Scientific Review of Definitions of Overfishing in U.S. Fishery Management Plans

Prepared for the
National Marine Fisheries Service

by

A. Rosenberg (Convener), P. Mace, G. Thompson, G. Darcy,
W. Clark, J. Collie, W. Gabriel, A. MacCall,
R. Methot, J. Powers, V. Restrepo, T. Wainwright,
L. Botsford, J. Hoenig, K. Stokes

BIBLIOGRAPHIC INFORMATION

Abstract: The 1989 Guidelines for Fishery Management Plans, 50 CFR Part 602, resulted in the inclusion of over 100 definitions of overfishing in Federal fishery management plans. The Guidelines are intended to protect U.S. fishery resources from recruitment overfishing, with resulting losses in productivity. The major general issues discussed by the Review Panel were: (1) defining overfishing in terms of a maximum fishing mortality rate, or a minimum stock abundance, or both; (2) distinguishing between management targets and overfishing thresholds; (3) the role of life history characteristics in defining overfish; (4) the role of uncertainty in developing and using the definitions; and (5) the linkage between the definition of overfishing and management actions.

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EXECUTIVE SUMMARY

The 1989 Guidelines for Fishery Management Plans, 50 CFR Part 602, resulted in the inclusion of over 100 definitions of overfishing in Federal fishery management plans. The Guidelines are intended to protect U.S. fishery resources from recruitment overfishing, with resulting losses in productivity. In March 1993, NMFS convened a panel of scientists from inside and outside the agency to review all of the current definitions of overfishing from a technical standpoint and report on their strengths and weaknesses for conserving fishery resources. The purpose of the review is to guide the preparation of future fishery management plan amendments to improve definitions of overfishing.

The Review Panel report contains introductory material on the 602 Guidelines, general discussion of the scientific basis for defining overfishing, a discussion of important issues in the development of overfishing definitions, and detailed evaluations of 117 definitions currently in use.

As a conceptual framework for defining overfishing, the Review Panel agreed that a stock is recruitment overfished if expected recruitment has fallen below one-half of the expected maximum. Any level of fishing that would result in expected recruitment falling below one-half of the expected maximum constitutes overfishing.

The major general issues discussed by the Review Panel were: (1) defining overfishing in terms of a maximum fishing mortality rate, or a minimum stock abundance, or both; (2) distinguishing between management targets and overfishing thresholds; (3) the role of life history characteristics in defining overfishing; (4) the role of uncertainty in developing and using the definitions; and (5) the linkage between the definition of overfishing and management actions.

The Panel recommended that a maximum fishing mortality rate (or appropriate proxy) should generally be part of a definition of overfishing. About 70% of the current definitions include a maximum fishing mortality rate. Setting a precautionary biomass level below which the maximum fishing mortality rate is reduced will provide additional protection for the stock. Many of the North Pacific and Pacific overfishing definitions include such a precautionary point. In addition, setting a minimum biomass level at a very low stock size that triggers a fishery closure can protect a seed stock for recovery, should the resource become depleted due to fishing or other causes, such as environmental effects.

The Panel also recommended that the overfishing definition should

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be treated as a threshold for the fishery and, if the threshold is exceeded, pre-agreed, strong management action should be taken. About half of the current definitions are used as thresholds. Fishing targets should be separate, and more conservative than the overfishing threshold. The overall management strategy should seek to maintain the fishery at the target level, on average, by fine tuning management actions when the target is exceeded. On the other hand, the strategy should avoid ever exceeding the threshold and take very strong action to rebuild the stock if it is exceeded. About one-third of the current definitions treat the overfishing definition as both a threshold and a target, which is inappropriate in the view of the Panel.

In general, insufficient attention has been paid to life history characteristics of specific stocks in defining overfishing. Life history features such as multiple spawning within a year, hermaphrodism, temporal variability in recruitment, the degree to which a stock can compensate for the mortality due to fishing, and the spatial distribution of the stock can strongly influence the ability of an overfishing threshold to protect the resource. In 10 cases, failure to include consideration of such features has meant that the current definition is unlikely to protect the stock from recruitment overfishing.

Uncertainty also plays an important role in the application of overfishing definitions. Uncertainty in setting the level that should protect the stock, the current status of the resource and long-term trends in the environment mean that scientific advice should ideally include an estimate of the probability that the stock will be overfished as the result of a given management action. Managers should, therefore, set a decision rule that limits the acceptable probability (e.g., 5%) that a given management action results in overfishing and which prescribes management's response in the event that overfishing is found to have occurred. Such a decision rule, together with the need for analysis of uncertainty, should be stated explicitly in the definition.

A definition of overfishing is truly conservative for a stock only if clear, rapid management action is taken when the threshold is crossed. The level chosen for a threshold should depend on how quickly the stock can be expected to recover if the threshold is crossed. An analysis of expected recovery time should be done routinely. Similarly, recovery plans for stocks that are already in an overfished condition should be developed with an explicit timeframe that is in keeping with the life history of the species. Less than half of the current definitions are explicitly linked to management action.

For the detailed reviews of each definition, the Review Panel grouped the 117 definitions into primary and secondary stocks.

Primary stocks were given a more detailed analysis, but this was purely for organizational purposes and was not intended to prejudge the results or imply that some stocks are more important than others. Also, the Panel was only able to review readily available information on the biology of each stock. Only the overfishing definitions were considered, not other aspects of the management plans.

In the view of the Review Panel, an ideal definition of overfishing would be applied as a threshold, rather than a target, at least neutrally conservative in protecting against recruitment overfishing, measurable, linked to management actions, unambiguous, and biologically sensible, with no obvious improvements evident. Four of the primary stocks reviewed (9%) meet these criteria. Many others (39%) nearly meet this ideal, but need some improvements, for example, to remove ambiguity or to enhance the linkage to management actions. For example, 70% of the definitions for the primary stocks are biologically sensible and 64% are at least neutrally conservative. Almost all (95%) of the priority definitions are measurable but 27% have some ambiguity. However, only 45% are used as thresholds separate from management targets in the Fishery Management Plans.

The Review Panel concluded that 20% of the definitions for the primary stocks, and 10% for the secondary stocks, are risky in terms of their ability to protect the resource. In these cases, about half require simple, quantitative modifications in order to make them more conservative. In the rest, the basis of the overfishing definition itself needs to be modified. There were also many cases (16% of the primary stocks and 33% of the secondary ones) in which the definitions could not be evaluated in terms of relative risk. These definitions could be improved by relating them more directly to what is known concerning stock productivity. In a sense, an overfishing definition is risky if there is no clear evidence to the contrary.

In conclusion, the Panel recommends that all of the definitions identified as risky, not measurable, ambiguous or not biologically sensible be reconsidered as soon as possible. For more than half of all the definitions (77% of primary stocks, 82% of secondary stocks) recommendations for improvements have been made and should be considered in future Fishery Management Plan amendments.

A point-by point summary of the recommendations of the Review
Panel for the development and evaluation of overfishing
definitions follows.

o   Overfishing definitions should be measurable, operationally
     unambiguous, based in sound theory, and biologically
     sensible.

o   An overfishing definition should set a limiting threshold
     for management of a stock that is distinct from a fishing
     target. Thresholds should be set at higher fishing
     mortality rates or lower biomass levels than targets.

o   An overfishing definition should, at the least, prevent
     recruitment overfishing, which is defined quantitatively
     herein as any stock size or level of fishing that would
     result in expected recruitment falling below one-half the
     expected maximum recruitment. In most cases, however, the
     Review Panel used this definition as a conceptual guide due
     to insufficient data for quantification.

o   An overfishing definition can be comprehensively expressed
     as a threshold harvest control law which relates target and
     threshold fishing mortality rates to stock biomass or
     abundance.

o   Overfishing definitions and threshold harvest control laws
     should have at least two components in most cases: a maximum
     fishing mortality rate, and a precautionary biomass level
     below which the maximum fishing mortality rate is reduced to
     further protect the stock. Additional protection can be
     afforded by the inclusion of an absolute minimum biomass
     (usually set at a very low level) below which the fishery is
     closed. The primary purpose of an absolute minimum biomass
     level is to provide complete protection to a seed stock to
     allow stock recovery in the event that a stock falls to
     exceedingly low levels in spite of other management actions.

o   An overfishing definition should be at least neutrally
     conservative in protecting against recruitment failure, but
     should not be overly restrictive.

o   Additional information on life history characteristics
     should be incorporated into overfishing definitions where
     needed.

          - Special treatment is required for certain types of
          life history characteristics; e.g. species that exhibit
          sequential hermaphrodism, and batch spawners.

          - Overfishing definitions should be conservative, and
          incorporation of absolute biomass thresholds should be

seriously considered for the following problematic
stocks: those that are already known to have collapsed
under high fishing pressure, those with low
compensation, those that appear to exhibit depensation
in recruitment, and those sustained by occasional large
year-classes.

o   An analysis of uncertainty is needed to evaluate the status
of the stock with respect to overfishing definitions.
Explicit decision rules are required to determine whether
the probability that the stock is overfished is unacceptably
high.

o   The overfishing definition should be explicitly linked to
management actions and rebuilding programs should be pre-
agreed while the stock is healthy to avoid delays in
remedial action should the stock become overfished.

o   The process for updating overfishing definitions when new
information becomes available should be explicit.

INTRODUCTION

In 1989, the National Marine Fisheries Service (NMFS) published Guidelines for fishery management plans, referred to as the 602 Guidelines, in the <u>Federal Register</u>. These Guidelines were developed by a team of scientists and managers from around the country to address two of the national standards set out in the Magnuson Fishery Conservation and Management Act (MFCMA). National standard 1 requires conservation and management measures to prevent overfishing. National standard 2 requires that the best scientific information available be used as a basis for conservation and management measures. The 602 Guidelines are intended to detail what is needed in each fishery management plan (FMP) in order to define overfishing with respect to these national standards.

To date, over 100 definitions of overfishing (OD's) within FMP's have been approved by NMFS as acceptable for meeting the 602 Guidelines. This initial development of OD's for all the stocks managed under the MFCMA took an enormous amount of effort and the NMFS Regional Offices, Science Centers and Fishery Management Councils should be commended for their work. There is undoubtedly room for improvement, however. Many of the definitions are tentative and may require updating as new information becomes available.

NMFS convened a panel of scientists from inside and outside the agency (Appendix 1) to review all the approved definitions, investigate their strengths and shortcomings and standardize, as far as possible, the criteria and basis for future evaluations of OD's. The goal of the review was to develop a <u>scientific</u> consensus on the appropriateness of the definitions and the criteria used for their evaluation. The resulting analysis and report is intended for use in preparation of future FMP's and FMP amendments, when the OD's might be revised, to improve the overall quality of the scientific basis for management.

The Review Panel first met in March of 1993 and the work of collating and evaluating the overfishing definitions has been done over the past year. This report presents the consensus opinion of the Review Panel concerning general issues with respect to the development and evaluation of overfishing definitions and the specific evaluations of each of the 117 definitions considered.

The report consists of four sections. The first section contains this introduction, some background material on the 602 Guidelines, and the administrative and scientific basis for defining overfishing. The second section contains general material on important issues the Review Panel discussed pertaining to the development of overfishing definitions and their use in fishery management. The third section contains a

summary of the stock-by-stock evaluation of the present
overfishing definitions and the general conclusions that can be
drawn from this summary. The fourth section contains the
detailed analysis of each definition.

For each reviewed stock, the Panel considered the FMP section
containing the overfishing definition, the readily available
stock assessment material and, when possible, other published
material on the population dynamics of the stock. It was not
possible to exhaustively research each stock and the provisions
for its management beyond this basic material. Further, the
Panel did not review in detail recovery plans for currently
overfished stocks nor consider ecosystem-level interactions
between stocks in evaluating the efficacy of the overfishing
definitions.

Background: Overfishing and Revised 50 CFR Part 602 Guidelines

On July 24, 1989, NOAA published (54 FR 30826) a final rule that
interprets two of the seven national standards of the MFCMA.
National standard 1 requires that conservation and management
measures prevent overfishing while achieving, on a continuing
basis, optimum yield (OY) from each fishery. National standard 2
requires that conservation and management measures be based on
the best scientific information available. Because the MFCMA
does not provide a definition of overfishing, and in order to
provide some objective measure of whether or not an FMP is in
compliance with national standard 1, the revised Guidelines
standardized the approach to defining overfishing and established
a schedule for implementation of acceptable definitions. In
addition, to satisfy national standard 2, Stock Assessment and
Fishery Evaluation (SAFE) reports are to be prepared, and updated
as necessary, for each fishery, to summarize the best available
biological, economic, social, and ecological information.

Revision of the 602 Guidelines was precipitated by the NOAA
Fishery Management Study in June 1986; that study recommended
that NOAA take responsibility for determining a biologically
"safe" harvest for each managed fishery. The intent was to
prevent recruitment overfishing and to have a "conservation
standard" for each fishery, such that the stocks are not driven
to, or maintained at, the threshold of overfishing. Initially,
NOAA considered establishing a maximum fishing mortality rate
that would maintain spawning stock size, taking into account
variability in spawning stock estimates; this would have been
used as a basis for setting biologically acceptable catch (ABC).
ABC would then have been used as a maximum allowable annual quota
for each fishery. Emphasis was on protecting the long-term
viability of the fishery resources.

Feedback from the Regions and the Councils, however, indicated

that it was not feasible to derive a single, generic definition of overfishing. Instead, Guidelines were developed that allow Council discretion in defining overfishing for each FMP, but within a specified timeframe and with fairly specific criteria for approval. In spring of 1988, a series of Council/NMFS regional workshops were held to discuss the conservation standard and its implementation. A proposed rule was published on December 30, 1988 (53 FR 53031) and a final rule on July 24, 1989.

Each Council must establish a specific, measurable definition of overfishing for each stock or stock complex covered by an FMP. Irreversible damage to a resource's ability to recover in a reasonable period of time is unacceptable; fishing on a stock at a level that severely compromises that stock's future productivity is counter to the goals of the MFCMA. Biologically acceptable catch (ABC) can be used as a step in deriving OY, but is not required. Councils may develop definitions of overfishing appropriate to the individual stocks, so long as the definitions allow the Councils and the Secretary of Commerce (Secretary) to evaluate the condition of the stocks relative to the definition.

Although the Guidelines recognize that it is difficult to define precisely the level at which overfishing jeopardizes recovery of a stock, there are indicators of existing or impending overfishing that should be heeded. In determining allowable fishing levels, Councils are to consider and attempt to estimate all sources of mortality on a stock, including non-targeted fishing, discards, and illegal catch. Total fishing mortality on a stock should be managed such that overfishing does not occur.

The Guidelines state that overfishing of a minor component species of a multispecies fishery could be warranted, based on net benefits expected. However, it is never acceptable to fish a species to the point that it requires protection under the Endangered Species Act. Some very limited overfishing may be acceptable, but only if it is identified and sufficiently analyzed and justified.

The 602 Guidelines define overfishing as a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce MSY on a continuing basis. Each FMP must specify, to the maximum extent possible, an objective and measurable definition of overfishing for each stock or stock complex covered by that FMP, and provide an explanation of how the definition was determined and how it relates to reproductive potential. Overfishing may be expressed in terms of a minimum level of spawning biomass ("threshold"); maximum level or rate of fishing mortality; or formula, model, or other measurable standard designed to ensure the maintenance of the stock's productive capacity. However, overfishing must be defined in a way to enable the Council and the Secretary to

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monitor and evaluate the condition of the stock or stock complex relative to the definition and must be based on the best scientific information available.

Councils must build into the definitions appropriate consideration of risk. In cases where scientific data are severely limited, the Councils' informed judgement must be used, and effort should be directed to identifying and gathering the data needed. Secretarial approval or disapproval of the overfishing definition is based on consideration of whether the proposal: (1) Has sufficient scientific merit; (2) is likely to result in effective Council action to prevent the stock from closely approaching or reaching an overfished status; (3) provides a basis for objective measurement of the status of the stock against the definition; and (4) is operationally feasible.

In addition to the overfishing definition, an FMP must contain management measures necessary to prevent overfishing. If overfishing is defined in terms of a threshold biomass level, the Council must ensure that fishing effort does not cause spawning biomass to fall and remain below that level. If overfishing is defined in terms of a maximum fishing mortality rate, the Council must ensure that fishing effort on that stock does not cause the maximum rate to be exceeded. If data indicate that an overfished condition exists, a program must be established for rebuilding the stock over a period of time specified by the Council and acceptable to the Secretary. If data indicate that a stock or stock complex is approaching an overfished condition, the Council should identify actions or a combination of actions to be undertaken in response.

Because the generic overfishing definition contained in the 602 Guidelines is subjective, the Panel felt that it would be useful to interpret this definition in a consistent and objective fashion. Since the primary intent of the Guidelines is to prevent recruitment overfishing, the Panel's interpretation was as follows:

> *Absent compelling evidence to the contrary, a finding that expected recruitment has fallen below one-half the expected maximum will be taken as sufficient evidence that the stock has been overfished (in the sense of the MFCMA), and any level of fishing that would result in expected recruitment falling below one-half the expected maximum (or remaining there indefinitely) will be taken to constitute overfishing.*

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Several points regarding the above interpretation should be noted: (1) For the purpose of this review, this interpretation was intended to provide a conceptual focus rather than a means of empirically evaluating each of the current stock-specific definitions; (2) it frames the overfished condition and the act of overfishing in the common currency of expected recruitment; and (3) because it links overfishing explicitly to expected recruitment, this interpretation provides a natural transition to definitions based on spawning biomass thresholds or on fishing mortality rates that are expressed in terms of equilibrium spawning per recruit.

Section II: General Issues in the Development of Overfishing Definitions

Scientific Principles of Defining Overfishing

Both fishing *targets* and overfishing *thresholds* are generally associated with biological reference points (BRP's) estimated from standard fisheries models. The most widely used BRP's are those derived from stock production models (e.g., maximum sustainable yield, MSY; the fishing mortality rate associated with MSY, F_{msy}; and the fishing effort associated with MSY, f_{msy}), yield per recruit (YPR) analysis (e.g., $F_{0.1}$ and F_{max}), spawning per recruit (SPR) analysis (e.g., various percentages of the maximum SPR, which occurs at zero fishing, and associated fishing mortality rates, such as $F_{20\%}$ and $F_{35\%}$), and stock-recruitment (S-R) observations.

Overfishing can take a number of forms; for example, target overfishing, growth overfishing, recruitment overfishing, and economic overfishing. While the first type of overfishing is associated with a *target*, growth and recruitment overfishing are generally associated with *thresholds*, and economic overfishing may be expressed in terms of either targets or thresholds, depending on the definition used. The difference is that while fishing activity is expected to fluctuate about targets, thresholds should generally not be crossed. Strictly, target overfishing could be said to occur whenever the target is overshot; however, small deviations would not generally be considered serious until and unless a consistent bias became apparent. Conversely, even a single violation of a threshold may indicate the need for immediate action to reduce fishing mortality. Economic overfishing will not be discussed further in this report, except to mention that, in terms of the amount of fishing pressure associated with each of the types of overfishing, it could fit anywhere in the sequence, depending on the economic objectives and the time horizon under consideration.

Target overfishing

The development of BRP's for use as fishing targets has a long history, and many useful reference points have been produced. They can be grouped into three main categories: (1) Yield-based reference points (e.g., maximum sustainable yield (MSY), optimum yield (OY), maximum sustainable rent (MSR), and maximum constant yield (MCY)); (2) fishing mortality rate reference points (e.g., $F=M$, F_{MSY}, $F_{0.1}$, F_{max}, $F_{20\%}$ and $F_{35\%}$); and (3) biomass-based reference points (e.g., constant escapement or the equilibrium stock size corresponding to a target fishing mortality rate such as B_{MSY}). The most frequently adopted targets are those based on reference levels of the fishing mortality rate (F). Management strategies that use variable levels of F as targets are also becoming more

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common; for example, fishery control laws (see below) that vary
fishing mortality as a function of stock condition to achieve
some objective, and experimental approaches, such as adaptive
management, where the system is probed to learn more about the
response of the stock to fishing.

<u>Overfishing thresholds</u>

The need to define overfishing thresholds has been largely
neglected until recent times, as the number and diversity of
fisheries that are considered overfished continues to increase.
Even now, far fewer BRP's have been developed to identify
overfishing thresholds, and their generality is often questioned.
Once $F_{0.1}$ was invented (Gulland and Boerema 1973), fisheries
scientists often advocated the use of $F_{0.1}$ as a target and F_{max} as
a threshold. Other early threshold reference points included
minimum spawning biomass levels based on observed stock
collapses, and 20% of the unfished stock biomass (20% B_0; e.g.,
Beddington and Cooke 1983). Alternative indicators of poor stock
condition that have long been advocated are truncated age
distributions, small or decreasing mean size in landings, and a
markedly declining survey index, but these have rarely been
articulated into measurable, unambiguous quantities.

Within the last 10 years, an important new class of reference
points associated with overfishing thresholds has been developed
based on percentiles of survival ratios estimated from S-R
observations. This work began with Shepherd (1982), who showed
how a standard spawner per recruit (SPR) analysis could be
combined with S-R observations to generate reference fishing
mortality rates. The relationship between the two types of
information is straightforward (Gabriel et al. 1989; Mace and
Sissenwine 1993; Figure 1); for any constant F (e.g., F = 1.0 in
Figure 1), there is a corresponding SPR level that can be
inverted and used as the slope of a straight line through the
origin of the S-R data. Points along the line represent the
average survival ratio (R/S) required to support that particular
constant F. Percentiles of observed survival ratios can
therefore be used to define threshold and target levels of F,
which can then be translated back to the SPR scale (see Gabriel
et al. 1989 for the computational details).

Two percentiles that have been advocated as reference points for
overfishing thresholds are the 90th percentile (denoted F_{high};
Shepherd 1982) and the median (denoted F_{med}; Sissenwine and
Shepherd 1987). Both are intended as indicators of *recruitment
overfishing*. The tangent through the origin of an S-R
relationship corresponds to $F_{extinction}$ (also referred to as F_r by
Mace and Sissenwine 1993; see Figure 2). F_{high} may overestimate
the tangent, since the highest survival ratios may just reflect
anomalously favorable environmental conditions, not the ability
of the population to sustain fishing under average environmental

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Figure 1

SPAWNING PER RECRUIT
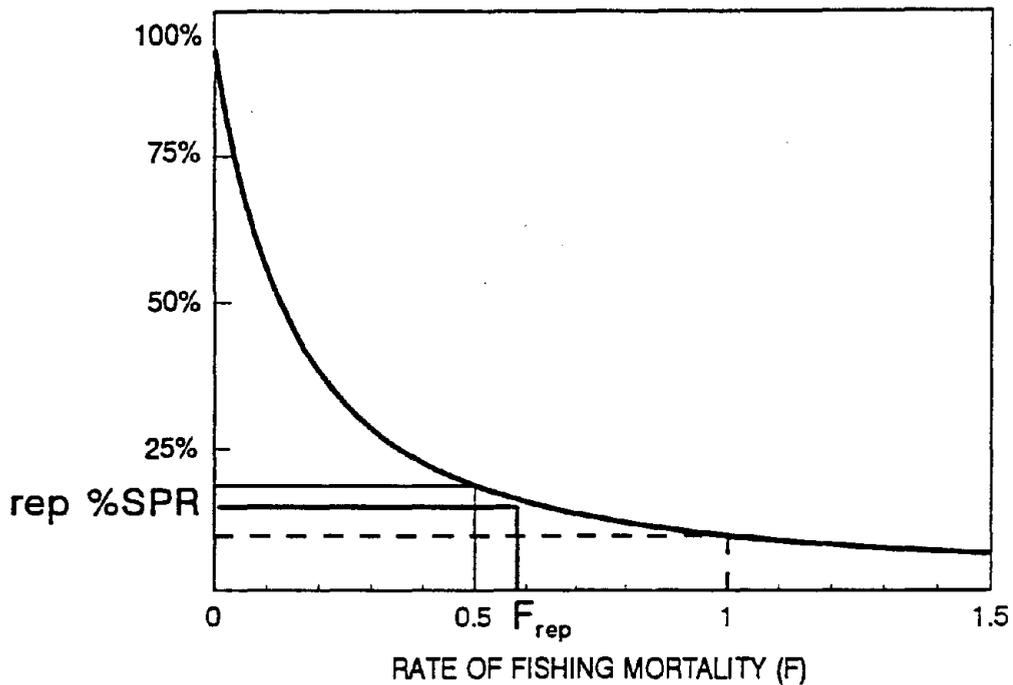
SPAWNER-RECRUIT RELATIONSHIP
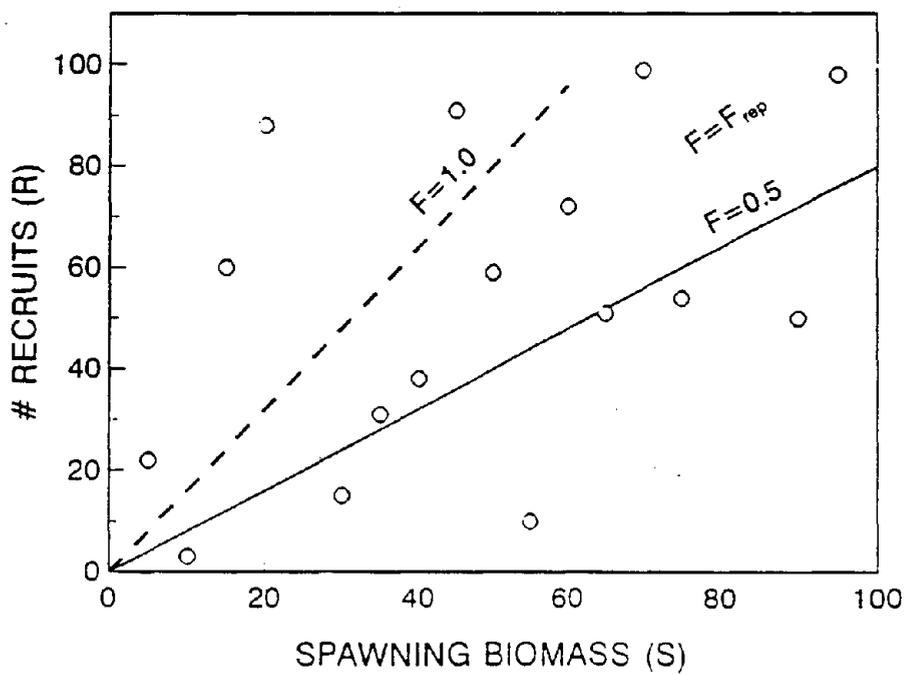
conditions. On the other hand, F_{med} may underestimate the slope if the data exhibit compensation (concavity). It is more correct to use F_{med} as an estimate of F_{rep} (F-replacement), the fishing mortality rate corresponding to the observed average survival ratio. Thus, F_{rep} is the fishing mortality rate that, on average, allows for replacement of successive generations over the observed range of S-R data. F_{rep} is a valid approximation of the slope at the origin in the case where the observations are restricted to low stock size, or where there is little compensation in the relationship (Figure 1). However, F_{rep} may forego potential yield if the stock has a recent history of light exploitation, and F_{med} may underestimate F_{rep} if the distribution of recruitment is highly skewed.

Mace and Sissenwine (1993) surveyed 91 well-studied European and North American fish stocks with sufficient data to construct stock-recruitment plots and conduct yield per recruit and spawning per recruit analyses to obtain estimates of reference points such as $F_{0.1}$, F_{max}, F_{med} and associated levels of %SPR. They estimated the median ratio of F_{med}/F_{max} at 1.3 and the median of $F_{med}/F_{0.1}$ at 2.3. The average %SPR corresponding to $F_{0.1}$ was 38%, the average %SPR corresponding to F_{max} was 21%, and the average %SPR corresponding to F_{med} was 19%. Mace and Sissenwine advocated use of 20% SPR as a recruitment overfishing threshold for stocks believed to have average resilience and 30% SPR for little-known stocks.

This study complements earlier theoretical and empirical work by Goodyear (1977, 1980, 1989), Gabriel et al. (1989) and Clark (1991) that has resulted in SPR becoming the most common basis for recruitment overfishing reference points in U.S. fishery management plans (Rosenberg et al. 1993). Generally, the OD's are based on theoretical considerations and analogy with other stocks, such that most definitions use either 20% SPR and 30% SPR as the reference level.

Note that the terminology for %SPR has not been standardized; alternative, synonymous terms, include spawning potential ratio, percent spawning stock biomass per recruit (%SSB/R), percent maximum spawning potential (%MSP), and percent eggs per recruit (%EPR). In all cases, higher levels of threshold %SPR and synonymous quantities are associated with lower compensation and resilience (Figure 2).

Biomass thresholds

There have also been developments in the use of S-R observations to define biomass-based thresholds. Despite the fact that theoretical stock-recruitment curves (e.g., Ricker 1954, Beverton and Holt 1957, Shepherd 1982) have been widely used for decades, there are no generally accepted methods for calculating biomass thresholds from the parameters. Some methods require that the

Figure 2

VARIABLES ASSOCIATED WITH S-R
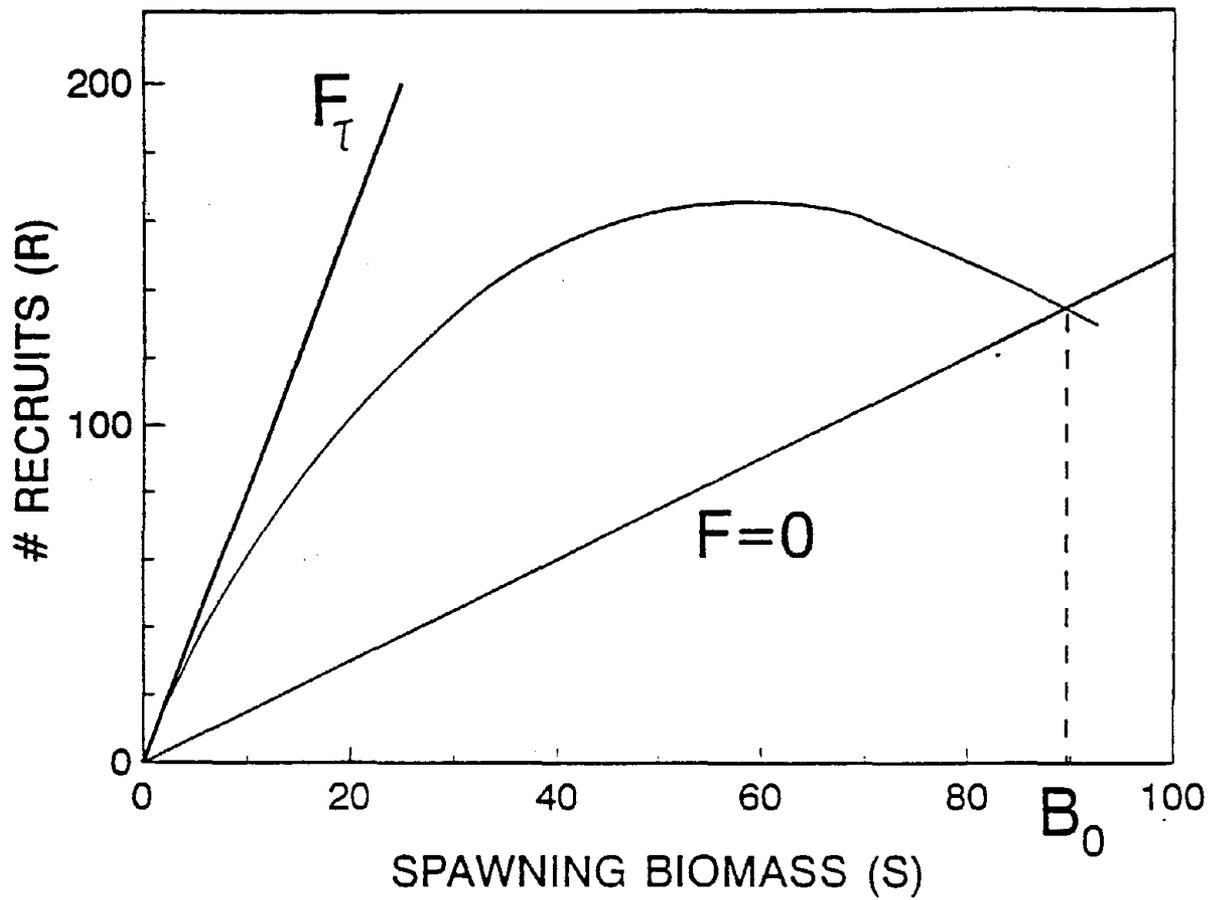
$$\tau = \frac{SPR_{F_\tau}}{SPR_{F=0}} = \frac{1}{Comp.\ ratio} = \frac{1}{Resilience}$$

$$= threshold\ \%SPR$$

data be fitted by theoretical relationships, whereas others are based on the observations themselves (non-parametric methods). The latter includes subjective, visual approaches that may be able to identify critical biomass levels below which recruitment appears to begin to decline rapidly. The main problem with subjective methods is that they do not always give consistent answers, and are often biased by the status quo.

Serebryakov (1991) and Shepherd (1991) suggested an objective, non-parametric method for estimating a threshold biomass. They defined the threshold by the intersection of the upper 90th percentile of the observed survival ratio and the upper 90th percentile of the recruitment observations. This intersection approximates the minimum stock size within the range of the observations that, based on the data, can be expected to be capable of producing a good year class when environmental condition are favorable for survival. Unfortunately, although this method generally performs well based on several different types of evaluation criteria, it is extremely sensitive to the range of the data observed (Myers et al. in press), with the threshold tending to get revised downward as a stock is fished down and new S-R observations are added.

A more common method of specifying biomass thresholds is to express them in terms of %B_0, most often using 20% B_0 as a default. However, it may be difficult to estimate B_0 for stocks that have been fished down substantially from virgin levels. In some cases, it may be reasonable to define virgin biomass as the point where the F=0 replacement line intersects a fitted S-R relationship, or the average or median observed recruitment. This method of estimation is likely to be less valid for stocks far below the virgin state, particularly if the observations only cover only the recent history of the fishery. Indeed, Myers et al. (in press) found that the point of intersection often occurs well outside the range of observations, at stock sizes where density-dependent effects may well differ from those in operation during the period of observations.

Ideally, threshold levels of biomass should be based on the associated level of recruitment relative to some reference level. Although some definitions of biomass thresholds refer to recruitment levels, the association is often somewhat vague. For example, the Advisory Committee on Fishery Management of the International Council for the Exploration of the Sea has recently adopted the process of specifying the minimum biologically acceptable level (MBAL) of biomass, defined as the biomass level below which the probability of poor recruitment increases as spawning biomass declines further. In practice, there are no set standards for calculating MBAL levels, and "poor" recruitment has not been defined explicitly.

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Recruitment-Based Thresholds

Few BRP's have been expressed in terms of recruitment, *per se*. One possibility that has recently been suggested by Mace (1993) is to define a threshold biomass which corresponds to the point on the SRR where expected recruitment is 50% of the maximum. A model presented by Thompson (1993b) supports the use of the 50% recruitment level in that 50% is the maximum reduction in recruitment that could be observed in equilibrium for a stock that is fished at the MSY rate. Myers et al. (in press) evaluated this reference point for 72 sets of stock-recruitment data from around the world. Although these analyses all measure relative recruitment in terms of the underlying (deterministic) stock-recruitment relationship, the 50% reduction can be generalized by framing it in terms of expected recruitment, and may provide a robust safeguard against recruitment overfishing. The challenge is in estimating the maximum recruitment, analogous to previously mentioned difficulties in estimating B_0.

This recruitment-based reference point can be translated into either a biomass-based or F-based reference point. When cast as a biomass threshold, this reference point has an advantage over biomass thresholds expressed as a fixed percentage of B_0, in that it takes account of the degree of compensation in the S-R relationship, setting more conservative (higher) thresholds for stocks with lower compensatory reserve. Such methods should be preferred over the blanket adoption of 20% B_0, which is unlikely to be applicable across the entire range of observed levels of stock resilience. However, rarely are there stock-recruitment data with sufficient contrast to estimate stock resilience precisely. For example, Myers et al. (in press) found that the biomass at 50% R_{max} sometimes appeared overly risky, particularly when the data exhibited zero or negative slope, resulting in extremely high estimates of the slope at the origin of the S-R curve. Conversely, for data exhibiting a positive slope overall, the method often estimated a threshold that was extremely large. These problems are related more to a lack of contrast in the data and the validity of the fitted curve than to the definition of the reference point itself.

When cast as an F-based threshold, a reference point based on relative expected recruitment can be expressed in terms of equilibrium spawning per recruit, providing (as above) that the degree of compensation in the S-R relationship can be estimated.

Proxies

There are many cases where neither F nor B can be estimated explicitly, due to lack of data. The only option is to develop proxies based on the type and quality of data that are available. Proxies that may index F include truncated age distributions and small or decreasing mean size in landings or measures of fishing

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effort; those indexing biomass include low commercial catch per unit effort (CPUE) and low or markedly declining research survey indices. For example, overfishing could be specified as a ratio of current commercial or research CPUE compared to the CPUE of some historic period when the stock was lightly exploited. As mentioned above, it is sometimes difficult to use such proxies to develop measurable, unambiguous and meaningful overfishing definitions. Proxies for F may be difficult to specify and interpret due to departures from a stable age distribution (e.g., a decrease in mean size may indicate a strong incoming year class rather than high F); proxies for B may be difficult to specify, due to the problem of selecting a suitable base period and changing catchability related to the efficiency of fishing or the distribution of the stock.

Relationships Between F and Biomass Thresholds

F-based reference points are indirectly related to biomass thresholds. That relationship depends on the stock-recruitment relationship. Under constant F over a period greater than the lifespan of a given species, levels of %SPR map 1:1 with F. Only in the theoretical case of stock-independent recruitment (perfect compensation) is a level of %SPR exactly equivalent to a percentage reduction from pristine levels of biomass ($\%B_0$).

In general, compensation in recruitment will result in the relationship $\%B_0 < \%SPR$, because a reduction in %SPR will cause some reduction in expected recruitment that will result in a further reduction in $\%B_0$. The following table illustrates the relationship between %SPR and $\%B_0$ for various levels of compensation (indexed by $1/\tau$, see Figure 2). The last two columns give the $\%B_0$ at which the replacement line for a given %SPR intersects the Beverton-Holt and Ricker stock-recruitment relationship, respectively. In most cases, the levels of %SPR and $\%B_0$ are quite different, so that these two reference levels can not be used interchangeably.

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τ	%SPR	%B_0 Beverton-Holt	%B_0 Ricker
0.05	10	7.7	23.1
	20	23.1	46.3
	30	38.5	59.8
	40	53.9	69.4
0.10	10	0	0
	20	16.7	30.1
	30	33.3	47.7
	40	50.0	60.2
0.20	10	-	-
	20	0	0
	30	20.0	25.2
	40	40.0	43.1
0.30	10	-	-
	20	-	-
	30	0	0
	40	11.1	23.9

Basing Definitions on Fishing Mortality Rate and/or Stock Biomass

About 70% of the approved definitions of overfishing are based on fishing mortality rates, rather than minimum biomass levels. The Review Panel discussed at length the appropriateness of these alternative types of definitions.

The 602 Guidelines specifically use the word "threshold" with reference to the setting of a minimum biomass below which the fishery will be closed. However, for the sake of simplicity, the term "threshold" will be used in this report to refer to any limit prescribed by an overfishing definition, regardless of its units (F or B). The management strategy should be designed to avoid exceeding the threshold. If a threshold has been exceeded, a rebuilding program is needed to enable the stock to recover. The rebuilding program should include substantial reductions in fishing mortality, even to the point of closure of the fishery if the stock condition is very poor.

One persuasive argument in favor of specifying the definition of overfishing as a maximum fishing mortality rate (F) is that it relates to the act of fishing and therefore can be controlled directly. In fact, the amount and characteristics of fishing on the stock are the only components of stock dynamics that can be controlled by management. However, the ultimate intent of management with respect to conservation of the resource is to ensure that there is sufficient spawning stock remaining after

the harvest for the stock to sustain itself.

Definitions that specify a maximum fishing mortality rate have
the further advantages that: (1) There is a theoretical and
empirical basis for the selection of maximum F thresholds such as
F_{med}, $F_{20\%}$, or $F_{35\%}$ (Goodyear 1977; 1980; 1989; Sissenwine and
Shepherd 1987; Gabriel et al. 1989; Clark 1991; Mace and
Sissenwine 1993); (2) when the fishery is operating near the
threshold a maximum harvest rate strategy may not result in
fishery closures, but rather require substantial reductions in
catches or effort if the threshold is crossed; (3) an appropriate
threshold can be estimated from relatively limited fishery data
and information on the life history characteristics of the stock
in question; and (4) an overfishing definition setting a maximum
F can prevent the stock from depletion due to fishing in the long
term.

On the other hand, there are some disadvantages in thresholds
specified in terms of a maximum fishing mortality rate only.
Maximum fishing mortality rate strategies do not increase the
protection afforded to the stock when it is in poor condition.
An F-based definition that is appropriate over some middle range
of biomass levels, may not necessarily be appropriate at the
extremes of biomass. For example, a maximum harvest rate, such
as $F_{20\%}$, set to prevent long-term decline of the stock from its
current level will not necessarily allow rebuilding of a stock
that was seriously overfished in the past. Nor will it allow a
fishery to develop its full potential if estimated from data
obtained only from a period of light fishing. Further, changing
environmental conditions and life history characteristics may
necessitate changing the threshold harvest rate in the
definition.

Definitions that specify a minimum biomass level for the stock,
below which the fishery is curtailed or, in the extreme case,
closed, have the advantages that: (1) Biomass is more directly
linked to recruitment than is the fishing mortality rate; (2)
minimum biomass levels provide a guide for management of stocks
that are already depleted by setting a standard for rebuilding;
and (3) during periods of adverse environmental conditions, a
minimum biomass level provides a seed stock for eventual recovery
when conditions are more favorable.

However, specifying minimum biomass levels can be difficult and
is often more demanding of the data than determining a maximum
harvest rate. This is particularly true if the biomass threshold
is treated as absolute, i.e., the fishery is closed if the
estimated biomass falls below the threshold, rather than
precautionary, i.e., when the stock is below the precautionary
biomass threshold the maximum allowable F is reduced. The
problem of lack of observations over the full range of stock
conditions (i.e., lack of contrast in stock abundance or changing

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environmental conditions) may cause the minimum biomass to be
mis-estimated. The strategy of closing a fishery below a biomass
threshold and opening it above may also result in highly variable
fishery yields and economic dislocation. Because the
consequences of crossing an absolute biomass threshold are so
extreme, their use will often be accompanied by intense
controversy about the accuracy of stock size estimates. In
addition, managers and the public may misinterpret a biomass
threshold as the point at which the resource will collapse,
heightening the controversy.

While F-based thresholds applied in a multispecies fishery afford
some protection to the suite of stocks fished, a biomass
threshold is, of necessity, set on a stock-by-stock basis. Many
U.S. FMP's are for large groups of species and in many cases
there may be detailed information for only a few species in the
group. A maximum fishing mortality rate is needed in these cases
particularly, even if a minimum biomass threshold is set for some
of the principle species in the suite.

Defining overfishing using a combination of a maximum fishing
mortality rate, a precautionary biomass level below which the
maximum allowable fishing mortality rate is reduced, and an
absolute minimum biomass threshold may provide good protection
for the resource. This is illustrated, schematically in Figure 3
in the form a harvest control law, such as are used for some
Pacific coast stocks. The harvest control law specifies a
maximum fishing mortality rate for a stock in healthy condition,
some strategy for reducing F progressively as biomass falls below
some precautionary level of stock biomass (regardless of the
reason for low stock size), and a (lower) absolute biomass
threshold below which fishing must cease or be restricted to
bycatch only. The option of closing down a fishery when stocks
become severely depleted should always be retained. One way of
incorporating such an absolute biomass threshold would be to set
it arbitrarily low (e.g., 10% of current biomass) to be used as a
safeguard only in extreme situations of failed management, poor
stock assessment or continuing adverse environmental conditions
that place the stock in jeopardy.

If a control law that reduces the fishing mortality rate
gradually as biomass is reduced below some designated
precautionary level is used: (1) It affords additional protection
for the resource when stock condition is apparently poorer; (2)
mistakes in the specification or estimation of thresholds are not
as serious; (3) relating F to biomass over some intermediate
range of biomass should allow more time and flexibility for
evaluating whether the stock is in a transition phase from one
stationary state to another; (4) temporary reductions in biomass
can be accompanied by temporary reductions in F that need not
result unnecessarily in permanent changes in the composition or
operation of the fishing fleet; and (5) small or gradual

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Figure 3: Schematic harvest control law

FISHING MORTALITY RATE

STOCK BIOMASS

OVERFISHING

OVERFISHED

THRESHOLD CONTROL LAW

TARGET CONTROL LAW

PRECAUTIONARY BIOMASS LEVEL

ABSOLUTE BIOMASS THRESHOLD

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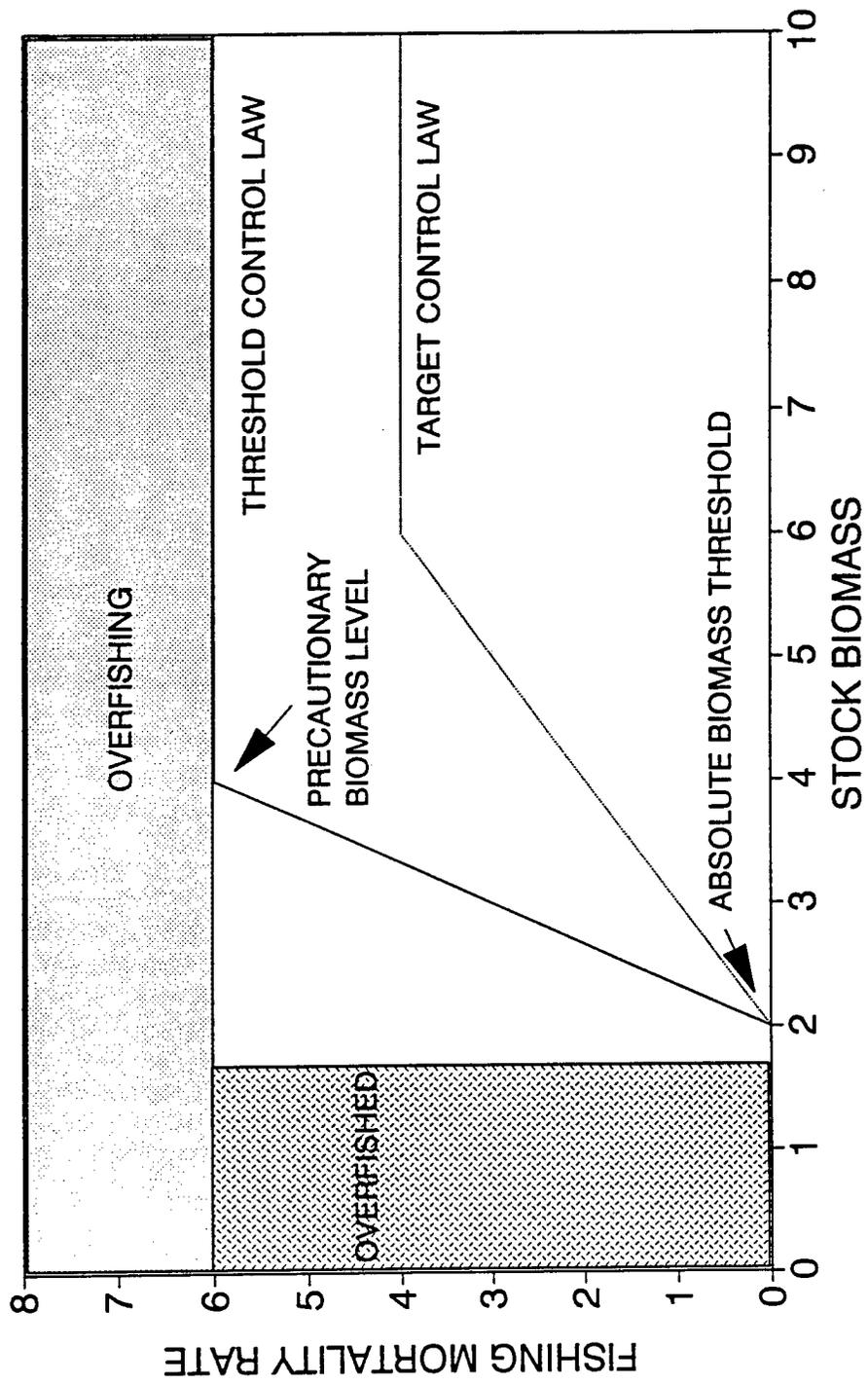
reductions (or increases) in F will be less controversial, and therefore less subject to litigation.

In summary, the Review Panel recommends the development of control laws that combine a maximum fishing mortality rate and a precautionary biomass level whenever it is practical to formulate and implement such laws (e.g., for data-rich stocks with stringent management regimes). Setting a maximum fishing mortality rate is appropriate for most stocks. The protection afforded the stock will be greater if there is sufficient information available to set a precautionary biomass threshold as well. Absolute biomass thresholds set at low biomass levels should be seriously considered for the following classes of stocks: Those that are already known to have crashed under high fishing pressure, those with low compensation (see Life History Characteristics section below), those that appear to exhibit depensation in recruitment, and those sustained by occasional large year-classes (see Life History Characteristics section below). For stocks in healthy condition, where only a small range of stock sizes has been observed, absolute biomass thresholds may be unnecessary, if controls on the fishery are adequate.

Target versus Threshold Reference Points

As noted above, in this review, the term "threshold" can refer to either a minimum biomass or a maximum fishing mortality rate. The Review Panel agreed that it is important to make distinctions between the management targets and overfishing definition thresholds. A set of management goals can be translated into a harvest strategy that consists of, for example, a target harvest rate, such as F_{MSY}, or a target spawner escapement level. Management then designs regulations to maintain the fishery at these targets, on average, such that the stock will vary around the target and management controls will be fine-tuned to correct deviations from the target.

Overfishing thresholds are intended to place conservation constraints on the management actions so that recruitment overfishing does not occur, or, if the stock is currently in an overfished condition, to initiate and frame the rebuilding process. The management strategy is designed to avoid ever crossing the threshold, but if it is crossed, a previously agreed rebuilding plan is implemented to take strong corrective action. Therefore, the stock will always be maintained well above the overfishing threshold.

In developing rebuilding plans for depleted stocks, the initial target may well be the overfishing definition. However, it should be clear in the management plan for rebuilding that once the OD is reached, a management target will need to be put in

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place to attain more appropriate long-term management objectives.

The Role of Life History Characteristics

The life history characteristics of the harvested animals are central to the question of whether a population is overfished. Many of these characteristics present problems in quantitatively defining overfishing, assessing population status and formulating recovery plans. In most cases, these can be accounted for only in a qualitative way because either (1) the necessary data do not exist for quantitative evaluation, or (2) the necessary methods of analysis have not been developed.

Characteristics of the Reproductive Stock

One factor not explicitly included in the evaluation of overfishing is the dependence of population persistence on the number of reproducing age classes. Computations based on total egg production per recruit do not account explicitly for the way reproduction is distributed over age. In general, for populations at low abundance, those with spawning spread across a greater number of age classes will be less susceptible to further decline (e.g., Murphy 1967).

A related problem is the use of spawning biomass as an index of total egg production in spawning per recruit calculations. Two example cases are fishes that spawn several times each year, and fishes exhibiting sequential hermaphrodism. In both of these cases the widespread practice of using spawning stock biomass, rather than total egg production, as an index of SPR can lead to serious loss of ability to detect overfishing.

A wide variety of temperate and tropical marine fishes are known to spawn many times during a year or a spawning season. Species exhibiting multiple spawning are known among the clupeids, carangids, lutjanids and scombrids. In some of these species, the number of annual or seasonal spawnings increases with age, although spawning dynamics may not be known in detail. Use of spawning biomass per recruit, as a proxy for SPR, fails to recognize the higher seasonal fecundity of older fish, and therefore fails to recognize the full reduction in SPR for these species. The extent of this error can be sufficiently large that a seemingly optimal spawning biomass per recruit of 35% could corresponds to an actual egg production per recruit of, say, 20%, and would constitute overfishing under commonly-used overfishing definitions.

Sequential hermaphrodites have a life history in which they function as females when they are young and later as males, or vice versa. The biological mechanisms controlling sex reversal in a population are usually poorly understood. If the age at sex reversal varies interannually, in relation to environmental

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factors or in a density-dependent manner, then the number of age groups contributing to egg production will vary. Equilibrium SPR computations that ignore such sex reversal mechanisms can lead to erroneous conclusions about reproductive output for a given harvest rate. Whenever possible, sex reversal should be accounted for in models used to estimate the biological reference points upon which the OD's will be based.

The Nature of Variability

Harvested stocks vary in the magnitude and temporal pattern of environmental variability in life history rates, and these differences affect population persistence. Generally, for populations that otherwise would not be expected to decline, the greater the magnitude of variability, the greater the likelihood of decline to low levels. For populations with the same percent spawning per recruit, those with the greater variability in egg to recruit survival will be more susceptible to decline.

In addition to the magnitude of variability, the temporal pattern can vary. In particular, there may be long periods of favorable or unfavorable environmental conditions. In addition, there is a small but problematic group of fish stocks where strong recruitment is a relatively rare event, and most recruitments are at or below the replacement level in the absence of fishing. These tend to be long-lived species (viz. low M). The nature of appropriate fishing strategies and overfishing protections for these stocks has not received much treatment in the fishery literature.

The available knowledge of the compensatory capacity of these stocks is usually inadequate to guide management, since there may only be two or three data points representing the strong year-classes. Such a small sample size is inadequate to describe a relationship between stock abundance and strength of "successful" recruitments, providing little direct evidence of compensatory capacity.

Similarly, estimates of the frequency of those strong year-classes (an equally important vital statistic) are usually imprecise. For example, suppose there have been three strong year-classes in 30 years of observations. This gives an expected 10% chance of a strong year-class in each year. However, the Poisson distribution can be used to estimate a 95% confidence interval around that value, giving a range of 2% to 29% as the annual chance of a strong year-class. Thus, it cannot be determined whether, over the past 30 years, strong recruitment has been unusually frequent or unusually infrequent.

It is difficult to separate the goal of preventing overfishing from the goal of optimizing yield from such a resource. Limits on fishing intensity are appropriate to assure continuity of

catches during the years between recruitments, while a threshold
biomass is appropriate as a safety feature if there is a
prolonged period without a strong recruitment.

The Shape of the Stock-Recruitment Relationship

The persistence of populations as they are harvested to low
levels depends, in part, on the shape of the stock-recruitment
relationship. Although some of the important aspects of this
problem are discussed above under the Scientific Principles of
Defining Overfishing section, not all have been included in the
development of the existing definitions of overfishing.

Perhaps the most important characteristic of the stock-
recruitment relationship is the degree of compensation. In other
words, how much additional mortality due to fishing can the stock
withstand (compensate for) in the long term without a substantial
decline in expected recruitment. Although fish stocks may be
capable of a variety of compensatory responses, our review
emphasizes compensation in the stock-recruitment relationship
(SRR). The SRR is typically the strongest source of compensation
in exploited fish populations. For example, for an OD that sets
a maximum F level, in the deterministic case, stock viability
requires that the SRR must lie above the OD replacement line over
some range of abundance, indicating a tendency for the population
to recover once it has fallen within that range. At higher
abundances, the rate of increase in recruitment gradually slows
until the SRR crosses the OD replacement line, establishing an
asymptotic equilibrium abundance. Compensatory capability is
related to the relative surplus of recruitment over the
replacement level (surplus production), and hence to the amount
of curvature in the SRR. This is admittedly a simplified
description of stock-recruitment dynamics, but more realistic
(e.g., stochastic) models exhibit analogous properties.

For stocks exhibiting strong compensatory capacity, constraints
on maximum fishing mortality rate should in most cases provide
adequate protection from overfishing. Provided management
faithfully avoids such high mortality rates, and provided the SRR
is stable over time (not subject to prolonged "good" and "bad"
periods), there should be little need for supplementary
precautions, such as specification of a minimum spawning biomass.

In contrast, constraints on fishing mortality rates alone may not
provide adequate protection for stocks that exhibit weak
compensatory capacity. Imprecision in stock assessments, runs of
adverse environmental conditions, and slow management response
can combine to deplete such a stock quickly, despite sincere
attempts to limit fishing pressure. As a corollary, weak
compensation implies that recovery from a depleted level will be
slow, and loss of benefits to society will be prolonged. These
weakly compensatory stocks are better afforded protection by

specification of a minimum abundance level, below which fishing is severely curtailed. Because of their low surplus production, these stocks are also vulnerable to natural fluctuations, and low abundance can occur due to a prolonged period of poor reproductive success. Once low abundance is reached, recovery is an important goal whether the cause is excessive fishing or adverse natural variability.

Another important characteristic of the stock-recruitment relationship is the possibility of a depensatory relationship (i.e., the Allee effect) at low spawning levels. Depensatory stock-recruitment dynamics mean that per capita reproductive success declines at low population levels. Because defining overfishing involves determination of the decline in recruitment at low spawning stock levels, it is important to know whether recruitment will drop to negligible levels before parental stock goes to zero. Although there are several possible mechanisms for an Allee effect (e.g., limited ability to find mates at low densities), such effects are difficult to detect in S-R data. However, they can be identified through direct observations of processes. For example, Levitan et al. (1992) have shown that spawning efficiency in a broadcast spawner, the red sea urchin, declines precipitously near the density that is currently observed in some West Coast fisheries (Botsford et al. 1993). Dennis (1989) has shown that harvesting amplifies the impact of an Allee effect on the probability of decline, while Thompson (1993a) has shown that safeguards on harvesting can avoid problems due to Allee effects.

Other Density-Dependent Factors

While most of the overfishing literature focuses on density dependence in recruitment, density may affect growth, natural mortality, and maturation processes, too, and these factors in turn influence persistence and estimates of population status. When growth rates increase as densities are reduced by harvesting, the maturity schedule is shifted to lower ages. The effect is usually an increase in egg production per recruit, a compensatory response. This presents problems in the determination of stock status and planning for the recovery of overfished stocks.

A change in growth rate also affects population dynamics by modifying equilibrium levels. While the increase in eggs per recruit is a compensatory response, if a size-dependent influence on recruitment is present (e.g., cannibalism of pre-recruits by larger individuals), the overall effect per recruit can be depensatory (Botsford 1981). Declines in several fisheries are consistent with such a mechanism (e.g., Pacific sardine and central California Dungeness crab).

Density-dependent changes in individual growth and egg production

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can be important components of stock compensation. When
implementing overfishing definitions, it is prudent to utilize
life history characteristics from lightly exploited stocks. When
biological reference points are calculated from the life history
characteristics of a heavily exploited stock, there is a danger
of rationalizing high exploitation rates for a stock that may
already have exhausted much of its compensatory capacity. When
considering life history characteristics, it is important to
recognize that a stock reduced to low abundance by a high level
of fishing mortality will have a low mean age, while a stock
reduced to the same level of spawning biomass by a sequence of
poor recruitments will have a high mean age. This difference in
mean age can directly affect egg production and the potential to
produce strong recruitment. Therefore, it is preferable to
define overfishing in terms of actual, viable egg production,
rather than in the simple terms of spawning biomass.

In addition, fisheries may introduce slow changes in life history
characteristics due to genetic selection. Fishing operations are
predators that usually target on larger, adult individuals, so
fishing may exert a genetic selective pressure unlike that
imposed by most natural predators which typically target smaller
prey. For example, some stocks of Atlantic salmon now have males
that mature at a small size without ever leaving the freshwater
phase. Genetic selection is not considered in any of the OD's,
but its potential argues for caution.

Spatial Pattern

The fact that many stocks are distributed over a large area
affects population dynamics, but is seldom included in the
development of overfishing definitions. If a population is
composed of a number of independent subpopulations, it may have
an advantage in compensating for harvesting. The probability of
several independent populations declining to low levels is less
than the probability of a single population declining (Quinn and
Hastings 1987). However, if the spatial pattern is ignored,
subpopulations can be lost even if the aggregate population is
not depleted. Explicit account of spatial distribution is
necessary to prevent local overfishing. Note, however, that
local overfishing is not prohibited by the 602 Guidelines.

Distribution over a large geographic area is also problematic for
the estimation of critical population parameters. In many cases
migration between subpopulations is not well known, yet the
resilience of the population to harvesting may depend on it.
Some populations with excess reproductive capacity may be sources
of potential recruits, while others may be sinks, sustained by
immigration. The American lobster in the northeast and the spiny
lobster in the Gulf of Mexico are examples. The nearshore Gulf
of Maine populations have an extremely low percent spawning per
recruit (<1%; Botsford et al. 1986), and hence may be sustained

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by the less intensively harvested offshore populations.

In summary, the consideration of life history characteristics highlights the weakness of simple definitions of overfishing that may miss fundamental aspects of stock dynamics. As a stock is fished down to very low levels, increased biological monitoring is prudent because the greatly altered age composition of the population and the potential for altered growth and reproductive output may have unanticipated effects on the relationship between expected recruitment and a simple measure of spawning biomass. Stochastic models of expected recruitment become increasingly important as the reduced mean age of heavily exploited populations transforms recruitment variability into large relative changes in population abundance. Finally, understanding changes in the spatial distribution of overfished populations can aid assessment of the potential of the stock to recover throughout its range.

The Role of Uncertainty

The section on the Role of Life History Characteristics describes some of the uncertainty that impacts upon the efficacy of the definitions of overfishing. The difficulty of adequately accounting for some life history features in the OD's means that there is uncertainty about the dynamics of the stock. In effect this means that the determination of a safe threshold is uncertain because of the difficulty of describing the relationship between stock and recruitment.

A second major source of uncertainty that affects the definitions of overfishing is measurement error in the determination of the current state of the stock. For many stock assessments, estimates of measurement errors are available and these should be used directly in advising managers on the probability that a stock is overfished relative to a given OD.

All assessment methodologies contain some amount of error and/or bias. One aspect of OD performance is its ability to identify accurately a condition of overfishing, even when implemented according to imprecise or inaccurate stock assessments. This property can be called robustness. A stock-by-stock review of the robustness of overfishing definitions was not possible.

In many instances, the overfishing definition called for information that is not available, resulting in the use of substitute measures that are generally assumed to be equivalent. Examples are percentage reduction in CPUE from some earlier level, or use of spawning biomass instead of egg production for estimating SPR levels. These substitutions frequently introduce systematic error into detection of overfishing. This error can be either of two types: Falsely indicating overfishing when it

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would not be indicated by the more accurate method, or alternatively, failing to indicate overfishing when it would be indicated by the more accurate method (so-called Type I and Type II errors).

Often, a variety of stock assessment methods are available to provide scientific advice on current stock status. In most cases, the methods are well established, based on scientific tradition or proven performance. However, when assessment methodologies are changed, effects on performance of the overfishing definition should be considered. In some OD's, this relationship is formalized as a tiered set of definitions that are used according to the nature and quality of the assessment information. A minor weakness of this approach can be lack of objective criteria for deciding when a newer "improved" method is to be adopted.

Assessment methods are subject to errors due to variability in input data and to model mis-specifications. In some cases, errors tend to cancel. For example, the natural mortality rate M is rarely known accurately, and errors in M result in systematic errors in assessments. However, if the OD is based on models using the same erroneous value of M, performance of the OD may prove to be robust. A more disturbing possibility is the so-called "retrospective problem" (ICES 1991). Experience has shown that assessment methods in some cases consistently overestimate or consistently underestimate current abundance for a given stock, as compared with estimates based on subsequent information. As stocks approach a condition of being overfished, assessment methods may be prone to Type I and Type II errors, due to the "retrospective problem." The error may be recognized only after passage of several years. This leads to the question of how management should address such retrospective errors, especially when there is reason to believe the error is an ongoing phenomenon.

A third source of uncertainty relates to possibly changing environmental conditions that affect stock productivity. Such environmental changes may mean that the OD must be changed, but it is difficult to detect and forecast environmental trends and their impacts.

Most stock assessment models and overfishing definitions assume that life history characteristics are constant and that long-term changes in stock abundance are determined principally through a stationary stock-recruitment relationship. Short-term fluctuations in the environment introduce variability into the stock-recruitment relationship, but do not create a fundamental problem for the analysis. However, long-term trends in the environment and changes in the density-dependent nature of individual growth and egg production can change the shape and scale of the stock-recruitment curve. The short duration of most

time series hinders unambiguous detection of these trends and changes. In a short time series, the stock is typically observed over only a narrow range of abundance. The resulting lack of contrast in stock-recruitment data can lead to large measurement error in estimates of biological reference points, and to estimates of biological reference points that may not be applicable to other levels of stock abundance or environmental conditions. While extending the time series can alleviate problems caused by lack of data contrast, it can exacerbate problems caused by long-term trends in the environment.

Overfishing definitions based on an absolute minimum biomass level differ from definitions based on a maximum fishing mortality rate in terms of their ability to protect a stock during prolonged periods of adverse environmental conditions. A minimum biomass threshold may be preferable, because it can protect a stock until there is sufficient information on production capacity. However, if the environmental carrying capacity for new recruits alone has changed (i.e., if the slope at the origin of the stock-recruitment curve is unchanged), then the new climate regime may not change the appropriate fishing mortality rate. In this case, an OD based on maximum fishing mortality rate would be robust; the corresponding yield and biomass levels would simply be scaled down by the change in recruitment potential.

Managers should choose a "decision rule" that sets an acceptable probability of overfishing, given the uncertainty in knowledge of the true dynamics of the stock, the estimates of current stock status, and the possibility of environmental trends. The acceptable probability of overfishing is related to the time frame considered, the consequences of crossing the OD threshold, and the action to be taken if it is concluded the stock is overfished. For example, a given probability of overfishing might be acceptable if the only consequence is a slightly increased risk of poor recruitment in one year. However, the same probability might not be acceptable if there was thought to be a high chance of recruitment failure that would affect the fishery for several years to come. Similarly, if the actions taken upon crossing the threshold are likely to redress the situation quickly (e.g., if crossing a maximum F threshold is followed by corresponding quota reductions), then the decision rule may allow a higher probability of overfishing than if the action is merely to begin a 20 year gradual decrease in fishing.

These types of uncertainties and the need for a decision rule on the acceptable probability of overfishing apply to both F-based and biomass-based thresholds. The Review Panel recommends that an analysis of uncertainty with respect to interpreting the definition of overfishing should be done whenever possible in formulating scientific advice. As additional information is obtained, the OD and the uncertainty analysis should be updated.

Finally, the Review Panel noted the problem of fisheries that operate on groups of species where there is little or no information on some, or even many, components of the assemblage. Precautionary reference points for some species may help protect the assemblage as a whole, but this cannot be concluded in general. It should be clearly recognized that the prevention of recruitment overfishing can only be addressed by the collection of additional data on species composition, life history and fishery impacts. It is beneficial to be conservative in setting overfishing definitions on groups of poorly known species, but this should only be considered an interim measure until more information is available. There may be a high probability that some components of the assemblage will be overfished.

Linkage To Management Actions

The Review Panel recommends that the management actions to be taken if the overfishing definition threshold is crossed should be explicitly stated in conjunction with the definition itself. If there is no explicit linkage to management actions, the OD should be chosen conservatively, though it should be recognized that the degree of conservatism is related to what management actions will be taken. It is important that the determination of management actions be made prior to reaching the threshold, so that action to protect the stock is not delayed. If this is done, and the threshold is set conservatively, then the time for the stock to recover from any short period of overfishing should be short. It is recommended that the expected time for a stock to recover from the threshold level to the target level be considered in developing overfishing definitions.

In many cases, overfishing definitions were put in place when resources were already in poor condition. When the definitions were approved, the stocks were immediately determined to be overfished. In these cases, rebuilding plans are required under the 602 Guidelines, but little guidance on the time frame for recovery has been given. The Review Panel noted that the time frame for recovery plans should be linked to the life history of the species and the character of the fishery. Calculations should be done to estimate how rapidly recovery could occur with high probability if the fishery were closed. For example, the rebuilding program could be designed to result in a high probability of recovery in not more than one generation longer than the time needed under a complete closure.

The development of rebuilding plans also requires a decision rule for determining when a stock is rebuilt. Since the overfishing definition *per se* may only relate to the act of fishing (if it is in terms of a fishing mortality rate) and not the condition of the stock (such as might be measured by spawning biomass), the OD may not be sufficient to define a rebuilt stock. For stocks in

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need of a rebuilding plan, a specific definition of the rebuilt stock should be developed in terms of stock biomass and other factors, such as its age structure.

Exceeding the overfishing threshold implies strong management action to rebuild the stock, e.g., major reductions in allowable catch or fishing effort. If a fishing target is exceeded the implied actions are different. Targets are intend to be achieved on average, so minor adjustments should be used to damp fluctuations around the average, from both above and below the target, e.g., slightly increasing catches when F is below the target and decreasing when it is above.

Section III: Summary of Review Panel Findings

Approaches to Defining Overfishing in U.S. FMP's

Of the OD's reviewed in this report, 67% are fishing mortality rate based definitions. Only a few of these (5 of 79) also include a biomass threshold below which the fishing mortality rate is reduced. The remaining 33% of the definitions are based on stock biomass, though most of these are salmon stocks. All OD's for salmon are based on minimum spawning escapement.

Of the F-based definitions, the majority set a minimum spawning biomass per recruit as a percentage of the unfished level. Two levels predominate. Half of the F-based definitions use 20% SPR. Nearly one-third use 30% SPR. This is indicative of the fact that most of the OD's are set by analogy with other stocks and theoretical work presented in papers by Goodyear (1977; 1980; 1989), Gabriel et al. (1989); Clark (1991) and Mace and Sissenwine (1993). Only a few are developed by direct analysis of recruitment data for the stock in question.

The biomass-based definitions utilize historical patterns in survey indices or spawning stock estimates. Usually, the rationale for the level chosen is near the lowest level observed in the time series. Only in a few cases is the minimum stock level derived from a population dynamics model directly. The North Pacific OD's, which use a control law relating F to stock biomass with F reduced below B_{MSY}, are exceptions. In other cases, though not specifically reviewed here, a target fishing control law may be related to a dynamic model, even if the OD is not (e.g., northern anchovy).

Evaluation of the Overfishing Definitions

To evaluate the current set of overfishing definitions, it is necessary to examine the available information on the population dynamics of each stock under management. The Panel did not attempt to comment on the overall management of the stock, management objectives beyond the specification of a recruitment overfishing threshold as described in the 602 Guidelines, the management measures in place, or on other aspects of the scientific advice, such as the assessment methods used. These other components of the fishery assessment and management procedure were only considered with respect to the scientific basis and appropriate interpretation of the definition of overfishing in the management plan.

The Panel considered 117 stocks, in total, from around the country. In each case, the landings and exploitation history of

the stock along with available information on stock productivity
under exploitation were considered in order to determine whether
the scientific basis for the overfishing definition for that
stock is sound. Of the 117 overfishing definitions considered,
44 primary stocks were chosen for detailed analysis. For each of
these stocks, the Panel analysis is based on four graphs shown in
Section IV below (in some cases there were insufficient data
available for all four graphs). The first graph gives the
pattern of landings and abundance of the resource. The second
graph gives productivity expressed by the pattern of spawning
stock abundance and recruitment data. For many stocks, a
Shepherd curve (Shepherd 1982) was fitted to the data to guide
the eye, though the parameter estimates were not explicitly used
in the Panel's analysis. The third graph gives productivity
expressed as yield, yield per recruit and spawning biomass per
recruit versus fishing mortality rate. Finally, a control law
graph was prepared giving the current overfishing definition
expressing fishing mortality as a function of stock biomass.
Superimposed on the control law is the observed trajectory of
fishing mortality and biomass over the history of the fishery.
Some variation on this standard set of graphs on a case-by-case
basis was necessary, depending upon the data available.

The remaining 73 overfishing definitions were designated as
secondary for the purposes of this analysis. For these
resources, a less detailed analysis was conducted to confirm the
evaluations for the primary stocks. No graphs are presented for
these stocks. The designation of stocks as primary or secondary
was purely for the purposes of organizing the work of the review.
The primary stocks were chosen to represent a diverse set of life
histories and types of definitions across all regions. These
categories are not intended to reflect importance of the
resources or to pre-judge the results of the review.

For each stock, the following questions were considered by the
Review Panel in evaluating each overfishing definition. Tables 1
and 2 below give the Panel's consensus answers (coding for the
answers in the tables is shown in boldfaced type). Background
information and analysis along with comments on major concerns or
suggestions for revising the overfishing definitions on each
stock are given in Section IV.

1) Is the definition intended as a - **Target, Threshold, Both,
Neither?**

2) Is the definition appropriate as a - **Target, Threshold,
Neither?**

3) Is the overfishing definition measurable? **Yes, No, (?)**unknown

4) Is the definition of overfishing operationally unambiguous?
Yes, No, (?)unknown

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5) Is recruitment beyond the overfishing definition level - Reduced, Unchanged (?)unknown?

6) Is the fishery - **OK**, Overfished, Severely Overfished, Under fished, Under Recovery, ?)unknown?

7) Is the overfishing definition explicitly linked to corrective management actions? Yes, **No**, (?)unknown

8) Is the overfishing definition - **Risky**, **Neutral**, Conservative, (?)unknown?

9) Is the overfishing definition biologically and theoretically sensible overall? Yes, **No**, (?)unknown

10) Can the overfishing definition be improved with existing data? Yes, **No**
    a) If so, how?

Detailed interpretations of these questions follow:

1) The definition wording or history of the exploitation of the resource may indicate how it is interpreted in practice. It is intended as a target if management seeks to maintain the fishery, on average, at the OD level, in terms of fishing mortality rate or stock abundance. It is intended as a threshold if the OD defines a stock or fishery condition to be avoided. (Note: The term threshold here refers to either a maximum fishing mortality rate or a minimum spawning biomass). If the OD is exceeded, a rebuilding program is needed.

2) In the opinion of the Review Panel, the OD may be clearly more appropriate as a target or a threshold. In some cases, a very conservative OD may be more appropriate as a target than as a threshold for fishing. Alternatively, a risky OD is appropriate as neither one.

3) This question asks if the basic quantity used to define overfishing is measurable for the stock in question. In some cases, an OD may be measurable with the information on hand, even if the calculations have not been done. An OD is judged not measurable if the relevant biological information to calculate the current status relative to the OD is not currently available.

4) A definition is operationally unambiguous if it is clear how to calculate the OD and the current stock status relative to the OD. For tiered definitions, there should be explicit mention of the method used to determine which tier applies for each stock and who is to make this decision.

5) Reduced recruitment at the OD is indicated when the stock and recruitment data show substantially lower average recruitment at

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fishing mortality rates (or stock abundances) higher (lower) than the overfishing definition rate (abundance). If there are no data points to make such a determination, the answer is unknown. A substantial reduction in expected recruitment when the overfishing threshold is violated means that productivity is reduced beyond the overfishing threshold. If expected recruitment is lower, the overfishing definition should protect the stock from further losses of productivity. If expected recruitment is unchanged, some yield may be sacrificed by constraining the fishery by the threshold.

6) This question asks for a qualitative judgement on the current status of the resource relative to the overfishing definition.

7) For some definitions it is clear what action is to be taken if the threshold is exceeded. For example, if a rebuilding plan is agreed upon, then the action is clear. In other cases, the overfishing definition stands in isolation and is not explicitly linked, a priori, to management actions. Of course, management actions may be taken because of the status of the resource. The question is, are they clearly stated as a corollary to the definition?

8) This question is interpreted with respect to the main intent of the overfishing definitions as mandated by the 602 Guidelines, to prevent recruitment overfishing. The Panel agreed by consensus that, conceptually, recruitment overfishing would be taken to mean that the spawning stock resulting from fishing in excess of the OD threshold is expected to produce substantially less recruitment, on average, than a larger spawning stock would produce. The Panel agreed upon the following framework to answer this question: An OD was interpreted as risky if recruitment is expected to be reduced substantially as the threshold is approached and the time to recovery is prolonged. An OD is neutral if there is little expected reduction in recruitment until the threshold is crossed. An OD is conservative if little reduction in recruitment is expected until the stock is well beyond (i.e., on the "overfished side of) the threshold.

9) A definition is sensible if it sets a threshold to guide management that is expected, from the available data and theory, to protect the resource without being overly restrictive, is unambiguous and measurable. If the OD is developed by analogy with other species, the basis for that analogy should be sound.

10) For some definitions, the Panel concluded that there are better alternatives that are more sensible for a given stock. In some cases, additional work is needed to determine an appropriate definition and the answers to this question, along with the comments in the Section IV write-ups suggest possible lines of investigation to improve the OD.

In the view of the Review Panel, an ideal definition of overfishing would be applied as a threshold rather than a target, at least neutrally conservative in protecting against recruitment overfishing, measurable, linked to management actions, unambiguous and biologically sensible with no obvious improvements evident. Four of the primary stocks reviewed here (9%) meet these criteria. Many others (39%) nearly met this ideal but need improvements, for example, to remove ambiguity or link to management actions. For example, 70% of the definitions for the primary stocks are biologically sensible and 64% are at least neutrally conservative. Almost all of the priority definitions are measurable (96%), but 43% have some ambiguity. However, only 45% are used as thresholds separate from management targets in the FMP's.

For the secondary stocks, the results are similar. Over half (59%) of the OD's for secondary stocks are biologically sensible and 57% are at least neutrally conservative. Most are measurable and unambiguous, but only 56% are applied as thresholds rather than targets.

There is a sizable fraction of the definitions that the panel concluded are risky for protecting the resource (20% of the primary stocks, 9% of the secondary). In these cases, about half simply require modification of the current definition to a more conservative harvest rate (higher %SPR) or minimum stock biomass. In the rest, the basis of the overfishing definition needs to be modified to make it more conservative. There were also many cases (16% of the primary stocks and 33% of the secondary stocks) in which the definitions could not be evaluated in terms of relative risk. These definitions could be improved by relating them more directly to what is known concerning stock productivity. In a sense, an OD is risky if there is no clear evidence to the contrary (i.e., that it is at least neutrally conservative).

Less than half of all the definitions are explicitly linked to management action. This is worrying, as the definitions are intended to set management thresholds where some strong action to protect the resource should be taken if the threshold is crossed. It would be preferable if such action were specified a priori, to avoid further decline in stock abundance once the stock is known to be in danger.

In conclusion, the Panel recommends that all of the definitions identified as risky, not measurable, ambiguous or not biologically sensible be reconsidered as soon as possible. For more than half of all the definitions (77% of primary stocks, 88% of secondary stocks) recommendations for improvements have been made and should be considered in future FMP amendments.

Table 1: Primary Stock Evaluations Page numbers for detailed write-ups are given in parentheses in the first column. (Questions: 1, intended as; 2, appropriate as; 3, measurable?; 4, unambiguous?; 5, recruitment reduced?; 6, status of fishery; 7, linked to management?; 8, risky, neutral, or conservative; 9, sensible?; 10, can it be improved?; 10a, how to improve.)

	QUESTIONS	1	2	3	4	5	6	7	8	9	10	10a
1 (46)	American Lobster OD=F10%	B	Th	N	N	?	O	N	N	Y	Y	Remove the second paragraph of the OD as this clause is ambiguous and unmeasurable.
2 (50)	Long-finned squid OD= 3 yr average pre-recruit survey index below lower quartile	Th	N	Y	Y	R	OK	N	R	N	Y	Set a minimum biomass threshold on an annual basis and set a maximum F level.
3 (54)	Georges Bank Scallops OD=F5%	B	Th	Y	N	Uc	O	N	N?	Y	Y	Clarify ambiguity between the use of %SSB and %SPR.
4 (54)	Mid-Atlantic Scallops OD=F5%	B	Th	Y	N	Uc	O	N	N?	Y	Y	Clarify ambiguity between the use of %SSB and %SPR.
5 (54)	South Channel Scallops OD=F5%	B	Th	Y	N	Uc	O	N	N?	Y	Y	Clarify ambiguity between the use of %SSB and %SPR.
6 (54)	S. E. Georges Scallops OD=F5%	B	Th	Y	N	Uc	O	N	N?	Y	Y	Clarify ambiguity between the use of %SSB and %SPR.Use a more conservative SPR
7 (54)	Delmarva Scallops OD=F5%	B	Th	Y	N	Uc	O	N	N?	Y	Y	Clarify ambiguity between the use of %SSB and %SPR.
8 (67)	Atlantic Surf Clams OD= exceeding the annual quota	B	N	Y	N	Uc	OK	Y	R	N	Y	Specify biological criteria for protecting the stock in the OD including a minimum biomass threshold for a seed stock
9 (71)	Northwest Atlantic Mackerel OD= SSB<600,000 mt	Th	Th	Y	Y	Uc	UF	Y	C	Y	Y	Include a maximum F in addition to or instead of minimum biomass
10 (75)	Mid Atlantic Bight Summer Flounder OD=Fmax	Ta	N	Y	Y	Uc	UR	N	N	N	Y	Relate OD to spawning potential and recruitment rather than yield per recruit
11 (78)	Northern Silver Hake OD=F31%	B	Th	Y	N	R	O	N	N	Y	Y	Make definition a threshold, consistent for both stocks and specify how it should be updated.
12 (78)	Southern Silver Hake OD=F42%	B	Ta	Y	N	R	O	N	C	Y	Y	Same as Southern stock above.
13 (78)	Georges Bank - Gulf of Maine Am. Plaice OD=F20%	B	Th	Y	Y	Uc	O	N	N	Y	Y	Use a more conservative %SPR to rebuild.
14 (78)	Southern New England Yellowtail Flounder OD=F20%	B	Th	Y	Y	Uc	SO	N	N	Y	N	
15 (78)	Georges Bank Yellowtail Flounder OD=F20%	B	Th	Y	Y	Uc	O	N	N	Y	N	

	QUESTIONS	1	2	3	4	5	6	7	8	9	10	10a
16 (78)	Gulf of Maine Cod OD=F20%	B	Th	Y	Y	Uc	SO	N	C	Y	N	
17 (78)	Georges Bank Cod OD=F20%	B	Th	Y	Y	Uc	SO	N	C	Y	N	
18 (78)	Gulf of Maine-Georges Bank Redfish OD=F20%	N	N	Y	Y	?	SO	N	R	N	Y	Reduce F at low abundance and set a minimum biomass to preserve a seed stock.
19 (78)	Georges Bank Haddock OD=F30%	B	N	Y	Y	R	SO	N	R	N	Y	Set control law to reduce F at low stock abundance.
20 (103)	Wreckfish OD=F30%	B	Th	Y	Y	?	OK	N	?	Y	N	
21 (103)	South Atlantic Jewfish OD=F40%	B	Th	Y	Y	?	O	N	?	Y	Y	Be more conservative to account for sex reversal life history in OD
22 (103)	South Atlantic Red Porgy OD=F30%	B	Th	Y	Y	?	O	N	?	Y	Y	Be more conservative to account for sex reversal life history in OD
23 (110)	Caribbean Red Hind OD=F20%	Th	Th	Y	N	?	?	N	?	Y	Y	The decision rule is sensible but there is confusion between SPR and relative CPUE.
24 (113)	Caribbean Spiny Lobster OD=F20%	Th	Th	Y	N	?	?	N	?	Y	Y	Same as Red Hind
25 (116)	Brown Shrimp OD= <125 million spawners	Th	Th	Y	Y	?	OK	N	N	Y	Y	Formulate more flexible definition in relative units of biomass or maximum F.
26 (120)	Gulf of Mexico Red Snapper OD=F20%	Th	Th	Y	Y	?	SO	Y	N	Y	Y	Reduce F at low biomass and set milestones for a rebuilding program
27 (125)	Gulf of Mexico King Mackerel OD=F20%	Th	Th	Y	Y	?	UR	Y	N	Y	N	
28 (130)	Gulf of Mexico and South Atlantic Spiny Lobster OD=F5% and 3yrs declining recruitment	B	N	N	N	?	O	N	R	N	Y	Stock structure is unclear. F level is very high and 3 yrs of declining recruitment is too long a period

	QUESTIONS	1	2	3	4	5	6	7	8	9	10	10a
29 (134)	Sablefish OD=F20%	Th	Th	Y	Y	?	OK	Y	N	Y	N	
30 (134)	Dover sole , Columbia area OD=F20%	Th	Th	Y	Y	?	O	Y	N	Y	N	
31 (134)	Boccacio OD=F20%	Th	N	Y	Y	?	OK	Y	R	N	Y	Reduce F at low stock biomass or consider a low biomass threshold to preserve a seed stock
32 (134)	Pacific Ocean Perch OD=F20%	Th	N	Y	Y	R	O	Y	R	N	Y	Reduce F at low stock biomass or consider a low biomass threshold to preserve a seed stock
33 (134)	Canary Rockfish OD=F20%	Th	Th	Y	Y	?	OK	Y	N	Y	N	
34 (152)	Northern Anchovy OD= SSB < 50,000 MT for two consecutive seasons	Th	N	Y	Y	?	OK	Y	R	N	Y	There is a target control law which protects the stock but the OD is at a very low level.
35 (134)	Pacific Whiting OD=F20%	Th	N	Y	Y	?	OK	Y	R	N	Y	More conservative SPR
36 (156)	*Oregon Coastal Natural Coho Salmon OD=Failure to meet escapement goal of 200,000 for 3 consecutive years	B	Ta	Y	Y	R	O	N	C	N	Y	Tie OD to a distinct biological reference point as a threshold and clarify management actions if threshold crossed. Individual stocks may be overfished even if the aggregate is not.
37 (163)	Western Pacific Spiny Lobster OD=F20%	Th	Th	Y ·	Y	?	OK	N	?	Y	N	
38 (166)	Western Pacific Opakapaka OD=F20%	Th	Th	Y	N	?	OK	N	?	N	Y	Clarify ambiguity in the definition concerning SPR and CPUE. Use a tiered approach with different levels of information.
39 (172)	Eastern Bering Sea Pollock OD=Fmsy if B>Bmsy	B	Ta	Y	N	Uc	OK	Y	C	Y	Y	Set a threshold separate from the target and make explicit how it is determined which tier of the definition to use.
40 (172)	Eastern Bering Sea Cod OD=Fmsy if B>Bmsy	Th	Th	Y	N	Uc	OK	Y	C	Y	Y	Clarify the ambiguity in tier 2 between SSB and SPR and make explicit how it is determined which tier of the definition to use.
41 (181)	Gulf of Alaska Pollock OD=Fmsy if B>Bmsy	Th	Th	Y	N	Uc	OK	Y	N	Y	Y	Clarify the ambiguity in tier 2 between SSB and SPR and make explicit how it is determined which tier of the definition to use..

QUESTIONS	1	2	3	4	5	6	7	8	9	10	10a
42 (186) Eastern Bering Sea Red King Crab OD=Fmsy	Th	?	Y	N	Uc	OK	Y	N	N	Y	Link OD directly to SPR rather than YPR and consider trawl fishery impact.
43 (172) Eastern Bering Sea Yellowfin Sole OD=Fmsy if B>Bmsy	Th	Ta	Y	N	Uc	OK	Y	C	Y	Y	Clarify ambiguity in tier 2 between SSB and SPR and make explicit how it is determined which tier of the definition to use..
44 (191) Nushagak River Chinook Salmon OD=Failure to meet escapement goal of 65,000	B	Th	Y	N	Uc	OK	Y	N	Y	Y	Specify how escapement threshold is set to clarify ambiguity.
Summaries	45% Th	66% Th	95% Y	57% Y	14% R	39% OK	36% Y	64% N + C	70% Y	23% N	

Table 2: Secondary Stock Evaluations. Page numbers for detailed write-ups are given in parentheses in the first column. (Questions: 1, intended as; 2, appropriate as; 3, measurable?; 4, unambiguous?; 5, recruitment reduced?; 6, status of fishery; 7, linked to management?; 8, risky, neutral, or conservative; 9, sensible?; 10, can it be improved?; 10a, how to improve.)

		1	2	3	4	5	6	7	8	9	10	10a
45 (78)	Georges Bank-Gulf of Maine Witch Flounder OD=F20%	Ta	Th	Y	N	?	O	N	N	Y	N	Estimates of F are needed to compare with the OD to eliminate ambiguity
46 (78)	Georges Bank Winter Flounder OD=F20%	Ta	Th	Y	N	?	O	N	N	Y	N	Estimates of F needed to compare with the OD to eliminate ambiguity.
47 (78)	Southern New England Winter Flounder OD=F20%	Ta	Th	Y	N	?	O	N	N	Y	N	Estimates of F needed to compare with OD to eliminate ambiguity.
48 (67)	Ocean Quahogs OD= landings greater than annual quota	B	N	Y	N	?	OK	Y	R	N	Y	Include biological criteria and specify quota setting rule
49 (194)	Bluefish OD= Fmsy	B	Ta	Y	N	?	OK	N	C	Y	N	Estimates of F needed to compare with OD to eliminate ambiguity.
50 (78)	Gulf of Maine Haddock OD=F20%	Ta	N	N	N	?	SO	N	R	N	Y	Use a biomass threshold from the survey index since there is no analytical assessment.

		1	2	3	4	5	6	7	8	9	10	10a
51 (78)	Red Hake OD=3 yr average of survey index below lower quartile of time series	Th	Th	Y	Y	?	UF	N	N	Y	N	
52 (50)	Short-finned Squid OD= 3 yr average of pre-recruit survey index below lower quartile	Th	N	Y	Y	R	OK	N	R	N	Y	Set a minimum biomass threshold on an annual basis and set a maximum F level.
53 (195)	Butterfish OD= 3 yr average of survey index below lower quartile	Th	N	Y	Y	R	OK	N	R	N	Y	Set a minimum biomass threshold on an annual basis and set a maximum F level.
54 (78)	Ocean Pout OD= 3 yr average of survey index below lower quartile of time series	Th	Th	Y	Y	?	OK	N	N	Y	N	
55 (103)	Other South Atlantic Snapper Grouper and Reef fish OD=F30%	Th	Th	Y	Y	?	OK or O	N	?	Y	Y	Account for sex reversal life history pattern in developing OD
56 (125)	Spanish Mackerel OD=F20%	Ta	Th	Y	N	Uc	U	Y	N	Y	Y	Account for multiple spawning life history and clarify ambiguity between tiers of the OD.
57 (125)	Other SE Coastal Pelagics OD=F20%	Ta	Th	Y	N	Uc	?	Y	N	Y	Y	Clarify ambiguity between tiers of the OD.
58 (110)	Caribbean Reef Fish OD=F20%	Th	Th	?	N	?	?	N	?	Y	Y	The decision rule is sensible but there is confusion between SPR and relative CPUE.
59 (197)	Caribbean Corals OD=Landings > OY	Ta	Ta	Y	Y	?	OK	Y	C	Y	N	
60 (116)	Gulf of Mexico Pink Shrimp OD= <100 million spawners	Th	Th	Y	Y	?	OK	N	N	Y	Y	Formulate more flexible definition in relative units of biomass or maximum F.
61 (116)	Gulf of Mexico Royal Red Shrimp OD= Landings > OY	B	Ta	?	N	?	OK	N	C	Y	Y	Current definition more appropriate as a target
62 (120)	Gulf of Mexico Vermillion Snapper OD=F20%	Th	Th	Y	Y	?	OK	Y	N	Y	Y	Account for sex reversal life history pattern in developing OD.
63 (120)	Gulf of Mexico Other Snapper Groupers OD=F20%	Th	Th	Y	N	?	O	Y	N	Y	Y	The decision rule using relative abundance is sensible, but is not equivalent to SPR making the definition ambiguous. Account for sex reversal life history pattern in developing OD.
64 (120)	Gulf of Mexico Red Grouper OD=F20%	Th	Th	Y	Y	?	OK	Y	N	Y	Y	Account for sex reversal life history pattern in developing OD.
65 (134)	Lingcod OD=F20%	Th	Th	N	?	?	OK	?	N	Y	N	

		1	2	3	4	5	6	7	8	9	10	10a
66 (134)	Pacific Cod OD=F20%	Th	Th	N	?	?	OK	?	N	Y	N	
67 (134)	English Sole OD=F20%	Th	Th	Y	Y	?	OK	N	N	Y	N	
68 (134)	Petrale sole OD=F20%	Th	Th	Y	Y	?	OK	N	N	Y	N	
69 (134)	Widow Rockfish OD=F20%	Th	Th	Y	Y	?	OK	Y	R	N	Y	Use a more conservative SPR because of life history considerations.
70 (134)	Yellowtail Rockfish OD=F20%	Th	Th	Y	Y	?	OK	Y	R	N	Y	Use a more conservative SPR because of life history considerations.
71 (134)	Shortbelly Rockfish OD=F20%	Th	Th	?	Y	?	OK	Y	N	Y	N	No fishery.
·72 (134)	Chilipepper Rockfish OD=F20%	Th	Th	Y	Y	?	OK	Y	R	N	Y	Use a more conservative SPR because of life history considerations.
73 (156)	Sacramento River fall Chinook OD=Failure to meet escapement goal of 122,000-180,000 spawners for 3 yrs.	B	Ta	Y	Y	?	O	N	?	N	Y	Tie OD to a distinct biological reference point as a threshold and clarify management actions if threshold crossed.
74 (156)	Klamath River Fall Chinook OD= Failure to meet escapement goal of 35,000 spawners for 3 yrs.	B	Ta	Y	Y	R	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
75 (156)	Other CA Coastal Chinook OD= variable spawner goal.	?	?	N	Y	?	?	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
76 (156)	OR Coastal Chinook OD=Failure to meet escapement goal of 150,000-200,000 spawners for 3 yrs.	B	Ta	N	Y	Uc	?	N	C	N	Y	Same as # 73 Sacramento fall Chinook.
77 (156)	Columbia River Upriver Fall Chinook OD=Failure to meet escapement goal of 40,000 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
78 (156)	Columbia River Upriver Summer Chinook OD=Failure to meet escapement goal of 80,000-90,000 spawners for 3 yrs.	B	Ta	Y	Y	?	O	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
79 (156)	Columbia River Upriver Spring Chinook OD=Failure to meet escapement goal of 115,000 spawners for 3 yrs.	B	Ta	Y	Y	?	O	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
80 (156)	Columbia River Lower Fall Hatchery Chinook OD = variable spawner goal.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
81 (156)	Columbia Lower River Fall Wild Chinook OD=variable spawner goal.	?	?	Y	Y	?	?	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
82 (156)	Columbia Lower River Spring Chinook OD=Failure to meet escapement goal of 30,000-45,000 spawners for 3 yrs	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.

		1	2	3	4	5	6	7	8	9	10	10a
83 (156)	*WA Coast Fall Chinook OD=Failure to meet escapement goal of 29,800 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
84 (156)	*WA Coast Spring and Summer Chinook OD=Failure to meet escapement goal of 4,500 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
85 (156)	*Puget Sound Summer and Fall Chinook OD=Failure to meet escapement goal of 74,500 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
86 (156)	Columbia River Coho OD= variable goal	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
87 (156)	OR Coast Coho OD=Failure to meet escapement goal of 135,000-200,000 spawners for 3 yrs.	B	Ta	Y	Y	Uc	O	N	C	N	Y	Same as # 73 Sacramento fall Chinook.
88 (156)	WA Coast Wild Coho OD=Failure to meet escapement goal of 49,500-70,700 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
89 (156)	WA Coast Hatchery Coho OD=variable spawner goal.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
90 (156)	Puget Sound Coho OD=Failure to meet escapement goal of 150,800 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
91 (156)	Lake Washington Sockeye OD=Failure to meet escapement goal of 300,000 spawners for 3 yrs.	B	Ta	N	Y	?	?	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
92 (156)	Columbia River Sockeye OD=Failure to meet escapement goal of 65,000 spawners for 3 yrs.	B	Ta	N	Y	?	?	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
93 (156)	Puget Sound Pink Salmon Odd Year OD=Failure to meet escapement goal of 900,000 spawners for 3 yrs.	B	Ta	Y	Y	?	OK	N	?	N	Y	Same as # 73 Sacramento fall Chinook.
94 (166)	Other Western Pacific Bottom and Seamount Groundfish OD=F20%	Th	Th	N	N	?	O or OK	N	?	N	Y	Clarify ambiguity in the definition concerning SPR and CPUE.
95 (198)	Western Pacific Corals OD= 20% unfished stock	Th	Th	Y	N	?	U	Y	N	Y	Y	Check more species and sites.
96 (200)	Western Pacific Tunas OD=F20%	Th	Th	Y	N	?	OK	N	?	Y	N	
97 (172)	Eastern Bering Sea Greenland Turbot OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Clarify ambiguity in tier 2 between SSB and SPR and make explicit how it is determined which tier of the definition to use.
98 (172)	Eastern Bering Sea Arrowtooth Flounder OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.

		1	2	3	4	5	6	7	8	9	10	10a
99 (172)	Eastern Bering Sea Rock Sole OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
100 (172)	Eastern Bering sea Other Flatfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
101 (172)	Eastern Bering Sea Pacific Ocean Perch OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
102 (172)	Eastern Bering Sea Other Rockfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
103 (172)	Eastern Bering Sea Atka mackerel OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
104 (172)	Eastern Bering Sea Squid OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
105 (172)	Eastern Bering Sea Other Groundfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
106 (181)	Gulf of Alaska Deep Water Flatfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
107 (181)	Gulf of Alaska Shallow Water Flatfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
108 (181)	Gulf of Alaska Arrowtooth Flounder OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
109 (181)	Gulf of Alaska Flathead Sole OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
110 (181)	Gulf of Alaska Slope Rockfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
111 (181)	Gulf of Alaska Pelagic Shelf Rockfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
112 (181)	Gulf of Alaska Demersal Shelf Rockfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
113 (181)	Gulf of Alaska Thornyhead Rockfish OD=F30%	Th	Th	Y	N	?	OK	Y	C	Y	Y	Same as #97 EBS turbot.
114 (186)	Eastern Bering Sea Tanner Crab OD=Fmsy	Th	?	Y	Y	?	OK	Y	?	N	Y	Link OD directly to SPR rather than YPR and consider trawl fishery impact.
115 (181)	Gulf of Alaska Cod OD=F30%	Th	Th	Y	N	?	OK	Y	N	Y	Y	Same as #97 EBS turbot.
116 (181)	Sablefish OD=F30%	Th	Th	Y	N	?	OK	Y	N	Y	Y	Same as #97 EBS turbot.
117 (190)	Alaska Salmons OD=persistent failure to meet escapement target	Ta	Ta	Y	N	?	OK	Y	C	Y	Y	Clarify basis for setting escapement goals to remove ambiguity.
Summaries		56% Th	59% Th	85% Y	51% Y	4% R	74% OK	45% Y	57% N, C	59% Y	18% N	

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* aggregate of several substocks with individual escapement goals. Some sub-stocks may be overfished, even if the aggregate is not.

Conclusions and Recommendations

The Review Panel concluded that the majority of the definitions are biologically sensible and, if adhered to as thresholds beyond which strong conservation measures are taken, should protect the stocks. An important problem that needs to be addressed for many of the definitions is the linkage to management action. This linkage needs to be made explicit for each overfishing definition to ensure that it will in fact protect against recruitment overfishing. When developing an overfishing definition, the FMC's and NMFS should consider the time it may take a stock to recover should the threshold be exceeded, because this has implications for the types of management action that need to be specified. It is most important that such actions be specified prior to the stock being overfished, so that recovery to a healthy condition can occur as rapidly as possible.

The Panel identified several definitions that are inherently risky and basically ill-conceived. These OD's should be revised as soon as possible in upcoming FMP amendments. In most cases, the definitions are risky because insufficient attention has been paid to the basic life history features of the species under management. In other cases, there is ambiguity in the definition itself which may mean that the stock is not protected because the threshold itself is insufficiently specified. Definitions for which a judgement as to relative riskiness is not possible should be reconsidered as well. For stocks where no biological information is available, little improvement may be possible until further data can be collect. However, relating the OD to a known reference point should be possible for most stocks.

The majority of the overfishing definitions specified as %SPR were chosen by analogy with other stocks. This is not inappropriate, but the analogy should be checked carefully whenever possible by examining the available population dynamics data. In this review, the Panel attempted to consider all readily available data, but more in-depth studies for each stock would be advisable to verify that the OD chosen by analogy is appropriate.

None of the definitions explicitly refer to uncertainty in either the reference point itself or in estimates of current stock or fishery status. In the future, the decision rule used to decide whether a stock is overfished should be made explicit. In other words, what probability that the stock has crossed the OD threshold will trigger agreed management actions? The answer to this question will help clarify whether OD's are, in fact, conservative.

Overfishing definitions should include a fishing mortality rate threshold to control the fishery. Where practical, an OD should also include a precautionary biomass level, below which fishing mortality is

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gradually reduced, to give further protection if the stock is depleted. Furthermore, an absolute minimum biomass threshold, below which the fishery is closed or reduced to bycatch only may be used as a component of the definition. The Panel agreed that these biomass thresholds should not be overly restrictive such that long term yield is needlessly reduced, and that in the absence of good data on a range of stock abundances, they should be set at low levels as a safeguard or to preserve a seed stock if the resource is severely depleted.

In the future, as the overfishing definitions evolve, more account must be taken of life history feature such as spatial distribution, the characteristics of the reproductive stock and the nature of the variability in recruitment. This will require additional data and research, but is needed to protect the stocks.

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Section IV: Findings for Specific Definitions

Management unit - East Coast American Lobster (#1)

Species/stocks:

    1. American lobster (*Homarus americanus*)

FMP/Amendment Defining Overfishing: Amendment 5 to the American Lobster Fishery Management Plan (New England Fishery Management Council).

Overfishing Definition:

"The American lobster resource is considered recruitment overfished when, throughout its range,the fishing mortality rate (F), given the regulations in place at the time under the suite of regional management measures, results in a reduction in estimated egg production per recruit of less to 10% or less of a non-fished population."

"The development of the status of the stock report and the evaluation of fishery induced effects will consider information based upon one or more indices including but not limited to: a) Larval abundance index in surface waters; b) larval settlement index (the relative success of each new yearclass in reaching the benthos); c) pre-recruit indices by year-class; d) landings; e) size composition of the landings; f) spawning stock biomass; g) numbers of egg-bearing females; h) effort levels and catch-per-unit-of-effort; and i) possible development of relationships of biological parameters to water temperatures or other environmental parameters."

Assessment Method and Decision Rule:

Modified DeLury estimators are based on pre-recruit and recruit survey indices and landings by region, and provide estimates of F and biomass contingent on assumptions about relative catchability of pre-recruits and recruits, and emigration patterns. For the first clause of the definition, overfishing occurs when EPR is 10% or less of an unfished stock as determined by the estimated fishing mortality rate for the stock. For the second clause of the definition it is unclear what decision rule is implied.

Relevant Life History Features:

American lobsters are distributed coastally in rock areas or occasionally buried in mud, and are distributed offshore in submarine canyons. Offshore segments of the population may contribute larvae to the coastal region. Because growth and maturation rates are distinctly different between regions, separate analyses have been made for lobsters in the Gulf of Maine (coastal), Georges Bank (offshore), and Southern Cape Cod - Long Island Sound

(coastal). Exchange between these areas is documented by tagging studies, but estimates of emigration and immigration rates are not available. Semi-discrete stock units may exist in separate southern canyon areas. The DeLury estimates require assumptions about relative catchability of pre-recruit and recruited components of the population to trawl surveys, and assume no new immigration or emigration of either segment of the population.

Revised eggs-per-recruit analyses reflect alternative levels of v-notching (voluntary return of large egg-bearing females by fishermen), the use of maximum size limits, and restrictions on landings of berried females. Recruitment occurs over a range of five ages (ages 5-9), making estimation of total year-class strength from a year's spawning stock biomass problematic. Analyses are primarily length-based, rather than age-based.

Evaluation of Overfishing Definition:

The first clause of the overfishing definition, which was largely contained in Amendment 4 to the FMP, is judged to be neutral, on the basis of analogy with other stocks, although stock-recruit data for crustaceans are sparse. Direct observations of realized eggs-per-recruit are not possible with current data and analyses though recent estimates of fishing mortality rate have been made to compare with the overfishing definition.

The second clause of the definition lists several types of biological data or processes, but it is ambiguous how these relate to overfishing and there are no specified, measurable criteria accompanying these indices which relate them to overfishing. The definition could be clarified by reverting to the previous version from Amendment 4 which includes only the 10% EPR criterion. The various indices contained in the second clause may be interesting from a research perspective for further study, but do not provide any clear guidance for defining overfishing.

Assessment Background Papers:

Fogarty, M.J. and J.S. Idoine. 1988. Application of a yield and egg production model based on size to an offshore American lobster population. Trans. Amer. Fish. Soc. 117:350-362.

NEFSC 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop (14th SAW). Northeast Fisheries Science Center Reference Document 92-07.

NEFSC 1993. Report of the Sixteenth Northeast Regional Stock Assessment Workshop (16th SAW). Northeast Fisheries Science Center Reference Document 93-18.

American Lobster: Trends in Landings, Biomass; Stock and Recruitment by Region
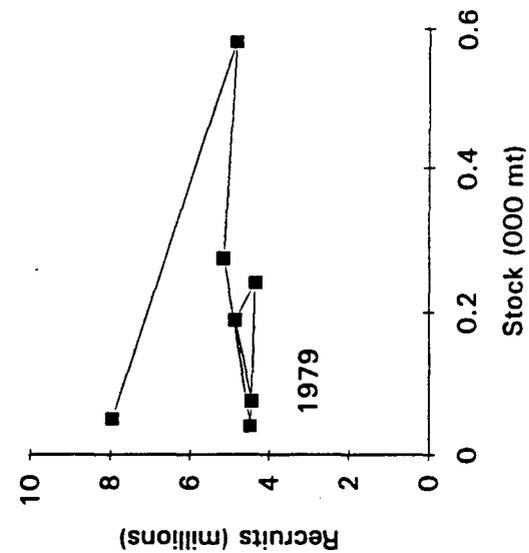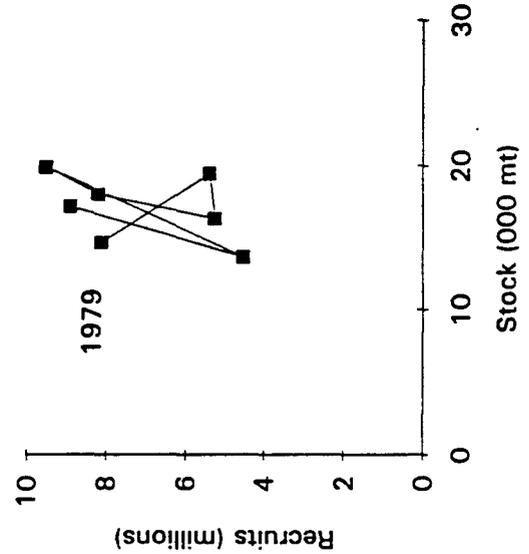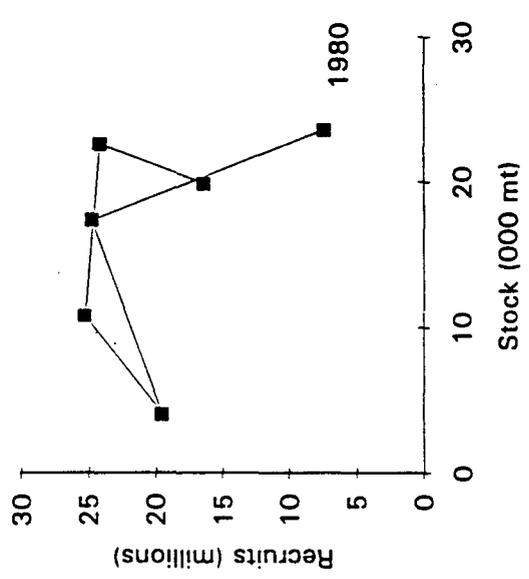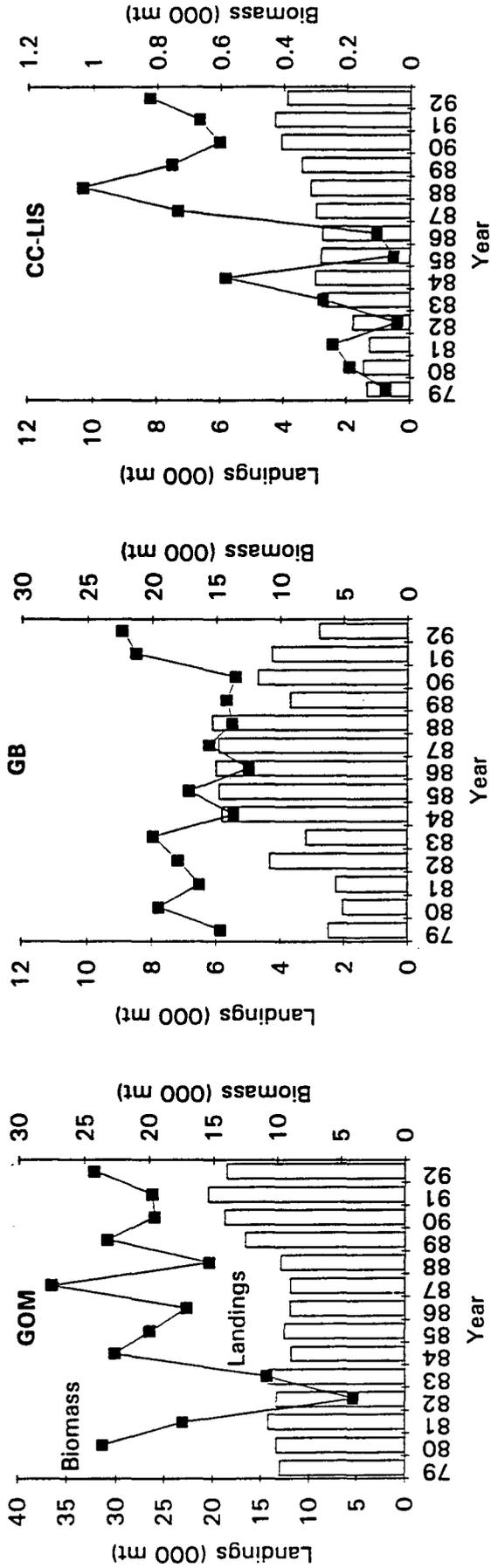
GOM = Gulf of Maine, GB = Georges Bank, CC-LIS = Cape Cod- Long Island Sound.   Biomass = fully-recruited stock, recruits =   smallest size class in stock, both as of 1 Oct.

American Lobster: SSB/R, Y/R; Control Law and Historic Performance
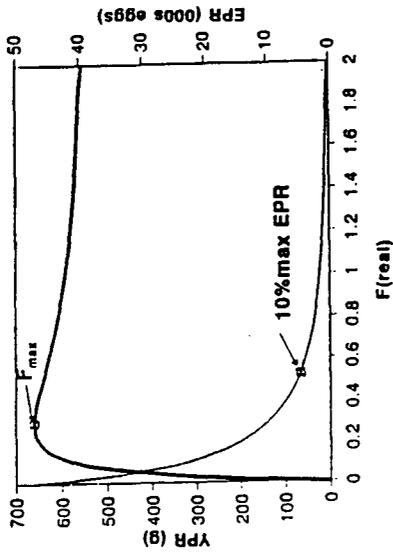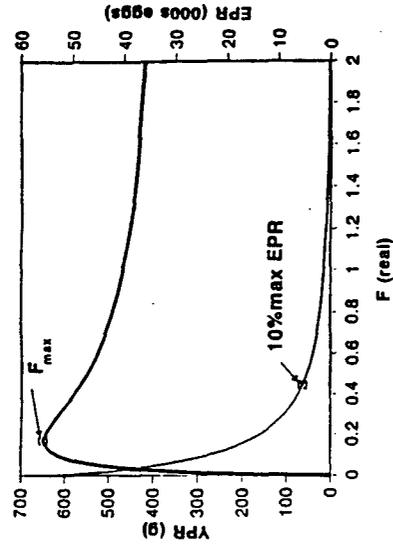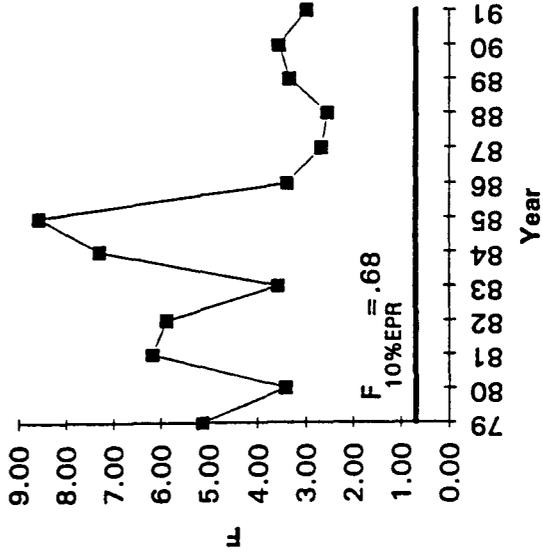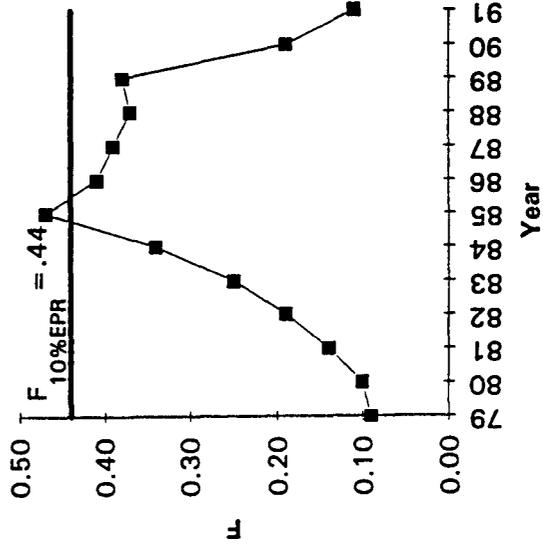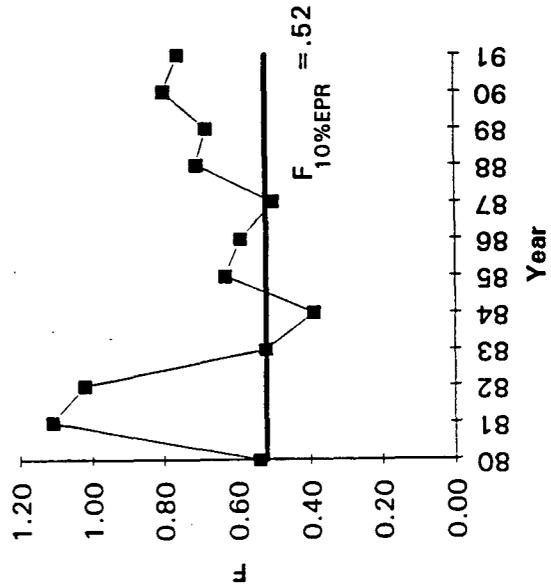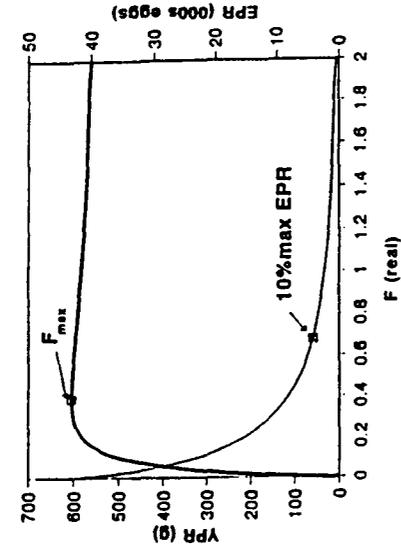
GOM = Gulf of Maine, GB = Georges Bank, CC-LIS = Cape Cod- Long Island Sound. Biomass = fully-recruited stock, recruits = smallest size class in stock, both as of 1 Oct.

Management unit - Mid-Atlantic Squid (#2, 52)

Species/stocks:

    2. Long-finned squid (*Loligo pealei*)
    52. Short-finned squid (*Illex illecebrosus*)

FMP/Amendment Defining Overfishing: Amendment 3 to the Fishery Management Plan for Atlantic Mackerel, Squid and Butterfish Fisheries (Mid-Atlantic Fishery Management Council).

Overfishing Definition:

    Loligo pealei

"For purposes of meeting the 602 Guidelines, overfishing for *Loligo pealei* is defined as occurring when the three year moving average of pre-recruits from the Northeast Fisheries Science Center's autumn bottom trawl survey (mid-Atlantic to Georges Bank) falls within the lowest quartile of the time series (1968 to present)." (p. 3)

    Illex illecebrosus

"For purposes of meeting the 602 Guidelines, overfishing for *Illex illecebrosus* is defined as occurring when the three year moving average of pre-recruits from the Northeast Fisheries Science Center's autumn bottom trawl survey (mid-Atlantic to Georges Bank) falls within the lowest quartile of the time series (1968 to present)." (p. 3)

Assessment Method and Decision Rule:

Yield- and spawning-stock-biomass-per-recruit models (incremented monthly) have been developed for long-finned squid. Stocks are assessed by monitoring indices of abundance from research surveys and commercial landings per unit effort.

Overfishing is indicated when the three-year moving average of pre-recruits from the Northeast Fisheries Science Center's autumn bottom trawl survey (mid-Atlantic to Georges Bank) falls in the lowest quartile of the time series (1968 - present).

Relevant Life History Features:

The lifespan of long-finned squid may be less than one year, based on recent research using daily growth increments of statoliths. One spawning event occurs in the early spring (March-April); back-calculated estimates of dates of hatching also indicate spawning in early winter (December). Autumn survey indices split into length groups (pre-recruit, recruit) reflect results of spring spawning (pre-recruit) and adult abundance (recruit). (The latter is

correlated with recruit abundance from a spring survey index.)

The lifespan of short-finned squids may likewise be less than one year, again, based on recent research using daily growth increments of statoliths. Much of the stock is distributed outside U.S. waters.

Development of stock-recruitment relationships for both species (i.e., superimposition of reference F levels as R/SSB) from available survey data is problematic, as survey catchability appears to be size-specific.

Evaluation of Overfishing Definitions:

Especially in light of the short lifespan of these species, potentially as short as 1 year, an overfishing definition based on the lowest quartile of 3-year running average of pre-recruit indices is highly risky. Catastrophic (pre-)recruitment failure in 1 year, followed by collapse of resulting spawning stock before the second year, could conceivably still lead to the stocks' not being designated as overfished. As well, by basing the quartile on all observations to date, the definition could allow a decline in the threshold recruitment level over time.

The definition could be improved by making the timeframe to observe/determine potential overfishing consistent with the lifespan of the species. Evaluations throughout a year (cohort lifespan), based on research surveys and commercial fishery indices and the uncertainty associated with those indices, could provide a more accurate basis for defining overfishing and determining overfishing status. A better approach is to set a minimum biomass threshold and a maximum harvest rate which applies within each fishing year. This would require real time monitoring.

Assessment Background Papers:

Brodziak, J. 1993 MS. Stock assessment for long-finned squid, *Loligo pealei*, in the Northwest Atlantic during 1992. Northeast Fisheries Science Center, Woods Hole, MA 02543.

NEFSC 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop (14th SAW). Northeast Fisheries Science Center Reference Document 92-07.

NEFSC 1994 (In prep.). Report of the Seventeenth Northeast Regional Stock Assessment Workshop (17th SAW). Northeast Fisheries Science Center Reference Document.

Long-finned squid *(Loligo pealei)*: Trends in Landings, Abundance; Stock and Recruitment
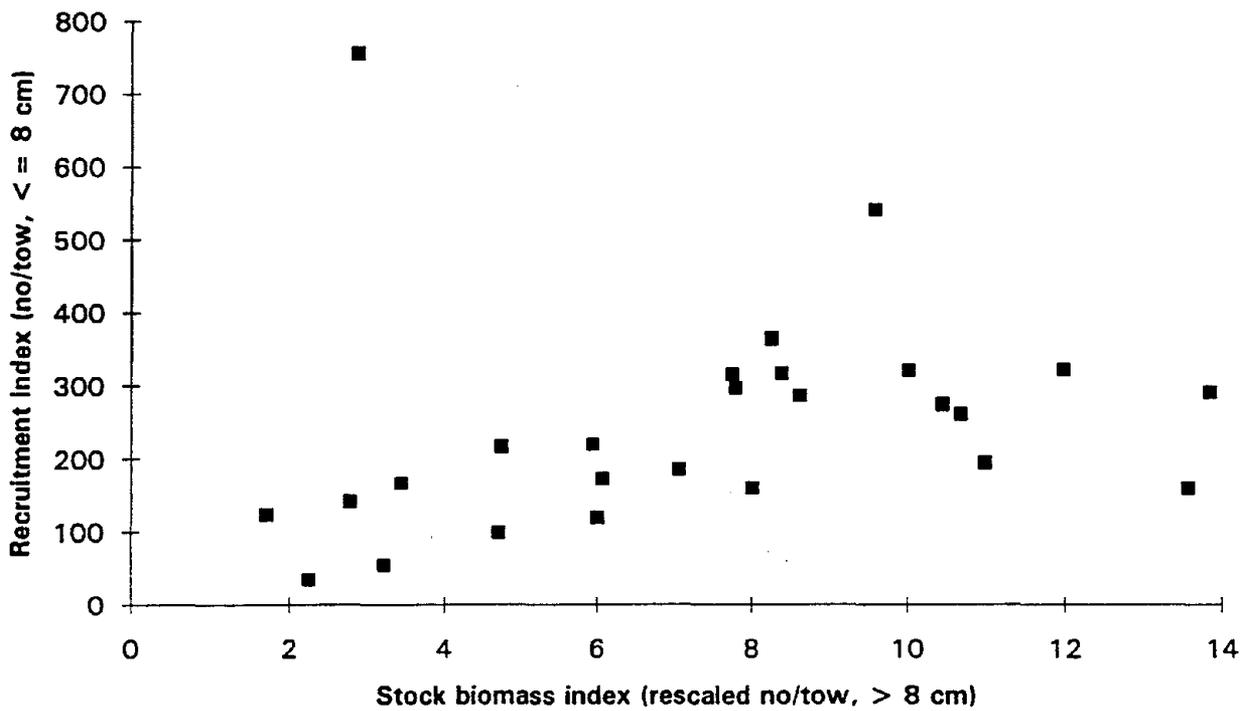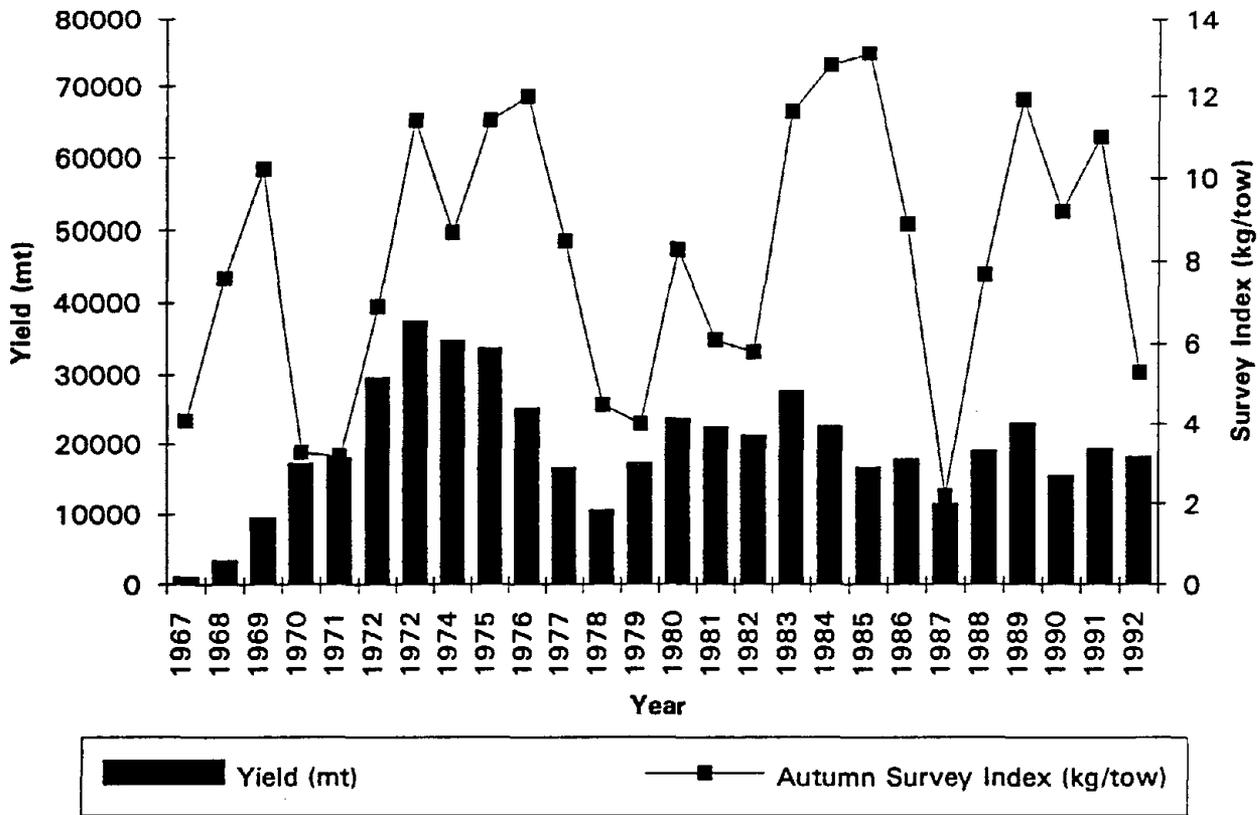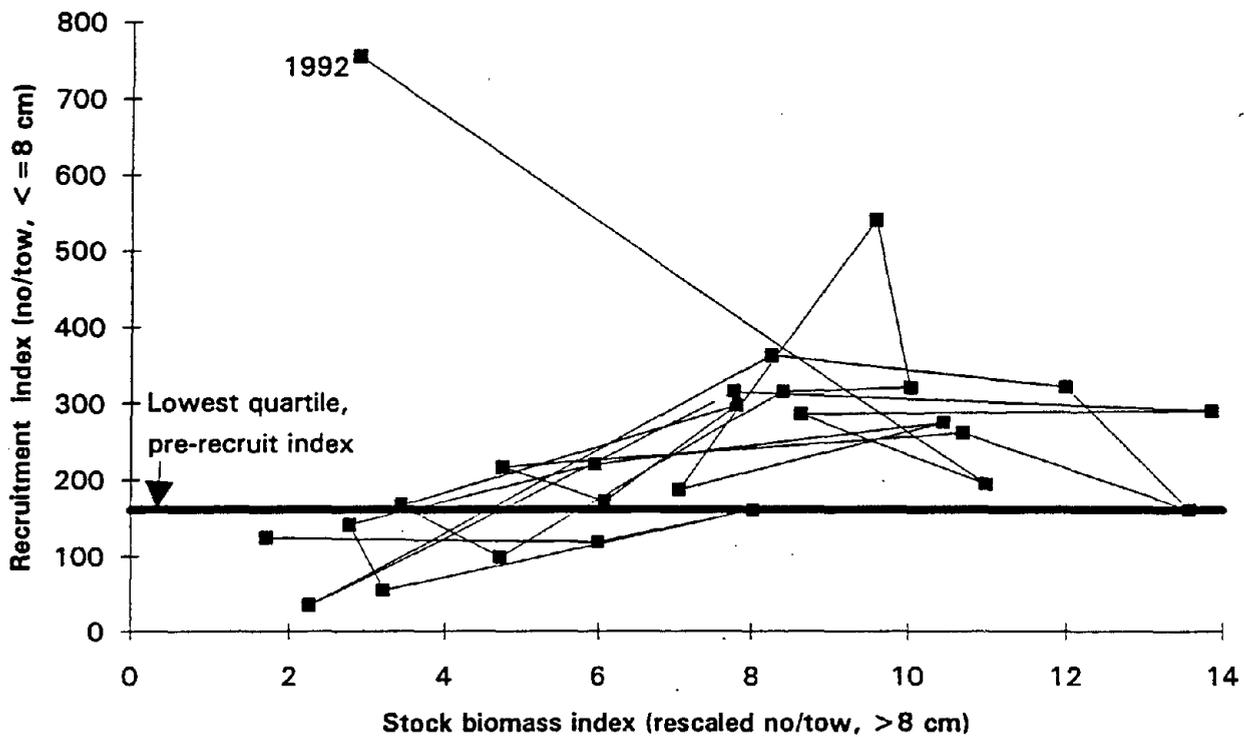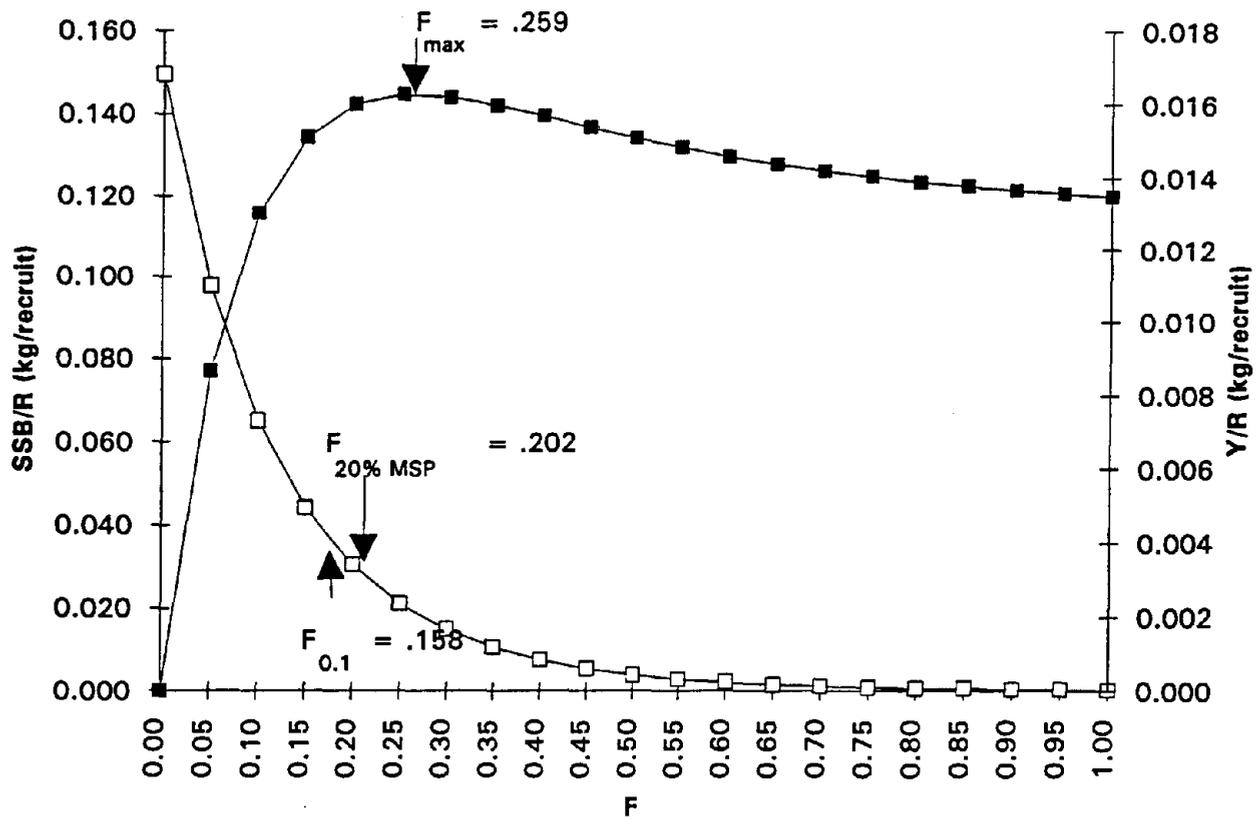
Management unit: **Atlantic Sea Scallops (# 3-7)**

Species/stocks:

   3. Georges Bank scallops (*Placopecten magellanicus*)
   4. Mid-Atlantic scallops (*Placopecten magellanicus*)
   5. South Channel scallops (*Placopecten magellanicus*)
   6. S. E. Georges Scallops (*Placopecten magellanicus*)
   7. Delmarva scallops (*Placopecten magellanicus*)

FMP/Amendment Defining Overfishing: Amendment 4 to the Fishery Management Plan for Atlantic Sea Scallops (New England Fishery Management Council).

Overfishing Definition:

" Overfishing is defined as a fishing mortality rate that, if continued, results in a spawning stock biomass of five percent of the maximum spawning potential. The corresponding target fishing mortality (F) will be calculated as a level that will result in a 5%MSP under equilibrium conditions."

"The MSP threshold may be adjusted as additional biological evidence becomes available. to make changes to the MSP level, the updated targets will be reviewed by the Scallop Plan Development Team, and approved by the Scallop Committee and Council."

Assessment Method and Decision Rule:

The Scallop Plan notes: "The fishing mortality rate that estimates the current level of fishing on all stocks is defined as the average mortality on fully recruited age classes weighted by the relative number of scallops within each stock. When age-structured assessments are not available for individual stocks, current fishing mortality estimates from other sources, such as changes in fishing effort or survey based data will be used."

Until recently, there was no rigorous assessment of Atlantic sea scallops, although annual reports containing detailed research survey and commercial data (e.g., research survey indices, commercial CPUE) were produced. In 1990-91, NEFMC staff used the research survey data to construct preliminary S-R relationships and estimate replacement levels of %SPR. In 1991-92, the NEFSC SAW began to assess scallops using a modified DeLury model that produces separate stock size and fishing mortality estimates for new recruits (age 3) and full recruits (ages 4+). The advantages of the former approach are that it includes the entire resource (the latter has only considered the South Channel and southeast parts of Georges Bank and the Delmarva area of the Mid-Atlantic) and uses a longer time series of data (the latter approach results in only seven S-R observations); the advantages of the latter approach are that it provides a more rigorous treatment of the data, including estimates of fishing mortality rates, and it is more up to date. Both sets of analyses were considered here.

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Relevant Life History Features:

Atlantic sea scallops are found in western North Atlantic continental shelf waters from Newfoundland to North Carolina. Principal U.S. commercial fisheries are conducted in the Gulf of Maine, on Georges Bank, and in the Mid-Atlantic offshore region. Scallops grow rapidly during the first few years of life, maturing at ages 2-4, and have extremely high fecundity. Larvae remain in the water column for 4-6 weeks before settling to the bottom.

Evaluation of Overfishing Definition:

The fishing mortality rate corresponding to a threshold of 5% SPR is below the current F-replacement (based on the median of the S-R observations) for all assessments and stock components examined, except for the stock component on the southeast part of Georges Bank. In the latter case, the median replacement level corresponds to a %SPR of 10.7%; however, this analysis was based on only seven observations and since scallops are managed as a unit stock, it is not practical or desirable to have a separate definition for one particular stock component. In all cases, the 5% SPR threshold corresponds to a lower fishing mortality than either F_r or the F associated with the maximum observed R/S, however, the available time series of data are quite short.

Existing data support the use of a 5% SPR threshold as neutrally conservative. The short time series of data from a period of heavy exploitation was cause for concern and the Panel noted that it is difficult to conclude the definition will be neutral without additional data. The overfishing definition could be improved with re-wording. First, the definition uses the terms "spawning stock biomass" and "% MSP" interchangeably; this is not reasonable unless recruitment is independent of stock size over the entire range of stock sizes and results in some ambiguity. The intent seems to be to use a reference point based on spawning biomass per recruit (termed % MSP in New England), not spawning biomass. Second, the definition mixes thresholds and targets -- an overfishing threshold should not also be a target. The yield per recruit curves suggest that a target of $F_{5\%}$ will result in considerable losses in yield. The word "target" in the first paragraph should be replaced by the word "threshold".

Data Sources:

Conser, R.J. 1991. A DeLury model for scallops incorporating length-based selectivity of the recruiting year-class to the survey gear and partial recruitment to the commercial fishery. Res. Doc. 2, 12th SAW, NEFSC.

Dan Hayes, pers. comm. Northeast Fisheries Science Center.

Mace, P.M., H. Russell and P. Kurkul. MS1990. Report of the ad hoc working group on sea scallop overfishing. Manuscript held by NEFMC, Saugus, MA.

Mace, P.M. MS1991. Re-evaluation of Atlantic sea scallop overfishing definitions.

Manuscript held by NEFMC, Saugus, MA.

NEFSC 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop (14th SAW). Northeast Fisheries Science Center Reference Document 92-07.

NEFSC MS1992. Report of the Workshop on Consensus Assessments for Atlantic Sea Scallops. Unpublished SAW Report, July 1992, NEFSC.

Wigley, S.E. and F.M. Serchuk. 1992. Status of the sea scallop fisheries off the Northeastern United States, 1991. Working Paper 11, 14th SAW, NEFSC.

Wigley, S.E., F.M. Serchuk and N.G. Buxton. 1992. Current resource conditions in USA Georges Bank and Mid-Atlantic sea scallop populations: results of the 1991 NEFSC sea scallop research vessel survey. Working Paper 14, 14th SAW, NEFSC.
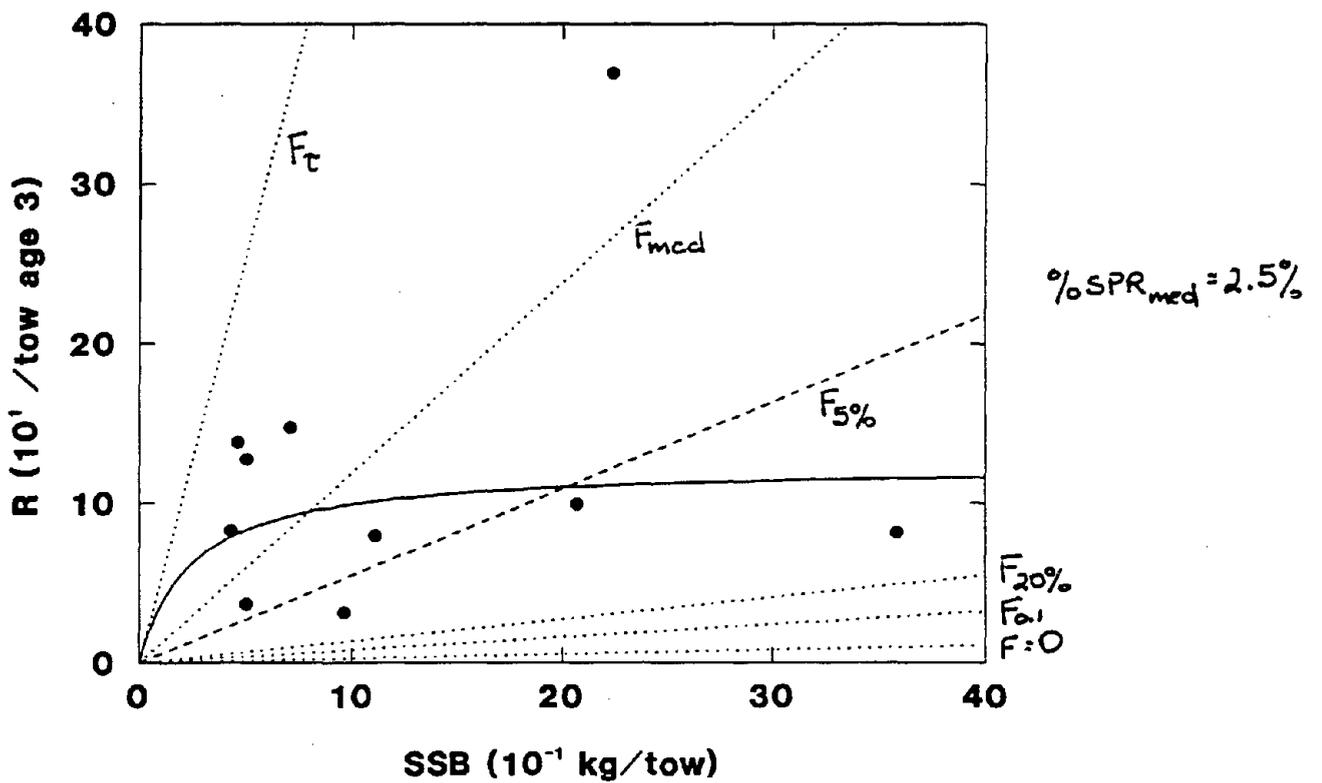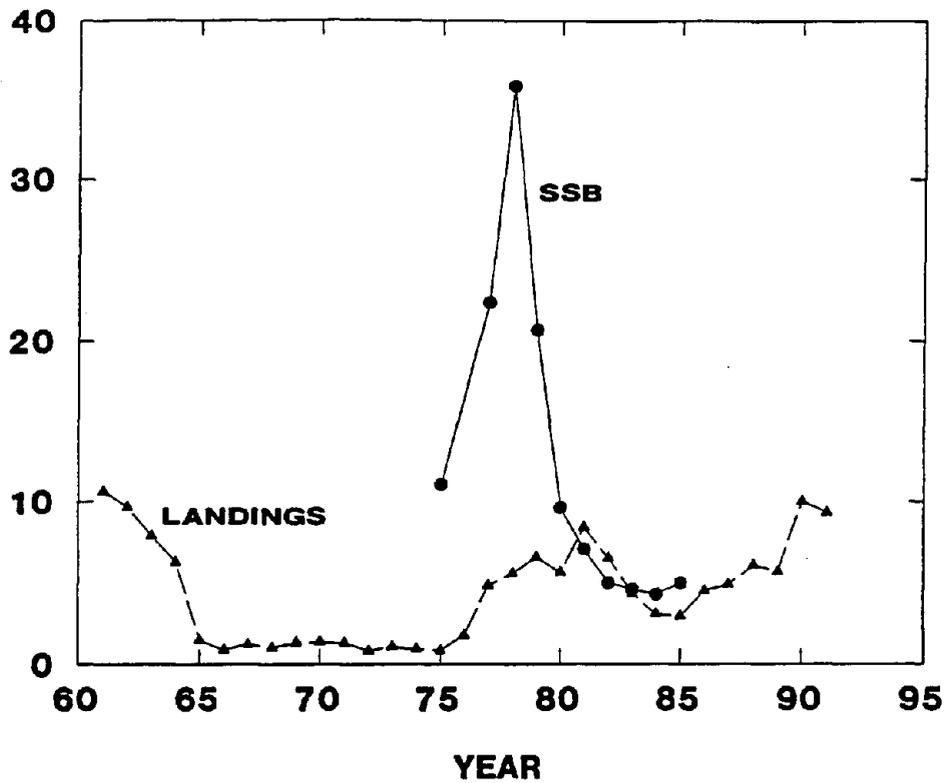
Georges Bank scallops. A. SSB (10⁻¹ kg/tow) and landings ('000t);
B. S-R relationship with Shepherd model fit (solid line),
overfishing definition (heavy broken line), and other reference
fishing mortality rates.
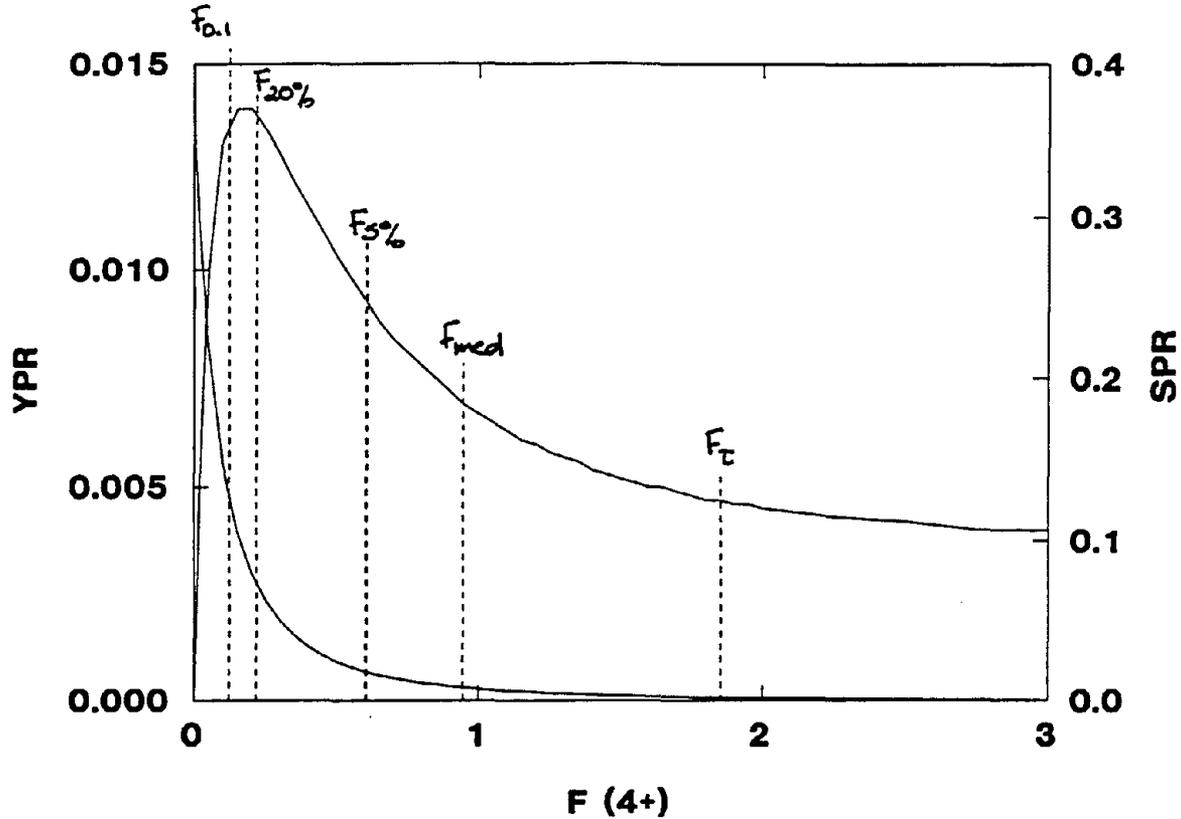
Georges Bank scallops A. YPR (kg) and SPR (kg).
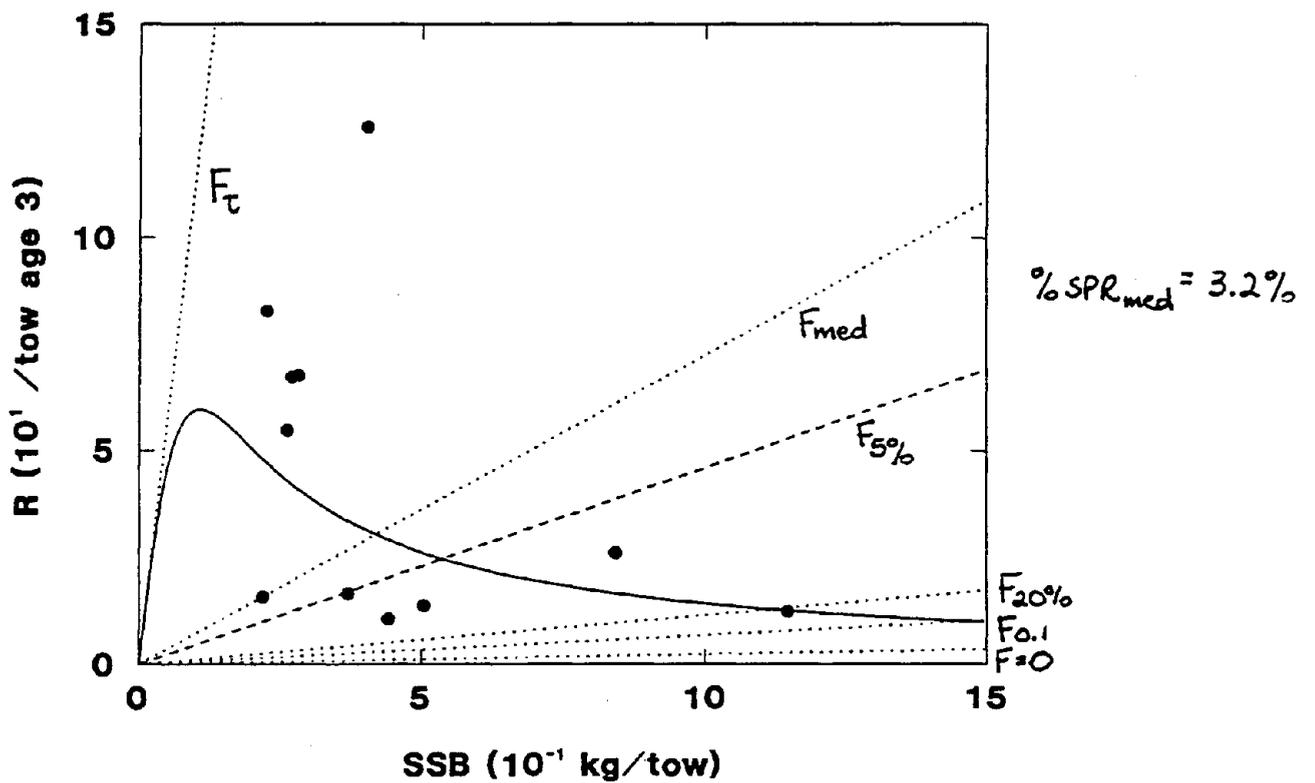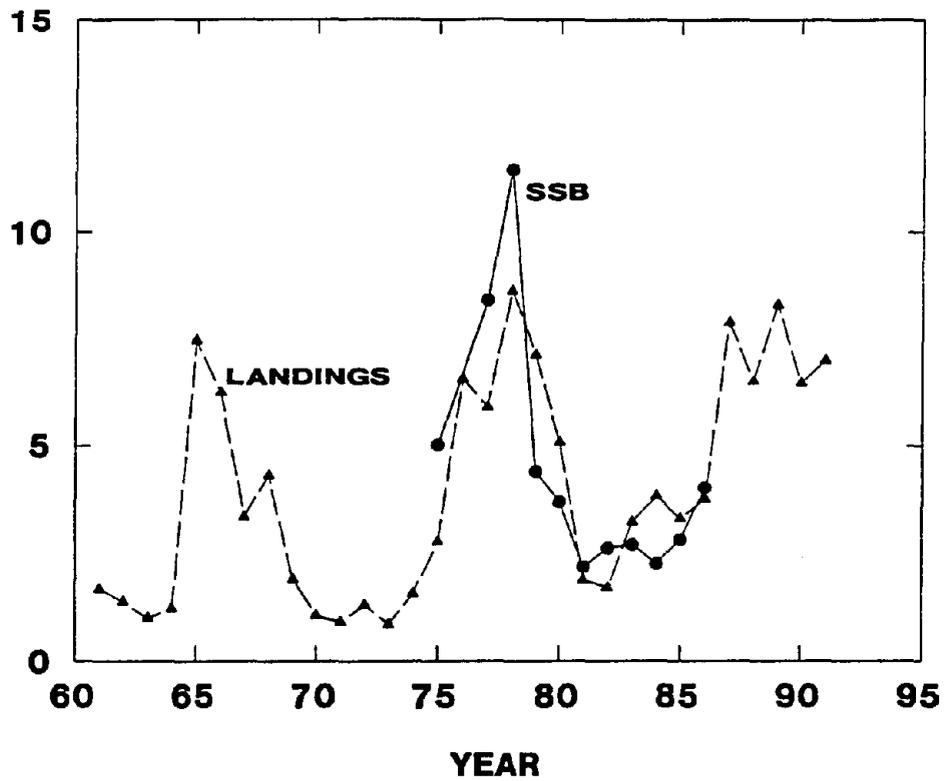
Mid-Atlantic scallops. A. SSB (10^{-1} kg/tow) and landings ('000t):
B. S-R relationship with Shepherd model fit (solid line),
overfishing definition (heavy broken line), and other reference
fishing mortality rates.
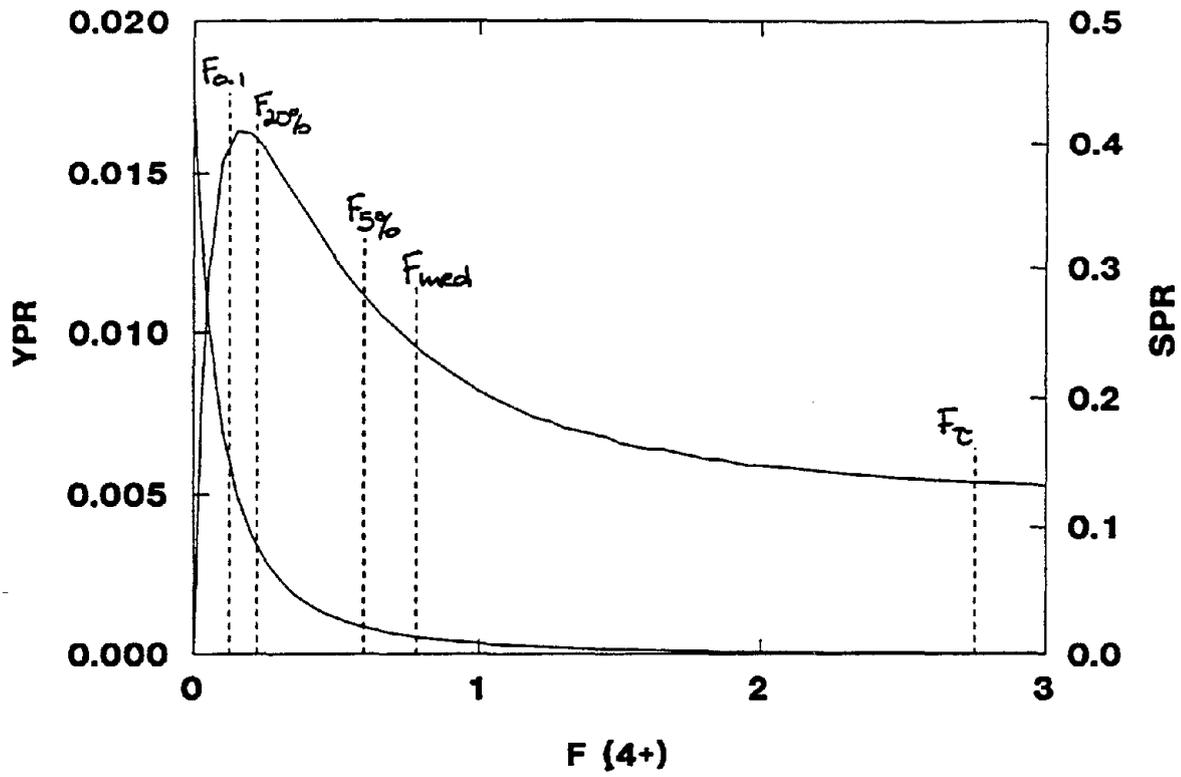
Mid-Atlantic scallops A. YPR (kg) and SPR (kg).
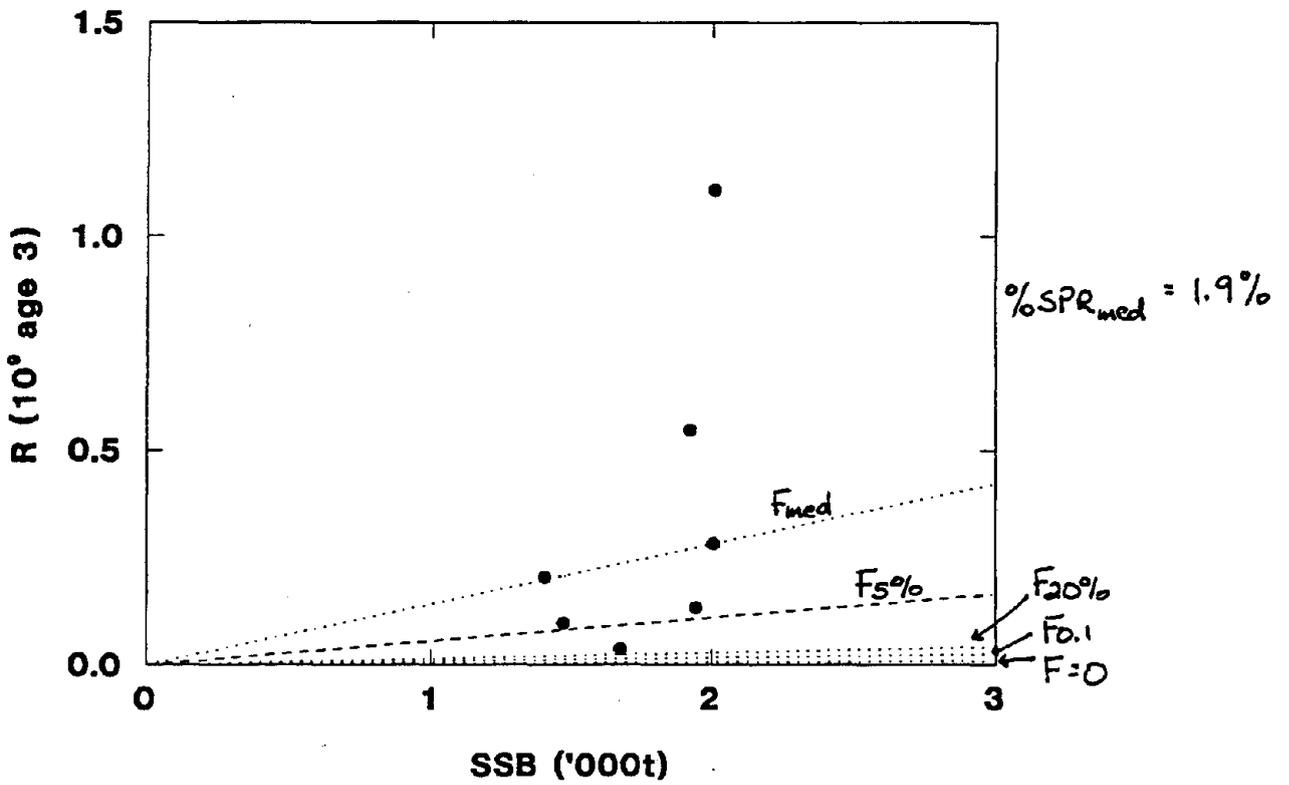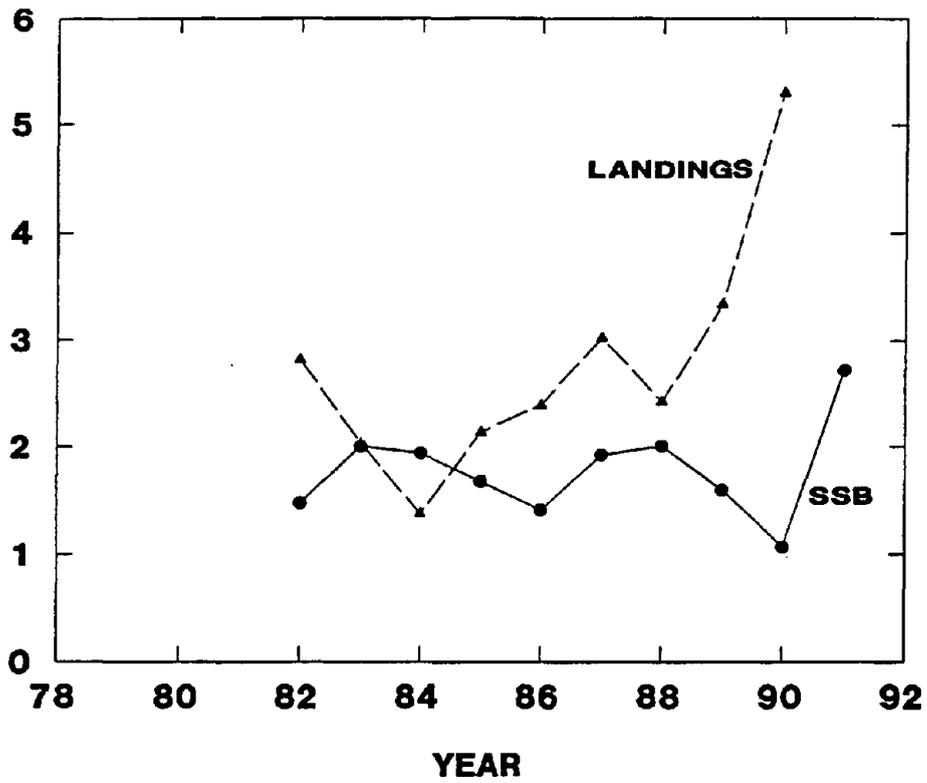
South Channel Georges Bank scallops. A. SSB ('000t) and landings ('000t);
B. S-R scatterplot with overfishing definition (heavy
broken line), and other reference fishing mortality rates.
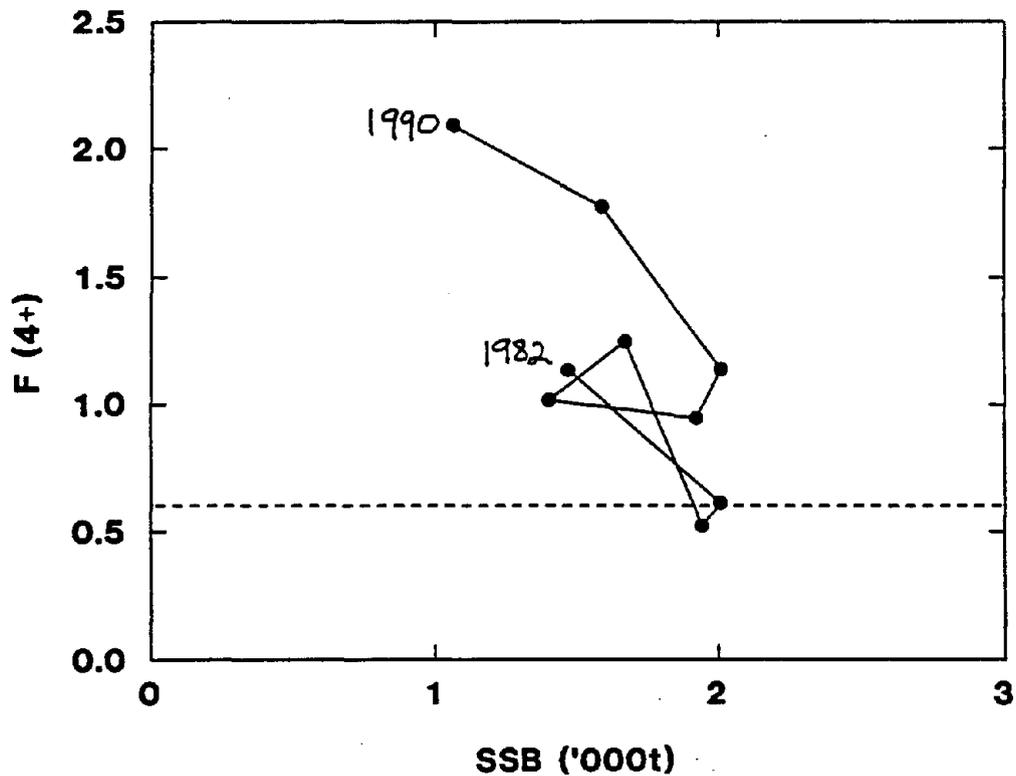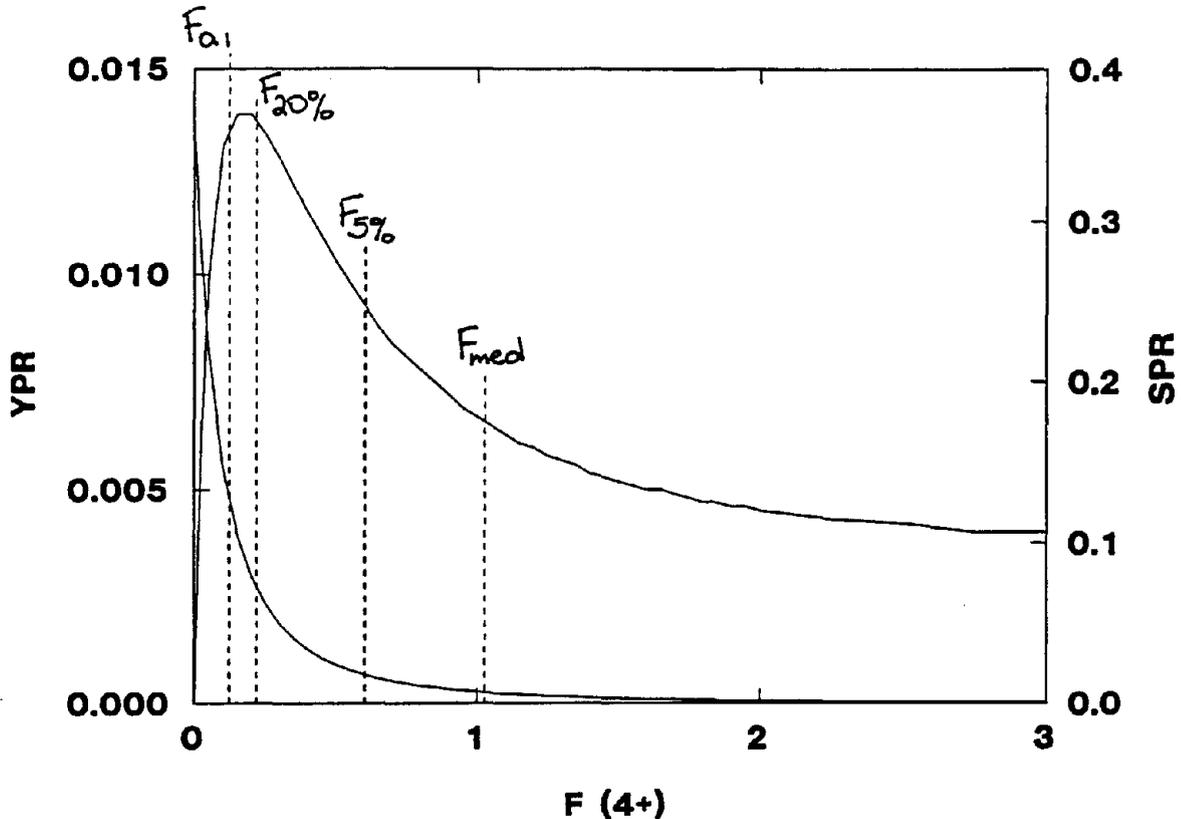
A. Georges Bank scallops YPR (kg) and SPR (kg):
   B. South Channel Georges Bank scallops control law
   (F=0.60. broken line) with historic estimates.
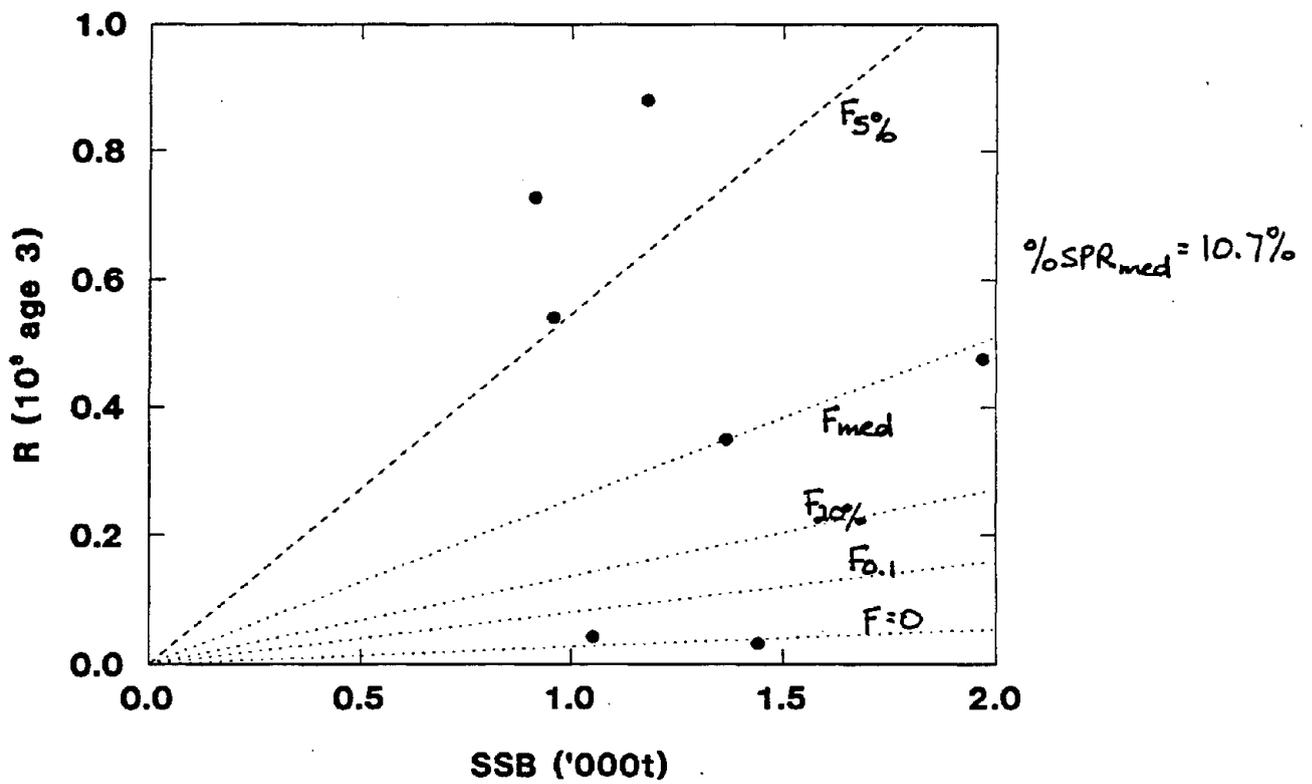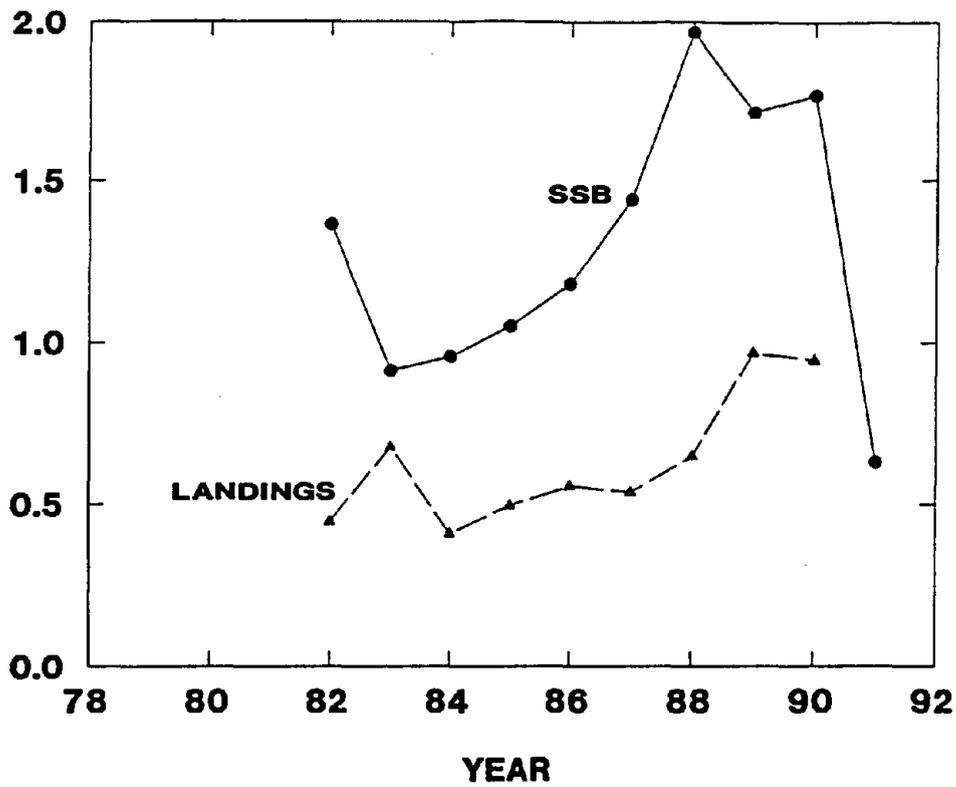
Southeast Georges Bank scallops. A. SSB ('000t) and landings ('000t);
B. S-R scatterplot with overfishing definition (heavy
broken line), and other reference fishing mortality rates.
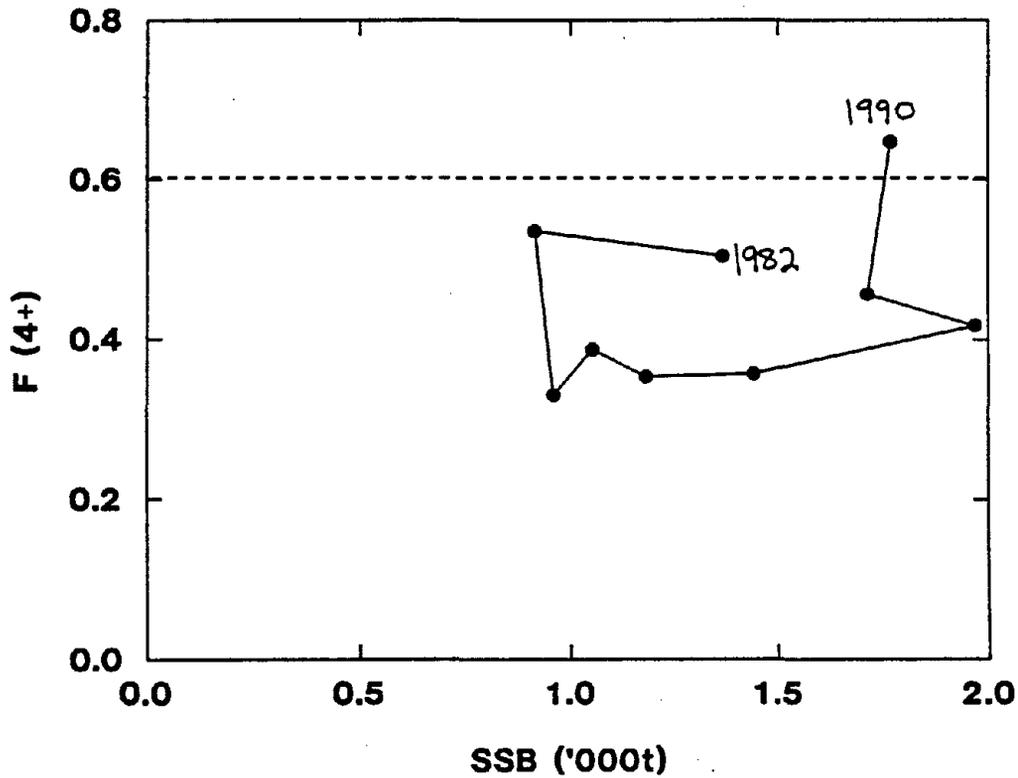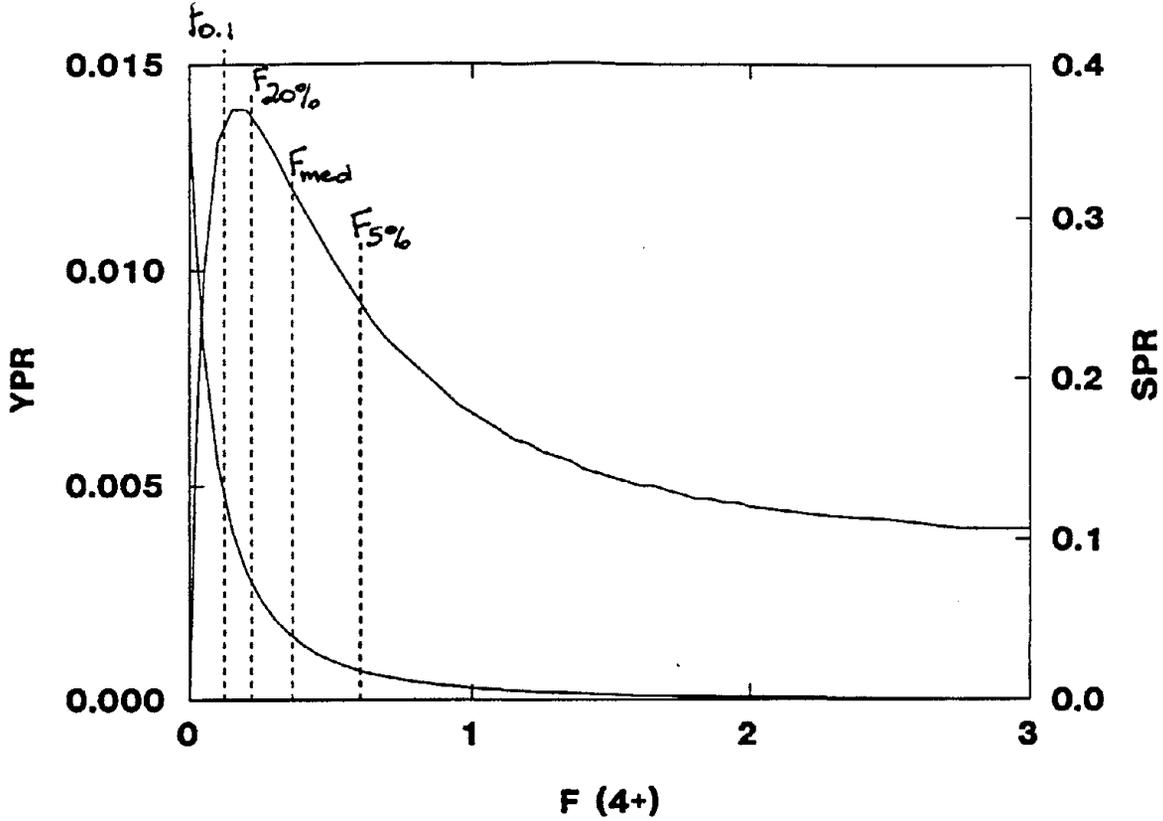
A. Georges Bank scallops YPR (kg) and SPR (kg):
   B. Southeast Georges Bank scallops control law
   (F=0.60, broken line) with historic estimates.
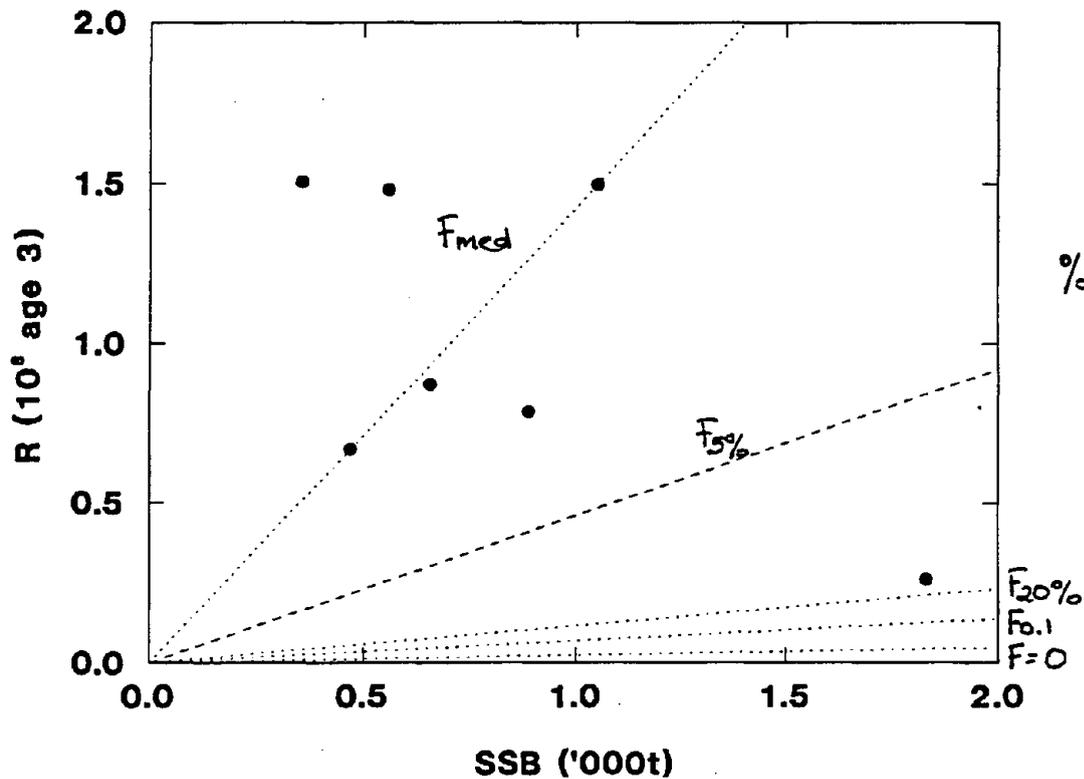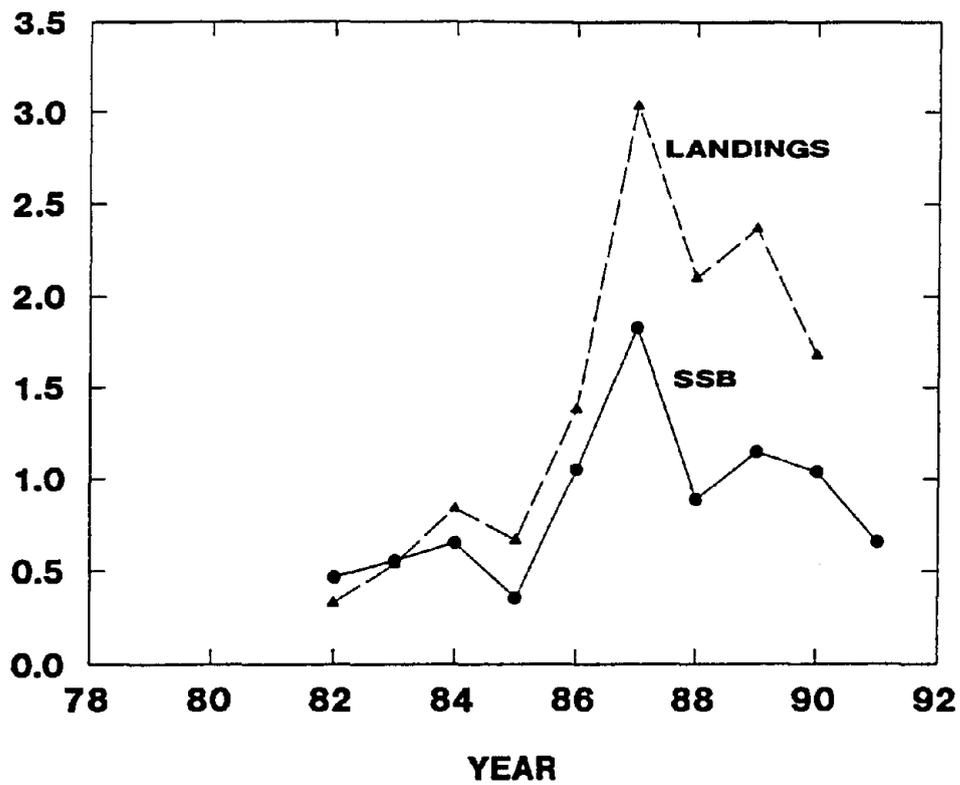
Mid-Atlantic Delmarva scallops. A. SSB ('000t) and landings ('000t):
B. S-R scatterplot with overfishing definition (heavy
broken line), and other reference fishing mortality rates.
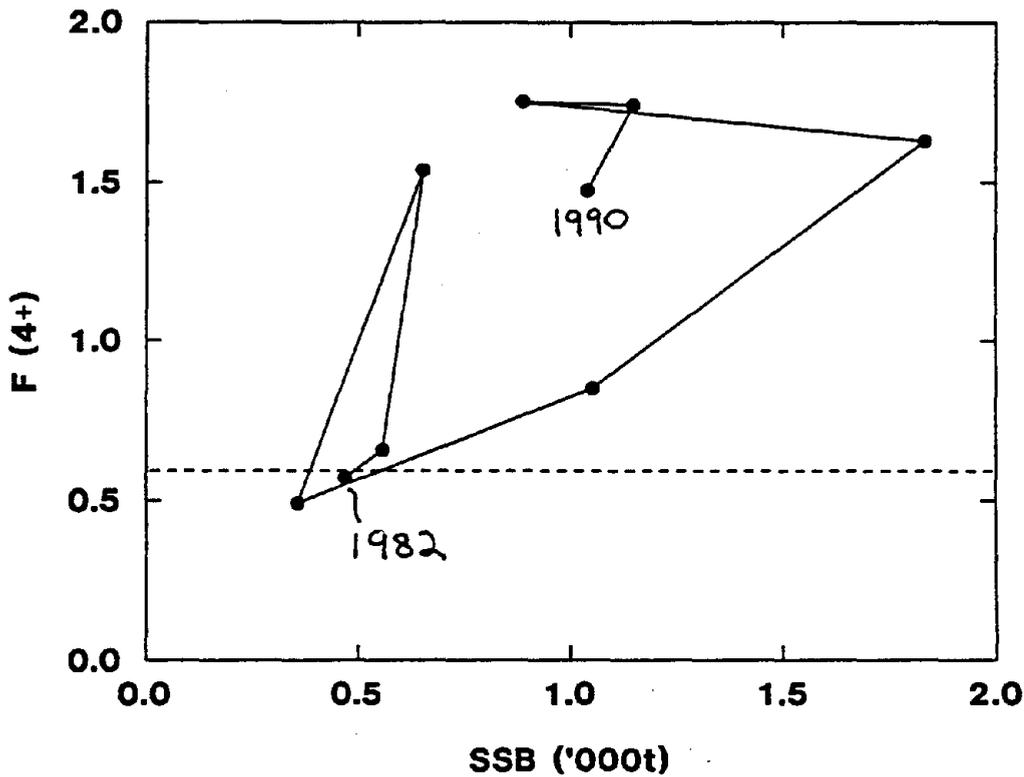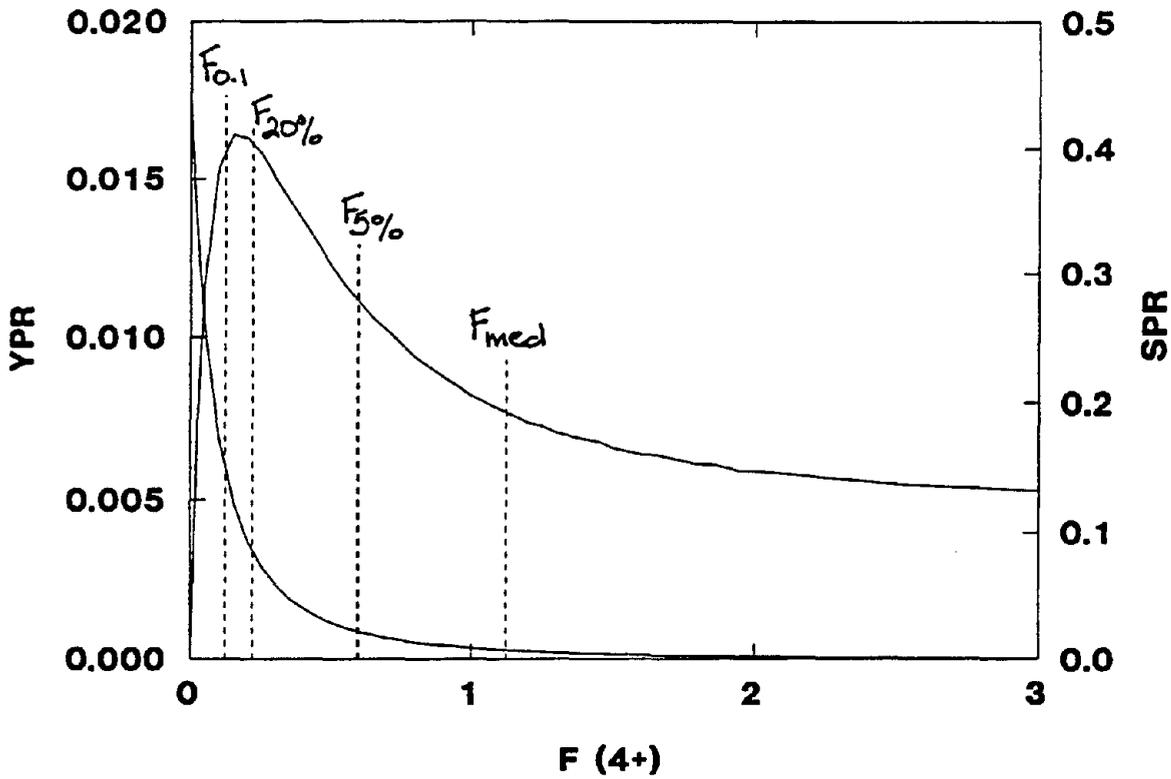
A. Mid-Atlantic scallops YPR (kg) and SPR (kg):
   B. Mid-Atlantic Delmarva scallops control law
   (F=0.59. broken line) with historic estimates.

Management Unit - Atlantic Surf Clams and Ocean Quahogs (# 8,48)

Species/Stock:
    8.   Surf clams (*Spisula solidissima*)
    48. Ocean quahog (*Arctica islandica*)

FMP/Amendment Defining Overfishing: "Surf Clam and Ocean Quahog Fishery
Management Plan, Section 9.2.1.1, Amendment 8, p.60"

Overfishing Definition:

 Overfishing is defined as the catch of surf clams or ocean quahogs exceeding the annual
quota for each species.

Assessment: Survey-based abundance index

Relevant Life History Features:

For both species recruitment is exceedingly rare, and reproductive performance at low
abundance is unknown. surf clams grow relatively rapidly and mature in 2 years. Ocean
quahogs grow slowly and may live more than 100 years. Only one large recruitment event
has been observed in each area. Small recruitments in local areas have been observed in
other years. Abundance history depends on location. The two areas of highest production
historically are northern New Jersey and Delaware-Maryland-Virginia.

Evaluation of Overfishing Definition:

Surf Clams and Ocean Quahogs - The overfishing definition itself places no restriction on the
quota, and therefore must be termed "risky." While seemingly unambiguous (i.e., catch
either is, or is not in excess), there is no specific restriction on what is set to be the annual
quota. This approach was rejected for many other FMPs. By itself, this definition offers no
objective protection from overfishing. Its effectiveness depends entirely on competent
management by the Council. Current management policy favors a supposedly risk-averse
constant quota (MAFMC 1992) but is actually risk-prone in that the policy (a) is based on a
highly speculative computer simulation, and (b) does not specify conditions explicitly
requiring a reduction in ABC.   The definition has no biological or theoretical content, and
therefore cannot be called sensible from this point-of-view. An improved definition would
codify the key biological elements in the FMP that protect against overfishing. Criteria such
as a maximum wide-area average $F_{50\%}$ with a nominal age at recruitment seem feasible.

Data Sources:

Anon. 1993. Report of the 15th Northeast Regional Stock Assessment Workshop (15th SAW). NEFSC Ref. Doc. 93-06.

Mid-Atlantic Fishery Management Council. 1992. 1993 optimum yield, domestic annual harvest, domestic annual processing, joint venture processing,and total allowable level of foreign fishing recommendations for surf clams and ocean quahog FMP. MAFMC, Sept. 1992.

Weinberg 1993. Surfclam populations of the middle Atlantic, southern New England, and Georges Bank for 1992. NEFSC Ref. Doc. 93-01.

Weinberg 1993. Ocean quahog populations from the Middle Atlantic to the Gulf of Maine in 1992. NEFSC Ref. Doc. 93-02.

Top chart

YIELD PER RECRUIT (g) — 100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0

% SPAWNING BIOMASS PER RECRUIT

New Jersey

RECRUITMENT AGE = 7

DelMarVa

Y/R

RECRUITMENT AGE = 3

S/R

Fave?

FISHING MORTALITY RATE — 0, 0.2, 0.4, 0.6, 0.8, 1

Bottom chart

APPROXIMATE F — 0.15, 0.1, 0.05, 0

Current Management Policy
for No. New Jersey

No. New Jersey

DelMarVa

F50% If Rect at 7 yr

F50% If Rect at 3 yr

1992

1980

1980

1992

APPROXIMATE BIOMASS (MILLION TONS) — 0, 0.04, 0.08, 0.12, 0.16, 0.2, 0.24, 0.28

70

Management Unit - Northwest Atlantic Mackerel (# 9)

Species/Stocks:

9. Atlantic Mackerel (*Scomber scombrus*)

FMP/Amendment Defining Overfishing:

Amendment 3 to the Fishery Management Plan for Atlantic Mackerel, Squid, and Butterfish Fisheries (Mid-Atlantic Fishery Management Council) (December 17, 1990).

Overfishing Definition:

"Overfishing is defined as the catch of Atlantic mackerel exceeding the annual quota for the species. The provision of the FMP concerning setting annual quotas prevents overfishing."

[Note: Amendment 4 revised the definition for Atlantic mackerel to clarify that the "annual quota" refers to the ABC, which is based on maintaining a minimum stock spawning biomass of 600,000 mt while allowing for a predicted Canadian catch and a fishing mortality rate that fluctuates according to the size of the stock.]

Assessment Method and Decision Rule:

Mackerel are assessed using an age structured VPA method tuned by the ADAPT procedure. The stock is considered to be overfished if the fishery harvests more than the ABC, which is set to maintain a biomass of 600,000 mt.

Relevant Life History Features: .

Mackerel are migratory pelagic fish ranging from Cape Hatteras to Canada.   There are two major spawning groups, one that spawns in the Mid-Atlantic Bight in the spring and one that spawns in the Gulf of St. Lawrence in the summer. Mackerel have a maximum age of about 20 years, maturing at age 2. Mackerel biomass has been increasing since the mid-1980's and is now at record high levels near 3 million mt. Current landings are very low, around 55,000 mt, half of which is taken by Canada.

Evaluation of Overfishing Definition:

The overfishing definition is conservative, and there is no indication that recruitment is reduced below the overfishing biomass threshold. Because the OD is an absolute biomass level, it will not be robust to either environmental changes or changes in biological parameters if the life history parameters change. The overfishing definition could be improved by including a threshold maximum fishing mortality rate to protect against over-expansion of the fishery should it begin to develop. If a maximum fishing mortality rate was included, the minimum biomass threshold could probably be lower than the current OD.

Data Sources:

NEFSC 1991. Report of the Twelfth Northeast Regional Stock Assessment Workshop . NEFSC Lab. Ref. Doc.

Mackerel NAFO 2 to 6

## Landings and Fishing Mortality (Ages=11)
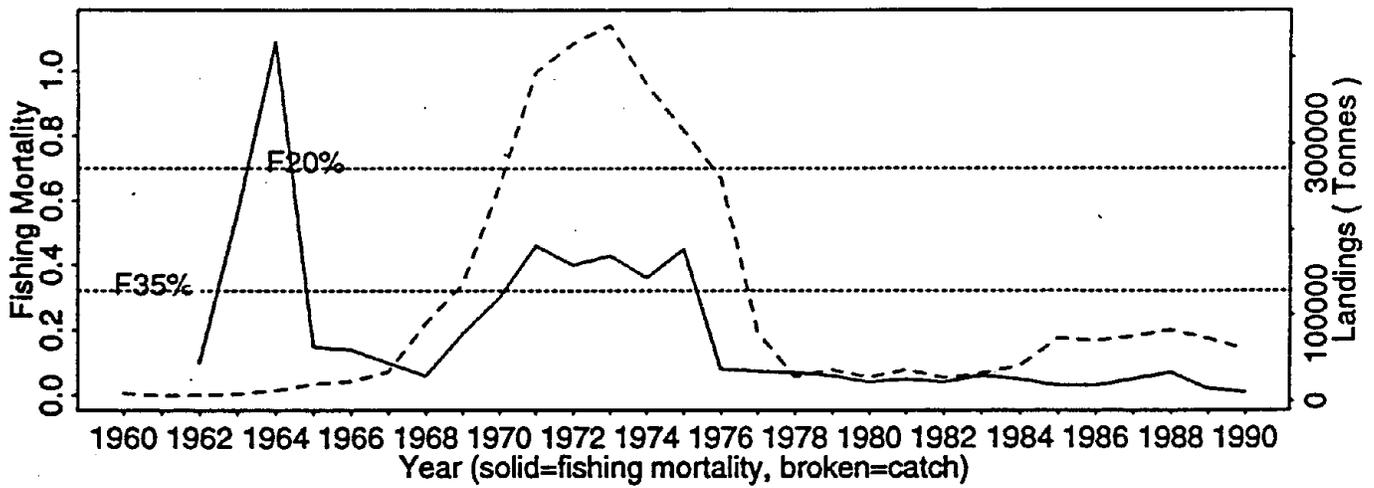
Time series of Recruitment and Stock
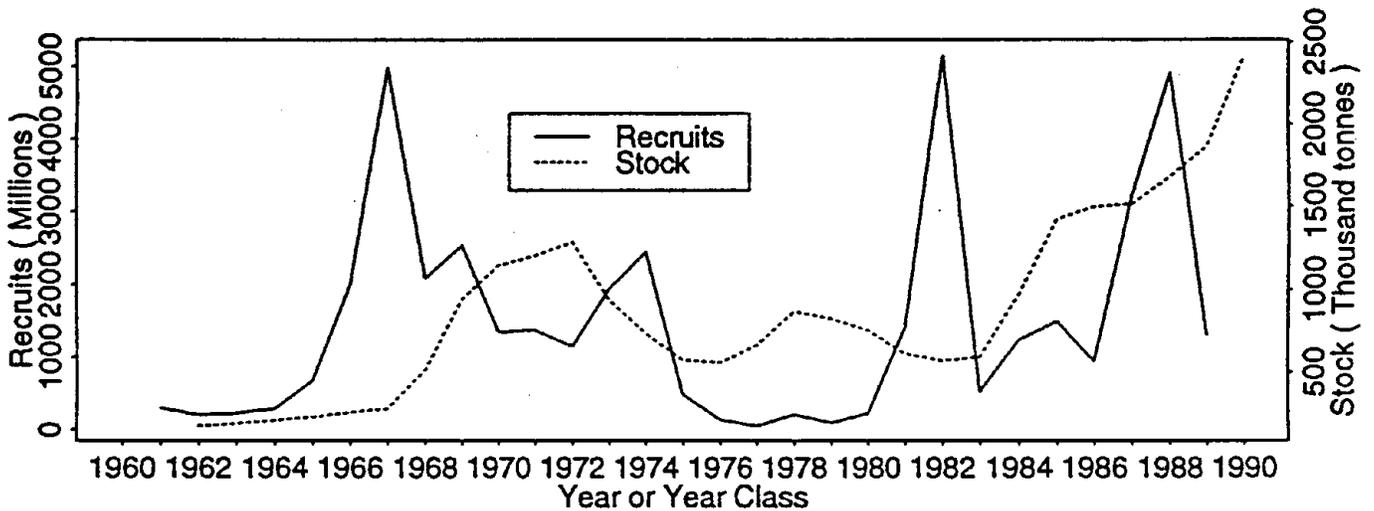
Recruit vs Stock with Bounded Shepherd Model
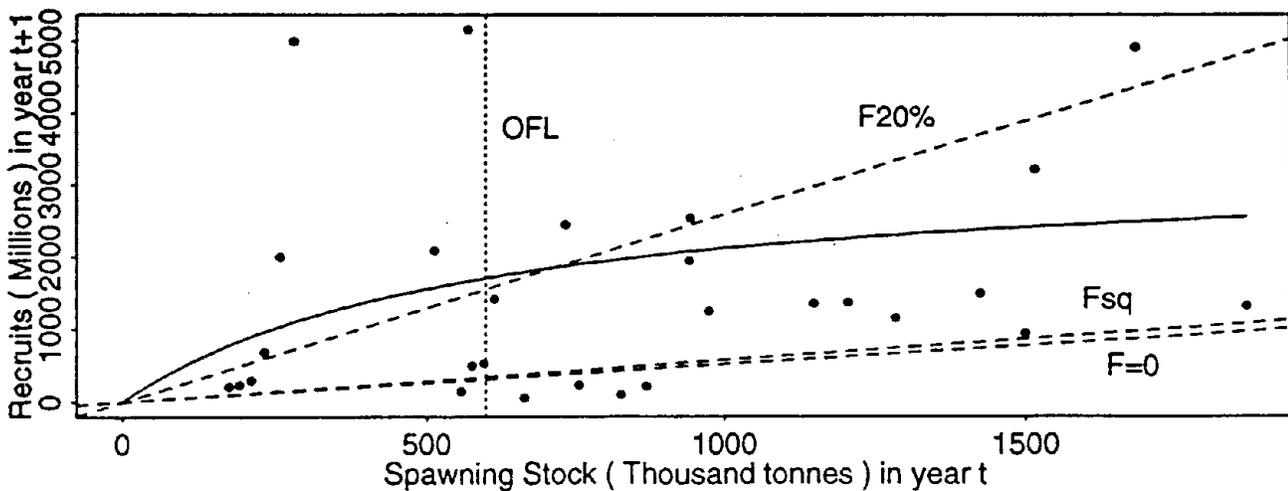
Mackerel NAFO 2 to 6

Landings and Equilibrium Yield Curve
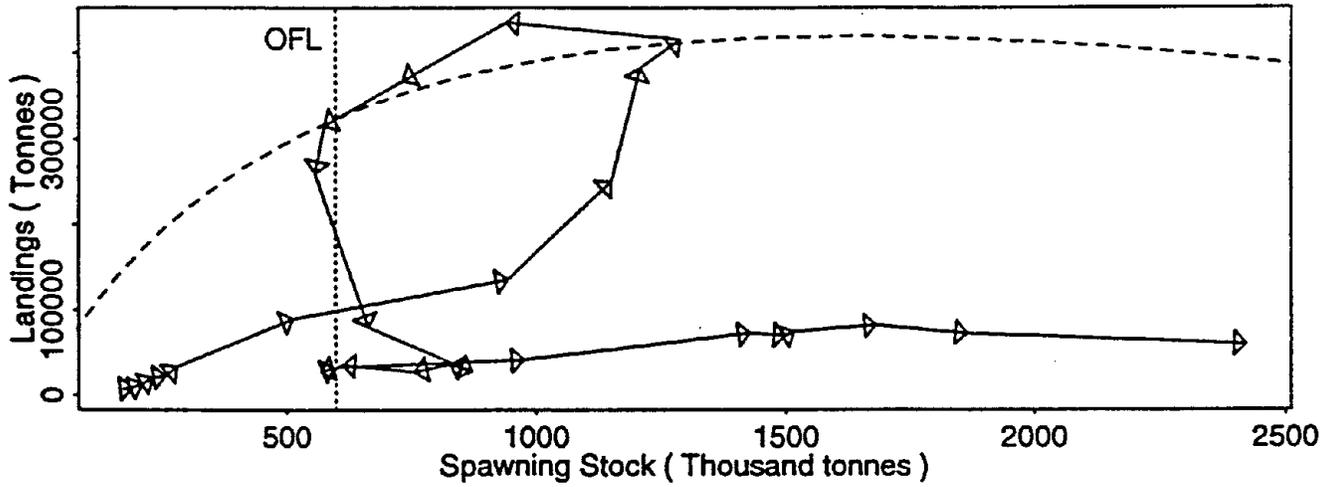
Landings and Equilibrium Yield Curve
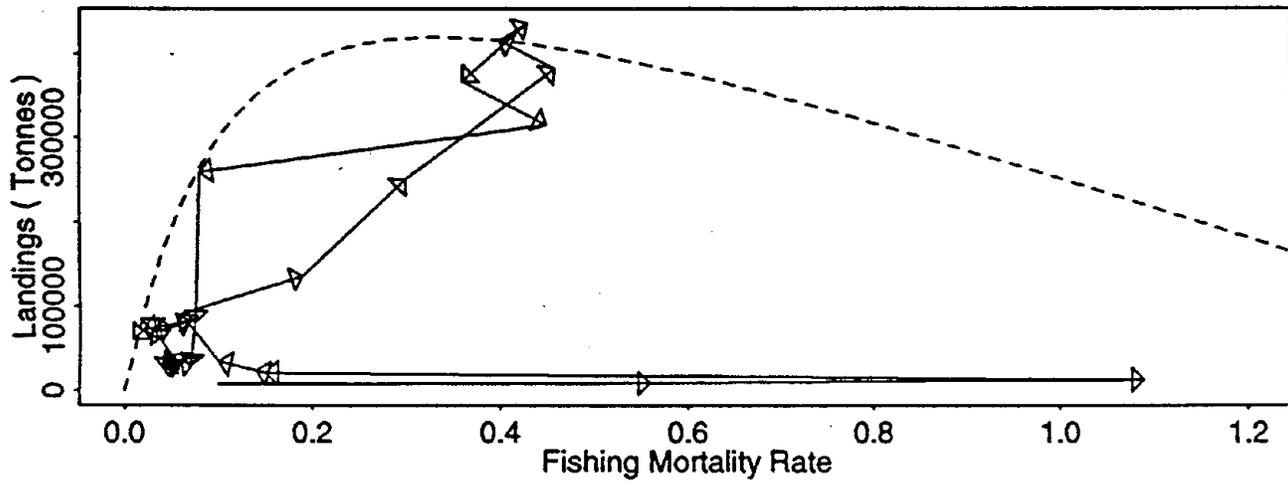
Yield and Spawning Biomass per Recruit
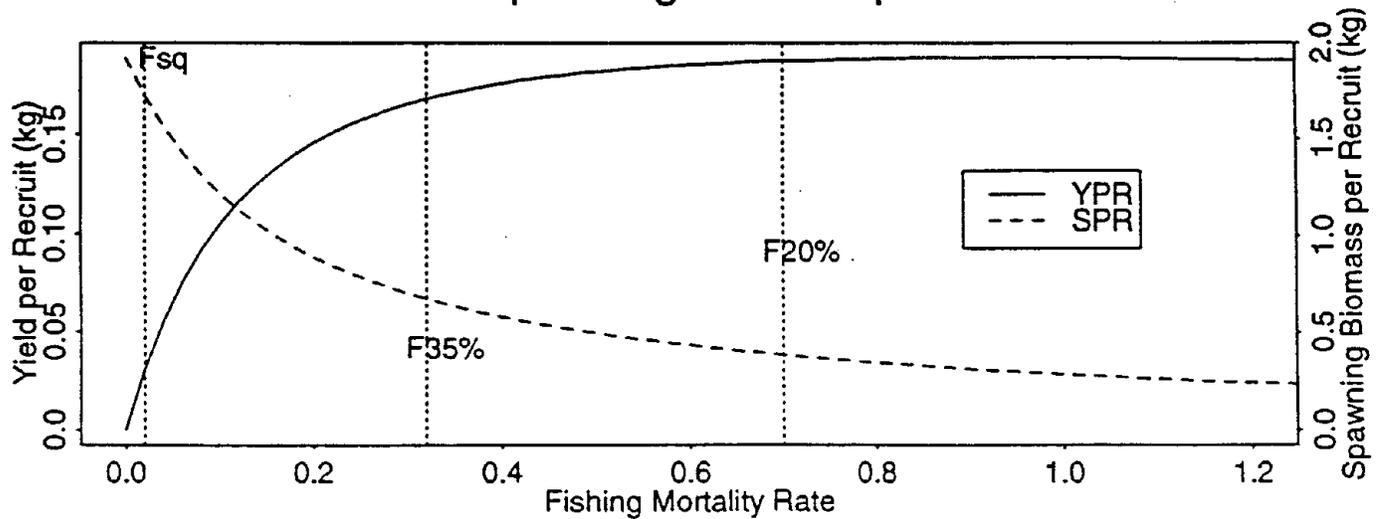
Management Unit - Mid-Atlantic Summer Flounder (# 10)

Species/Stock :

10. Summer Flounder (*Paralichthys dentatus*)

FMP/Amendment Defining Overfishing: Amendment 1 to the Fishery Management Plan for the Summer Flounder Fishery (Mid-Atlantic Fishery Management Council) (November 1990).

Overfishing Definition :

"Overfishing for summer flounder is defined as fishing in excess of the F_{MAX} level." (9.2.1.1., page 47)

Assessment Method and Decision Rule:

Summer flounder are assessed using an age structured VPA model tuned, using the ADAPT method, to the NMFS spring survey and surveys from several states, along with fishery-dependent indices.

Relevant Life History Features:

Summer flounder occur from Maine to South Carolina. They live up to 20 years and mature at age 1. The stock has been severely overfished and is depleted. Recent landings are around 10,000 mt. There are both commercial and recreational fisheries.

Evaluation of Overfishing Definition:

The definition is appropriate as an interim target while the stock is rebuilt. It is unclear whether the OD is conservative, since all the information on stock productivity was obtained under very high fishing mortality rates. However, F_{max} is derived from yield-per-recruit analysis, so it is not a sensible reference point for recruitment overfishing. The definition will need to be changed to one based on SPR or related to recruitment productivity when the stock is rebuilt.

Data Sources:

NEFSC 1990. Report of the Eleventh Northeast Regional Stock Assessment Workshop (SAW)"(Northeast Center, NMFS; Fall 1990)

NEFSC 1991. Report of the Thirteenth Northeast Regional Stock Assessment Workshop (SAW); Stock Assessment Review Committee Consensus Summary of Assessments (SARC)(Northeast Center, NMFS; December 1991)

Summer flounder Middle Atlantic Bight

Landings and Fishing Mortality (Ages=16)
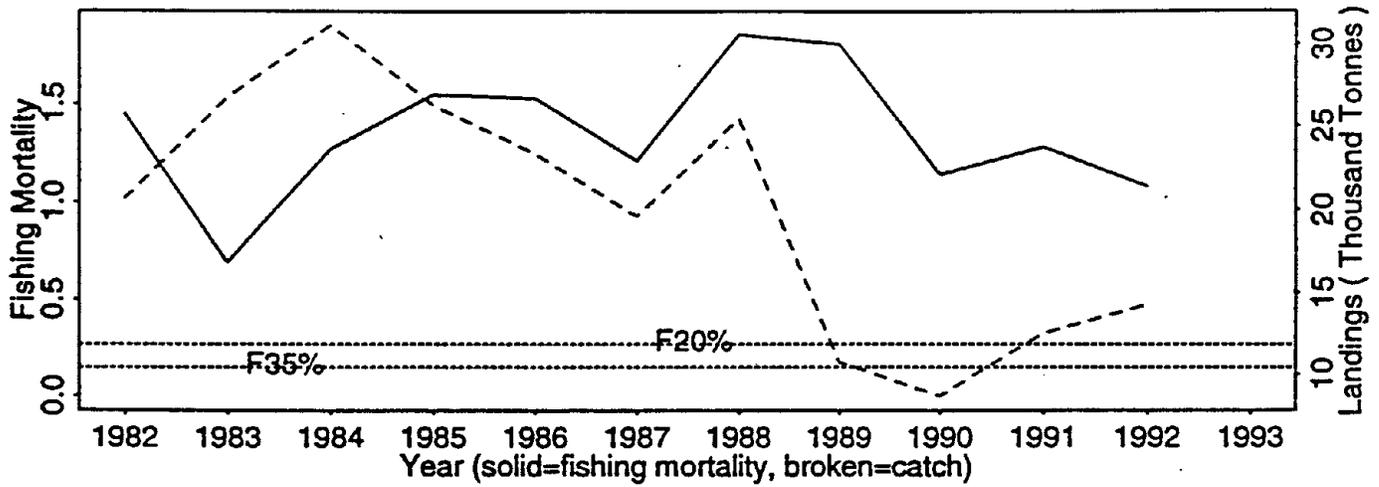
Time series of Recruitment and Stock
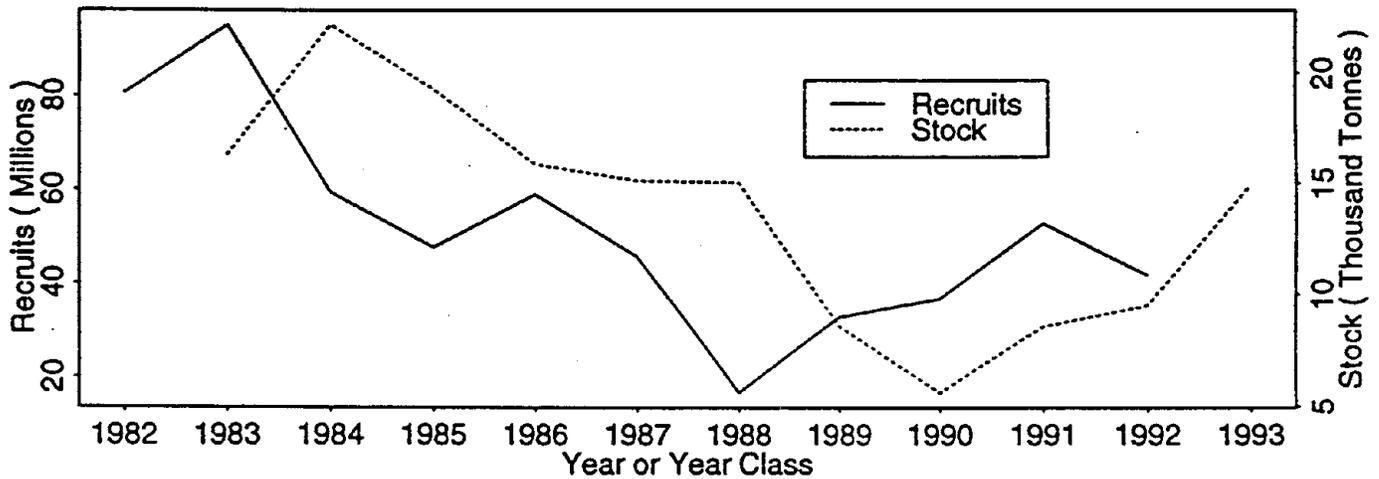
## Recruit vs Stock with Bounded Shepherd Model
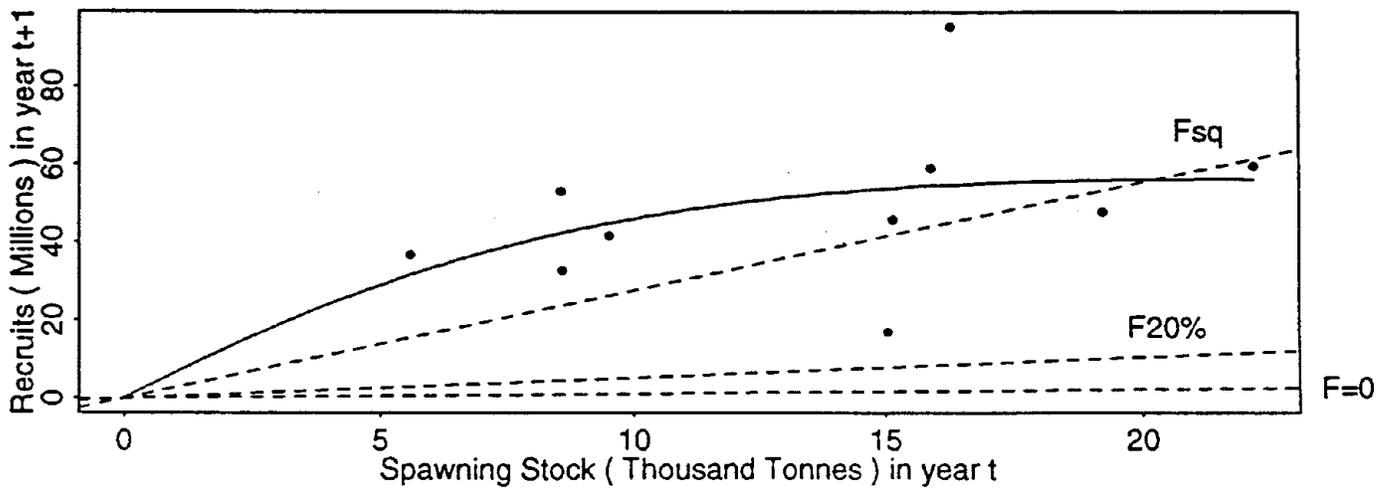
Summer flounder Middle Atlantic Bight

Landings and Equilibrium Yield Curve
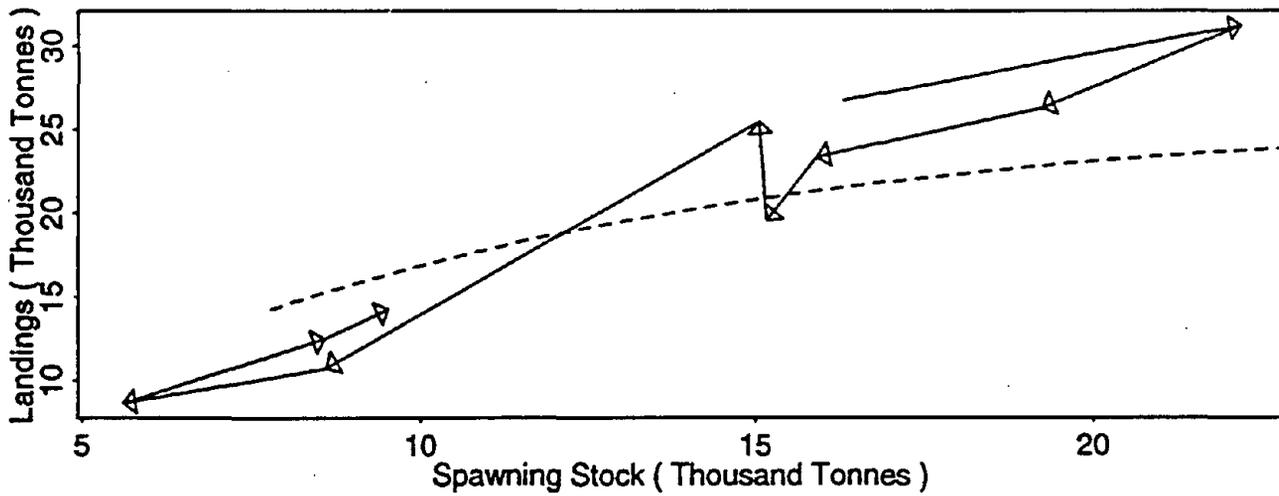
Landings and Equilibrium Yield Curve
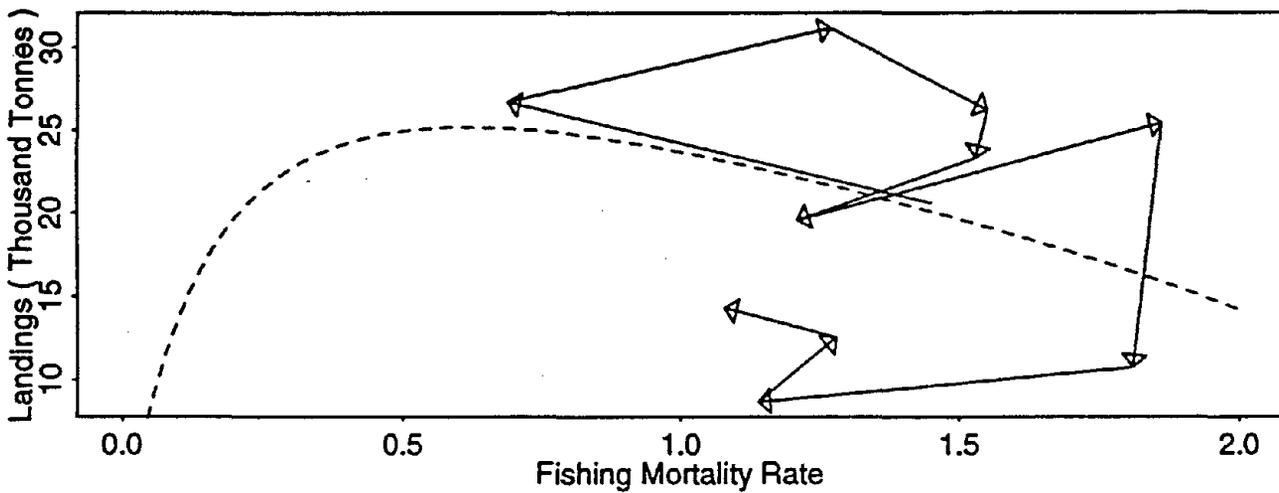
Yield and Spawning Biomass per Recruit
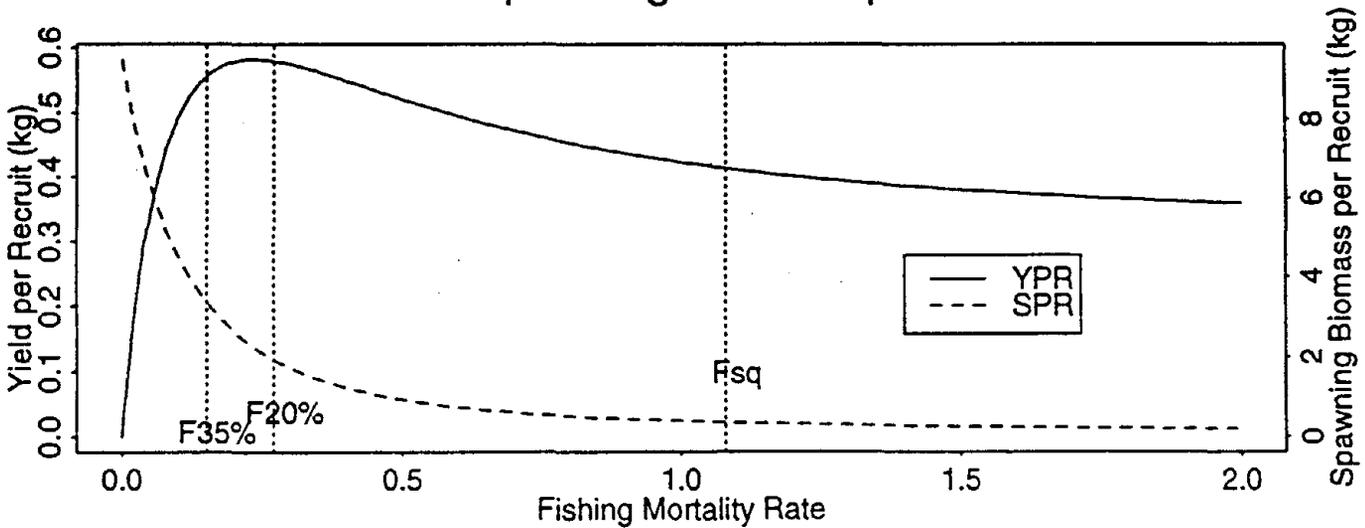
Management Unit - New England Groundfish (# 11-19, 45-47, 50-54)

Species/Stock:

11. Northern Silver Hake (*Merluccius bilinearis*)
12. Southern Silver Hake (*Merluccius bilinearis*)
13. Georges Bank - Gulf of Maine American Plaice (*Hippoglossoides platessoides*)
14. Southern New England Yellowtail Flounder (*Limanda ferruginea*)
15. Georges Bank Yellowtail Flounder (*Limanda ferruginea*)
16. Gulf of Maine Cod (*Gadus morhua*)
17. Georges Bank Cod (*Gadus morhua*)
18. Gulf of Maine - Georges Bank Redfish (*Sebastes marinus*)
19. Georges Bank Haddock (*Melanogrammus aeglefinus*)
45. Georges Bank-Gulf of Maine Witch Flounder (*Glyptocephalus cynoglossus*)
46. Georges Bank Winter Flounder (*Pseudopleuronectes americanus*)
47. Southern New England Winter Flounder (*Pseudopleuronectes americanus*)
50. Gulf of Maine Haddock (*Melanogrammus aeglefinus*)
51. Red Hake (*Urophycis chuss*)
54. Ocean Pout (*Macrozoarces americanus*)

FMP/Amendment Defining Overfishing: Northeast Multispecies FMP Amendment 4

Overfishing Definition:

"The Council defines overfishing as occurring when the target percent maximum spawning potential (%MSP) levels described in the Northeast Multispecies FMP are not achieved. The %MSP targets are described on page 6.4 of the FMP. "

For Silver hake: "Overfishing is deemed to have occurred or be occurring whenever the four-year running average percent maximum spawning potential (%MSP) is less than the threshold %MSP."

"The current estimate of the threshold % MSP is 31% for the Maine/Northern Georges Bank stock and 42% for the Southern Georges Bank/Mid-Atlantic stock. These numbers are subject to periodic revision as appropriate new scientific information becomes available."

For other stocks, the OD is 20% MSP, with the following exceptions: For Georges Bank haddock, the OD is 30% MSP. For red hake and ocean pout the OD is when the 3 year moving average of the species abundance index from the Northeast Fisheries Science Center's bottom trawl survey falls below the lowest quartile of the time series.

<u>Assessment Method and Decision Rule:</u>

The assessments for all of the primary stocks except redfish are based on age-structured information on catch and survey indices. The methodology is VPA, tuned using ADAPT. Redfish are assessed based on inspection of trends in research survey indices and landings trends. An age-structured assessment was conducted in 1983, but subsequently there are no estimates of fishing mortality rate or absolute abundance available.

For the secondary stocks, the assessments consist of examining trends in survey indices of relative abundance, calculation of biological reference points and examination of landings trends.

A stock is deemed overfished when the point estimate of the fully recruited fishing mortality rate estimated in the assessment is greater than the fishing mortality rate corresponding to the overfishing definition level on the spawning stock biomass per recruit curve, termed %MSP in New England. For silver hake, overfishing is indicated when the 4-year running average of fishing mortality exceeds the constant fishing mortality rate that corresponds to the stated threshold %SPR.

<u>Relevant Life History Features</u> :

Silver hake range from Newfoundland to South Carolina. Two stocks have been identified in U.S. waters based on morphological differences: One extending from the Gulf of Maine to northern Georges Bank and the other from southern Georges Bank to the Mid-Atlantic. Silver hake are important predators on juvenile fish. They migrate extensively, from shallow waters in spring and summer to deeper waters in fall and winter. Currently, both stocks appear to be at extremely low levels of abundance relative to the highs estimated for the late 1950s through the 1960s.

American plaice are moderately long-lived flatfish with a natural mortality rate of 0.2, maturing at age 3 and recruiting to the fishery at ages 2-3. Discards of 2 - and 3-year-old fish are high. Recent landings have been around 4,000 mt and the stock is considered to be overexploited.

Yellowtail flounder are one of the mainstays of the New England commercial fishery. They are moderately long lived maturing around 2 years of age. The stock has been severely overexploited and recent landings (1991) were only around 4,000 mt, while MSY is estimated to be around 23,000 mt. The two major stocks of yellowtail are off southern New England and on George's Bank, with the former being larger and more heavily exploited.

Atlantic cod are moderately long-lived with a natural mortality rate of 0.2. Cod in both stocks mature at age 2 and are fully recruited to the fishery at age 4. Cod stocks in general have been found to be quite resilient to fishing pressure. Atlantic cod have been exploited in the Gulf of Maine and on Georges Bank for several hundred years. Gulf of Maine landings

have fluctuated between 4 and 18,000 mt in the last 100 years. In the last 17 years landings have increased from a low period in the 1950's and 1960's to the 8-18,000 mt level. The estimated biomass for the stock increased in response to a few good year classes in the latter half of the 1980's, but over the entire period since 1963 has declined to historic low levels. Landings statistics for Georges Bank are available from 1893 on (NEFSC 1993). This resource was heavily exploited by foreign fishing vessels in the period 1960 - 1976, with over 50,000 mt landed in 1966. Domestic landings increased sharply following the implementation of the MFCMA in 1976, and peaked at 57,000 mt in 1982. Landings in 1992 were around 28,000 mt (Figure 1). The stock biomass has declined sharply since 1978, the earliest year for which a full stock assessment is available, and are currently at historic low levels.

Redfish are very slow growing and long-lived, similar to many of the Sebastes species on the West Coast. The rate of natural mortality is estimated to be 0.05. Redfish are 50% mature at age 6 and are 50% vulnerable to fishing at this age as well. Full recruitment is at age 9. Redfish have been harvested extensively since the 1930's off the New England coast. The stock declined under heavy fishing pressure from peak landings of 50,000 mt in the 1940's and less than 1,000 mt have been landed annually since 1989. The estimated biomass is near historic low levels currently. The recruitment pattern is sporatic, with an occasional good yearclass responsible for most of the biomass.

Haddock are moderately long-lived with a natural mortality rate of 0.02. Currently, the fish are 50% mature at age 2 and recruit to the fishery at age 3-4. There have been strong shifts in the life history pattern of the Georges Bank stock. The age at maturity has declined and the growth rate has increased as the stock has been reduced by fishing. It is not known whether this process will reverse if the population rebuilds. The New England haddock fishery developed around the beginning of the century along with otter trawling. From the 1930's to 1960's landings averaged around 45,000 mt. Foreign fishing increased landings to a peak of 150,000 mt in the 1960's and the stock declined precipitously. Recent landings are around 5000 mt, shared with Canada. Recent stock levels are near historic lows for both stocks. Current landings of haddock from the Gulf of Maine are negligible, though peak landings in the early 1980's were over 7,000 mt. Though this stock is assumed to be separate from the George's Bank stock, this assumption has not been re-examined in recent years. The growth and maturity pattern for the two areas are essentially the same.

Witch flounder are long-lived, maturing at 3-4 years. The stock is thought to be overfished and the recent relative abundance indices are at historic low levels.

Winter flounder are fished both commercially and recreationally. Landings have declined to near historic low levels along with the survey index of relative abundance. These flounder are long-lived and mature at age 3-4.

Red hake live to be 8-10 years of age and mature in their second year of life. They are distributed very widely along the coast from North Carolina to Canada. Relative abundance

has been increasing since the early 1970's though landings are very low since foreign fishing vessels were excluded.

Ocean pout occur from Labrador to Delaware, but relatively little is known about their life history or population dynamics. Relative abundance has fluctuated over the last decade, with a low point in the mid 1970's. Recent levels have been near the average of the time series since the late 1960's.

Evaluation of Overfishing Definition:

Silver Hake - The estimate of the threshold % SPR level for the southern stock appears to be somewhat high, making the OD conservative for the southern stock and neutral for the northern stock. This is due to the fact that the calculations used in the development of the definitions considered too few age groups and only the most recent 14 years of S-R observations. Revised calculations using unlimited age groups and 32 S-R observations result in a median replacement level of 22.0% SPR. The corresponding level for the northern stock is 35.9%. The estimates for both stocks vary considerably, depending on the time period chosen. For the most recent 14 years, the estimates based on unlimited age groups are 26.7% for the northern stock and 36.2% for the southern stock. It is suggested that the same level be used for both stocks (since they are not currently managed as separate units) and that the estimate be rounded to either 30% or 35%. To remove ambiguity in future, the procedure for revising the OD's should be made explicit.

American Plaice - The overfishing definition for plaice is judged to be neutral, but the stock is depleted and good recruitment has not been observed at very low biomass. The replacement line corresponding to the OD indicates that the stock would continue to decline if fished at that level (more points below the line than above). The OD is currently interpreted as a target and this is inappropriate. It should be considered a threshold rate of fishing. Though the definition is theoretically sensible, a more conservative target is needed to rebuild the stock. Then the OD can be re-evaluated.

Yellowtail Flounder - The overfishing definitions are currently interpreted as targets, though they are more appropriate as a neutrally conservative thresholds. The OD's appear to be appropriate as maintenance levels for healthy stocks, judging from the two sets of stock and recruitment data. These stocks are severely overfished and the definitions will need to be re-evaluated when they are rebuilt.

Gulf of Maine Cod - The overfishing definition fishing mortality rate is slightly greater than F_{max} and nearly twice as high as $F_{0.1}$. The data are inadequate to obtain a good estimate of the relationship between stock and recruitment. However, the replacement line corresponding to 20% SPR lies to the right of most of the data points on the stock and recruitment plot, indicating that this is a reasonably conservative level for stock maintenance. Some rebuilding should occur if the stock is harvested at the 20% SPR rate if the recruitment pattern stays the same. However, this harvest rate appears to be greater than F_{msy} and is

probably too high for a target harvest rate. Although the definition is treated as a target harvest rate in the FMP, it is more appropriate for a threshold level. In addition, more rapid rebuilding is indicated if the fishing mortality rate is below the 20% SPR level.

Georges Bank Cod - The stock and recruitment data indicate that a replacement line corresponding to 20% SPR should allow some stock rebuilding and is conservative for maintaining the stock. $F_{20\%}$ is greater than F_{msy}, which is nearer to the $F_{0.1}$ level. $F_{20\%}$ is similar to F_{max}. The definition of overfishing appears to be conservative for this stock. However, it is higher than the level that is estimated to harvest at MSY and is probably more appropriate as a threshold, rather than a target harvest rate.

Redfish - The stock and recruitment data for 1969-1983 show that there are two large yearclasses and the rest of the years had very low production of recruits. The 20% SPR replacement line indicates that year classes similar to these large recruitments will be necessary to afford any stock rebuilding. The replacement line for 100% SPR is also above most of the recruitment points. Clearly, this stock can only be sustained under very low harvest rates until a large year class appears. The present definition of overfishing appears to be too high to be sustainable by this stock in the long term. The information on recruitment is scant, but given the life history of this species, very low harvest rates are warranted. It may be possible to increase the harvest somewhat when a large year class appears, but in general, the current definition should be reconsidered. A minimum biomass threshold to preserve a seed stock would provide some additional protection. A precautionary biomass level below which F is reduced would also be sensible.

Georges Bank Haddock - This stock has undergone substantial changes in growth and maturity under harvesting. The Panel agreed that the life history characteristics corresponding to the early period of the fishery should be used for calculating reference points for defining overfishing. The recent stock and recruitment observations indicate that the replacement line for 30% SPR may have a slope greater than the initial slope of the stock and recruitment curve, i.e., it is an unsustainable harvest rate. Most of the recent points fall below the replacement line. Similarly, if the equilibrium yield curve is drawn, 30% SPR appears to exceed sustainable harvest levels. Even $F_{0.1}$ gives a stock biomass to the left of B_{msy}. Based on this analysis, the current overfishing definition for haddock does not appear to be conservative nor appropriate. Even if fishing mortality rates are reduced to the level mapping to the overfishing definition, this will likely be insufficient for rebuilding the stock. The OD is risky for protecting this stock from further recruitment overfishing though it may be appropriate as a threshold when the stock is rebuilt. A more conservative %SPR level should be chosen when biomass is low.

Gulf of Maine Haddock - The overfishing definition for Gulf of Maine haddock is inappropriate for a stock which has been so severely depleted. A 20% SPR target fishing mortality rate would only maintain the stock at its current level, not prevent further declines. Though there are some weak estimates of fishing mortality rates of this stock it is difficult to evaluate its status compared to the overfishing definition. A definition based upon the survey

index of relative abundance, using either a minimum relative biomass threshold or some measure of the trend in the index would be more appropriate for evaluating this stock.

Witch Flounder - There is no information on the pattern of recruitment for this stock. The definition is neutral by analogy with other species if it is applied as a threshold. There are currently no estimates of F available in the management advice so the OD is operationally ambiguous.

Winter Flounder - Recruitment data are not available for this stock. It is probably appropriate as a threshold by analogy with other species. However, the definition is operationally ambiguous since no estimates of fishing mortality rates are available for these stocks.

Red Hake - There is no explicit information on stock and recruitment for this species to evaluate the definition. Relative abundance is used, appropriately, to maintain the stock above low levels observed in the historic time series. This appears to be a sensible procedure given recent trends and the lack of population dynamics information. However, it is unclear what action is needed if the stock approaches or goes below the overfishing definition level. Closure of the fishery may not be appropriate, since it is unknown if lower levels than those previously observed are really problematic. A more gradual reduction in harvesting would probably be better than a fixed threshold. The intent of the three year moving average is presumably to protect against the influence of any one data point and provide some smoothed measure of abundance. This is sensible, but a three year average may still be very subject to end effects. This leaves some ambiguity in the definition.

Ocean Pout - This definition is the same as that used for red hake and the comments for that species pertain here as well.

Data Sources:

Almeida, F.P. 1987. Status of silver hake resources off the Northeast coast of the United States - 1987. Woods Hole Lab. Ref. Doc. 87-03.

NEFMC 1990. Amendment #4 to the Fishery Management Plan for the Northeast Multispecies Fishery. NEFMC.

NEFSC 1990. Report of the Eleventh NEFC Stock Assessment Workshop Fall 1990. Northeast Fisheries Science Center Reference Document 90-09.

NEFSC 1992. Report of the Thirteenth Northeast Regional Stock Assessment Workshop. NEFSC Reference Doc. 92-02.

NEFSC 1993. Report of the Fifteenth Northeast Regional Stock Assessment Workshop. NEFSC Lab Reference Doc. 93-06.

NEFSC 1993. Status of Fishery Resources off the Northeastern United States for 1992. NOAA Tech. Memo. NMFS-F/NEC-95.
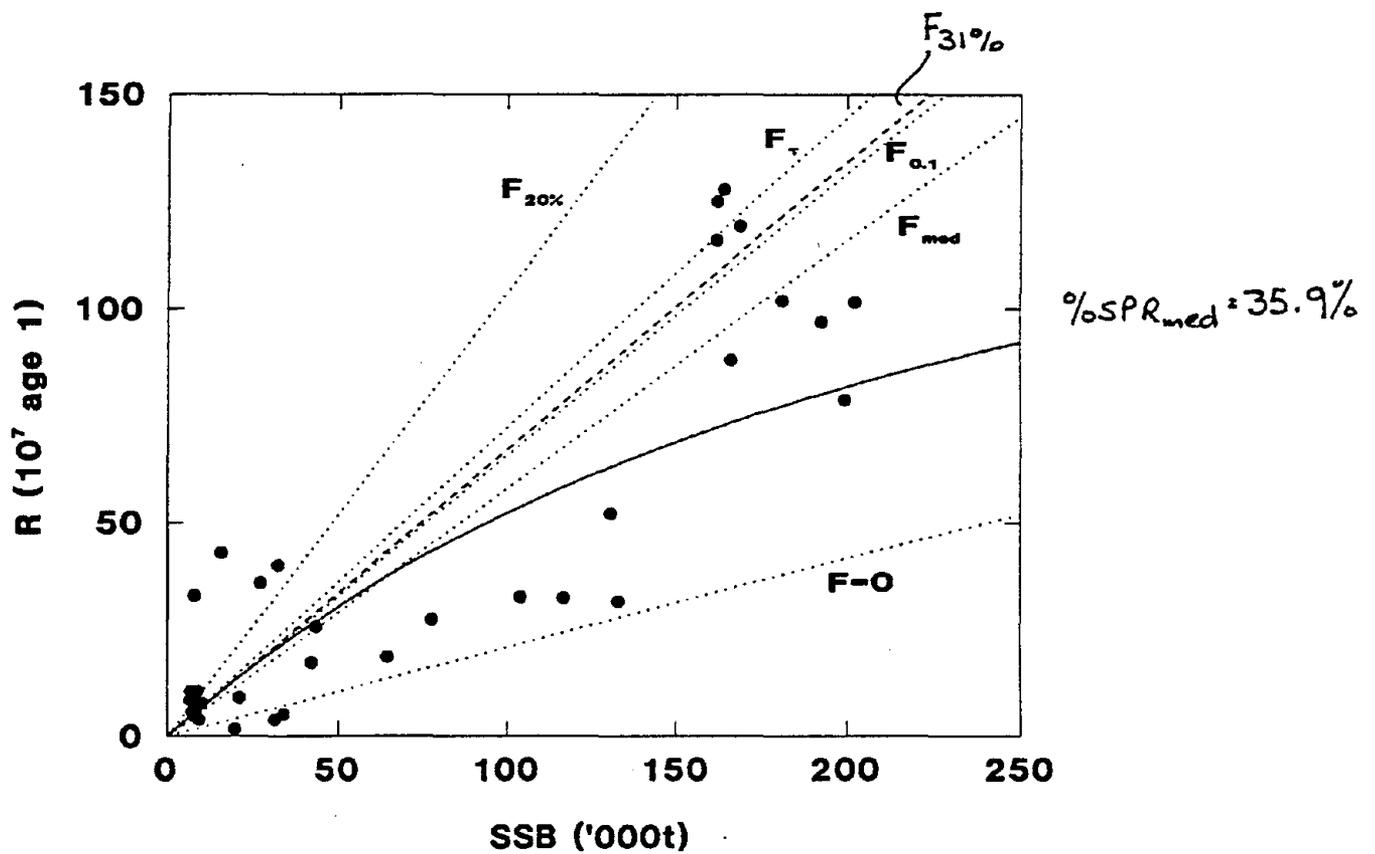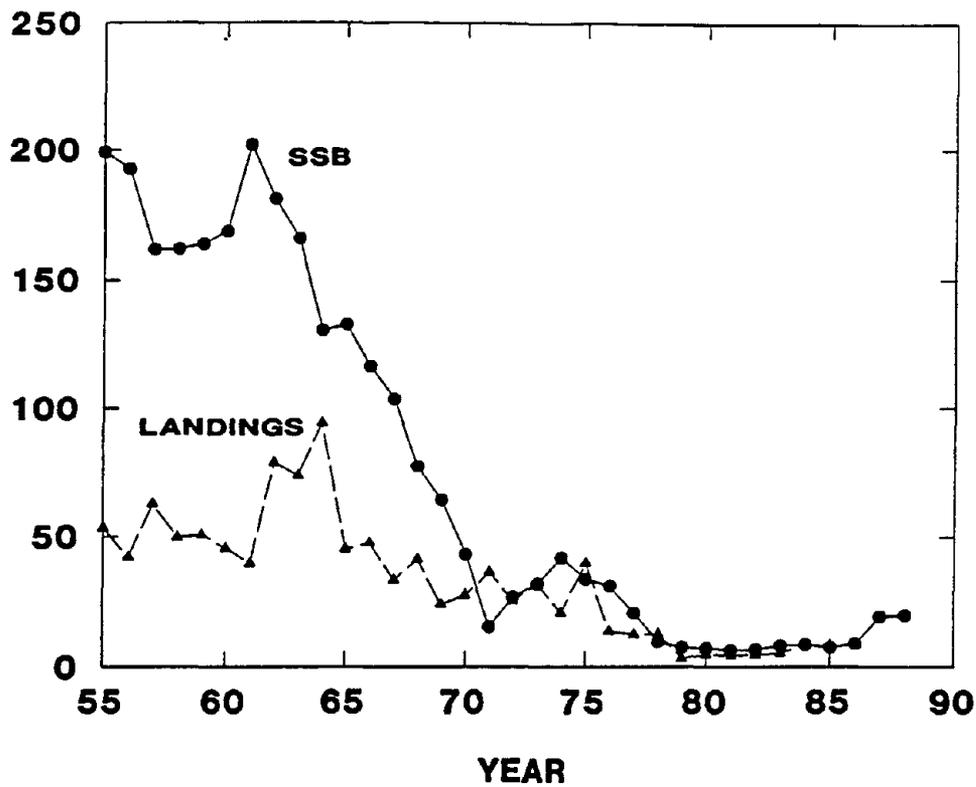
Northern silver hake. A. SSB ('000t) and landings ('000t);
B. S-R relationship with Shepherd model fit (solid line),
overfishing definition (heavy broken line), and other reference
fishing mortality rates.
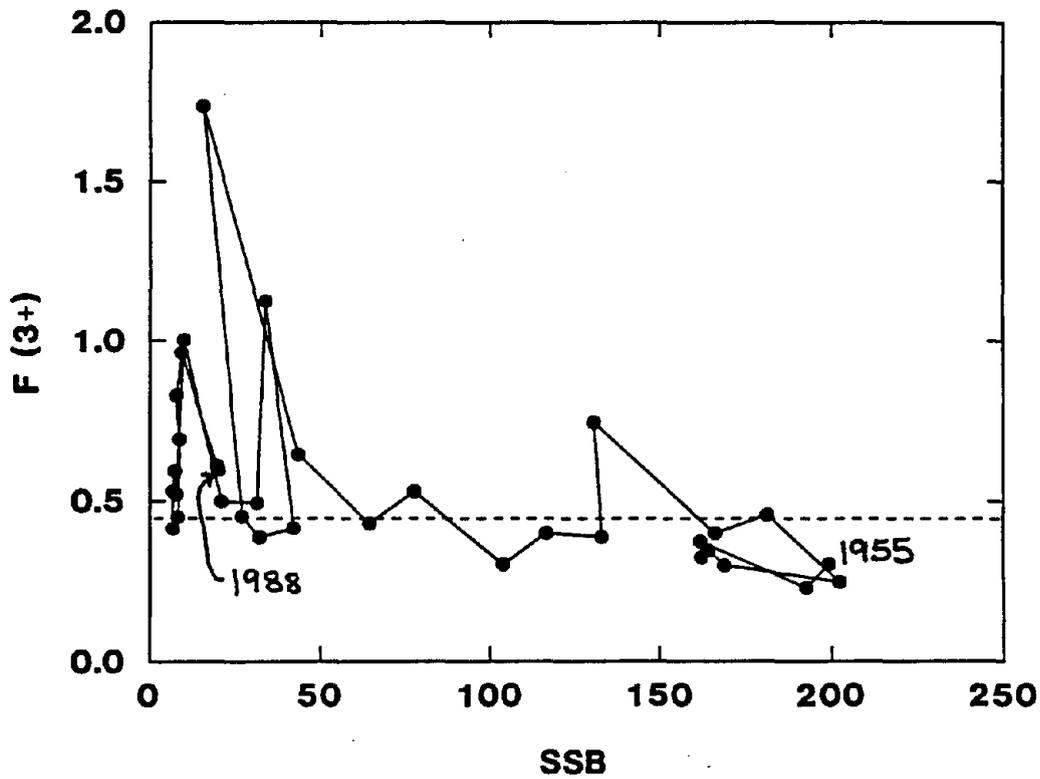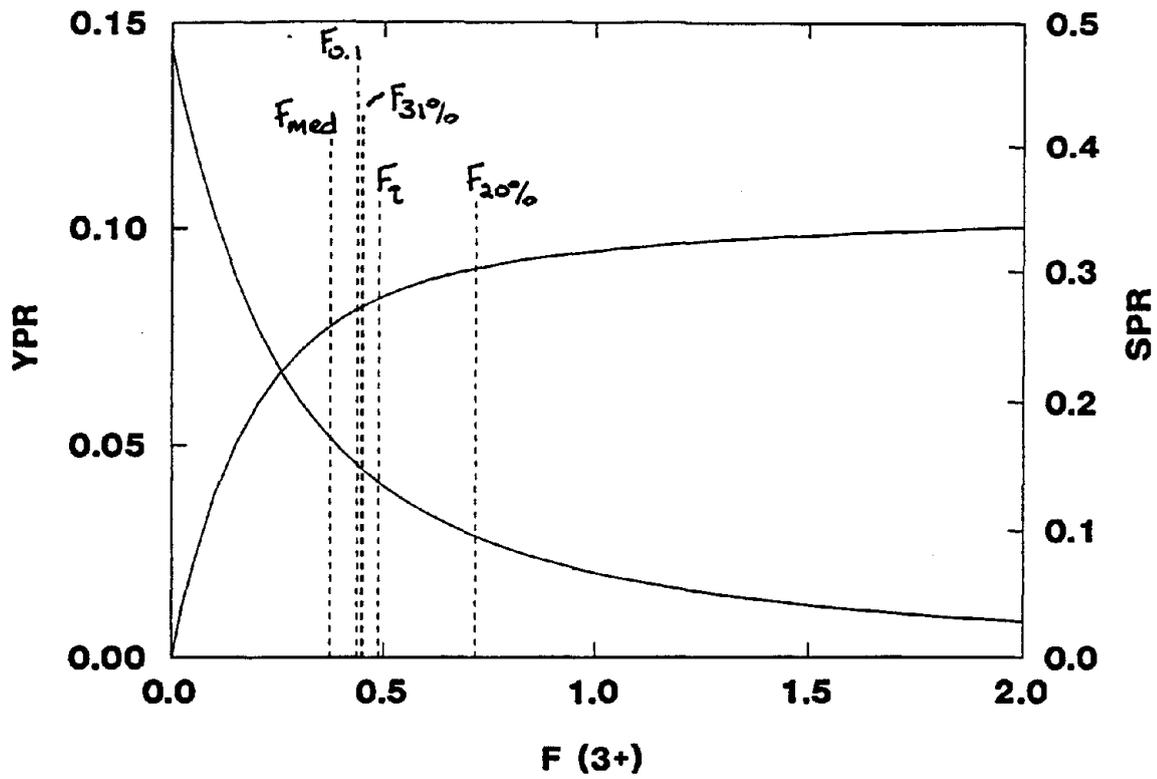
Northern silver hake. A. YPR (kg) and SPR (kg);
                      B. Control law (F=0.45, broken line) with historic estimates
                      of F for the years 1955-88.
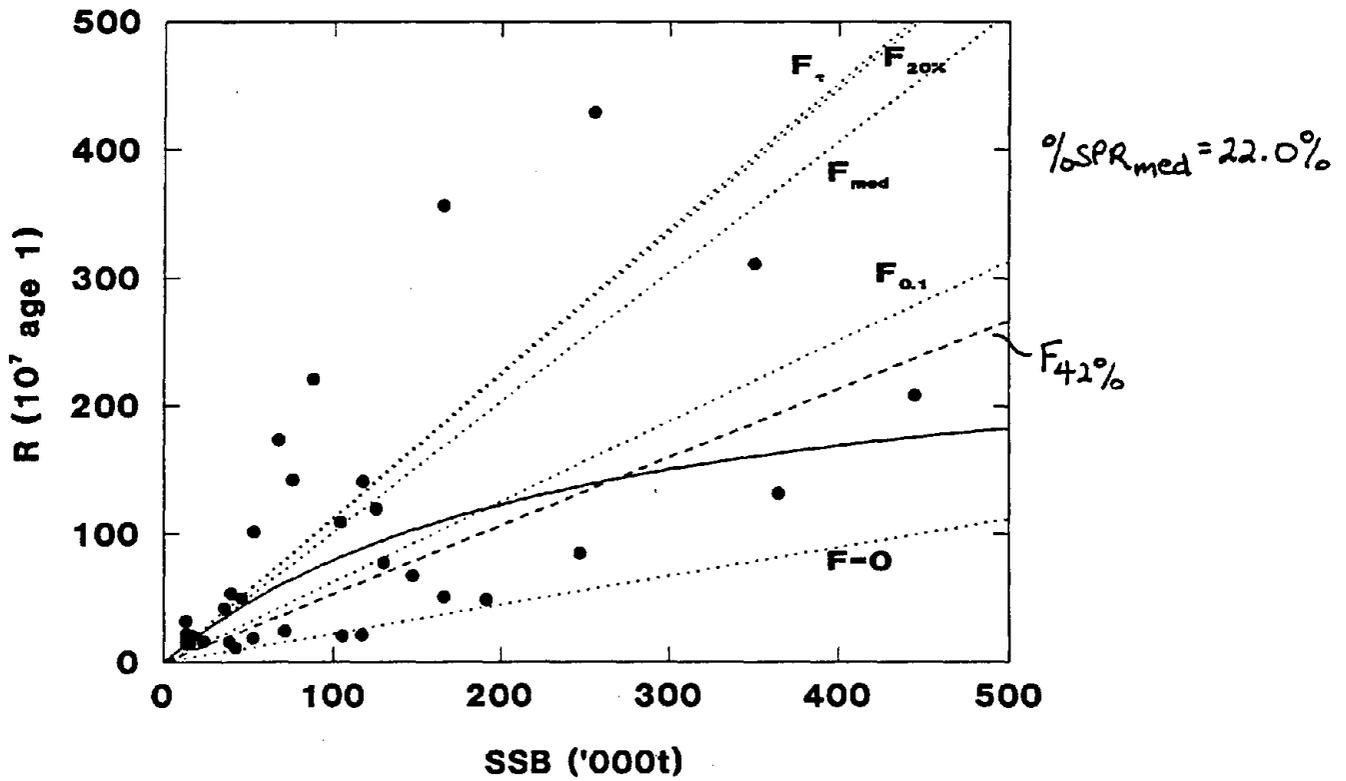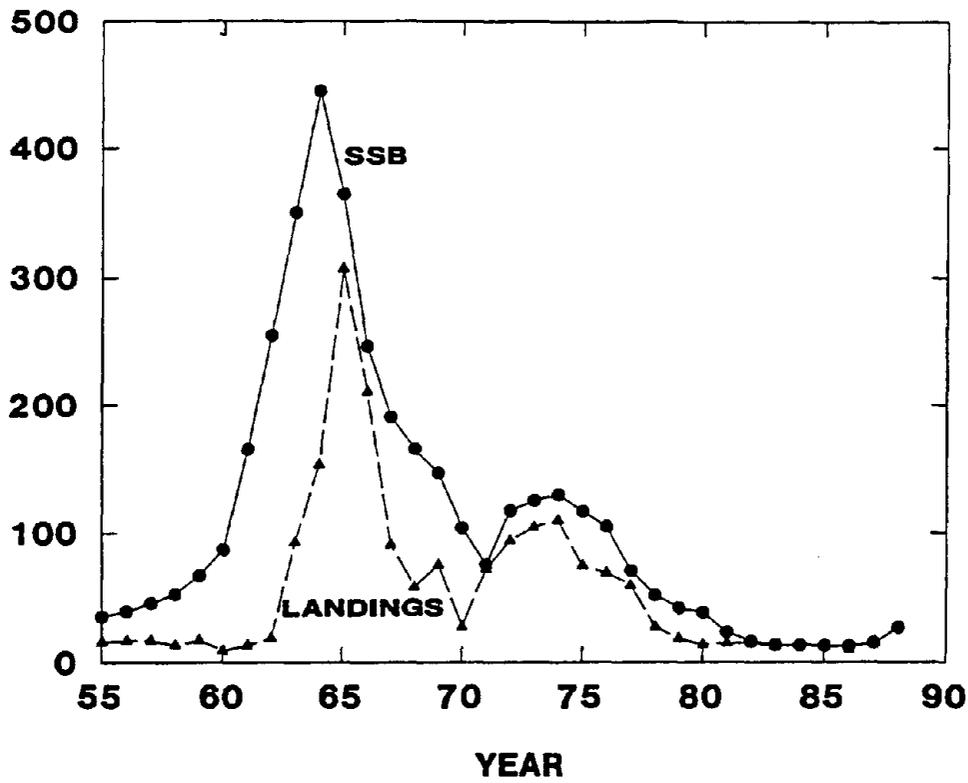
Southern silver hake. A. SSB ('000t) and landings ('000t):
B. S-R relationship with Shepherd model fit (solid line).
overfishing definition (heavy broken line). and other reference
fishing mortality rates.

87
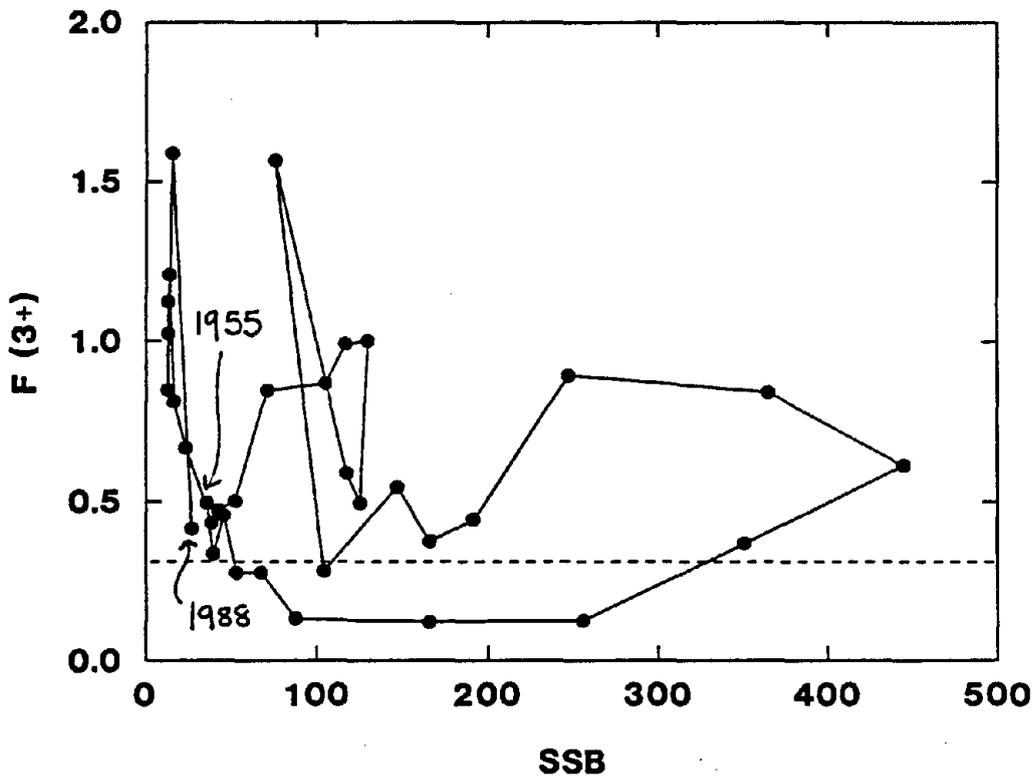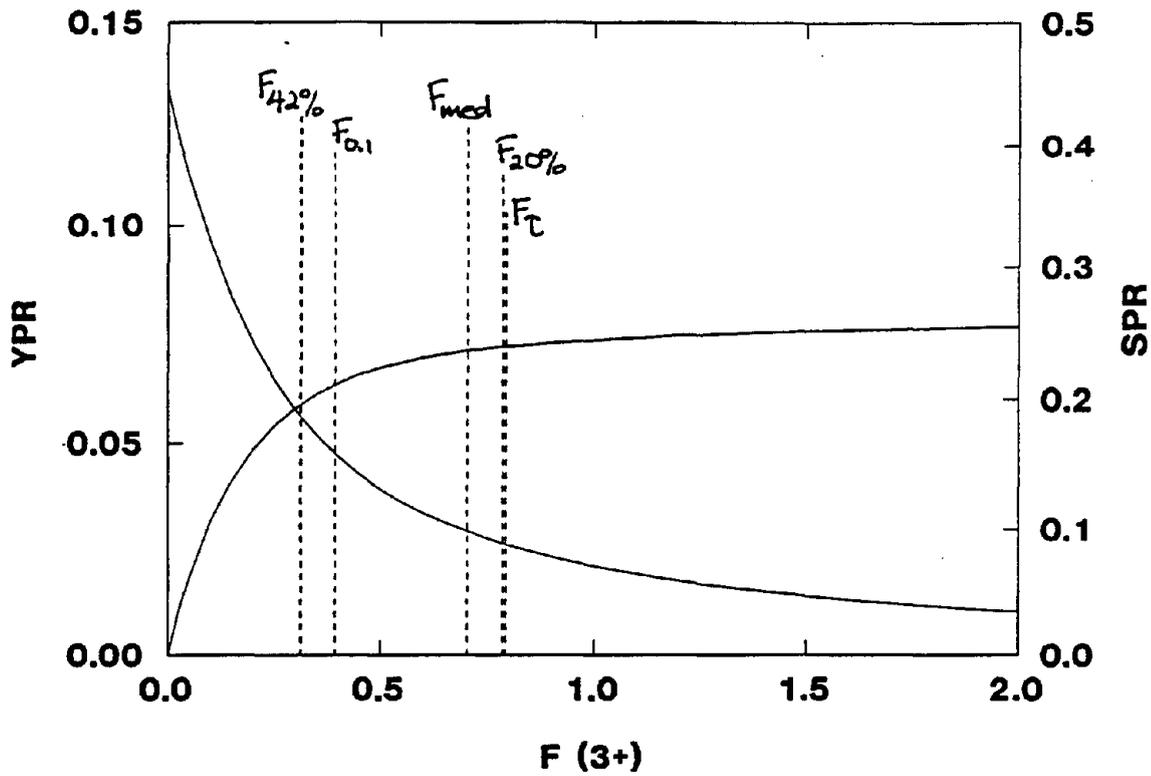
Southern silver hake. A. YPR (kg) and SPR (kg):
B. Control law (F=0.31, broken line) with historic estimates
of F for the years 1955-88.

88

American plaice NAFO 5YZ

Landings and Fishing Mortality (Ages=9)
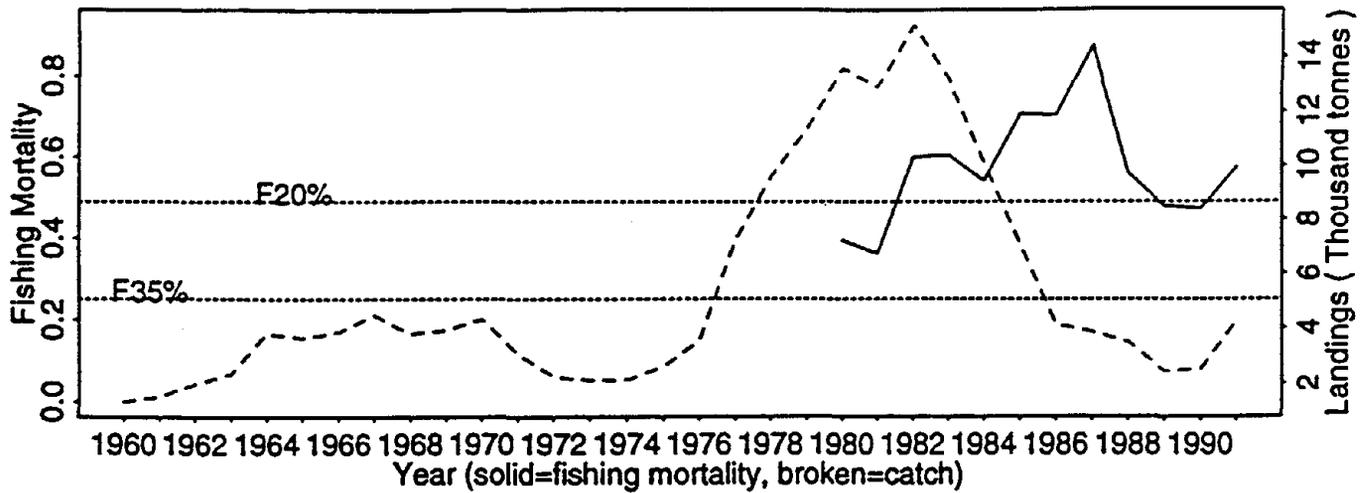
Year (solid=fishing mortality, broken=catch)

Time series of Recruitment and Stock

Year or Year Class

Recruit vs Stock with Bounded Shepherd Model

Spawning Stock (Thousand tonnes) in year t
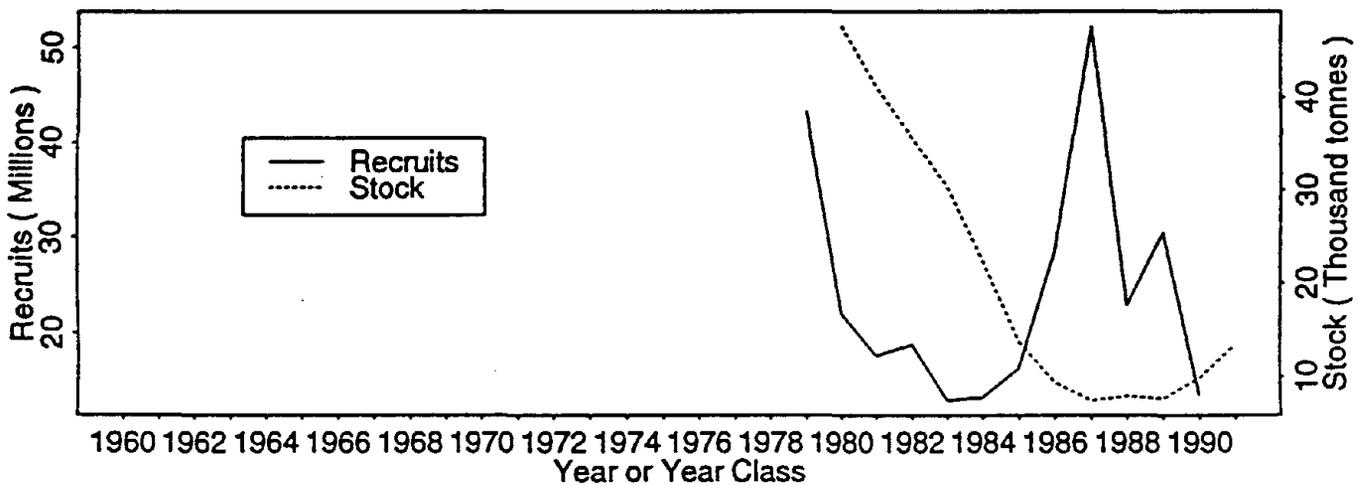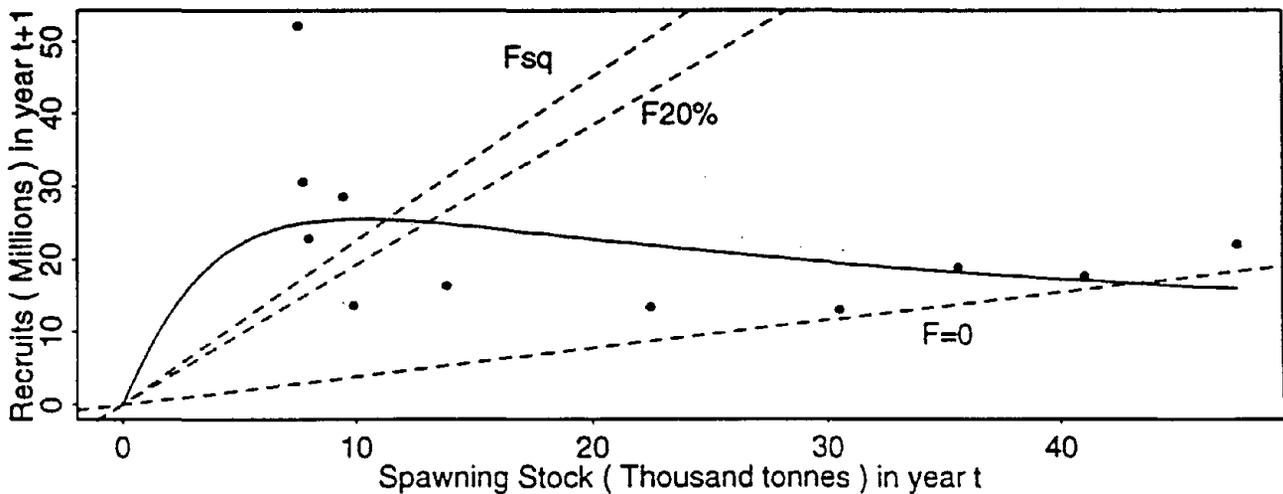
American plaice NAFO 5YZ

Landings and Equilibrium Yield Curve

Landings and Equilibrium Yield Curve

Yield and Spawning Biomass per Recruit

Yellowtail flounder NAFO 5Z

Landings and Fishing Mortality (Ages=7)

Year (solid=fishing mortality, broken=catch)

Time series of Recruitment and Stock

Year or Year Class

Recruit vs Stock with Bounded Shepherd Model

Spawning Stock (Thousand tonnes) in year t

Yellowtail flounder NAFO 5Z

## Landings and Equilibrium Yield Curve

Landings and Equilibrium Yield Curve

Yield and Spawning Biomass per Recruit

Yellowtail flounder Southern New England
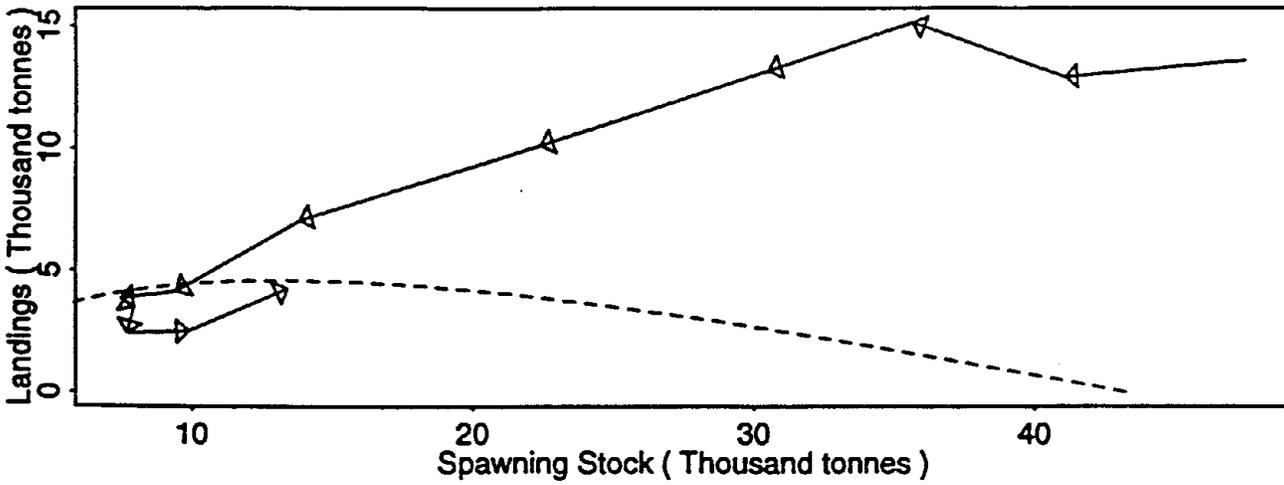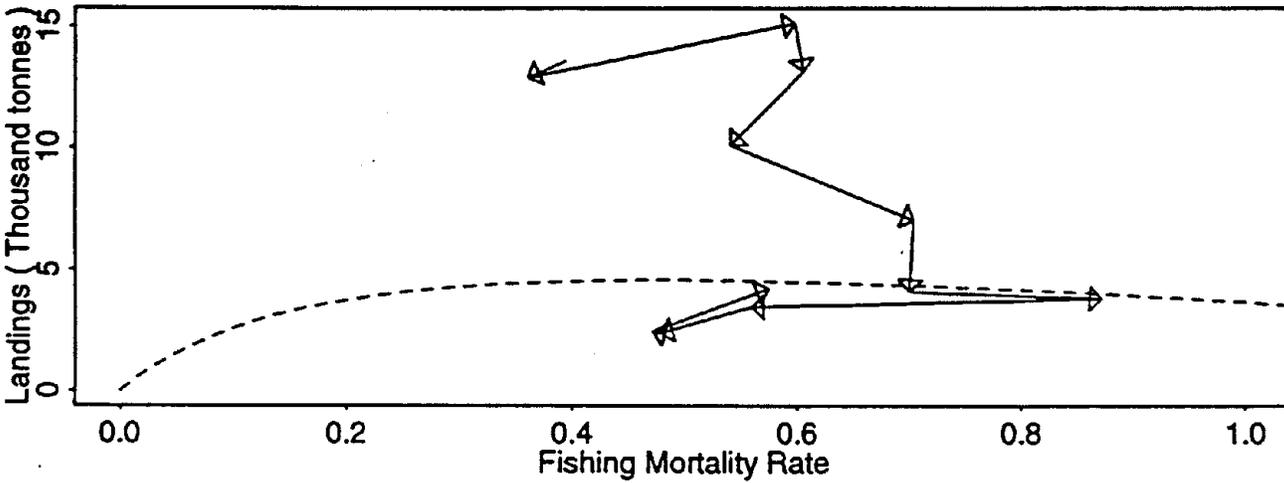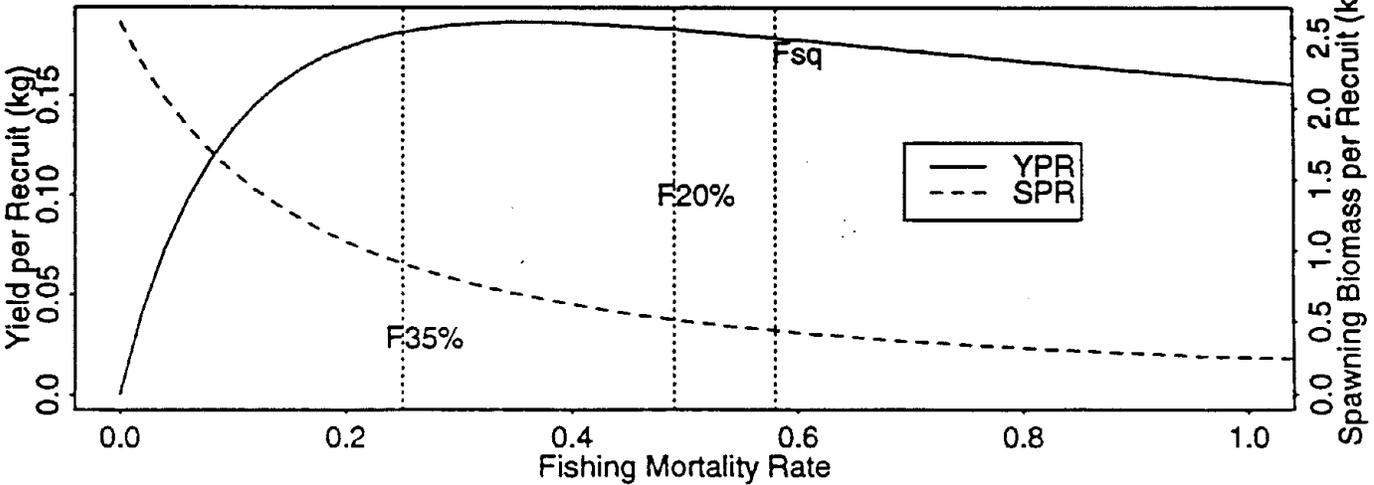
Landings and Fishing Mortality (Ages=7)
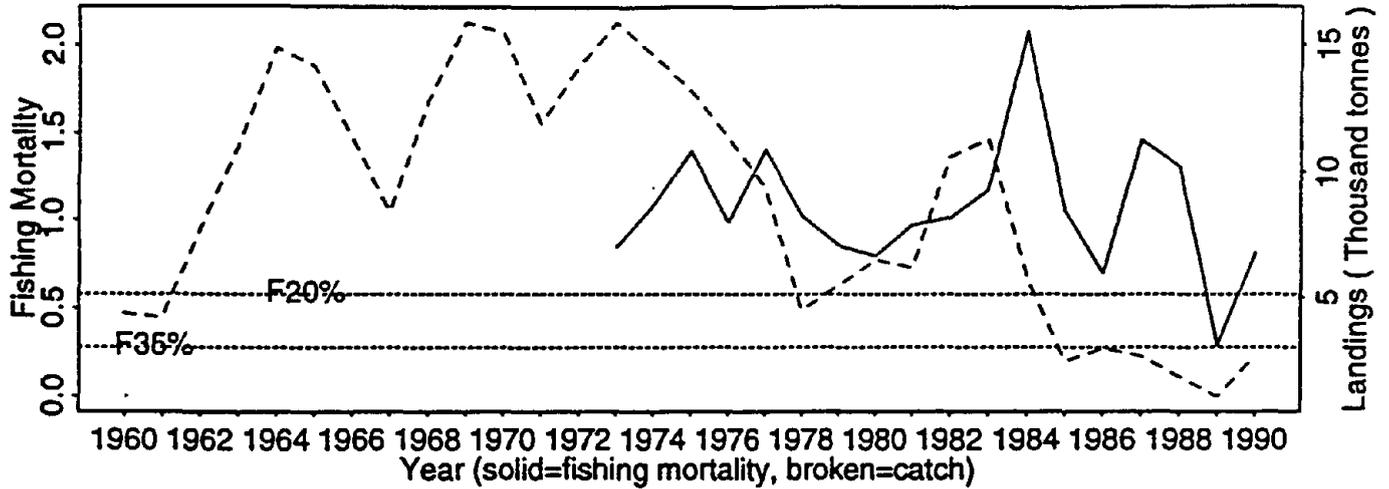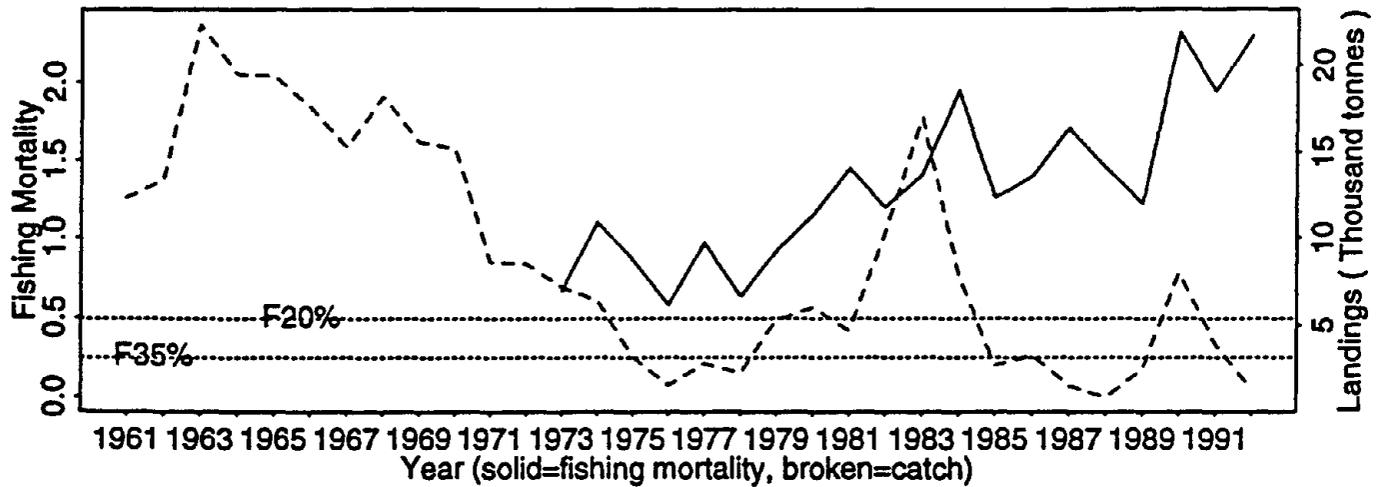
Time series of Recruitment and Stock
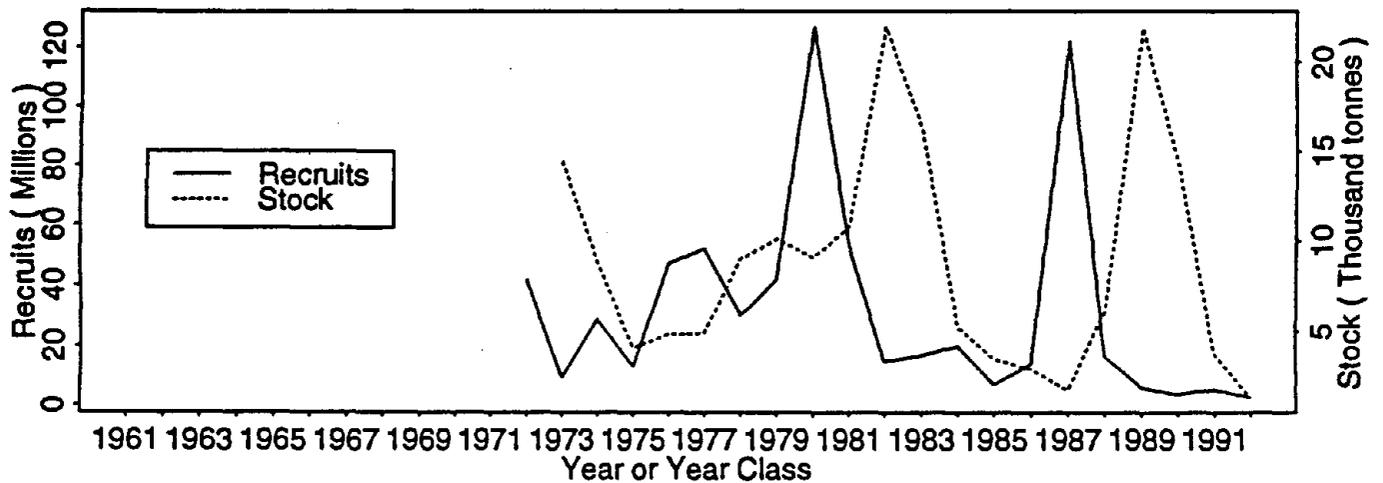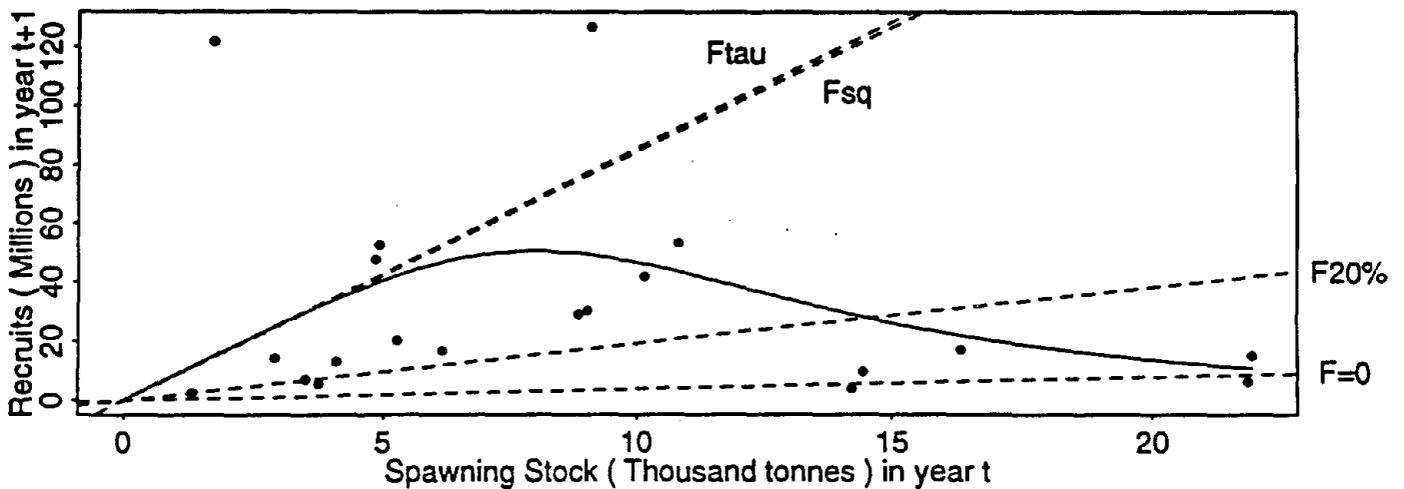
Recruit vs Stock with Bounded Shepherd Model

Yellowtail flounder Southern New England

Landings and Equilibrium Yield Curve
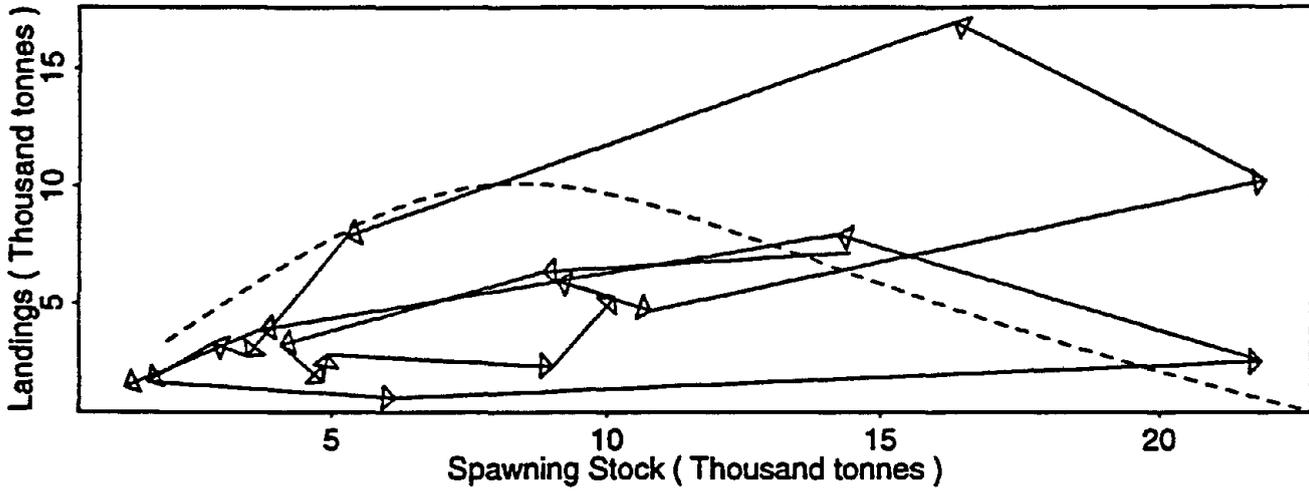
Landings and Equilibrium Yield Curve


## Yield and Spawning Biomass per Recruit

Gulf of Maine Cod Biomass and Yield

Gulf of Maine Cod 1982-1990

95
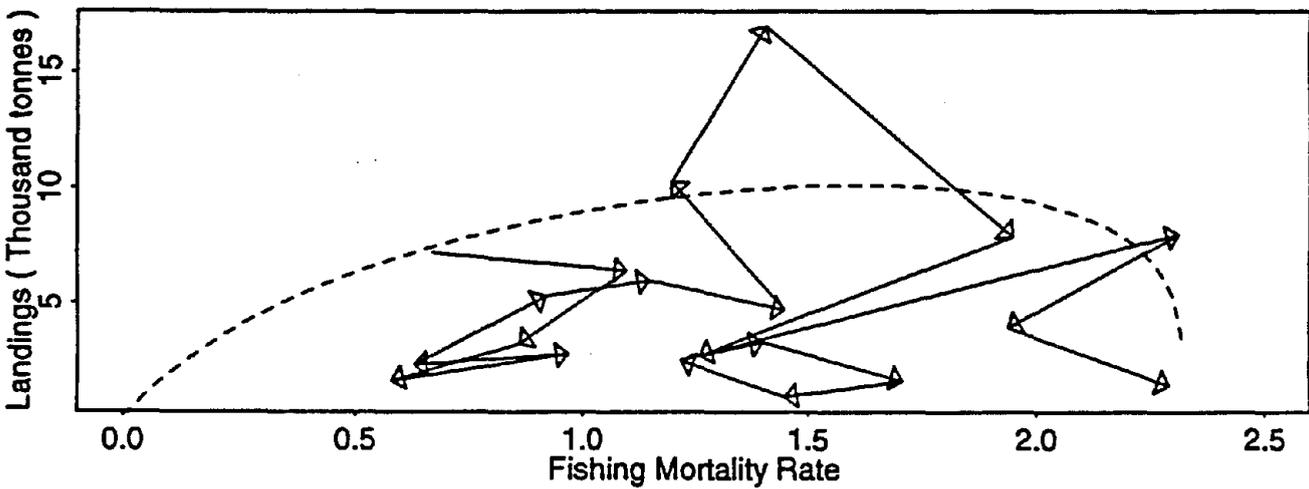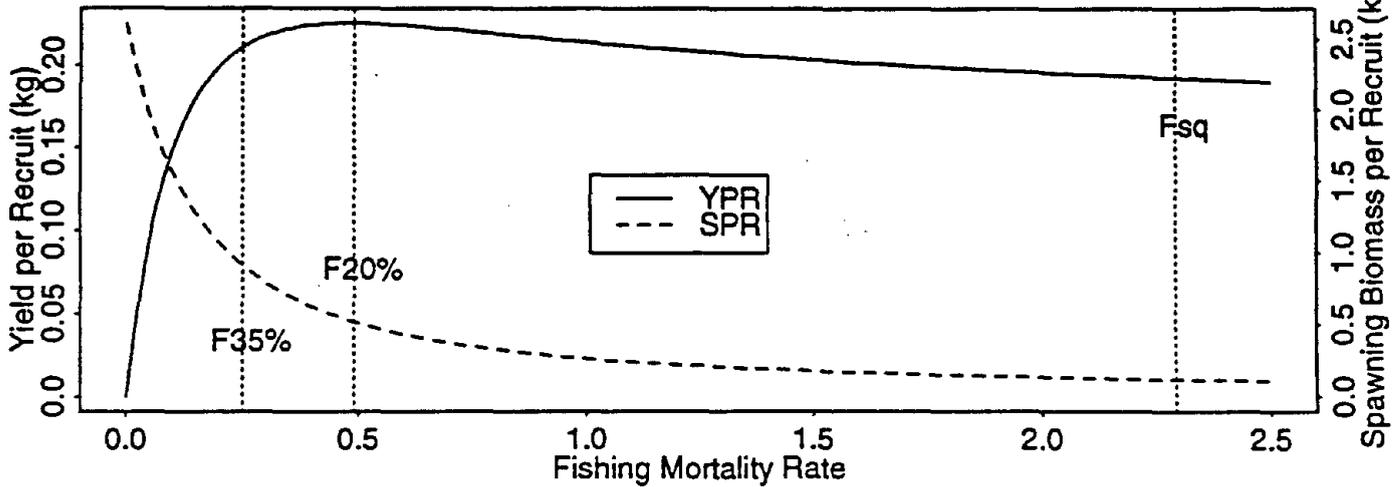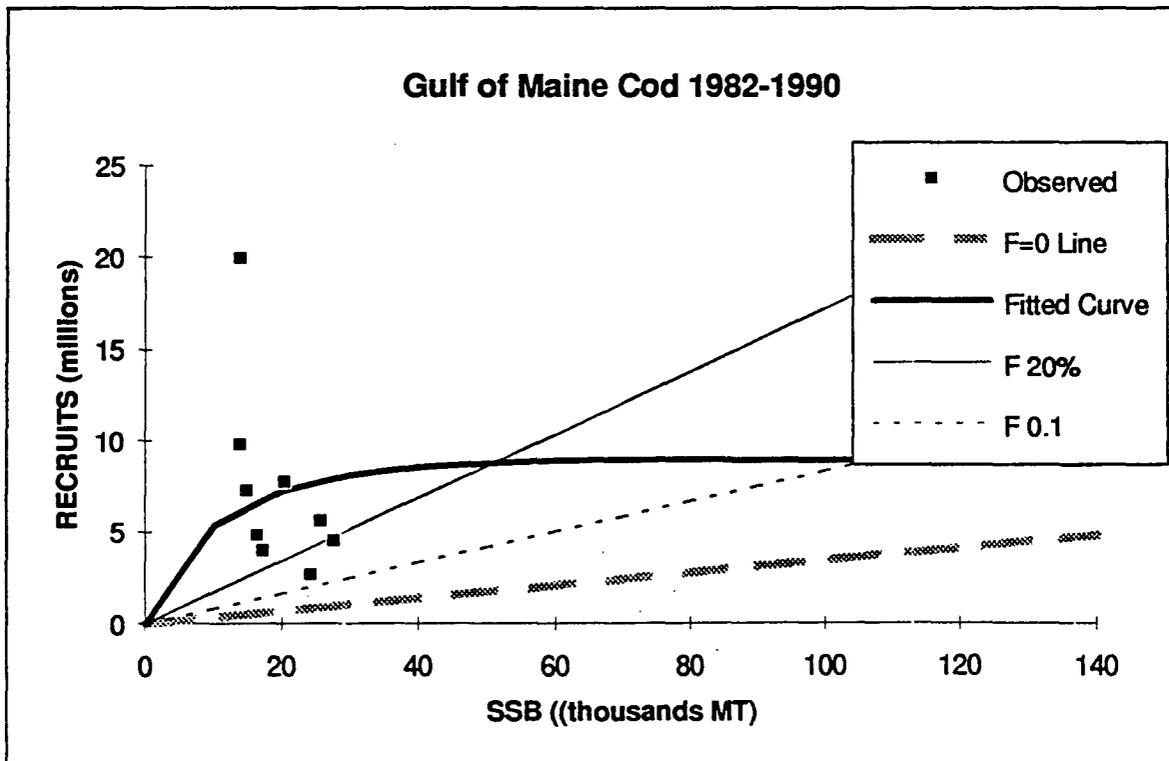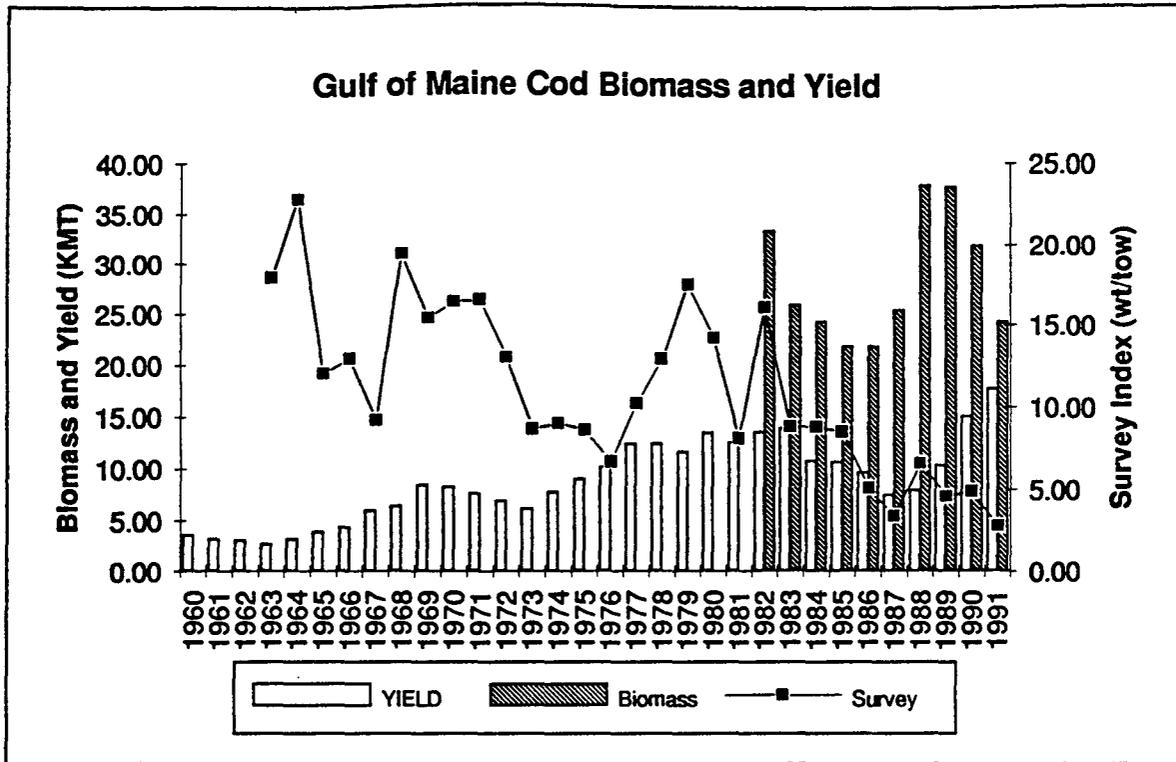
Georges Bank Cod Biomass and Yield

George's Bank Cod 1978-1991

Gulf of Maine Cod
Control Law

Gulf of Maine Cod

Gulf of Maine Cod
Observed Data 1982-1991

97

George's Bank - Gulf of Maine Redfish

YIELD — Biomass

Georges Bank-Gulf of Maine Redfish 1969-1979

◇ Observed   · · · · · F=0 line   ——— Fitted Curve   — — · f 20% line

Georges Bank Cod 1978-1992
Control Law

George's Bank Cod

# Georges Bank Cod
Observed Data 1978-1991

Gulf of Maine-Georges Bank Redfish
Control Law
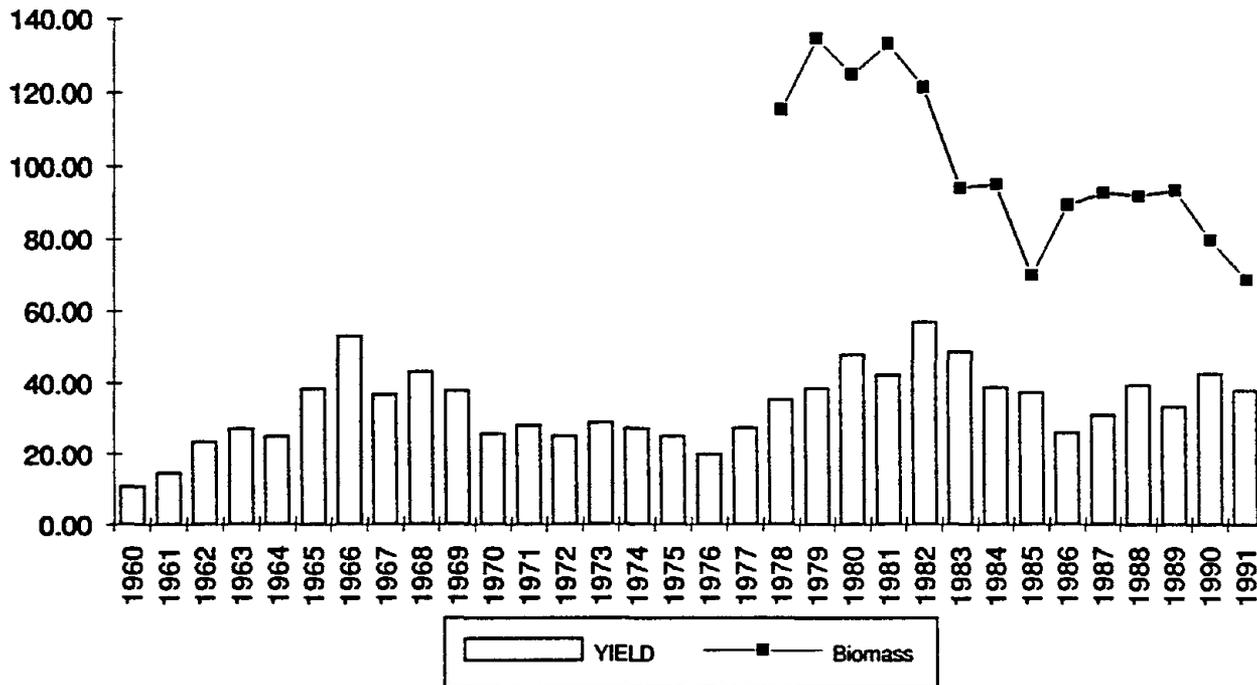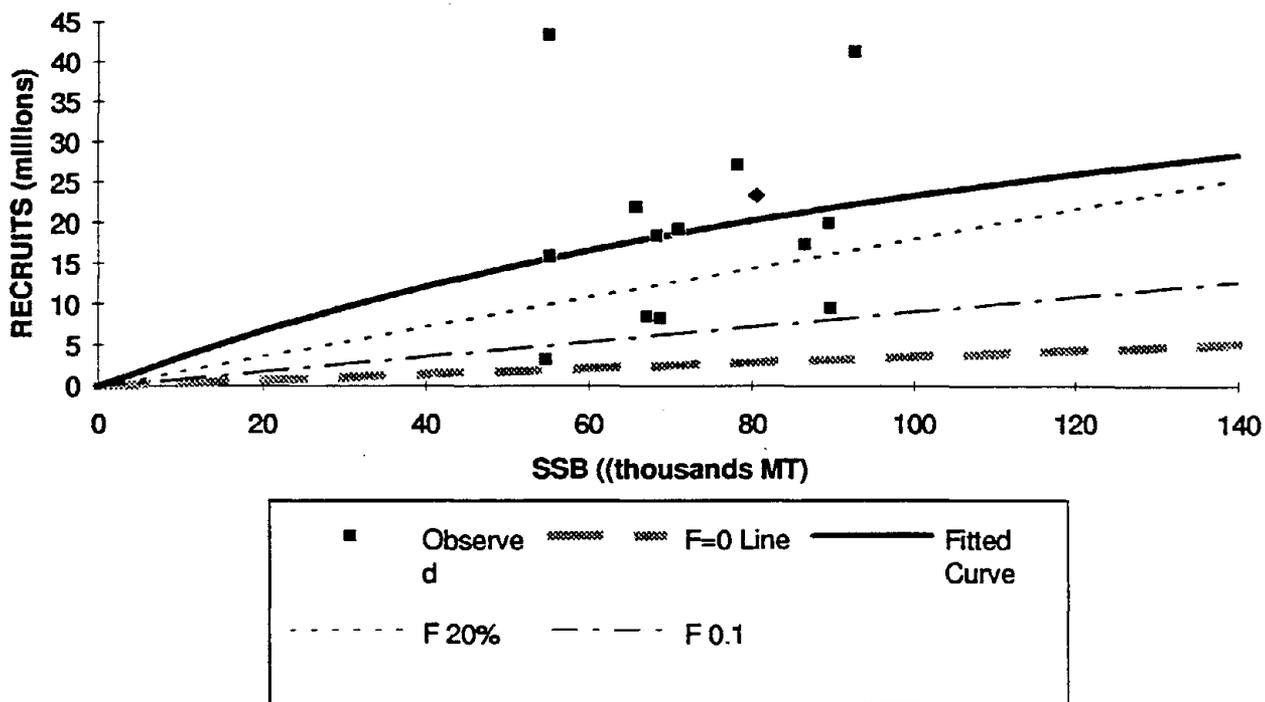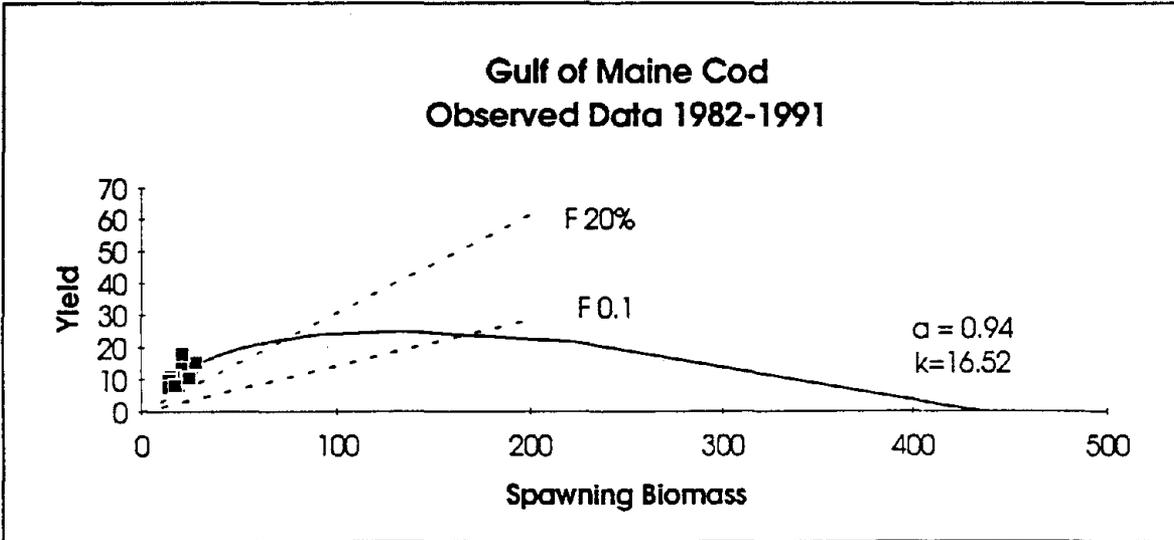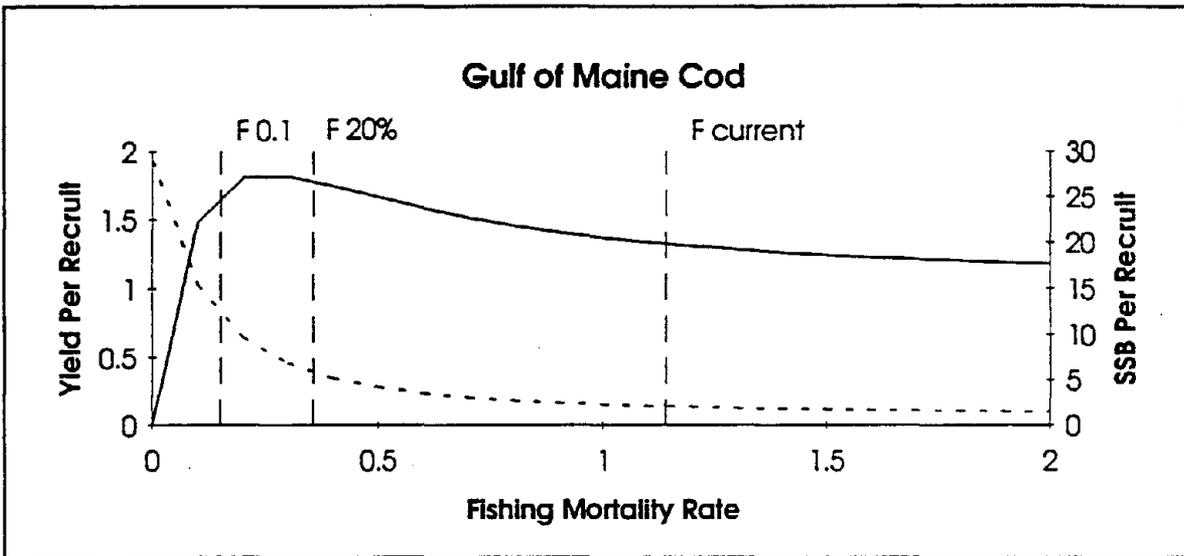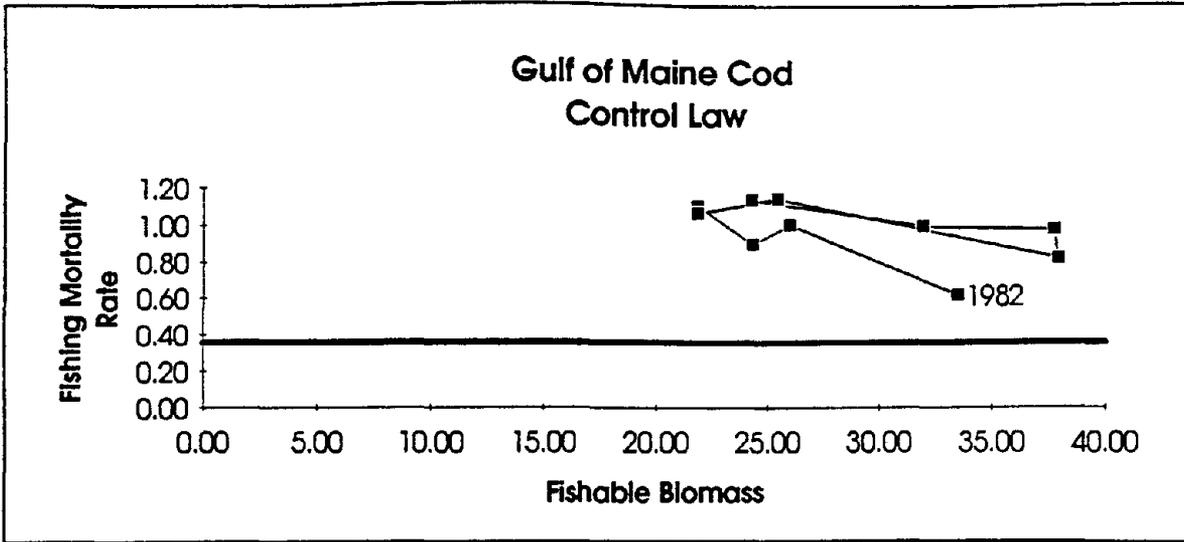
## George's Bank-Gulf of Maine Redfish

Gulf of Maine-Georges Bank
Redfish
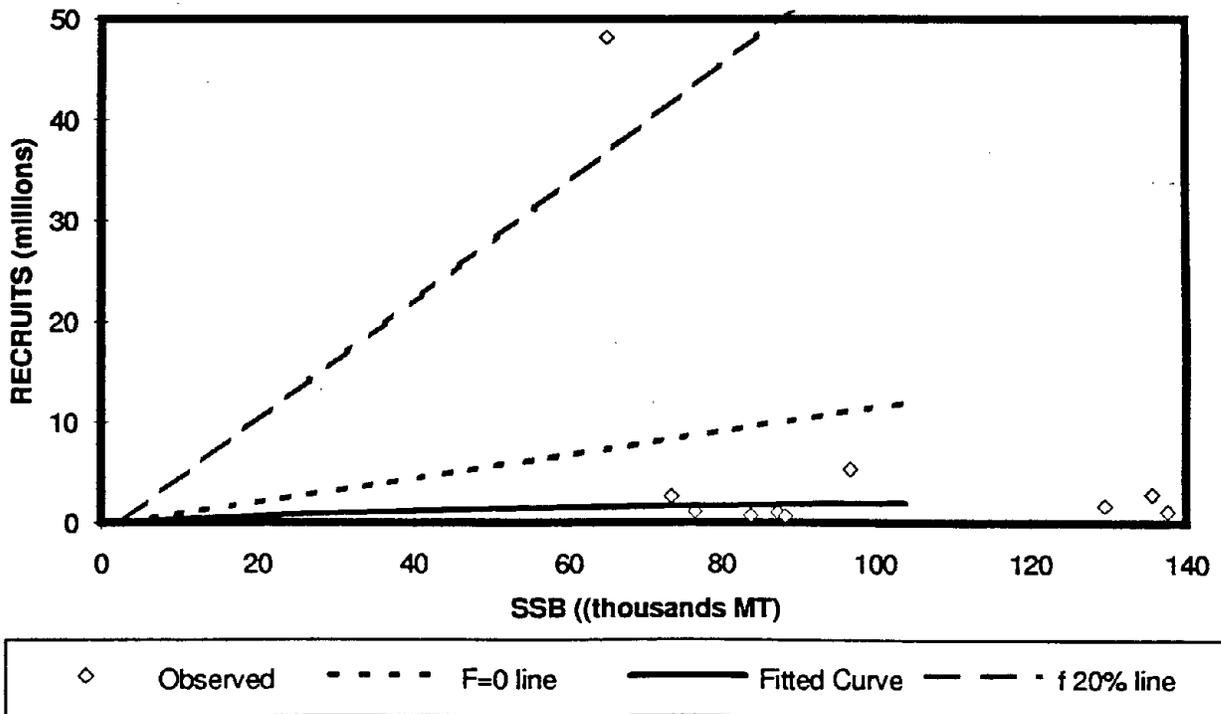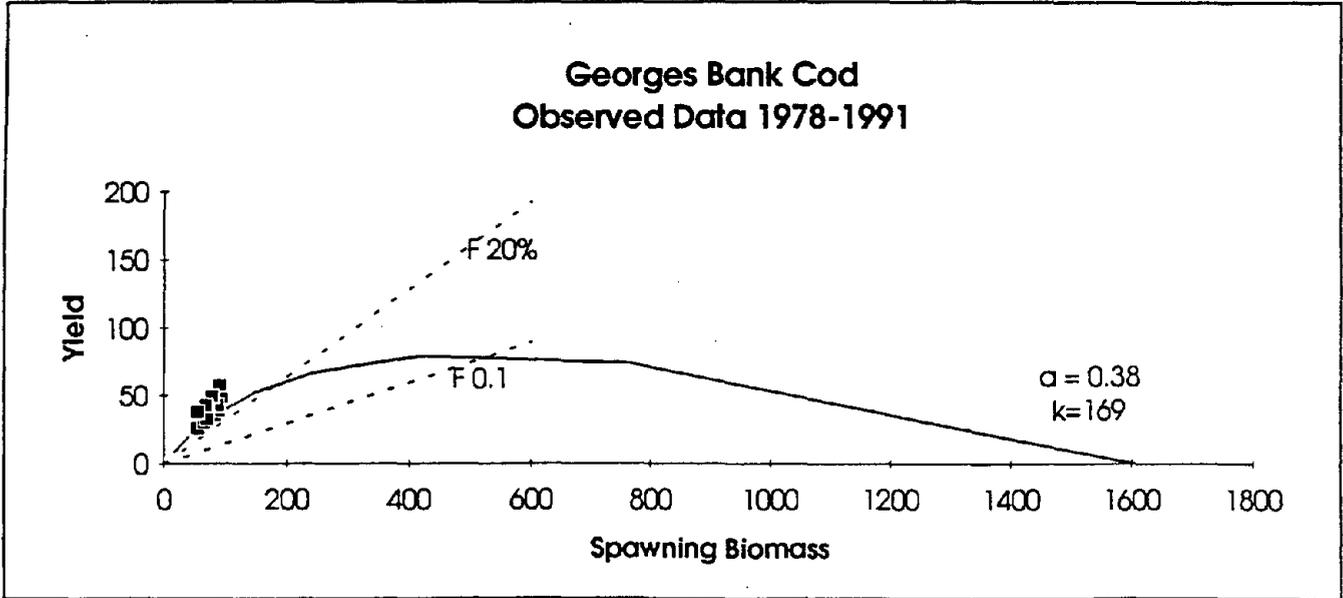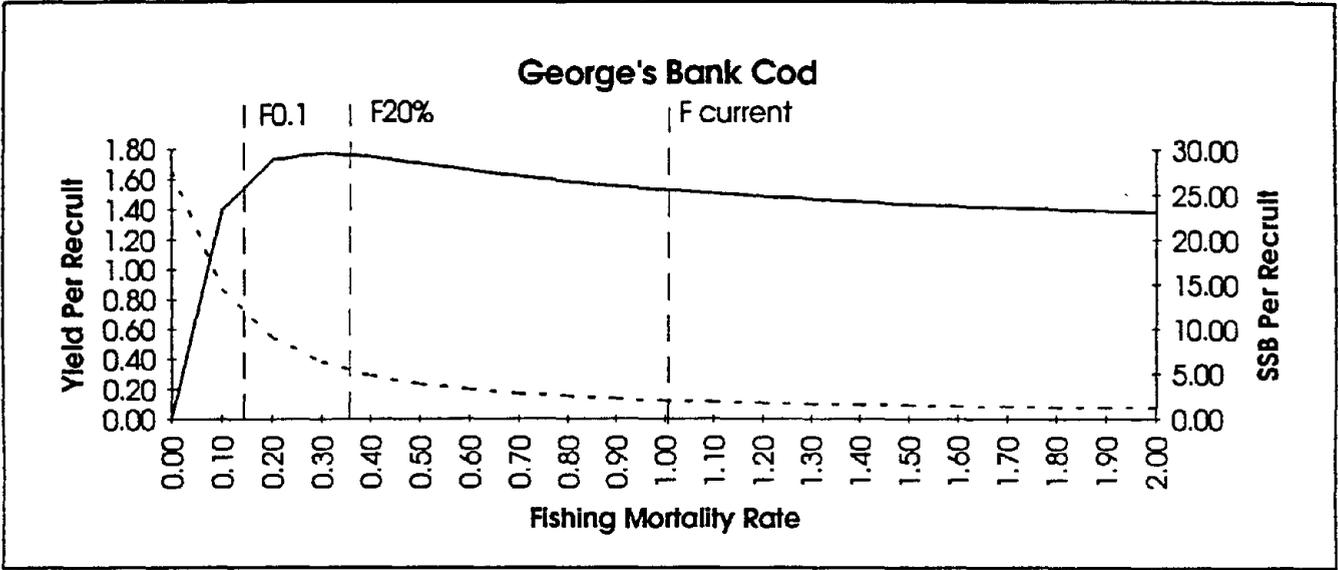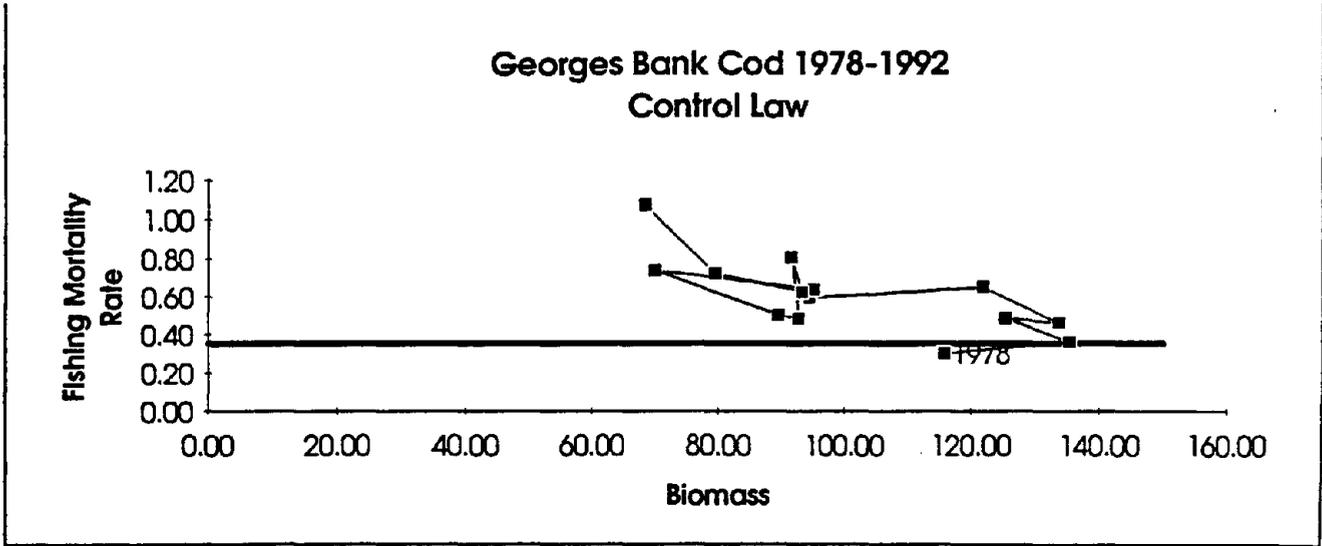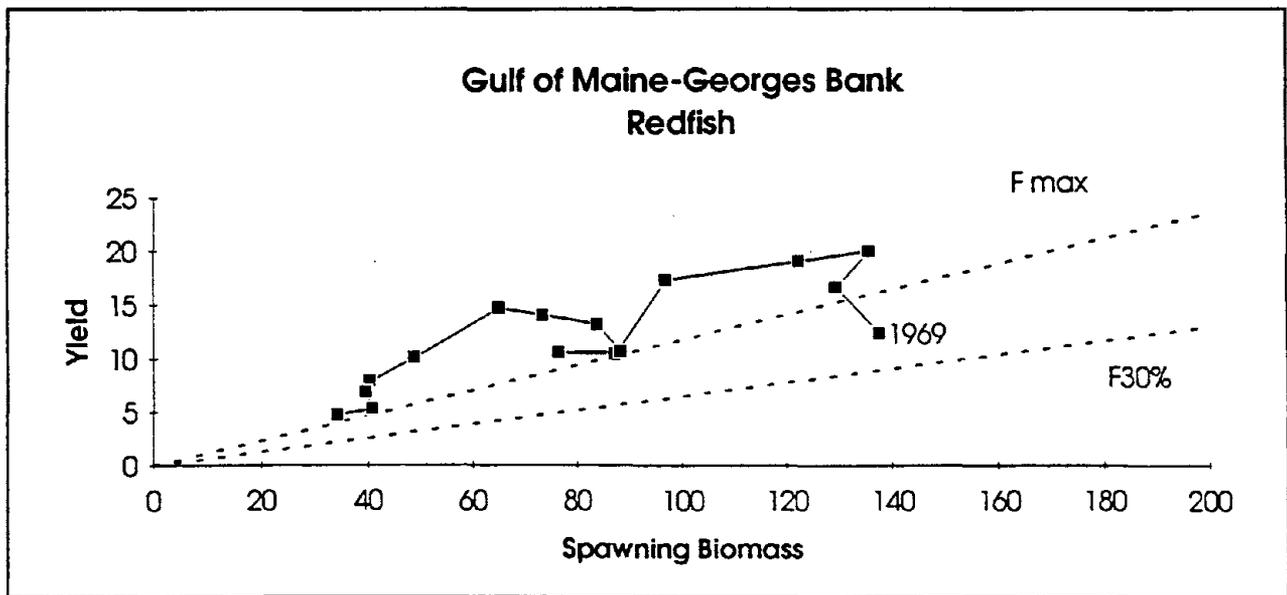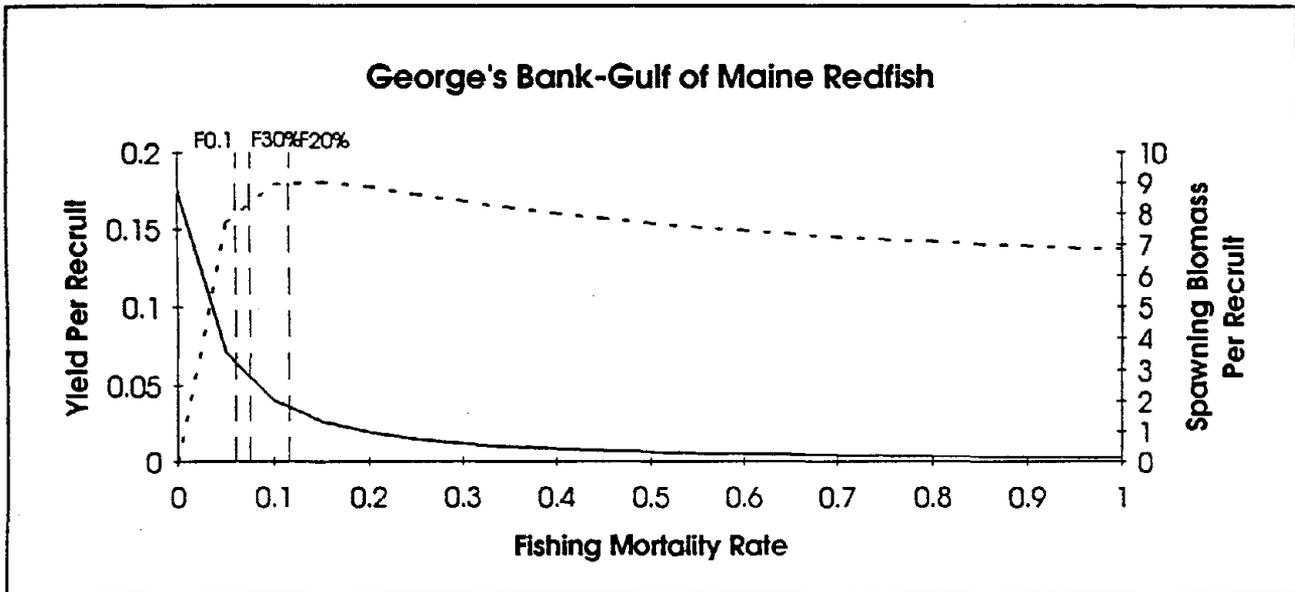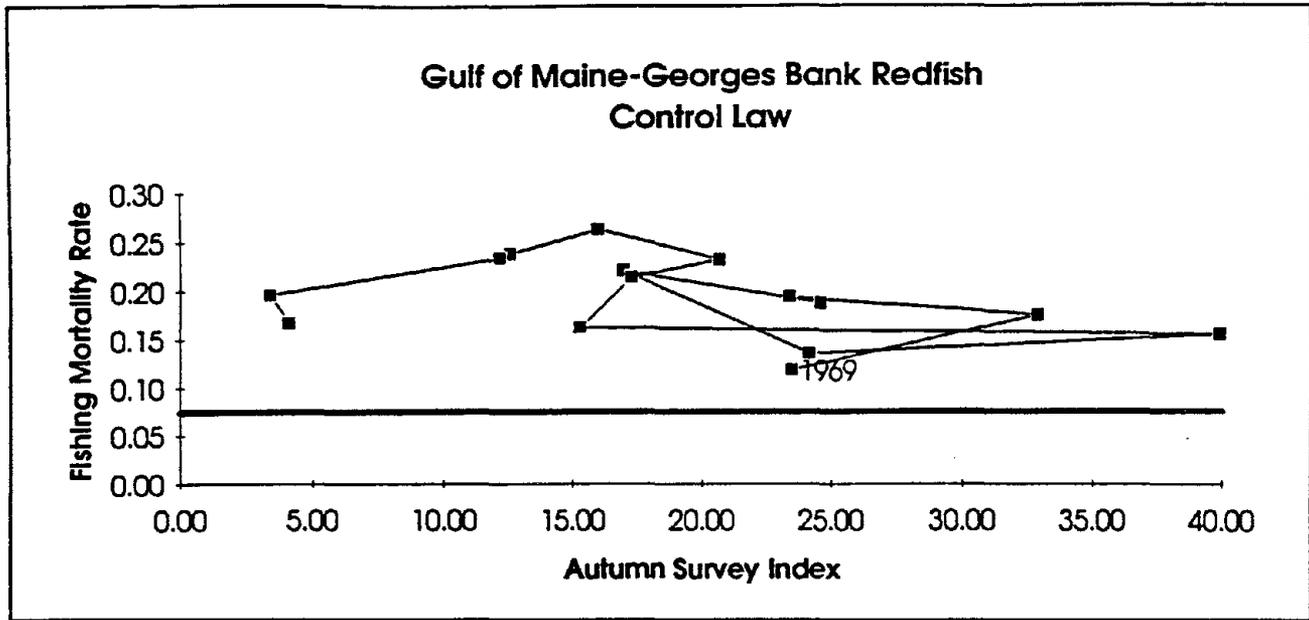
Georges Bank Haddock Biomass and Yield

Legend: YIELD, Biomass
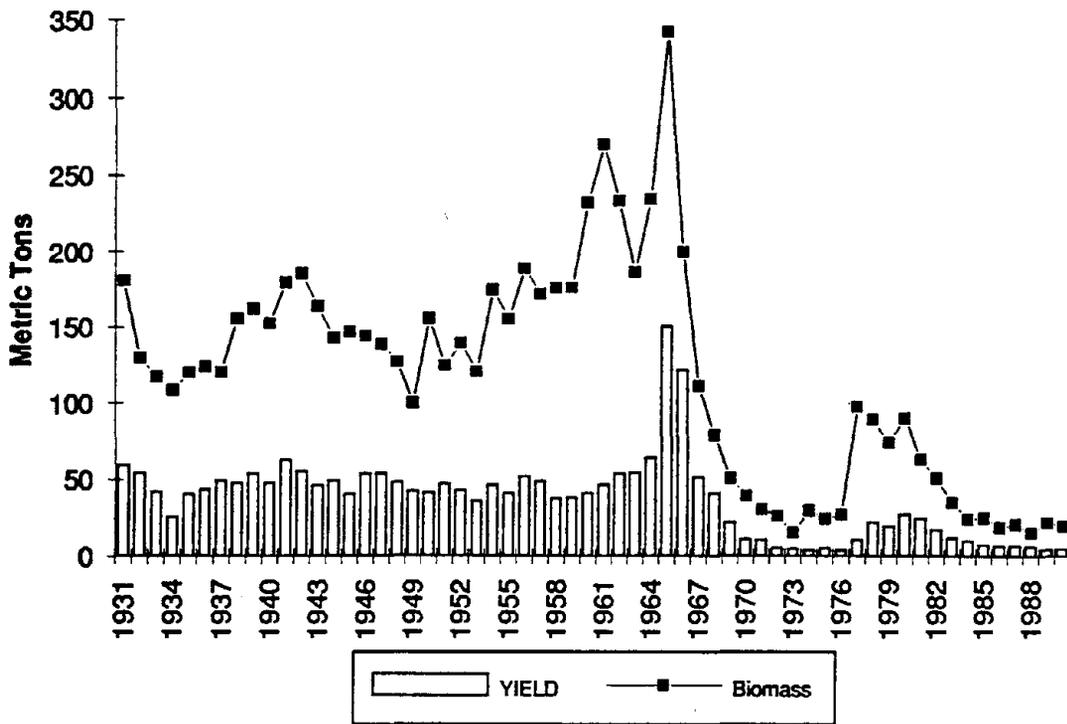
George's Bank Haddock 1931-90

471.9

Legend: Observed, F=0, F30%

Georges Bank Haddock Control Law

Georges Bank Haddock

George's Bank Haddock Equilibrium Yield
(1990 life history parameters)
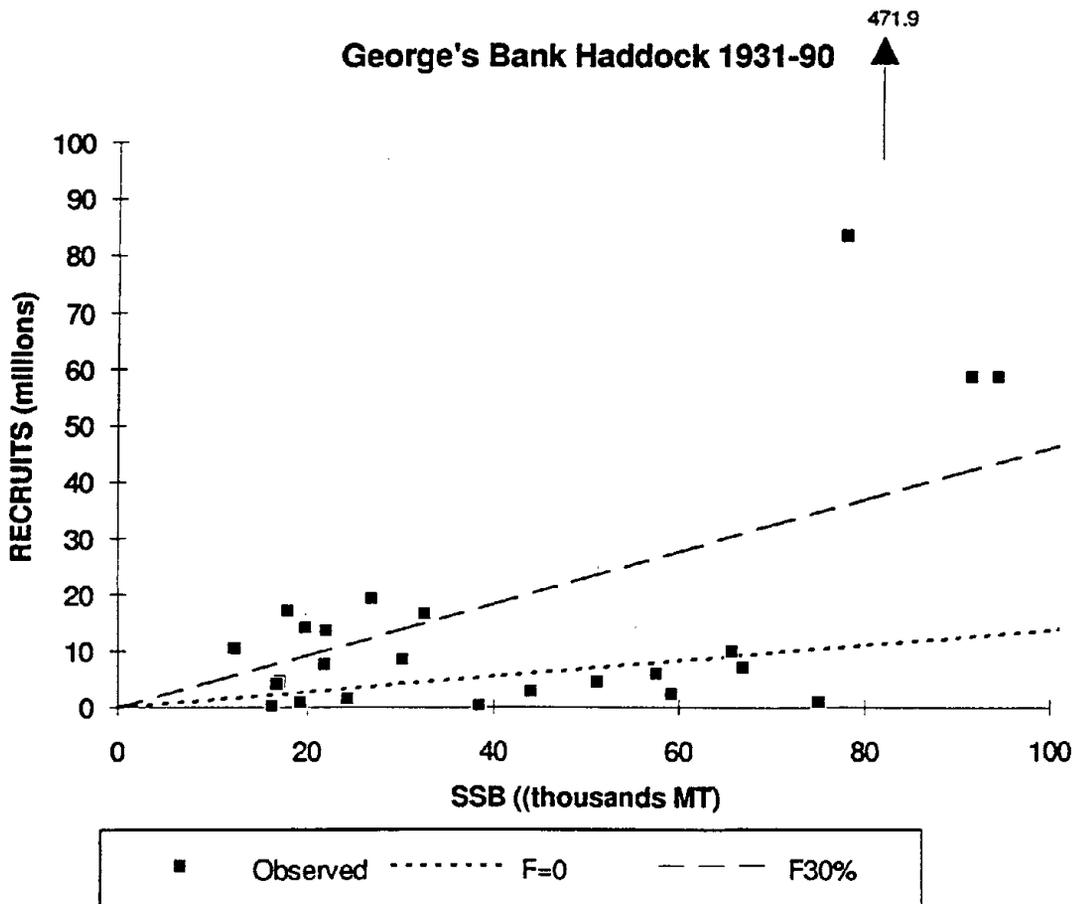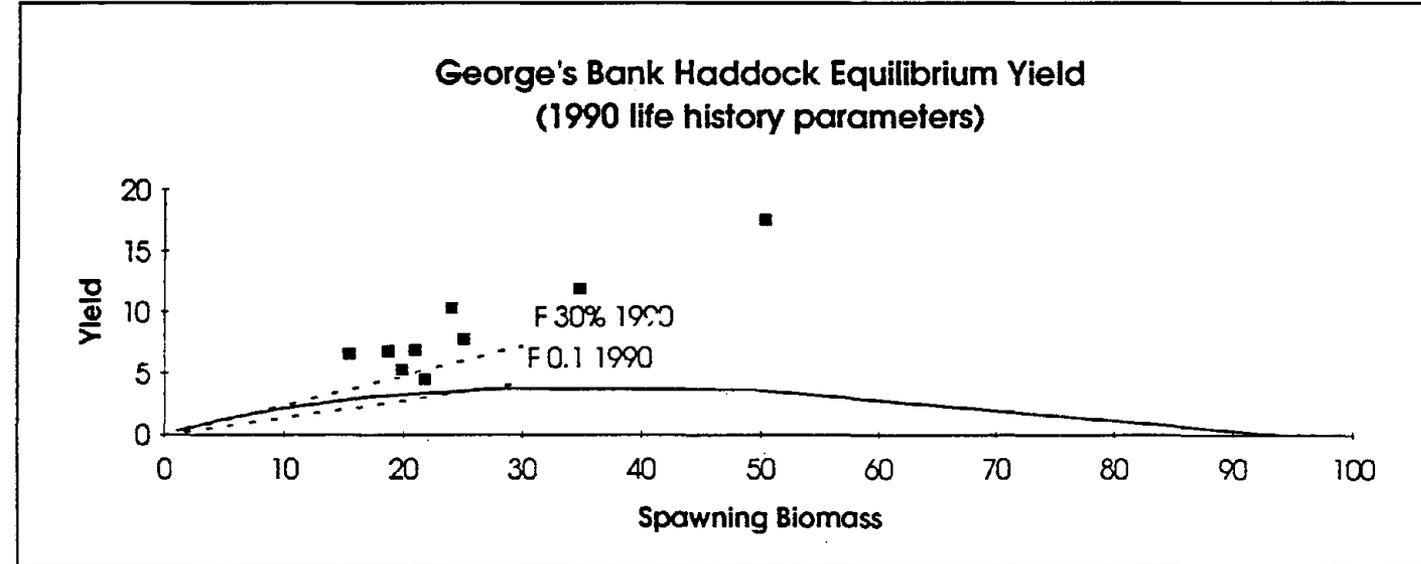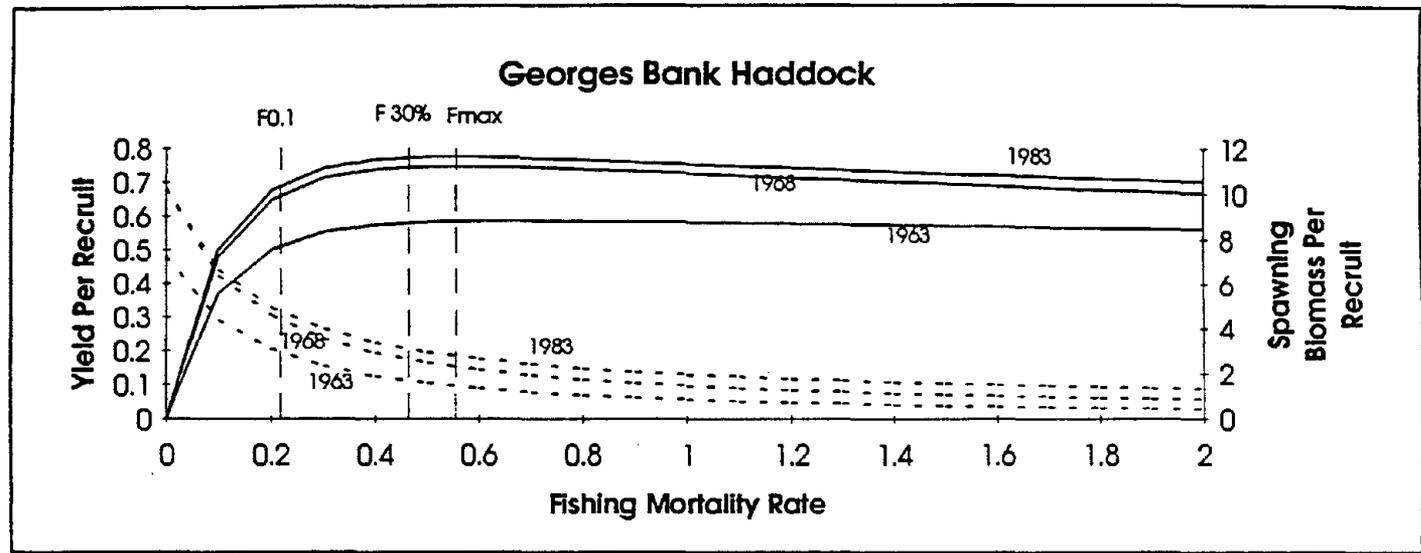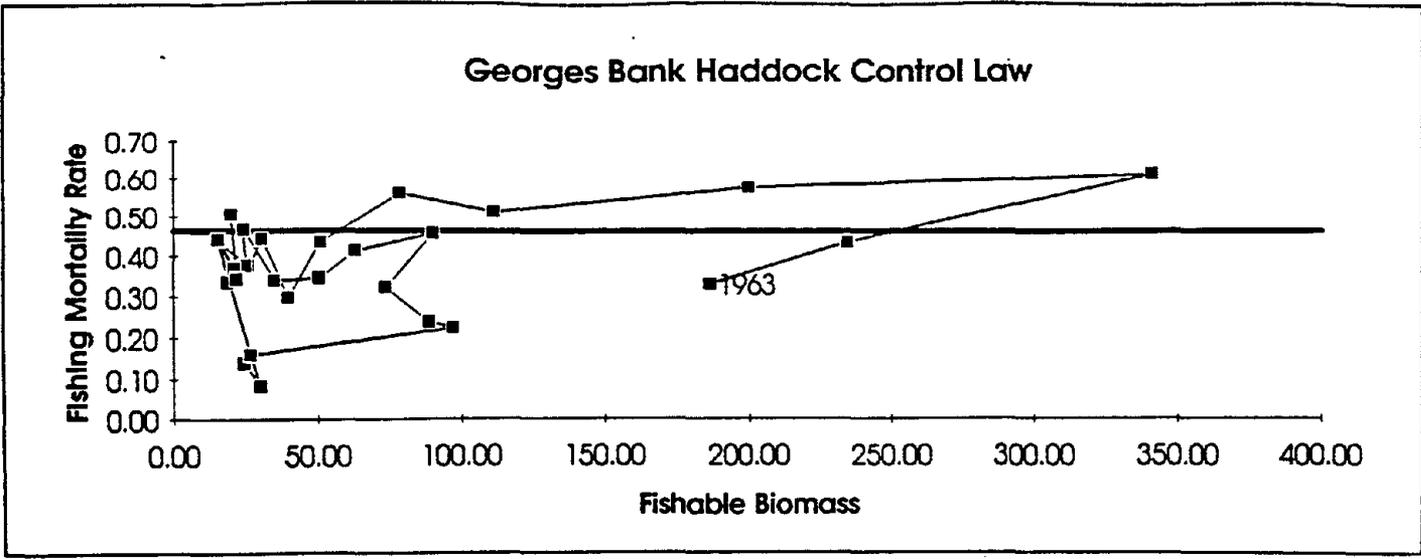
Management unit - South Atlantic Snapper-Grouper and Reef-fish (# 20,21,55)

Species/stocks: The Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region lists 73 species, of which 32 are actually snappers or groupers. The following list includes some of the more important (numerically or economically) stock components:

20. Wreckfish (*Polyprion americanus*)
21. Jewfish (*Epinephelus itajara*)
55. Other South Atlantic Snapper Grouper
    Mutton snapper (*Lutjanus analis*)
    Red snapper (*Lutjanus campechanus*)
    Gray snapper (*Lutjanus griseus*)
    Lane snapper (*Lutjanus synagris*)
    Yellowtail snapper (*Ocyurus chrysurus*)
    Vermilion snapper (*Rhomboplites aurorubens*)
    Speckled hind (*Epinephelus drummondhayi*)
    Red grouper (*Epinephelus morio*)
    Warsaw grouper (*Epinephelus nigritis*)
    Snowy grouper (*Epinephelus niveatus*)
    Nassau grouper (*Epinephelus striatus*)
    Black grouper (*Mycteroperca bonaci*)
    Gag grouper (*Mycteroperca microlepis*)
    Scamp grouper (*Mycteroperca phenax*)
    Black sea bass (*Centropristis striata*)
    Red porgy (*Pagrus pagrus*)
    Greater amberjack (*Serioloa dumerili*)

FMP/Amendment Defining Overfishing:

Amendments 2 (jewfish and other species in the management unit) and 3 (wreckfish) to the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region (South Atlantic Fishery Management Council).

Overfishing Definition:

There are two overfishing definitions in Amendment 2: one for jewfish, and one for all other species in the management unit. Amendment 3 added wreckfish to the management unit and contains an overfishing definition for wreckfish:

Jewfish

"The overfishing definition for jewfish is as follows:

"1. Jewfish are overfished when the stock is below the level of 40% of the spawning stock biomass per recruit that would occur in the absence of fishing.

"2. When jewfish are overfished, overfishing is defined as harvesting at a rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 40% spawning stock biomass per recruit level.

"3. When jewfish are not overfished, overfishing is defined as a harvesting rate that, if continued, would lead to a state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis.

"4. The threshold level is 30% SSBR; below this level, no harvest or possession of jewfish is allowed."

Note that the definition of Optimum Yield (OY) is also 40% SSBR (p. 4 of Amendment 2).

Other species in the management unit

"Overfishing for all other species in the management unit is defined as follows:

"1. A snapper grouper stock or stock complex is overfished when it is below the level of 30% of the spawning stock biomass per recruit that would occur in the absence of fishing.

"2. When a snapper grouper stock or stock complex is overfished, overfishing is defined as harvesting at a rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 30% spawning stock biomass per recruit level.

"3. When a snapper grouper stock or stock complex is not overfished, overfishing is defined as a harvesting rate that, if continued, would lead to a state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis."

Wreckfish

"Overfishing for wreckfish is defined as follows:

"1. Wreckfish are overfished when the stock is below the level of 30% of the spawning stock biomass per recruit which would occur in the absence of fishing.

"2. When wreckfish are overfished, overfishing is defined as harvesting at a rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 30% spawning stock biomass per recruit level.

"3. When wreckfish are not overfished, overfishing is defined as a harvesting rate that, if continued, would lead to the state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis."

Note that the definition of Optimum Yield is also 30% SSBR. Optimum yield is defined as follows:

"Optimum yield is any harvest level for wreckfish which maintains, or is expected to maintain, over time, a survival rate of biomass into the stock of spawning age fish to achieve at least a 30% spawning stock biomass per recruit (SSBR) population level, relative to the SSBR that would occur with no fishing." (p. 4 of Amendment 3).

These overfishing definitions were based on results from Gabriel (1985), Goodyear (1989), unpublished work by Goodyear, and the NMFS overfishing workshop held 12-14 February 1990. Detailed discussions of the rationale used for the definitions are provided in Amendment 4 and the SAFE document.

Assessment Method:

For most stocks, equilibrium yield per recruit (YPR) and spawning per recruit (SPR) analyses have been made, although not frequently. Separable VPA is available for wreckfish (1988-1992 data). An age-structured VPA was made for red porgy off the Carolinas (1972-1986 data). VPAs have also been made for vermilion snapper and black sea bass.

In most cases, stock status is derived from catch curve analyses of length (age)- frequency distributions assuming equilibrium conditions. The descending limb of the distributions provides an estimate of fishing mortality, which is then compared to that corresponding to the overfishing definition in order to determine whether the stock is overfished.

Relevant Life History Features:

Most groupers and porgies are protogynous hermaphrodites (functioning first as females and later as males). Estimates of the age or size at sex reversal are available for some species, but it is not clear whether these may vary interannually or in a density-dependent manner. Modelling of the timing and factors leading to sex reversal clearly impacts SSBR computations. A better quantitative understanding of sex reversal for individual species is highly desirable.

Many snapper and grouper species have been observed to spawn in aggregations, which have been targeted by fishers in the past. The disruption of such aggregations may bring about behavioral changes that can affect spawning success.

Evaluation of Overfishing Definitions:

The overfishing definition for species in this management unit is 30% SSBR (40% for jewfish), which is thought to be conservative with respect to the 20% SSBR definition more commonly used for other species with relatively poor information. As mentioned above, sex reversal in groupers and porgies is not well understood and must play an important role in SSBR computations. For some species, equilibrium SSBR computations and the rationale for overfishing definitions were made assuming 50% maturity at an age equal to one-half of the age when asymptotic size is reached. Given the general lack of quantitative information on sex reversal, it is difficult to tell whether this is a reasonable and robust assumption and whether a 30% SSBR level is conservative.

Detailed quantitative assessments are available for only a couple of stocks in this group. Based on the assessment results for South Atlantic red porgy (Vaughan et al. 1992) and wreckfish (Vaughan et al. 1993), it appears that a 30% SSBR level is not very conservative (see accompanying figures). However, it should be noted again that the fishing mortality rates corresponding to the overfishing level are sensitive to assumptions made about sexual maturity.

Data Sources:

Huntsman, G.R., J. Potts, R. Mays, R.L. Dixon, P.W. Willis, M. Burton and B.W. Harvey. 1992. A stock assessment of the snapper-grouper complex in the U.S. South Atlantic based on fish caught in 1990. Southeast Fisheries Science Center (Beaufort Laboratory).

Vaughan, D.S., C.S. Manooch, J. Potts and J.V. Merriner. 1993. Assessment of South Atlantic Wreckfish Stock for Fishing Years 1988-1992. Draft MS, Southeast Fisheries Science Center (Beaufort Lab.), NMFS.

Vaughan, D.S., G.R. Huntsman, C.S. Manooch, F.C. Rohde, and G.F. Ulrich. 1992. Population characteristics of the red porgy, *Pagrus pagrus*, stock off the Carolinas. Bull. Mar. Sci. 50:1-20.

S. Atl. Wreckfish
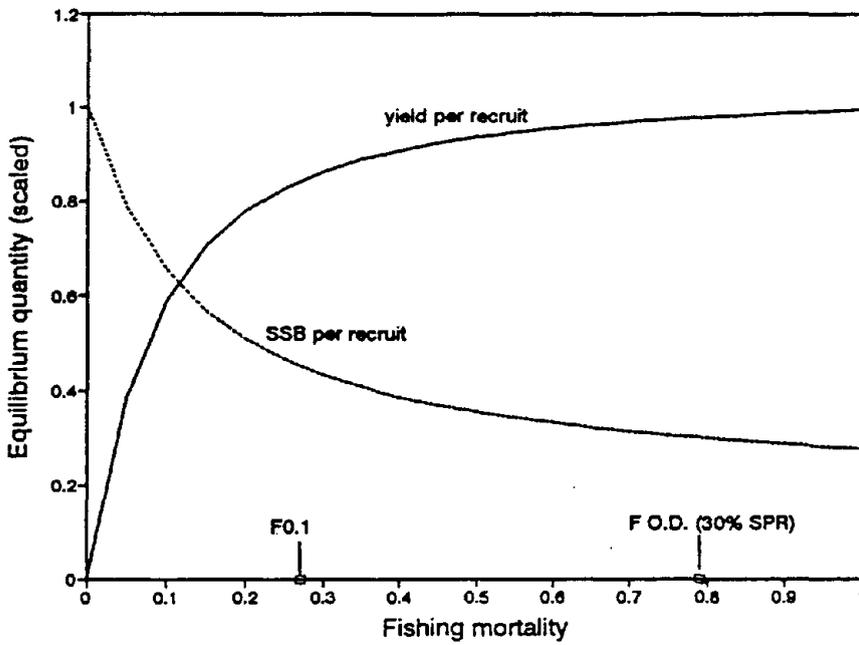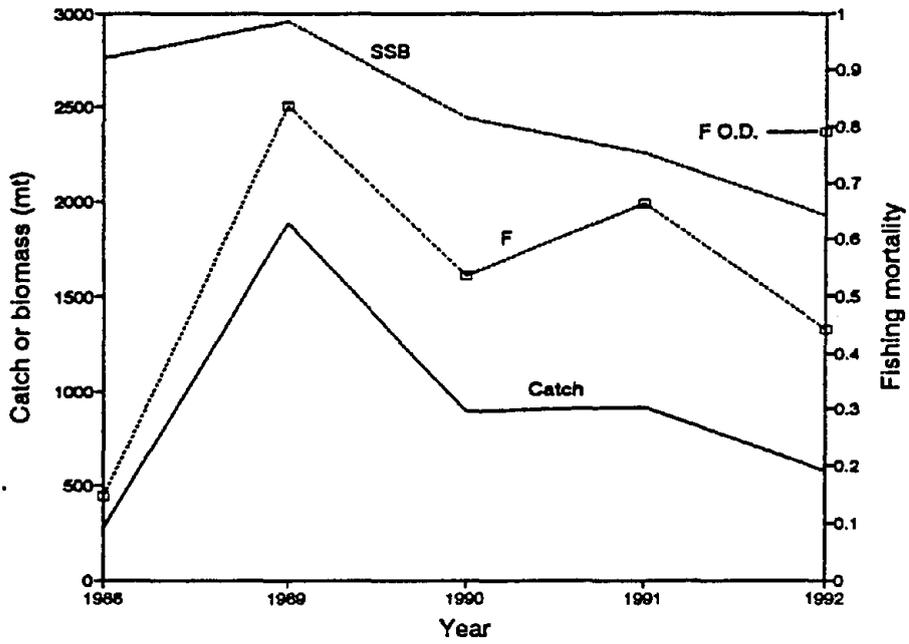
S. Atl. Red Porgy
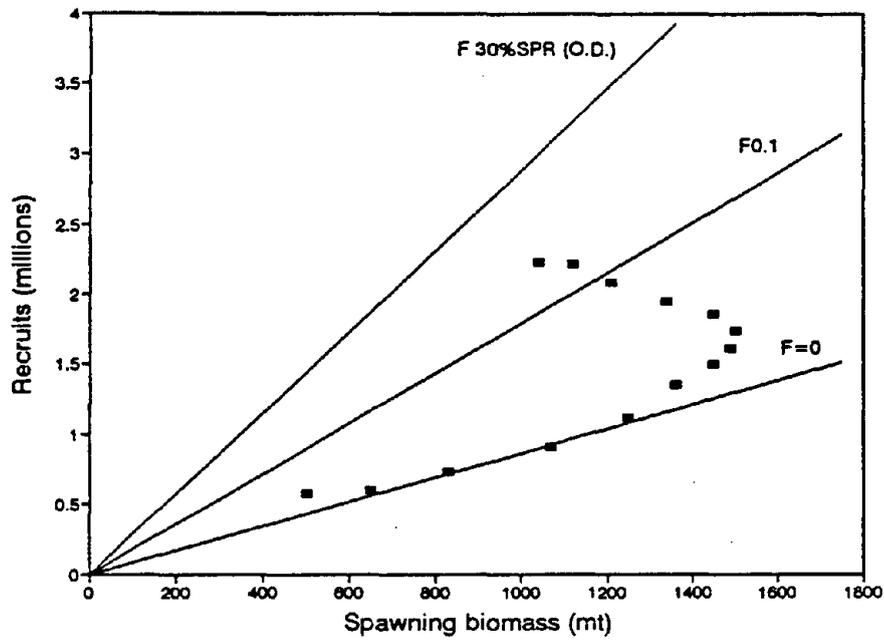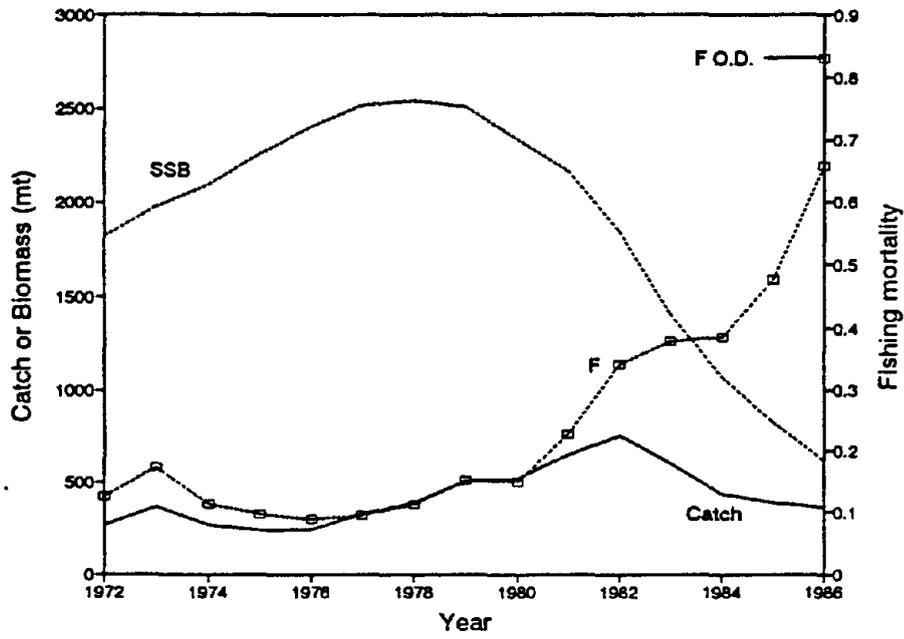
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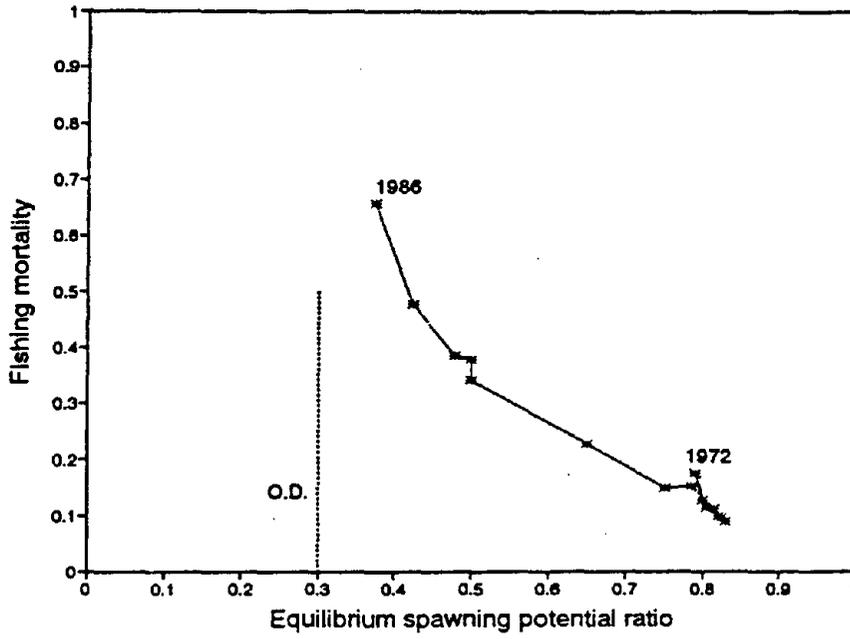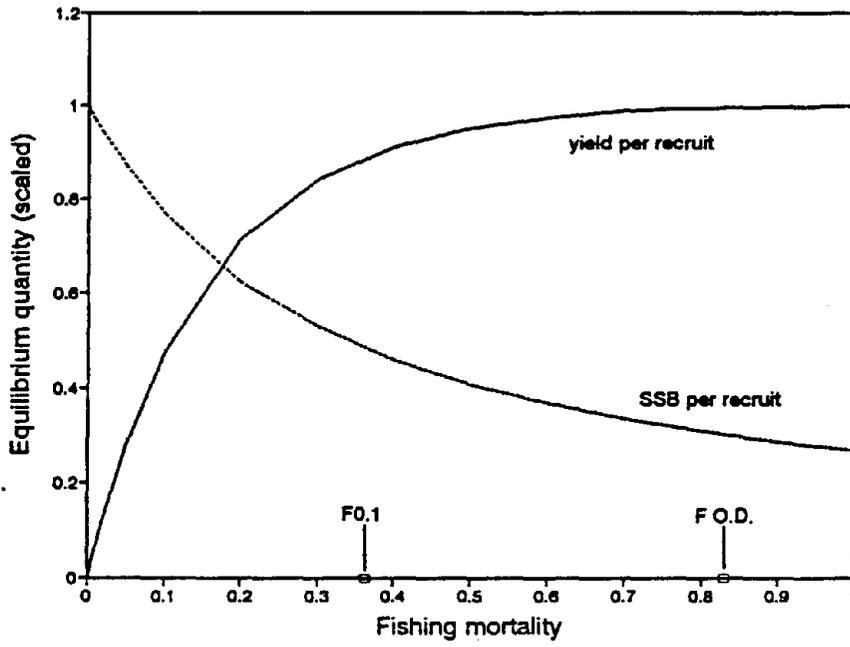
Management Unit - **Caribbean Reef Fish (# 23,58)**

Species/Stock:
23. Caribbean Red Hind (*Epinephelus guttatus*)
58. Other Caribbean Reef Fish

FMP/Amendment Defining Overfishing: Fishery Management Plan for the Shallow-Water Reef Fish Fishery of the Caribbean, Amendment 1.

Overfishing Definition:

A reef fish stock or stock complex is overfished when it is below the level of 20 percent of the spawning stock biomass per recruit that would occur in the absence of fishing.

When a reef fish stock or stock complex is overfished, overfishing is defined as harvesting at a rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 20 percent spawning biomass per recruit level.

When a reef fish stock or stock complex is not overfished, overfishing is defined as a harvesting rate that if continued would lead to a state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis

Assessment Method and Decision Rule:

The red hind stock complex has been assessed around the island of Puerto Rico and St. Thomas using data on length compositions to estimate growth and mortality rates (using catch curves) and through the calculation of yield per recruit and spawning biomass per recruit. For other reef fishes, some basic biological information is available, but generally less than for red hind.

Relevant Life History Features:

Most of the species in this complex are long-lived, slow growing and many are hermaphodites. Red hind change from female to male at older ages (50% males by age 6-7). They aggregate for spawning and fishing tends to concentrate on these aggregations. Landings of all grouper species have declined and red hind landings have done so as well.

Evaluation of Overfishing Definition:

The decision rule in the FMP concerning when a stock is to be considered overfished is sensible given the paucity of data, but there is also some confusion concerning spawning biomass per recruit and spawning biomass. The FMP states, for reef fish in general, that reductions in catch rates are indicative of reductions of the overall resource abundance. It concludes that, if the catch rate of a species is less than 20% of what it was during some

previous time period, then it is likely that spawning biomass per recruit is less than 20% of the unexploited state. This is not a well thought out criterion, since SPR relates to mortality rate, not absolute biomass level, and catch per unit effort is often assumed proportional to abundance but not necessarily mortality rate. This needs correction and clarification in the decision rule for overfishing for Caribbean reef fish in general.

The overfishing definition is difficult to evaluate because of the lack of knowledge concerning the dynamics of the population. Because landings and biomass have continued to decline, even though the current fishing mortality rate is likely to be below the overfishing definition level, the 20% SPR level seems to be too low. For other grouper stocks 30 or 40% is used in the South Atlantic. Note that $F_{0.1}$ is substantially lower than $F_{30\%}$ and the current F. This may be a more cautious target harvest rate than in the FMP. The effect of the protogynous sex change on the use of SPR is not well investigated and makes the OD operationally ambiguous. When the change is from male to female with increasing size, SPR can be a very misleading indicator of spawning potential. The problem is less straightforward in this case of a sex change from female to male. If males are limiting spawning success a problem with using female SPR arises, but there must be some interaction with the recruitment pattern as well. Further investigation is warranted and another type of definition is probably wise. Note that these remarks apply to many of the reef fishes. Even less information is available concerning most of the others.

Data Sources:

Sadovy, Y. and M. Figuerola. 1992. The status of the red hind fishery in Puerto Rico and St. Thomas as determined by yield per recruit analysis. Proc. Gulf Carib. Fish. Instit. 42:23-38.

Sadovy, Y., M. Figuerola and A. Roman. 1992. Age and growth of red hind in Puerto Rico and St. Thomas. Fish. Bull. U.S. 90: 516-528.

Sadovy, Y. 1993. Spawning stock biomass per recruit: Epinephelus guttatus (Puerto Rico). Caribbean Fishery Management Council, San Juan, Puerto Rico.

Caribbean Red Hind

Puerto Rico Red Hind

112
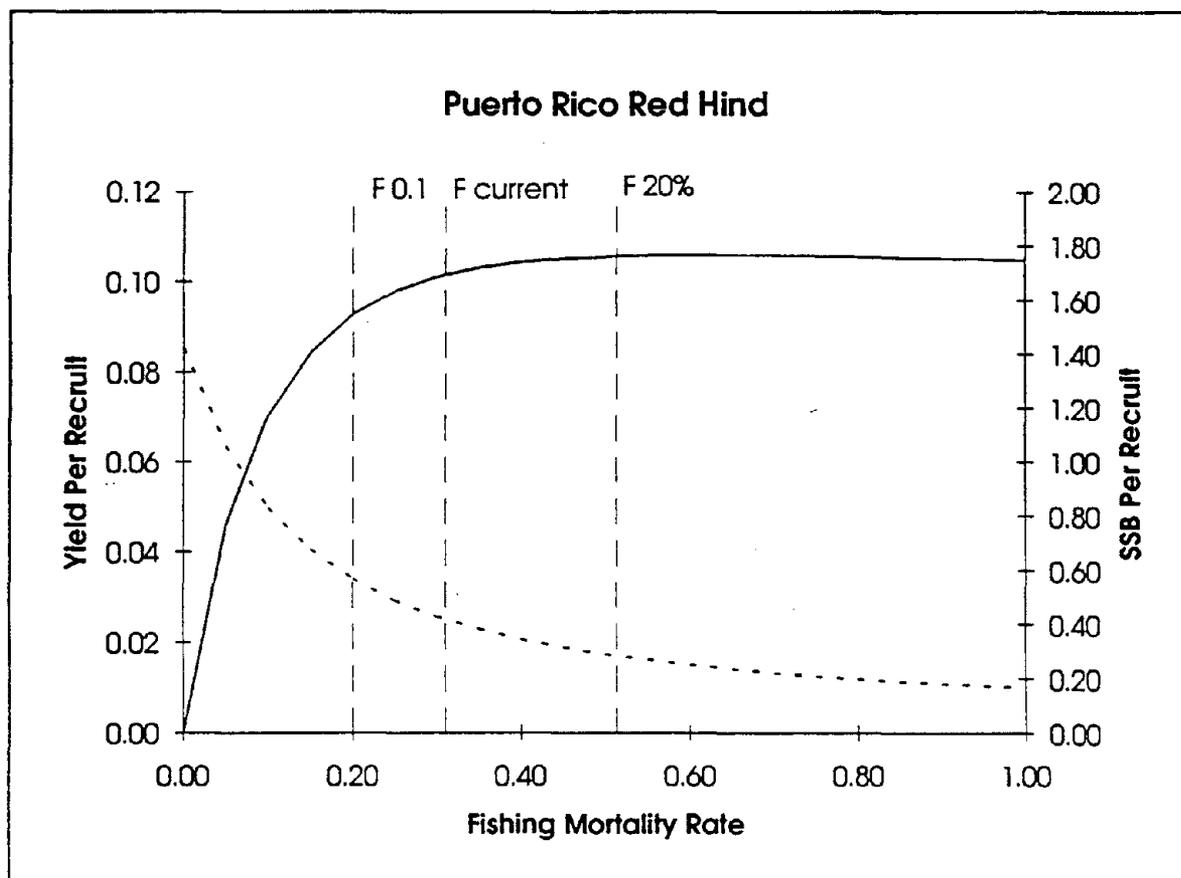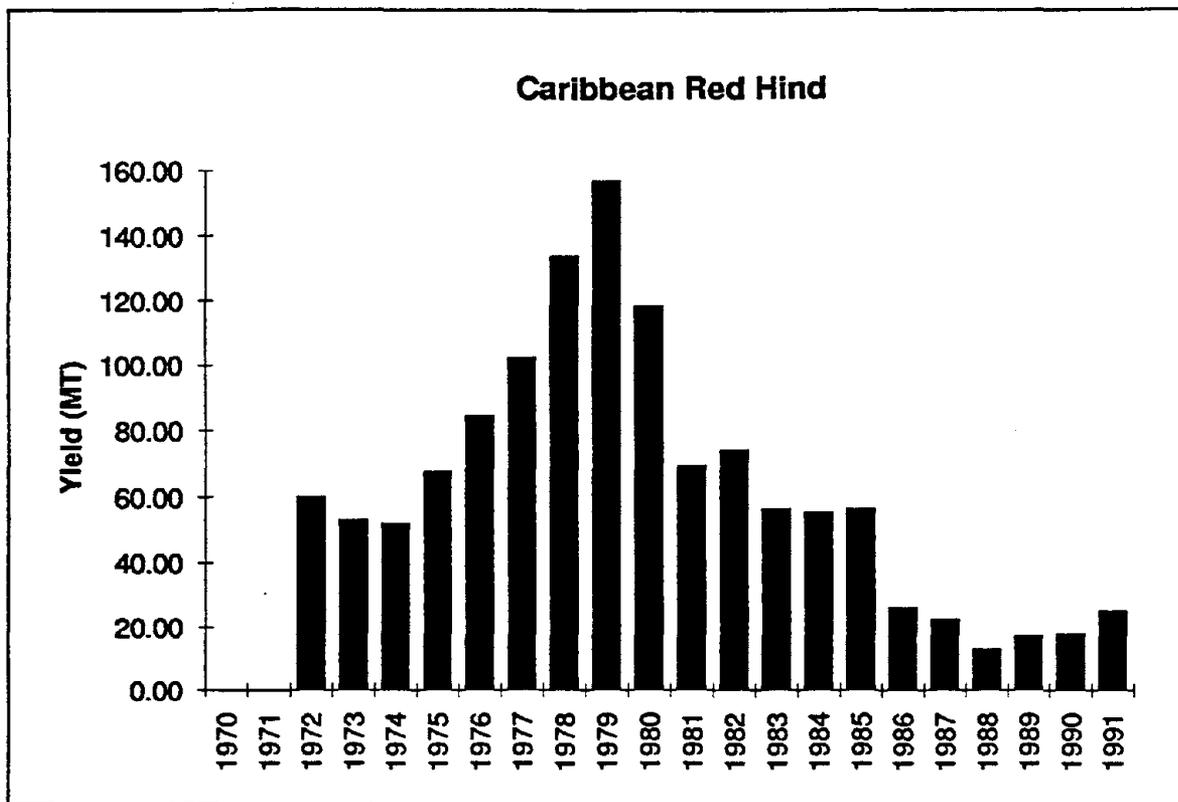
Management unit - Caribbean spiny lobster (# 24)

Species/stocks:

24. Spiny lobster (*Panulirus argus*)

FMP/Amendment Defining Overfishing: Amendment 1 to the Fishery Management Plan for the Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands (Caribbean Fishery Management Council).

Overfishing Definition:

"A spiny lobster stock or stock complex is overfished when it is below the level of 20 percent of the Spawning Potential Ratio.

"When a spiny lobster stock or stock complex is overfished, overfishing is defined as the harvesting rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 20 percent Spawning Potential Ratio.

"When a spiny lobster stock or stock complex is not overfished, overfishing is defined as a harvesting rate that if continued would lead to a state that would not allow harvest at OY on a continuing basis." (p. 2 of Amendment 1).

The SPR for spiny lobsters is measured in terms of eggs per recruit. The overfishing definition was developed by the Scientific and Statistical Committee (SSC) of the Caribbean Fishery Management Council, based on examination of the available literature. The SSC found that "it has been documented that fisheries have a high probability of collapse when the spawning biomass was below the range of 20% to 40% (in some cases below 10%) of the virgin stock biomass. Not having enough information to precisely estimate the appropriate level for spiny lobster, the SSC chose the 20% SPR estimate as a level with an acceptable probability of protecting the stock biomass from long-term reductions or fluctuations in recruitment and yields." ... "For monitoring the Spawning Potential Ratio, the method described by Gregory et al. (1982) will be used to compare female fecundity by length class within fished areas to that in unfished areas." (p. 2-3 of Amendment 1).

Assessment Method and Decision Rule:

Stock status is assessed by monitoring relative catch rates to indicate changes in abundance and/or availability.

Overfishing is indicated when catch rate is less than 20% of levels "during some previous time," based on the evaluation of a panel of expert biologists.

Evaluation of Overfishing Definition:

The definition of overfishing is not related to the actual criteria used to evaluate whether the stock is overfished. The operational indicator of overfishing for this stock is the decline in catch rate to less than 20% of previously observed levels. This indicator is related to a biomass-based threshold, while the spawning potential ratio relates to a fishing mortality rate. In spite of the assertion in the FMP of a "likely" relationship, there is no theoretical basis for the equivalence of the two levels. The relative catch rate level may be especially risky if the "previously observed levels" were from developed fisheries rather than from fisheries on virgin stocks; if catchability were to increase over time with technological improvements or learning; if availability of the stock were to increase over time; and/or if catch rates were maintained by sequentially exploiting different areas within the stock region.

The overfishing definition could be improved by incorporating criteria related to measurable quantities (e.g., catch rates) and the uncertainty associated with those quantities (e.g., shortcomings in using commercial catch rate data to track abundance levels). If size/age data for the stock are also available, as possibly indicated in the FMP, size/age-based criteria may also be incorporated in a definition. Alternatively, it may be possible to fit a surplus production model to available catch and effort data to develop either F_{MSY}-related definition, which could be used to compare f_{MSY} with observed effort levels; or estimates of catchability which could be used to rescale observed effort levels for comparison with F-based reference points.

Data Sources:

Gregory, D.R., R.F. Labisky and C.L. Combs. 1982. Reproductive dynamics of the spiny lobster, *Panulirus argus*, in south Florida. Trans. Amer. Fish. Society. 111:575-584.

SERO 1992. Stock Assessment and Fishery Evaluation Report: Caribbean Spiny Lobster Fishery. Southeast Regional Office, NMFS, St. Petersburg, FL.

Carribean Spiny Lobster: Trends in Landings

St Croix

St Thomas, St Johns

Puerto Rico

115
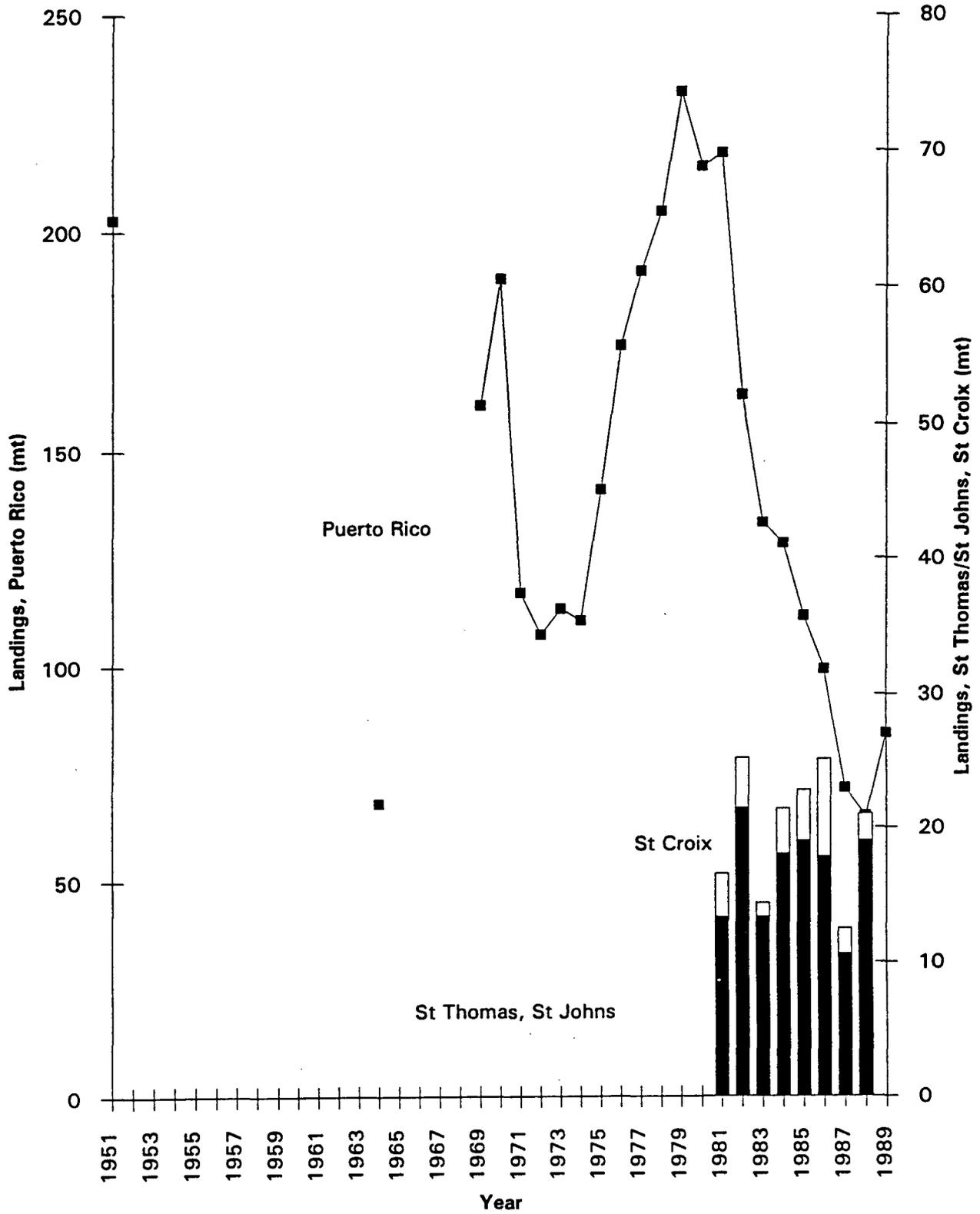
Management unit - **Gulf of Mexico shrimp** (# 25, 60, 61)

<u>Species/stocks</u>:

> 25. Brown shrimp (*Penaeus aztecus*)
> 60. Pink shrimp (*Penaeus duorarum*)
> 61. Royal red shrimp (*Hymenopenaeus robustus*)

<u>FMP/Amendment Defining Overfishing</u>: Amendment 5 to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico (Gulf of Mexico Fishery Management Council).

<u>Overfishing Definition</u>:

"Brown shrimp recruitment overfishing is indicated where parent stock levels are reduced below 125 million shrimp. This value is slightly lower than the 1983 level of parent stock which is the lowest observed value since 1960. Parent stock for brown shrimp is defined as the number of age 7+ (months) shrimp during the period of November through February." (p. 11)

"Pink shrimp recruitment overfishing in the eastern Gulf of Mexico (statistical areas 1-12) is indicated when parent stock levels are reduced below 100 million shrimp. Parent stock for pink shrimp is defined as the number of shrimp age 5+ (months) during the period July through June. Pink shrimp in the western Gulf are not included in this definition because mixed catches of brown and pink shrimp there are not separated and are landed, sold, and statistically treated as brown shrimp." (p. 12)

"Overfishing royal red shrimp is defined as fishing in excess of OY. Royal red shrimp differ from brown, white, and pink shrimp in that they are not estuarine dependent but exist in a relatively constant environment in the deeper waters of the Gulf (100 to 300 fathoms). They are not an annual crop but are harvested from grounds believed to contain at least five year classes. Thus, they conform more closely to a classical Schaefer-type fishery. For this reason, the optimum yield of royal red shrimp should be the total pounds of royal red shrimp which can be harvested without biologically overfishing the resource." (p. 14)

[Note: There is currently no definition for white shrimp. One has been proposed in Amendment 7 to the FMP and is currently under Secretarial Review.]

These definitions are based on stock-recruitment plots, and other considerations. Rationale for the definitions are given in NOAA Tech. Memo. NMFS-SEFC-264 (1990).

<u>Assessment Method</u>:

Age-structured VPAs for brown, white and pink shrimp; none for royal red shrimp. The VPA is not calibrated but convergence is rapid because of the high exploitation rates. Time

steps in the VPAs are monthly so that recruitment is estimated for 12 cohorts per year.

Relevant Life History Features:

Penaeid shrimp are short-lived (under 2 years) and highly fecund. Recruitment is thought to be largely influenced by habitat and environmental conditions. Nursery areas for brown and white shrimp (northern Gulf) tended to increase during the last few years; habitat degradation has occurred in pink shrimp nursery areas.

Evaluation of Overfishing Definitions:

Only data for brown shrimp were examined in detail, but most of the following comments apply to all penaeid shrimp in the Gulf. The definitions given as absolute parent stock sizes serve a clearly unambiguous role as thresholds. However, because they are in absolute magnitude (number of parents), they are not robust to changes in assessment methods, etc. Alternative definitions that are more flexible could be sought and expressed in relative units. In addition, if recruitment is largely influenced by habitat availability and environmental conditions, efforts should be made to quantify this influence and include it as part of the definitions, e.g., by making recruitment a function of parental stock and environmental variables.

For royal reds, overfishing is defined as fishing greater than optimum yield (MSY). This reference point is likely to be conservative and act better as a target than a threshold.

Data Sources:

Nance, James. personal communication. NMFS-SEFC, Galveston Laboratory.

NOAA Tech. Memo. NMFS-SEFC-239, 1989. Gulf of Mexico Shrimp Stock Assessment Workshop.

NOAA Tech. Memo. NMFS-SEFC-264. 1990. Workshop on definition of shrimp recruitment overfishing.

Gulf of Mexico Brown Shrimp

Gulf of Mexico Brown Shrimp

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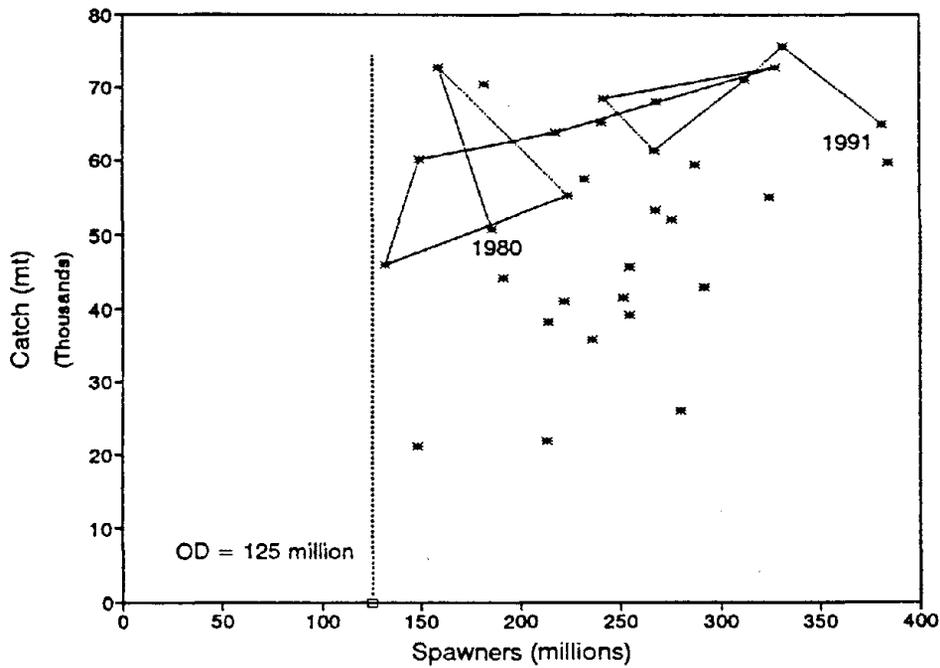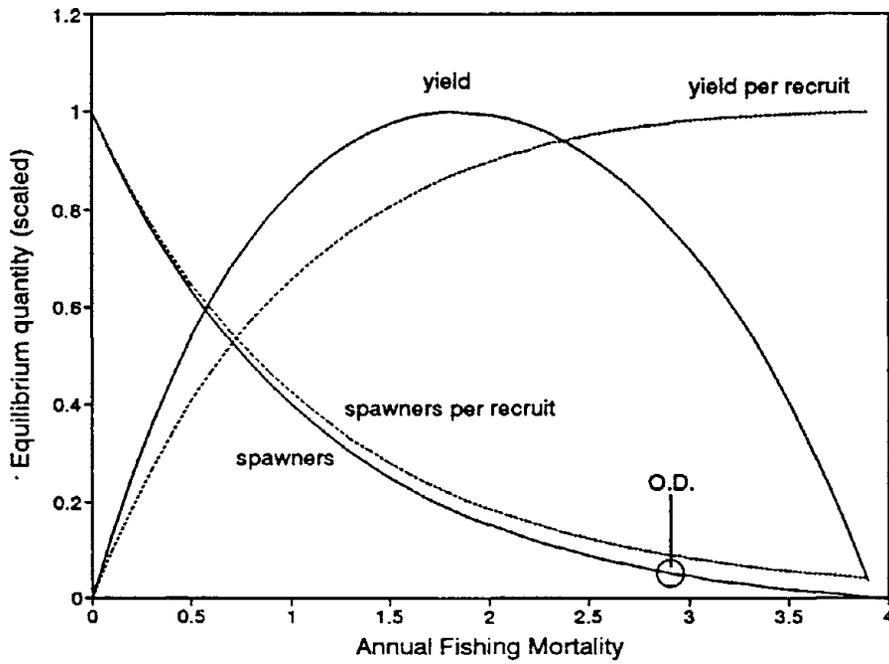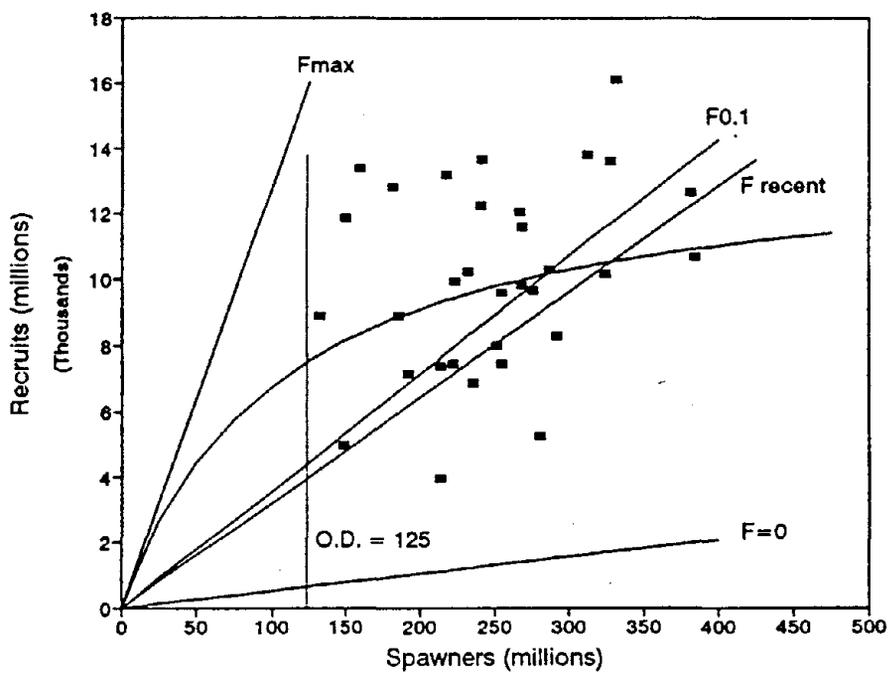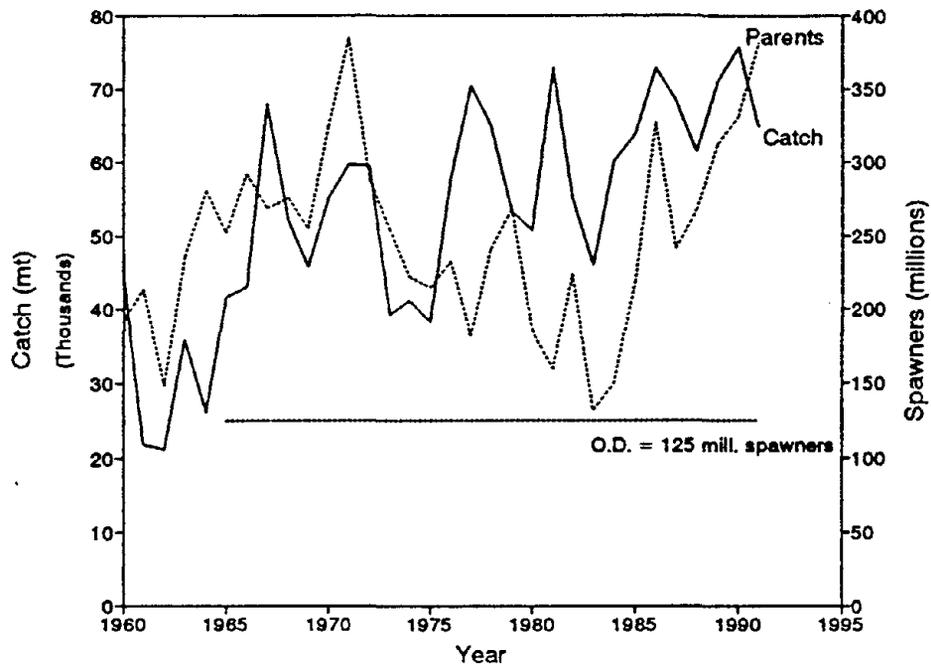
Management Unit - **Gulf of Mexico Reef Fish (# 26, 62-64)**

Stock:
> **26.** Gulf of Mexico Red Snapper *(Lutjanus campechanus)*
> **62.** Gulf of Mexico Vermilion Snapper *(Rhomboplites aurorubens)*
> **63.** Gulf of Mexico Red Grouper *(Epinephelus morio)*
> **64.** Other Gulf of Mexico Snapper/Groupers

FMP/Amendment Defining Overfishing: Gulf of Mexico Reef Fish FMP

Overfishing Definition:

"Overfishing is defined as:

> "1. A reef fish stock or stock complex is overfished when it is below the level of 20 percent of the [SSBR] that would occur in the absence of fishing.

> "2. When a reef fish stock or stock complex is overfished, overfishing is defined as harvesting at a rate that is not consistent with a program that has been established to rebuild the stock or stock complex to the 20 percent [SSBR] level.

> "3. When a reef fish stock or stock complex is not overfished, overfishing is defined as a harvesting rate that [,] if continued[,] would lead to a state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis."

> Rebuilding Plan: A rebuilding plan for **red snapper** in the Gulf of Mexico is contained in Amendment 1 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico.

Assessment Method and Decision Rule:

Red snapper, vermilion snapper and red grouper are assessed based on age structured catch and relative abundance index data, including research surveys. These data are analyzed using the VPA-based ADAPT model. For these species, current fishing mortality rates and SPR levels are compared to the OD to determine status.

Other stocks are assessed based on basic biological data to calculate reference points and catch-per-unit-effort indices of relative abundance over time. Overfishing is determined by comparing the decline in relative abundance to a reference year. This approach is taken as a matter of necessity, given the lack of data for the estimation of fishing mortality rates.

The overfishing definition contains the following statement concerning decision rules: "The Council will convene a scientific stock assessment panel, appointed by the Council, that will, as a working group, review the SEFC assessment(s), current harvest statistics, economic,

social, and other relevant data and will prepare a written report to the Council specifying a range of ABC for each stock or stock complex that is in need of catch restrictions for attaining or maintaining OY. The ABC's are catch ranges that will be calculated for those species in the management unit that have been identified by the Council, NMFS, or the working panel as in need of catch restrictions for attaining or maintaining OY. The range of ABC's shall be calculated so as to achieve reef fish population levels at or above the 20 percent SSBR goal by January 1, 2000 [January 1, 2007, for red snapper]. For stock or stock complexes where data in the SEFC reports are inadequate to compute an ABC based on the SSBR model, the above working group will use other available information as a guide in providing their best estimate of an ABC range that should result in at least a 20 percent SSBR level. The ABC ranges will be established to prevent an overfished stock from further decline. To the extent possible, a risk analysis should be conducted showing the probabilities of attaining or exceeding the stock goal of 20 percent SSBR and the annual transitional levels (i.e., catch streams) calculated for each level of fishing mortality within the ABC range and the economic and social impacts associated with those levels."

Relevant Life History Features:

Red snapper are long-lived and slow growing, with a natural mortality rate of 0.2 and maturity at age 2. Gulf of Mexico red snapper have been heavily exploited for many years . Most notable in this exploitation is the large amount of shrimp trawl bycatch of ages 0 and 1 and subsequent fishing mortality rate, which at the present time remains unregulated. Although recreational catch estimates are not available prior to 1979, and bycatch prior to 1972, it is safe to say that both components in the early years were probably significant and that the overall catch levels were large. Recent fishing mortality rates were of the order of 0.8.

Vermilion snapper have not been heavily exploited until recently, as fishing switched to vermilion snapper when other resources have been depleted or regulated. They are long-lived and slow growing, maturing as early as age 1 and as late as age 3 or 4.

Red grouper appears to have been moderately exploited since 1979. However, U.S. commercial fisheries have been in existence since the 1950's and a large Cuban fishery for red grouper off the west coast of Florida existed until the early 1970's. The total commercial catch during those years averaged about 3,000 mt, which is comparable to present yields. Red grouper are protogynous hermaphrodites, as are most other groupers, switching from female to male beginning at about 5 years of age. It is unclear how best to measure spawning potential for this type of life history.

Evaluation of Overfishing Definition:

Red Snapper - The time series of stock and recruitment information for red snapper is quite short and does not show a clear pattern. A replacement level of fishing mortality (the rate estimated to keep the stock in its present, depleted condition but without further decline) is

much higher than the overfishing definition level of fishing mortality. The overfishing level ($F_{20\%}$) is greater than the level giving the highest yield per recruit, but there is not sufficient data to indicate whether recruitment is reduced at the overfishing definition level from the stock and recruitment data. However, other historical survey data indicates past recruitment was much higher when stock biomass was higher. With the information available, the definition appears to be neutrally conservative as a threshold level. Including a minimum biomass level along with the SPR definition may improve the definition and make it more conservative given that the major impact on the fishery is through bycatch and the stock is in a severely depleted condition in need of rebuilding.

Vermilion Snapper - There are only four data points of stock and recruitment for this stock so it is difficult to evaluate productivity. However, these points fall below the replacement line corresponding to the overfishing definition, indicating the corresponding harvest rate is above a replacement rate for these yearclasses. However, the stock abundance has been relative high for these years, so the definition is still judged to be neutrally conservative. The stock should be closely monitored and the definition may need to be changed as a better picture of the production function is obtained.

Red Grouper - There are only five stock and recruitment data points for this stock, and they are scattered either side of the replacement line corresponding to the definition of overfishing. Ther is no indication that recruitment is declining. However, the uncertainty due to the relationship between spawning potential and age, size and sex mean that the SPR criterion and the interpretation of current F and SPR levels with respect to the OD should be viewed with caution.

Other Snapper/Groupers - The use of the ratio of current relative abundance to a reference year as a proxy for spawning potential assumes that the relative abundance index is representive of the dynamics of the spawning stock and that CPUE is proportional to abundance. There is difficulty in specifying a reference year for these stocks and in using a localized index to measure stock-wide changes. If the OD is set to 20% of the relative abundance in the reference year, then these assumptions on representitiveness should be viewed with caution. Relative abundance is not necessarily a good proxy for spawning potential ,particularly for species with more complex life histories such as the groupers. These problems need to be closely monitored as more information accumulates for these stocks.

Data Sources:

Goodyear, C. P. 1992. Red snapper in the U.S. waters of the Gulf of Mexico. MIA Contribution 91/92-70

SEFSC, 1992. Status of the fishery resources off the southeastern United States for 1991. NOAA Tech. Memo. NMFS/SEFSC/306.

Gulf of Mexico Red Snapper
Yield and Biomass

Figure U8GRS-1

Gulf of Mexico Red Snapper
Exploitation History
Directed Yield (mt) and Bycatch (#)

Figure U8GRS-2

Gulf of Mexico Red Snapper
Age 0 and 1 Abundance
and Spawning Egg Mass

Figure U8GRS-3

Gulf of Mexico Red Snapper
Yield and Spawning Potential Per Recruit

Figure USGRS-4

Gulf of Mexico Red Snapper
Spawner-Recruit Relationship

Figure USGRS-5

Gulf of Mexico Red Snapper
Spawner-Recruit Relationship

Figure USGRS-6

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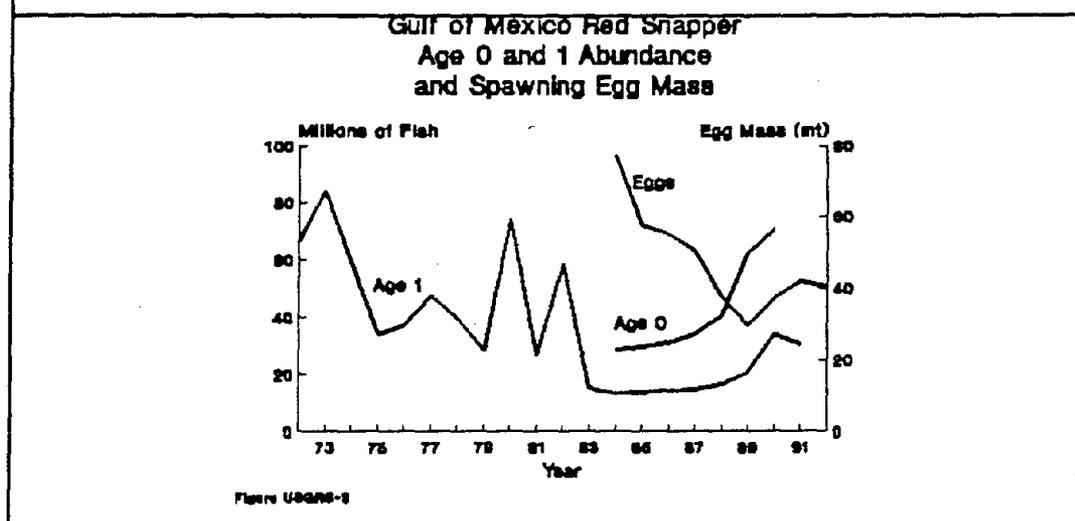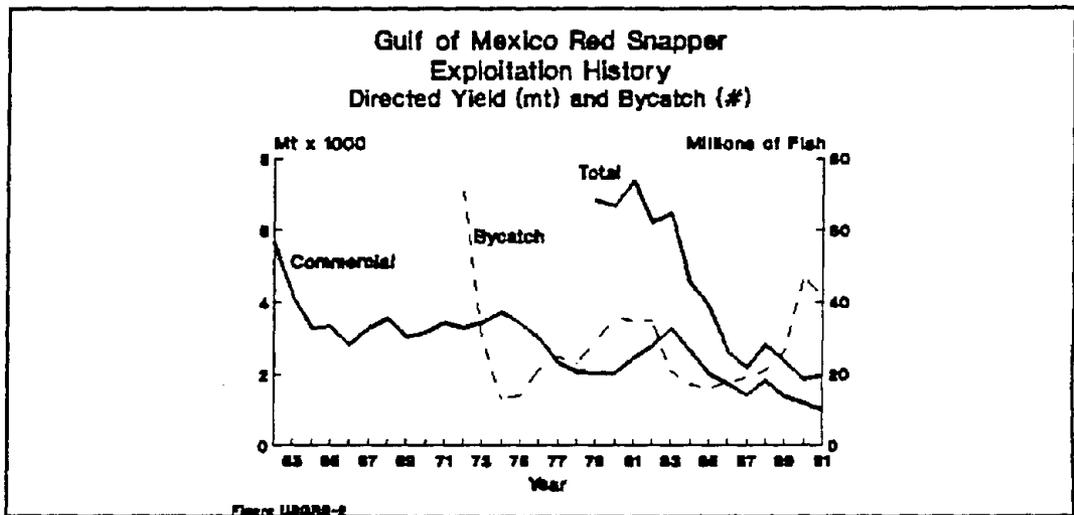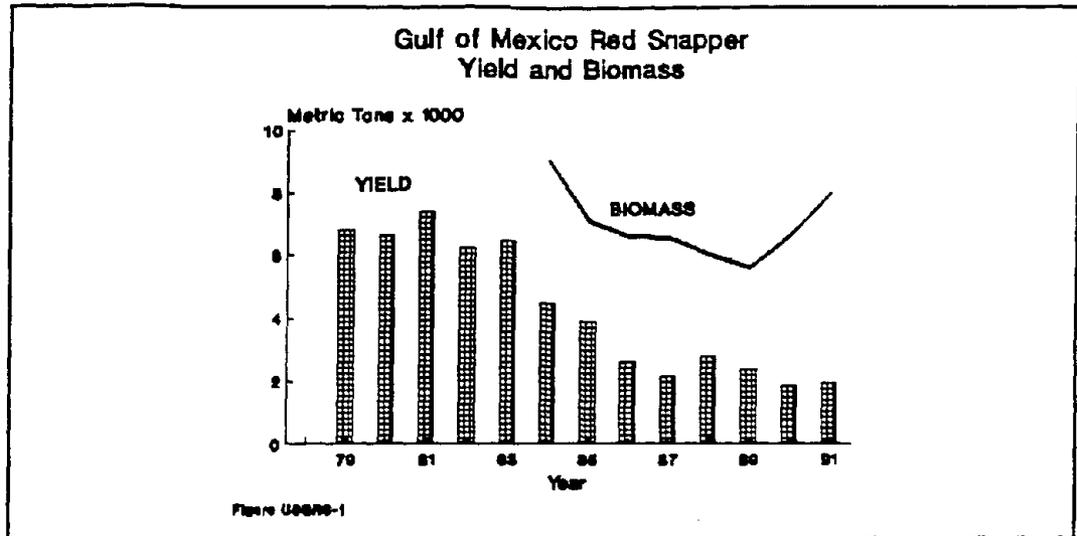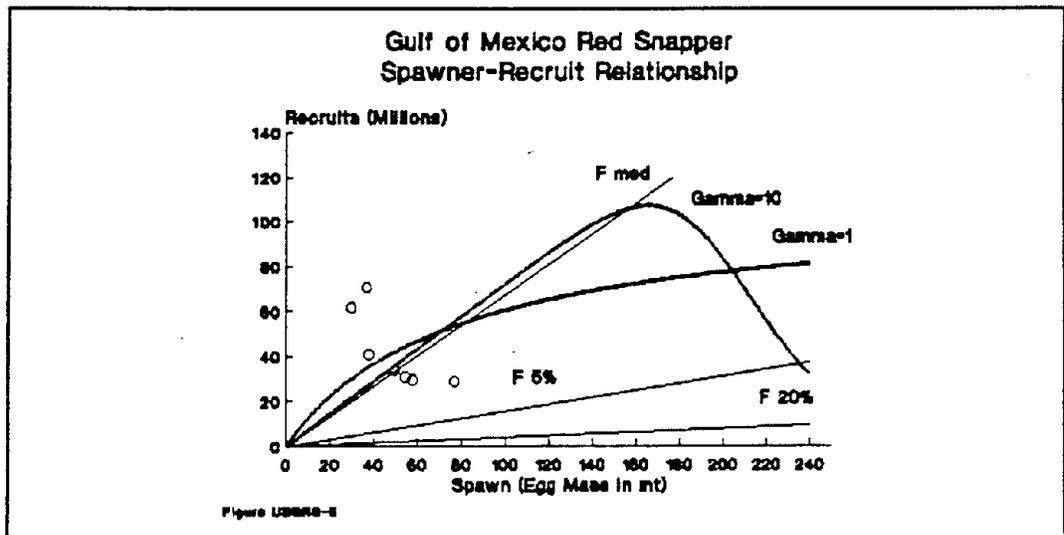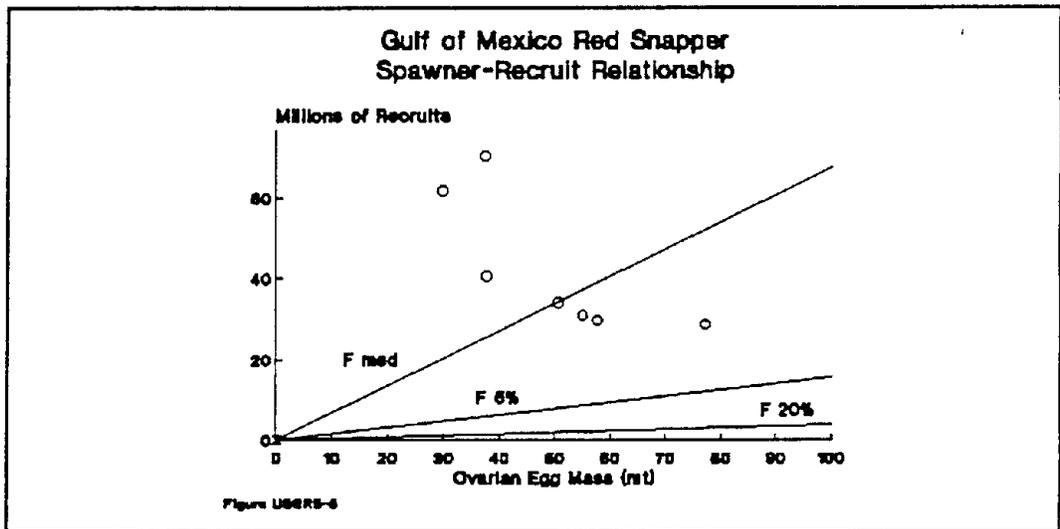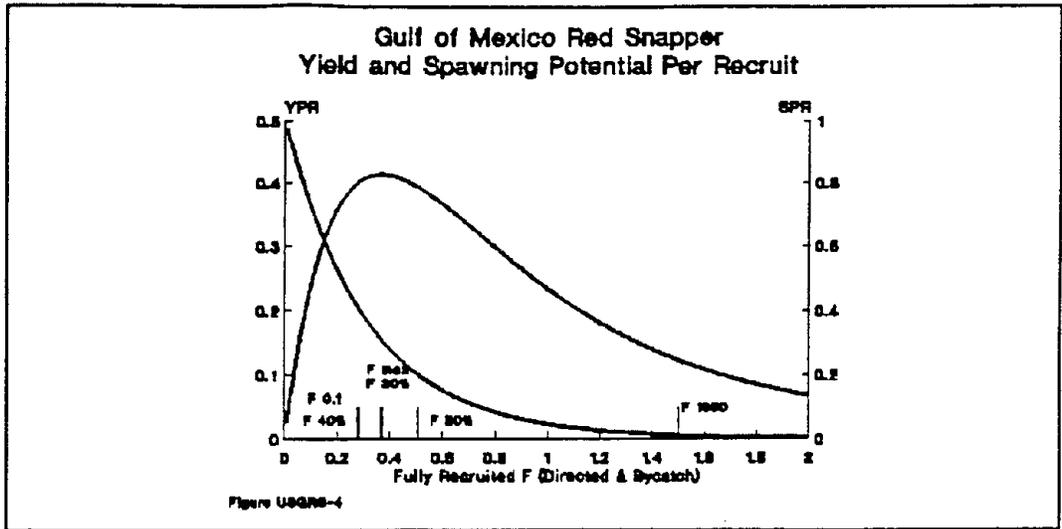
Management Unit - Gulf of Mexico Coastal Migratory Pelagics (# 27, 56, 57)

Stock:
       27. Gulf of Mexico King Mackerel (*Scomberomorus cavalla*)
       56. Spanish Mackerel (*Scomberomorus maculatus*)
       57. Other Coastal Pelagics
           Dolphin (*Coryphaena* spp.)
           Cobia (*Rachycentron canadum*)
           Cero (*Scomberomorus regalis*)

FMP/Amendment Defining Overfishing: Coastal Migratory Pelagic Resources FMP Amendment 5

Overfishing Definition:

"(a) A mackerel or cobia stock shall be considered overfished if the spawning stock biomass per recruit (SSBR) is less than the target level percentage recommended by the assessment group, approved by the Scientific and Statistical Committee (SSC), and adopted by the Councils. The target level percentage shall not be less than 20 percent.

"(b) When a stock is overfished (as defined in (a)), the act of overfishing is defined as a harvest rate that is not consistent with a program to rebuild the stock to the target level percentage, and the assessment group will develop ABC ranges for recovery periods consistent with a program to rebuild an overfished stock.

"(c) When a stock is not overfished (as defined in (a)), the act of overfishing is defined as a harvest rate that if continued would lead to a state of the stock that would not at least allow a harvest of OY on a continuing basis, and the assessment group will develop ABC ranges based upon OY (currently MSY)." (p. 10)

Rebuilding Plan: A rebuilding plan was established for king and Spanish mackerel in Amendment 6 to the Fishery Management Plan for Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic.

Section 12.6.1.1, number A-4, paragraph b. of the FMP was revised to read as follows:

"When a stock is overfished (as defined in (a)), the act of overfishing is defined as harvesting at a rate that is not consistent with programs to rebuild the stock to the target level percentage, and the assessment group will develop ABC ranges based on a fishing mortality rate that will achieve and maintain at least the minimum specified spawning potential ratio (currently set at 30 percent). The recovery period is not to exceed ... 7 years for Spanish mackerel beginning in 1987."

Discussion in Amendment 2 indicates that this option was chosen because the recovery

periods are slightly more than a generation time (5 years for Spanish mackerel) and were deemed appropriate periods for remedial management measures to be effective. The recovery periods began when the migratory groups were identified as being overfished and when remedial recovery programs were initiated.

Assessment Method and Decision Rule:

King mackerel and Spanish mackerel are assessed by an age-structured analysis of catch and index data using the VPA-based ADAPT method. The decision rule is included in the Council's definition: " When a stock is overfished, the act of overfishing is defined as harvesting at a rate that is not consistent with a program to rebuild the stock to the target level percentage, and the assessment group will develop ABC ranges for recovery periods consistent with a program to rebuild an overfished stock." When a stock is not overfished, the act of overfishing is defined as a harvest rate that if continued would lead to a state of the stock that would not at least allow a harvest of OY on a continuing basis, and the assessment group will develop ABC ranges based upon OY (currently MSY).

Analytical assessments are not available for the other species.

Relevant Life History Features:

King mackerel are long lived, with a natural mortality rate of 0.15. They mature at age 5-6. Similar to red snapper, Gulf of Mexico king mackerel have been heavily exploited, but not to the extent of red snapper. Notably, the shrimp bycatch rates have generally not been as great as those for red snapper and are limited to age 0. Additionally, the time series of absolute abundance estimates goes back to the 79/80 fishing season (July 1, 1979 to June 30, 1980). However, other index data provide evidence that recruitment in the 1970's and before was significantly higher than that at present.

Spanish mackerel and the other coastal pelagics are shorter lived than king mackerel. Spanish mackerel live to about 7-10 years and mature at age 2. They are currently considered overexploited.

Evaluation of Overfishing Definition:

King Mackerel - The available data on spawning stock biomass and recruitment indicate that the replacement level of fishing mortality (to maintain the stock) is well above the overfishing definition level. All of the data points fall above the $F_{20\%}$ replacement line on the stock-recruitment plot, indicating stock recovery if fished at the threshold level. On this basis, the definition appears to be moderately conservative. Recent management actions that have reduced the harvest rate to near the overfishing defintion level have apparently resulted in some stock recovery further supporting the sensibility of the definition. The control law used in 90/91 and 91/92 has been moderately successful. But if it had been fully implemented, then recovery to 30% SPR would probably been achieved by now. However,

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note that this is not exactly the present rendition of the control law. With the advent of 602 guidelines, an overfished fishery must have a plan to recover within a fixed time frame. For the Gulf of Mexico king mackerel, the time frame is based upon the mean life span (12 years) with recovery to occur by 1997. But, this has allowed the Council to accept multiple-year controls laws, i.e., overshooting F 30% SPR in one year is acceptable if there is still a reasonable chance that the SPR target can be achieved by 1997. This is the strategy chosen by the Council in the last 2 years.

Spanish Mackerel and Other Coastal Pelagics - The threshold SSBR is not explicit, except that it may not fall below 20%. Based on the latter default value, and the use of SSB for a multiple spawner, the policy could range from risky to neutral. Under option B, the definition is formally neutral because the Rebuilding Plan specifies a target "spawning potential ratio"; but is operationally risky because spawning stock biomass is assumed to be equivalent. In the case of multiple spawners, definitions based on spawning biomass are not robust to changes in critical parameters (e.g., age-specific spawning frequency and duration) or assessment errors (age structure). Spawning biomass is not an accurate index of egg production. The intent is to achieve recovery in 7 years; there is no way of evaluating performance until the seven years are completed. The definition is not measurable in an ongoing sense without milestones by which to judge whether the program is on-track. The definition could be improved by adding progressive milestones for recovery. Physiological information needs improvement to allow implementation of the stated spawning potential ratio criterion. Under option C, the definition is still risky to neutral because OY is not defined; performance depends on Council behavior, and the only objective constraint remains the 20% SSBR specified under Definition (a).

Data Sources:

Powers, J. E. 1993. Updated assessments for six stock delineations of mackerel: a working paper prepared for the mackerel stock assessment panel meeting March 29-April 1, 1993. Miami Lab Contribution MIA-92/93-44.

SEFSC, 1992. Status of the fishery resources off the southeastern United States for 1991. NOAA Tech. Memo. NMFS/SEFSC/306.

**US Gulf of Mexico King Mackerel
Directed Yield and Biomass**
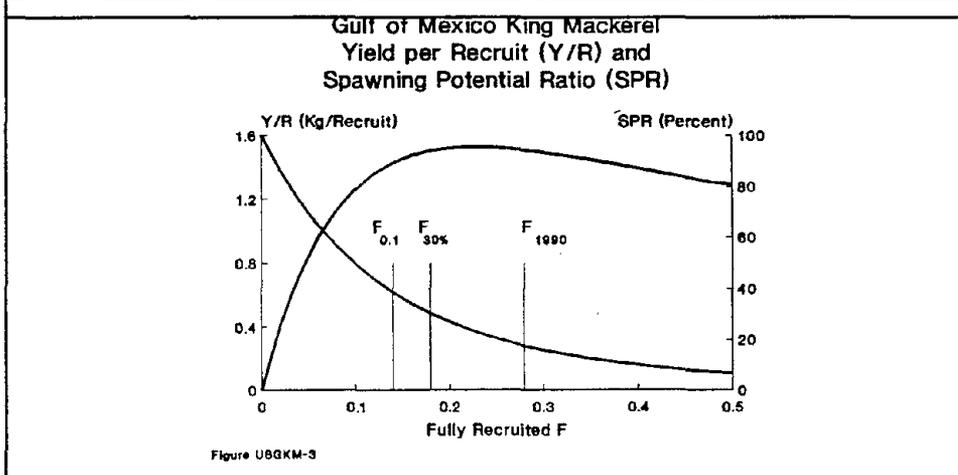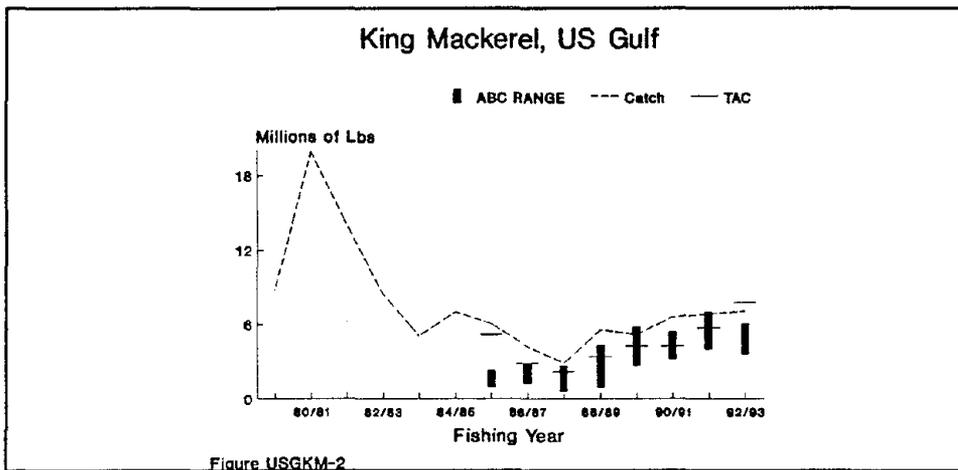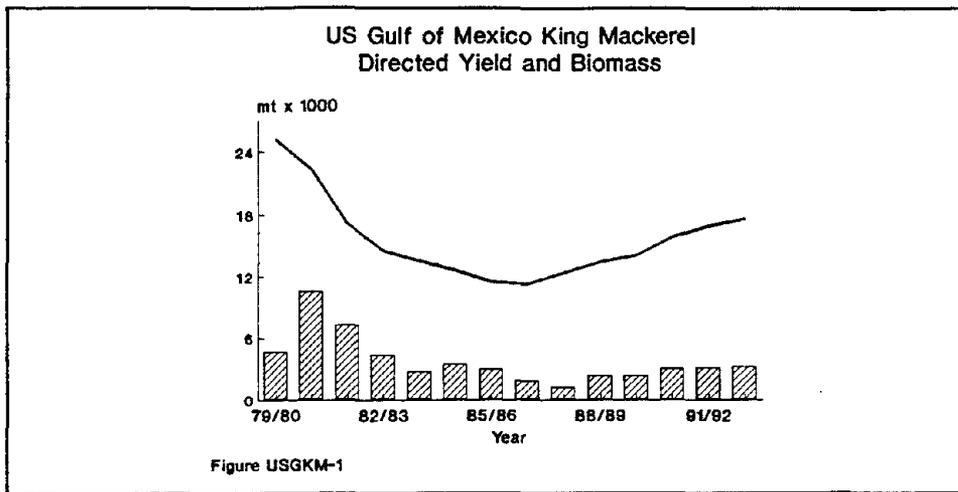
Figure USGKM-1

King Mackerel, US Gulf

Figure USGKM-2

**Gulf of Mexico King Mackerel
Yield per Recruit (Y/R) and
Spawning Potential Ratio (SPR)**

Figure USGKM-3

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US Gulf King Mackerel
Spawning Potential Ratio (SPR)
Median with 80% Confidence Interval

Figure USGKM-4

US Gulf King Mackerel
Spawner-Recruit Relationship
Eggs vs Age 0 Recruits

Figure USGKM-6

US Gulf King Mackerel
Control Law: F vs SPR
SPR vs Age 0 Recruits

Figure USGKM-8
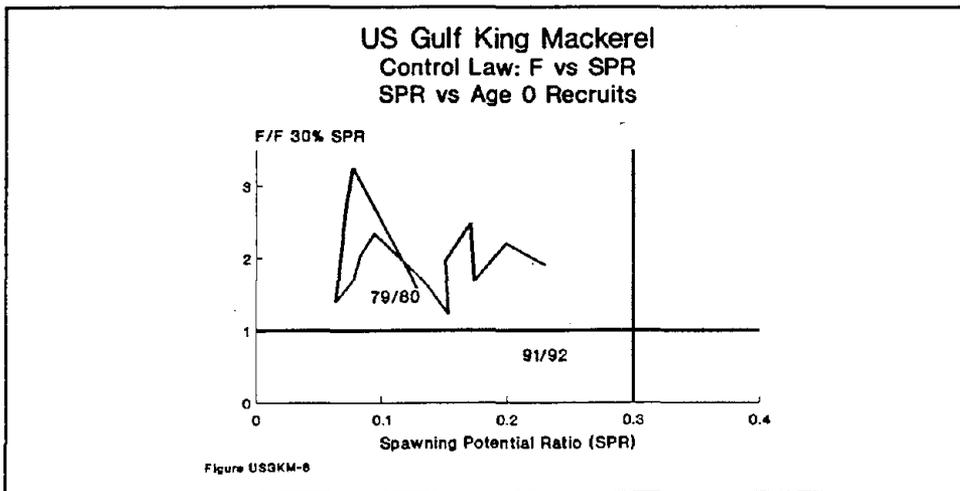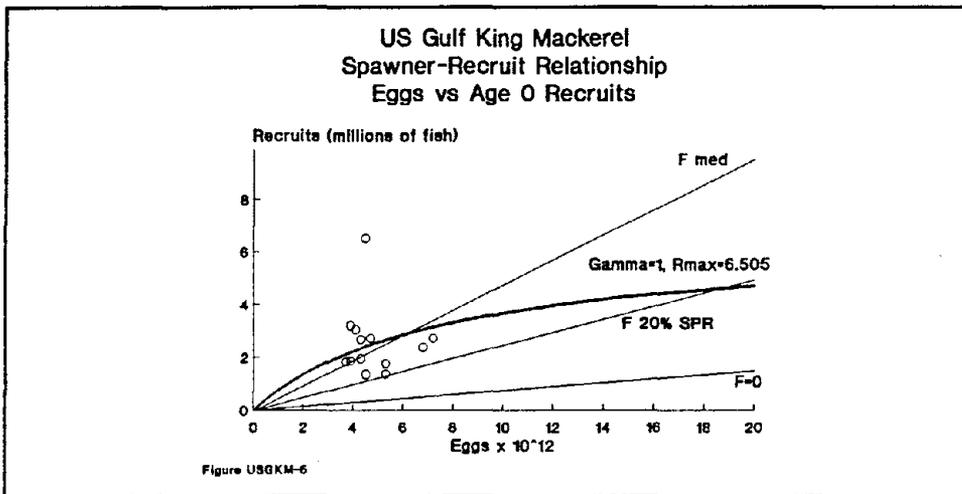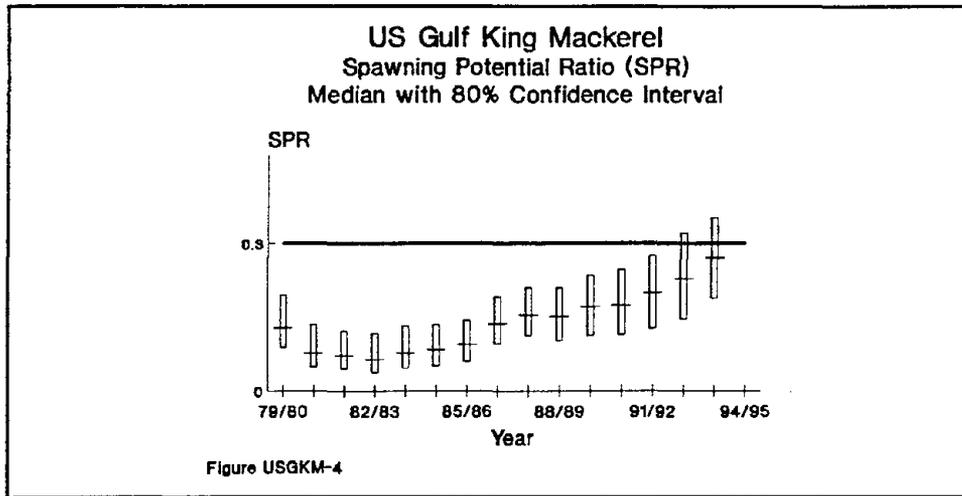
Management unit - Gulf of Mexico and South Atlantic spiny lobster (#28)

Species/stocks:

  28. Spiny lobster (*Panulirus argus*)

FMP/Amendment Defining Overfishing: Amendment 3 to the Fishery Management Plan for the Spiny Lobster Fishery in the Gulf of Mexico and South Atlantic (Gulf of Mexico and South Atlantic Fishery Management Councils).

Overfishing Definition:

"Overfishing exists when the eggs per recruit ratio of the exploited population to the unexploited population is reduced below five percent and recruitment of small lobsters into the fishery has declined for three consecutive fishing years. Overfishing will be avoided when the eggs per recruit ratio of exploited to unexploited populations is maintained above five percent." (p. 3)

This definition is based on papers by Gregory et al. (1982) and Powers and Sutherland (1989).

The FMP also manages the slipper lobsters, *Scyllarides* spp., which are incidental catch in bottom trawl fisheries. These species are a minor component of the catch and are so broadly and sparsely distributed over the range of the management unit that insufficient information is available to either monitor their abundance or assess their status relative to overfishing. It is believed that their principal or preferred habitats are areas of rough and irregular bottom where trawling is not possible; this may afford them adequate protection against overfishing.

Assessment Method and Decision Rule:

Assessments of stock status have primarily involved yield- per-recruit and egg-per-recruit analyses. Fishing mortality rates have not been estimated in recent years, but based on studies in the early 1980's are believed to be of the order of F=2. This corresponds to an eggs-per-recruit ratio of about 6%. There is no indication that recruitment has either increased or declined.

The decision rule is that if the estimated current eggs per recruit ratio was below 5 percent and recruitment indices declined for 3 or more consecutive years, then actions should be taken to increase the eggs-per-recruit ratio.

Relevant Life History Features:

The larval dispersal stage of spiny lobsters is capable of drifting for 9 months at sea. This makes it difficult to determine the stock structure of spiny lobsters in Florida and the U.S.

Caribbean. The distribution and amount of recruitment originating from the Caribbean and local areas is unknown. Fishery yields depend on new recruitment, since few lobsters large enough to enter the fishery escape capture to survive into the next season. Spiny lobster are dependent on shallow-water algal reef habitat flats for recruitment and feeding.

Evaluation of Overfishing Definition:

It is difficult to develop a definition of recruitment overfishing when the source of recruitment is largely unknown. A related problem is the difficulty of obtaining estimates of current fishing mortality rates or %EPR. A simpler alternative may be to formulate an overfishing definition explicitly in terms of fishing effort, without trying to equate it directly to a level of %EPR.

The spiny lobster is of considerable importance to both commercial and recreational fishermen. The fishery is considered overcapitalized, with about twice the number of traps required at optimum levels of fishing effort. The fishery is not considered overfished, despite the fact that the EPR ratio may be near or below the threshold, because there is no evidence that recruitment has been declining.

Data Sources:

Gregory, D.R., R.F. Labisky and C.L. Combs. 1982. Reproductive dynamics of the spiny lobster, *Panulirus argus*, in south Florida. Trans. Amer. Fish. Society. 111:575-584.

Powers, J.E. and D.L. Sutherland. 1989. Spiny lobster assessment, CPUE, size frequency, yield per recruit and escape gap analysis. Southeast Fisheries Center. Coastal Resources Contribution No. CRD-88/89-24. 73p.
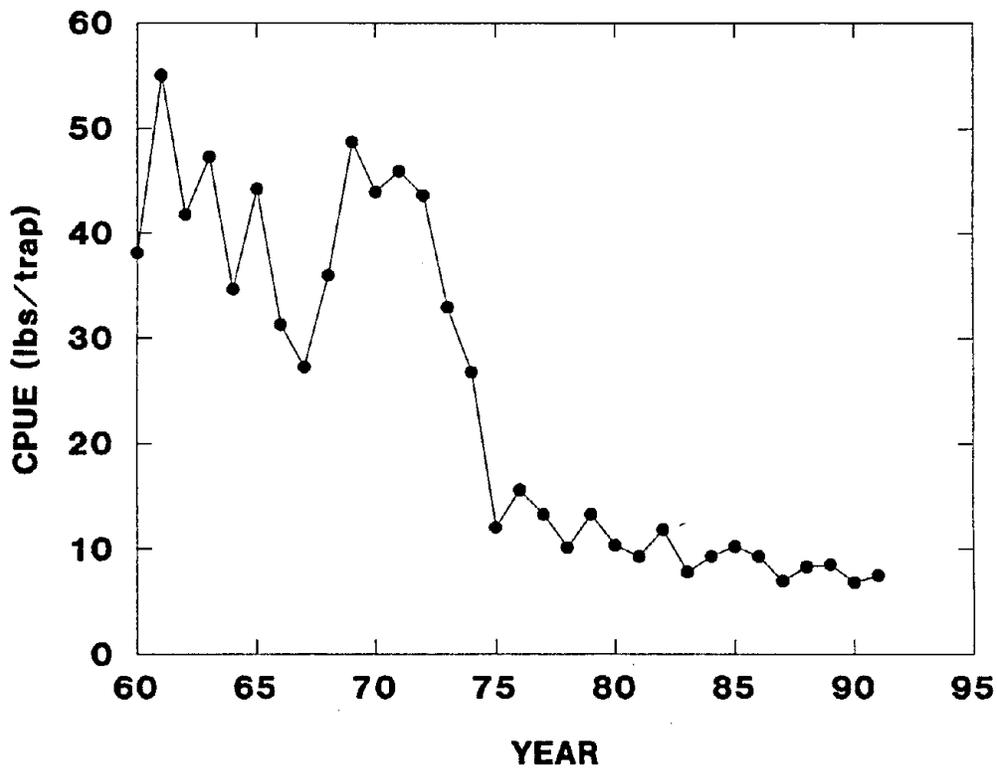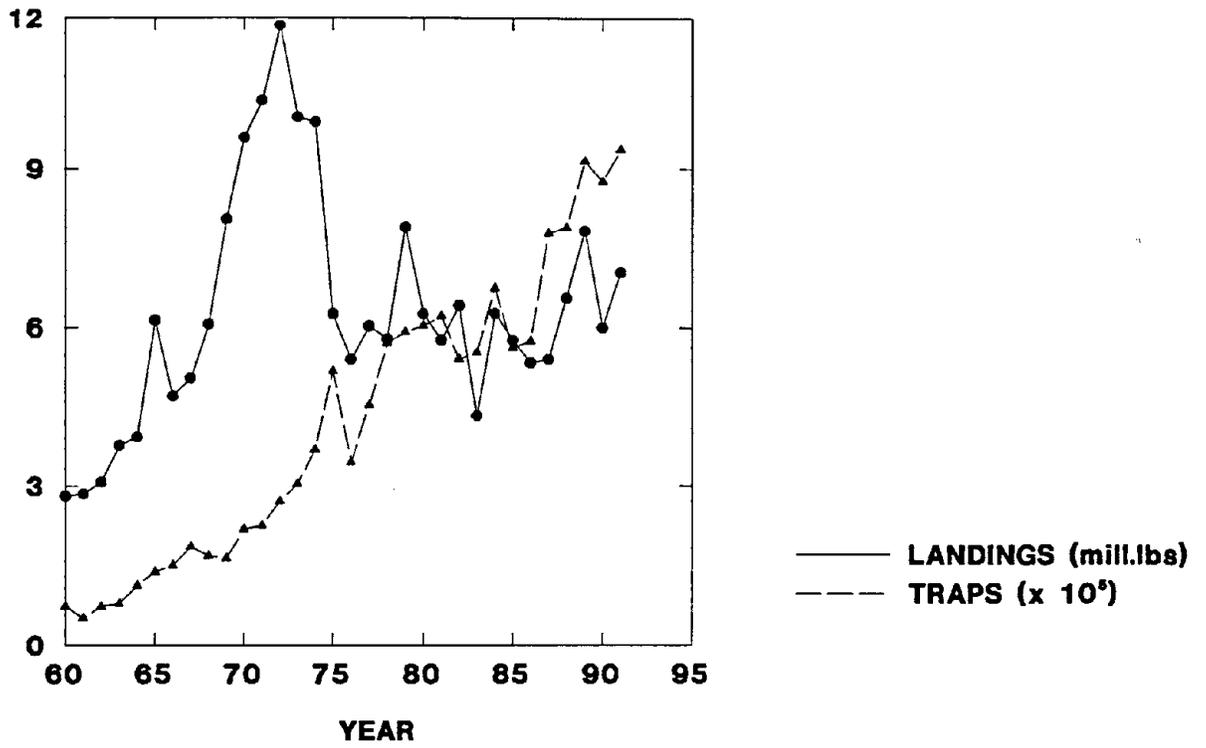
Florida spiny lobster. A. Landings and effort. B. Catch per unit
effort (CPUE).

SPINY LOBSTER TRAPS & LANDINGS

## BY SEASON, FLORIDA WEST COAST
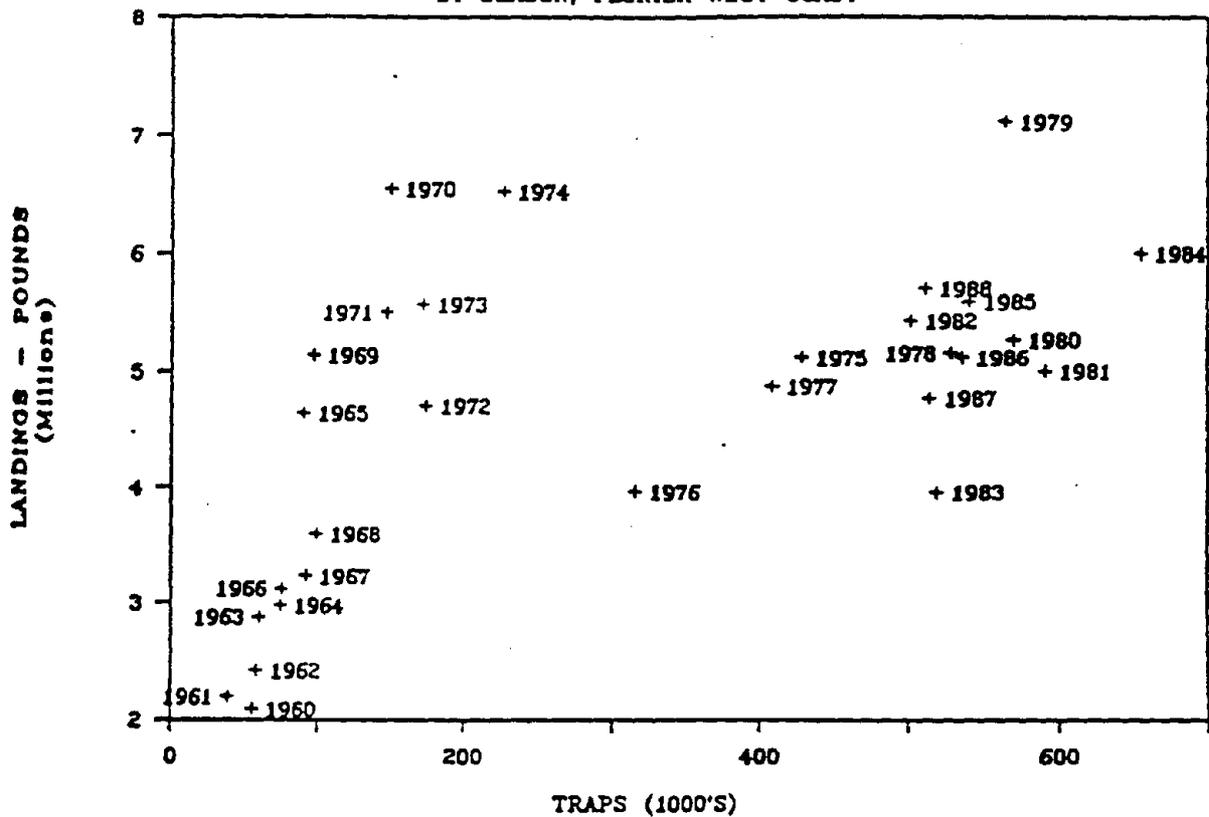
Figure 8. Seasonal reported spiny lobster landings of the west coast of Florida commercial fishery versus the number of traps in the fishery. From Powers and Sutherland (1989).

Florida Spiny Lobster: Landings vs. effort

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Management Unit - Pacific Coast Groundfish (# 29-33, 35)

Species/ Stock:

29. Sablefish (*Anoplopoma fimbria*)
30. Dover Sole (*Microstomus pacificus*)
31. Boccacio (*Sebastes paucispinis*)
32. Pacific Ocean Perch (*Sebastes alutus*)
33. Canary Rockfish (*Sebastes pinniger*)
35. Pacific Whiting (*Merluccius productus*)
65. Lingcod (*Ophiodon elongatus*)
66. Pacific Cod (*Gadus macrocephalus*)
67. English sole (*Pleuronectes vetulus*)
68. Petrale sole (*Eopsetta jordani*)
69. Widow Rockfish (*Sebastes entomelas*)
70. Yellowtail Rockfish (*Sebastes flavidus*)
71. Shortbelly Rockfish (*Sebastes jordani*)
72. Chilipepper Rockfish (*Sebastes goodei*)

FMP/Amendment Defining Overfishing: Pacific Coast Groundfish FMP Amendment 5 (November 1990)

Overfishing Definition:

Overfishing is defined as exceeding the fishing mortality rate that would reduce spawning biomass per recruit to 20 percent of its unfished level.

When spawning biomass is greater than that which produces MSY, set F_{OF} equal to the greater of $F_{20\%}$ and the rate that would, in 1 year, reduce the spawning biomass to the level that produces MSY.

Overfishing parameters to be compared to the standards cannot be estimated for all species because of the wide range of knowledge available for the species managed under the FMP. Three categories of species are identified. The first includes the few species for which a quantitative stock assessment can be conducted on the basis of a catch-at-age or other data. The second category includes a large number of species for which some biological indicators are available, but a quantitative analysis cannot be completed. The third category includes minor species that are caught, but for which there is, at best, only partial information on landed biomass.

Assessment Method and Decision Rule:

Sablefish, bocaccio, Dover sole, perch, Canary rockfish, and whiting are assessed using the stock synthesis model. Annual harvest guidelines (e.g. , TAC) are set so that the fishing

mortality rate will be at the level that would reduce spawning biomass per recruit to 35% of its unfished level.

For whiting, the assessment model explicitly takes into account the annual migration pattern of the stock. Annual harvest levels are set so that the long-term proportion of the years with very low stock levels increases from 0.1% in the unfished state to 20% in the fully exploited state. In addition, the fishing mortality rate is reduced in proportion to the spawning biomass as the spawning biomass declines below the long-term average level. This conservative harvest policy results in a long-term spawning biomass level that is about 54% of the unfished level.

A coastwide assessment of lingcod has not yet been conducted. In southern areas, the ABC is set according to historical catch levels, and in northern areas it has been set at 0.5 M B_0, with B_0 coming from the 1977 trawl survey. The coastwide ABC has not been achieved and, beginning in 1994, a lower harvest guideline has been set in order to restrain growth in this fishery until an updated assessment is available.

English and petrale sole are assessed using age-structured methods.

No assessment of Pacific cod has been conducted off Washington, Oregon and California. Catch levels of Pacific cod are not actively managed.

Widow, yellowtail and chilipepper rockfish are assessed using Synthesis to analyze fishery catch-at-age and catch-at-length data and indices of abundance from commercial fishing operations or research surveys. The annual harvest guidelines (TAC) are set to approximate a 35% MSP rate of exploitation. Shortbelly rockfish are assessed by hydroacoustic methods, with harvest guidelines set conservatively at the estimate of MSY.

Relevant Life History Features:

Sablefish recruit to the fishery and mature at around 5 years of age. Spawning biomass has been declining since the 1970's, while the catch has remained relatively constant.

Bocaccio have relatively rapid growth compared to most rockfish and year-class strength is highly variable. Fish are recruited to the fishery at age 2 and mature at age 4. Recruitment has been weak since the late 1970's, compared to earlier periods. Recent yields are about half of the peak yields of the early 1980's.

Dover sole in the Columbia area biomass has remained relatively constant since the late 1960s, though the catch increased through the 1980's. These flatfish are live as much as 50 years and grow slowly. Dover sole move offshore into deeper water as they age.

Pacific ocean perch are very slow growing and long lived, with a maximum age of 90 years and a natural mortality rate of 0.05. They enter the fishery between ages 5 and 10 and

mature over this same age range. There are apparent productivity shifts, so that recruitment was relatively high in the late 1950's and early 1960's, and is currently very low. Yields have followed the recruitment pattern.

Canary rockfish, like Pacific ocean perch, are very long lived, with a natural mortality rate of 0.05. There are substantial differences in growth rates, and possibly mortality rates, between the sexes. These fish mature and recruit to the fishery at ages 7-9. Recruitment has been relatively constant over the past 20 years. Catch and biomass increased since the late 1960's to a peak in 1983 and has since declined to moderate levels.

Pacific whiting migrate along the West Coast from Baja to Canada. Whiting natural mortality rate is estimated to be 0.24 and the fish recruit to the fishery at age 4. This stock is characterized by highly variable recruitment with occasionally very large year-classes dominating the biomass. Because the biomass is dominated by the few large year-classes, the median bisector of the spawner-recruitment plot implies that stock could not sustain itself even with zero fishing mortality.

The lingcod sexes separate during part of the year, and the males guard the eggs in demersal nests. Thus, particular gear types may be able to target on only one sex.

English and petrale soles occur all along the West Coast from Baja to Alaska. They both are fished commercially, with recent landings of English sole of about 2,000 mt and of petrale sole of 1,000 mt. They are moderately long-lived and recruit to the fishery at around 4 years of age.

Pacific cod in this area are at the southern extreme of their wide range. Fluctuations in abundance in this area are considered to be primarily in response to changing oceanographic conditions.

Widow rockfish is a semi-pelagic member of the *Sebastes* genus, with a natural mortality rate estimated to be 0.15. It is not amenable to assessment by trawl surveys.

Yellowtail rockfish is one of the more abundant *Sebastes* species. It has a natural mortality rate of only 0.05, but older females appear to have a higher rate. Fish begin recruitment to the fishery at age 4, but maturation for females occurs at ages 5-9 so there is a high risk of over-exploitation. Evidence of stock differentiation along the coast has led to three assessment areas.

Shortbelly rockfish is a small-bodied, pelagic schooling species with a higher rate of natural mortality than other rockfish. No fishery has developed for this species.

Chilipepper rockfish are abundant off California and are exploited by several different types of fishing gear. The different selectivity patterns of these fisheries complicates calculation of MSP levels. Chilipepper exhibit large variation in recruitment and their abundance increased

substantially during the late 1980s.

Evaluation of Overfishing Definition :

Sablefish - This overfishing definition was judged to be neutrally conservative, though the available stock and recruitment data indicate that at the OD level of fishing mortality the stock would not be able to replace itself. Given the estimated degree of compensation in the stock and recruitment relationship, it appears that the OD replacement line should still protect the stock from collapse. Though this stock is in an overfished condition, it is not currently being fished at a rate exceeding the OD.

Bocaccio - The available stock and recruitment data points mostly fall below the replacement line corresponding to the overfishing definition level. The replacement fishing mortality rate, the rate needed to maintain the stock in its current condition, is much lower than the overfishing definition fishing mortality rate. Some further decline in biomass may occur even with current fishing mortality rates at the target F35% level. Recruitment has been poor. The overfishing definition may be appropriate for the stock productivity in terms of recruitment seen in the late 1970's, but not for the current levels. The overfishing definition is risky with respect to conservation and should be reconsidered. This stock seems to be sustained on an occasional large year-class. Having a minimum biomass threshold as a component of the definition may be appropriate for this type of recruitment pattern (see above).

Dover Sole, Columbia Area - There is little contrast in the stock and recruitment data so fitting a stock and recruitment relationship gives little indication of the production function for this stock. The OD is judged to be neutrally conservative as a threshold harvest rate. It is below F_{max} and at least some observed year-classes fall above the replacement line on the stock and recruitment plot.

Pacific Ocean Perch - The available stock and recruitment data clearly show two levels of productivity for this stock. The replacement line on the stock and recruitment plot corresponding to the overfishing definition appears to be at a reasonable maintenance level for the points from the late 1950's and early 1960's, but clearly is too high to maintain the stock given recent recruitment levels. Recent exploitation has been close to the overfishing definition level; the stock is continuing to decline as expected given the pattern of stock and recruitment. The definition appears to be risky in this light. Fishing mortality needs to be reduced to expect any recovery toward historic levels. However, under the target exploitation rate of F35%, only about a 40% increase in yield over the current, bycatch-only fishery would be expected as the biomass was rebuilt to about double the current level. The recent lack of biological samples from the fishery and low frequency of surveys provides little ability to monitor the progress of rebuilding.

Canary Rockfish - The available stock and recruitment reflect the relative stability of recruitment. The replacement line corresponding to the overfishing definition indicates that

the stock is likely to decline over the long term if fished at that level. However, the target harvest rate of $F_{35\%}$ about bisects the points and should maintain the stock around its current level if productivity doesn't change. The overfishing definition is probably a neutrally conservative threshold based on these data.

Pacific Whiting - The overfishing definition provides too large a buffer between the current target level of fishing (about F54%) and the overfishing level (F20%). The exploitation rate corresponding to F20% is more than three times greater than the current exploitation rate and would severely reduce the number of age groups contributing to the spawning biomass.

Lingcod - The current exploitation rate is not known, so the quantitative overfishing definition cannot be evaluated. In this case, the overfishing amendment calls for monitoring of trends and initiation of greater data collection effort if declining trends are detected. At this time, the only compiled trend indicator is the triennial trawl survey.

Pacific Cod - The current exploitation rate is not known, so the quantitative overfishing definition cannot be evaluated. In this case, the overfishing amendment calls for monitoring of trends and initiation of greater data collection effort if declining trends are detected. At this time, the only compiled trend indicator is the triennial trawl survey.

English and Petrale Sole - Assessments of West Coast flatfish stocks are very imprecise and $F_{20\%}$ may be difficult to distinguish from alternative possibilities. Therefore, the robustness of the OD is unclear. This definition is considered to be neutrally conservative based on analogy with other stocks.

Widow Rockfish - The time series of exploitation for widow rockfish is too short to determine whether it can sustain exploitation at the target, 35% MSP level. A level of 20% MSP would certainly be inappropriate as a target, and probably is risky even as a threshold.

Yellowtail Rockfish - The overfishing definition, 20% MSP, may be too risky for a stock that recruits before it matures. However, the stock appears healthy after a long period of exploitation.

Shortbelly Rockfish - The appropriateness of 20% MSP for this species cannot be evaluated because it has never been substantially exploited. If a fishery develops, annual harvest guidelines would be used to keep exploitation rates well below the 20% MSP level.

Chilipepper Rockfish - Exploitation rates near the 20% MSP overfishing level have never occurred for chilipepper. This definition is risky, because the 20% MSP exploitation rate is more than 50% greater than the target 35% MSP rate; thus, substantial excess harvest could occur before triggering the overfishing level.

<u>Data Sources</u> -

<u>Status of the Pacific Coast Groundfish Fishery Through 1992 and Recommended Acceptable Biological Catches for 1993: Stock Assessment and Fishery Evaluation</u>" [and Appendices] (Pacific Fishery Management Council, October 1992; Appendices August 1992)

Sampson 1993. An Assessment of the English Sole Stock off Oregon and Washington in 1992. Appendix H in Appendices to the Status of the Pacific Coast Groundfish Fishery through 1993 and recommended Acceptable Biological Catches for 1994. Pacific Fishery Management Council, October 1993.
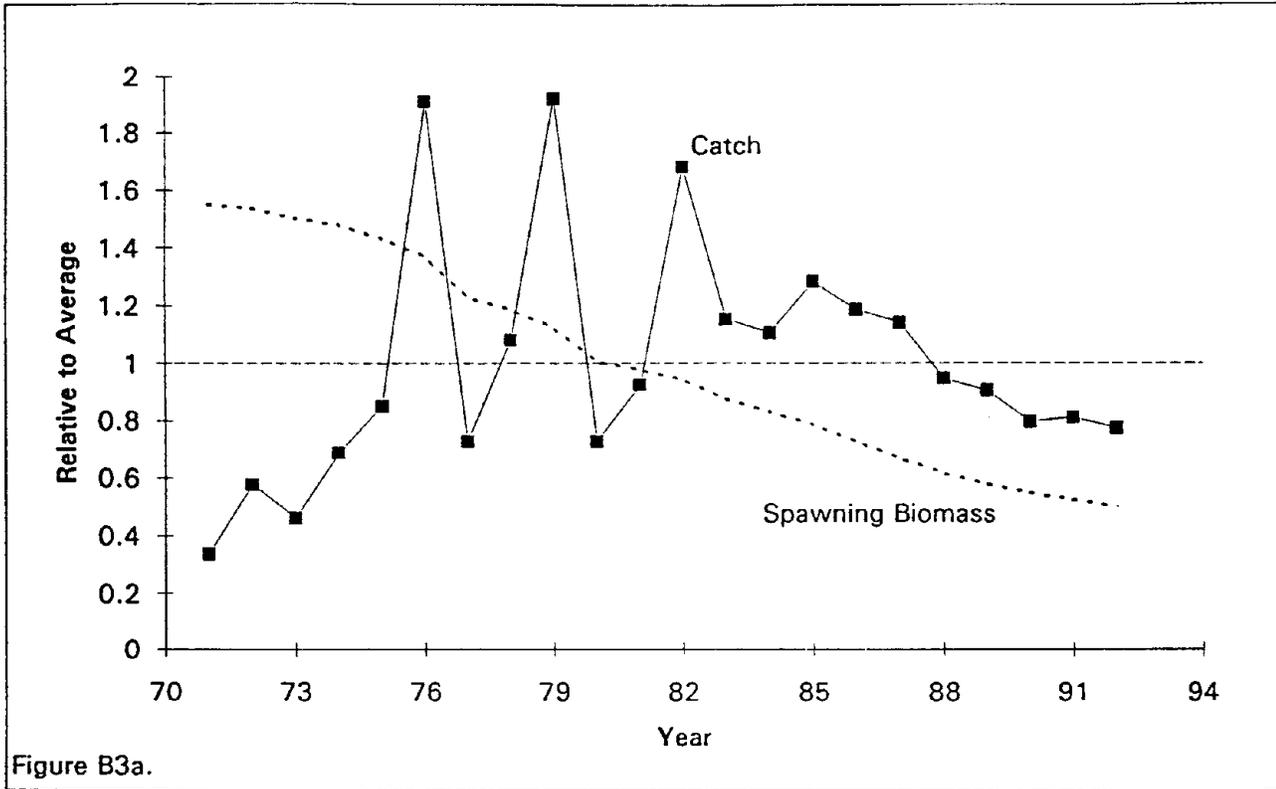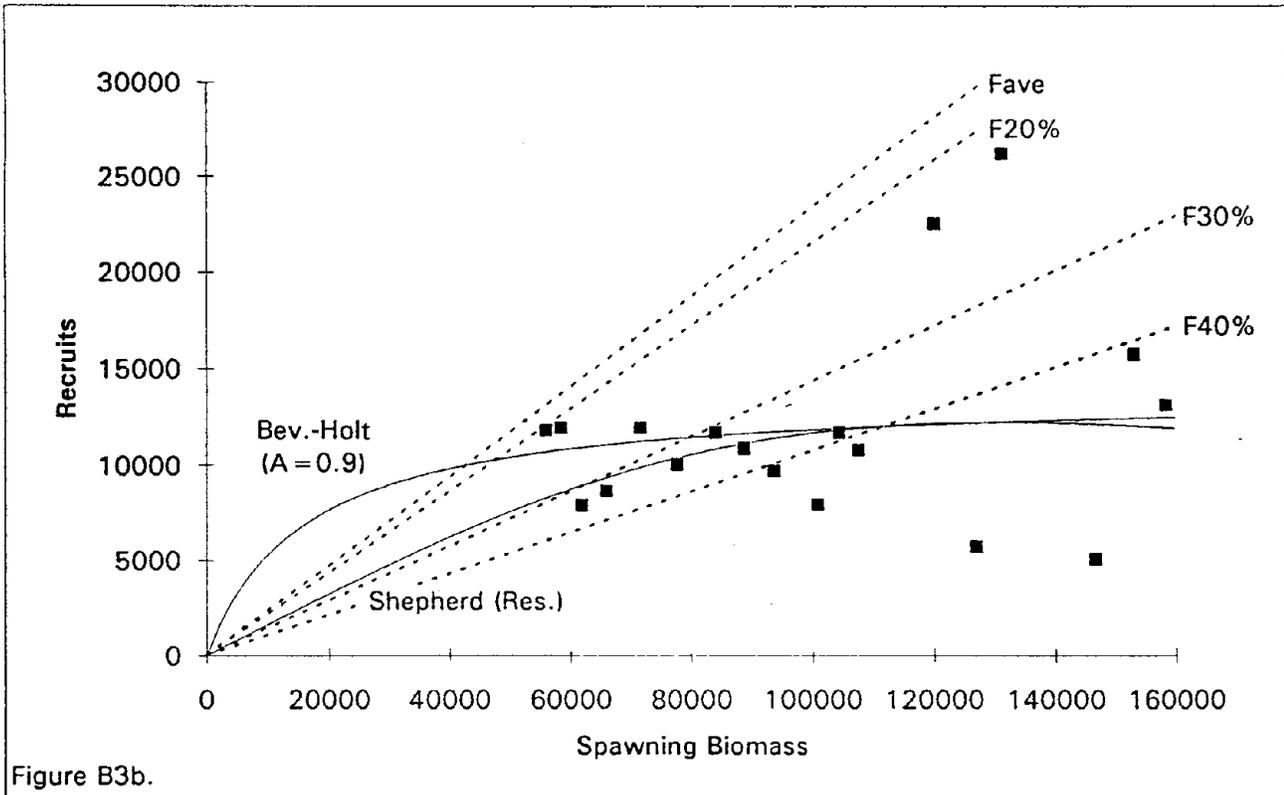
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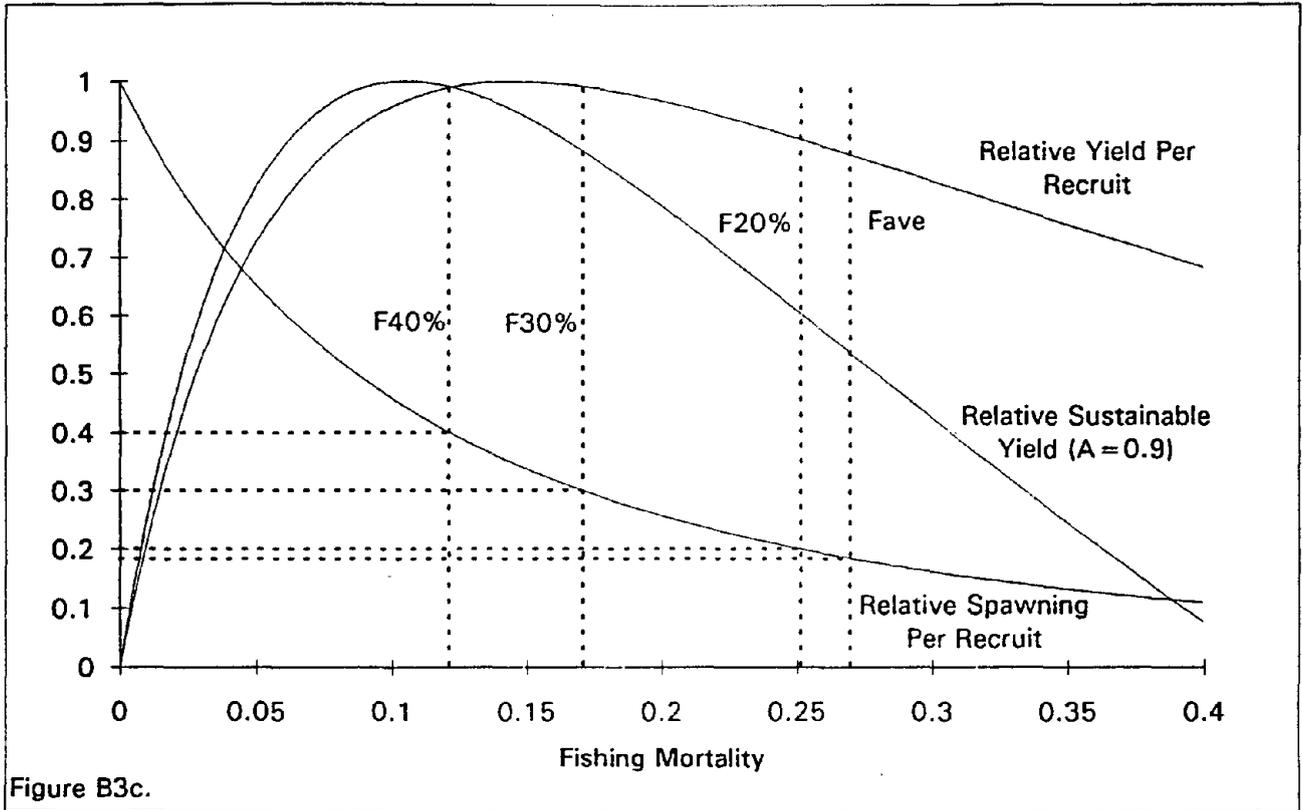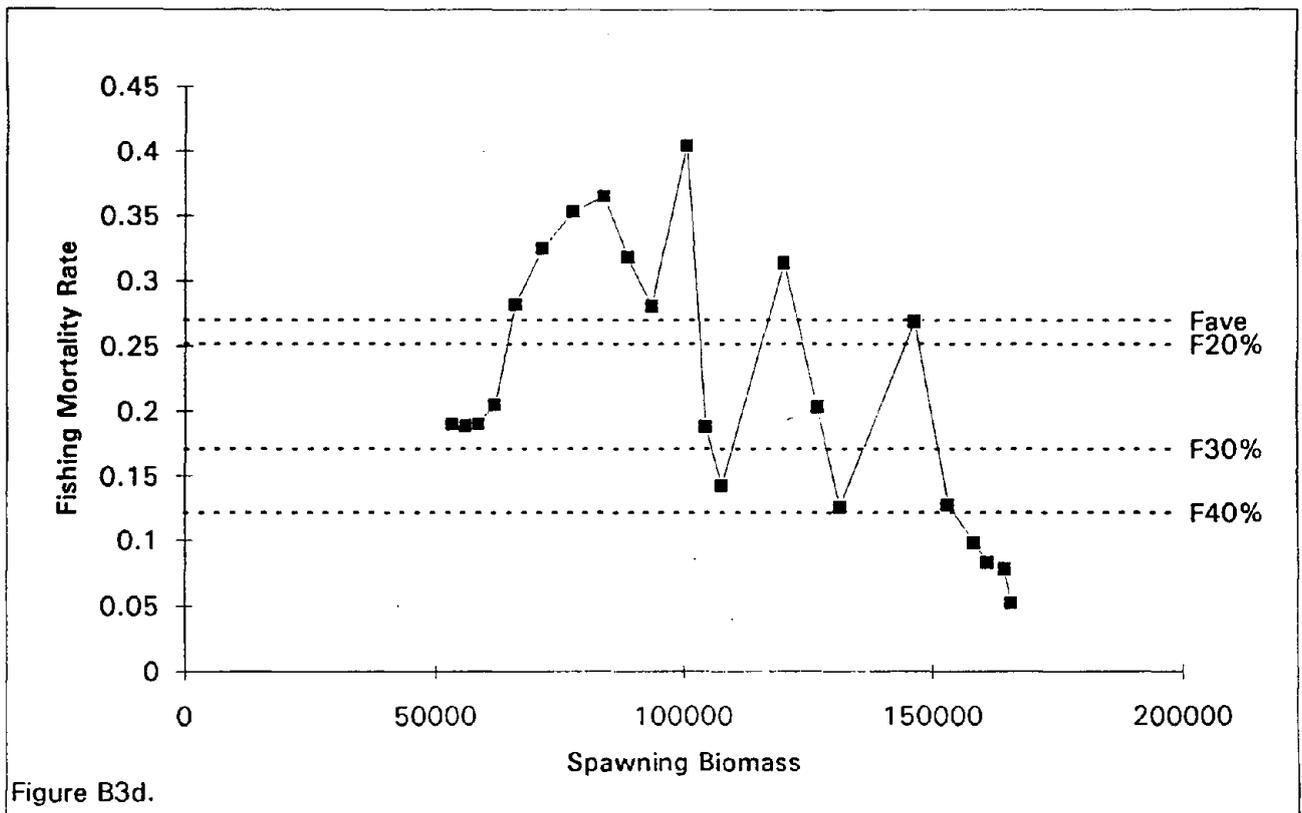
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Figure B3d.
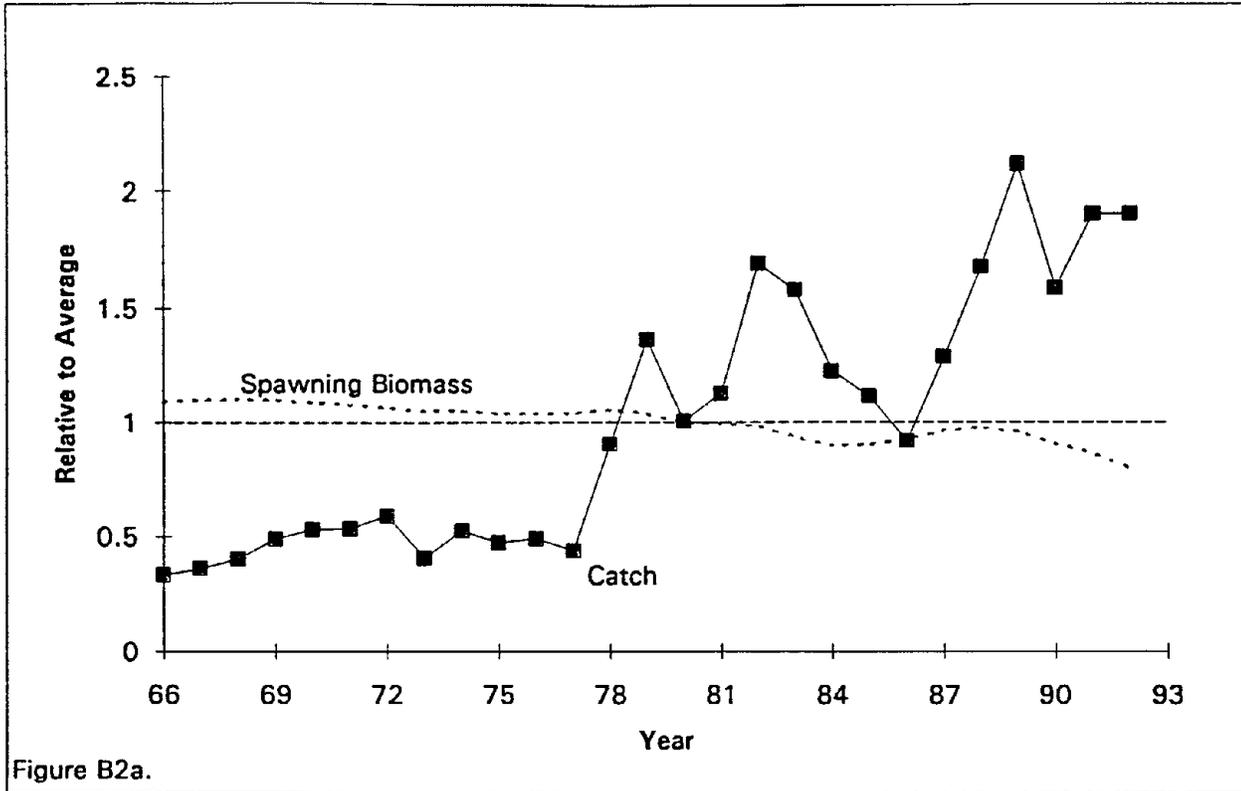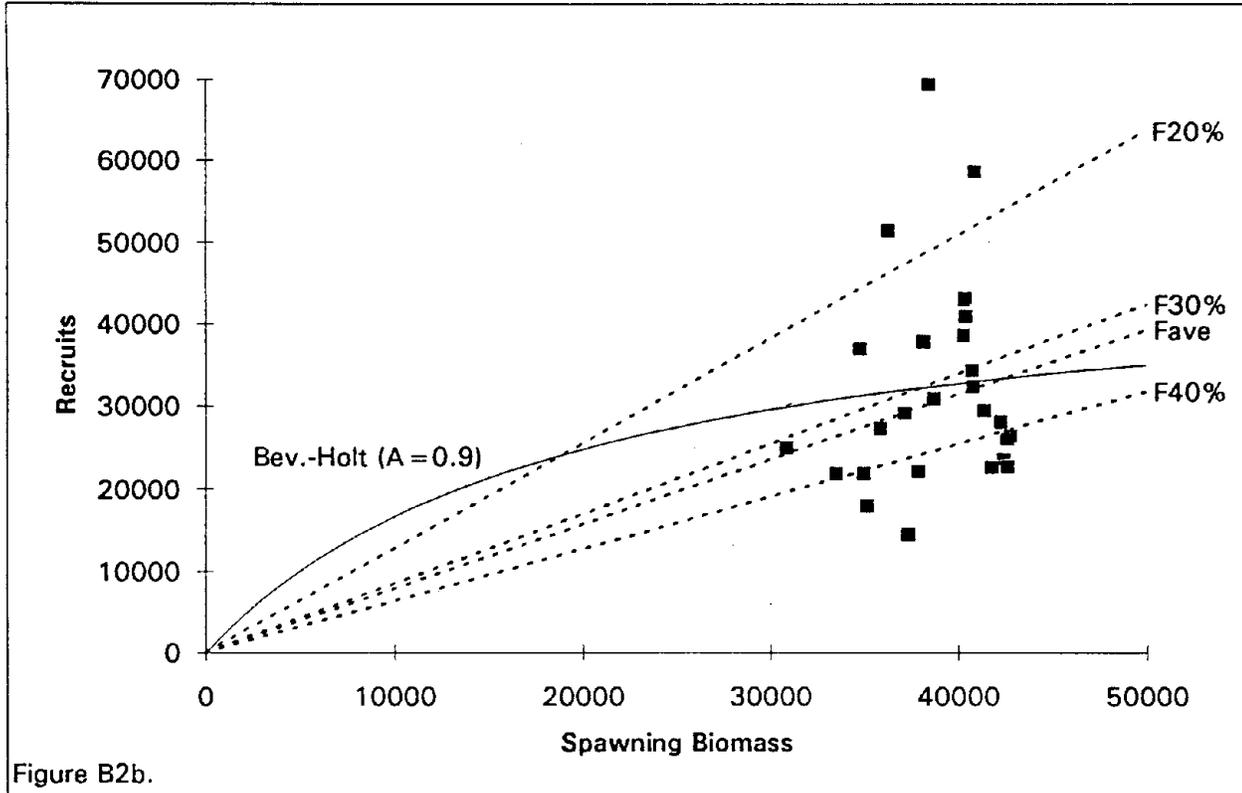
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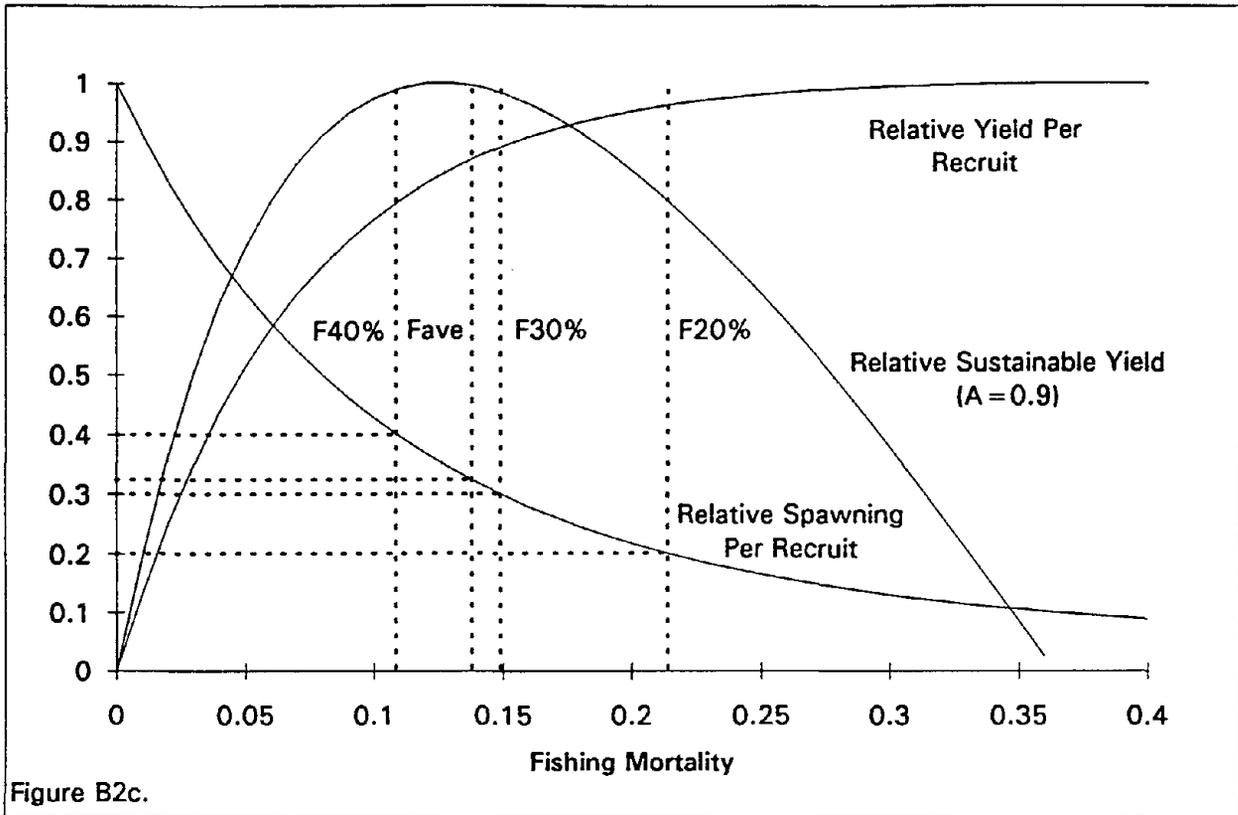
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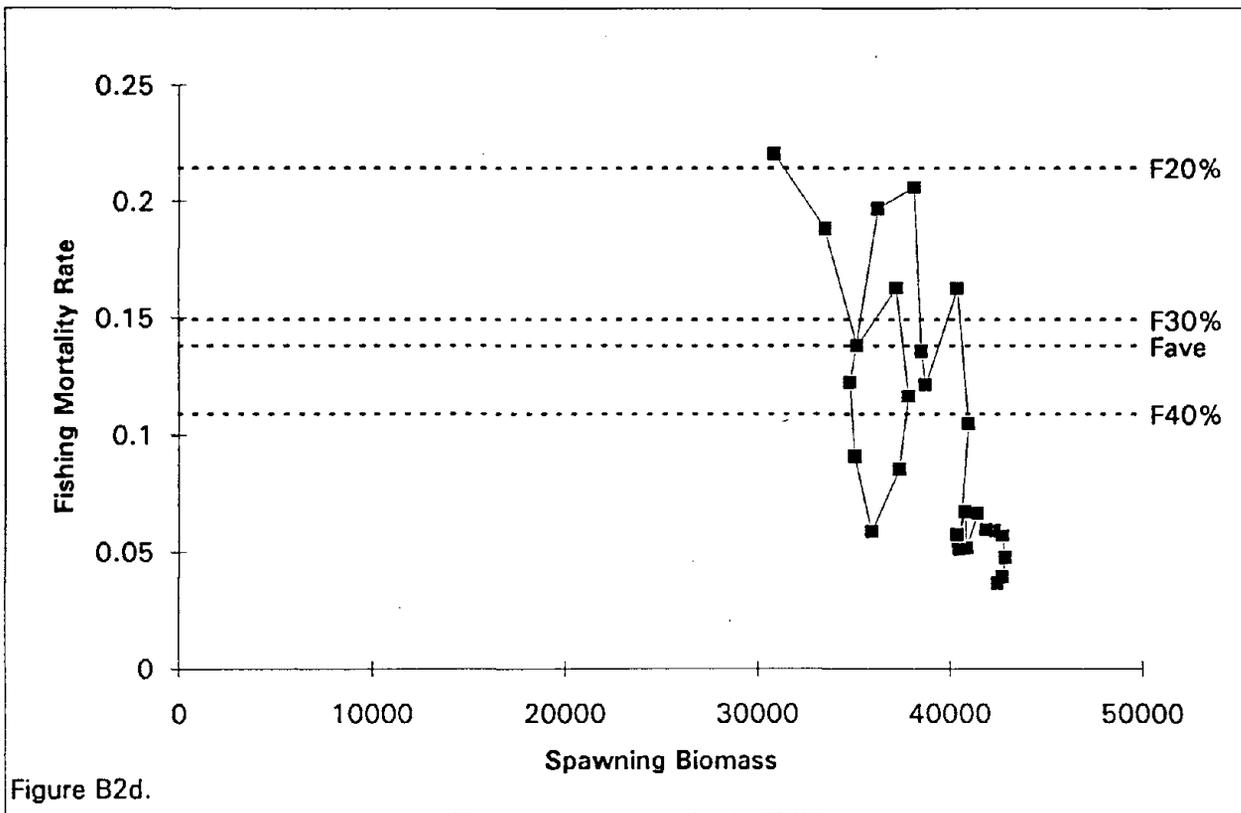
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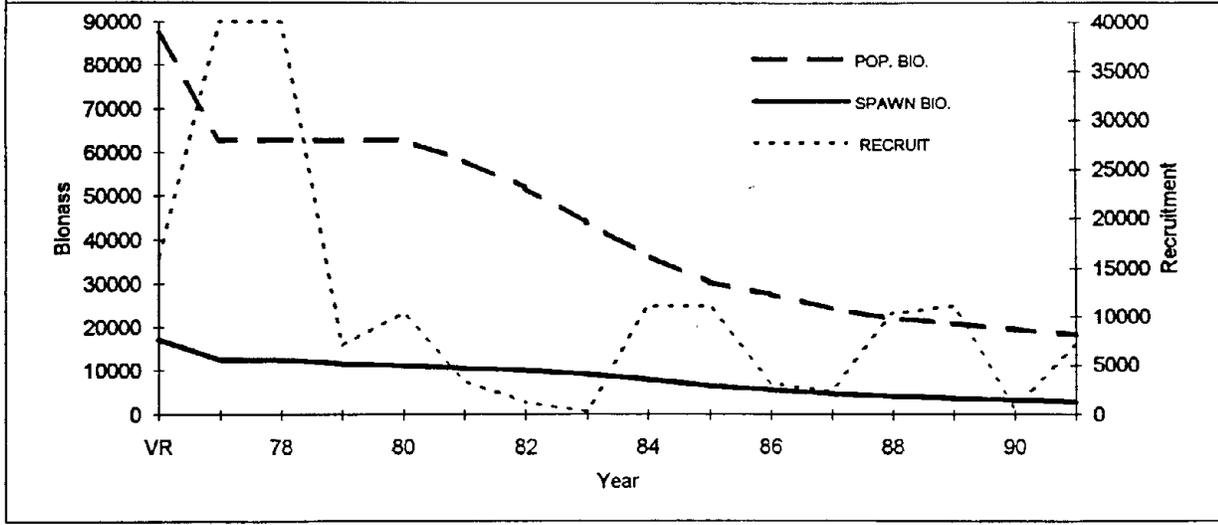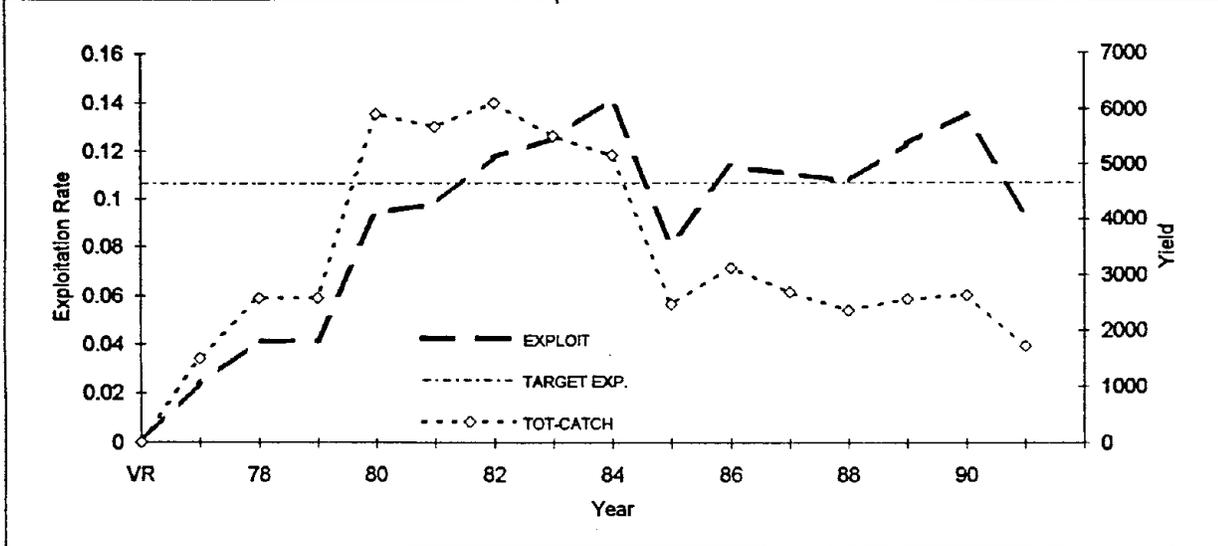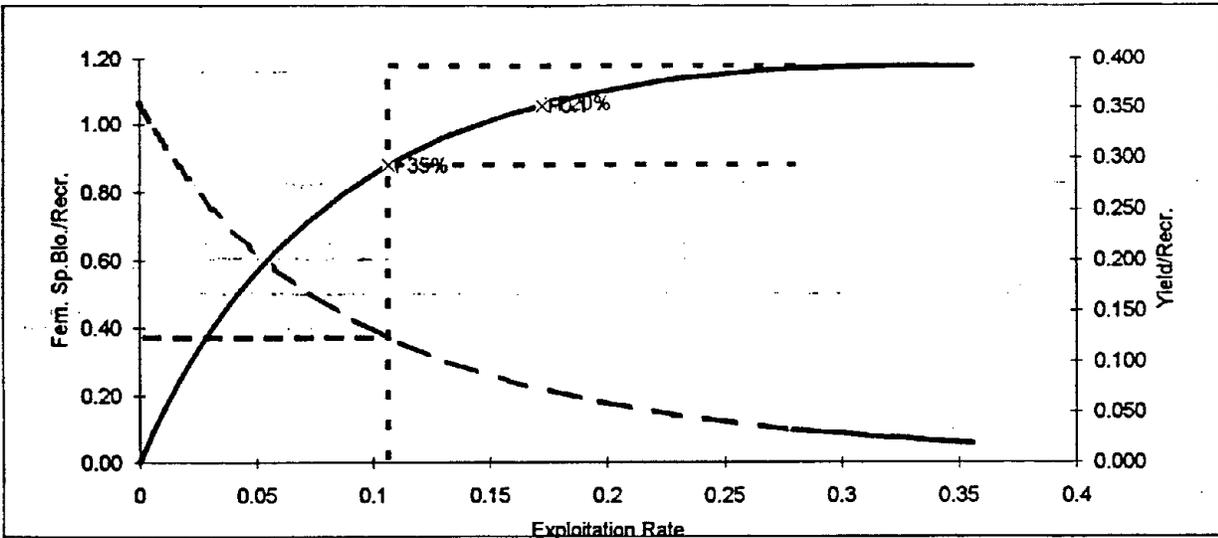
BOCACCIO

	ENTER		CONSTANT RECR.		DEN.-DEP. RECRUIT.		
	CRITER.	EXPLOIT	F.SP.BIO.	YIELD	RECRUIT	F.SP.BIO.	YIELD
VIRGIN	------	0.000	17086	0	16063	17086	0
MSY	0.889	0.107	------	------	12329	4582	3619
SPR	35%	0.107	5980	4712	12337	4593	3618
SPR	20%	0.176	3417	5694	7876	1711	2779
YLD. SLOPE	0.1	0.172	3521	5657	8179	1828	2867

| YEAR	91	92	93	94	95	long-term
FORECAST	1731	1838	1823	1855	1978	2296
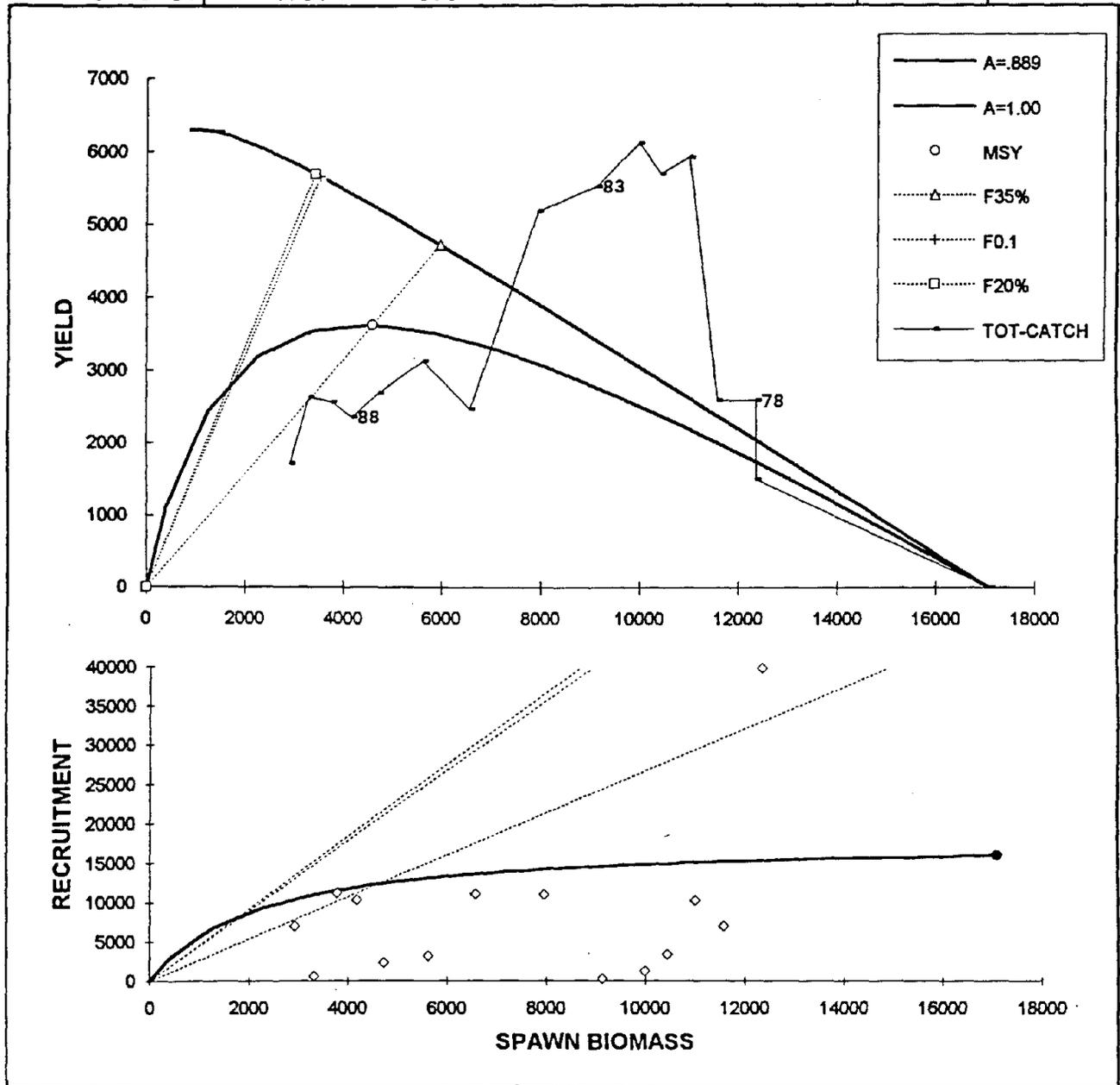
BOCACCIO
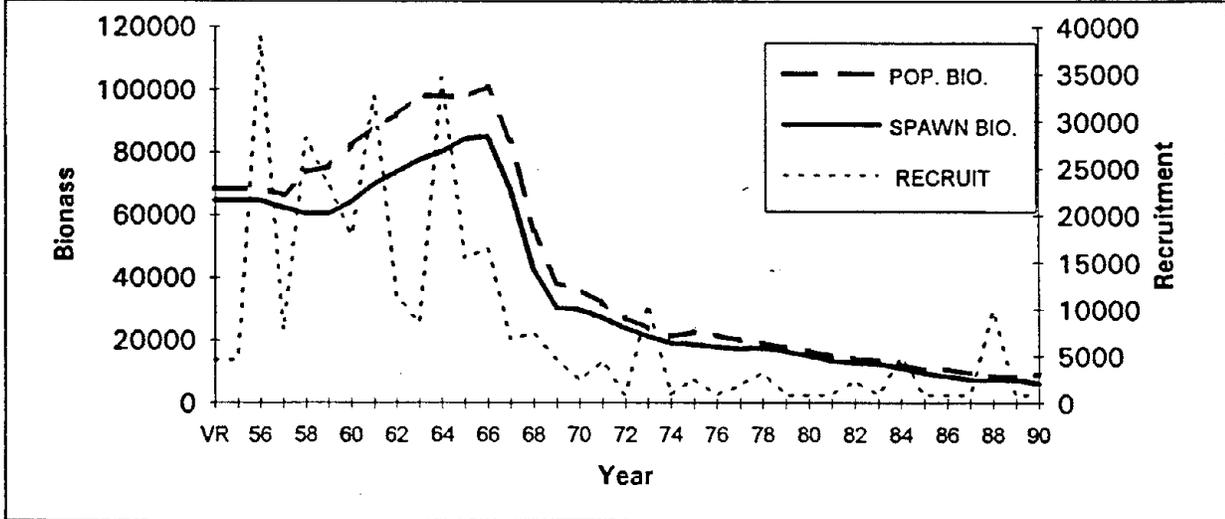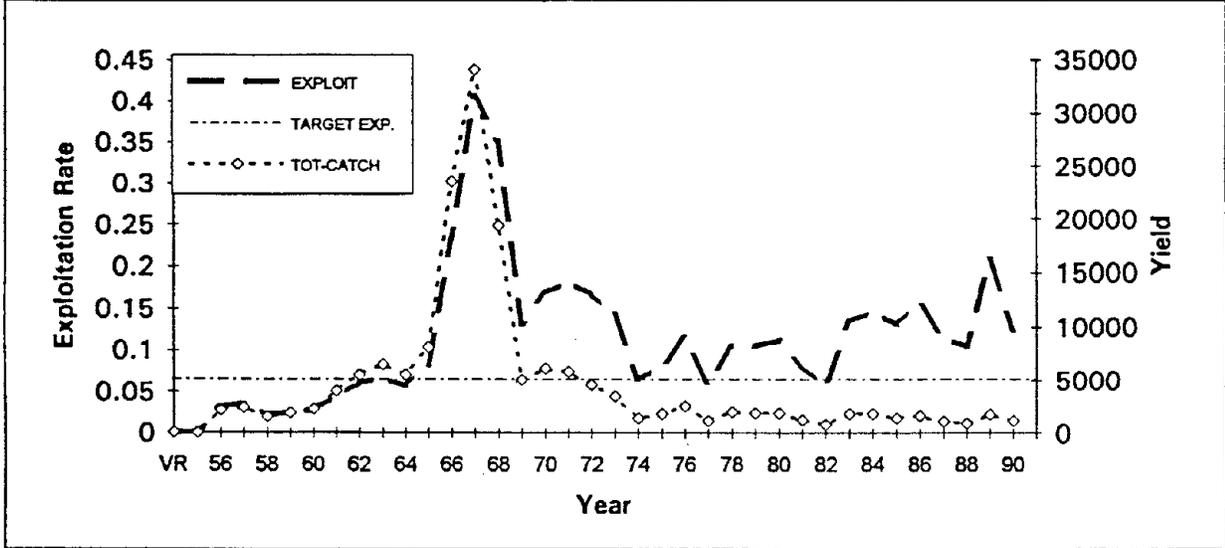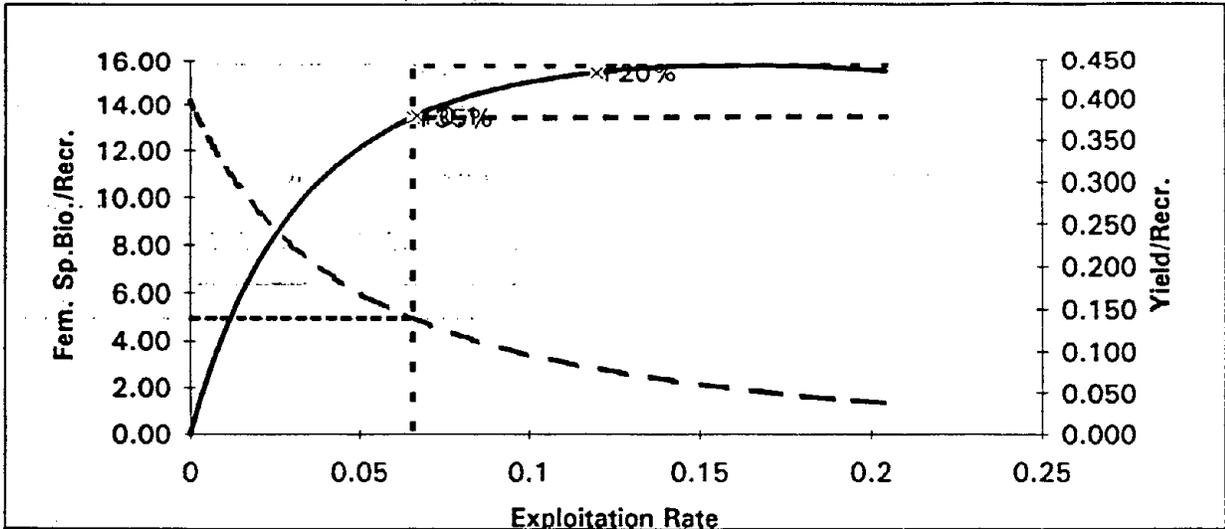
WEST COAST PACIFIC OCEAN PERCH

	ENTER CRITER.	EXPLOIT	CONSTANT RECR.		DEN.-DEP. RECRUIT.		
			F.SP.BIO.	YIELD	RECRUIT	F.SP.BIO.	YIELD
VIRGIN	------	0.000	64681	0	4570	64681	0
MSY	0.889	0.060	-------	-------	3612	19080	1326
SPR	35%	0.066	22638	1729	3504	17389	1323
SPR	20%	0:120	12936	1989	2273	6475	988
YLD. SLOPE	0.1	0.067	22327	1739	3481	17039	1323

| YEAR	90	91	92	93	94	long-term
FORECAST	1174	411	460	541	640	3134
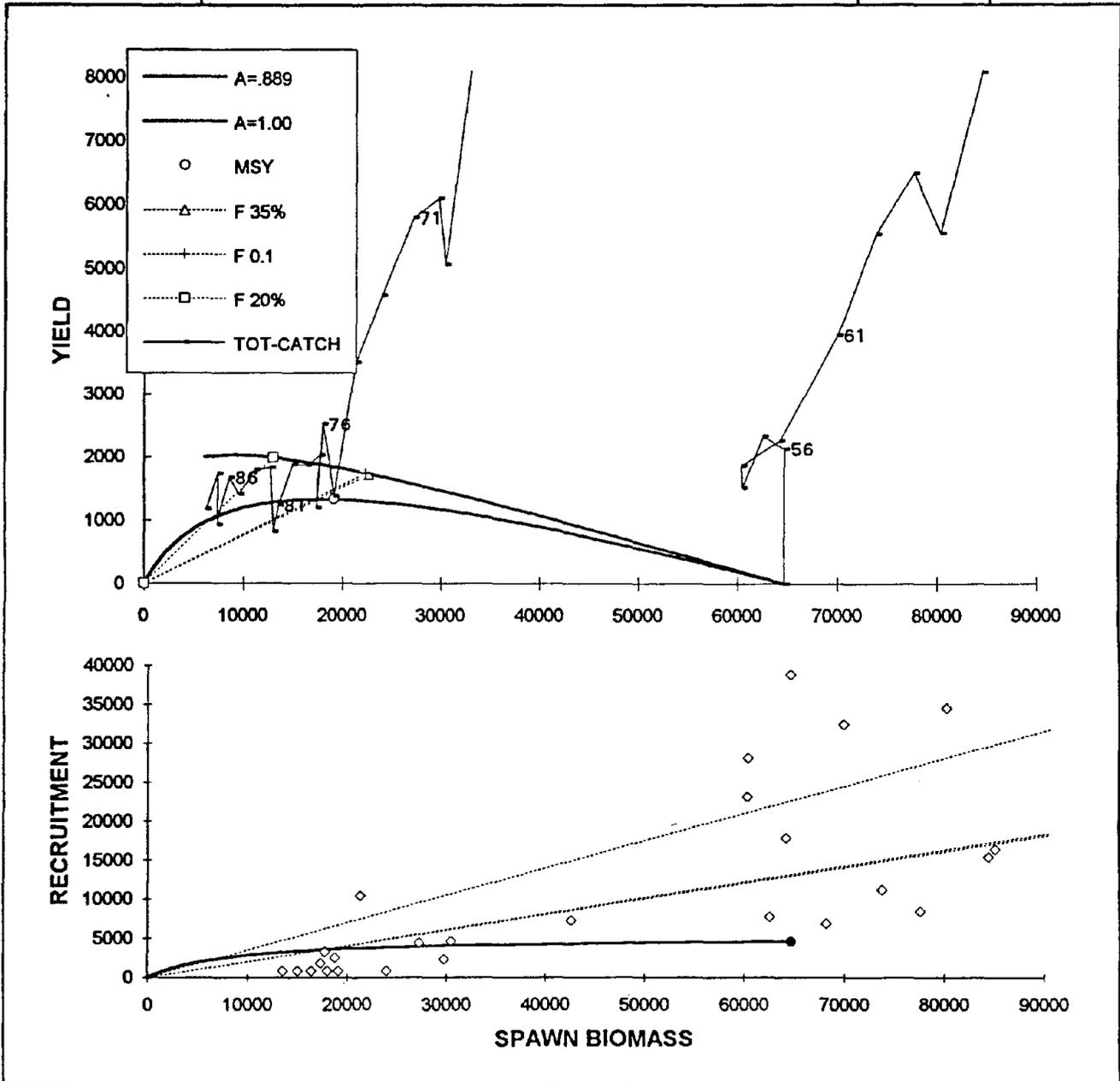
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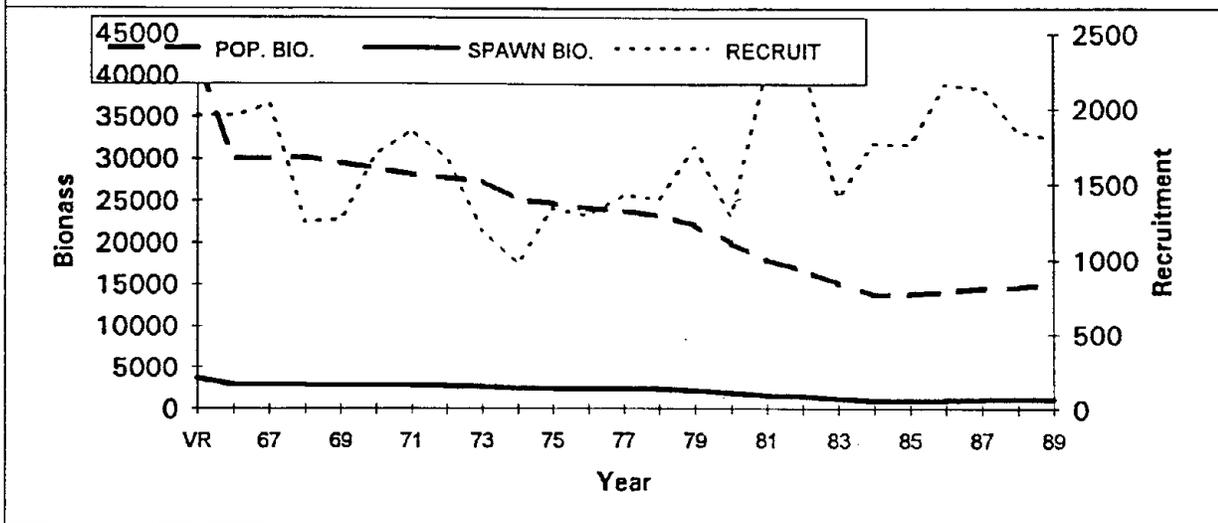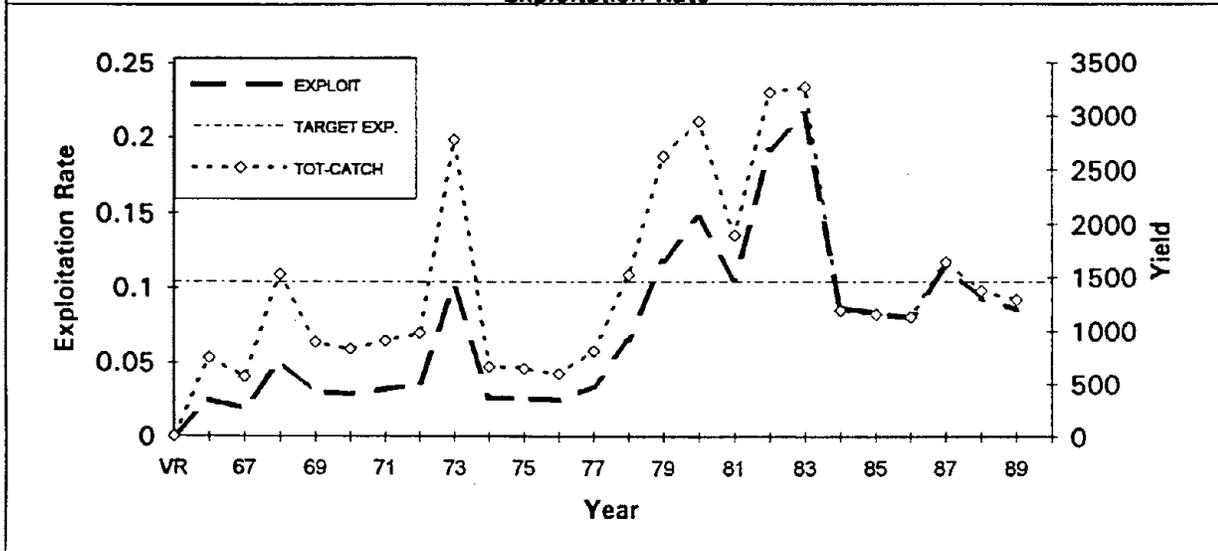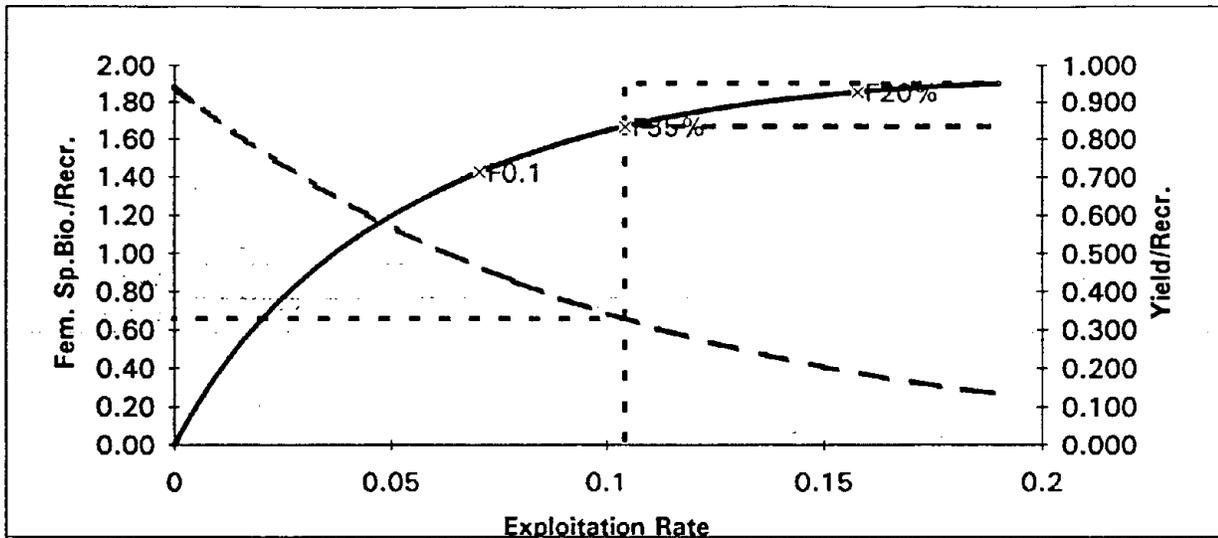
CANARY ROCKFISH

	ENTER		CONSTANT RECR.		DEN.-DEP. RECRUIT.		
	CRITER.	EXPLOIT	F.SP.BIO.	YIELD	RECRUIT	F.SP.BIO.	YIELD
VIRGIN	-------	0.000	3667	0	1952	3667	0
MSY	0.889	0.089	-------	-------	1600	1231	1261
SPR	35%	0.104	1283	1628	1497	986	1247
SPR	20%	0.158	733	1809	971	367	899
YLD. SLOPE	0.1	0.071	1811	1395	1702	1579	1215

| YEAR	89	90	91	92	93	long-term
FORECAST	1289	1583	1585	1598	1610	1394
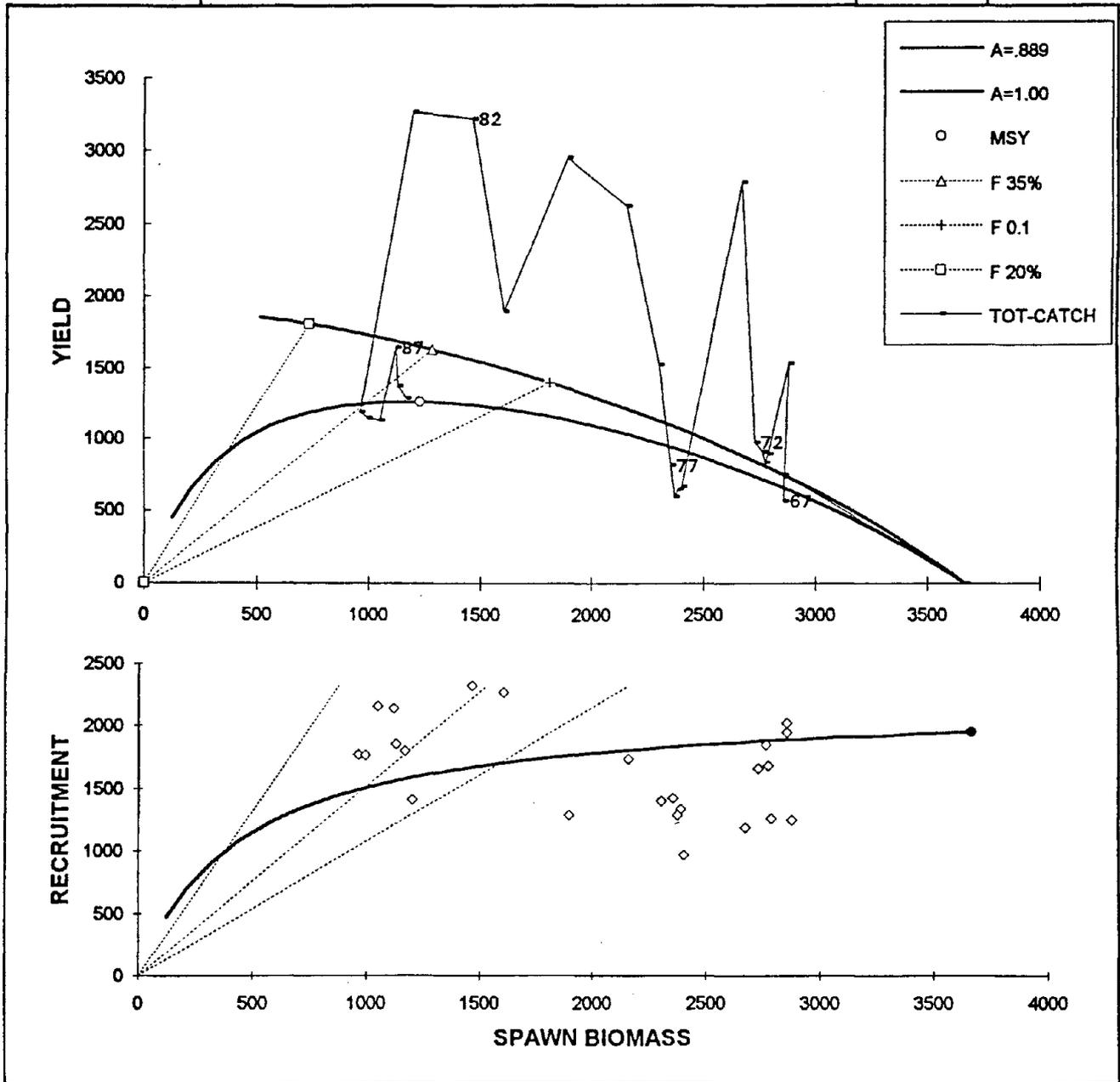
CANARY ROCKFISH

|	ENTER CRITER.	EXPLOIT	CONSTANT RECR.		DEN.-DEP. RECRUIT.		
			F.SP.BIO.	YIELD	RECRUIT	F.SP.BIO.	YIELD
VIRGIN	------	0.000	1366936	0	1526793	1366936	0
MSY	0.889	0.236	-------	-------	1204809	401137	252648
SPR	54%	0.131	743613	241401	1366652	665785	216021
SPR	35%	0.255	478428	329110	1171133	367489	252292
YLD. SLOPE	0.1	0.198	578489	297915	1266172	480044	246962

YEAR	91	92	93	94	95	long-term
FORECAST	316380	548435	363162	298423	300133	383410
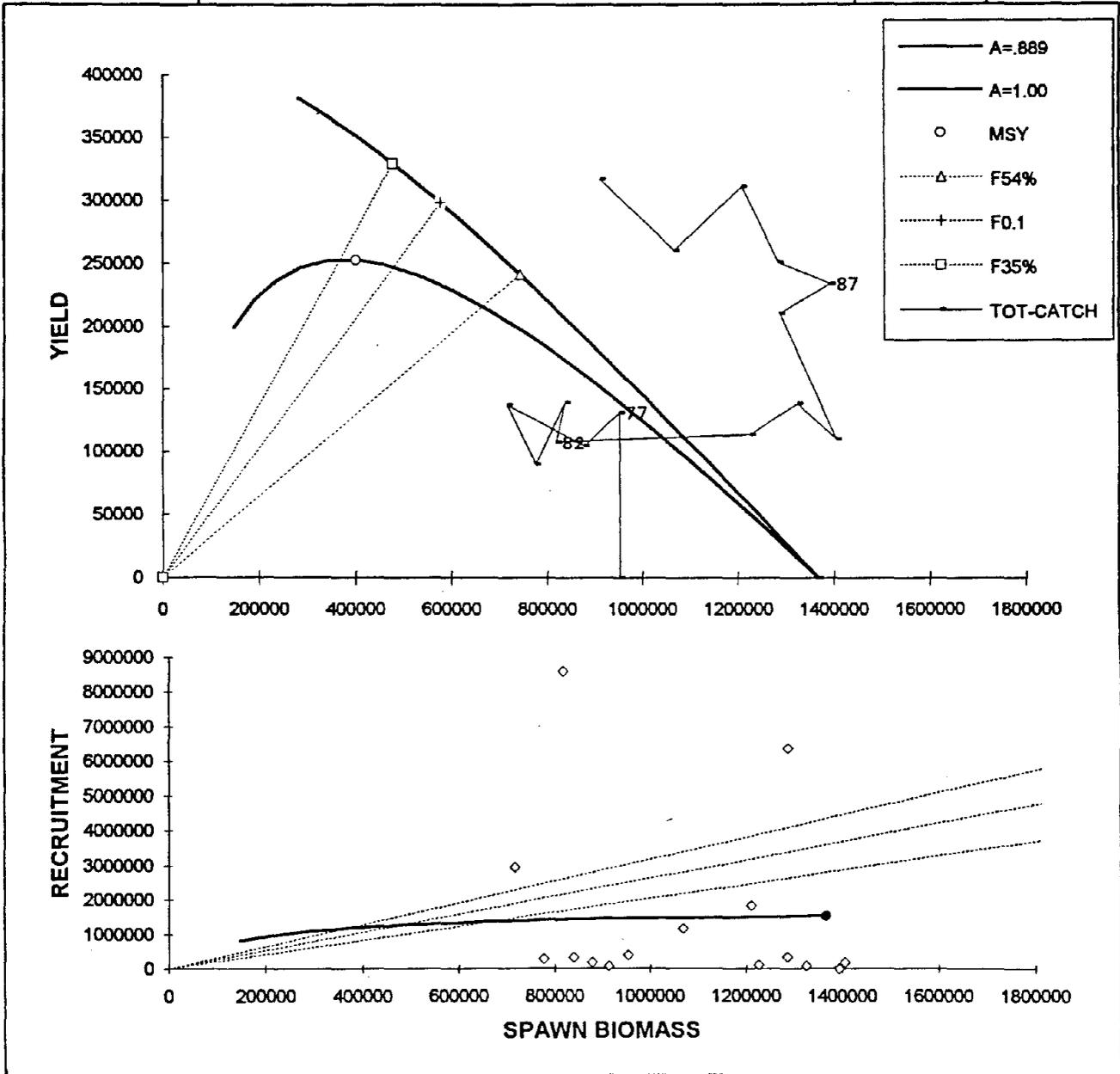
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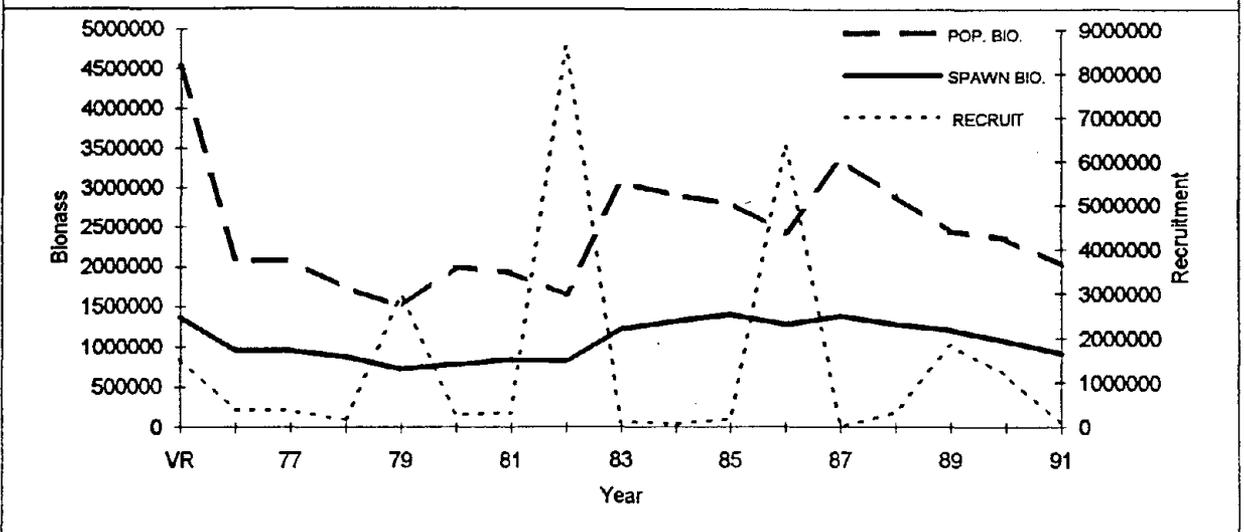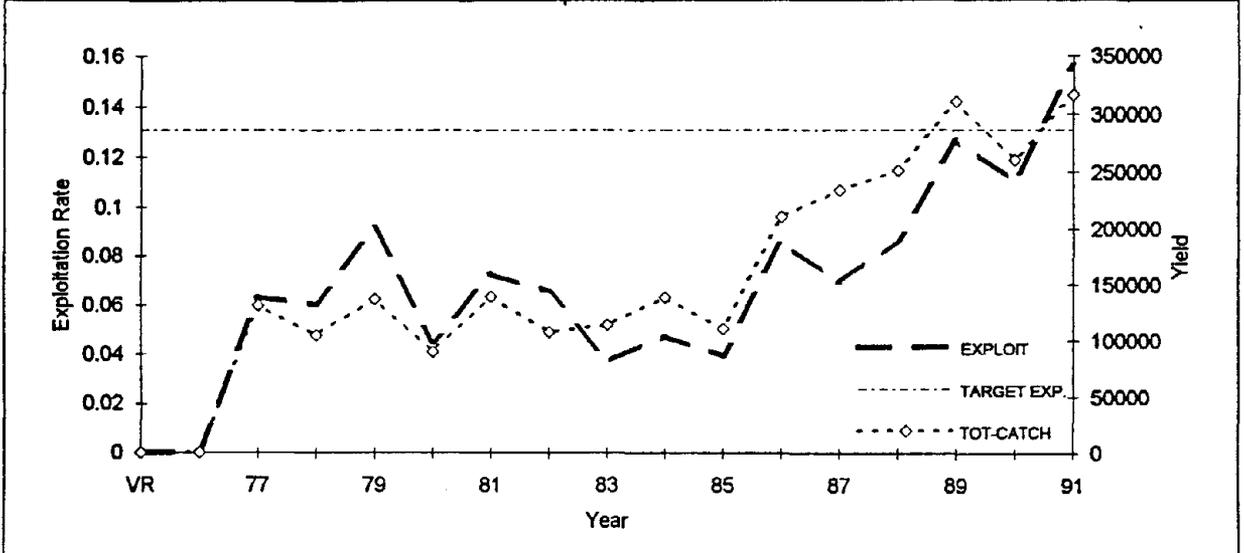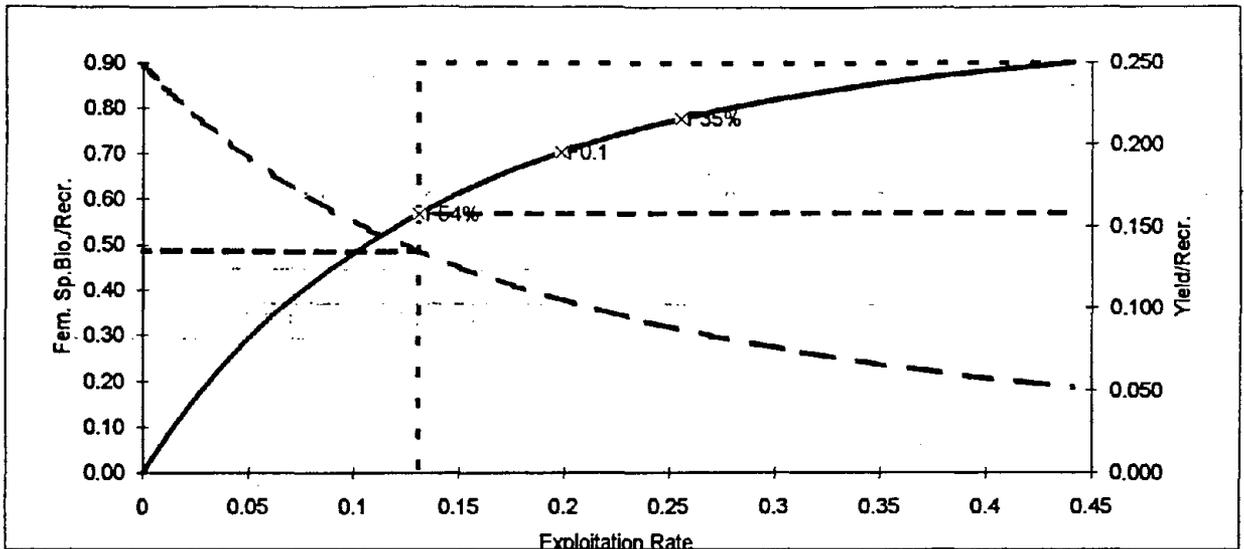
PACIFIC WHITING

Management unit - **Northern anchovy (# 34)**

Species/stocks:

> **34.** Northern anchovy (*Engraulis mordax*)

FMP/Amendment Defining Overfishing: Amendment 6 to the Northern Anchovy Fishery Management Plan (Pacific Fishery Management Council).

Overfishing Definition:

"The two-year-lower-cutoff option defines overfishing as harvests of any kind when the spawning biomass during the current <u>and</u> preceding season was less than 50,000 mt. Under this option, all fisheries (reduction, live bait, and other non-reduction) are closed in the second season when the spawning biomass falls below 50,000 mt for 2 consecutive seasons, and the closure continues in subsequent seasons until the spawning biomass equals or exceeds 50,000 mt." (p. ES-3)

Rebuilding Plan: Prohibit all U.S. harvests if spawning biomass falls below 50,000 mt in 2 consecutive years.

Assessment Method and Decision Rule:

An age-structured approach is used, incorporating indices of egg production in a stock synthesis-type model. The most recent assessment incorporates different methodology for stock-size estimation and requires indirect estimation of numbers of recruits.

Overfishing is indicated when the spawning stock biomass (as estimated from the assessment) was less than 50,000 mt in both the current and preceding seasons.

Evaluation of Overfishing Definition:

Although the Review Panel noted that this stock is well protected under other provisions of the management plan, a spawning stock biomass threshold of 50,000 mt in 2 consecutive years is a risky definition of overfishing, as it represents a level more than 100,000 mt lower than any historically observed level. In this case, a significant portion of the fishery is beyond the jurisdiction of the FMP (Mexican waters).

An alternative approach may be to incorporate a framework for more stringent controls on fishing mortality rates as stock sizes decline or are projected to decline with specified degrees of certainty. This may reduce the risk that stock sizes would be reduced to extreme low levels, perhaps to a level at which average annual production equalled foreign fishery removals, excluding the possibility of rebuilding spawning stock biomass to levels at which a U.S. fishery would be re-allowed.

Data Sources:

Jacobson, L.D. and N.C.H. Lo. 1992. Spawning Biomass of the Northern Anchovy in 1992. Southwest Fisheries Science Center Administrative Report LJ-92-24.

Thompson, C., G. Walls and J. Morgan 1992. Status of the California Coastal Pelagic Fisheries in 1991. Southwest Fisheries Science Center, NMFS, Administrative Rep. LJ-92-25.

Northern Anchovy: Trends in Landings, Spawning Stock Biomass; Stock and Recruitment
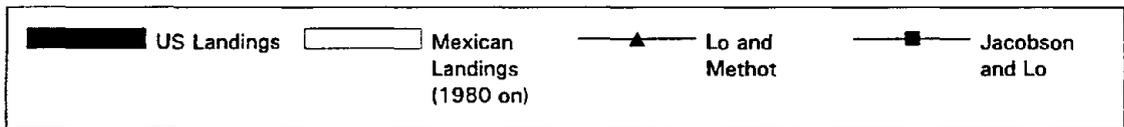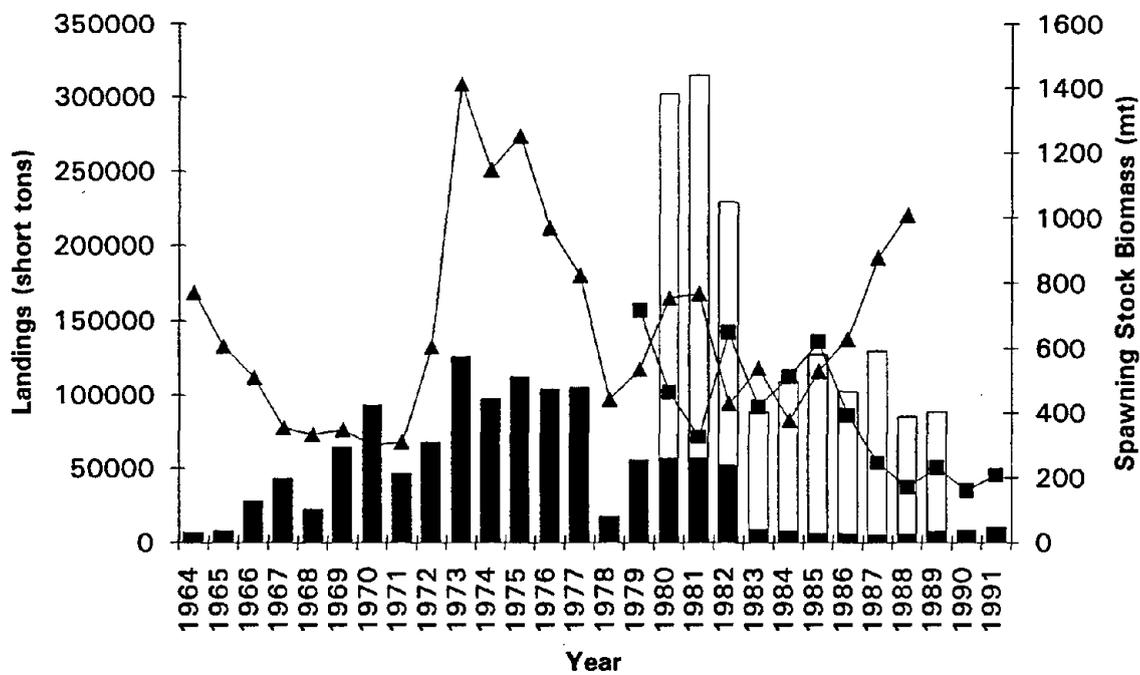
Legend: US Landings | Mexican Landings (1980 on) | Lo and Methot | Jacobson and Lo

Lo and Methot

α=0.286
β=1.468
K=302.77

Jacobson and Lo

α=0.35
β=4.82
K=592.7
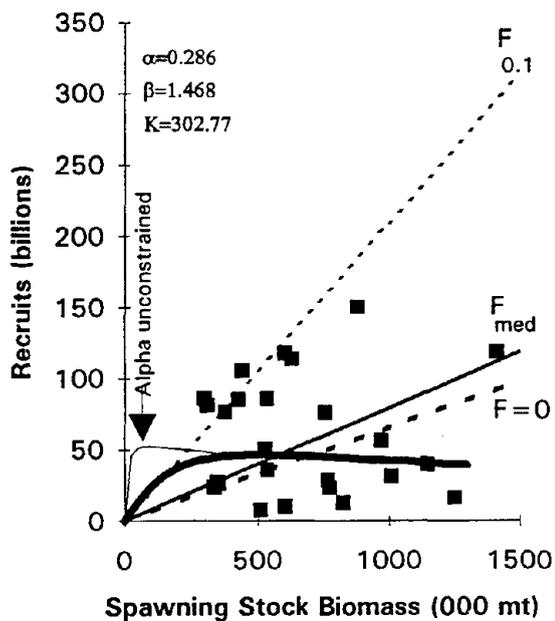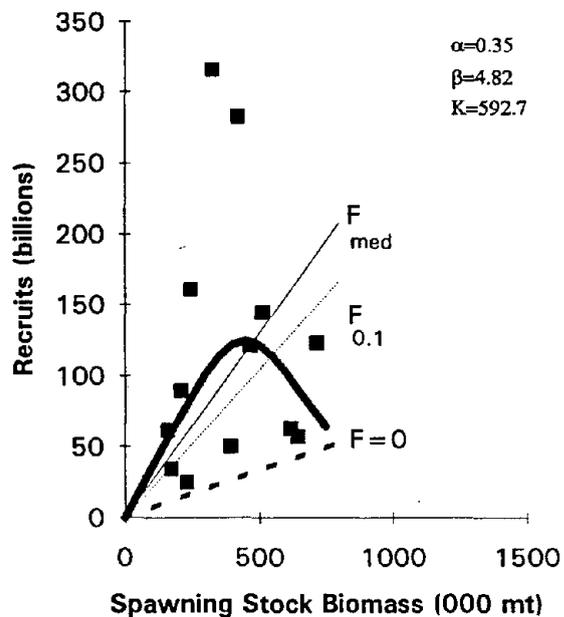
Northern Anchovy: Y/R, SSB/R; Control Law and Historic Performance
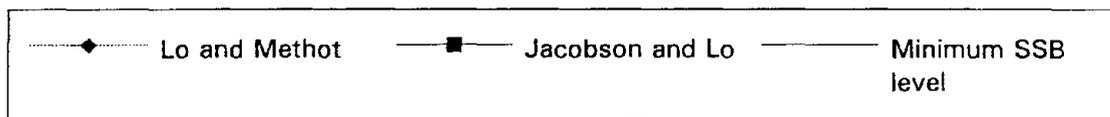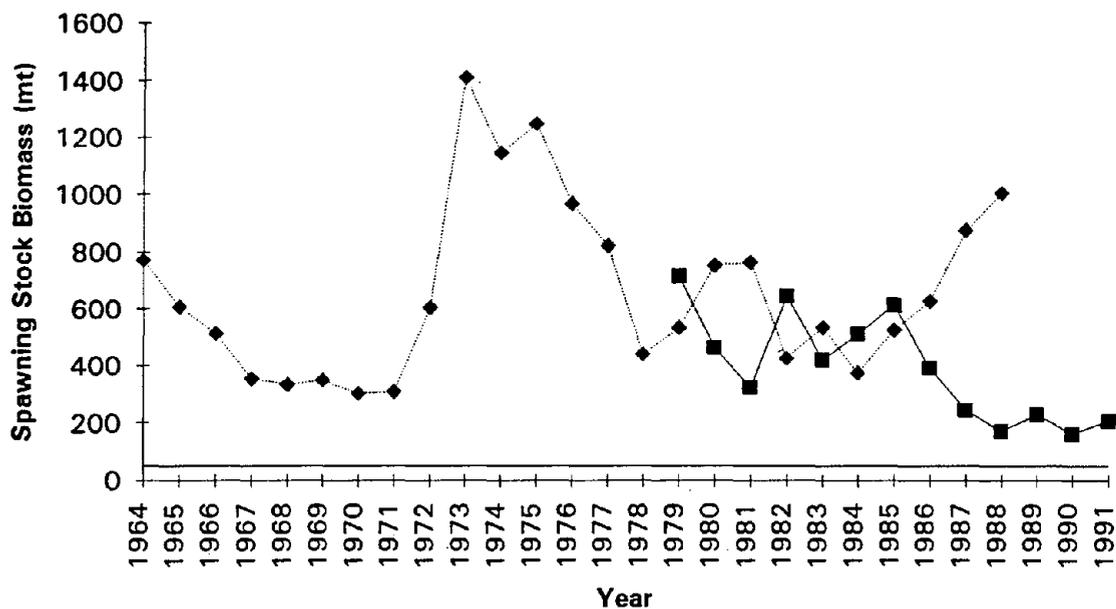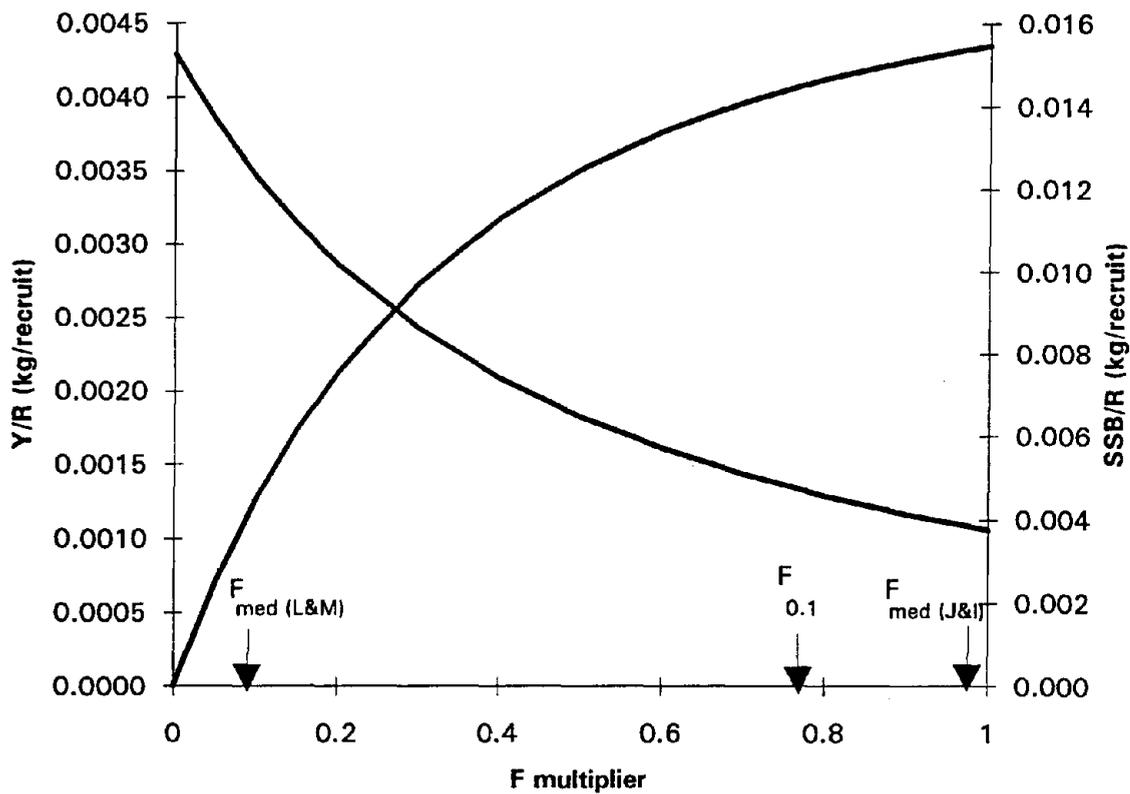
Management unit - Ocean Salmon (Washington, Oregon, California) (# 36, 73-93)

Species/stocks:

36. Coho salmon (*Oncorhynchus kisutch*): many stocks
73-93. Other Pacific Coast Salmon
     Chinook salmon (*Oncorhynchus tshawytscha*): many stocks
     Pink salmon (*Oncorhynchus gorbuscha*): many stocks
     Sockeye salmon (*Oncorhynchus nerka*): many stocks
     Chum salmon (*Oncorhynchus keta*): many stocks

FMP/Amendment Defining Overfishing: Amendment 10 to the Fishery Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California (Pacific Fishery Management Council).

Overfishing Definition:

"Overfishing is an occurrence whereby all mortality, regardless of the source, results in a failure of a salmon stock to meet its annual spawning escapement goal or management objective, as specified in Section 3.5 of the salmon FMP for three consecutive years, and for which changes in the fishery management regime offer the primary opportunity to improve stock status. While this condition is defined as overfishing in the broad sense, it is recognized that this situation may also be the result of nonfishing mortality and fishery management actions may not adequately address the situation." (p. 21 of Amendment 10).

"When a specific stock or stock grouping fails to meet its annual spawning escapement objective for three consecutive years, the Council shall appoint a work group to investigate the causes of the apparent shortfall (e.g., due to causes within or outside of Council control). ... For those actions within Council control, the Council may change analytical or procedural methodologies to improve the accuracy of estimates ... and/or to reduce ocean harvest impacts when shown to be effective in stock recovery to MSY levels. ..." (p. 25 of Amendment 10).

"Stocks without specified goals in the FMP are also provided significant protection against overfishing because the Council bases its management on the stock which is first reduced to its annual specified goal level by the fisheries." (p. 25 of Amendment 10).

Assessment Method and Decision Rule:

Varies by species and stock.

"The Council's definition of overfishing is based on the spawning escapement goals for chinook and coho salmon stocks specified in the salmon FMP ... Spawning escapement

goals are based on such factors as estimates of spawning or rearing habitat or historical production from a range of observed spawning escapements. Spawning escapement goals are generally expressed in numbers of adult fish or as an escapement rate, often with a numerical floor." (p. 21 of Amendment 10).

Data used in the assessment include estimates of adult escapement from a variety of sources, including run reconstructions base on coded-wire tag recoveries of hatchery fish, dam passage counts, and in-stream spawner surveys (carcass or redd counts). The quality and availability of data are quite variable from stock to stock.

Relevant Life History Features:

The species considered here are anadromous, relatively short-lived (typically 2-6 years), and semelparous (spawning once and then dying). Patterns of reproductive age are quite variable among species, ranging from essentially single-age spawning (pink salmon) to spawning over several age classes (chinook salmon). Salmon are well known for their homing abilities and specificity to particular spawning grounds, which has led to management based on individual spawning stocks. Commercial and sport fisheries for salmon use a variety of capture techniques and occur on the high seas, in coastal oceans, in estuaries, and in rivers. The combination of life history and fishing patterns leads to complicated multi-stock, multi-fishery, multi-jurisdictional management problems.

Evaluation of Overfishing Definition:

Only the Oregon Coastal Natural (OCN) coho salmon stock was examined in detail for this review. It provides a good illustration of some common problems. Other stocks are summarized below.

Recent history and management of the OCN coho salmon stock are illustrated in the associated figures. Escapement forcasts are based on a fitted production function using spawning ground survey estimates of natural spawners combined with fishery recruitment and harvest rate estimates calculated by adjusting total regional harvest for hatchery production (PFMC 1993b). There is substantial evidence that historical spawning abundance estimates have been seriously biased (Oregon Coastal Natural Coho Review Team 1992), but the effect of that bias on management goals has not been fully evaluated. The management goal for this stock since 1987 has been 200,000 natural spawners. At stock sizes below 400,000, the goal is reduced for "optimum yield" considerations, reaching a minimum of 135,000 spawners at a stock size of 270,000. The 200,000-spawner goal has only been achieved in two of the last 23 years. The goal is also somewhat higher than our estimate of MSY (derived by fitting a Shepherd SR function to recent spawner-recruit data) and so would appear to be a conservative definition of overfishing for this stock complex as a whole. This does not mean that it will be conservative in protecting all of the sub-stocks within the complex however.

Management goals (overfishing thresholds) and recent run sizes for other salmon stocks listed in the FMP are summarized in the table below. To the extent that management objectives reflect MSY for the stocks, the definition would appear to be conservative for the stock complexes, but not necessarily for the individual sub-stocks within each complex. It is unclear from the available documents how well many of the escapement objectives reflect MSY. For the majority of the stocks, the FMP does not define the biological basis for the goal, so it is difficult to evaluate the goal as an overfishing threshold. For only two stocks (Oregon coastal chinook and coho salmon) is the management goal clearly based on an estimate of MSY. For some others, management goals reflect a mixture of natural escapement and hatchery production goals. Many salmon stocks do not have specific escapement goals listed in the Fishery Management Plan. For some of these, annual management objectives are developed under procedures set in the U.S. District Court, and these annual goals are used in the overfishing definition. For other stocks, especially most stocks of pink, sockeye, and chum salmon, no objectives are set.

Two characteristics of this overfishing definition are of particular concern. The definition equates overfishing with failure to meet management objectives, and only a review is mandated if a stock meets this definition. While it is certainly wise to institute a review when management goals are not being met, this type of review does not seem to be the intent of the 602 guidelines. The definition could be improved by tying the threshold to a distinct biological reference point that clearly indicates reduced recruitment potential for the stock, and mandating specific management actions to be instituted when that threshold is crossed, regardless of the cause.

Another area where there is room for improvement is in dealing with complex life histories and multi-jurisdictional management. Wording in the overfishing definition appears to not require action when stocks are depressed for reasons outside the immediate control of the Management Council. The 602 guidelines mandate management action "regardless of the cause of the low population level"--50 CFR 602.10(b)(7). The accelerating frequency of petitions to list salmon stocks under the Endangered Species Act suggests that current management has not been successful at protecting the production capacity of certain salmon populations.

Data Sources:

Oregon Coastal Natural Coho Review Team. 1992. An assessment of the status of the Oregon natural coho stock as required under the definition of overfishing. Report prepared for the Pacific Fishery Management Council (PFMC).

Puget Sound Salmon Stock Review Group. 1992. Assessment of the status of five stocks of Puget Sound chinook and coho as required under the PFMC definition of overfishing. Summary Report for the Pacific Fishery Management Council (PFMC).

PFMC 1993a. Review of 1992 Ocean Salmon Fisheries. Pacific Fishery Management Council, February 1993.

PFMC 1993b. Preseason Report I: Stock Abundance Analysis for 1993 Ocean Salmon Fisheries. Pacific Fishery Management Council, February 1993.

PFMC 1993c. Preseason Report II: Analysis of proposed regulatory options for 1993 ocean salmon fisheries. Pacific Fishery Management Council, April 1993.

PFMC 1993d. Preseason Report III: Analysis of Council-adopted management measures for 1993 ocean salmon fisheries and biological assessment of impacts on Snake River salmon species from the salmon fisheries off the coasts of California, Oregon, and Washington managed under the Council regulatory recommendations for 1993. Pacific Fishery Management Council, April 1993.

Salmon Technical Team (STT). 1993. Salmon technical team report on salmon stocks not meeting Council escapement goals for the past three years. Pacific Fishery Management Council, March 9, 1993.

Summary of management goals and recent run sizes for Pacific salmon in WA, OR, and CA.

Stock	Goal (1000's)	Goal Type	Actual Run Size Estimate (1000's)				
			1992	1991	1990	1989	1988
Chinook Salmon							
Sacramento R. Fall	122-180	mixed	84.3	112.3	108.3	149.6	244.9
Klamath R. Fall	35+	??	25.9	32.4	35.6	123.9	190.8
Other CA coast	none	??	nd	nd	nd	nd	nd
OR Coast	150-200	msy	nd	nd	nd	nd	nd
Columbia R.							
Upriver Fall	40	mixed	51.2	46.7	57.6	96.5	114.7
Upriver Summer	80-90	mixed	15.0	18.8	25.0	28.7	30.2
Upriver Spring	115	mixed	82.7	53.3	87.3	75.0	83.5
Lower R. Fall Hatchery	var.	hatchery	62.5	62.7	59.9	130.9	310.0
Lower R. Fall Wild	none	??	12.6	19.9	20.3	38.6	41.7
Lower River Spring	30-45	??	39.7	48.7	69.1	65.9	68.7
WA Coast Fall*	29.8	??	24.7	38.7	54.2	67.5	72.5
WA Coast Spr/Sum*	4.5	??	4.1	4.1	8.7	11.7	9.2
Puget Sound Sum/Fall*	74.5	??	nd	69.6	112.5	113.4	87.0
Coho Salmon							
Columbia River	var.	hatchery	208.1	930.3	198.0	714.6	668.9
OR Coast	135-200	msy	131.4	135.8	104.0	144.5	160.8
WA Coast Wild-Mgt*	49.5-70.7	??	nd	80.2	60.9	75.3	77.6
WA Coast Hatch.-Mgt*	var.	hatchery	nd	211.5	96.7	124.9	107.3
Puget Sound*	150.8	mixed	nd	136.5	203.5	213.5	235.0
Sockeye salmon							
Lake Washington	300	??	nd	nd	nd	nd	nd
Columbia River	65	??	nd	nd	nd	nd	nd
Pink Salmon							
Puget Sound Odd-year	900	??		920.0		2280.0	

*These stocks represent an aggregate of several sub-stocks with individual goals.

Goal types are:

hatchery--managed to meet hatchery production goals.

msy--managed to meet MSY of naturally-spawning stock.

mixed--managed for a combination of hatchery and natural production goals.

nd--no data in SAFE documents (PFMC 1993a-d).

OCN Coho Salmon

OCN Coho Salmon

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OCN Coho Salmon

OCN Coho Salmon
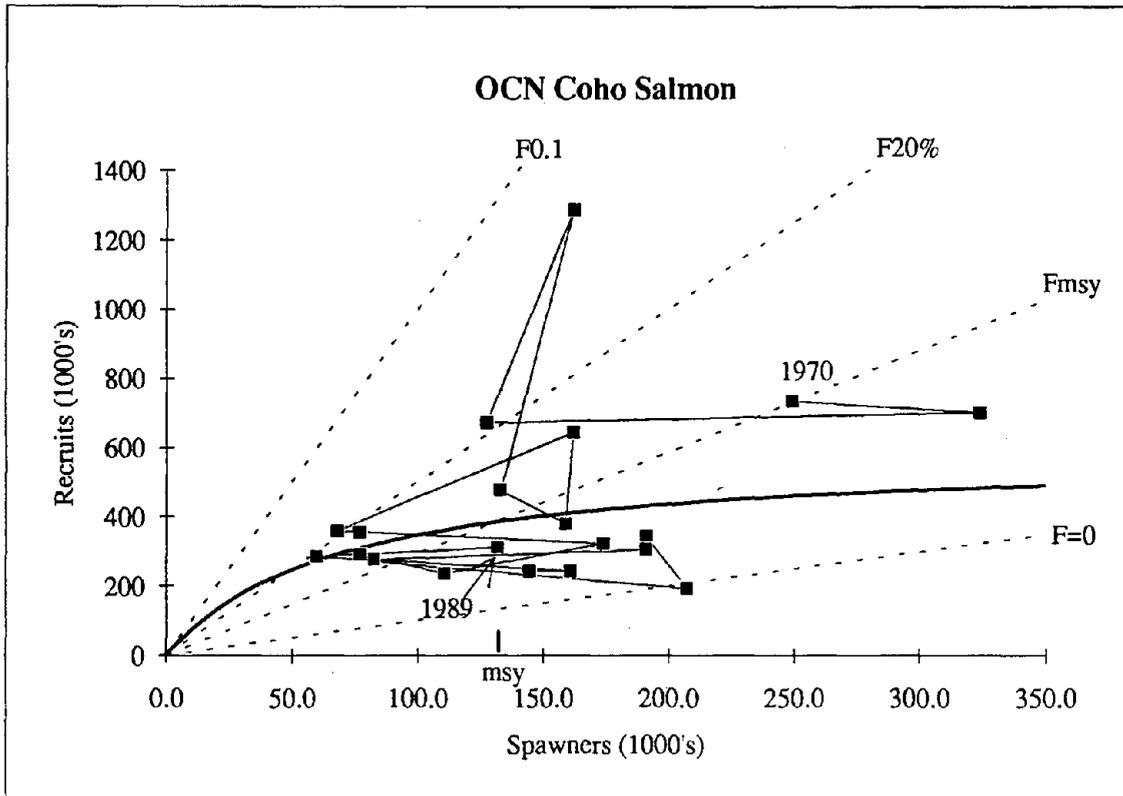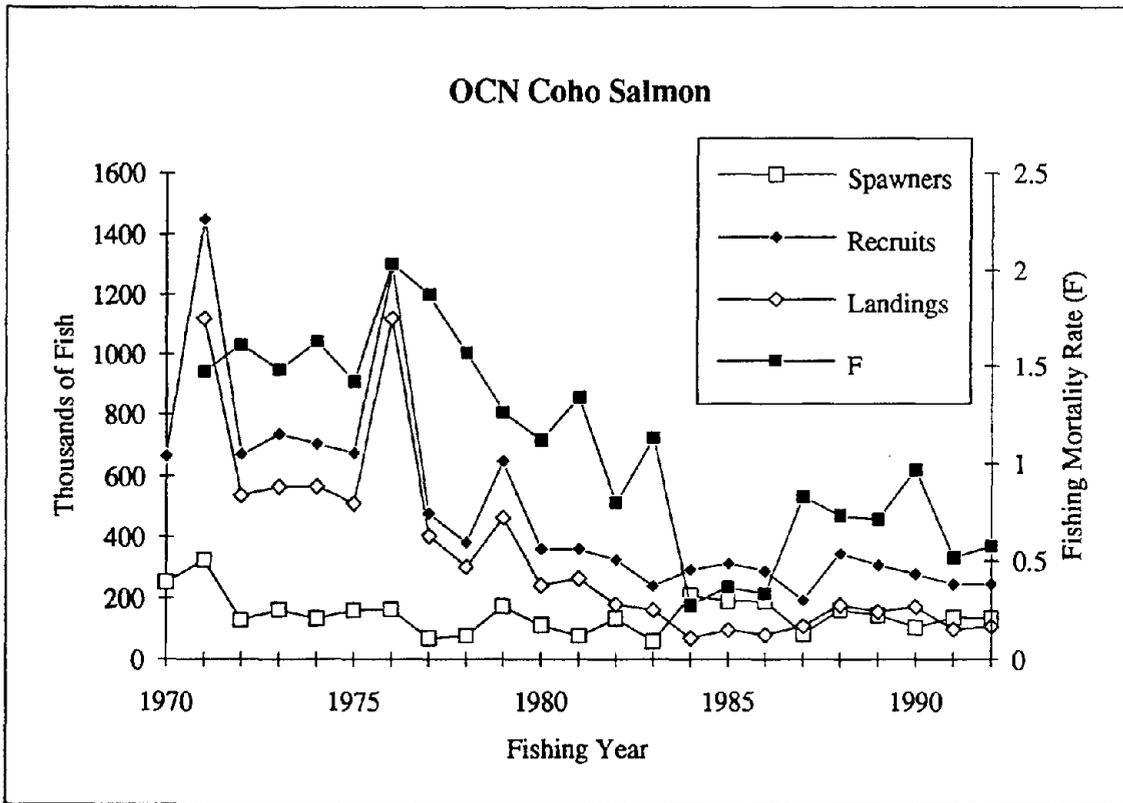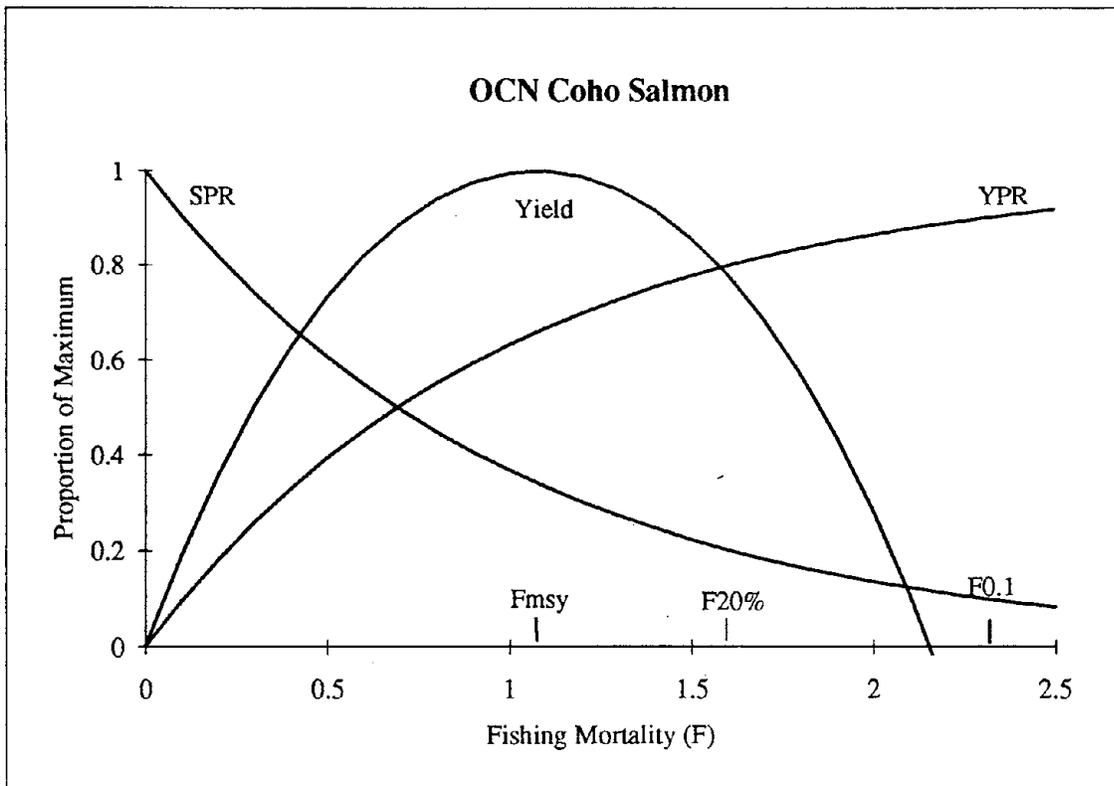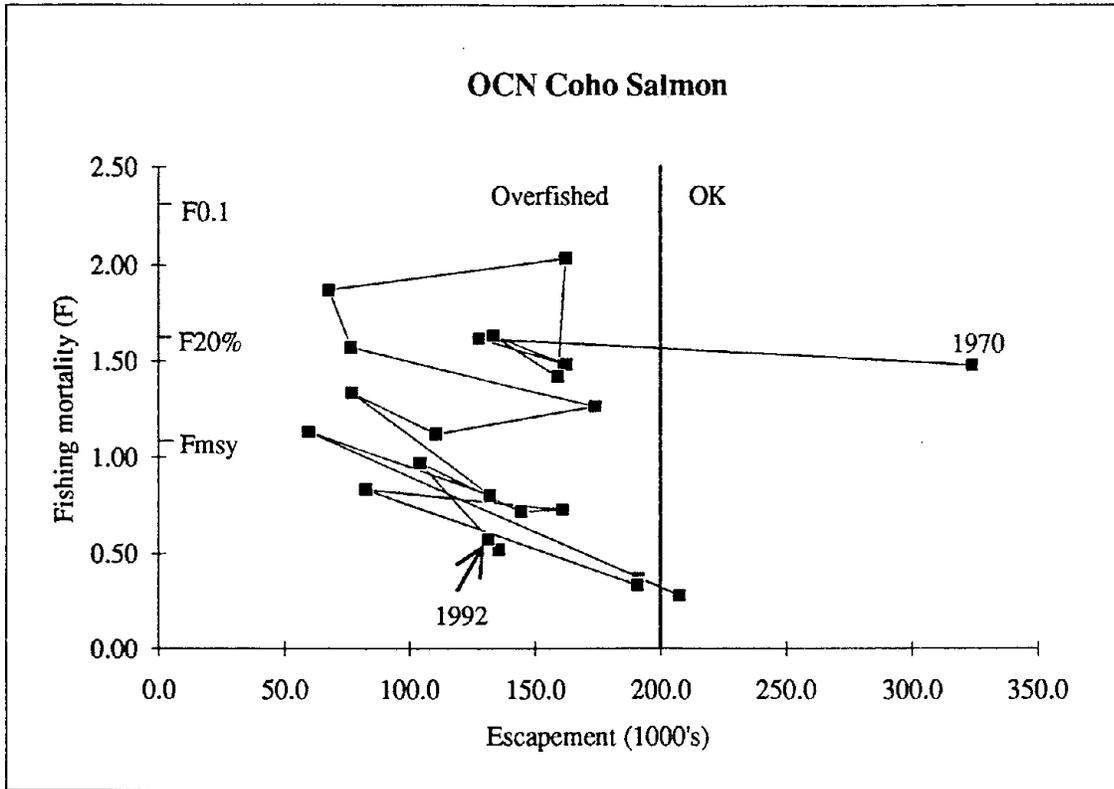
Management unit - Western Pacific crustaceans (#37)

Species/stocks:

      37. Spiny lobster (*Panulirus marginatus*)
          Slipper lobster (*Scillarides squammosus*)

FMP/Amendment Defining Overfishing: Amendment 6 to the Fishery Management Plan for the Crustacean Fishery of the Western Pacific Region (Western Pacific Fishery Management Council).

Overfishing Definition:

"Lobster stocks shall be deemed overfished with regard to recruitment when the spawning potential ratio (measured for a specific fishing area) is 0.2 or below." (p. 6)

The Council, in section 6.4, also requested that NMFS "enhance the annual report process to explicitly discuss the status of stocks relative to overfishing, both for the NWHI as a whole and for localized areas."

"If the status indicates that stocks have declined to a range between the recruitment overfishing threshold (SPR = 0.2) and Optimum Yield (SPR = 0.5), associated with the minimum size limits, the report would:
      a) discuss the risk to stocks if no management actions are taken,
      b) recommend management measures that the Plan Team concludes are necessary to ensure that recruitment overfishing is not achieved,
      c) present an analysis of the impacts that the recommended management changes would generate." (p. 12).

Assessment Method and Decision Rule:

Current spawning biomass per recruit is estimated from an SPR model using approximations that require estimates of F/K, M/K and L_∞, rather than all parameters separately. Other data available include age-specific CPUE from recent research surveys.

Overfishing is indicated when the calculated SPR is below 0.2.

Relevant Life History Features:

Both species exhibit the typical life-history patterns for spiny lobsters, having pelagic larvae, a benthic juvenile phase residing in nursery areas, and an adult phase. *P. marginatus* has a long (ca. 1 yr.) pelagic phase, while *S. squammosus* has a shorter pelagic phase (ca. 3 mo.). Both reach sexual maturity and recruit to the fishery at approximately 3 yr. age. Recruitment of *P. marginatus* is probably controlled by a combination of oceanographic

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variation (Polovina and Mitchum 1992) and density-dependence (Polovina 1989).

Evaluation of Overfishing Definition:

An SPR level of 0.2 was based on Goodyear's (1989) suggestion that this should be a minimum value in the absence of stock-recruitment information. This level is probably a reasonable threshold for these fisheries, but it is not clear that SPR can be accurately estimated for these stocks with available data. The substantial decline in CPUE for these stocks is cause for concern. It is not possible from the available data to conclude if the OD will protect the stock.

Data sources:

Goodyear, C.P. 1989. Spawning biomass per recruit: the biological basis for a fisheries management tool. ICCAT Working Doc. SCRS/89/82. 10 p.

Haight, W.R. and J.J. Polovina. 1992. Status of lobster stocks in the northwestern Hawaiian Islands, 1991. Southwest Fisheries Center Administrative Report H-92-02.

Polovina, J.J. 1989. Density dependence in spiny lobster, Panulirus marginatus, in the northwestern Hawaiian Islands. Can. J. Fish. Aquat. Sci. 46:660-665.

Polovina, J.J. 1991. Status of lobster stocks in the Northwestern Hawaiian Islands, 1990. Southwest Fisheries Science Center (Honolulu Lab.), NMFS Admin. Rep. H-91-04.

Polovina, J.J. and G.T. Mitchum. 1992. Variability in spiny lobster, *Panulirus marginatus*, recruitment and sea level in the Northwestern Hawaiian Islands. Fish. Bull., U.S. 90:483-493.

SWFSC 1991. Annual Report of the 1990 Western Pacific Lobster Fishery. Prepared by the Southwest Fisheries Science Center (Honolulu Laboratory), NMFS, with contributions from Southwest Region, NMFS, Southwest Enforcement, NMFS, and the Western Pacific Council.

NW Hawaiian Islands Lobster
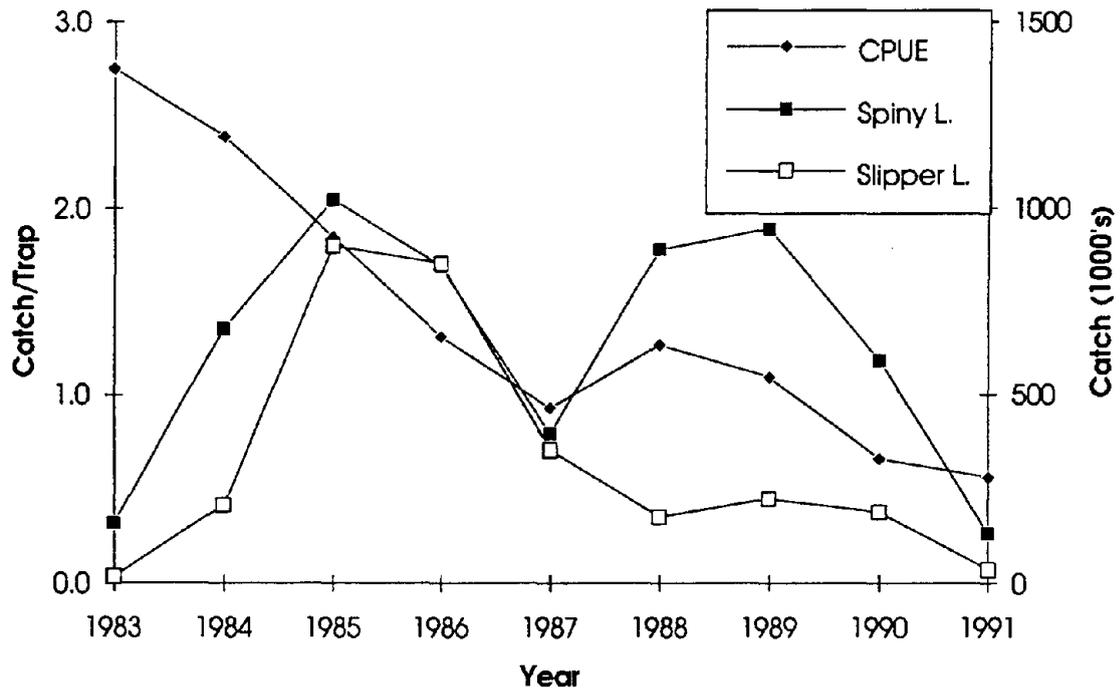
Management unit - Bottomfish and Seamount Groundfish of the Western Pacific (#s 38, 94)

Species/stocks:

38. Opakapaka (pink snapper, *Pristipomoides filamentosus*)
94. Other Western Pacific Bottom and Seamount Groundfish

        Onaga (longtail snapper, *Etelis coruscans*)
        Uku (gray jobfish, *Aprion virescens*)
        Butaguchi (thick-lipped trevally, *Pseudocaranx dentex*)
        Hapuupuu (seabass, *Epinephelus quernus*)
        Armorhead (*Pseudopentaceros wheeleri*)

FMP/Amendment Defining Overfishing: Amendment 3 to the Fishery Management Plan for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region (Western Pacific Fishery Management Council).

Overfishing Definition:

"A bottomfish species is recruitment overfished when the Spawning Potential Ratio (SPR; Goodyear 1989), (i.e., the ratio of the spawning stock biomass per recruit at the current level of fishing ($SSBR_f$) to the spawning stock biomass per recruit that would occur in the absence of fishing ($SSBR_u$)), is equal to or less than .20." (p. 6)

Two estimators of SPR are proposed; their use depends on the type and amount of data available. The **"equilibrium estimator"** is the usual estimator based on yield-per-recruit theory, although in most cases use is made of an approximation that requires estimates of F/K, M/K and L_∞, rather than all parameters separately. The **"dynamic estimator"** of SPR is a ratio of an estimate of the current relative spawning stock biomass (SSB) to the SSB existing at the initiation of the fishery. SSB is estimated by the product of catch per unit effort (CPUE) and the proportion of the catch, corrected for size selection, of that species that is mature. The bottomfish fishery is multispecies; therefore aggregated CPUE data are used in preference to individual species CPUE data to reduce the effects of changes in species targetting over time. The "dynamic SPR" is the only one reported in the SAFE report.

Assessment Method and Decision Rule:

Stock assessments of Western Pacific bottomfish involve analysis of CPUE and size-frequency distributions. These data are then used to calculate the "dynamic SPR".

Overfishing is indicated if the estimated "dynamic SPR" is less than the reference SPR.

<u>Relevant Life History Features:</u>

Western Pacific bottomfishes comprise a broad array of species, the most important of which are in the snapper, jack and grouper families. They are most abundant on rock and coral bottoms between depths of 50 and 400 m. Seamount groundfish are represented by the pelagic armorhead, which is fished on undersea peaks of various seamount chains. Currently there is a moratorium on fishing for pelagic armorhead in U.S. waters. Basic population dynamics information is lacking for many of the bottomfish and seamount groundfish stocks.

In the Main Hawaiian Islands, the bottomfish catch consists primarily of opakapaka, onaga and uku, which together represent about 72% of the total managed western Pacific bottomfish catch.

<u>Evaluation of Overfishing Definition:</u>

The only stock examined in detail in this evaluation is the Main Hawaiian Islands stock of opakapaka. However, since the same definition is used for all stock components, most of the following comments apply to the other species and stocks included in the Bottomfish and Seamount Groundfish FMP.

The term "dynamic SPR" is misleading and the overfishing definition should be changed to reflect what is actually being calculated; i.e., perhaps the overfishing definition should be stated in terms of relative biomass rather than %SPR, or as an either/or (20%SPR or $20\%B_0$, recognizing that these are not the same quantity). It may even be useful to adopt a two-tiered approach: %SPR and corresponding constant F estimates when available, and ratios of CPUE otherwise. The effects of likely changes in catchability (q) on the relationship between CPUE and relative biomass need to be investigated (e.g. simulated) or discussed.

For opakapaka, it appears that there are already adequate data to calculate the "equilibrium SPR" and determine where recent fishing mortality rates fall relative to reference points from the "equilibrium model" (see Somerton and Kobayashi 1990).

An alternative solution that may prove useful for some stocks is to fit a stock production model to the CPUE data, estimate the level of effort associated with MSY and convert this to a fishing mortality rate scale by assuming that F_{msy} can be approximated by F_{max} (i.e. $q=F_{max}/f_{msy}$). In this way, reference points from SPR curves can be roughly translated into units of effort.

Data Sources:

Kobayashi, D.R. 1993. Effects of increasing the minimum size limit or imposing fishing closureon three species of Hawaiian deepwater snappers. NMFS SWFSC Honolulu Lab. Admin. Report H-93-01.

Somerton, D.A. and D.R. Kobayashi. 1990. A measure of overfishing and its application on Hawaiian bottomfishes. NMFS SWFSC Honolulu Lab. Admin. Report H-90-10.

WPFMC 1992. Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region: 1991 Annual Report. Prepared by the Bottomfish Plan Team and Western Pacific Fishery Management Council staff.
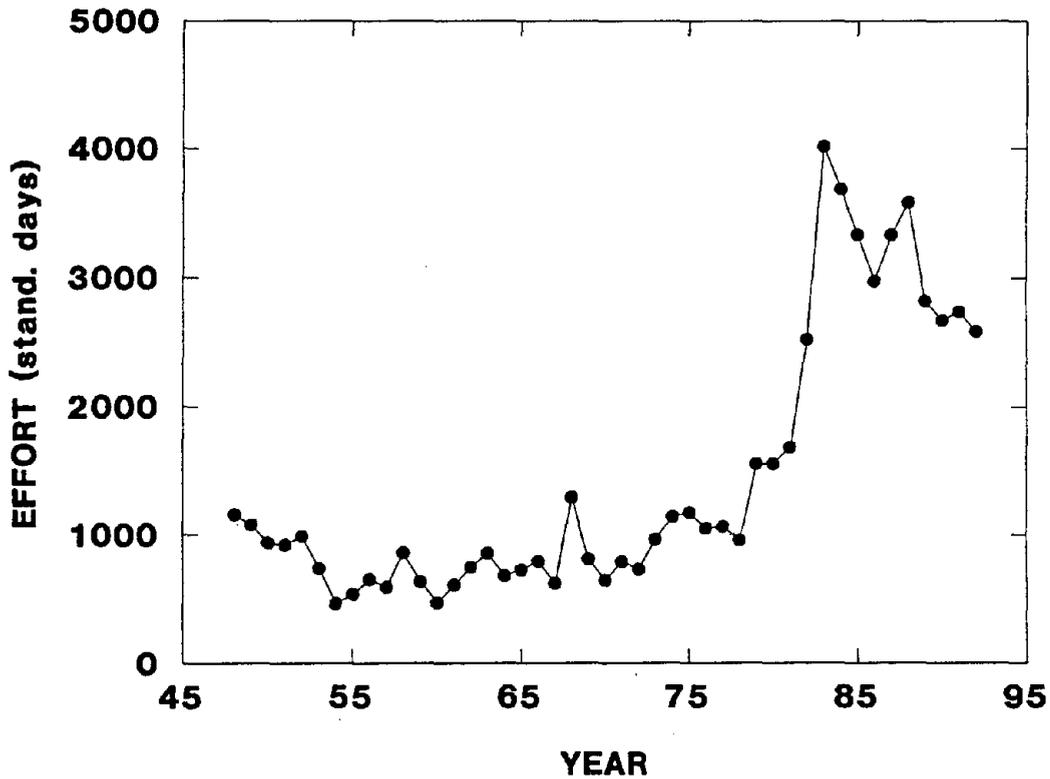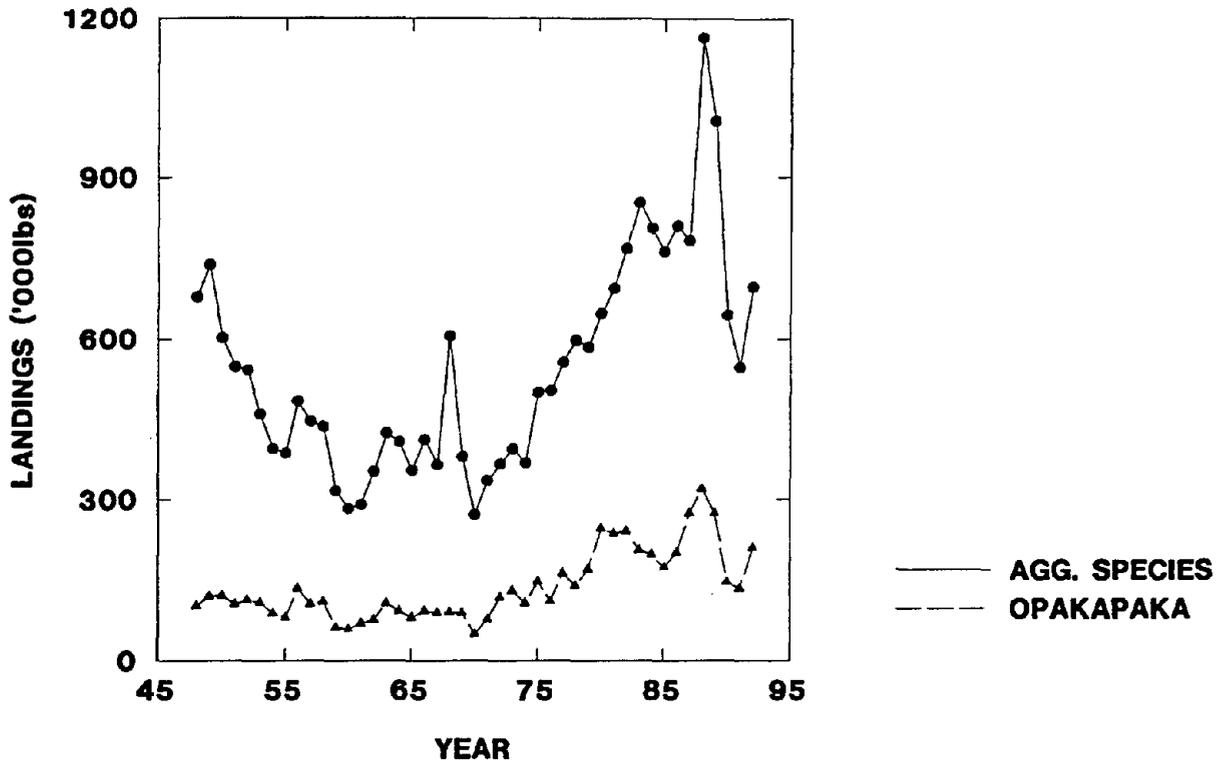
Opakapaka. A. Main Hawaiian Islands landings: aggregrated bottomfish
species, and opakapaka component alone.
B. Standardized days fished for bottomfish.

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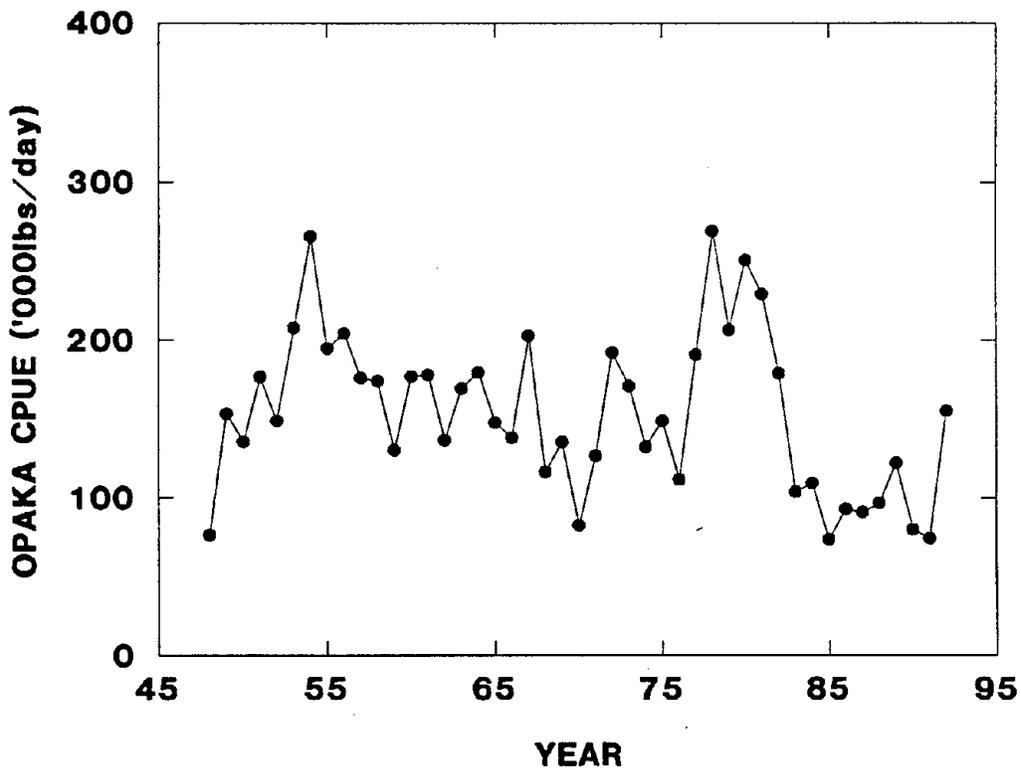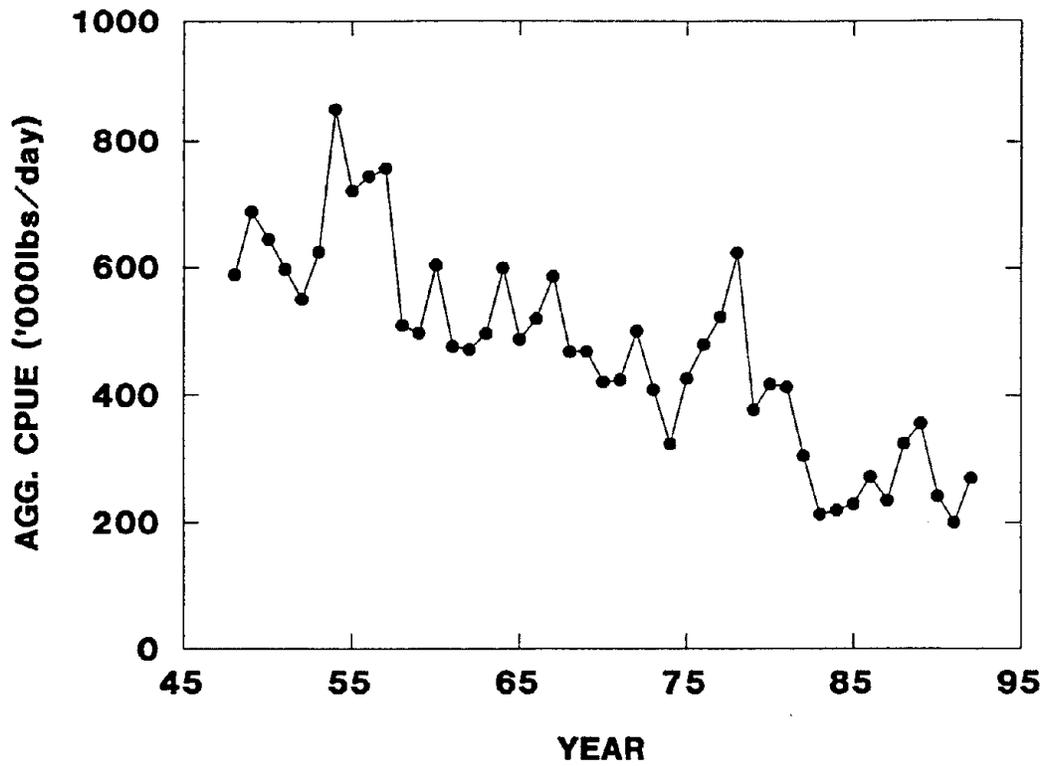
Opakapaka. A. Aggregate CPUE. B. Opakapaka CPUE.
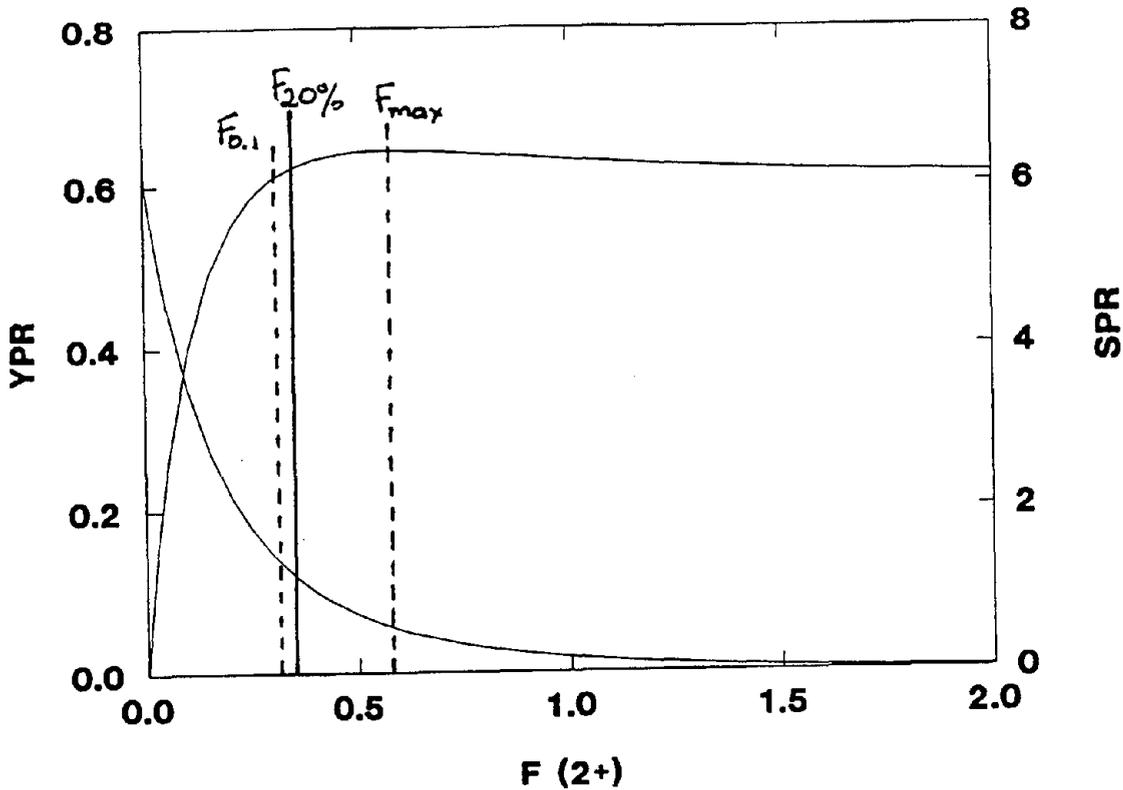
SPAWNING POTENTIAL RATIO (SPR) FOR MHI BOTTOMFISH
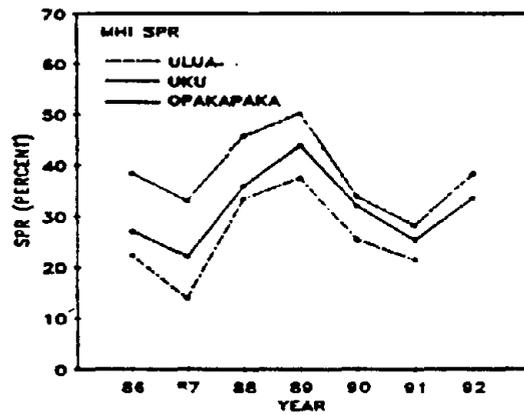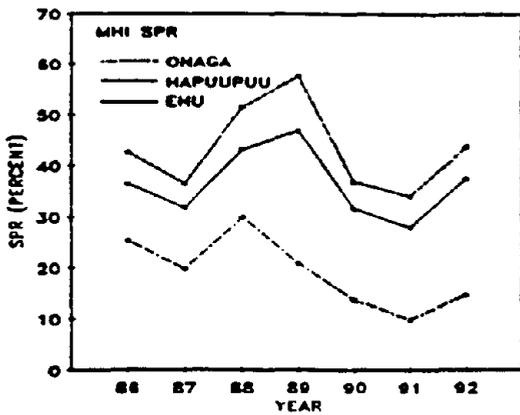
FIGURE H-17

From: Western Pacific Fishery Management Council Annual Report (1992).

Opakapaka. A. Yield per recruit (YPR) and spawning per recruit (SPR) (units = kg). B. Recent estimates of dynamic SPR.

Management Unit - **Bering Sea and Aleutian Islands Groundfish (# 39,40,43, 99-105)**

Species/Stocks -
- **39.** Pollock (*Theragra chalcogramma*)
- **40.** Cod (*Gadus macrocephalus*)
- **43.** Yellowfin Sole (*Pleuronectes asper*)
- 97. Greenland Turbot (*Reinhardtius hippoglossoides*)
- 98. Arrowtooth Flounder (*Atheresthes stomias*)
- 99. Rock Sole (*Pleuronectes bilineata*)
- 100. Other Flatfish
- 101. Pacific Ocean Perch (*Sebastes alutus*)
- 102. Other Rockfish (*Sebastes* spp.*)
- 103. Atka Mackerel (*Pleurogrammus monopterygius*)
- 104. Squid
- 105. Other Groundfish

FMP/Amendment Defining Overfishing: Bering Sea and Aleutian Islands Groundfish FMP, Amendments 16

Overfishing Definition:

Suboptions are listed here in order of preference (most to least), which is also the approximate order of data requirements (most to least). The minimum information requirement is an estimate of current stock biomass and the natural mortality rate. In the event that even these minimal data requirements cannot be satisfied for a particular stock, it is anticipated that the Council will define overfishing as exceeding the average catch for that stock calculated over the years since implementation of the MFCMA.

1) *Data available: Stock-recruitment, fecundity, maturity, growth, and mortality parameters.* The maximum allowable fishing mortality rate will be set at F_{MSY} for all biomass levels in excess of B_{MSY}. For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the origin and increasing to a value of F_{MSY} at B_{MSY}.

2) *Data available: Fecundity, maturity, growth, and mortality parameters.* The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine level.

3) *Data available: Growth and mortality parameters.* The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine level.

4) *Data available: Natural mortality rate.* The maximum allowable fishing mortality rate will be set equal to the natural mortality rate.

Assessment Method and Decision Rule:

The assessment method for pollock, cod and yellowfin sole is the stock synthesis approach applied to age-structured catch and survey data. The triennial survey is viewed as a measure of absolute biomass. The decision rule for overfishing is whether the point estimate of fishing mortality rate exceeds the rate given by the control law given in the overfishing definition above.

Turbot, rock sole, perch and Atka mackerel are also assessed using the stock synthesis method on age-structured data. The other stocks in this management unit are assessed using the bottom trawl survey estimates of biomass.

Relevant Life History Features:

Natural mortality rate is assumed to be 0.30 for pollock and they are 50% mature between the ages of 3 and 4. The fishery harvests ages 3 and older, with 50% selection at between ages 4 and 5. This is the most productive groundfish stock in Alaska, with a long-term potential yield of the order of 2 million mt per year. Catches have been 1-2 Mmt per year for the last 20 years, or so, and the spawning stock has remained quite large. Current fishing mortality rates are around 0.3 - 0.4. Stock biomass is well above the level needed for MSY.

Cod recruit to the fishery at age 3 and mature at age 5. Natural mortality is estimated to be 0.35. Recent fishing mortality rates are around 0.4. There was a large increase in abundance of cod during the 1970's and remained high throughout the 1980's but has been declining in the last few years. Current biomass is around the level estimated to produce MSY.

Yellowfin sole recruit at age 7-8 years and mature at age 9. Sole are projected to live up to 30 years, with a natural mortality rate of 0.12. The current stock increased dramatically in the late 1970s and early 1980's, and the catch increased as well. More recently, the biomass and yield has been high and stable.

The other stocks in this group are currently not overfished, though turbot and ocean perch have been at low levels for some years. Many of the flatfish stocks have undergone large increases in abundance in the early 1980s. All of these species ,with the exception of squid, are long-lived (15-90 years) and slow growing. Squid are annual, with rapid growth and high mortality.

Evaluation of Overfishing Definition:

Pollock - The estimate of F_{MSY} is quite high because, on average, fish mature before recruiting to the fishery. For the available stock and recruitment data, it appears that recruitment is not likely to be reduced by fishing unless a much higher fishing mortality rate was exerted on the stock. Therefore, the overfishing definition appears to be conservative. The harvest rate is to decrease linearly with biomass from B_{MSY} down to the origin; and given recent biomass levels, this is very conservative.

Cod - The available stock and recruitment data do not show a clear pattern. The replacement level of fishing mortality is well below the F_{MSY} level, but the fitted relationship does not indicate recruitment is expected to decline until fishing mortality is higher still. The overfishing definition level of fishing mortality is at the peak of the yield curve, and near the maximum yield per recruit. Therefore, it may be more appropriate as a target than as a threshold. However, given that the harvest rate is then specified to decrease linearly as biomass goes below the B_{MSY} level, the definition is probably appropriate and conservative.

Yellowfin Sole - The overfishing definition for this stock is given by 30% SPR. This appears to be conservative, given the fitted stock and recruitment and yield curves. The fishing mortality rate corresponding to 30% SPR roughly bisects the observed year-classes, indicating the stock can at least maintain itself if fished at this threshold. The OD does appear to be below MSY, however it still may be more appropriate as a target rather than a threshold.

For the other stocks in this management unit the OD of 30% SPR appears to set a conservative threshold for the harvest. None show marked declines in recruitment at the OD, but most do not have stock and recruitment data available. The OD was chosen by analogy to other stocks to be relatively conservative. Note, however, the very long-lived species may have relatively low ability to compensate for harvesting and need to be monitored closely.

Data Sources:

Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/ Aleutian Islands Region as Projected for 1992. The Plan Team for the Groundfish Fisheries of the Bering Sea and the Aleutian Islands, November 1991.

Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands (editor), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1993North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510

Proportion of maximum

Yield
Fishing mortality
Spawning biomass
Recruitment
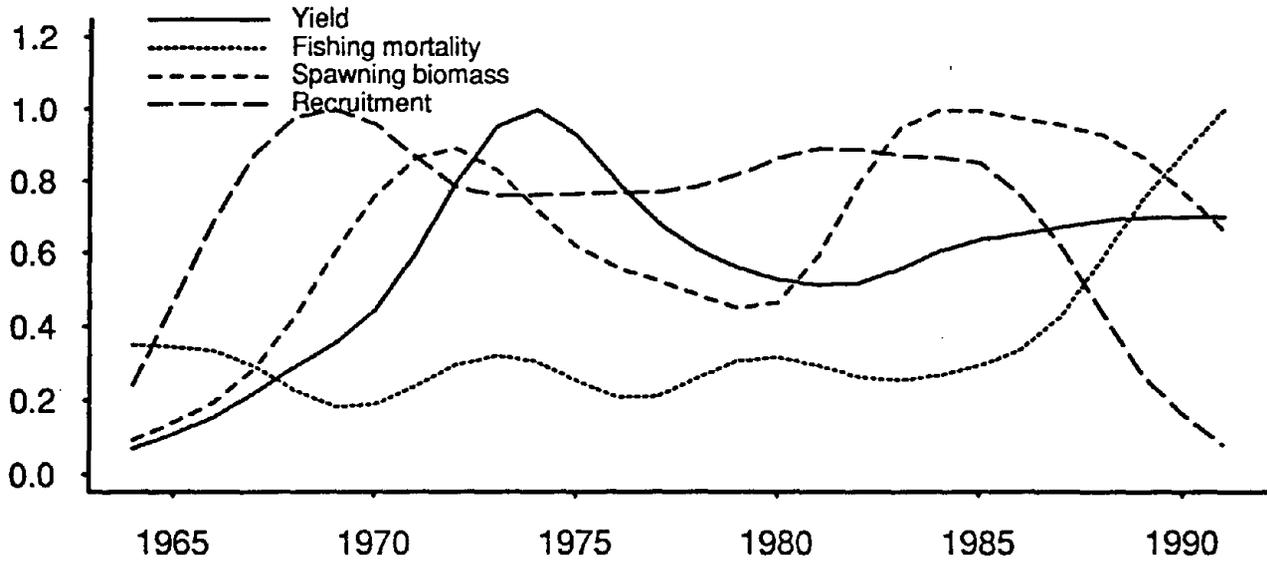
Eastern Bering Sea pollock: Time series

Recruitment (billions)

$F_{20\%}$ F_{msy}

$F_{30\%}$

F_{rep}

SHmsy

SH50   Sb

Spawning biomass (Mmt)
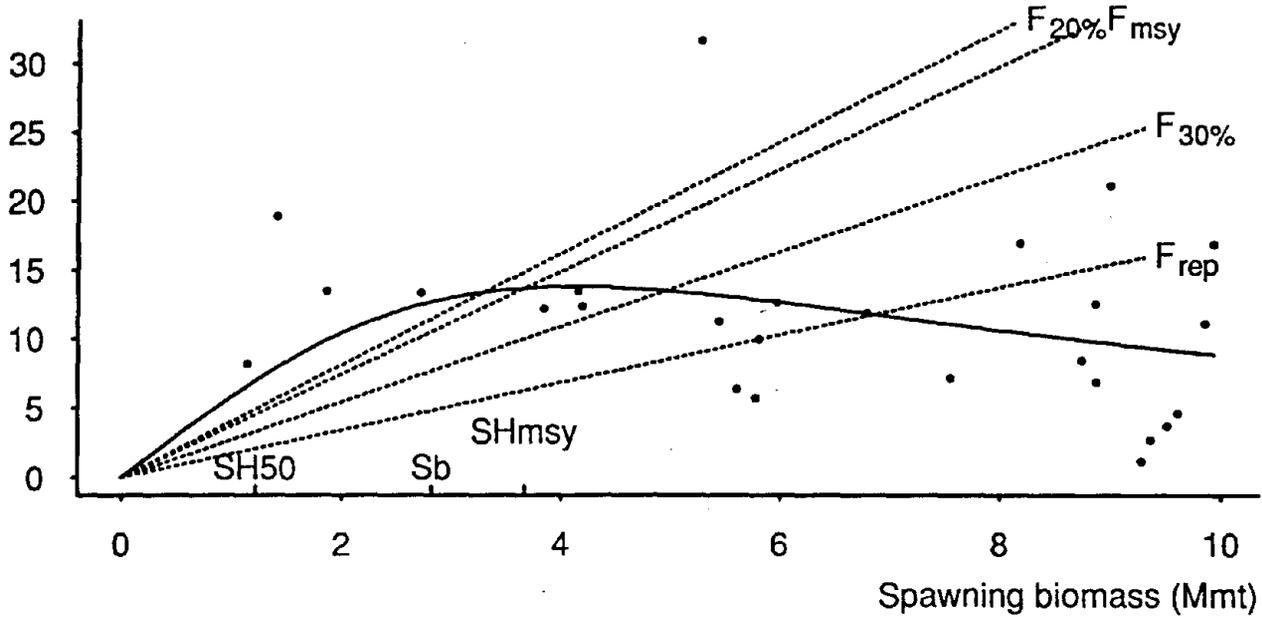
Eastern Bering Sea pollock: Spawner-recruit data and reference points

Proportion of maximum

Legend:
- Yield per recruit
- Spawning biomass per recruit
- Total yield
- Recruitment

1.2
1.0
0.8
0.6
0.4
0.2
0.0

0.0   0.5   1.0   1.5

Fishing mortality
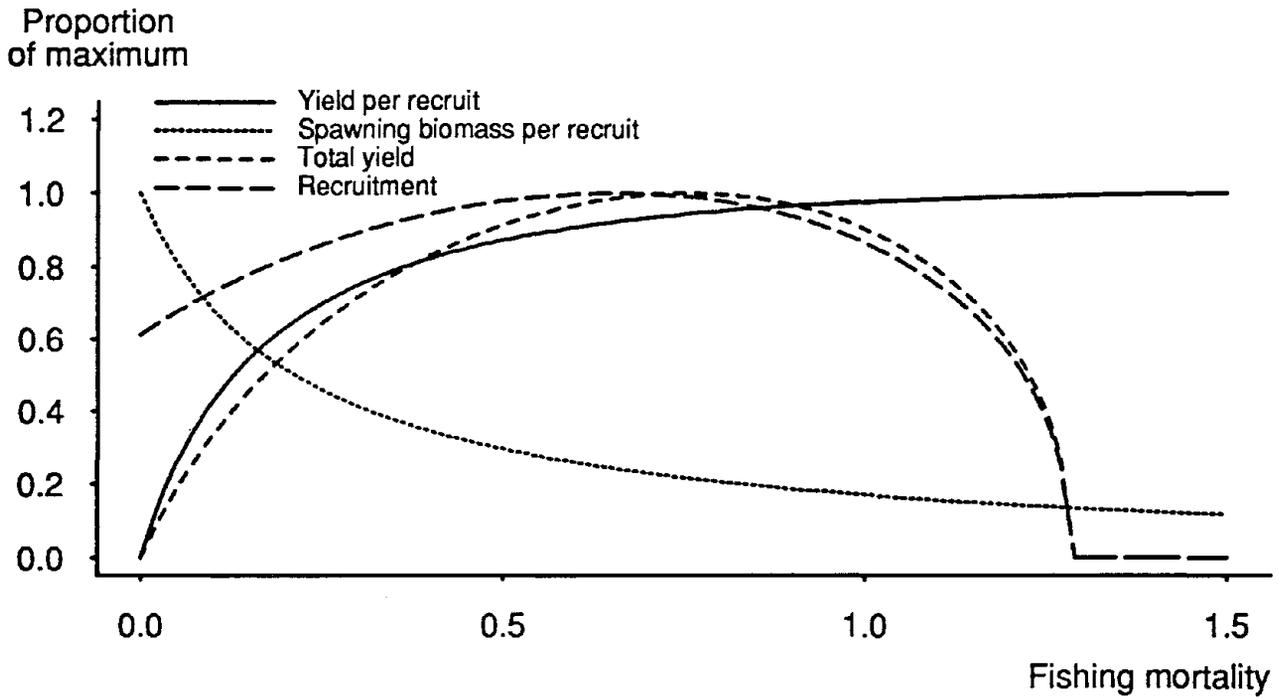
Eastern Bering Sea pollock: Yield curve etc.

Fishing mortality

Overfishing

F_{msy}

OK

0.8
0.6
0.4
0.2
0.0

B_{msy}

64

90

89

91

79 80

73 88

81

74

65 66   67

77 75

87 86 85

78 76 69

70   82   71 72   83

84

0   2   4   6   8   10

Spawning biomass (Mmt)
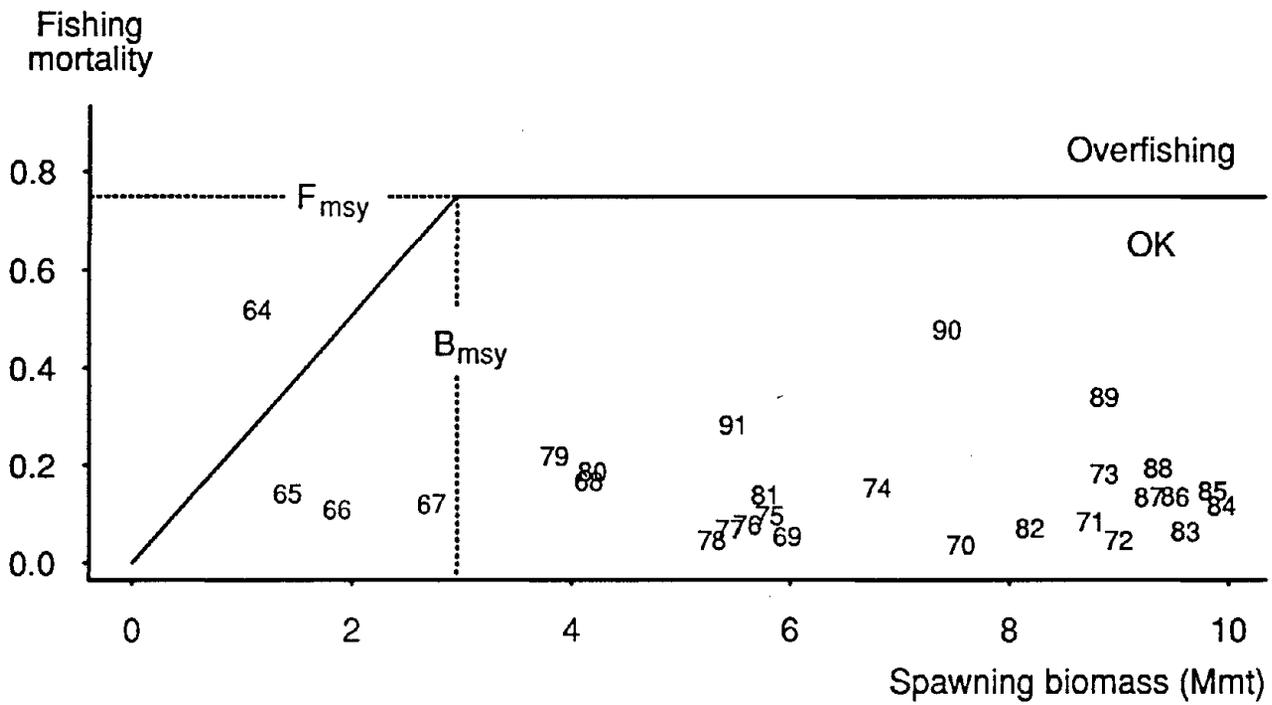
Eastern Bering Sea pollock: Overfishing control law and experience
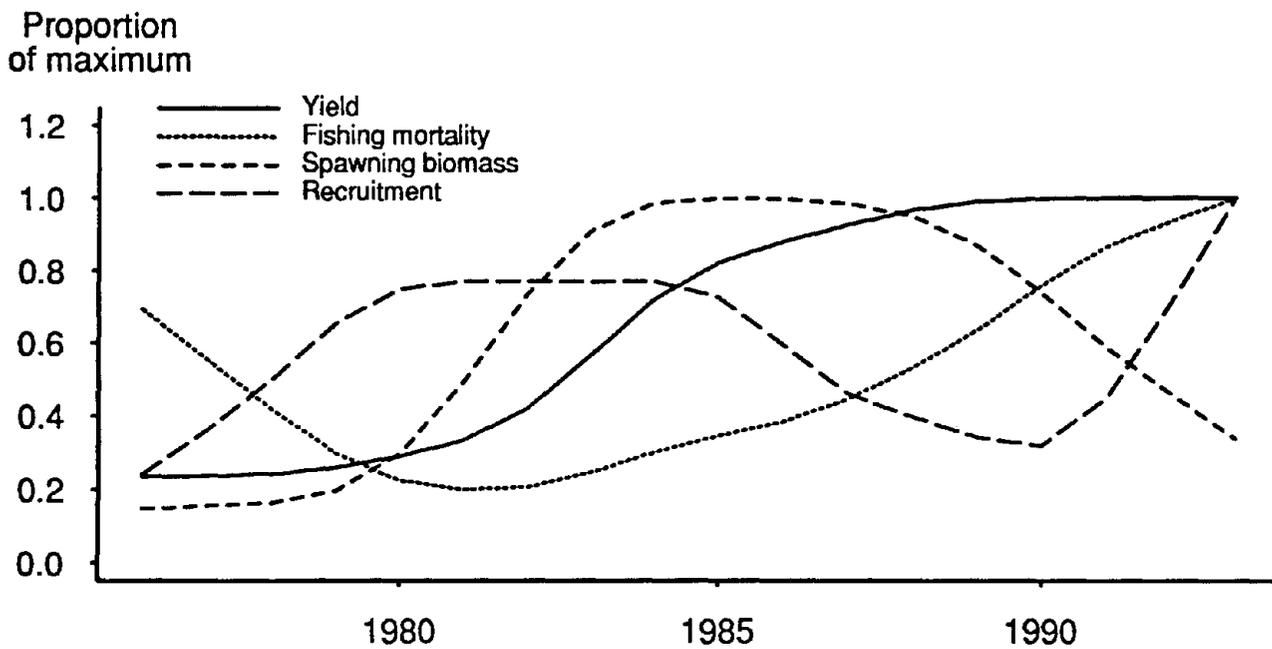
Bering Sea cod: Time series
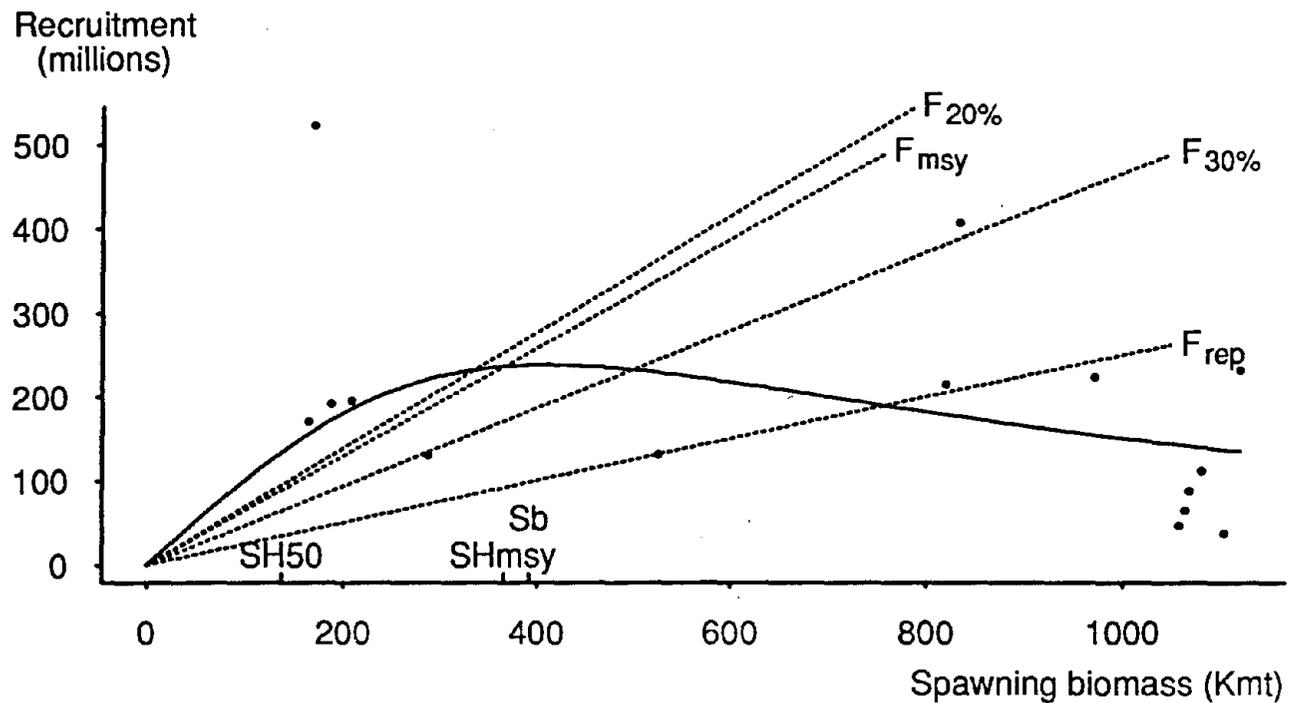

Bering Sea cod: Spawner-recruit data and reference points
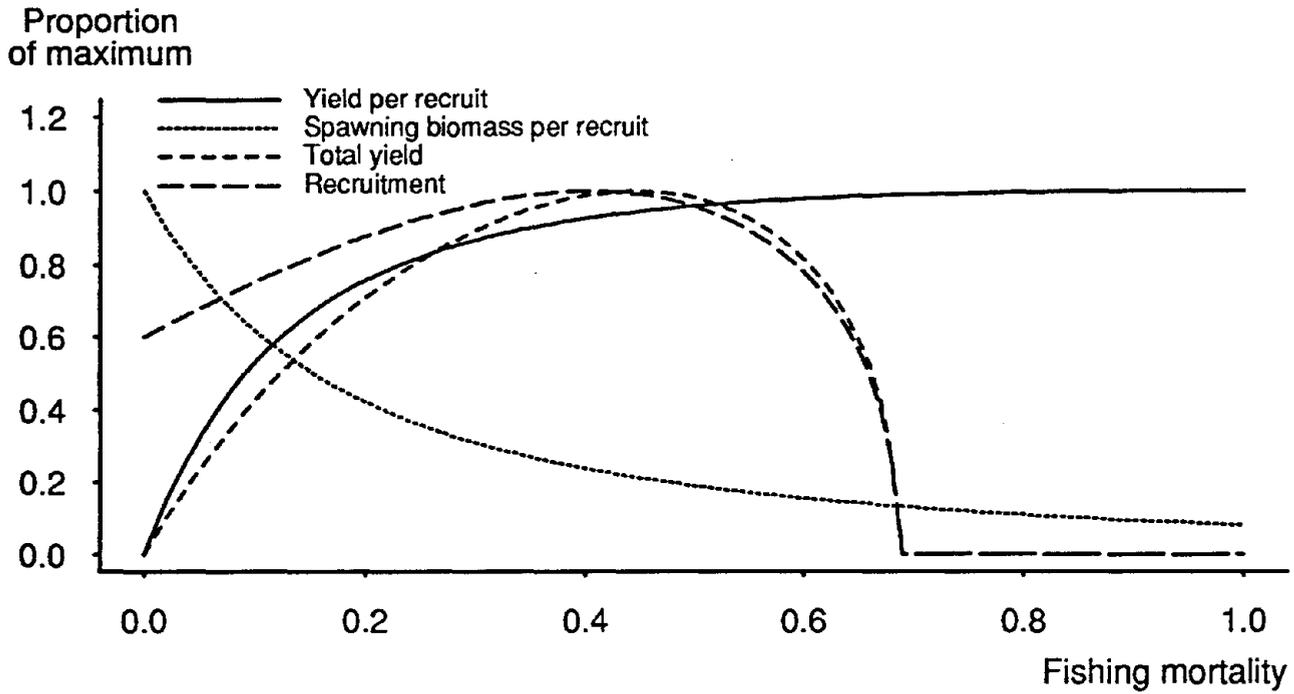
Bering Sea cod: Yield curve etc.
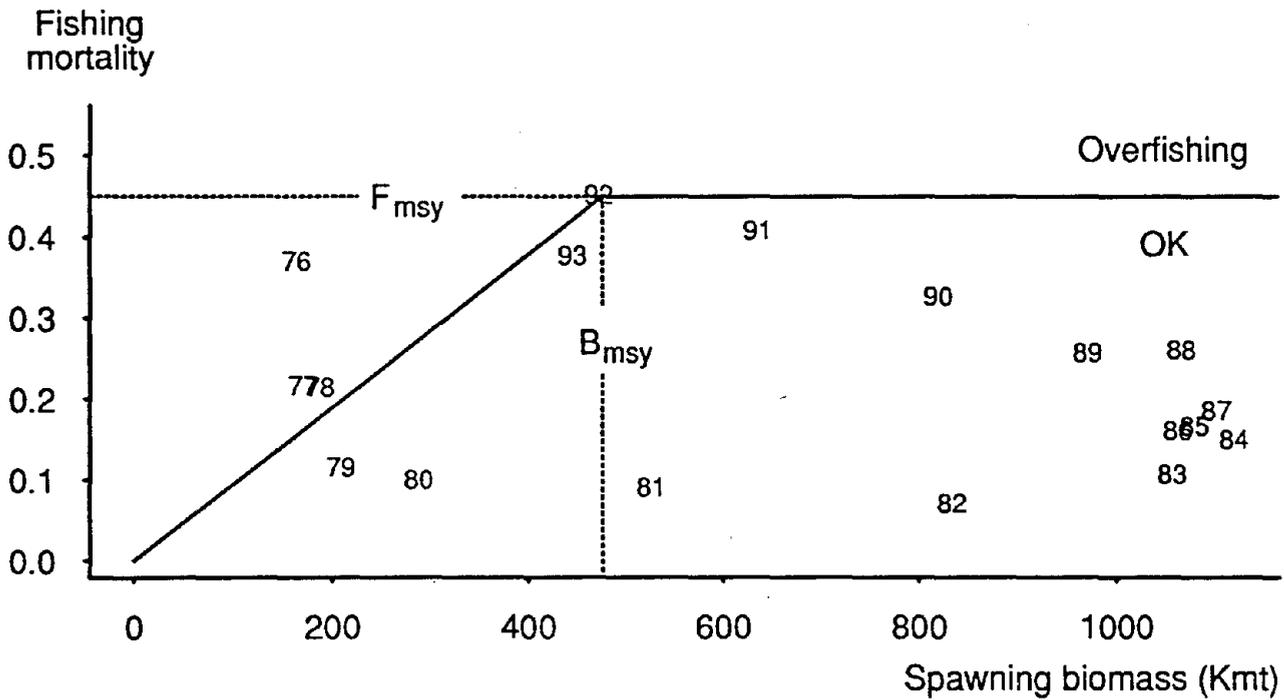
Bering Sea cod: Overfishing control law and experience

178
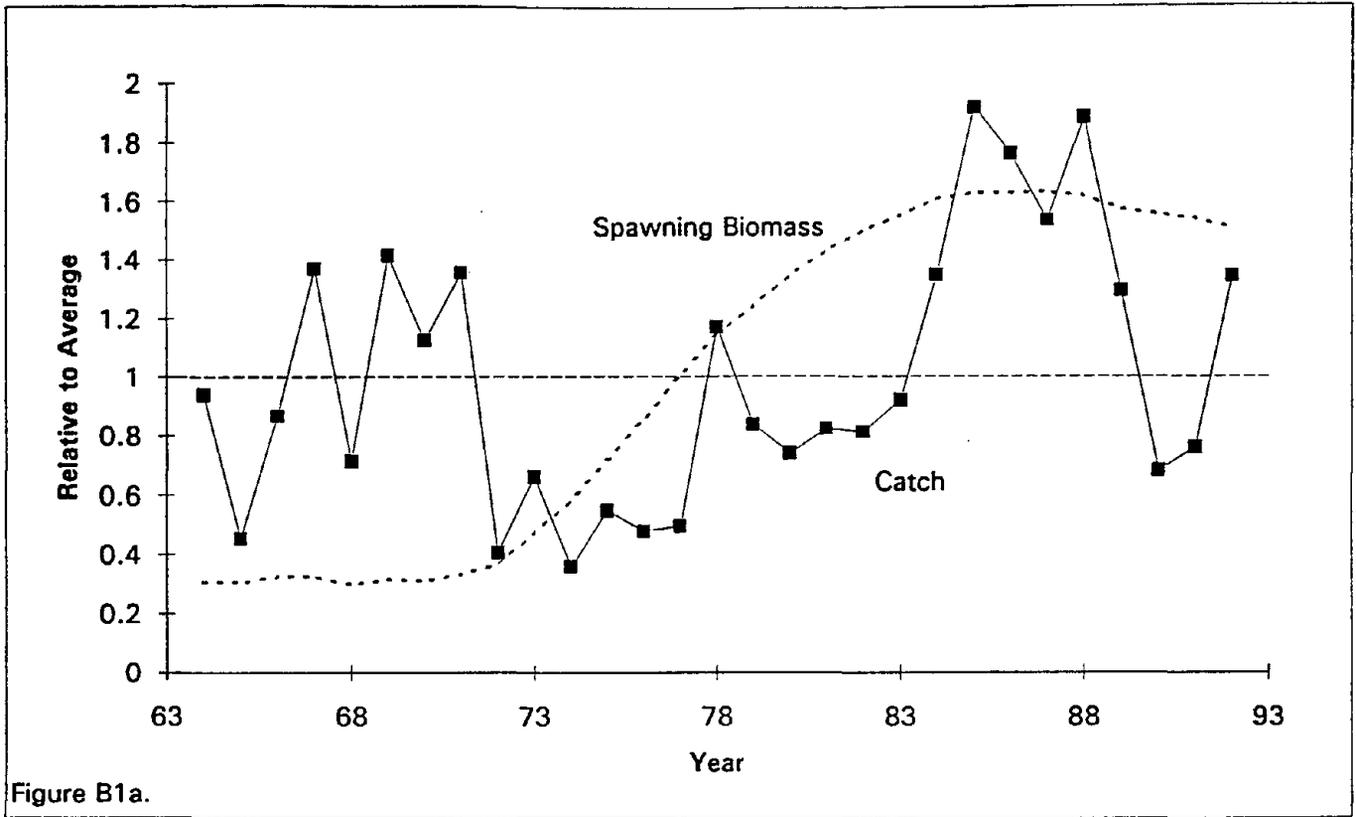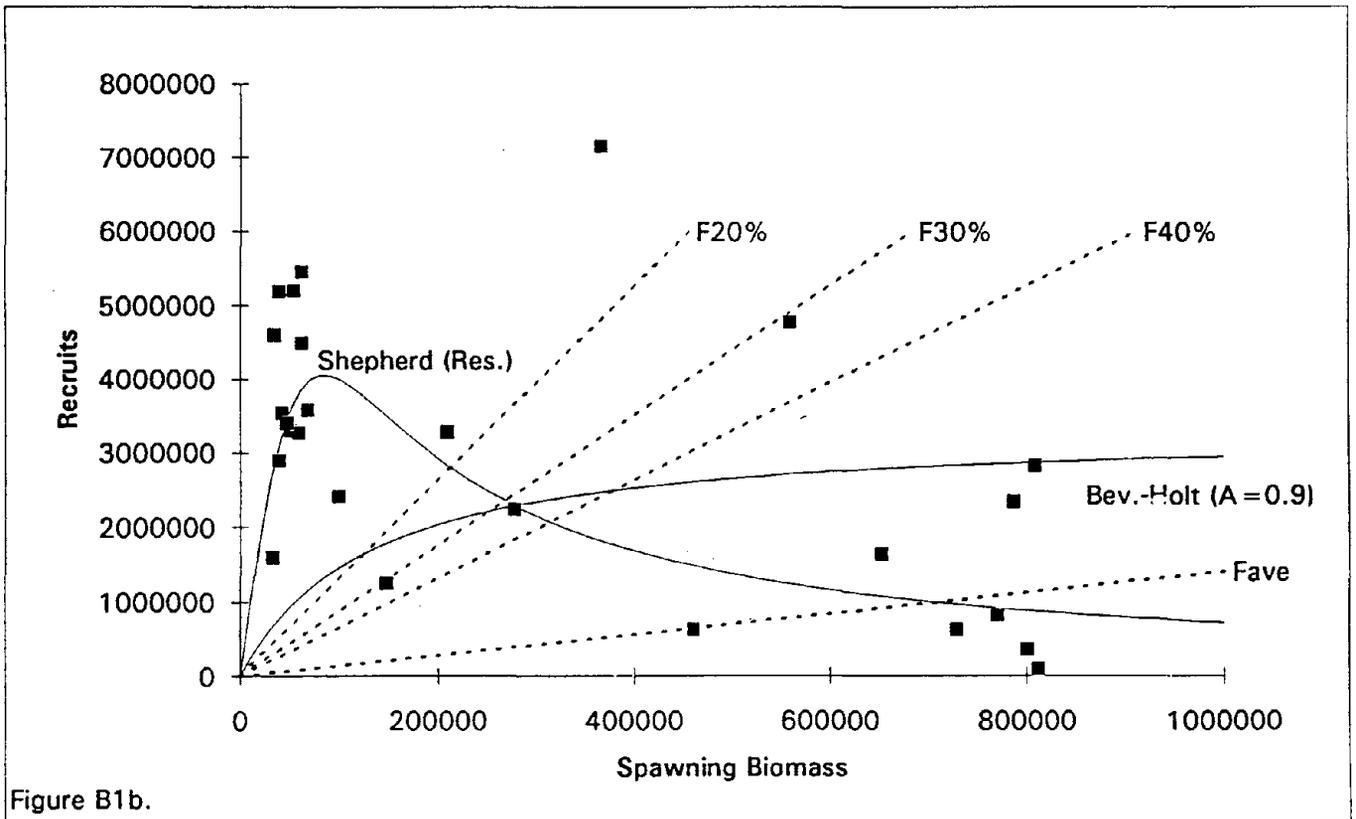
Figure B1a.

Figure B1b.
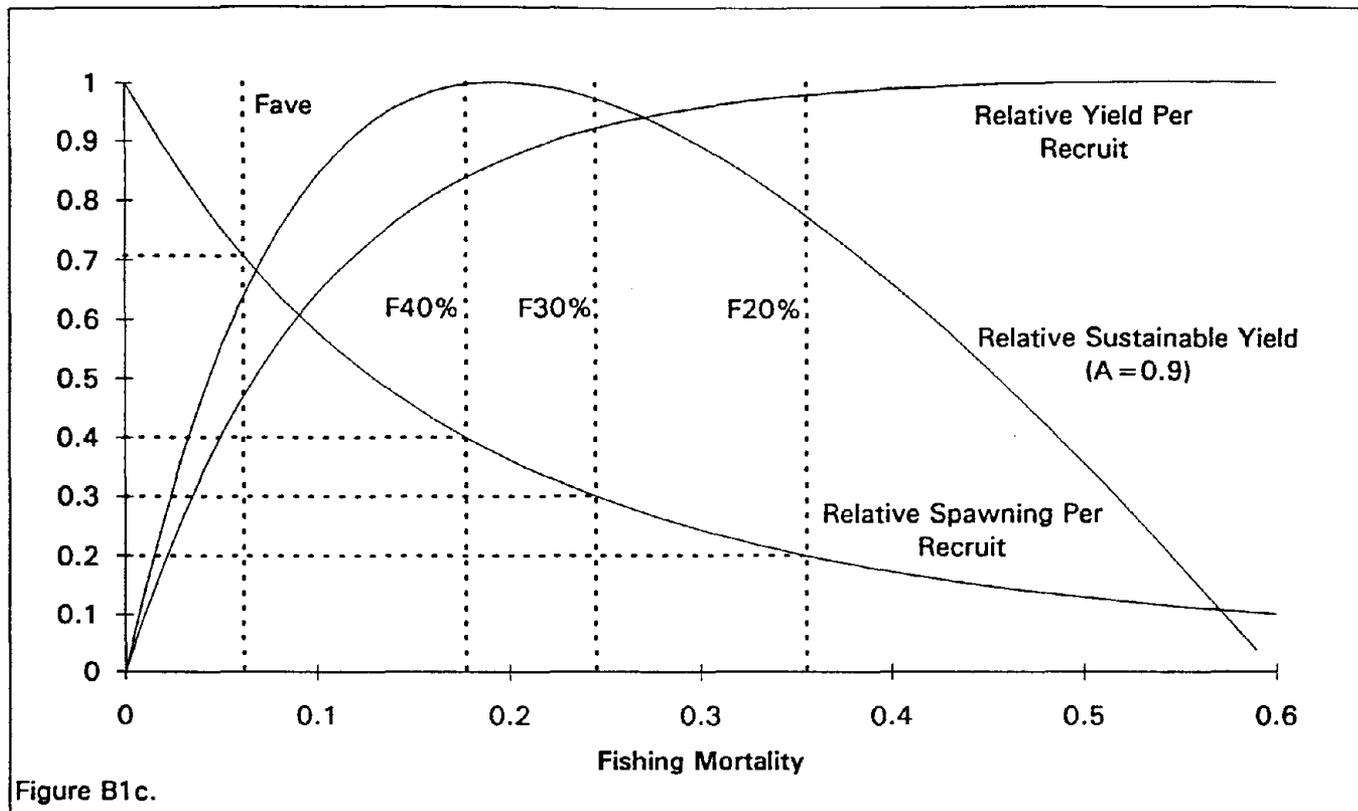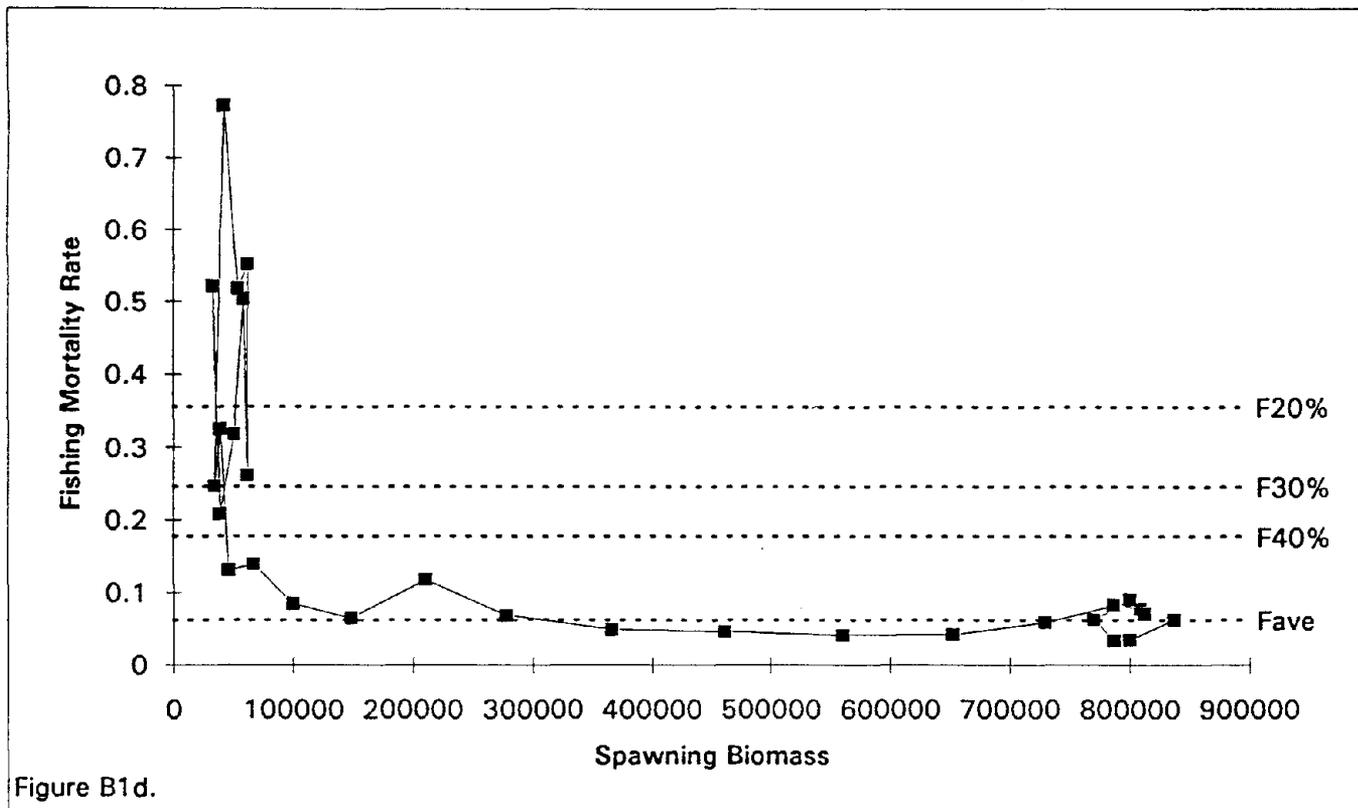
Figure B1c.

Figure B1d.

Management Unit - Gulf of Alaska Groundfish (# 41, 106-115)

Species/Stock:

    41. Gulf of Alaska Pollock (*Theragra chalcogramma*)
    106. Deep Water Flatfish
    107. Shallow Water Flatfish
    108. Arrowtooth Flounder (*Atheresthes stomias*)
    109. Flathead Sole (*Hippoglossoides elassodon*)
    110. Slope Rockfish (*Sebastes* spp.)
    111. Pelagic Shelf Rockfish (*Sebastes* spp.)
    112. Demersal Shelf rockfish (*Sebastes* spp.)
    113. Thornyhead Rockfish (*Sebastolobus* spp.)
    114. Pacific Cod (*Gadus macrocephalus*)
    115. Sablefish (*Anoplopoma fimbria*)

FMP/Amendment Defining Overfishing: Gulf of Alaska Groundfish FMP, Amendment 21

Overfishing Definition:

Suboptions are listed here in order of preference (most to least), which is also the approximate order of data requirements (most to least). The minimum information requirement is an estimate of current stock biomass and the natural mortality rate. In the event that even these minimal data requirements cannot be satisfied for a particular stock, it is anticipated that the Council will define overfishing as exceeding the average catch for that stock calculated over the years since implementation of the MFCMA.

    1) *Data available: Stock-recruitment, fecundity, maturity, growth, and mortality parameters.* The maximum allowable fishing mortality rate will be set at F_{MSY} for all biomass levels in excess of B_{MSY}. For lower biomass levels, the maximum allowable fishing mortality rate will vary linearly with biomass, starting from a value of zero at the origin and increasing to a value of F_{MSY} at B_{MSY}.

    2) *Data available: Fecundity, maturity, growth, and mortality parameters.* The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of spawning biomass) falling to 30% of its pristine level.

    3) *Data available: Growth and mortality parameters.* The maximum allowable fishing mortality rate will be set at the value that results in the biomass-per-recruit ratio (measured in terms of exploitable biomass) falling to 30% of its pristine level.

    4) *Data available: Natural mortality rate.* The maximum allowable fishing mortality rate will be set equal to the natural mortality rate.

Assessment Method and Decision Rule:

The assessment method for pollock, cod and sablefish is the stock synthesis approach applied to age-structured catch and survey data. The triennial survey is viewed as a measure of absolute biomass. The decision rule for overfishing is whether the point estimate of fishing mortality rate exceeds the rate given by the control law given in the overfishing definition above.

The assessment method for the flatfish and rockfish stocks is the estimate of abundance from the annual bottom trawl survey along with estimated biological parameters for calculating reference points.

Relevant Life History Features:

Gulf of Alaska pollock has an estimated natural mortality rate of 0.3. The age at 50% recruitment to the fishery is 3 and 50% maturity is at age 4. Recent fishing mortality rates are estimated to be around 0.1. There was apparently a peak of abundance for this stock in the 1970's, followed by a decline to lower levels in the 1980's, even though fishing mortality rates were estimated to be less than 0.1.

The flatfish species in this unit are long-lived, recruiting between 3 and 4 years of age and maturing between 5 and 6 years of age. Biomass and yields have been high for the last several years.

The rockfish species are very long lived, up to 100 years old. Pacific Ocean perch is the dominant slope rockfish and its biomass declined under heavy fishing pressure in the 1960's and early 1970's. The stock has remained low since and is currently a bycatch only fishery. There is little information available about most of the other species.

Pacific cod yields are high and stable. Cod recruit at age 2 and mature at age 5, with a natural mortality rate of 0.29.

Sablefish yields are also high and stable. They recruit to the fishery at age 5 and mature at ages 4-6, with a natural mortality rate estimated to be 0.1.

Evaluation of Overfishing Definition:

Pollock - The stock and recruitment data for this stock are difficult to interpret because of apparent changes in the environment over the past 2 decades. The overfishing definition level of fishing mortality in near a threshold (F_{tau}) harvest rate. But, there are no observations at low stock biomass and therefore the initial slope of the stock recruitment relationship is poorly determined. The stock has declined, in spite of fishing mortality rates being lower than even more conservative reference points such as $F_{0.1}$ and $F_{35\%}$, again indicating an environmental change to a different level of productivity. The current

overfishing definition is neutral with respect to the conservation risk, and the stock needs to be closely monitored, since it it now below the estimated biomass for MSY. There is some ambiguity in tier 2 of the definition between SPR and SSB and due to the lack of explanation of the process for assigning stocks to the various tiers.

Flatfish - The overfishing definition (30% SPR) for these stocks appears to be relatively conservative by analogy with other resources. It is appropriate as a threshold for the harvest. However, the lack of information on productivity for these stocks means that there is no direct evidence that the definition is in fact conservative. The same ambiguities as for pollock are relevant here as well.

Rockfish - The overfishing definition is judged to be a conservative threshold for these stocks based on analogy with other species. However, the very long life span and recent low productivity of the Pacific Ocean perch stock are cause for concern. These species may have very low compensatory capacity and some, at least, are sustained by occasional large year-classes. The same ambiguities as for pollock are relevant here as well.

Pacific Cod - The overfishing definition (30% SPR) appears appropriate for this stock and is likely to be neutral with respect to conservation, as the resource appears to be stable. The same ambiguities as for pollock are relevant here as well.

Sablefish - The overfishing definition (30% SPR) appears appropriate for this stock and is likely to be neutral with respect to conservation, as the resource appears to be stable. The same ambiguities as for pollock are relevant here as well.

Data Sources:

Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska Region as Projected for 1992. The Plan Team for the Groundfish Fisheries of the Bering Sea and the Aleutian Islands, November 1991.
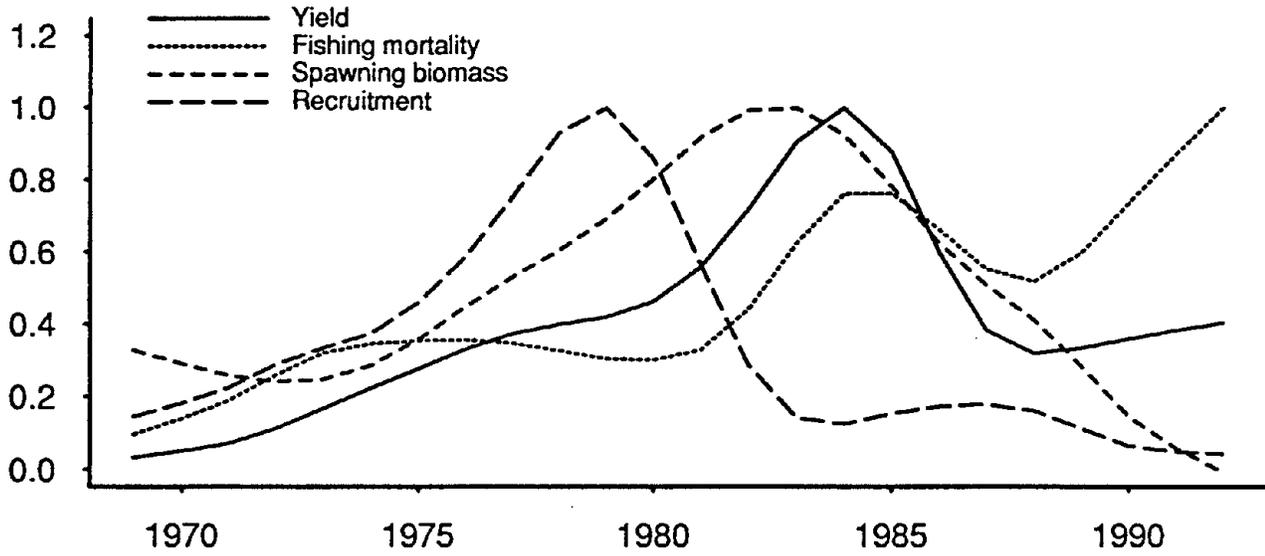
Gulf of Alaska pollock: Time series
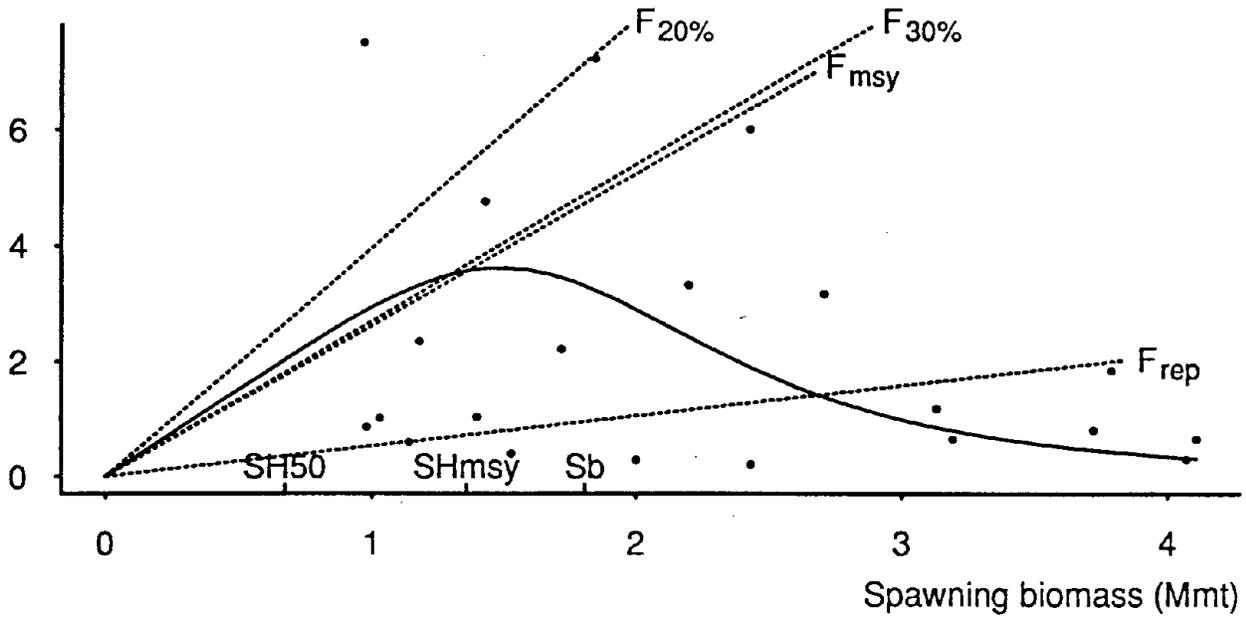
Gulf of Alaska pollock: Spawner-recruit data and reference points
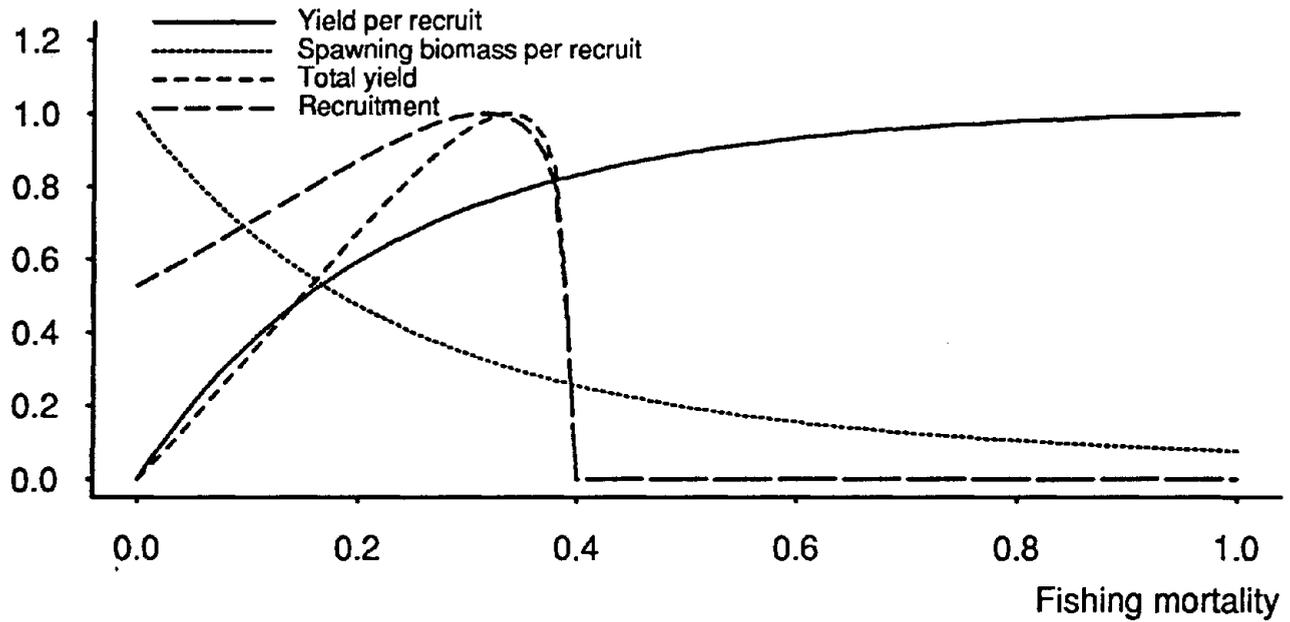
Gulf of Alaska pollock: Yield curve etc.
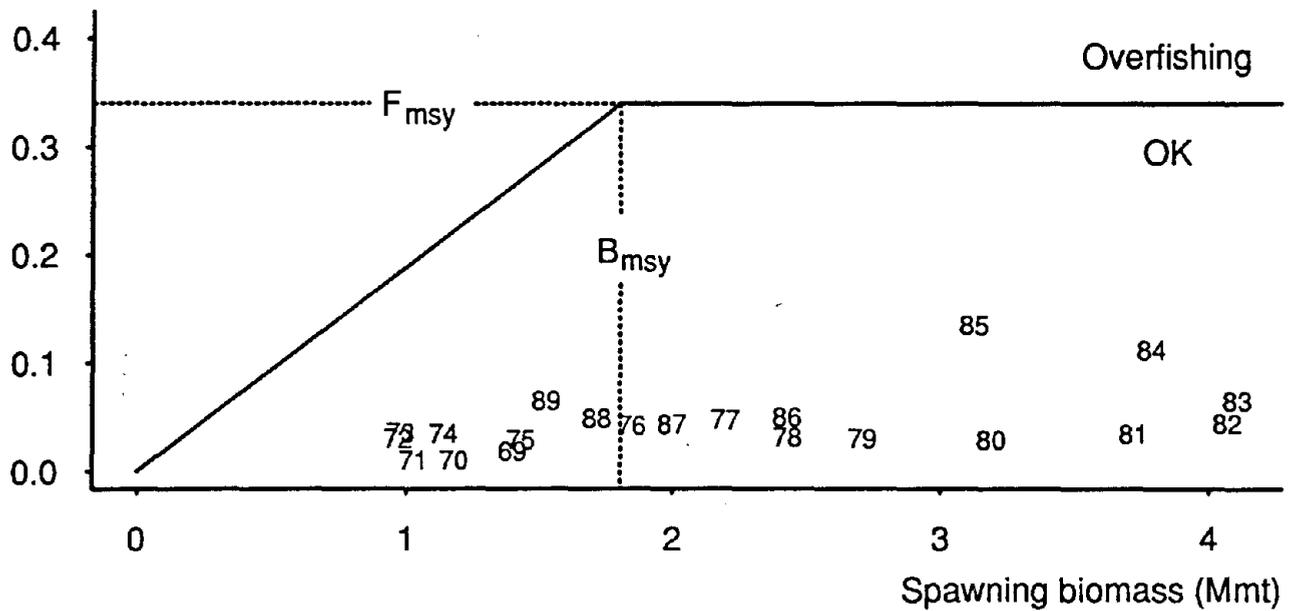
Gulf of Alaska pollock: Overfishing control law and experience

Management Unit - Bering Sea/ Aleutian Islands Crab (# 42, 114)

Species/Stocks:

42. Red King Crab (Paralithodes camtschaticus)
114. Tanner Crab (Chionoecetes bairdi)

FMP/Amendment Defining Overfishing:

Amendment 1 to the Bering Sea/Aleutian Islands King and Tanner Crab Fishery Management Plan (North Pacific Fishery Management Council; November 20, 1990).

Overfishing Definition:

Overfishing is defined as any rate of fishing mortality in excess of F_{MSY} for king and Tanner crab stocks in the Bering Sea/Aleutian Islands management area.

1) *Data available: Historical catch, sporadic inseason catch and effort data, and mortality.* Overfishing for stocks with level 1 data is defined as a fishing mortality rate in excess of F_{MSY} where the maximum allowable fishing mortality rate is estimated to equal the natural mortality rate of mature male crab. Inseason fishing mortality rate may be based on a change in the inseason ratio of CPUE of legal to mature male crab or a proportionate reduction in average weekly CPUE.

2) *Data available: Historical catch, continuous inseason catch and effort data, and mortality.* Overfishing for stocks with level 2 data is defined as a fishing mortality rate in excess of F_{MSY} where the maximum allowable fishing mortality rate is estimated to equal the natural mortality rate of mature male crab. Inseason fishing mortality rate may be based on inseason CPUE and cumulative catch of legal male crab.

3) *Data available: Historical catch, continuous inseason catch and effort data, stock assessment, stock-recruitment, growth, maturity, and mortality parameters.* Overfishing for stocks with level 3 data is defined as a fishing mortality rate in excess of F_{MSY} where the maximum allowable fishing mortality rate for these stocks cannot exceed F_{MSY} estimated as $F_{0.1}$, based on the size of first maturity for male crabs. Guideline harvest levels are estimated annually for level 3 stocks, therefore the fishing mortality rate is established prior to a fishery.

Assessment Method and Decision Rule:

Red king crab and Tanner crab are assessed using an area-swept expansion of bottom trawl surveys.

<u>Relevant Life History Features</u>:

Red king crabs are distributed throughout the North Pacific and Bering Sea and grow to carapace lengths of greater than 200mm. Males mature at an estimated age of 5-6 years at a size of 120mm and recruit to the fishery at a minimum size of 165 mm. Only male crab are landed, females are discarded. Therefore, the impact of the fishery on the spawning stock depends heavily on estimates of discard mortality. Landings declined sharply in the mid-1980's as the biomass fell rapidly under heavy fishing pressure.

Tanner crab are somewhat smaller than king crab and recruit at a small size as well. Recruitment is at about the same size and age. Tanner crab landings increased as king crab landings and stock declined and are currently at record high levels. Snow crab (*Chionoecetes opilio*) was close to being overfished in 1992, while true Tanner crab (*Chionoecetes bairdi*) was well within the overfishing limit.

<u>Evaluation of Overfishing Definition</u>:

Red King Crab - $F_{0.1}$ is the OD for this stock, and therefore is not directly related to recruitment. However, for current estimates of $F_{0.1}$, the OD is neutrally conservative as a threshold rather than a target. Though the stock is not currently being overfished, it is depleted relative to the 1970's period. The replacement line corresponding to the overfishing definition about bisects the available data points on the stock and recruitment plot, inticating that the stock will probably be maintained at the current level if fished at the OD rate. There is some ambiguity in the OD because the process for determining which tier to use is not specified (i.e., who decides). Also, the choice of a handling and discard mortality strongly affects the calculation of $F_{0.1}$ and needs to be investigated further.

Tanner Crab - There is little information on resource productivity, but the OD is considered to be neutrally conservative by analogy to other stocks. The comments for king crab apply here as well.

Data Sources:

Griffin, K. L. 1992. Bering Sea/Aleutian Islands shellfish fisheries and gear utilization. *In* Alaska Department of Fish and Game and Plan Team for the Commercial King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands (editors), Annual area management report/stock assessment and fishery evaluation report for the king and Tanner crab resources of the Bering Sea/Aleutian Islands region. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Low, Loh-Lee (editor). 1991. Status of living marine resources off Alaska as assessed in 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-211, 95 p.

Reeves, J. E. 1989. Evaluation of some errors in estimating recruitment for the Bristol Bay red king crab stock-recruit relationship. Proc. Int. Symp. King and Tanner Crabs, p. 447-468. Alaska Sea Grant.

Stevens, B. G., J. H. Bowerman, R. A. MacIntosh, and J. A. Haaga. 1992. Report to industry on the 1992 eastern Bering Sea crab survey. AFSC Proc. Rep. 92-12. National Marine Fisheries Service, Alaska Fisheries Science Center, Kodiak Facility, P.O. Box 1638, Kodiak, AK 99615.
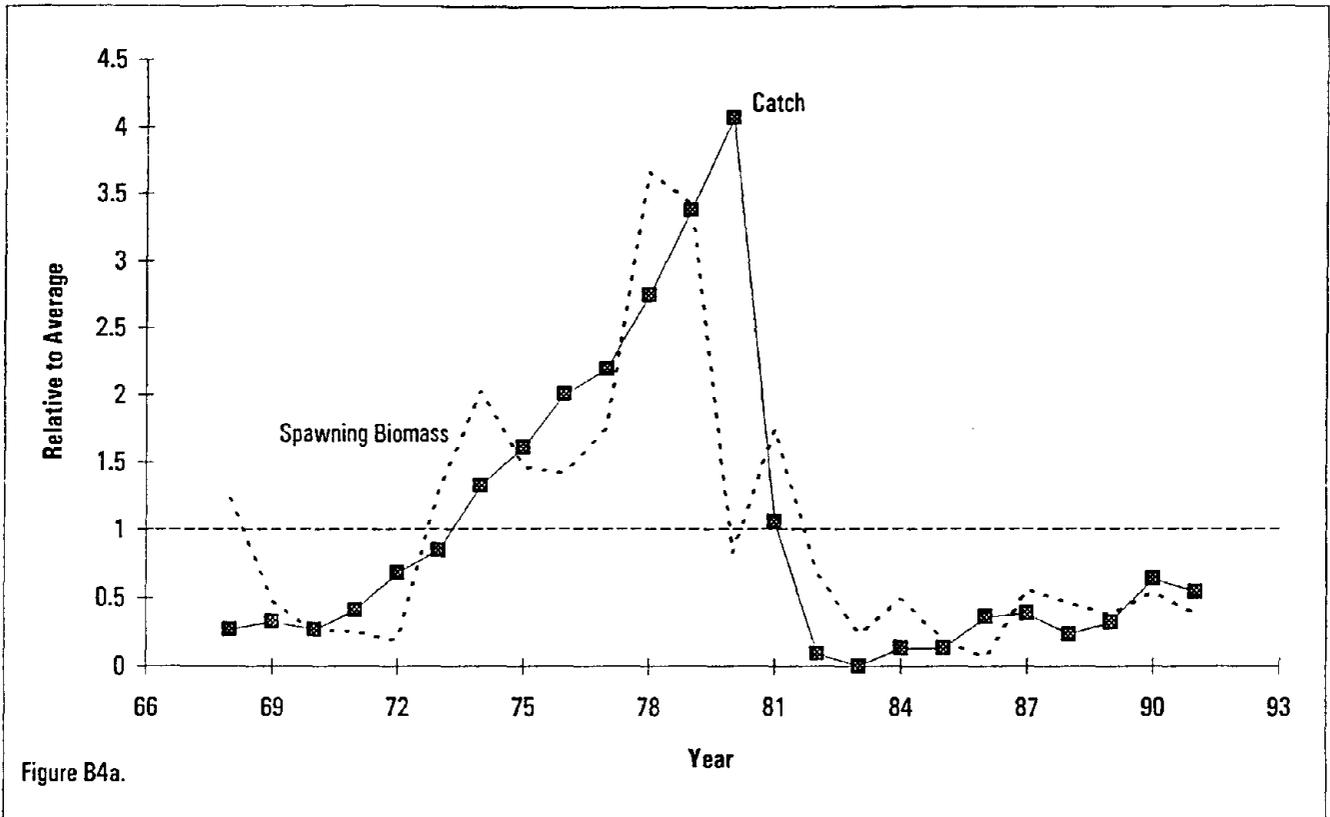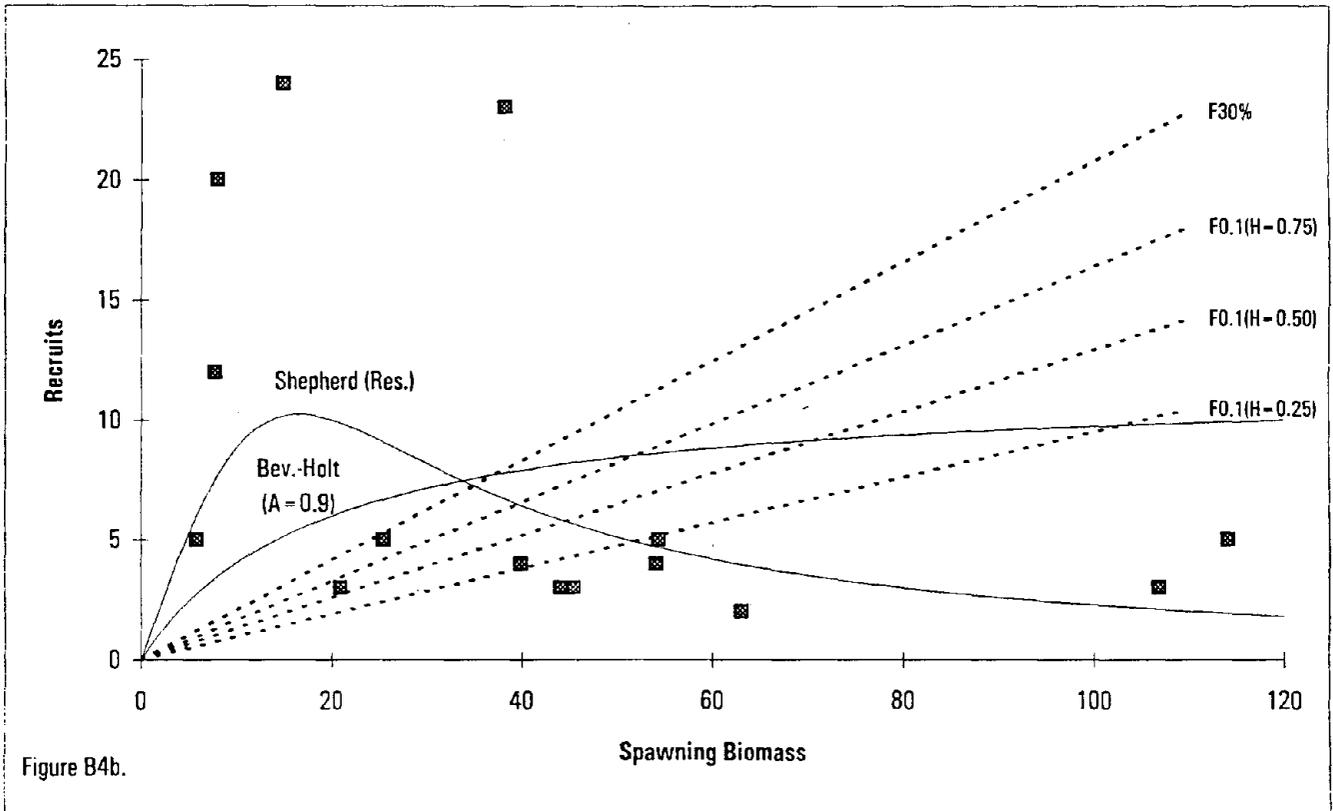
Figure B4a.

Figure B4b.
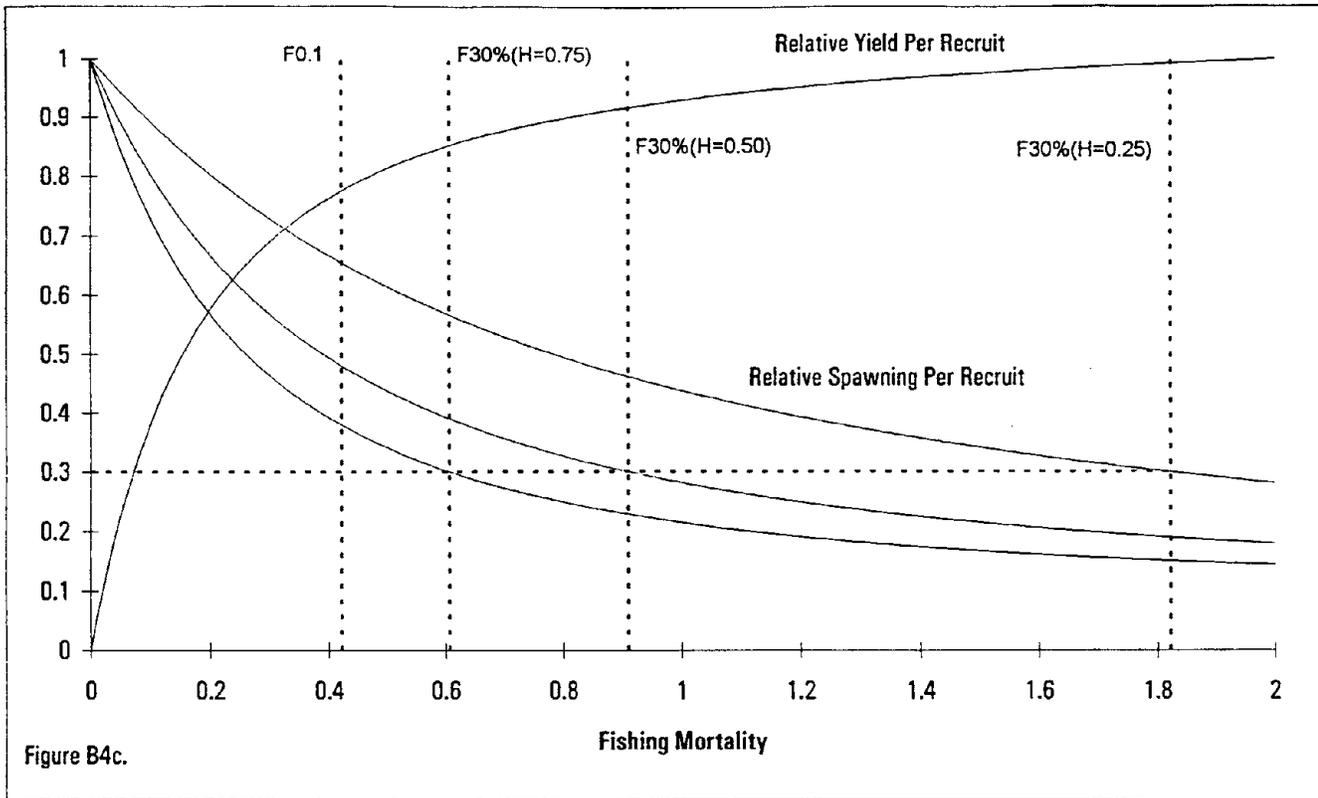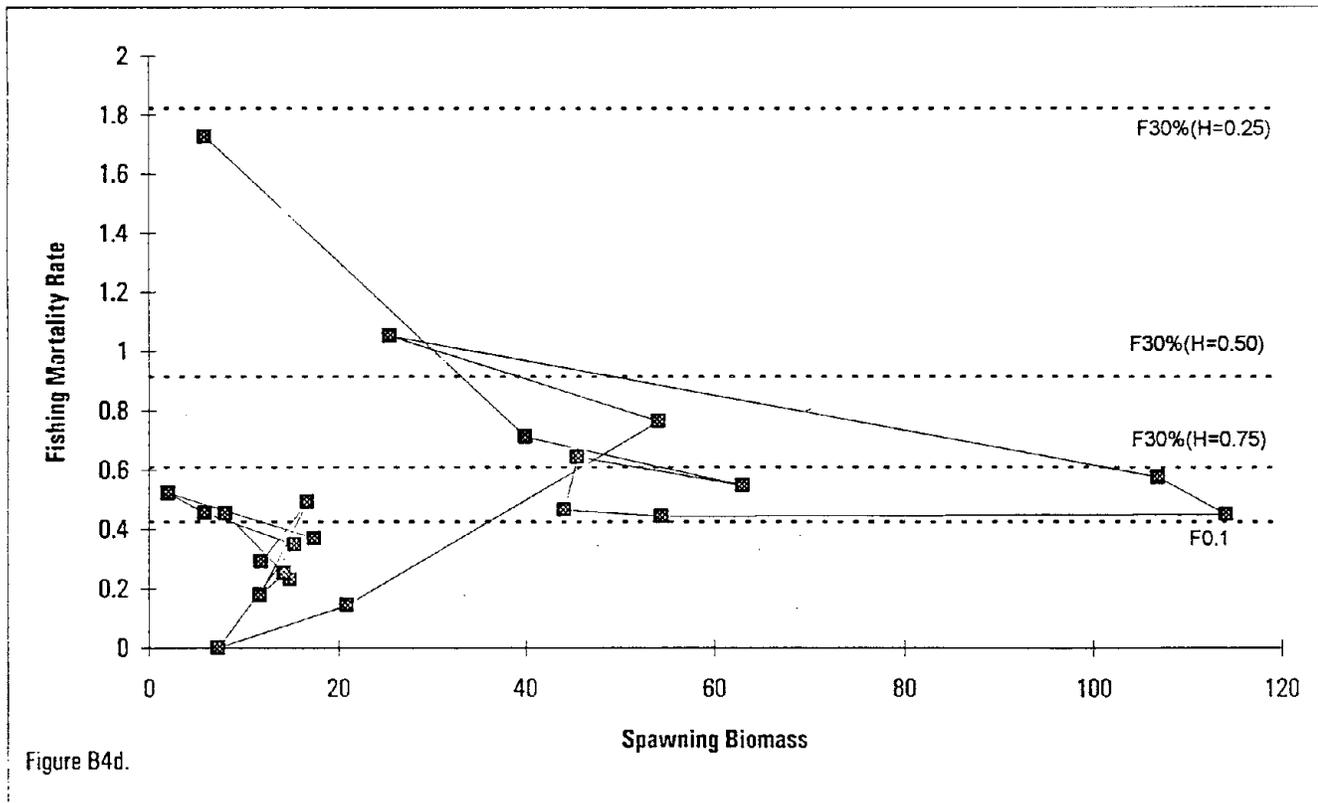
Figure B4c.

Figure B4d.

Management Unit - Alaska Salmon (44, 117)

Species/Stocks:

44. Nushagak River Chinook Salmon (*Oncorhynchus tsawytscha*)
117. Other Alaska Salmon Stocks
     Chinook Salmon (*Oncorhynchus tsawytscha*)
     Chum Salmon (*Onchorhynchus keta*)
     Coho Salmon (*Onchorhynchus kisutch*)
     Pink Salmon (*Onchorhynchus gorbuscha*)
     Sockeye Salmon (*Onchorhynchus nerka*)

FMP/Amendment Defining Overfishing: Pacific Salmon Commission and Alaska Department of Fish and Game salmon fishery management plan

Overfishing Definition:

Any fishing that results in the stock not meeting spawner escapement targets. Escapement targets are set by the ADF&G and the PSC so that escapement will not be significantly less than needed to produce MSY.

Assessment Method and Decision Rule:

Counts of harvest and spawner escapement. Recent escapement targets are 65,000 fish based on fitted stock and recruitment relationships.

Relevant Life History Features:

The species considered here are anadromous, relatively short-lived (typically 2-6 years), and semelparous (spawning once and then dying). Patterns of reproductive age are quite variable among species, ranging from essentially single-age spawning (pink salmon) to spawning over several age classes (chinook salmon). Salmon are well known for their homing abilities and specificity to particular spawning grounds, which has led to management based on individual spawning stocks. The combination of life history and fishing patterns leads to complicated multi-stock, multi-fishery, multi-jurisdictional management problems.

There has been a lot a variation in the number of fish returning to spawn, with very high numbers in the late 1970's and early 1980's. Smaller runs have been observed in recent years.

Evaluation of Overfishing Definition:

Nushagak River Chinook - There is little evidence in the stock recruitment data that recruitment declines around the 65,000 fish target level. There is a large amount of scatter in the data, but, nevertheless, the current overfishing threshold seems conservative, given this picture of the stocks dynamics. There are, however, clear changes in stock productivity over time implying the OD may not be robust to changing parameters. Close monitoring will be needed to adjust if future spawner productivity is substantially lower. Unfortunately, the life history, where recruits return over a series of years, means there is a long lag in the monitoring. Other measures of productivity should be investigated. The definition is inherently ambiguous, since it does not mandate how escapement targets are to be chosen.

Other Salmon Stocks - Maximizing the number of returning progeny should produce a yield near to MSY. The overfishing definition is appropriate as a target, rather than a limit, and the current escapement goals are probably conservative. However, there is some ambiguity in the OD because the procedure for choosing escapement goals is not specified.

Data Sources:

AFSC 1993. Status of living marine resources off Alaska as assessed in 1992. NOAA Tech. Mem. NMFS-F/NWC- .

Minard, M., J. Skrade, T. Brookover, D. Dunaway, B. Cross, and J. Schichnes. 1992. Escapement requirements and fishery descriptions for Nushagak drainage chinook salmon. Alaska Dept. Fish & Game. Regional Inform. Rept. No. 1D91-09. 67pp.

Thousands of fish

Total run
Escapement
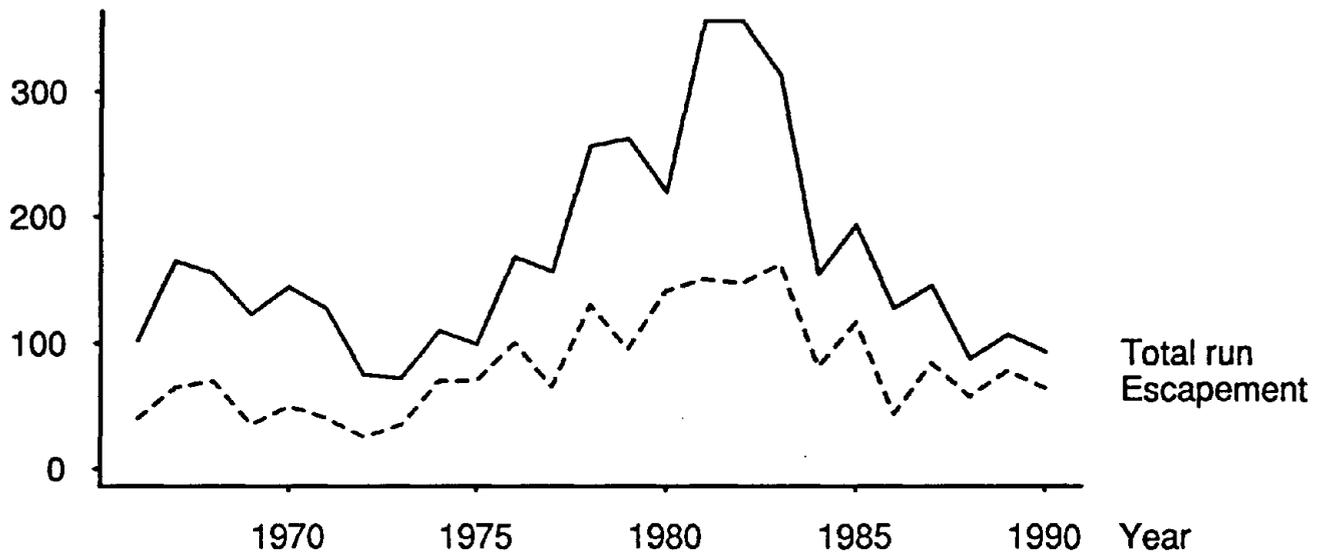
Nushagak River chinook: Time series

Recruits

Smoother
Shepherd
Ricker
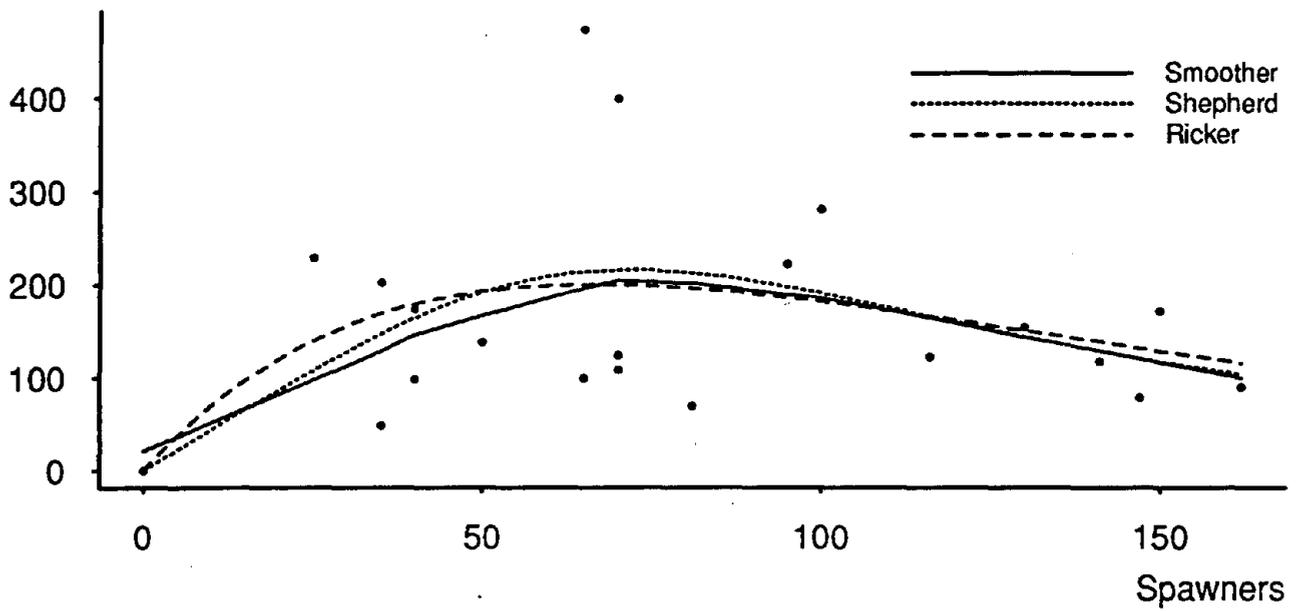
Nushagak River chinook: Spawner-recruit relationship

Management Unit: **Atlantic Bluefish (# 49)**

Species/Stock:

      49. Bluefish (*Pomatomus saltatrix*)

FMP/Amendment Defining Overfishing: Fishery Management Plan for Atlantic Bluefish (Mid-Atlantic Fishery Management Council).

Overfishing Definition: Overfishing is defined as a level of fishing that exceeds the fishing mortality rate that results in the highest sustainable yield or MSY, specifically a range of 0.35 to 0.4.

Assessment: Recreational Catch-per-Effort Index. Fishing mortality rate estimates are not available.

Relevant Life History Features - Bluefish migrate along the Atlantic coast from Maine to Florida. It is subjected to a large recreational fishery, accounting for some 85% of the landings, and a small commercial harvest. Bluefish are voracious predators and may live up to 12 years. Maturity is at age 1.

Evaluation of Overfishing Definition - The rule is not robust to assessment errors because the overfishing level is very close to the target level of F, and F cannot be estimated; however, if and when F becomes estimated, the conservative nature of the OD should help reduce risk. The overfishing definition is adequate, but assessments are inadequate to provide the information needed to implement the definition. No corrective action is specified. While it might be assumed that under OY management, F will be set so as not to exceed F_{DOF}, this is not presently possible because F is unknown.

Assessment Background Papers:

Anon. 1992. Bluefish. In Status of fishery resources off the northeastern United States for 1992. NOAA Tech. Mem. NMFS-F/NEC-95.

Report of the Eleventh Northeast Regional Stock assessment Workshop (SAW). NEFSC, Fall 1990.

Management unit: **Mid-Atlantic butterfish (#53)**

Species/stocks:

> 53. Butterfish (*Peprilus triacanthus*)

FMP/Amendment Defining Overfishing: Amendment 3 to the Fishery Management Plan for Atlantic Mackerel, Squid and Butterfish Fisheries (Mid-Atlantic Fishery Management Council).

Overfishing Definition:

"For purposes of meeting the 602 Guidelines, overfishing for butterfish is defined as occurring when the 3 year moving average of pre-recruits from the Northeast Fisheries Center's autumn bottom trawl survey (mid-Atlantic to Georges Bank) falls within the lowest quartile of the time series (1968 to present)." (p. 4)

Assessment Method and Decision Rule:

The stock is assessed by monitoring indices of abundance from research surveys and commercial landings per unit effort.

Overfishing is indicated when the three-year moving average of pre-recruits from the NEFSC bottom trawl survey (mid-Atlantic to Georges Bank) falls within the lowest quartile of the time series (1968 to present).

Relevant Life History Features:

Atlantic butterfish are short-lived, with few or no individuals observed beyond age 3. Instantaneous natural mortality rate (M) is 0.8. Juvenile butterfish first recruit to the spawning stock at the end of their first year.

Development of stock-recruitment relationships from available survey data is problematic, as changes in survey indices may reflect changes in natural mortality rates, discard mortality or availability of older individuals, rather than abundance.

Evaluation of Overfishing Definition:

In light of the short lifespan of individuals of this stock (3 years), an overfishing definition based on the lowest quartile of a 3-year running average of pre-recruit indices is risky. Two years of recruitment failure following a single year of exceptional recruitment could lead to severe reduction in spawning stock biomass (because few fish survive beyond age 3), yet the stock would not be defined as overfished.

The definition could be improved by making the timeframe to observe/determine potential overfishing consistent with the lifespan of the species. Evaluations throughout a cohort's lifespan, based on research surveys and commercial fishery indices, adding the uncertainty associated with those indices could provide a more accurate basis for defining overfishing and determining stock status.

Assessment Background Papers:

NEFSC 1992. Report of the Twelfth Northeast Regional Stock Assessment Workshop (12th SAW). Northeast Fisheries Science Center Reference Document 91-03.

NEFSC 1994 (In prep.). Report of the Seventeenth Northeast Regional Stock Assessment Workshop (17th SAW). Northeast Fisheries Science Center Reference Document.

Management Unit - Gulf of Mexico and South Atlantic Corals (# 59)

Stock:

    59. Gulf of Mexico and South Atlantic Corals

FMP/Amendment Defining Overfishing: Fishery Management Plan for Coral and Coral Reefs Amendment 1

Overfishing Definition:

Overfishing is defined as an annual level of harvest that exceeds optimum yield (OY). OY for coral reefs, sotny corals and sea fans in the EEZ is to be zero, except as may be authorized for scientific and educational purposes. Harvest of allowable octocorals (those other than sea fans) in the EEZ is not to exceed 50,000 colonies per year.

Assessment Method and Decision Rule:

Fishing is to cease when the harvest level of 50,000 colonies of octocorals is reached. The standing stock of octocorals has been estimated by survey to be 4.7 billion colonies in the Florida Keys alone.

Relevant Life History Features:

Corals are generally slow growing and provide critical habitat for many reef species. The octocorals are faster growing than the hard corals.

Evaluation of Overfishing Definition:

There is little or no information concerning the population dynamics of coral. Prohibiting the harvest of hard corals seems appropriate because of their habitat value and very slow growth rates. For octocorals, the harvest is such a small fraction of the total standing stock that it is unlikely to impact the various species. Loss of habitat and water quality/siltation are likely more important factors effect coral populations.

Data Sources:

Status of the Fishery Resources Off the Southeastern United States for 1992. NOAA Tech. Memo NMFS-SEFSC-362.

Amendment 1 to the Fishery Management Plan for Coral and Coral Reefs. Gulf of Mexico Fishery Management Council, Tampa, FL and South Atlantic Fishery Management Council, Charleston, S.C.

Management Unit - **Western Pacific Corals** (# 95)

Stock:

      95. Western Pacific Corals

FMP/Amendment Defining Overfishing: Fishery Management Plan for Western Pacific Precious Corals, Amendment 2

Overfishing Definition:

An established coral bed shall be deemed overfished with respect to recruitment when the total spawning biomass (all species combined) has been reduced to 20% of its unfished condition." (p. 10)

This definition applies to all species of precious corals, and is based on cohort analysis of the pink coral, Corallium secundum." (p. 10)

Assessment Method and Decision Rule:

An assessment of the pink coral in one 3.5 km^2 bed has been performed by transect surveys. This, along with age, growth and reproductive information has been used to develop an age-structured model of the population to calculated MSY. The result is applied to other areas and other species of octocoral.

Relevant Life History Features:

Pink coral is very long lived and slow growing living up to 80 years of age with an estimated natural mortality rate of 0.06. The coral is reproductively mature at approximately 15 years. Seventy percent of the spawning stock biomass is estimated to be older than 30 years, which corresponds to the minimum legal size.

Evaluation of Overfishing Definition:

The strategy taken is to control the minimum legal size for the harvest and thereby protect some proportion of the spawning stock. This is done based on the pink coral model for one small area and then applied across all areas and species. The assessment model has estimated that if 30% of the spawning biomass is protected, which corresponds to applying the current minimum legal size, the maximum sustainable yield will obtain. Therefore, the overfishing definition was set at 20% of the unexploited spawning biomass as a threshold. This appears to be a sensible approach, though the robustness of the model when applied to all areas and species of octocorals is and important issue. Note that the FMP confuses spawning potential ratio and proportion of the unexploited spawning biomass.

Data Sources -

Fishery Management Plan for the Precious Corals Fisheries of the Western Pacific Region. Amendment 2. 1990. Western Pacific Regional Fishery Management Council, Honolulu, HI

Status of Pacific Oceanic Living Marine Resources of Interest to the USA for 1991. NOAA Tech. Memo. NMFS-SWFSC 165.

Management Unit - **Pelagic Species of the Western Pacific (# 96)**

Stock:

      96. Western Pacific Tunas

FMP/Amendment Defining Overfishing: Fishery Management Plan for Pelagic Species of the Western Pacific Region, Amendment 1

Overfishing Definition:

A stock is overfished when its spawning potential ratio (SPR) is equal to or less than 0.20. .... SPR may be estimated in several ways, using estimates of spawning stock biomass, spawning stock biomass per recruit, spawning stock catch per unit of effort, and exploitable stock biomass. The common element for all calculations is the attempt to assess the status of current spawning potential against the spawning potential of an unfished population. The use of a specific measure will depend on the availability of data for the stock and fisheries involved.

Assessment Method and Decision Rule:

The species in this grouping are assessed by analysis of commercial catch-per-unit-effort as a measure of relative abundance, usually in a production model framework. In addition, some tagging study estimates are employed. The decision rule is unclear. All of these resources are subject to substantial international fisheries outside of U.S. waters. Therefore, action with respect to overfishing requires a concerted international effort, as does assessment of the resources.

Relevant Life History Features:

All of these species are highly migratory through international waters. Most of these species have an intermediate lifespan, with natural mortality rates thought to be between 0.2 - 0.4.

Evaluation of Overfishing Definition:

The overfishing definition is ambiguous because it is framed in terms of spawning biomass per recruit, which relates to fishing mortality, or in terms of the ratio of spawning biomass to unexploited spawning biomass, which is a biomass measure. The definition therefore is either a maximum harvest rate or minimum biomass. It is also unclear whether the 20% level is appropriate for either biomass or biomass per recruit measures for large pelagics. However, there is some suggestion that such a level is broadly sensible for a wide range of species. There is probably no real preferable alternative to the current definition, though it should be clarified which alternative is being chosen for each stock. More detailed population dynamics studies will be needed to improve the definitions.

Data Sources:

Status of Pacific Oceanic Living Marine Resources of Interest to the USA for 1991. NOAA Tech. Memo. NMFS-SWFSC 165.

Fishery Management Plan for the Pelagic Species Fisheries of the Western Pacific Region. Amendment 1. 1990. Western Pacific Regional Fishery Management Council, Honolulu, HI

Appendix I: List of Review Panel Members and Affiliations

Louis Botsford	University of California at Davis
Wiliam Clark	International Pacific Halibut Commission
Jeremy Collie	University of Rhode Island
Wendy Gabriel	Northeast Fisheries Science Center, NMFS
John Hoenig	Department of Fisheries and Oceans, Canada
Alec MacCall	Southwest Fisheries Science Center, NMFS
Pamela Mace	Highly Migratory Species Division, NMFS Headquarters
Richard Methot	Alaska Fisheries Science Center, NMFS
Joseph Powers	Southeast Fisheries Science Center, NMFS
Victor Restrepo	University of Miami
Andrew Rosenberg	Office of Senior Scientist, NMFS Headquarters
Kevin Stokes	Ministry of Agriculture, Fisheries and Food, United Kingdom
Grant Thompson	Alaska Fisheries Science Center, NMFS
Thomas Wainwright	Northwest Fisheries Science Center, NMFS

Appendix 2: Glossary of Acronyms and Technical Terms

ABC — Acceptable biological catches set annually to guide management for some stocks.

B_0 — Virgin or unfished equilibrium biomass.

BRP — Biological reference point.

CPUE — Catch per unit of fishing effort.

compensation — An increase (if any) in per capita reproductive success as stock abundance decreases. The amount of concavity (curvature) in the SSR expresses the amount the stock can compensate, by increased survival, for reduced abundance.

depensation — The decrease (if any) in per capita reproductive success as stock abundance decreases.

EPR — Egg production per recruit calculated from the growth, mortality, maturity and fecundity parameters estimated for a stock.

F — instantaneous fishing mortality rate.

$F_{extinction}$ — The replacement line on a plot of stock and recruitment which is tangent to the SRR through the origin.

F_{high} — The fishing mortality rate at which the replacement line on a plot of stock and recruitment that corresponds to the 90th percentile of the survival ratio R/S.

$F_{0.1}$ — A fishing mortality rate at which the slope of the yield per recruit curve is 10% of the slope at the origin.

F_{max} — The fishing mortality rate at which yield per recruit is maximized.

F_{med} — The fishing mortality rate at which the replacement line bisects the observations of recruitment plotted against parent stock.

F_{MSY} — The fishing mortality rate at which sustainable yield is maximized.

F_{rep}	The fishing mortality rate at which the stock can just replace itself over time, often estimated by F_{med}.
$F_{20\%}$ or $F_{35\%}$	The fishing mortality rates at which the spawning per recruit (usually using spawning biomass per recruit as a proxy) is reduced to 20 or 35% of the unfished level, respectively.
FMC	Regional Fishery Management Councils set up under the MFCMA to develop fishery management plans.
FMP	Fishery Management Plan.
Harvest control law	Expresses the management strategy to be taken as a function of the condition of the stock. Typically this is given as the fishing mortality rate target and/or thresholds expressed as a function of stock biomass.
MBAL	Minimum biologically acceptable level of abundance.
MCY	Maximum constant yield.
MFCMA	Magnuson Fishery Conservation and Management Act of 1976 as amended.
MSR	Maximum sustainable economic rent.
MSY	Maximum sustainable yield.
OD	Overfishing definition.
OY	Optimum yield determined from the maximum sustainable yield as modified by relevant social and economic factors.
R/S	Ratio of recruits to parent stock (survival rate).
SAFE report	Stock assessment and fishery evaluation report as required under the 602 Guidelines.
602 Guidelines	Section 50, Code of Federal Regulations Part 602 Guidelines for the preparation of fishery management plans under the MFCMA.
SPR	Spawning per recruit calculated from the mortality, growth or fecundity, selectivity and maturity parameters for a stock. Ideally, units should be total egg production taking into account difference in egg production with size/age or other factors. Spawning biomass is commonly used as a proxy for egg

production.

%SPR   SPR expressed as a percentage of the SPR for the stock at the unfished equilibrium.

S-R observations   Spawning stock biomass and recruitment observations.

SRR   Stock and recruitment relationship.

YPR   Yield per recruit calculated from the growth, selectivity, and mortality parameters for a stock.
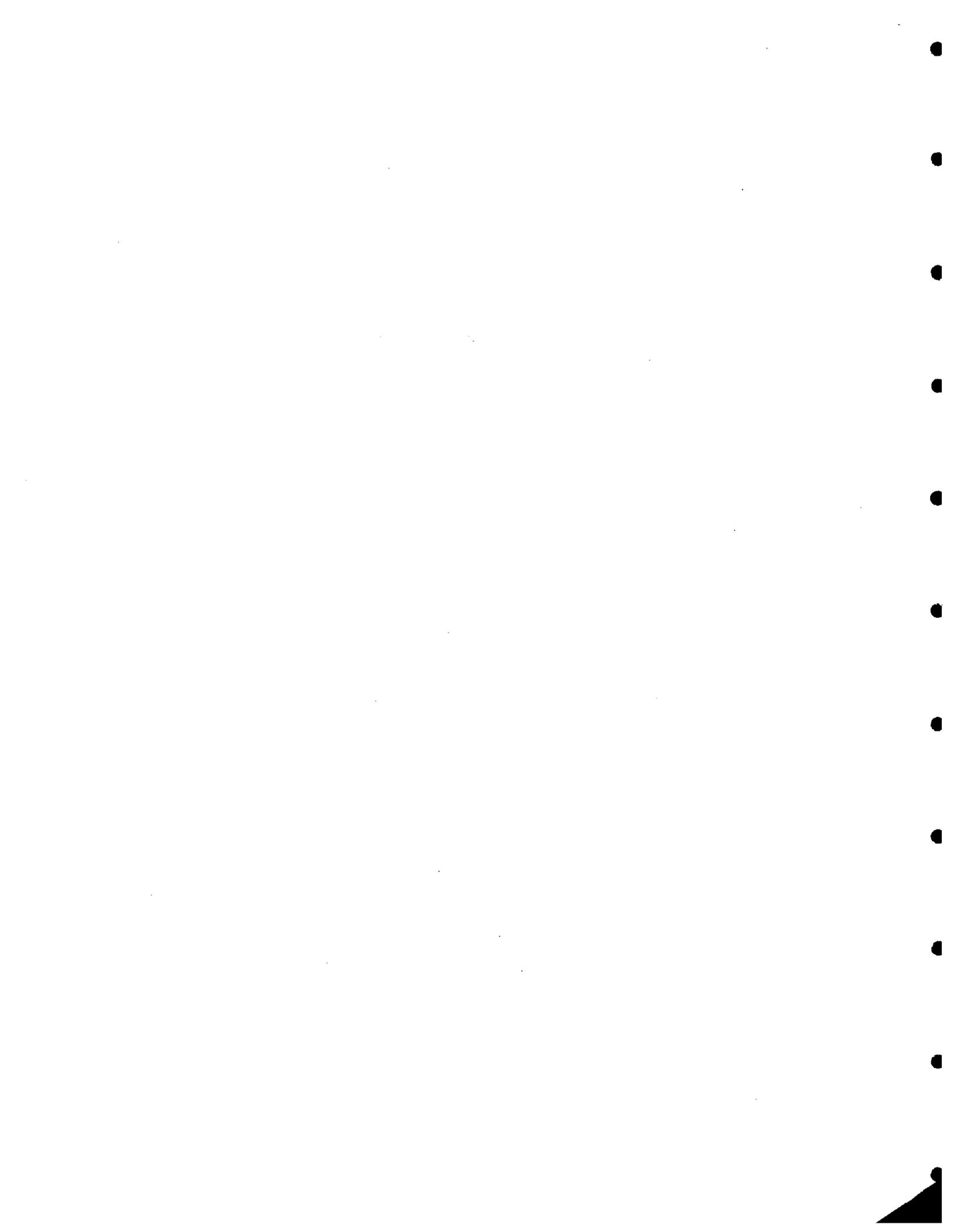
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