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Introduction

The Resource Evaluation and Assessment Division of the Northeast Fisheries Science Center (NEFSC), National Marine Fisheries Service (NMFS), with headquarters in Woods Hole, Massachusetts, regularly updates assessments of finfish and shellfish resources off the northeastern coast of the United States and presents information as needed to administrators, managers, the fishing industry, other stakeholders and constituency groups and the general public. Some of these assessments are prepared exclusively by NEFSC scientists; many others are prepared jointly with researchers at other federal and state agencies and academic institutions. This website summarizes the status of selected finfish and shellfish resources off the northeastern coast of the United States from Cape Hatteras to Nova Scotia.

This webpage includes review chapters on aggregate resource and landings trends, and stock status information for 62 stocks of marine finfish and shellfish from the Gulf of Maine to Cape Hatteras. The **Aggregate Resource and Landings Trends** section provides an overview of trends in abundance for major finfish assemblages on the northeast shelf, together with an overview of resource status. In most cases, this information is based on the most recent peer-reviewed assessment. In some cases, however, assessments have been infrequent, and the information included herein has been brought up to date without a formal review.

The species and stocks described herein can be logically grouped into 7 categories: principal groundfish, flounders, other groundfish, principal pelagics, other finfish, invertebrates, and anadromous fish. The region occupied by these stocks (including areas in Canadian waters occupied by resources exploited by both the U.S. and Canada) is shown in Figure 1. Such “transboundary stocks” include stocks such as Georges Bank cod, which are found on both sides of the international boundary line on eastern Georges Bank, and highly migratory stocks such as Atlantic mackerel which move seasonally between U.S. and Canadian waters. There are several other species of commercial and recreational importance that are not included in this report, such as bluefin and yellowfin tuna, swordfish, sand lance, sea urchin, menhaden, pelagic sharks, and inshore shellfish (including softshell and hard clams, oysters, and blue mussels). Some of these are migratory species that are present off the northeastern U.S. only seasonally, while others are resident primarily or exclusively within state waters and are routinely assessed and managed by state agencies.

Types of Assessments

Several different types of assessments may be performed depending on the nature of the fishery and the type and amount of data available. The simplest involve use of commercial landings and fishing effort data and/or research vessel survey data to generate indices of abundance. As research vessel surveys are performed using small mesh gear to sample juvenile fish and invertebrates, survey data are also used to develop indices of incoming recruitment. A second approach is to use commercial landings and effort data and/or information on population size and productivity to determine relationships between effort and yield; this is referred to as a surplus-production or surplus-yield model. Results from this model may be displayed as yield vs. biomass (Figure 2a) or fishing mortality vs. biomass (Figure 2b). Yield and spawning stock biomass-per-recruit curves may also be developed based on biological parameters (growth and natural mortality rates, maturation, etc.) generated from biological sampling or other sources of information (Figure 3).

The most complex (and useful) assessments can be performed when size and age composition of the catch and the population can be determined reliably through sampling of commercial and recreational catches at sea and at dockside and research vessel survey catches at sea. This allows development of more detailed analytic (size or age structured) assessments which provide information on stock size, recruitment and fishing mortality and exploitation patterns over time. These analyses are performed using virtual population analysis or statistical catch at age models . Such assessments may incorporate relationships between spawning stock size and recruitment (stock-recruitment models) which provide a basis for benchmark advice on management options. These models may account for changes in environmental conditions.

The type of assessment performed is usually driven by management needs. For moderately exploited fisheries where management is less intensive, surplus-production or index-based methods may be adequate. For intensively fished stocks, analytic assessments are generally required; and thus improvement of "fishery-dependent" and "fishery-independent" data collection programs and databases continues to be a high priority of the NEFSC and NMFS. Also, much remains to be learned about the biology of many species, and current biological information often requires updating since biological parameters may vary with exploitation and environmental changes. These needs will increase as research and management requirements continue to intensify.

For the purposes of this report, assessments are grouped in order of increasing complexity as follows:

Index: assessment involves development of an index of stock size from research vessel survey data (mean catch per tow) or from fishery catch-per-unit-of-effort (CPUE) data. This type of assessment may also involve a model framework.

Surplus production: assessment models the relationships between yield and fishing effort. Models are based on simple biological rules of increase and decrease and allow useful analyses with relatively little data, but cannot be readily adapted to account for detailed biological or fishery-related information.

Yield per recruit: assessment provides evaluations of yield as a function of fishing mortality and age at entry to the fishery, incorporating information on biological parameters (growth and natural mortality rates). Spawning stock biomass per recruit calculations are analogous in that they use such information along with maturation data to model trends in spawning biomass.

Age/size structured: assessment includes analysis of the observed size or age composition of the catch (*e.g.*, virtual population analysis, statistical catch at age models, modified DeLury analysis) and biological information (size and weight at age, maturation rates) to provide estimates of fishing mortality and total and spawning stock size (numbers and weight) over time.

Resulting estimates can be combined with estimates of incoming recruitment from research vessel surveys or other sources to make predictions of catch and stock size in upcoming years in relation to fishing mortality. They also provide data for a wide variety of more sophisticated analyses e.g., recruitment in relation to spawning stock size or multispecies modeling.

Increasing the level of complexity of an assessment requires a substantial additional commitment of resources to develop and maintain it at its more complex level. Conversely, the level and information content of an assessment can decrease relatively quickly if sufficient resources are not allocated to it.

The assessments on this webpage consider each species as a separate entity, with no consideration of species interactions. However, there are significant biological (predator/prey) as well as technological (bycatch) interactions for northeastern U.S. fishery resources, and a large part of the Center's research program is dedicated to modeling the effects of these interactions. The results of these studies are not presented here. The significance of the mixed-species nature of the northeast trawl fisheries is illustrated under **Aggregate Resource and Landings Trends**, where aggregate research trawl survey and commercial fishery data are presented illustrating major trends in abundance and catches. The approaches used, however, do not address species interactions and other resource complexities.

Management

Fisheries occurring primarily in the Exclusive Economic Zone (EEZ) off the Northeastern U.S. are managed under Fishery Management Plans (FMPs) developed by the New England and Mid-Atlantic Fishery Management Councils. Fisheries occurring primarily in state waters are managed by the individual states or under Interstate Agreements under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC). The management plans currently in place are shown in Table 1.

The current era of stock assessment and management began in 1976 with the establishment of the Fishery Conservation and Management Act or FCMA, now termed the Magnuson-Stevens Fishery Conservation and Management Act or MSFCMA. The Act sought to eliminate perceived overfishing in the EEZ by establishing eight regional fishery management councils (FMCs), which were charged with developing fishery management plans (FMPs) to achieve optimum yield (OY). The FCMA contained National Standards that provided guidance for the preparation of FMPs to achieve OY, defined as maximum sustainable yield, or MSY, as modified by relevant biological, social or economic factors. Thus it was permissible to harvest at or above the MSY level under certain conditions. While effective in removing effort by foreign nationals from the EEZ, the FCMA did not provide the stringent controls on domestic effort that were necessary for preventing overfishing and rebuilding overexploited stocks; and, during the 1980s, many resources were severely impacted.

In subsequent years additional legislation was formulated to increase the effectiveness of the FCMA. In 1989, NMFS published the "602 Guidelines" (50 CFR Part 602, Guidelines for the Preparation of Fishery Management Plans Under the FCMA), which provided a formal definition of overfishing and required that all FMPs be amended to include measurable definitions of overfishing for each stock or stock complex covered. Most of the resulting definitions were based on a limit fishing mortality rate designed to prevent recruitment overfishing, by maintaining some acceptable minimum spawning biomass per recruit level, e.g. $F_{20\%}$ or $F_{30\%}$ to achieve 20% or 30% of the unfished level. Further, the 602 guidelines required rebuilding plans for overfished stocks.

In 1996, the Sustainable Fisheries Act or SFA (PL 104-297) was passed and integrated into the Magnuson Act, which was subsequently renamed the MSFCMA. The SFA contained significant changes, notably a redefinition of OY to be no greater than MSY. Furthermore, FMCs were required to end overfishing and rebuild overfished stocks to biomass levels corresponding to MSY in 10 years or less, if the biology of the species allowed, or the time it would take for the stock to rebuild in the absence of any fishing mortality, plus one mean generation time, in the case of species that could not be rebuilt in 10 years or less. Final National Standard Guidelines published in 1998 require that FMPs include "status determination criteria" for evaluation of stock conditions relative to existing fishing mortality rates (overfishing occurring/not occurring) and existing biomass levels (overfished/not overfished). Overfishing is said to be occurring if fishing mortality exceeds the Maximum Fishing Mortality Threshold (MFMT, or $F_{THRESHOLD}$) which will normally be equivalent to F_{MSY}. A stock is considered to be overfished if biomass falls below the Minimum Stock Size Threshold (MSST, or $B_{THRESHOLD}$); usually ½ the stock biomass level that can produce MSY (B_{MSY}). NMFS is required to prepare a report to Congress each year summarizing the status of every stock within each FMC's geographical area of authority with respect to the above status determination criteria.

To comply with the National Standard Guidelines, rebuilding plans have been devised for many stocks, which specify how F should vary over time to allow the stock to reach Bmsy within the required time frame (see Figure 4 for an example). Here, levels of fishing mortality may be applied to achieve the desired biomass level e.g. $F_{REBUILD}$, typically a level of F that can be expected to achieve stock rebuilding within a set time frame. For rebuilt stocks, the threshold and target levels of F may be constant at B_{MSY} or higher, but as stock biomass declines below B_{MSY}, $F_{THRESHOLD}$ and F_{TARGET} may decline as well. If stock biomass declines to $B_{THRESHOLD}$ or below, $F_{THRESHOLD}$ could decrease to zero or the lowest level of F that is practicable. The form of the relationship is determined by biomass and recruitment projections that incorporate available data on resource productivity. Values for F at stock biomass values below B_{MSY} are projected to result in stock rebuilding to B_{MSY} within the required time frame. Note that $F_{THRESHOLD}$ is a limit reference point indicating the point at which the stock is overfished; thus, harvests should be constrained substantially and the probability for exceeding this value should be low. F_{TARGET} is set below $F_{THRESHOLD}$ to ensure that fishing mortality exceeds the threshold only rarely. In a rebuilding situation, F_{TARGET} might not be increased as stock biomass increases, until B_{MSY} is achieved.

As an illustration, Figure 5 shows the relationship between fishing mortality and biomass, relative to status determination criteria. The vertical lines representing ½ B_{MSY} and B_{MSY} and the horizontal line representing F_{MSY} form a grid indicating resource status. If the status determination criteria for a stock were ½ B_{MSY} for the MSST and F_{MSY} for the MFMT, the stock in Sector A, with biomass below ½ B_{MSY} and F above F_{MSY} would be classified as "overfished" (B is below $B_{THRESHOLD}$), and "overfishing is occurring" (F is above $F_{THRESHOLD}$).

In this case the FMC would be required to develop a rebuilding plan and an F reduction plan within one year. A stock falling in Sector B (biomass is below ½ B_{MSY} and F is below F_{MSY}) would again be classified as “overfished” although here “overfishing is not occurring” (F is below $F_{THRESHOLD}$). In this case only a rebuilding plan would be mandated. A stock falling in Sector C, between ½ B_{MSY} and B_{MSY} and above F_{MSY}, is not “overfished” (B is above $B_{THRESHOLD}$), although “overfishing is occurring” (F is above $F_{THRESHOLD}$), requiring an F reduction. Finally, for a stock for which B is between ½ B_{MSY} and B_{MSY}, and F is below F_{MSY} (Sector D) no action is required; however, since stocks are intended to be managed to produce MSY, the FMCs must pursue management policies to rebuild the stocks to and maintain them at B_{MSY} in such cases.

Pathways of Assessment Advice

Stock assessments and related analyses and documentation are sometimes provided directly to the Councils through Scientific and Statistical Committee meetings or to ASMFC via section meetings. Increasingly, however, managers are depending upon the Northeast Regional Stock Assessment Workshop (SAW) process for assessment advice.

The SAW originated in 1985 as a vehicle for in-house or local peer review of stock assessments and related research. As the condition of fishery resources in the Northeast deteriorated and pressure for assessment and management advice intensified, the SAW evolved into an intensive biannual review process involving four components: a Steering Committee, to oversee the process and determine priorities; working groups, responsible for completion of stock assessments and working papers; a Stock Assessment Review Committee (SARC) that reviews assessments and prepares management advice; and a Public Review Workshop that presents SARC reports and advice at meetings of the New England and Mid-Atlantic Fishery Management Councils. SARC membership was structured to include experts from the NEFSC and other NMFS Centers, the Councils and ASMFC, state agencies and academic institutions, and Canada; and all SAW-related meetings and workshops are open to participation by industry representatives and other interested parties. Since 2004, the SARC has consisted of a small panel of independent experts who convene to review the scientific merit of the assessment analyses and determine whether the assessments are sufficiently rigorous to form the basis of management advice. The SAW has been very effective in generating high quality assessment advice while enhancing the credibility of this advice through intensive peer review and participation by fisheries scientists, industry and the general public.

Since 2002, assessments of the 19-20 large mesh groundfish stocks managed by the New England Fishery Management Council under the Northeast Multi-Species Fishery Management Plan have been assessed on a three year cycle at Groundfish Assessment Review Meetings (GARM).

One additional pathway has recently become available, the Transboundary Resource Assessment Committee (TRAC) process for completion and peer-review of assessments for transboundary resources shared by Canada and the United States. The two countries have cooperated closely for many years in collecting and sharing data, preparation of joint assessments and peer review activities; and in recent years it has become obvious that a formal cooperative arrangement would promote efficiency and consistency in reporting. As a result, a unified process was started in 1998. This consists of both periodic assessment benchmark meetings and annual assessment update meetings. The benchmarks take place off the management cycle and perform in-depth model formulation and model comparison reviews. The annual updates apply the benchmark standards in the updated assessments and forward consensus-based reports for use in resource management by both countries. To date, the TRAC process has been used only for Georges Bank stocks of cod, haddock and yellowtail, as well as the Georges Bank/Gulf of Maine Atlantic herring complex and it provides a logical option for other transboundary resources.

Definitions of Technical Terms

Assessment terms used throughout this document may not be familiar to all. A brief explanation of some of these terms follows, organized alphabetically.

Assessment level: Categories of the level of complexity of each assessment included in this document are as given above (**Index, Surplus production, Yield per recruit, and Age/size structured**). The latter may include projections of future catch and stock sizes or modeling of relationships between recruitment and spawning stock size.

B_{MSY}: The long-term average stock biomass level required to achieve Maximum Sustainable Yield or MSY, when the stock is fished at F_{MSY}. Biomass is usually measured in terms of metric tons (mt).

$B_{THRESHOLD}$ (Minimum stock size threshold or MSST): One of two Status Determination Criteria specified in the national standard guidelines as the greater of (a) ½ B_{MSY}, or (b) the minimum stock size at which rebuilding to B_{MSY} will occur within 10 years when fishing at the Maximum Fishing Mortality Threshold or MFMT. At stock sizes below $B_{THRESHOLD}$, the stock is considered to be overfished.

Biological reference points: Specific values for variables that describe the state of a fishery, used to evaluate its status. These may include “target” reference points, corresponding to a desired goal or level and “limit” reference points, or “thresholds” carrying an unacceptably high risk to the stock if exceeded. Examples are $F_{0.1}$, F_{MSY}, $F_{THRESHOLD}$, and F_{max} .

Biomass-weighted F: An estimate of fishing mortality in which F for each age group in the stock, as determined from virtual population analysis or VPA, is weighted by corresponding stock biomass-at-age values. This calculation is needed to make F from age structured assessments comparable to F_{MSY} estimates obtained from surplus-production (e.g. ASPIC) modeling of all components in the stock.

Catch per unit effort (CPUE): A measure of relative success of fishing operations, often used as a proxy for relative abundance under the assumption of a linear relation to stock size. To be valid, should be standardized to account for differences in fishing power or temporal/spatial changes in catchability.

Control rule (MSY Control Rule): A protocol for specifying harvest rates in relation to stock status and limit and target reference points. Technically, a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY.

Exploitation pattern: The distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, areal and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear, for example, increasing mesh or hook size, or by changing the ratio of harvest by gears exploiting the fish (e.g., gill net, trawl, hook and line, etc.).

Exploitation rate: The proportion of a population at the beginning of a given time period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate (or annual fishing mortality rate) would be 0.72. Note that this rate cannot exceed unity; obviously, more fish cannot die than were originally present.

Fishing mortality rate (F): That part of the total mortality rate applying to a fish population that is caused by fishing. Fishing mortality is usually expressed as an instantaneous rate, as discussed under **Mortality rates**, and can range to values exceeding unity, such as 2.0 or higher.

F_{max}: The fishing mortality rate that results in the maximum level of yield-per-recruit. This is the point that defines growth overfishing.

F_{med}: The fishing mortality rate at which recruitment balances removals over time, as estimated from stock-recruitment data.

F_{MSY}: The fishing mortality rate that produces MSY by taking a constant fraction of a stock that is fluctuating around B_{MSY}.

$F_{0.1}$: The fishing mortality rate at which the increase in yield per recruit in weight for an increase in a unit of effort is 10 percent of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the $F_{0.1}$ rate is one-tenth the slope of the curve at its origin).

$F_{20\%}$: The fishing mortality rate at which spawning per recruit (usually using spawning biomass per recruit as a proxy) is reduced to 20% of the unfished level. Other levels may be used depending on biological characteristics of the target species and/or management objectives.

$F_{REBUILD}$: The fishing mortality rate(s) that, when applied over a specified time frame, will result in stock biomass increasing to B_{MSY} with some specified probability level).

F_{TARGET}: The fishing mortality rate which (with some specified probability level) will prevent $F_{THRESHOLD}$ from being exceeded.

$F_{THRESHOLD}$ (Maximum fishing mortality threshold or MFMT): One of two Status Determination Criteria specified in the national standard guidelines as the fishing mortality rate associated with the MSY Control Rule. Usually, $F_{THRESHOLD}$ is F_{MSY} if stock biomass is moderate to high, and a lower value if it is low. Exceeding $F_{THRESHOLD}$ for one year or more constitutes overfishing.

Fully-recruited F: An estimate of fishing mortality for all age groups fully vulnerable to fishing. It may or may not be weighted by population size in number.

Growth overfishing: The rate of fishing, as indicated by a yield-per-recruit curve, greater than that at which the loss in weight from total mortality equals the gain in weight due to growth. This point is defined as F_{max}.

Maturation: Reported in this document wherever possible as median length or age at maturity (L_{50} or A_{50}) as determined from length and age-specific maturation ogives.

Maximum sustainable yield (MSY): The largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. In order to achieve the maximum average yield over the long term it will usually be necessary to vary annual yields in response to natural fluctuations in stock size (e.g. by applying a constant fishing mortality rate of F_{MSY}).

Maximum spawning potential reference points: Reference points based on some fraction of maximum spawning potential (MSP) as determined from spawning stock biomass per recruit models, used to define overfishing. MSP is the spawning stock biomass per recruit in the absence of fishing; it is then reduced to a percentage of the maximum as F increases. If the %MSP level is reduced below the overfishing definition level, then the stock is considered to be overfished. This level is typically determined by stock-recruitment modeling, to determine the fishing mortality rate beyond which the stock will be unable to replace itself.

Mean biomass: The product of mean abundance (numbers) and the average weight of individual fish. Mean abundance is calculated from abundance at the beginning of the year and the annual mortality rate, while average weights are derived from population size and weight at age data. Mean abundance and biomass are usually calculated for each age group separately and then summed to estimate the mean biomass of the population.

Mortality rates: The rates at which fish die from fishing and/or natural causes. Mortality rates can be described in several ways.

One conceptually simple approach is to express mortality on an annual basis, *i.e.*, A, the annual mortality rate, expressed as a proportion (5% or 0.05 per year). This is the fraction of the population alive at the beginning of the year which dies during the year. The survivors may be represented by (1-A) = S, the annual survival rate.

In exploited populations, however, it is important to account for both fishing and natural mortality. This can pose complex problems, because population changes tend to be exponential; and different components tend to be multiplicative (that is, in any given period of time, individuals that die from natural causes would otherwise be killed by fishing and vice versa).

For these reasons, biologists tend to work with instantaneous rates, in which time intervals are sufficiently short so as to allow separation of the primary components as instantaneous fishing mortality (F) and instantaneous natural mortality (M). Together the two are equivalent to instantaneous total mortality (Z), i.e. $Z = F+M$.

The necessary mathematics are based on a logarithmic scale which relates well to biological processes (since they tend to be exponential); and effects which are multiplicative in nature become additive on a logarithmic scale.

The concept of instantaneous rates can be illustrated by a simple example. Imagine a year of a fish's life to be divided into a large number (n) of equal time intervals, and Z/n is the number dying within that interval. If $n = 1{,}000$ and $Z = 1.0$, then during the first time interval 1/1000 = 0.1% of the population dies. For a population of 1,000,000 fish, 1000 would die, leaving 999,000 survivors. In the next time interval 0.1% of 999,000 fish, or 999 fish die, leaving 998,001 survivors, and so on. Repeated 1,000 times, we would have:

$$1{,}000{,}000\ (1-0.0010)^{1000} = 367{,}695 \text{ survivors}$$

Or, we may use the relation:

$$S = e^{-Z} = 0.3679\ (1{,}000{,}000) = 367{,}879 \text{ survivors}$$

where e is the base of natural logarithms (2.71828).

The calculation provides the same approximate result. Note that the annual mortality rate $A = 1-e^{-Z}$, hence, 1-0.3679 or 0.6321 or 63% in our example. Again, A can never exceed unity, although F and Z can considerably exceed unity for heavily exploited stocks.

The utility of instantaneous rates for dealing with different sources of mortality over time can be illustrated as follows. Assume a population at the beginning of a given year consists of 1,000 fish, and that during the year it is subjected to an instantaneous fishing mortality rate of $F = 0.5$, while instantaneous natural mortality $(M) = 0.2$. The instantaneous total mortality rate (Z) is equal to $(F+M) = 0.7$. Removals by fishing are calculated by applying the annual exploitation rate

$$\frac{F}{Z}(1-e^{-Z})$$

$$= \frac{0.5}{0.7}(1-e^{-0.7})$$

$$= 0.3596$$

During the year, 0.3596(1000) = 360 fish are caught, and $S = e^{-0.7} = 0.4966(1000) = 497$ fish survive. The difference from the original number of 1,000 fish (1,000-360-497), or 143 fish, is the number dying from natural causes. The additive property of instantaneous rates allows us to obtain approximately the same result for natural mortality, i.e.,

$$\frac{M}{Z}(1-e^{-Z})$$

$$= \frac{0.2}{0.7}(1-e^{-0.7})$$

$$= 0.1438, \text{ or, } 144 \text{ fish.}$$

In the absence of fishing this number would be A = $(1-e^{-0.2})1000 = 0.1813 \times 1000 = 181$ fish, with 819 fish surviving to the beginning of the following year. If the process is continued for another year, the catch in the exploited population would be 179 fish, 71 fish would die from natural causes, and 247 fish would survive, while in the unfished population 149 fish would die, leaving 670 survivors. Continued for 10 years the exploited population would be essentially eliminated (1 surviving fish) whereas 14% of the unfished population (135 fish) would survive.

This example uses an annual exploitation rate (36%) for the exploited population that is somewhat high but was sustained historically by some Northeast stocks. For some heavily fished stocks exploitation rates have in some years exceeded 50-60 percent. The number of fish alive after 5 years from a year class of 1,000,000 fish exploited at F=1.0 and M=0.2 (58% exploitation rate) would be:

$$1{,}000{,}000\,[e^{-1.2 \times 5}] = 2{,}478 \text{ fish!}$$

Natural mortality rate (M): That part of total mortality applying to a fish population that is caused by factors other than fishing. It is common practice to consider all sources together since they usually account for much less than fishing mortality. It is usually expressed as an instantaneous rate as discussed above.

Nominal catch: The sum of the catches that are landed (expressed as live weight or equivalent). Nominal catches do not include discards.

Optimum yield (OY): The amount of fish that will provide the greatest overall benefit to the nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. Under the Magnuson-Stevens Fishery Conservation and Management Act or MFCMA, OY cannot exceed MSY.

Overfishing/overfished: According to the National Standard Guidelines, “overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis.” Overfishing is occurring if $F_{THRESHOLD}$ is exceeded for a year or more. An “overfished” stock has been reduced below $B_{THRESHOLD}$ requiring management actions to rebuild to the MSY level within an acceptable time frame.

Overfishing definition: An objective and measurable guideline or guidelines for a given stock defining a fishing mortality rate that constitutes overfishing, and/or the point at which the stock reaches an overfished condition; formerly required for each fishery management plan or FMP under revised guidelines (50 CFR Part 602) to National Standards 1 and 2 of the Magnuson Fishery Conservation and Management Act or MFCMA. Reauthorization of the Act (Magnuson-Stevens Fishery Conservation and Management Act or MSFCMA) under the Sustainable Fisheries Act or SFA resulted in a requirement for status determination criteria to describe both overfishing and the condition of being overfished.

Quota: A portion of a total allowable catch (TAC) allocated to an operating unit, such as a vessel size class or a country.

Recruitment: The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. The number of fish that grow to become vulnerable to the fishing gear in a given year would be the recruitment to the fishable population in that year. The term is also used in referring to the number of fish reaching a certain age or size.

Recruitment overfishing: The rate of fishing above which recruitment to the exploitable stock becomes significantly reduced. This is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch, and generally very low recruitment year after year.

Spawning stock biomass (SSB): The total weight of all sexually mature fish in the population. This quantity depends on year class abundance, the exploitation pattern, the rate of growth, fishing and natural mortality rates, the onset of sexual maturity and environmental conditions.

Spawning stock biomass-per-recruit (SSB/R): The expected lifetime contribution to the spawning stock biomass for a recruit of a specific age (e.g., per age 2 individual). For a given exploitation pattern, rate of growth, and natural mortality, an expected equilibrium value of SSB/R can be calculated for each level of F. A useful reference point is the level of SSB/R that would be realized if there were no fishing. This is a maximum value for SSB/R, and can be compared to levels of SSB/R generated under different rates of fishing. For example, the maximum SSB/R for Georges Bank haddock is approximately 9 kg for a recruit at age 1.

Statistical Catch at Age Model: An approach to estimating population abundance and fishing mortality rates from catch at age data and indices of abundance. These models start at the earliest point of available data and project forward through the time series. Fishing mortality is separated into age and year components. The models change parameters such as recruitment, fishing mortality by year, selectivity at age, and catchability coefficients until the predicted catch and indices most closely match the observed values. In essence, statistical catch at age models create a simulated population using a set of parameters that generates predicted values. The parameters are changed until the predicted values most closely match the observed values. There is a great deal of flexibility in the approach because missing data are easily handled and many types of data can be matched by the simulated population.

Status Determination Criteria: Objective and measurable criteria used to determine if overfishing is occurring or the stock is in an overfished state according to National Standard Guidelines.

TAC: Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Vessel class: Commercial fishing vessels are classified according to their gross registered tons (grt) of displacement. Vessels displacing less than 5 tons were not routinely monitored prior to the new mandatory reporting system implemented in the Northeast in 1994, and were referred to as undertonnage. The current classification scheme is as follows:

Vessel Class	GRT
1	<5
2	5 - 50
3	51 - 150
4	151+

Virtual population analysis (or cohort analysis): An analysis of the catches from a given year class over its life in the fishery. If 10 fish from the 1988 year class were caught each year for 10 successive years from 1990 to 1999 (age 2 to age 11), then 100 fish would have been caught from the 1988 year class during its life in the fishery. Since 10 fish were caught during 1999, then 10 fish must have been alive at the beginning of that year. At the beginning of 1998, there must have been at least 20 fish alive because 10 were caught in 1998 and 10 more were caught in 1999. By working backward year by year, one can be virtually certain that at least 100 fish were alive at the beginning of 1990.

A virtual population analysis goes a step further and calculates the number of fish that must have been alive if some fish also died from causes other than fishing. For example, if in addition to the 10 fish caught per year in the fishery, the instantaneous natural mortality rate was also known, then a virtual population analysis calculates the number that must have been alive each year to produce a catch of 10 fish each year plus those that died from natural causes.

If one knows the fishing mortality rate during the last year for which catch data are available (in this case, 1999), then the exact abundance of the year class can be determined in each and every year. Even when an approximate fishing mortality rate is used in the last year (1999), a precise estimate of the abundance can usually be determined for the stock in years prior to the most recent one or two (*e*.g., for 1990-1996 or 1997 in the example).

Accuracy depends on the rate of population decline and the correctness of the starting value of the fishing mortality rate (in the most recent year). This technique is used extensively in fishery assessments, since the conditions for its use are so common; many fisheries are heavily exploited, the annual catches for a year class can generally be determined, and the natural mortality rate is known within a fairly small range and is low compared with the fishing mortality rate.

Year class (or cohort): Fish in a stock born in the same year. For example, the 2005 year class of cod includes all cod born in 2005, which would be age 1 in 2006. Occasionally, a stock produces a very small or very large year class which can be pivotal in determining stock abundance in later years.

Yield per recruit: The expected lifetime yield for a fish of a specific age (*e.g.*, per age 2 individual). For a given exploitation pattern, rate of growth, and natural mortality, an expected equilibrium value of Y/R can be calculated for each level of F.

For further information

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Table 1. Federal, joint and interstate fishery management plans currently in place or under development for species-stocks mentioned on this website.

Plan	Jurisdiction (Responsibility)	Year Implemented	Last Amended (Number)
1. Northeast Multispecies	Federal (NEFMC)	1986	2004 (13)[1]
2. Atlantic Sea Scallop	Federal (NEFMC)	1982	2004 (10)[1]
3. American Lobster	Interstate (ASMFC) Federal [ACFCMA][2]	1979	Addendum 7(2005) 1997 (3)
4. Atlantic Surfclam and Ocean Quahog	Federal (MAFMC)	1977	1999 (12)[1]
5. Atlantic Mackerel, Squid and Butterfish	Federal (MAFMC)	1983	1999 (8)[1]
6. Summer Flounder, Scup and Black Sea Bass	Federal (MAFMC) Interstate (ASMFC)	1988	2003 (13)[1]
7. Bluefish	Federal (MAFMC) Interstate (ASMFC)	1990	1999 (1)
8. Atlantic Herring	Federal (NEFMC) Interstate (ASMFC)	2000 1994	1999 (1)[1]
9. Northern Shrimp	Interstate (ASMFC)	1986	2004 (1)[1]
10. Striped Bass	Interstate (ASMFC)	1981	2003 (6)[1]
11. Tilefish	Federal (MAFMC)	2001	-
12. Atlantic Salmon	Federal (NEFMC)	1988	1999 (1)
13. Winter Flounder	Interstate (ASMFC)	1992	2005 (1)
14. Spiny Dogfish	Federal (MAFMC/NEFMC)	2000	-
15. Atlantic Sturgeon	Interstate (ASMFC)	1990	1998
16. Shad and River Herring	Interstate (ASMFC)	1985	1998 (1)
17. Monkfish	Federal (NEFMC/MAFMC)	1999	2005 (2)
18. Northeast Skate Complex	Federal (NEFMC)	2003	-
19. Red crab	Federal (NEFMC)	2002	-
20. American Eel	Interstate (ASMFC)	2000	Addendum 1(2006)

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[1] New amendment in progress.

[2] Atlantic Coastal Fisheries Cooperative Management Act, which allows the Federal Government to work in concert with state agencies.

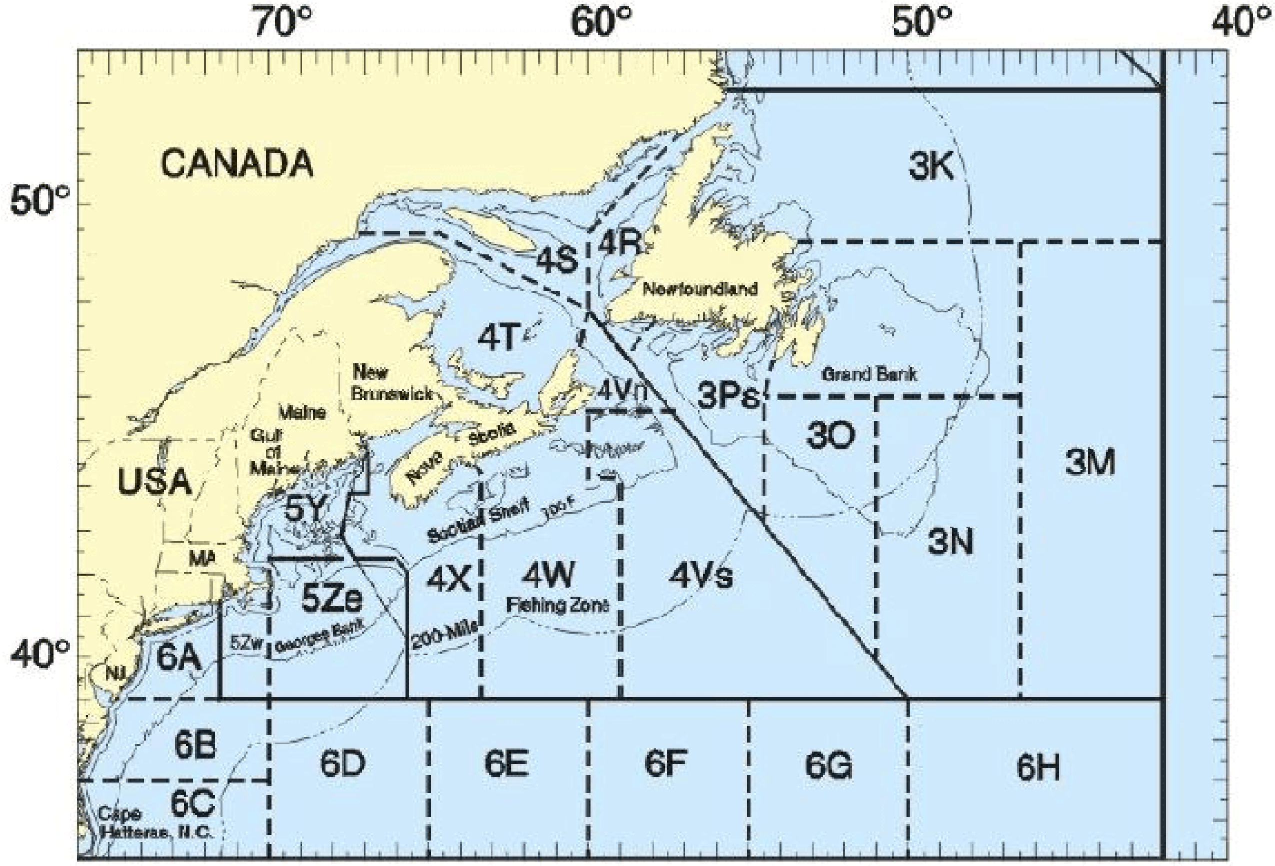


Figure 1. Regions of the Northwest Atlantic delineated by NAFO Divisions.

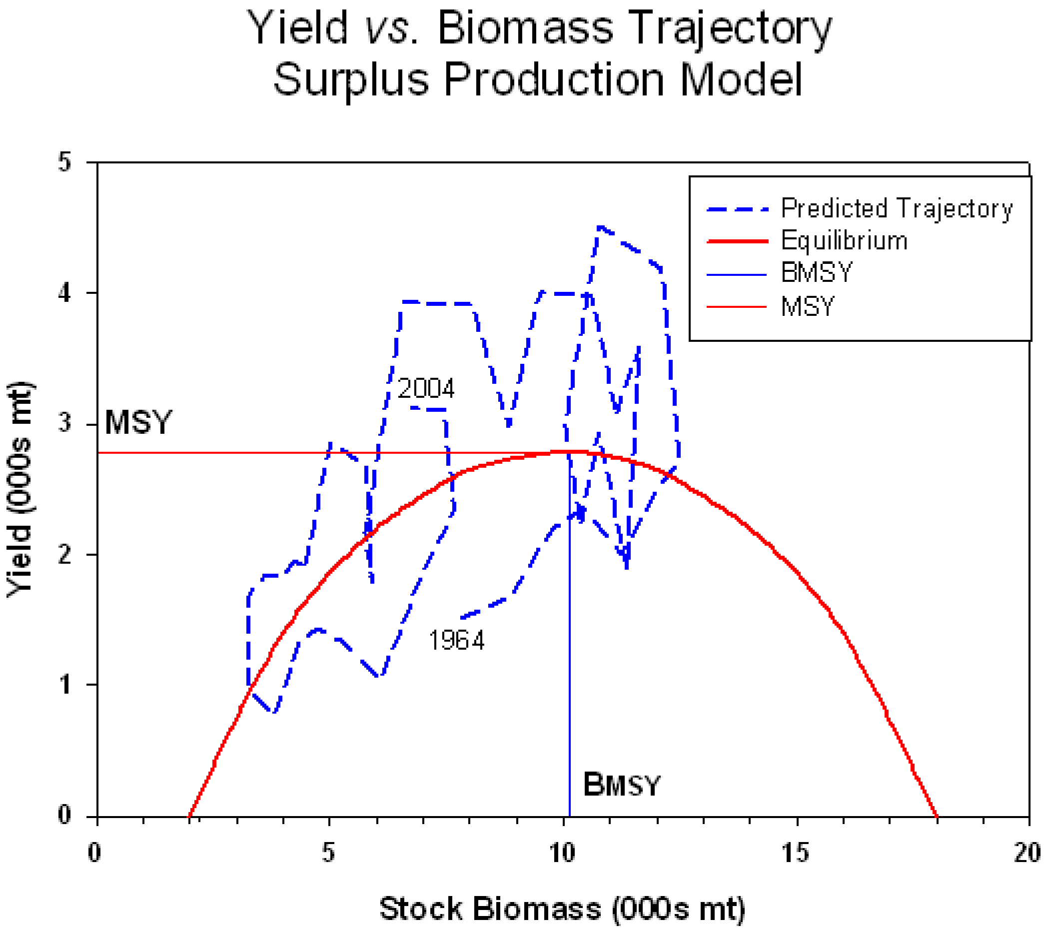


Figure 2a. Equilibrium state and predicted annuual trajectory of yield and biomass from a Surplus Production Model.

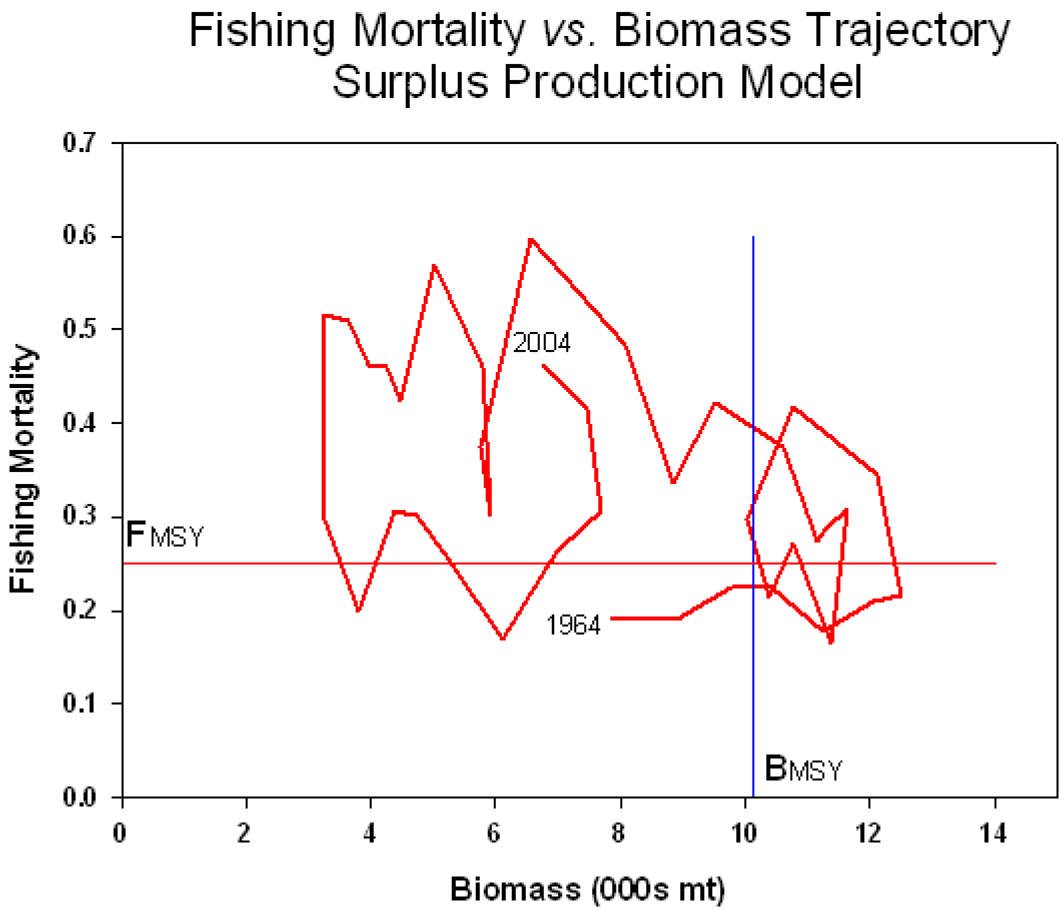


Figure 2b. Fishing Mortality vs. Biomass trajectory from a Surplus Production Model.

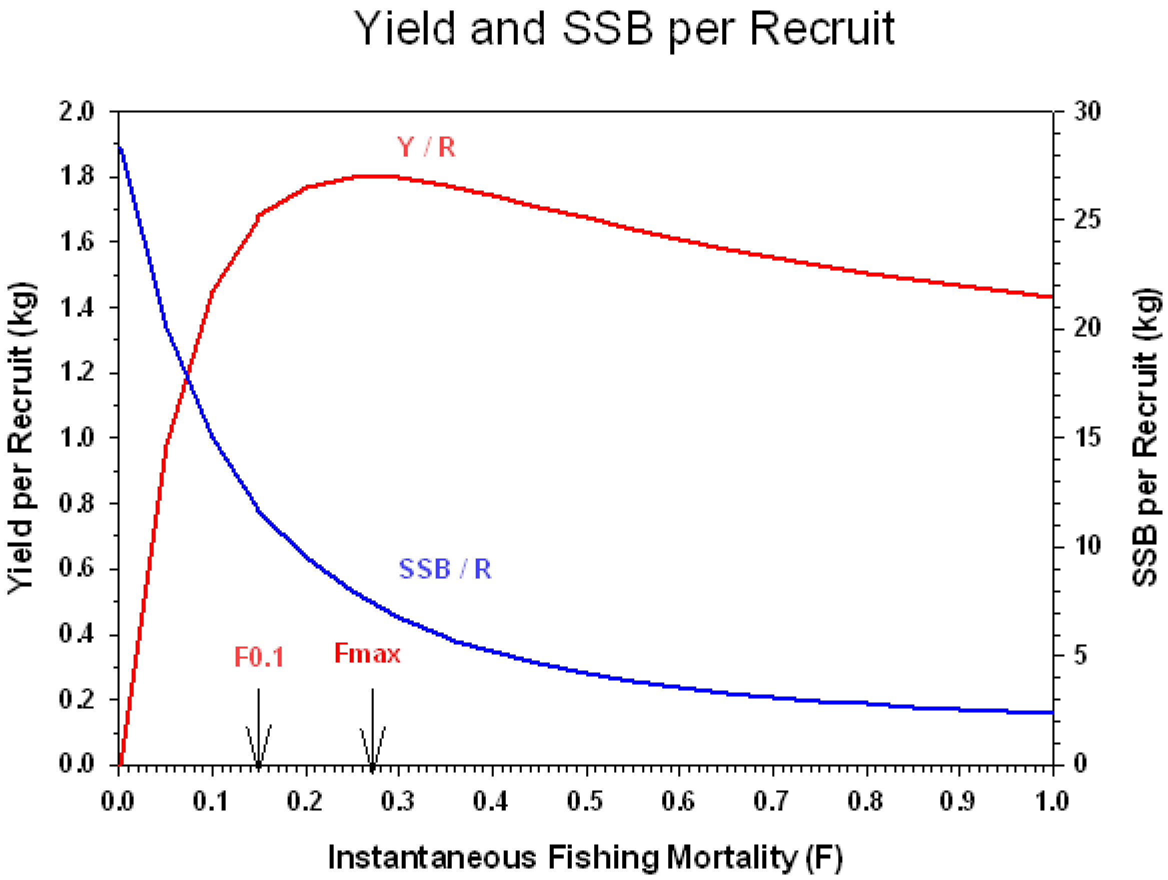


Figure 3. Yield and SSB per recruit model results.

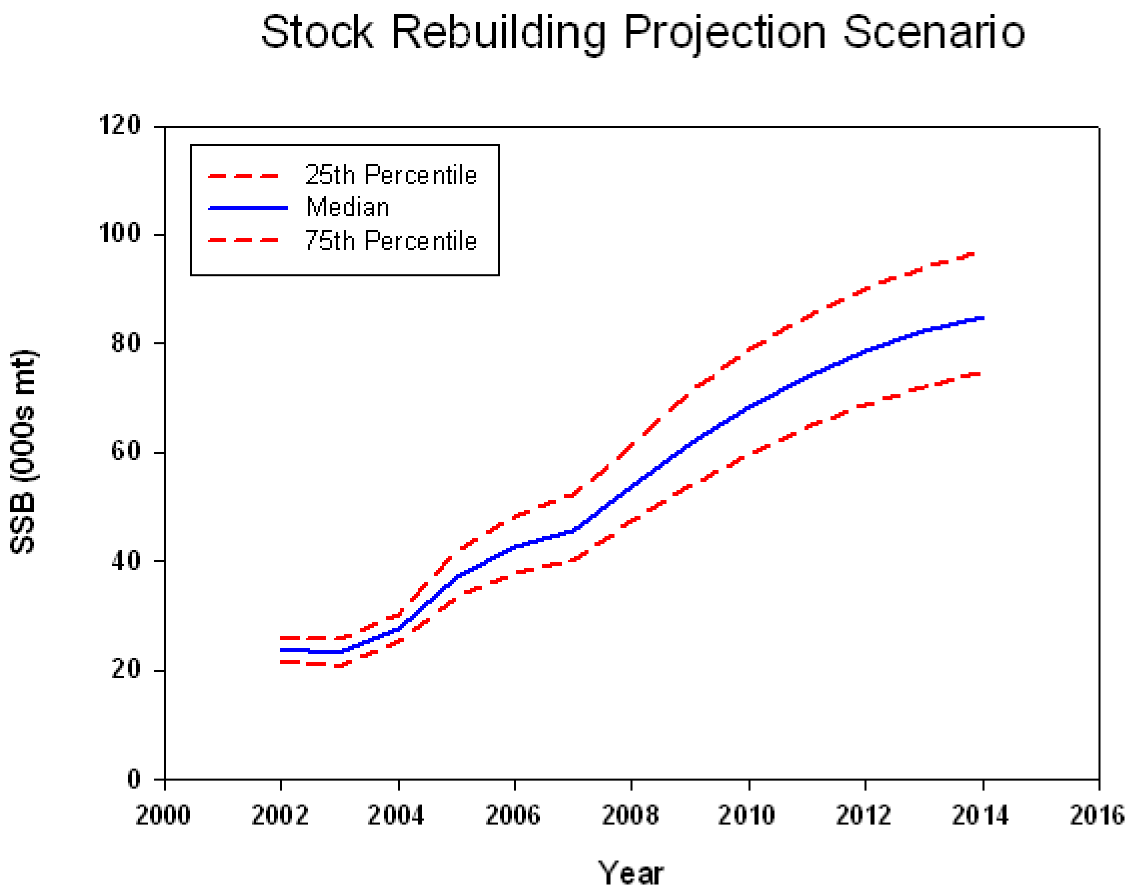
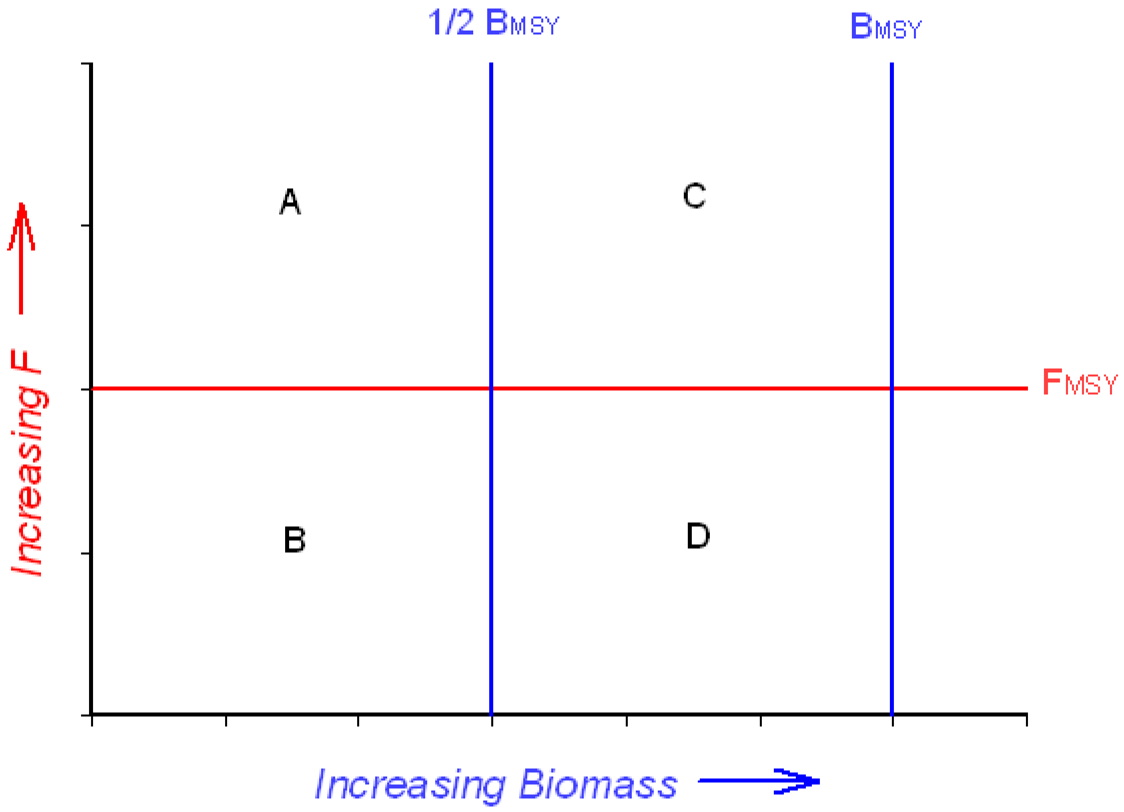


Figure 4. Stock biomass rebuilding projection results under a constant fishing mortality strategy.



A. Overfishing is occurring; stock is overfished
B. Overfishing is not occurring; stock is overfished
C. Overfishing is occurring; stock not overfished
D. Overfishing is not occurring; stock is not overfished

Figure 5. The relationship between fishing mortality and biomass relative to status determination criteria.