an adequate prey base for the rest of the ecosystem (Nichols and de la Mare 1993; Constable et al.

2000).

Despite the relatively small number of examples of current use of total removals as a management tool, there is growing interest in their use in the future. The EU has proposed using multiyear, multigear TACs in its revision of the Common Fisheries Policy (Commission of the European Communities 2001). The growing use and recognition of multispecies management approaches (Miller et al. 1996) presupposes that a system wide limit will be established for jurisdictions that adopt multispecies management. Given that such a goal is identified in the Chesapeake 2000 agreement it is likely that attention will be focused on the level of total removals in the Chesapeake Bay fishery ecosystem.

III. B. Status of knowledge in Chesapeake Bay

The goal of quantifying the level of total removals from the Chesapeake Bay requires that all sources of removals be identified. One may identify five sources of fishery removals from the Chesapeake Bay. For each source there are several potential sources of information for removals (Table 1). For these the components of the fishery in which they were likely to occur, as well as possible methods for estimating their relative contribution to the total catch can be identified. It is important to note that the availability of data on these sources of removals is not consistent. In the near future, the situation should change following adoption of a coastwide reporting system sponsored by the Atlantic States Marine Fisheries Commission. Once fully implemented, the Atlantic Coastal Cooperative Statistics Program (ACCSP) will provide estimates of both landings and catch for all principal fisheries along the mid-Atlantic coast. The ACCSP will include characterization of both the magnitude and the biological attributes of the catch. However, even when fully implemented, the ACCSP will not report landings and discards of non-commercial species.

The principal sources of removals are:

- Commercial landings. Landings are that portion of the harvest that is successfully brought to port. This category of removal is relatively well assessed. There are concerns over identifying those components of the landings that are taken in Chesapeake Bay and those individuals that are harvested elsewhere but landed in Chesapeake Bay. This concern is particularly pertinent to the menhaden fleet. Commercial
- Commercial discards. Fish and shellfish that are caught can either be landed or discarded. A portion of those individuals that are discarded will die following release. Thus even though these individuals are not recorded as part of the landings - they do represent a source of mortality and must be accounted for when assessing total removals. These are not well assessed in the Chesapeake region. Indeed I found no reliable estimates of the level of discarding, or mortality associated with it. It is likely that discard mortality is low in some fisheries, such as the pound net fishery. In contrast, discarding and associated mortality may be more substantial in fisheries such as the winter gill net fishery.
- Bycatch. Many commercial gear types do not catch a single species, but rather catch a diversity of taxa. These non-targeted species experience mortality as a result of the harvest process. Some are brought to port as while not targeted, the species do have commercial value. Other species may have no commercial value, or are illegal due to size or seasonal

restrictions on catch and are discarded. These discarded individuals would not normally be recorded in landings statistics. Information on bycatch is Chesapeake Bay fisheries is not consistently reported.

! Recreational landings. Landings are that portion of the recreational catch that are brought to shore for either consumption or as a trophy. This component of the total removals are assessed through a variety of fishery-dependent surveys, principally the Marine Recreational Statistical Survey (MRFSS). Recreational landings are reported in biweekly waves and can be identified to a geographic regions. Thus it is possible to identify a Chesapeake Bay catch. However, there are concerns over the temporal and spatial intensity of the survey especially when applied to restricted geographic areas. Moreover, the MRFSS targets marine species. Consequently coverage is poor in the fresher portions of the Chesapeake Bay, resulting in missing or imprecise estimates for these regions. Moreover, estimates of catches of freshwater species species taken in more urban areas are almost completely lacking Perhaps of most important is the fact that no survey currently exists to monitor the recreational catch for blue crabs. The magnitude of this recreational fishery in Maryland waters of Chesapeake Bay has been assessed to be from between 20-80% of the commercial harvest (Stagg et al. 1981). Miller et al. (2000) conducted a pilot survey of the recreational fishery in Maryland and Virginia. Their data indicate levels of participation of alomst 10% in coastal counties, with an average of 1.6 trips per 2 weeks, with an average harvest of 24.9 crabs per trip. These estimates suggest the recreational harvest may be significant.

! Recreational discards. Individual fish may be hooked but subsequently released. As with the commercial discards, a portion of the released fish will eventually die. These deaths must be included in the estimate of total removals. Within MRFSS recreational catches are estimated in three categories. Type A catches are estimated from the frequency of fish caught and inspected during intercept interviews. Type B1 catches are estimated from the frequency of fish caught but reported to be used as bait during intercept interviews. Together, A+ B1 represent the recreational landings reported above. A third category B2 is estimated from the fequency of fish reported as having been caught but released during intercept interviews. This later category may form the basis of an estimate of recreational discards. However, with the exception of striped bass, little is known of the mortality rate of these released fish. Thus, overall, recreational discards are not well assessed for the recreational catch in the Chesapeake Region.

III. PATTERNS IN FISHERIES HARVESTS AND ABUNDANCES.

III. A. Data Sources and Preparation.

Given the large discrepancies in the extent and reliability of commercial and recreational data, the two data sources were reviewed and analyzed separately.

Landings data provided to NOAA by the Virginia Marine Resources Commission and Maryland Department of Natural Resources for the period 1956 - 1999 were examined. It was impossible to standardize catch to fishing effort because effort data are unsystematically collected and recorded for most species. As a result, there is some uncertainty whether trends in the data reflect changes in overall population abundance or changes in fishing effort. Moreover, the available data are reported on a species by species basis. Data were not made available that would enable identification of the gear used to capture fish. As a result, the data presented do not shed light on the extent of technical interactions present in the fishery.

Historically, commercial landings records date to 1880 but are inconsistent until 1929. Changes in reporting and recording methods complicate analysis and interpretation of landings trends. There were difficulties in determining menhaden catches, the most abundant species landed by weight. Vaughan et al. (2001) provide estimates of menhaden catches from Chesapeake Bay for 1985-2000 based on the Captain's Daily Fishing Reports (CDFRs). In addition Vaughan et al (op. cit.) developed two approaches for estimating historical values prior to the availability of CDFRs (1955-1984). The first approach was based on estimates of landings by port and corresponding biostatistical sampling, 1955-2000. Biostatistical sampling, which provides location of final set, are also available from all ports. An estimate of the portion of landings by port can be made from these data by assuming that final set, and hence sampling, is proportional to location of set (i.e., inside or outside Chesapeake Bay). There has historically been concern about "topping off" in which vessels fishing from Reedville, VA, will make a final set upon returning to the Bay after fishing outside the Bay. This first approach would tend to overestimate the catch from Chesapeake Bay relative to outside the Bay under this condition. The second approach regressed estimates of landings within the Bay from CDFRs on the estimates from the biostatistical approach (no-intercept linear regression). The resultant estimates from this regression are likely unbiased relative to the "topping off" problem. These later data were used as estimates of the total removal of menhaden from the Bay. In addition, prior to 1952, landings reported for Maryland and Virginia were aggregated Chesapeake Bay and Atlantic catches landed at ports in the two states. After 1952, the landings from the Bay and Atlantic sources were separated, and thus, from 1953 onwards harvest data are specific to the waters of the Bay. However, in many cases the data had not been disaggregated to permit reconstruction of the Chesapeake Bay catch for the period 1953-1961. Thus, the commercial harvests specific to Chesapeake Bay for the years 1962-2000 were available for analysis

Recreational catches for the Chesapeake Bay were obtained by querying the MRFSS database (http://www.st.nmfs.gov/st1/). Data were obtained using the following criteria: years - 1981- 2000, Wave - annual, Species - all, Geographic area - mid Atlantic by State, Fishing mode - all, Fishing area - inland, type of catch - A+B1. The data were then sorted by state and those for Maryland and Virginia were retained. It was assumed that these catches related only to the

Chesapeake Bay.

III. B. Ecological Classification.

In order to determine the extent to which removals external to the system which will not be considered in further analyses, we characterized species recorded in the Chesapeake Bay catch records by life history category. Individual species can be categorized into one of these three patterns. Resident species are the simplest case. For resident species, such as white perch, knowledge of the intrinsic losses and gains are sufficient to describe the dynamics of the population (Fig 2A). Based on these estimates, traditional single species management approaches are sufficient to describe the dynamics and to estimate safe levels of removal. Species that exist only in the Chesapeake Bay and the coastal ocean are the next simplest level of population structure (Fig 2B). An example of species existing in only two components is blue crab. Knowledge of the five intrinsic losses and gains are not sufficient to describe the population: in addition we require estimates of extrinsic rates. However, the extrinsic rates are often the most difficult to estimate. The most complex case is the one in which the population exists in at least three components (Fig 2C). Menhaden were considered to be an example of a species requiring three components. It should be recognized that the S_{EST} component may in fact be multiple alternative estuaries along the mid-Atlantic coast, and thus the dimensionality of the system may be greater than three. For this most complicated case, knowledge of all intrinsic and extrinsic rates (or knowledge of all stock sizes) are required to understand the population dynamics.

The species for which data were available were categorized on the basis of several ecological attributes using information provided in Murdy et al. (1997). Species were categorized into one of three life history categories: 1 – resident, 2– existing in CB and coastal ocean, 3– exist in CB, coastal ocean and other estuaries. Species were also categorized either as to whether or not they spawn in Chesapeake Bay. Species were further categorized by habit, that is whether they are recognized as freshwater (fw), estuarine resident (res), seasonal visitor (seas), opportunist visitor (opp) or occasional visitor (occ). Species were also categorized according to their trophic status as PLANKtivore, PISCivore, BENTHivore or DETRITivore. Species could be assigned more than one trophic status. Table 2 presents information on the principal species of interest in the Chesapeake Bay.

III. C. Distribution of life history categories in commercial removals

The total average annual commercial harvest from Chesapeake Bay is 385.03 MT x10^3. Based on the classifications developed above, the contribution of each category to the annual landings was determined. When categorized by life history category, the data indicate that approximately 86 % of the landings come from species whose life history involves Chesapeake Bay, the coastal ocean and other estuaries along the eastern seaboard (Fig. 3). A further 9% of the landings come from species whose life histories rely on the coastal ocean, in addition to Chesapeake Bay. Currently only 5% of the average annual harvest is comprised of resident species. Eighty-six percent of the average annual catch is comprised of species that do not spawn in the Bay (Fig 4). However, in contrast, fully 99% of the landings come from species for which Chesapeake Bay is an important nursery area (Fig. 5). The dominant trophic category in the landings are the planktivores which together comprise 90% of the average annual catch (Fig .6). The benthivores are the second-most represented group in the harvest, comprising 9% of the catch.

III. D. Time series of commercial removals

The total annual commercial harvest from Chesapeake Bay varied over the period 1962 - 1999 (Fig 7). In 1962 the total catch was 616.58.78 x 10^3 MT. Catches dropped until the late 1960's. Total commercial removals have been relatively constant since 1970, with an average level of removals of 380.9 ± 69.4 x10^3 MT . In 2000, the total catch was 201.6 x 10^3 MT. There is some evidence in the figure of a declining trend in total removals over the period of the 1990's. The trend in Chesapeake Bay landing is driven largely by changes in estimated landings of menhaden. Menhaden contribute between 68 - 87% of the total commercial harvest from the Chesapeake Bay in any one year. Changes in menhaden landings are likely driven as much by economic considerations within the menhaden fishery as they are by changes in underlying abundances. Thus, caution should be exercised when examining patterns in these data. However, a level of removals of approximately 300-350 x 10^3 MT for all fishes, and removals of may represent a sustainable level of removals.

To examine the pattern in the data in more detail, one can disaggregate the catch and look at the trends in the principal component species (Fig. 8). When viewed at this scale, a variety of different trends in landings become apparent. Landings time series for blue crab appear variable but relatively consistent until the most recent years (Fig .8). In contrast landing time series for oyster and shads have declined consistently (Fig .8). There is also evidence for coherent variation, both in and out of phase for individual species pairs. (Fig 9). Thus, some species apparent respond to the same forcing, while other species respond differently - whether these responses are due to environmental, biological or technical interactions is unclear.

To explore multispecies patterns in the data set, species were reported in commercial landings were group into two broad categories. Some species were assigned to more than one category. The two categories were life history form, trophic mode. Details of the classification are presented in Table 2.

Patterns in the time series of landing of broad life history modes were explored (Fig.10). The patterns are dominated by menhaden but do still suggest a steady increase in the proportion of taxa in the landings who use Chesapeake Bay as one of potentially many nursery or breeding areas. The landings species identified as using the Chesapeake Bay and the coastal ocean have been highly variable, but appear to have varied without trend. In contrast, the landings of the resident species have declined relatively steadily over the 1950 - 1999 period. This decline is driven largely by the declines in oyster over this period.

We explored patterns in the time series of broad trophic groupings. The landings of planktivorous species reflect changes in the landings of menhaden over the period 1962-2000 (Fig. 11). If menhaden are removed from consideration, the landings of planktivores feeders have declined over the same period. This reflects the continuing decline of anadromous clupeoid fishes and oysters. Landings of piscivorous species declined slowly. However, considering that a complete fishing moratorium was imposed on striped bass in Maryland from 1985-1989, the overall trend indicates relative stability in levels of total piscivore landings. Yet, the time series of landings of individual predator species is highly variable, especially for bluefish and striped bass (Fig. 9). Peak years of striped bass landings (1960s to 1970s) coincided with a period of low bluefish and weakfish catches. Moreover, commercial catches of bluefish only peaked in the mid to late 1970's when striped bass catches were declining rapidly and weakfish catches were at low levels. We do not suggest that there is necessarily any causal relationship in these patterns, because they are not simple replacements. We do, however, suggest that they may be driven by the same underlying mechanisms. Shifts in the dominance of piscivore species almost certainly do reflect a combination of varying natural abundances and the behavior of the fishery, which can shift its effort in accord with both availability of fish and marketing opportunities.

In contrast to the planktivores and piscivores, the probable abundances of benthivorous fishes, as indexed by landings, have fluctuated widely around a long-term mean, with no clear long-term trend (Fig. 11). The fluctuations represent variation in the harvests of component species, including spot, croaker and blue crab. With the exception of blue crab, landings of which remained relative steady until recent years, due most likely to increased effort, responses by other species of the benthivore group are more similar. Catches of benthivore species, primarily croaker and spot, peaked in the 1940s and 1950s at levels exceeding 30,000 t and then declined. Landings of channel catfish have increased recently, although it is uncertain if this reflects an increase in their abundance.

Overall, there is no direct or clear evidence in these summary plots of dramatic species replacements in the Bay, nor of complementary patterns in abundance. However, there is ample evidence of complex patterns of covariation in the landings time series of groups of species. The presence of covariation and its potential to affect harvests and overall well being of resources and fisheries should be considered by resource managers. To explore further the degree of covariation in time series of landings, more sophisticated methods are required.

III. E. Time series of recreational removals

Recreational harvests were examined for eleven species were examined for the period 1981 - 2000. The species included in the analysis were striped bass, bluefish, Atlantic croaker, black drum, red drum, summer flounder, black sea bass, spotted seatrout, spot, weakfish and southern flounder. There were no other data available from MRFSS on a consistent basis.

The average recreational harvest in Chesapeake Bay of these species was $4.73 \pm 1.54 \times 10^3$ MT.   There was considerable variation early in the time series (Fig 12), but the variability diminshed in the 1990s to be replaced by a consistent trend of increasing recreational catches. The principle contributors to the catch were bluefish in the first decade and striped bass and Atlantic croaker in the second decade of the time series (Fig 13).

These preliminary data suggest that the recreational catch does not contribute significantly to the level of overall removals.   However, this interpretation should be viewed with caution. Firstly, and most importantly, the recreational fishery for blue crab is not included in the data analyzed. There is belief that this fishery is substantial and likely of a similar magnitude to the commercial landings for blue crab. This could add an additional 10-30 x 10^3 MT to the level of recreational removals.

IV. RECOMMENDATIONS

IV. A. General Recommendations.

The following seven recommendations are made. The recommendations recognize that insufficient information is available currently to permit the immediately development of thresholds for total removals. The recommendations offered would lead however to the eventual development of such thresholds.

1. The NOAA CBO should maintain and make available on its web site a qa/qc'd database of removals by species for the Chesapeake Bay. This data base should include as they become available time series of commercial landings, estimates of discard mortalities, by catch, recreational landings and recreational discards.

2. The NOAA CBO should publish annually a report that summarizes the levels and patterns in the total removals from Chesapeake Bay.

3. Each single species FMP should include explicit estimates of commercial landings, discard mortality, bycatch, recreational landings and recreational discards. In cases where such estimates are not available, each FMP should present a review of the missing data for regional fisheries for the same species if available. In cases where no information is available this should be noted.

4. Each single species FMP should include an estimate of the contribution of the fisheries for the species considered to the total removals for the Chesapeake Bay.

5. Each single species FMP should include an estimate of the impact of proposed changes to the total removals from the Chesapeake Bay.

6. Through CBSAC, the NOAA CBO should promote and support modelling and analysis of patterns in total removals to identify appropriate thresholds and targets for the total removals from the Chesapeake Bay.

7. In consultation with the regional management agencies, the Chesapeake Bay Fisheries Committee should establish, based on the best scientific advice available, thresholds for total removals from the Chesapeake Bay. The thresholds should identify an upper limit on the biomass of fish and shellfish that can be removed the waters of Chesapeake Bay annually, and should allocate that amount to the various fisheries based upon the historical pattern of exploitation.

IV. B. Recommendations for Data Collection.

The seven goals identified above are broad recommendations to the federal and regional management authorities. In support of these, an additional 5 recommendations specific to data collection needs are identified to assist progress toward the general goals identified above.

1. The management agencies in the mid-Atlantic should continue efforts to maintain and improve estimates of removals and their characteristics by species, gear, time and location. Sampling programs should be implemented at the spatial and temporal scales appropriate to the dominant components of the system under consideration.
2. The management agencies should seek the resources to greatly expand the intensity of sampling of the MRFSS to ensure that species that are not of utmost interest and concern are adequately covered in the survey.
3. The management agencies should initiate or greatly expand efforts to estimate unreported landings.
4. The management agencies should initiate broad efforts to quantify the magnitude, pattern and characteristics of discard mortalities. Currently only one or two species are the focus of efforts to estimate discard mortality. However, a broad-scale program presupposes an effort to develop suitable and efficient sampling designs which are currently poorly understood.
5. Establish goals and objectives for complemented fishery-independent surveys of fish resources in Chesapeake Bay. Current surveys do not fully cover all life stages of fisheries resources of all species. Given the magnitude of this task, the workgroup recommended that detailed and careful discussion, analysis and planning be undertaken prior to initiation of the full complemented survey design to ensure that the required data are estimated as accurately and precisely as possible.

IV. C. Recommendations for Data Interpretation and Modeling

An additional three recommendations are identified to promote the interpretation and analysis of total removals data collected .

1. Identify and quantify technical interactions in commercial and recreational removals are appropriate spatial and temporal scales
2. Identify and quantify patterns in removals with respect to trophic levels, life histories and habitat associations at the appropriate spatial scales to improve knowledge of biological interactions
3. Initiate development of MS models of consequences and patterns of removals. It is suggested that MS biomass dynamic models are the most likely to be successful in the short term.

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Table 1. Summary of the state of knowledge of the magnitude and characteristics of reported, unreported and discard mortality. No entry in a cell indicates that the workgroup concluded that the particular source of mortality did not apply to that component of the fishery. A ✓ indicates that the source of mortality is thought to occur, but its magnitude is unknown. "None" indicates that the source of mortality is known to occur, but no reporting system is in place. MRFSS is the National Marine Fisheries Marine Recreational Fishery Statistical Survey.

Mortality Source	Finfish			Shellfish		Crustacean	
	Commercial	Boat for Hire	Recreational	Commercial	Recreational	Commercial	Recreational
Reported							
Landings	Trip ticket	Log book	MRFSS	Trip ticket	Reports	Trip ticket	None
Characteristics	Sampled	MRFSS *1. insufficient coverage for many non-dominant species* *2. Public vs. private access*		Min. size only	None	Market category, sex	None *1. Identification of sampling frames* *2. Public vs. private access.*
Unreported							
1. Incidental	✓		✓	✓		✓	
2. Unlicenced	✓		✓	✓		✓	
	1. Could be estimated y analysis of arrest rates as a function of number of trips or other effort indicator, but this would not estimate the magnitude or characteristics of the catch						
3. Basket trade	✓			✓		✓	

	1 .Could be estimated by sampling roadside and other non-standard outlets, but would be expensive *2. Sampling frames difficult to determine*					
4. Unclassified	✓					
	1. Can be sampled effectively					
5. Quasi-recreational		✓		✓		✓
	1. Can be sampled with increased reporting requirements for recreational fishers with licenses for “large” gear types, e.g. gill nets, trot lines					
6. Live bait	?		?		?	
Discards						
1. Undersize	ACCSP	MRFSS	None		None	
2. Regulatory	ACCSP					
3. No market	ACCSP					
	1. Estimates of the magnitude of the release will be available, but knowledge of post release mortality poor for all except striped bass *2. Knowledge of the magnitude of the release is not available for shellfish or crustaceans*					

Table 2. Classification of common Chesapeake Bay species important either ecologically or in the commercial catch into taxonomic, trophic, and life history groups. Groups were identified by life history, based on the categories identified in figure 1 as : (1) species that complete their life history entirely within Chesapeake Bay, (2) species that complete their life history within Chesapeake Bay and the coastal ocean and (3) species that complete their life history within eastcoast estuaries including Chesapeake Bay and the coastal ocean. Taxonomic groups were shellfish (S) and finfish (F), based upon taxonomic order. Trophic criteria were planktivore (P), benthivore (B), piscivore (C) and detritivore (D) based upon the primary dietary items. Habit groups were resident (res), seasonal (seas) and occasional (occ). Resident species were those which remained in the Bay for the entire year, and completed the bulk of their life history within the Bay. Blue crab were included in this group even though they do spend a brief period as larvae outside of the Bay. Seasonal species were ones that have an obligate estuarine phase, and prolonged periods outside of the Bay. Spot and croaker were included in this group as adults leave the bay system to spawn. The final group were occasional visitors, which were defined as ones that are caught in Bay waters, but are not obligate estuarine species.

Common Name	Species	Family	Life History	CB Sapwn	CB Nursery	Habit	Fish/ Shellfish	Trophic Status	Mean Landings (MT)
Bowfin	*Amia calva*	Amiidae	1	y	n	fw	fish	pisc	2.8
Crappie	*Pomoxis spp.*	Centrarchidae	1	y	n	fw	fish	pisc	65.6
Bay anchovy	*Anchoa mitchelli*	Clupeidae	1	y	y	res	fish	plank	
Gizzard shad	*Dorosoma cepedianum*	Clupeidae	1	y	y	res	fish	plank/detri	9,872.3
Common carp	*Cyprinus carpio*	Cyprinidae	1	y	n	fw	fish	pisc/detri	3,884.5
Soft clam	*Mya arenaria*	Hiatellidae	1	y	y	res	shell	plank	51,164.7
Catfishes	*Ameiurus*	Ictaluridae	1	y	n	fw	fish	pisc	37,120.7
Gars	*Lepisosteus osseus*	Lepisosteidae	1	y	n	fw	fish	pisc	30.3
White perch	*Morone americana*	Moronidae	1	y	y	res	fish	pisc	38,647.8
Eastern oyster	*Crassostrea virginica*	Ostreidae	1	y	y	res	shell	plank	708,362.4
Yellow perch	*Perca flacescens*	Percidae	1	y	y	res	fish	pisc	4,050.6
Hogchoker	*Trinectes maculatus*	Solediae	1	y	y	res	fish	benth	38.3
Hard clam	*Mercenaria mercenaria*	Veneridae	1	y	y	res	shell	plank	29,917.3
Sturgeons	*Acipenser*	Acipenseridae	2	y	y	seas	fish	benth	185.8
Hickory shad	*Alosa mediocris*	Clupeidae	2	y	n	seas	fish	pisc	393.2
Alewife	*Alosa psuedoharengus*	Clupeidae	2	y	y	seas	fish	plank	164,123.1

American shad	*Alosa sapidissima*	Clupeidae	2 y	n	seas	fish	plank	25,364.3
Tautog	*Tautoga onitis*	Labridae	2 n	y	opp	fish	benth	128.1
Blue crab	*Callinectes sapidus*	Portunidae	2 y	y	res	shell	benth	16,184,577
Black sea bass	*Centropristis striata*	Serranidae	2 n	y	opp	fish	pisc	121.9
Butterfish	*Peprilus triacanthus*	Stromateidae	2 y	n	seas	fish	pisc	9,218.4
American eel	*Anguilla rostrata*	Anguillidae	3 n	y	seas	fish	pisc	23,112.9
Atltantic menhaden	*Brevoortia tryannus*	Clupeidae	3 n	y	seas	fish	plank	16,184,200
Atlantic herring	*Clupea harengus*	Clupeidae	3 n	y	opp	fish	plank	4,193.8
Horseshoe crab	*Limulus polyphemus*	Limulidae	3 y	y	res	shell	benth	6,751.0
Striped bass	*Morone saxatilis*	Moronidae	3 y	y	seas	fish	pisc	101,402.1
Summer flounder	*Paralichthys dentatus*	Paralichthydiae	3 n	y	seasonal	fish	benth	
Bluefish	*Pomatomus saltatrix*	Pomatomidae	3 n	y	opp	fish	pisc	27,521.2
Spotted seatrout	*Cynoscion nebulosus*	Sciaenidae	3 n	y	opp	fish	pisc	390.4
Weakfish	*Cynoscion regalis*	Sciaenidae	3 n	y	seas	fish	pisc	32,510.9
Spot	*Leiostomus xanthurus*	Sciaenidae	3 n	y	seas	fish	benth	39,729.8
Atlantic croaker	*Micropogonias undulatus*	Sciaenidae	3 n	y	seas	fish	benth	51,000.4
Black drum	*Pogonias cromis*	Sciaenidae	3 n	y	opp	fish	benth	1,260.0
Red drum	*Sciaenops ocellatus*	Sciaenidae	3 n	y	opp	fish	benth	139.3
Scups and Porgies		Sparidae	3 n	n	opp	fish	benth	35,898.9

Figure 1. Conceptual figure representing the structure of populations in the Chesapeake Bay. Three component stocks are identified: Chesapeake Bay (S_{CB}), coastal (S_{CST}) and other estuarine (S_{EST}). For each stock up to seven processes that either increase or decrease the spawning stocks are indicated.

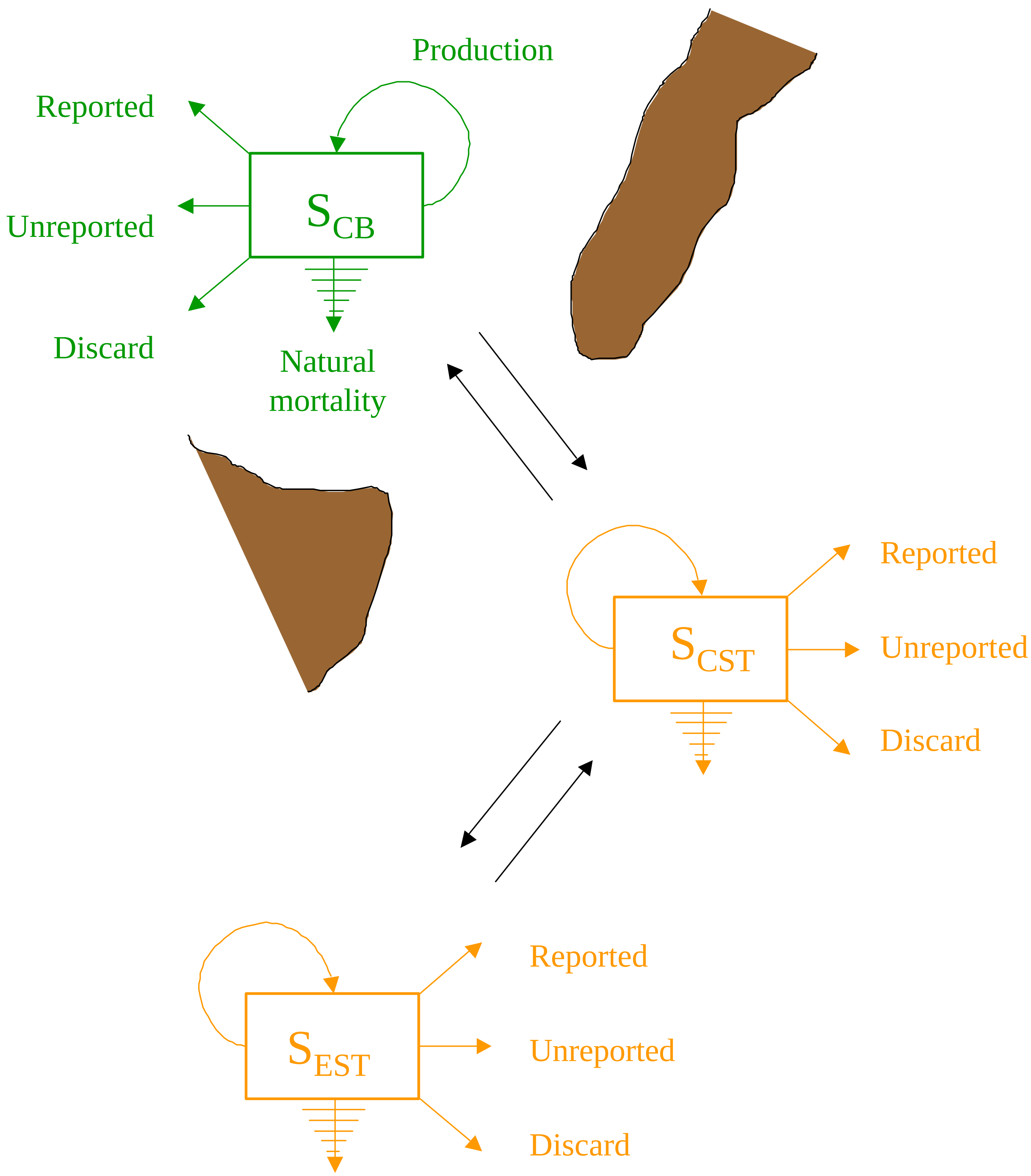


Figure 2. Conceptual figure representing three possible population structures for exploited marine resources in the Chesapeake Bay. The three different structures: A) resident, such as white perch; B) two-component, such as blue crab, and c) multi-component, such as menhaden, were identified. Within each structure a different number of standing stocks can be identified. For each stock up to seven processes that either increase or decrease the spawning stocks are indicated.

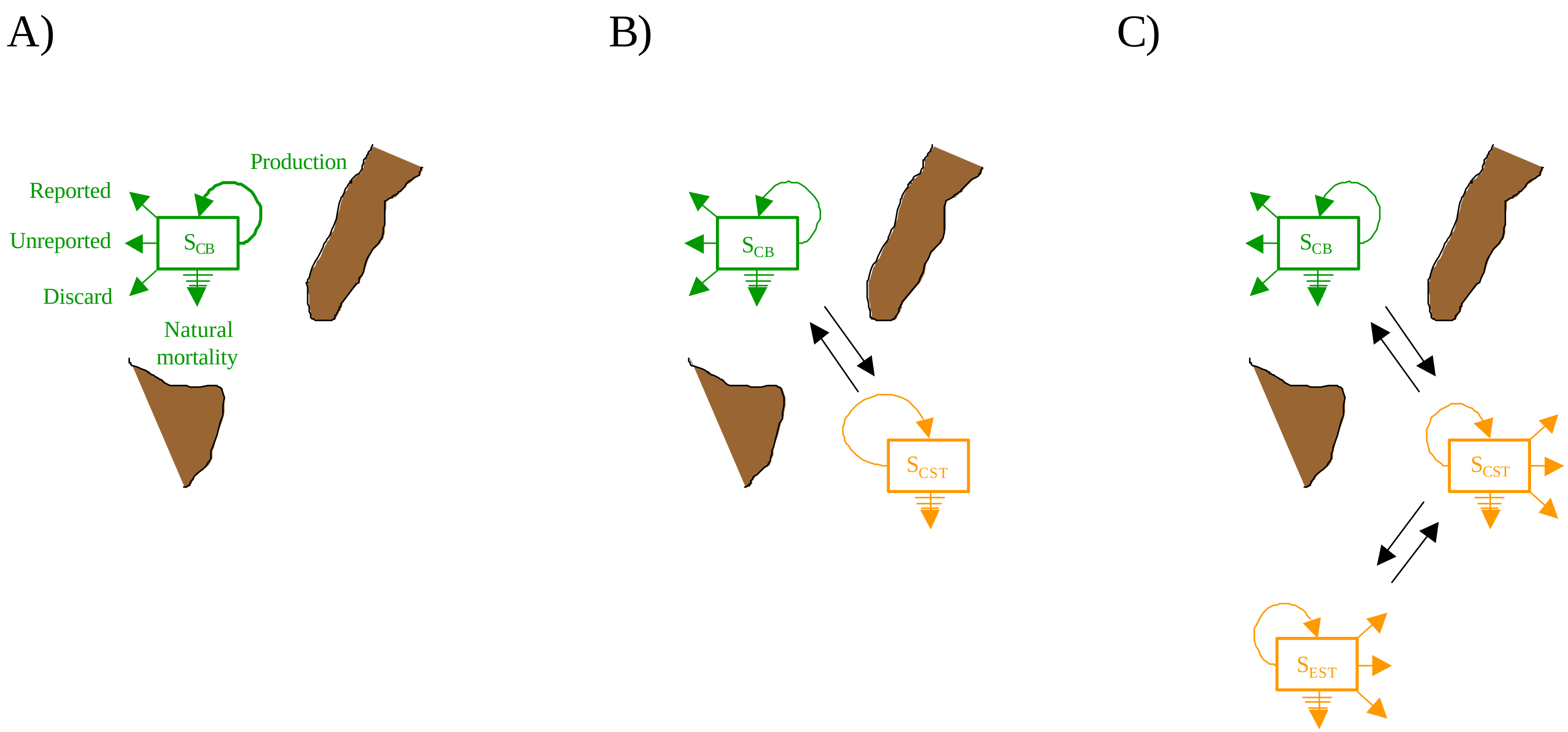


Figure 3. Commercial removals by life history mode

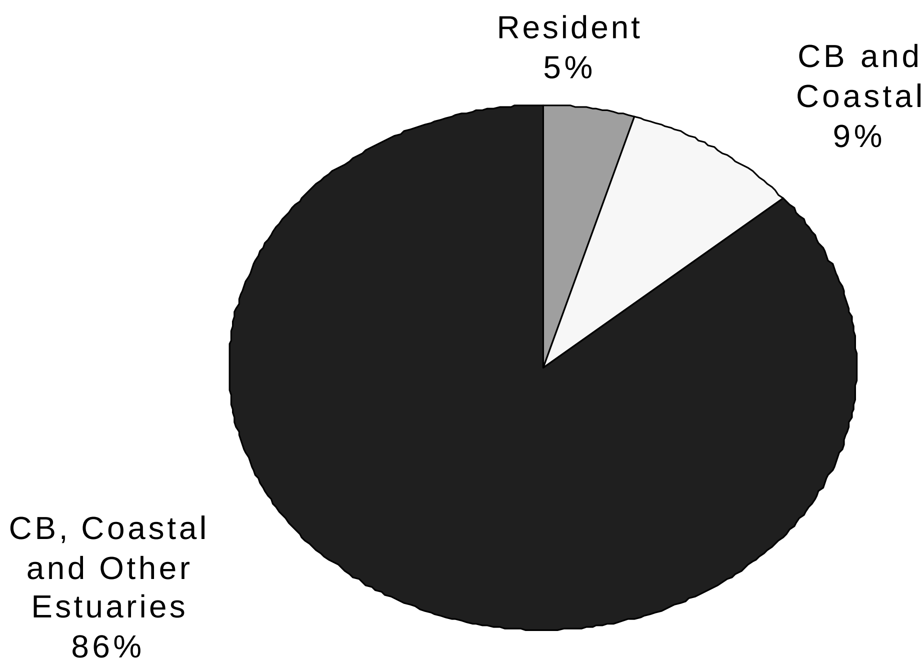


Fig. 4. Commercial removals by spawning location.

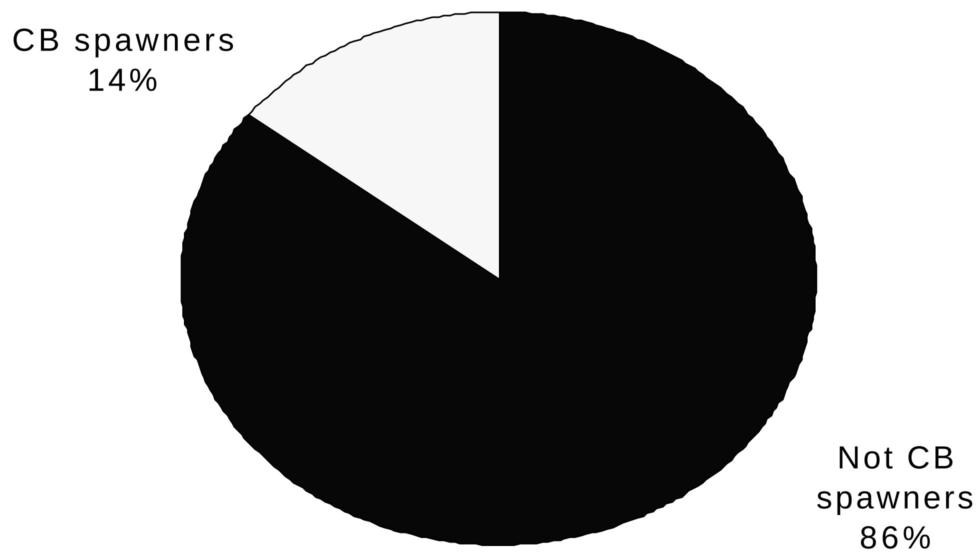


Fig 5. Commercial removals by nursery areas.

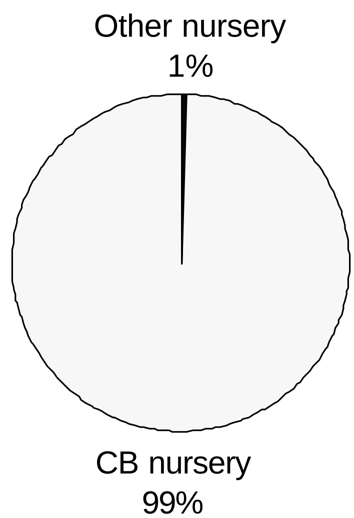


Figure 6.

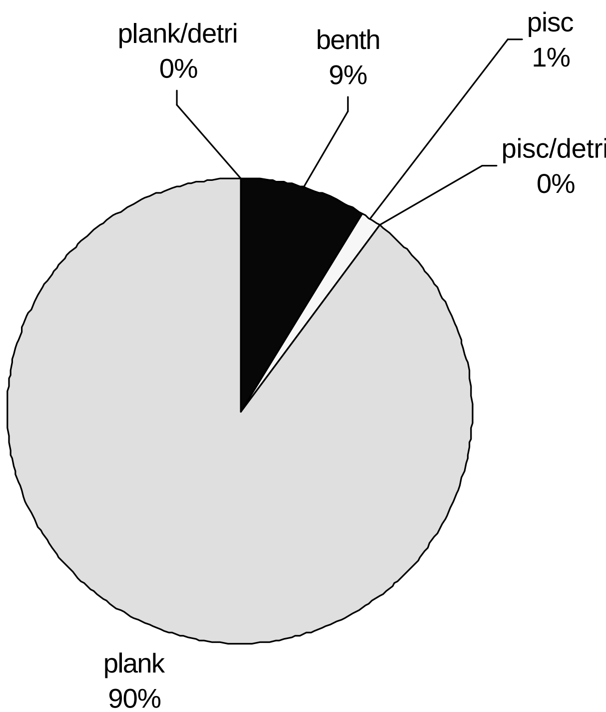


Fig 7. Time series of commercial removals

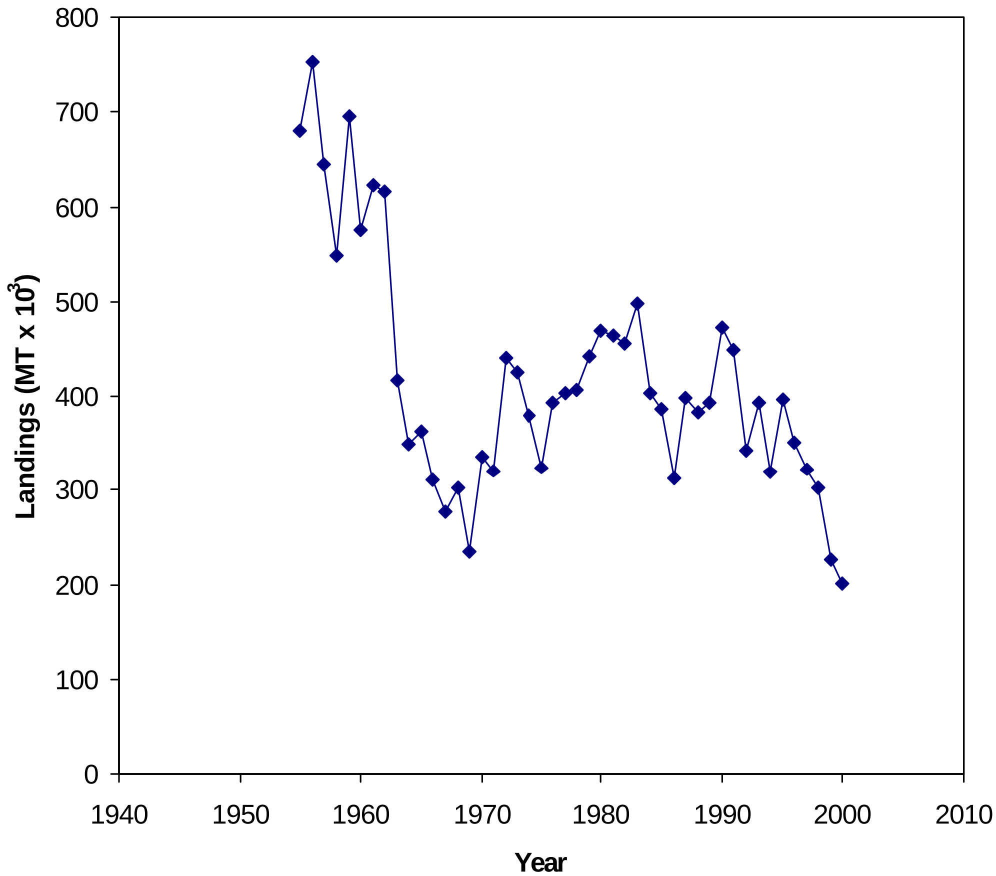


Fig 8. Time series of commercial removals for principal species in commercial catches.

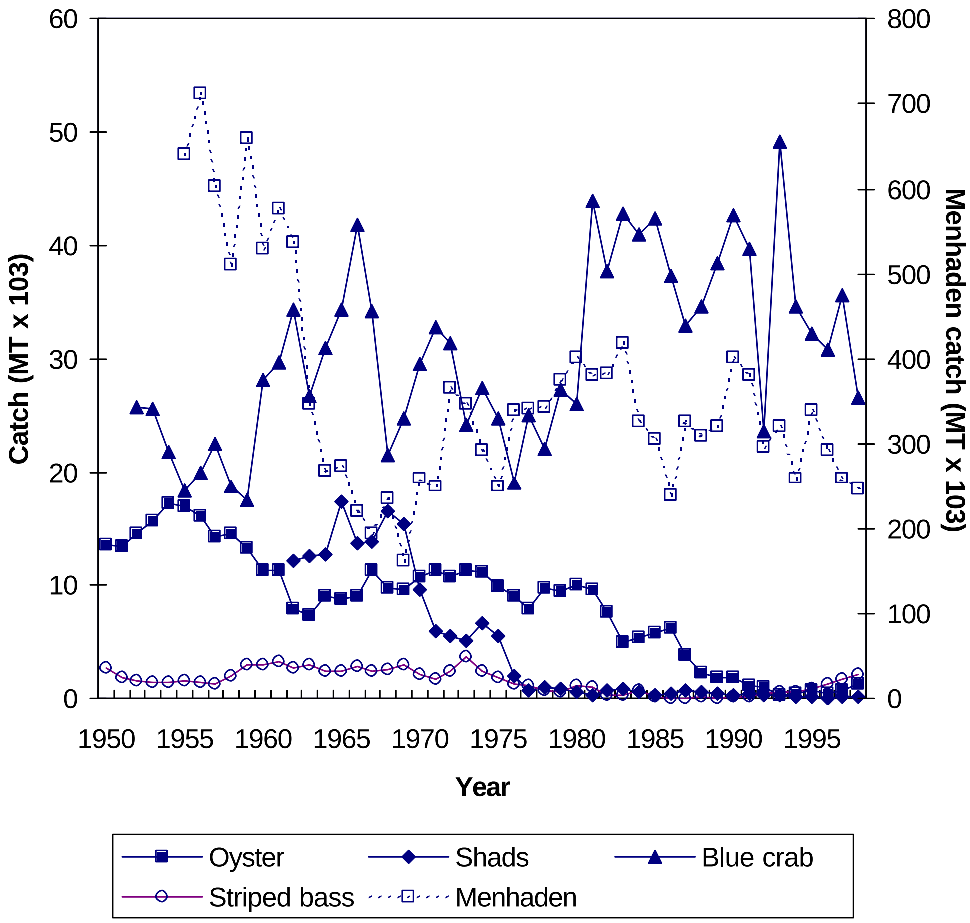
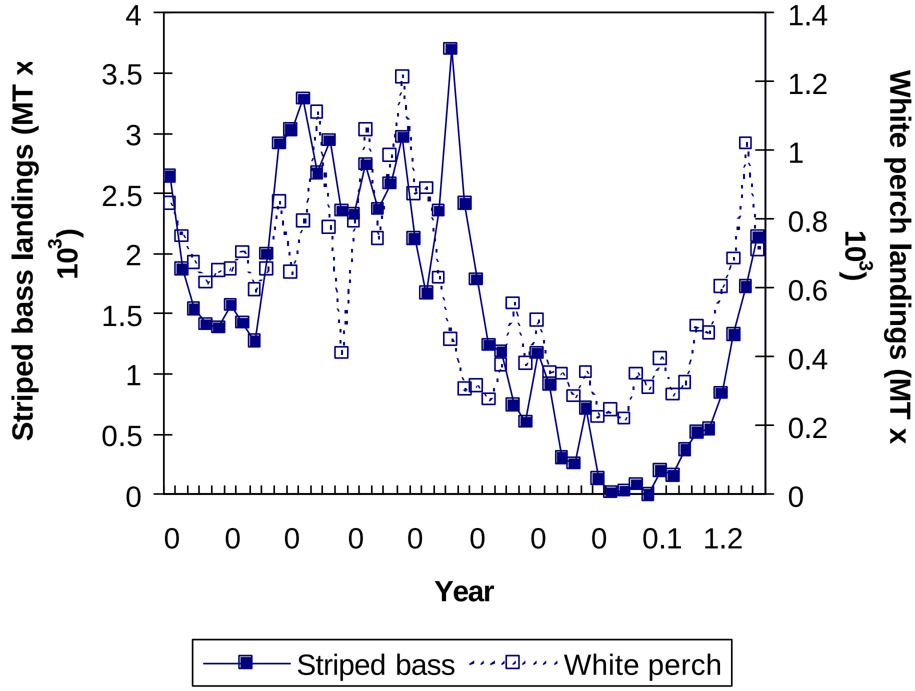


Fig 9. Time series of commercial removals for species pairs that show coherent variation either A) in phase, or B out of phase.



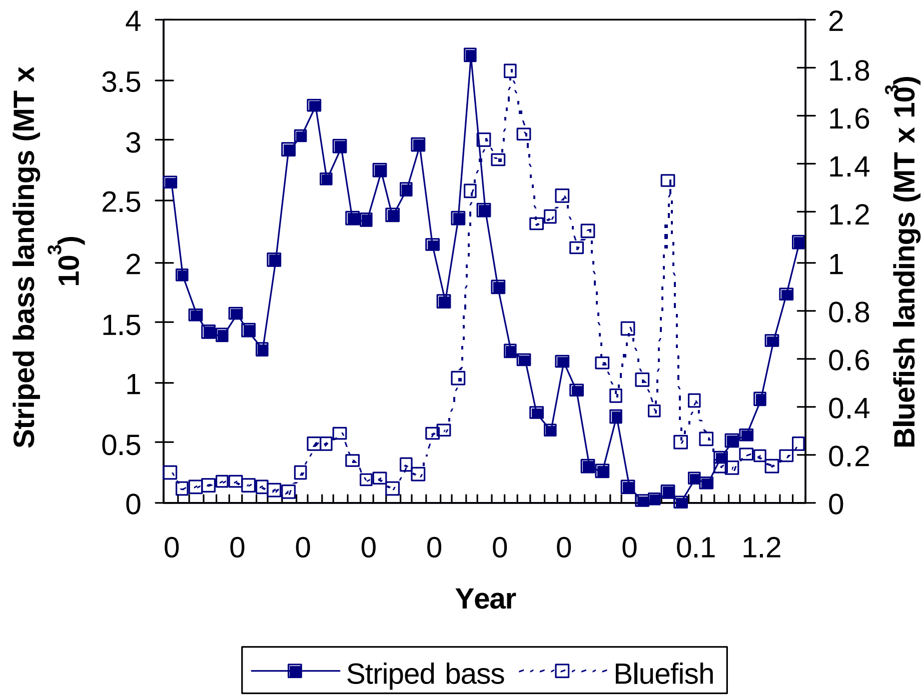


Fig 10. Time series of commercial removals by life history mode.

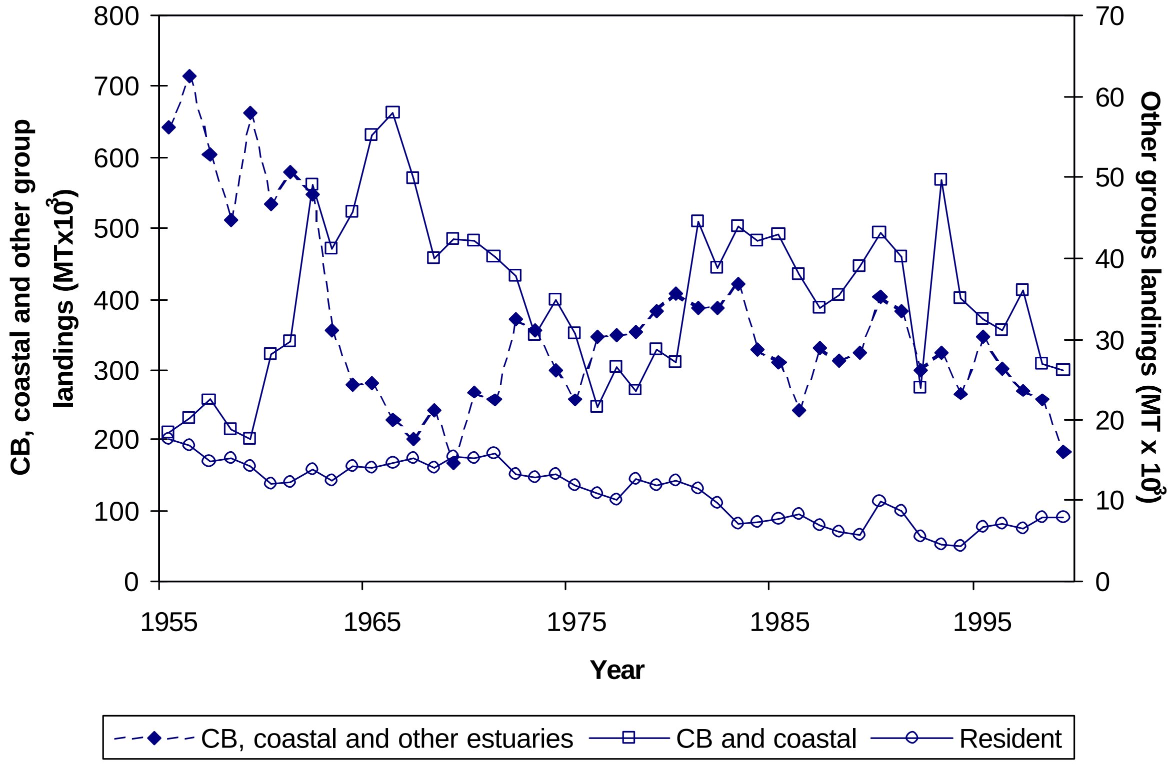


Fig 11. Time series of commercial removals by trophic category.

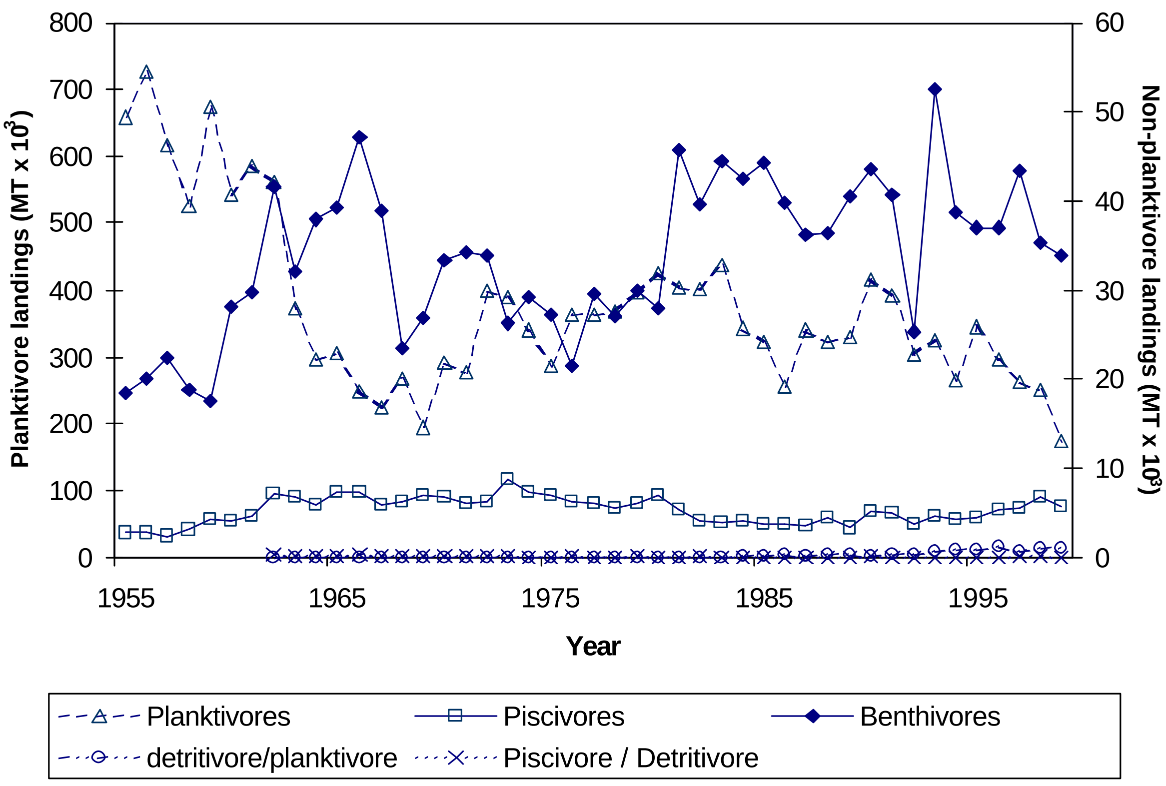


Figure 12. Total recreational harvest from Chesapeake Bay based on 11 species.

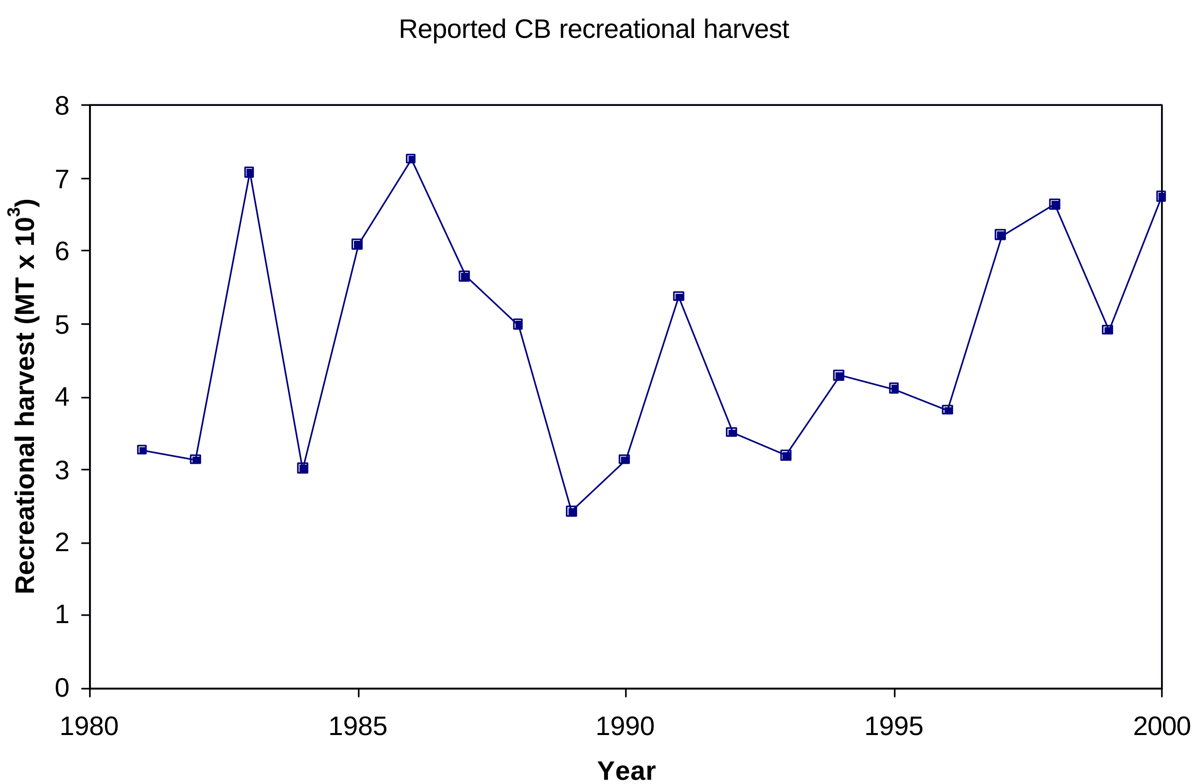


Figure 13. Total recreational harvest from Chesapeake Bay by species.