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AN EVALUATION OF THE USE OF SPR LEVELS AS THE BASIS FOR OVERFISHING DEFINITIONS IN GULF OF MEXICO FINFISH FISHERY MANAGEMENT PLANS

by

Gulf of Mexico SPR Management Strategy Committee

for

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FINAL REPORT
6 May 1996

COUNCIL'S CHARGE TO THE COMMITTEE

"To address SPR strategies for species in various FMP's and appropriate biological management goals relative to biological reference points available to assess stock conditions."

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PREFACE

An earlier version of this report (March 1995) was considered incomplete pending further evaluation of a class of biological reference points, commonly referred to as "non-equilibrium" measures of SPR (where the acronym refers either to Spawning Per Recruit or Spawning Potential Ratio; see Section I - Terminology for a discussion of the distinction between these quantities), that are frequently used as reference points for fisheries in the southeastern United States. Whereas a National Marine Fisheries Service (NMFS) Review Panel had previously conducted an extensive review of so-called "equilibrium" measures of SPR (NMFS Scientific Review of Definitions of Overfishing in U.S. Fishery Management Plans; Rosenberg *et al.* August 1994), the Panel had not considered non-equilibrium measures. In addition, there are at least two distinct methods of calculating non-equilibrium SPR, both of which have been applied to Gulf of Mexico fisheries.

After the Gulf of Mexico SPR Management Strategy meeting in December 1994, it was determined that NMFS should reconvene the Review Panel that conducted the original scientific review of definitions of overfishing so that the analysis could be extended to non-equilibrium measures of SPR. For various reasons, the supplemental Review Panel meeting did not take place until February 1996.

The March 1995 version of this report used the terms "equilibrium" and "non-equilibrium" to differentiate between traditional measures of spawning (biomass) per recruit that assume constant mortality, growth and maturity schedules, and measures of spawning potential ratio that use empirical estimates of population numbers and fishing mortality. However, at the supplemental meeting, the NMFS Review Panel determined that the terms "static" and "transitional" were more accurate descriptors of the traditional and empirical measures.

The only substantive changes that have been made since the incomplete (March 1995) report was distributed, are the changes from "equilibrium" to "static" and "non-equilibrium" to "transitional," as well as a rewrite of the following sections or subsections: the Executive Summary, Terminology, Static vs. Transitional SPR, and Recommendations 1, 3, 4, 5, 6, 7, 15 and 16; and the addition of this preface. Rewritten sections incorporate conclusions reached at the NMFS supplemental review, and relate mostly to the interpretation of transitional SPR. Assessment results reported in the March 1995 version of this report have been updated for red snapper and Spanish mackerel, but not for other species.

EXECUTIVE SUMMARY

Overall, the SPR Committee concluded that the Gulf Council's use of SPR measures in finfish overfishing definitions is scientifically sound, and that the levels chosen are in line with levels used by other U.S. Fishery Management Councils. Many of the Committee's recommendations reinforce the Council's approach; nevertheless, the Committee did recommend revision of the overfishing definitions to make them more rigorous and to address inconsistencies between definitions developed in different FMP's. The main recommendations of the SPR Committee include:

- that standardized terminology for SPR should be adopted and used consistently; in particular that the need to distinguish between static and transitional SPR be recognized;
- that overfishing *thresholds* should be distinct from management *targets* (OY);
- that definitions of overfishing should incorporate definitions of both the degree of *overfishing* (i.e. the current fishing mortality rate) and the *overfished* condition (i.e. the extent of stock depletion due to fishing), provided that there are sufficient data to evaluate both quantities;
- that if there is a need for a threshold below which fishing activities should cease or be severely curtailed (e.g. restricted to bycatch only), then that threshold should be based on measures of absolute or relative stock biomass;
- that the goal of a rebuilding plan should be to restore the stock to the level which can produce OY on a continuing basis (where OY is defined as MSY modified by relevant factors), and rebuilding plans should be designed to make consistent progress towards this goal;
- that all of the overfishing definitions reviewed by the SPR Committee should be revised to ensure consistency between FMP's, define both *overfishing* and *overfished*, describe the quantities used to measure *overfishing* and *overfished*, and provide alternative definitions that reflect the amount or quality of data available for different stocks (a suggested general format for the revised definitions is provided).

This report summarizes the discussions and conclusions of the SPR Committee, which covered the following broad areas: general considerations about the applicability of SPR reference points (Section I), topics of special relevance to Gulf of Mexico fisheries (Section II), evaluation of current SPR reference points for Gulf of Mexico species (Section III), and recommendations for future development of OY and overfishing definitions (Section IV).

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BACKGROUND: OVERFISHING AND REVISED 50 CFR PART 602 GUIDELINES

In 1989, the National Marine Fisheries Service (NMFS) published guidelines for fishery management plans, referred to as the (50 CFR Part) 602 Guidelines. These guidelines were developed by a national team of scientists and managers to address two of the National Standards set out in the Magnuson Fishery Conservation and Management Act (Magnuson Act) of 1976. 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. The 602 guidelines were intended to detail what is needed in each fishery management plan (FMP) in order to define overfishing with respect to the National Standards. The revised guidelines standardized the approach to defining overfishing and established a schedule for implementation of acceptable definitions.

The intent of the Guidelines is to prevent recruitment overfishing and to have a "conservation standard" for each fishery such that stocks are not driven to, or maintained at, the threshold of overfishing. Overfishing is defined as a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis. Fishing on a stock at a level that severely compromises the future productivity of that stock is unacceptable. 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, maximum level or rate of fishing mortality, or other acceptable measurable standard. 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 of Commerce.

To date, over 100 definitions of overfishing have been approved by NMFS. In 1993-94, NMFS convened a panel of scientists from inside and outside of the agency to review the approved definitions, investigate their strengths and shortcomings, and to standardize as far as possible the criteria and basis for future evaluations of overfishing definitions (Rosenberg *et al.* 1994). The goal of the review was to develop a scientific consensus on the appropriateness of the definitions and the criteria used for their evaluation. The broad criteria adopted by the panel were that the overfishing definition must have scientific merit, be intended as a reference point or level that should never be reached or even closely approached, be measurable, and be operationally feasible. Much of the material in Section I is excerpted or summarized from the report submitted to NMFS by the panel (hereafter referred to as the NMFS Overfishing Review). The material relating to transitional SPR in Section II is derived from the February 1996 supplement to the original Review Panel report (referred to as the NMFS Overfishing Supplemental Review).

SECTION I: GENERAL CONSIDERATIONS REGARDING THE APPLICABILITY OF SPR REFERENCE POINTS

Terminology

Within the U.S., SPR is one of the most common methods for defining overfishing thresholds. However, the terminology (and to some extent, methods of calculation) has not been standardized. The following terms are used to represent absolute amounts of spawning products per recruit: SSB/R or SSBR (spawning biomass per recruit), EPR (eggs per recruit) and the general term SPR (spawning per recruit -- in units of biomass, eggs, etc.). Synonymous terms used to represent these quantities as percentages of the maximum (attained when $F=0$) include %SSB/R or %SSBR (percent spawning biomass per recruit), %EPR (percent eggs per recruit), %SPR (percent spawning per recruit -- in units of biomass, eggs, etc.), and %MSP (percent maximum spawning potential). The related quantity, $F_{x\%}$, has been used to represent the reference fishing mortality corresponding to x% SPR. All of the above quantities have generally been used in the context of static %SPR analyses. However, the acronym, SPR, has also been used to represent "spawning potential ratio," which is usually expressed as a proportion rather than a percentage, and is applied as a transitional measure.

Although the conceptual foundation for spawning per recruit and spawning potential ratio is similar, the fact that the former is a static measure while the latter is a transitional measure is a fundamental point of departure. For spawning per recruit (static measure), the reference points are calculated from a standard (Beverton-Holt) "spawning per recruit analysis" which is analogous to the familiar yield per recruit analysis, and uses exactly the same inputs (e.g. constant weights at age, a constant natural mortality vector, and a constant fishing mortality vector), with the addition of a constant maturity ogive. For the spawning potential ratio (transitional measure), the reference points are calculated from empirical estimates of population numbers and fishing mortalities by age and year derived from age-structured stock assessments. With the exception of some of the work conducted by Goodyear (see below), virtually all of the theoretical development and empirical analyses of SPR reference points relate to the static approach, for which each level of SPR (or %SPR) corresponds directly to a unique level of fishing mortality (for a given selectivity ogive).

Section I of this report deals exclusively with the original NMFS Overfishing Review, which in turn dealt exclusively with the static interpretation of SPR, and did not include any discussion of transitional SPR measures. Therefore, for the remainder of Section I, the acronym, SPR, will refer only to the static "spawning per recruit" (often used interchangeably with the term "spawning biomass per recruit," since the most common unit of measurement is biomass). The extension to transitional SPR (spawning potential ratio), based on the NMFS Overfishing Supplemental Review, is covered in Section II.

Background: Scientific Basis for the Use of SPR Reference Points in Overfishing Definitions

The chronology of development of approaches based on SPR is roughly as follows (although the list of authors is by no means complete). A considerable amount of pioneering work was conducted by Goodyear (1977, 1980) who first suggested the use of a compensation ratio, which is the ratio between reproductive potential for an unfished population and reproductive potential for a fished population. Subsequently, Shepherd (1982) showed how a standard (Beverton-Holt) spawning biomass per recruit analysis could be combined with spawning biomass and recruitment (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): for any constant fishing mortality rate, F, there is a corresponding static spawning (biomass) per recruit 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 static spawning per recruit scale (see Gabriel *et al.* 1989 for the computational details).

Shepherd's (1982) ideas were further developed by the International Commission for the Exploration of the Sea (ICES) Stock Assessment Methods Working Group which advocated routine calculation of reference points called F_{high} (Shepherd 1982) and F_{med} (Sissenwine and Shepherd 1987), the 90th and 50th (median) percentile survival ratios calculated from stock and recruitment observations. Subsequently, Sissenwine and Shepherd (1987) introduced the concept of the replacement F (F_{rep}), the fishing mortality rate that, on average, allows for replacement of successive generations over the observed range of S-R data, and suggested that F_{med} could be used as an estimate of F_{rep}. A number of papers have since applied the methodology. One comprehensive example is that by Gabriel *et al.* (1989) who applied the method to Georges Bank haddock and suggested a standardized method of computation.

Both F_{med} and F_{high} have been used as indicators of *recruitment overfishing*. The tangent through the origin of an S-R relationship corresponds to $F_{extinction}$ (also referred to as F_τ; e.g. Mace 1994). F_{high} may overestimate this slope since the highest survival ratios may reflect anomalously favorable environmental conditions, not the ability of the population to sustain fishing under average environmental conditions. On the other hand, F_{med} may underestimate the slope if the data exhibit compensation (concavity).

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 analysis to obtain estimates of reference points such as $F_{0.1}$, F_{max}, F_{med} and associated levels of %SPR. 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 the fishing mortality rate corresponding to 20% SPR (i.e. $F_{20\%}$) as a recruitment overfishing threshold for stocks believed to have average resilience and 30% SPR (approximately the 80th percentile result) for little-known stocks or for stocks with relatively low resilience.

This study, along with earlier theoretical and empirical work by Goodyear (1977, 1980, 1989), Gabriel *et al.* (1989) and Clark (1991) has resulted in the two alternatives of 20% SPR and 30% SPR becoming the most commonly used measures of recruitment overfishing in U.S. fishery management plans (Rosenberg *et al.* 1994). However, there are few cases where these estimates have been derived empirically; generally they are based on analogy with results from the aforementioned studies, and on theoretical considerations.

Targets (OY) vs. Thresholds

Subsequent to the adoption of the 602 Guidelines, overfishing definitions often seem to have taken on more importance than optimum yield (OY) definitions. The latter represents a management target, which may include biological, economic, social and other considerations. The former incorporates biological considerations only; namely, the risk of recruitment overfishing. In some cases, overfishing thresholds have actually become management targets as well. However, it does not make sense to use the same reference point as both a target and a threshold: how can one achieve a goal while at the same time trying to avoid it? The NMFS Overfishing Review concluded that it is important to make a distinction between management targets and overfishing definition thresholds. If targets and thresholds are expressed as fishing mortalities then fishing mortality should fluctuate about a target level, but never exceed the threshold level. If targets and thresholds are expressed as biomass levels then biomass should fluctuate about the target biomass, but never fall below the threshold biomass. Fish stocks should always be maintained well away from overfishing thresholds.

F vs. Biomass Overfishing Thresholds

The NMFS Overfishing Review contains detailed discussions of the pros and cons of defining overfishing in terms of maximum fishing mortality (F) or minimum biomass (B). 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, the NMFS Review considered the term, "threshold," to refer to either a minimum biomass or a maximum fishing mortality rate, beyond which some remedial action must be taken. The Review also states that the appropriate action is not necessarily closure of the fishery. For example, if a maximum fishing mortality rate is part of (or the entire) definition of overfishing, the appropriate action if the harvest rate exceeds this maximum is to reduce the harvest rate immediately. Similarly, if a minimum biomass level is chosen as a precautionary point, the appropriate action if the biomass goes below this level is again to reduce the harvest rate.

A threshold associated with a maximum fishing mortality essentially represents the act of *overfishing*, whereas a threshold associated with a minimum biomass represents a *depleted* stock condition or state. A depleted stock may or may not be in an *overfished* condition, depending on whether fishing or other (environmental) factors are responsible for the depleted state. The NMFS Overfishing Review recommended use of a fishing mortality threshold combined with a precautionary level of biomass, whereby the target fishing mortality would be reduced progressively as biomass falls below the precautionary level. The overfishing definition might also include an absolute biomass level which would trigger complete closure of the fishery.

Control Laws

Overall, the approach favored in the NMFS Overfishing Review was to define management strategies using control laws that combine reference levels of fishing mortality and biomass and specify both targets and thresholds (see Figure 1 for an example of a schematic control law). Harvest control laws express the two dimensions of the overfishing problem. On a control law graph, the abscissa usually refers to biomass or some other quantity which relates to the condition of the stock. The ordinate refers to fishing mortality rate or the catch quota, which relates to the act of fishing. The graph is termed a control law because it specifies the control that will be placed on the act of fishing given different stock conditions.

The harvest control law specifies a maximum fishing mortality rate for a stock in healthy condition, and some strategy for reducing F progressively as biomass falls below some precautionary level of stock (regardless of the reason for low stock size). It may or may not be desirable to also specify as part of the strategy a lower absolute biomass threshold below which fishing must cease or be restricted to bycatch only. 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 should provide good protection for the resource.

Alternative Biological Reference Points for Overfishing

Both fishing *targets* and overfishing *thresholds* are generally associated with biological reference points (BRP's) estimated from standard fisheries models (however, targets may also incorporate economic, social and other factors). 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}), static 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.

BRP's used as fishing targets can be grouped into three main categories: (1) yield-based reference points; for example, OY, MSY, maximum sustainable rent (MSR), and maximum constant yield (MCY), (2) fishing mortality rate based reference points (e.g.

$F=M$, F_{msy}, $F_{0.1}$, F_{max}, $F_{20\%}$ and $F_{35\%}$), and (3) biomass based reference points; for example, constant escapement, or the average or equilibrium stock size corresponding to a target fishing mortality rate (e.g. B_{msy}). The most frequently adopted targets are those based on reference levels of the fishing mortality rate (F).

Fewer BRP's have been developed to identify overfishing thresholds. The four main categories are (1) fishing mortality rate based reference points, (2) biomass based reference points, (3) recruitment based reference points, and (4) proxies. Examples follow:

<u>Fishing mortality thresholds:</u>

- F_{max}
- Fishing mortality rates associated with the slope at the origin of the stock-recruitment relationship (F_{ext}, F_{τ}, F_{high}, F_{rep}, F_{med})
- Fishing mortality rates associated with stock replacement (F_{rep}, F_{med})
- Constant fishing mortality rates associated with various levels of %SPR (e.g. $F_{20\%}$, $F_{10\%}$)
- Fishing mortality corresponding to 50% of the maximum recruitment estimated from a fitted stock-recruitment relationship.

<u>Biomass thresholds:</u>

- Minimum spawning biomass levels based on observed stock collapses
- 20% of the unfished stock biomass (20% B_0; e.g. Beddington and Cooke 1983)
- Other %B_0
- Biomass corresponding to the intersection of the 90th percentile survival ratio (R/S) and the 90th percentile of observed recruitments (Serebryakov 1991 and Shepherd 1991)
- Biomass corresponding to 50% of the maximum recruitment estimated from a fitted stock-recruitment relationship (Mace 1994).

<u>Recruitment thresholds:</u>

- Recruitment at 50% of the maximum recruitment estimated from a fitted stock-recruitment relationship.

<u>Proxies:</u>

- There are many cases where neither F nor B can be estimated explicitly due to lack of data. Proxies that may index F include truncated age distributions and small or decreasing mean size in landings or measures of fishing effort; those indexing biomass include low commercial catch per unit effort (CPUE) and low or markedly declining research survey indices.

Summary Conclusions from NMFS Scientific Review of Overfishing Definitions in U.S. FMP's

The NMFS Scientific Review of Overfishing Definitions ("NMFS Overfishing Review") was completed in August 1994 (Rosenberg *et al.* 1994). A panel of experts conducted a scientific review of the definitions of overfishing contained in U.S. fishery management plans. The review covered general scientific issues concerning the development and application of definitions of overfishing, established a set of criteria for evaluating definitions, and considered definitions for 117 U.S. stocks using these criteria. A summary of the criteria for evaluation and the overall results is given here.

Evaluation criteria and overall conclusions

The criteria adopted in the NMFS Overfishing Review for evaluating overfishing definitions are expressed as a set of 10 questions that should be answered for any definition:

1) Is the definition intended as a - **Target, Threshold, Both,** Neither? 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 overfishing definition level, in terms of fishing mortality rate or stock abundance. It is intended as a threshold if the overfishing definition defines a stock or fishery condition to be avoided. About half (52%) of the definitions are intended as threshold levels of fishing mortality rate or stock biomass. Most of the rest (45%) are intended as either a target level or as both a target and a threshold combined, though the latter the NMFS Overfishing Review concluded was inappropriate. In a few cases it could not be determined if the definition was intended as a target or a threshold.

2) Is the definition appropriate as a - **Target, Threshold,** Neither? The NMFS Overfishing Review judged that some overfishing definitions were clearly more appropriate as a target or a threshold. In some cases, a very conservative overfishing definition may be more appropriate as a target than as a threshold for fishing. A risky overfishing definition is appropriate as neither one. Most of the definitions (62%) are appropriate as threshold levels, with only 22% appropriate as targets.

3) Is the overfishing definition measurable? {Yes, No, (?)unknown} This question asks if the basic quantity used to define overfishing is measurable for the stock in question. In some cases, an overfishing definition may be measurable with the information on hand, even if the calculations have not been done. An overfishing definition is judged not measurable if the relevant biological information to calculate the current status relative to the overfishing definition is not currently available. Most of the definitions are measurable (89%).

4) Is the definition of overfishing operationally unambiguous? {Yes, No, (?)unknown} A definition is operationally unambiguous if it is clear how to calculate the overfishing definition and the current stock status relative to the overfishing definition. 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. About half (53%) of the definitions are unambiguous. The remainder need some clarification, although often only minor changes are needed.

5) Is recruitment beyond the overfishing definition level - Reduced, Unchanged (?)unknown? Reduced recruitment at the overfishing definition is indicated when the stock and recruitment data show substantially lower average recruitment at 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 when the fishery passes beyond the overfishing threshold. If expected recruitment declines, 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. Only 8% of the stocks clearly show reduced recruitment beyond the overfishing definition. However, for 72% of the stocks it is unknown whether recruitment is reduced, because the definition is set at or near the lowest observed level of abundance.

6) Is the fishery - OK, Overfished, Severely Overfished, Under fished, Under Recovery, (?)unknown? This question asks for a qualitative judgement on the current status of the resource relative to the overfishing definition. Most of the stocks (61%) under management are currently fully-exploited, but are not over-exploited.

7) Is the overfishing definition explicitly linked to corrective management actions? {Yes, No, (?)unknown} For some definitions it is clear what action is to be taken if the threshold is exceeded. For example, if a rebuilding plan has already been 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 the definition? Less than half (42%) are clearly linked to management actions. This mber may be an underestimate because the NMFS Overfishing Review did not consider ions of fishery management plans other than those relating to the overfishing definitions iselves.

8) Is the overfishing definition - Risky, Neutral, Conservative, (?)unknown? The NMFS Overfishing Review used the following framework to answer this question: An overfishing definition 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 overfishing definition is neutral if there is little expected reduction in recruitment until the threshold is crossed. An overfishing definition is conservative if little reduction in recruitment is expected until the stock is well beyond (i.e. on the "overfished" side of) the threshold. Most of the definitions (60%) are neutral or conservative. However, 16% were judged to be risky and should be revised as soon as possible.

9) Is the overfishing definition biologically and theoretically sensible overall? {Yes, No, (?)unknown} 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; and if it is unambiguous and measurable. If the overfishing definition is developed by analogy with other species, the basis for that analogy should be sound. Most definitions (63%) are sensible although many possible improvements were noted in the NMFS Overfishing Review. A definition may be sensible, but for some fisheries, additional benefits may accrue from being more or less conservative than the current definition.

10) Can the overfishing definition be improved with existing data? (Yes, No) and if so how. In some cases there were obvious improvements that could be made to a definition given the data at hand. In other cases, further research is needed before a clear improvement can made. Most of the definitions (80%) could be improved with the data currently available although the modifications are often very minor or simple, such as removing some ambiguity. The NMFS Overfishing Review suggested specific changes to each of these definitions.

In the view of the panel that conducted the NMFS Overfishing Review, 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.

The SPR Committee adopted the recommendations of the NMFS Overfishing Review insofar as possible.

Conclusions with respect to Gulf FMP's

The NMFS Overfishing Review concluded that all of the overfishing definitions examined for Gulf of Mexico finfish were biologically and theoretically sensible overall, but that they could almost all be improved to a greater or lesser extent. A summary of the suggestions for improvement follows.

Reef fish

Red snapper: Reduce fishing mortality at low biomass and set milestones for a rebuilding program.

Gulf of Mexico Red Grouper: Sex reversal needs to be accounted for in developing the overfishing definition.

Gulf of Mexico Vermillion snapper: None.

Gulf of Mexico Other Snapper-Groupers: The decision rule using relative abundance is sensible, but it is not equivalent to SPR, which makes the overall definition ambiguous. Sex reversal needs to be accounted for in developing the overfishing definition.

Coastal migratory pelagics

Gulf of Mexico King Mackerel: None

Gulf of Mexico Spanish Mackerel: Account for multiple spawning life history and clarify ambiguity between tiers of the overfishing definition.

Other coastal pelagics: Clarify ambiguity between tiers of the overfishing definition.

Red drum

Not evaluated.

SECTION II: TOPICS OF SPECIAL RELEVANCE TO GULF OF MEXICO FISHERIES

Rationale for Choosing SPR for Gulf of Mexico Fisheries

The SPR concept (both spawning per recruit and spawning potential ratio) was adopted by the Gulf of Mexico Fishery Management Council because it provided a conceptual basis for fish stock conservation that was not dissimilar to the more traditional management concepts of F_{max} and $F_{0.1}$, but seemed to place more emphasis on protection of spawning stock rather than maximization of yield.

This conceptual shift is useful when addressing multiple and diverse user groups. Maximization of yield or efficiency may be appropriate for commercial harvesting interests; however, when a fishery is also prosecuted by part-time commercial fishermen and recreational fishermen, it is more practical to focus management on goals such as conservation of spawning potential that may be common to all groups. Intrinsic constraints on overharvest may vary considerably between full-time commercial, part-time commercial, and recreational fishermen.

The SPR concept was adopted from stock assessment work that was being conducted on the northeast U.S. fisheries where a series of stock and recruitment data were available. These analyses indicated that a reasonable threshold of overfishing was the fishing mortality rate that, on average, provided for a spawning stock size that produced sufficient recruits to replace itself (Sissenwine and Shepherd 1987, Gabriel *et al.* 1989).

The SPR concept was first used in the southeast U.S. in the red drum FMP. It received even greater emphasis in the reef fish plan (Amendment 1). The SPR concept seemed to be a management paradigm that could unite all sectors of the fishing community with a single, universally applicable management constraint. Everyone, commercial and recreational fisherman alike, understands the need to "protect spawning stock" or "spawning females." In addition, reef fish had previously been managed under the more abstract concept of multispecies maximum sustainable yield which did not provide protection for individual stocks within assemblages.

From the outset it was recognized that use of a default 20% overfishing threshold was just a starting point, and that ultimately the threshold would be refined by spawner-recruit data collected from years of monitoring individual fish stocks.

For other overfishing definitions developed after those for red drum and reef fish (e.g. coastal pelagics and swordfish), overfishing thresholds were set at the 30% SPR level in order to be more "risk-averse." In none of the fisheries, including reef fish and red drum, was the goal to prevent overfishing clearly identified separately from the goal to restore a population to a healthy "target" level. This resulted in confusing, and sometimes seemingly contradictory, definitions of overfishing and optimum yield from one FMP to another.

Static vs. Transitional SPR

Conclusions reported in this subsection are excerpted from the Scientific Review of Definitions of Overfishing in U.S. Fishery Management Plans Supplemental Report (hereafter referred to as the NMFS Overfishing Supplemental Review), which resulted from a meeting conducted by NMFS in February 1996. The sole purpose of the meeting was to review transitional measures of SPR. A previous version of the current report used the terms "equilibrium" and "non-equilibrium" to differentiate between traditional measures of spawning (biomass) per recruit that assume constant mortality, growth and maturity schedules, and measures of spawning potential ratio that use empirical estimates of population numbers and fishing mortality. At the supplemental meeting, the NMFS Review Panel determined that the terms "static" and "transitional" were more accurate descriptors of the traditional and empirical measures.

All of the measures considered here relate primarily to fishing mortality, and do not index biomass *per se*, except in special circumstances (e.g. when most or all life history parameters are stationary, or tightly linked by a stock-recruitment relationship).

The NMFS Overfishing Supplemental Review identified several different methods of calculating transitional SPR. In this section, only two of these are considered: the (unweighted) transitional SPR which is the spawning production per recruit in year t relative to that which would have been produced in year t if there had been no fishing on the cohorts that exist in year t (SPR2 in Powers MS), and the weighted transitional SPR, which is the spawning production in year t relative to that which would have been produced in year t if there had been no fishing on the cohorts that exist in year t (SPR1 in Powers MS). Note that the term "transitional SPR" by itself is taken to mean the *unweighted* transitional SPR.

Equations for static and transitional SPR are given below, using the following notation:

- t = year
- r = age of recruitment into the fishery.
- G = maximum age of fish in the stock
- $N_{i,t}$ = number of fish of age i at the beginning of year t
- $P_{i,t}$ = per capita reproductive output of fish of age i at the beginning of year t (measured in egg mass per female or suitable proxy; most commonly expressed as average weight of fish of age i in year t multiplied by average proportion mature of age i in year t)
- $M_{i,t}$ = natural mortality rate of fish of age i during year t
- $F_{i,t}$ = fishing mortality rate of fish of age i during year t
- $Z_{i,t}$ = total mortality rate of fish of age i during year t ($= F_{i,t}+M_{i,t}$).

Static %SPR

$$\text{Static } \%SPR_t = \frac{\sum_{i=r}^{G} \left\{ P_{i,t} \prod_{\substack{j=r \\ i \neq r}}^{i-1} [\exp(-Z_{j,t})] \right\} \bullet 100\%}{\sum_{i=r}^{G} \left\{ P_{i,t} \prod_{\substack{j=r \\ i \neq r}}^{i-1} [\exp(-Z_{j,t})] \right\}}$$

The interpretation of the static %SPR (sometimes referred to as an equilibrium SPR, although its application need not be limited strictly to equilibrium conditions) is simple and unambiguous. It is the amount of spawning (measured as egg production or spawning biomass) per recruit for one or more cohorts fished using a constant fishing mortality pattern (constant selectivity combined with constant reference fishing mortality) throughout their lifespans, relative to the amount of spawning that would have occurred under the same conditions if there had been no fishing. While it assumes stationarity in terms of growth rates and mortality and maturity schedules, it does not require that recruitment be constant. For a given selectivity pattern, static %SPR maps 1:1 with fishing mortality. Thus, it can be used as a measure of the act of *overfishing*; i.e. it is a measure of the future outcome obtained by repeatedly applying a particular fishing mortality rate and selectivity pattern.

Transitional SPR

$$SPR2_t = \frac{\sum_{i=r}^{G} \left\{ P_{i,t} \prod_{\substack{j=r \\ i \neq r}}^{i-1} [\exp(-Z_{j,t-i+j})] \right\}}{\sum_{i=r}^{G} \left\{ P_{i,t} \prod_{\substack{j=r \\ i \neq r}}^{i-1} [\exp(-Z_{j,t-i+j})] \right\}}$$

Transitional SPR (SPR2 in Powers, MS; original derivation and discussion in Goodyear 1980, 1993) represents a straightforward extension of static %SPR that corresponds conceptually (although not mathematically) to a running average of fishing mortality rates. Transitional SPR is particularly useful in the context of rebuilding plans because it is tied to an implicit rebuilding target rather than an absolute biomass target which may be difficult to specify. If, for example, the rebuilding target was 20% SPR, then use of the static %SPR would imply that all that was necessary for "recovery" to have occurred would be for the fishing mortality to dip below $F_{20\%}$ in a single year, whereas use of the transitional SPR would imply that "recovery" will not have occurred until the negative effect of past high fishing mortality rates has been eliminated. Essentially, the aim is to rebuild the age structure of the stock. Transitional SPR indicates how close the age structure of the stock is to being rebuilt (even though the rebuilding target is expressed in relative rather than absolute terms). The supplemental Review Panel advocated more widespread utilization of (unweighted) transitional SPR, particularly in the context of rebuilding plans where it can be considered as a recovery target. The supplemental Review Panel further recommended that transitional SPR be used as a measure of the *overfished* condition. However, it must be recognized that "*overfished*" is not necessarily synonymous with "*depleted.*" Spawning or total biomass may be *depleted* due to adverse environmental effects, yet the stock may not be considered *overfished* based on estimates of transitional SPR. Similarly, a stock can be *overfished*, even though spawning or total biomass is high relative to optimum or historical levels. In effect, the term "*overfished*" can be thought of an index of the degree of distortion in the age structure due to historical fishing practices, whereas "*depleted*" simply implies low biomass. An *overfished* stock will often also have low biomass, but need not.

Weighted transitional SPR

$$SPR1_t = \frac{\sum_{i=r}^{G} \left\{ N_{r,t-i+r} \, P_{i,t} \, \prod_{\substack{j=r \\ i \neq r}}^{i-1} [exp(-Z_{j,t-i+j})] \right\}}{\sum_{i=r}^{G} \left\{ N_{r,t-i+r} \, P_{i,t} \, \prod_{\substack{j=r \\ i \neq r}}^{i-1} [exp(-Z_{j,t-i+j})] \right\}}$$

The weighted transitional SPR (SPR1 in Powers, MS) is not strictly analogous to static %SPR or transitional SPR, since it is not measured on a per recruit basis (i.e. it is sensitive to year class size). It is essentially the realized reproduction in a given year as a fraction of the maximum reproduction which would have been realized if existing cohorts had never been fished. Although conceptually appealing, the supplemental Review Panel concluded that interpretation of this index is not straightforward. The fact that the absolute value of the index is above or below the overfishing threshold reference point may not always be a good indicator of stock status.

Implementation of Static and Transitional SPR

Neither the unweighted or weighted transitional SPR is necessarily expected to correlate with biomass in any given year. Thus, neither measure is a good indicator of the extent of stock depletion *per se*, although both do in some way index the extent to which overfishing is responsible for the current stock condition: the unweighted transitional SPR reflects effects of historical fishing patterns on age structure, while the weighted transitional SPR reflects effects of both historical fishing patterns and recent recruitment on age structure.

In terms of the use of transitional SPR measures in control laws, the supplemental Review Panel believes that the unweighted transitional SPR can be considered an index of stock condition in terms of whether or not the stock is *overfished* (i.e. whether or not the age structure is distorted due to historical fishing patterns), but not in terms of whether or not the stock is *depleted* (with respect to total or spawning biomass) for reasons other than fishing). Thus, controls laws that specify lower thresholds beyond which fishing should cease probably need to consider explicit indices of biomass as well as, or instead of, the unweighted transitional SPR. Ideally, a control law (or series of control laws) would have axes corresponding to the act of *overfishing* (indexed by the static %SPR), the *overfished* condition (indexed by the unweighted transitional SPR, and used primarily as a recovery target) and *biomass* (indexed by absolute or relative estimates of biomass).

Both transitional measures suffer from a practical implementation problem. In order to calculate the denominators (i.e. amount of reproduction with zero fishing), it will often be necessary to expand the age classes well beyond the maximum age used in the stock assessment, and to extend estimates of recruitment back in time (so that there are at least as many years as ages). The net effect is that the fishing mortalities for many of the older ages may be based on simplifying assumptions (e.g. constant recruitment) rather than empirical observations. Elements of the same problem apply for the static %SPR, except that the static %SPR explicitly assumes a stable age distribution, and so the expansion to older ages is more straightforward. Another consequence of the need for extending the age distribution is that a number of years (equal to the number of assumed ages) will be incomplete and cannot be included in time series of calculations of the indices. Therefore, a long time series is required before estimates of transitional SPR can be calculated.

Sources of Bias and Uncertainty

Uncertainty in SPR estimation (both static and transitional) derives from uncertainties in the input parameters used. These uncertainties may be due to error and/or bias in parameter estimations or simply due to lack of knowledge. The SPR Committee recognized the relative importance of uncertainty of the following parameters:

1. Natural Mortality. Because of the cryptic nature of natural mortality processes, in the southeastern U.S. fisheries this parameter is usually estimated indirectly from knowledge of growth rates. Thus, uncertainty is not only related to the most likely value of M but also to its covariance with growth characteristics. Uncertainty in M is also related to a potential "drifting" of the true or effective natural mortality as a consequence of exploitation on predators and competing species. In general, target F's based on SPR appear to be less sensitive to uncertainties in M than ABC estimates based on these F's.

2. Potential Fecundity. Changes in the fecundity vector may have a significant impact on SPR estimates. Of significance in this case are uncertainties related to the dynamics of batch spawning and the effect of variable temporal-spatial exploitation rates on potential fecundity.

3. Exploitation Patterns. Changes in exploitation patterns are perhaps the most significant sources of variance in SPR estimation. These changes are due to: a) temporal-spatial changes in the availabilities of fishing effort relative to fish abundance, b) changes in gear

types historically used in the fisheries, c) changes in minimum size, and d) spatial gear restrictions.

4. Maturity Schedules. Uncertainty in SPR estimations due to uncertainty in maturity schedules originate from: a) length to age conversions of maturity at length fractions and the absence of maturity age-length keys, b) maturity schedules estimated from procedures significantly differing in the way the express maturity (e.g. GSI, vitellogenesis, etc.). These uncertainties directly affect SPR estimation.

5. Recruitment Patterns. Recruitment variability can play a major role when defining reference fishing mortality since recruitment patterns may influence the choice of threshold and target values. Uncertainty in recruitment patterns may be due to natural variability associated with parent stocks and the environment, or to estimation errors. In southeastern U.S. fisheries, a significant amount of the uncertainty about recruitment patterns may be associated with short term changes in the environment. Uncertainty in recruitment patterns only affects estimation of the weighted transitional SPR. It is important to remember that the unweighted transitional SPR is insensitive to year class size. Thus, a large year class moving through the fishery shortly after implementation of restrictive measures might appear to represent a "recovery" to fishermen because of the increased abundance of fish. However, unless restrictive measures remain in place long enough to rebuild the age structure of the stock (i.e. to sufficiently increase the proportion of older mature fish in the stock), the large year class may soon be fished out and the stock will quickly revert to its previous condition. It appears that this situation has occurred with both Gulf red snapper and king mackerel. Fortuitously large year classes can occur due to favorable environmental conditions in a particular year but sustained strong year classes can only be maintained with a stock that has sufficiently large numbers of adult spawning fish.

6. Growth. Although growth appears to be the easiest population parameter to estimate, there are many uncertainties as to the accuracy and precision of the estimates. Some of the uncertainties may be due to an artifact of fishing (i.e. exploitation patterns) on sampling, as well as selective removal of larger but not necessarily older fish. Thus, there is confusion if in fact changes in growth parameters are due to density dependent effects or to statistical artifacts. Since uncertainties in growth parameter estimation is expanded to M estimation, then covariance among these parameters must be understood before this uncertainty can be incorporated into SPR estimates.

At present, computer intensive methods such as bootstrapping and Monte Carlo simulations greatly facilitate exploration and evaluation of uncertainty and bias in SPR estimation. One concern, however, is related to the appropriate linkages of the different sources of uncertainty and their functional relationships (covariance) on overall SPR and ABC estimation.

Special Considerations Based on Relevant Life History Strategies

Protogynous vs. gonochoristic species

Two of the species considered by the SPR Committee, *Epinephelus morio*, red grouper, and *Mycteroperca microlepis*, gag, are protogynous hermaphrodites which means that juveniles usually mature into females and later some females become males (Table 1). Not all females will become males and transition to males occurs at intermediate ages (Moe 1969). Bannerot (1984, Bannerot *et al.* 1987) evaluated the influence of protogynous hermaphrodism on population dynamics through simulation and concluded that if sperm were not limiting, then these species would be more resilient regarding fishing pressure.

Unfortunately, there has not been any direct experimental work on sperm limitation on either gag or red grouper. Shapiro showed that the sex change can be completed rapidly (initiated by median day 3 and completed within two weeks) based on his experimental work with a Pacific species of serranid, *Anthias squamipinnis*, in which 58 males were removed and 57 females changed sex (1980). He later argued that the scarcity of transitional fish is additional evidence of a quick sex change (Shapiro 1987). His work also indicated that sex change depended upon the loss of a male and that a mature female could change independent of size or age. Red hind from Puerto Rico, another protogynous hermaphrodite, occur in small clusters of two to seven fish, and some of the clusters contain one male while others contain no males. These clusters with many females to one male illustrate a mechanism for density-dependent compensation in the spawner-recruit relationship. The underlying assumption is that during the spawning season one of the females in a cluster without males will become male. Shapiro (1987) concluded that the removal of a male is no different than the removal of a female.

Shepherd and Idoine (1993) noted that the effect of transition of females to males acts like higher natural mortality on females and thus by ignoring the transition, the percent maximum spawning potential (%MSP) will be under-estimated. Huntsman and Schaaf (1994) simulated the effects of fishing using the life history parameters of graysby, *Epinephelus cruentatus*, that also illustrated that the higher spawning potential of protogynous hermaphrodism is due to a lower biomass for unfished females. An extension of their model showed no differences in spawning potential between protogynous hermaphrodism and gonochorism when spawning potential was calculated using both sexes. Thus, the management consideration is that not incorporating sex change into spawning potential may result in a more useful, albeit conservative, measure of stock status.

Warm water vs. temperate species

Conover (1992) noted that the onset of spawning tends to occur earlier in lower latitudes and lasts longer. The species of interest here spawn at various times of the year, mature between ages two and six, are batch spawners, and are long lived except for the mackerels (Table 1). Murphy (1968) noted that having a long life and reproducing many times is a good strategy if the conditions favoring good recruitment are variable. Koslow (1992) further argues that while this reproductive strategy results in the wastage of reproductive output, it provides resilience by spreading reproductive products over a spatially and temporally heterogeneous environment, thus providing opportunity for successful development.

Batch spawning

Batch spawning allows for higher annual fecundity without having to maintain a correspondingly larger body size and it makes a population more resilient to recruitment failure by having fertilized eggs in the environment in the event that conditions are conducive for egg or larval survival. Another benefit is that the fish incur a smaller investment in eggs at any one time.

Spawning biomass frequently is used as a proxy for egg release based upon linear relationships between body weights and number of mature eggs in the ovaries. Many species have shown wide variability in the estimated number of batches per season. Collins *et al.* (1994) suggested that older female gags (ages 7-9) may spawn more frequently than younger fish (ages 4-6). If older fish typically spawn longer or more frequently during the season then using spawning biomass as a proxy for fertilized egg production will overestimate the spawning potential ratio (i.e. underestimate the negative effects of high fishing mortality) because the increased contributions of older fish are not taken into account.

TABLE 1. Life history summary.

Species	Reproductive Strategy	Spawning Season	Spawning Peak	Age of Maturity	Batch Spawner	Maximum Age	Natural Mortality
Gag[1,2,3]	Protogynous	Dec-- May	Feb - Mar	3	Yes	26	0.15 - 0.20
Red Grouper[4,5]	Protogynous	Mar - May	Apr	4-6	?	24	0.20
Red Snapper[6,7]	Gonochoristic	May - Sep	Jun - Aug	3-7	Yes	42	0.20
King mackerel[8,9]	Gonochoristic	May - Oct	Jun - Aug	4	Yes	11+	0.15
Spanish mackerel[10,11]	Gonochoristic	Apr - Sep	May - Jul	2	Yes	7+	0.30
Red Drum[12,13]	Gonochoristic	Aug - Oct	Sep - Oct	3-6	Yes	39	0.13 - 0.31

1. Hood and Schlieder 1992; 2. Collins *et al.* 1987; 3. Schirripa and Goodyear 1994; 4. Moe 1969; 5. Goodyear and Schirripa 1993; 6. Nelson and Manooch 1982; 7. Goodyear 1994; 8. Finucane *et al.* 1986; 9. Beaumariage 1973; 10. Powell 1975; 11. Finucane and Collins 1986; 12. Murphy and Taylor 1990; 13. Wilson and Nieland 1994

Habitat degradation and enhancement

Fishermen and managers alike often point to habitat degradation or destruction, such as loss of wetlands, as a factor in decreased abundance of stocks. Conversely, some reef fish fishermen and proponents of artificial reefs have suggested that increased reef habitat from oil and gas rigs or artificial reef building may increase stock abundance by increasing the recruitment success of reef fish. If changes in habitat availability result in changes in recruitment survival for a given level of spawning stock biomass, then it can be inferred that static and transitional SPR levels for OY targets and/or overfishing thresholds, or TAC's associated with a given SPR level, will also change. Increased recruitment survival would allow a higher TAC for a given SPR (or a lower SPR to sustain a given TAC), and the reverse would occur for decreased recruitment survival. However, changes in habitat availability affect recruitment survival only if recruitment is habitat limited. In stocks which are depressed due to other human induced factors, such as overfishing or bycatch mortality, habitat is unlikely to be the limiting factor in the current status of stocks or in the early stages of recovery.

SECTION III: EVALUATION OF CURRENT SPR REFERENCE POINTS FOR GULF OF MEXICO SPECIES

The SPR Committee considered definitions of optimum yield (OY) and overfishing for three Gulf FMP's: the Reef Fish FMP, the Coastal Pelagics FMP and the Red Drum FMP. The species singled out for special consideration were:

red snapper
red grouper
gag
king mackerel
Spanish mackerel
red drum

The current definitions of optimum yield and overfishing for each FMP are given below, along with the plan amendment and publication date in which the current wording first appears. For each of the species, there is a brief narrative covering background information on life history and fishery characteristics, data and methods used to determine stock status, current stock status, and recommendations. The recommendations for each FMP or species are carried forward and reiterated in Section IV. It should be noted that the SPR Committee restricted its evaluation to the basis for the overfishing definitions, but did not evaluate the basis for the stock assessments themselves (including the basis for stock boundaries).

Reef Fish FMP
(red snapper, red grouper, gag)

Definition of Optimum Yield (from Reef Fish Amendment 1, August 1989)

The primary objective and definition of Optimum Yield (OY) for the Reef Fish Fishery Management Plan is any harvest level which maintains, or is expected to maintain, over time a survival rate of biomass into the stock of spawning age to achieve at least a 20 percent spawning potential ratio (SPR).

Definition of Overfishing (from Reef Fish Amendment 1, August 1989)

1. A reef fish stock or stock complex is *overfished* when it is below the level of 20 percent SPR.

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 SPR 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 optimum yield on a continuing basis.

(Note: Reef Fish Amendment 1 originally used the term SSBR - Spawning Stock Biomass per Recruit. This was changed to SPR in Reef Fish Amendment 3, February 1991.)

Recommendation

The definition of OY for reef fish should not be the same as the definition of overfishing, as is currently the case. However, any change that is made should specify OY in measurable terms.

<u>Red snapper</u>

<u>Background:</u> Red snapper are long-lived and slow-growing, with an age of 50% maturity of about 3-4. Natural mortality has recently (1995) been revised from 0.2 to 0.1. Gulf of Mexico red snapper have been heavily exploited for many years. A particularly notable aspect of the exploitation pattern is the large amount of shrimp trawl by-catch of ages 0 and 1, resulting in extremely high juvenile fishing mortality rates. Historic survey data indicate that recruitment was much higher in the period pre-dating the current Virtual Population Analysis (VPA) assessments (i.e. in the 1970s; see Figure 2).

<u>Assessment methods and data:</u> The status of the red snapper stock relative to overfishing is assessed using transitional SPR based on estimates derived from VPA. This places red snapper into the first tier definition of overfishing, as recommended by the SPR Committee (see Section IV). Data have been compiled from a variety of sources, including the Fall Groundfish Survey, the Summer SEAMAP Survey, the Marine Recreational Fishery Statistics Survey, the NMFS Headboat Survey, and samples of commercial and recreational catches from the Trip Interview Program of the State/Federal Cooperative Statistics Program.

<u>Current stock status:</u> The red snapper resource is currently defined as overfished, as it is estimated to be well below the 20% SPR minimum required by the Gulf of Mexico Reef Fish FMP. Estimates of static %SPR and (unweighted) transitional SPR for red snapper in 1993 were about 1.3% and less than 1%, respectively. A rebuilding plan for red snapper in the Gulf of Mexico was developed in Amendment 1 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico. Conservation measures now in place for the directed commercial and recreational fisheries are enhancing the resource, but unless the bycatch of juvenile red snapper in the commercial bottom trawl fishery for shrimp is reduced by 50%, it is unlikely that the 20% SPR goal can be reached by the recently-revised 2019 target date.

The median fishing mortality rate based on stock-recruitment estimates is considerably higher than either $F_{20\%}$ or $F_{5\%}$ (Figure 3), suggesting that the stock could potentially sustain itself at recent levels, even at relatively high levels of fishing mortality; however, the present stock size is not considered "optimal" since it is known that recruitment was much higher in the period pre-dating the stock-recruitment estimates (i.e. in the 1970s; see Figure 2).

Recommendations

The definition of overfishing for red snapper should incorporate measures of both the overfished condition and the act of overfishing (see Section IV). A static %SPR of 20% is considered to be a reasonable overfishing threshold, because there is no reason to believe that red snapper is any more or less resilient than an "average" finfish, for which a static level of 20% has been repeatedly advocated in the scientific literature. The red snapper rebuilding program should make consistent progress toward restoring the stock beyond the overfished state within a reasonable time frame.

Red grouper

Background: Red grouper are primarily landed in the eastern Gulf of Mexico and typically account for about 70% of shallow-water groupers. They appear to have been moderately exploited since 1979, with average landings of approximately 3,000 MT (6.6 million pounds). Historical landings varied without trend until 1990 when the minimum size was increased to 20 inches. Red grouper are protogynous hermaphrodites, switching from female to male beginning at about five years of age.

Assessment methods and data: Red grouper have been assessed by VPA (ADAPT). However, Goodyear (1994) concluded that sampling procedures introduce substantial bias into stock assessments in the case where ages are assigned using growth models based on observations collected with length-stratified sampling, size selective gears, or from fisheries with minimum size regulations. He was unable to adjust for the bias resulting from the minimum size and noted that the 1993 stock assessment results may not reflect the state of the stock.

Current stock status: Goodyear (1994) presented eight estimates of pre-regulation transitional SPR that ranged from 20% to 52% depending upon the growth model assumed. While he was unable to determine the current transitional SPR, it would be unlikely that the current SPR would be lower after the increase in minimum size. The 20% threshold seems reasonable based on (i) the life history of red grouper (protogynous hermaphrodites) which probably increases their resilience, (ii) their steady historical landings, and (iii) the estimates of transitional SPR prior to the change in minimum size.

Recommendations

The status of red grouper should be evaluated based on a measure of overfishing only (see Section IV). The SPR Committee recommended a static %SPR of 20% (i.e. $F_{20\%}$) to index the overfishing threshold. The reasons that red grouper is assigned a threshold of 20% (rather than the 30% level recommended for other species with insufficient reliable data) are that (i) despite problems with VPA analyses, these and other preliminary stock assessment runs lead to a high degree of confidence that the stock is not currently overfished, suggesting that the current fishing mortality rate may be sustainable, (ii) examination of static yield per recruit and spawning per recruit results shows that $F_{20\%}$ is not unreasonably high compared to other reference points (e.g. $F_{current}$ and F_{max}), (iii) in contrast to some other protogynous species, red grouper do not appear to have exhibited any detectable decline in the relative proportion of males over the last 30 or so years, and (iv) females mature at a small size and the stock may therefore have relatively high compensatory reserve.

Gag

Background: Gag stocks are primarily located in the eastern Gulf of Mexico where they sustain modest commercial and recreational fisheries. Landing statistics are usually biased since gag grouper can be easily misidentified as black grouper. In stock assessment work a correction is made to landings to reflect this bias. Gag landings are available since 1986 as separate statistics from overall grouper landings. Gag landings have been stable at about 1.5 million pounds, with 78% of the landings in numbers attributed to the recreational fishery and 22% to the commercial sector.

Assessment methods and data: Biological data available for stock assessment are limited to maturity and fecundity, length frequencies of landings, and age-length relationships. These data are used to estimate age compositions in the landings since no age-length keys are available for this purpose. The status of exploitation is obtained from VPA, catch curve analysis, and yield and egg per recruit analyses. Fishery data consist of corrected landings and catch per unit effort from the hook and line commercial fishery and head boat fishery. These indices are used to calibrate VPA using the ADAPT algorithm.

Current stock status: Stock assessment results indicate that the highest fishing mortality for 1992 was 0.21 for age 5 fish (assuming $M = 0.20$). With available information on growth and natural mortality, the biological reference point, $F_{0.1}$, was estimated to be 0.17. The static %SPR assuming a 30% release mortality among undersized fish was estimated to be 30% in 1992. These results, coupled with CPUE trends which are characterized as stable, indicate that the fishery is probably not overfishing gag stocks. The 1992 estimate of static %SPR for gag is about 30%. (The median fishing mortality rate based on existing stock-recruitment estimates suggests that fishing mortality rates much lower than either $F_{30\%}$ or $F_{20\%}$ are needed for stock replacement (Figure 5); however, there are too few data to draw useful conclusions.)

In order to improve the reliability of stock assessment results, it is necessary to obtain age-length keys for aging landed fish, and to determine the best way to measure spawning potential for protogynous hermaphrodites.

Recommendations

As is the case for red grouper, the status of gag stocks should be evaluated based on a measure of overfishing only (see Section IV). The SPR Committee recommended a static %SPR of 30% (i.e. $F_{30\%}$) to index the overfishing threshold. The reasons that gag is assigned a threshold of 30% (rather than the 20% level recommended for red grouper) are that (i) there is greater uncertainty about current stock status, and therefore about the sustainability of the current fishing mortality rate, (ii) examination of static yield per recruit and spawning per recruit results shows that $F_{20\%}$ is about 3-4 times higher than $F_{current}$, and also considerably higher than F_{max}, and (iii) there is a possibility that the proportion of males in the stocks may have declined to very low levels in recent years.

Coastal Migratory Pelagics FMP
(king mackerel, Spanish mackerel, cobia)

The Coastal Pelagics OY definition was copied verbatim from the Amendment and includes specific poundage estimates of MSY and TAC. The poundages vary from year to year, and the specific amounts are part of the OY definition only for the year in which they appear (and subsequent years until modified).

Definition of Optimum Yield

OY for Mackerels (from Coastal Pelagics Amendment 1, April, 1985)

The long-term goal of optimum yield from mackerels is maximum sustainable yield. The yield which may be harvested annually for each species, defined as total allowable catch (TAC) may vary due to fluctuating recruitment; fluctuating abundance by area or unit of stock; intensity of fishing effort by area or unit of stock; social, economic, or ecological factors; and improved estimates of MSY.

OY for Cobia (from Coastal Pelagics original Fishery Management Plan, February, 1983)

For cobia, optimum yield is defined as all cobia equal to or larger than 33 inches in length from the tip of the head to the center of the tail (fork length) (37 inches in TL) which can be harvested by U.S. fishermen. MSY is estimated at 1,057,000 pounds, estimated domestic annual harvest (EDAH) is estimated as 1,000,000 pounds, and total allowable level of foreign fishing (TALFF) is zero.

Note: Coastal Pelagics Amendment 3 (January 1990) further states (on page 17), "Under the FMP, the TAC from which allocations and quotas are derived represents the annual specification of OY."

Definition of Overfishing (Appendix I, Coastal Pelagics Amendment 6, June 1992)

a. A mackerel or cobia stock shall be considered *overfished* if the spawning potential ratio (SPR) is less than the target level percentage recommended by the assessment panel, approved by the Scientific and Statistical Committee (SSC), and adopted by the Councils. The target level percentage shall not be less than 20 percent.

   (Based on the recommendation of the assessment panel and approved by the SSC, the Councils and the Regional Director (RD) have approved an SPR of 30 percent for king and Spanish mackerels.)

b. 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 panel will develop ABC ranges based on a fishing mortality rate that will achieve and maintain at least the minimum specified SPR. The recovery period is not to exceed 12 years for king mackerel beginning in 1985 and 7 years for Spanish mackerel beginning in 1987.

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 panel will develop ABC ranges based upon OY (currently MSY).

King mackerel, Spanish mackerel, cobia

Background: Coastal pelagics within the purview of the South Atlantic and Gulf of Mexico Fishery Management Councils include king mackerel, Spanish mackerel and cobia. Current scientific understanding indicates that each of these species can be effectively managed by dividing stocks into Atlantic versus Gulf of Mexico components. However, the stock boundaries are not coincident with Council boundaries. In particular, the current boundary between Atlantic and Gulf king mackerel is on the east coast of Florida: shifting from the north (Volusia-Flagler county line) in the winter to the south (Monroe-Collier county line) in the summer. Additionally, there has been evidence for further genetic division of king mackerel within the Gulf of Mexico. However, that evidence has not precluded the effective management of U.S. Gulf of Mexico king mackerel as a separate management unit.

King and Spanish mackerels are relatively fast growing species compared to the "average" finfish. King mackerel may mature at 2 years of age but most do not mature until 4 years of age. Spanish mackerel mature at 1 year of age. The growth rate of king mackerel is slower than that of Spanish mackerel. Brody growth coefficients (K) are about 0.21-0.35 for king mackerel and 0.45-0.48 for Spanish mackerel. Cobia are also considered to be fast-growing fish with estimates of K of about 0.23-0.28. Natural mortality rates are assumed to be 0.15 for king mackerel, 0.3 for Spanish mackerel and 0.4 for cobia.

Assessment methods and data: King mackerel stocks are evaluated using virtual population analyses (VPA's) for the years 1979 to the present. The initial year (1979) represents the first year for which recreational catch estimates were available. However, significant recreational and commercial fisheries existed in the 1970s; therefore, the 1979 stock status was already in an exploited state (especially in the Gulf of Mexico). Additionally, in the Gulf of Mexico there is a significant fishing mortality rate on age 0 fish due to bycatch in shrimp trawls. This detracts from the directed fisheries. Currently, the allowable biological catch (ABC) for the king mackerel stocks is defined as the catch resulting from the fishing mortality rate on the directed fisheries which will produce a static %SPR of 30%. The estimates of ABC are presented as a probability distribution from which the Councils make their total allowable catch (TAC) selection.

Spanish mackerel are evaluated using similar methods and criteria as those used for king mackerel except that the initial year for VPA analyses is 1984. Significant fisheries on Spanish mackerel existed prior to 1984; however, size sampling was not sufficient to allow inclusion of the prior years in the VPA. Additionally, as with king mackerel, recreational catches represent a large proportion of the overall catch of Spanish mackerel, and recreational estimates were not available prior to 1979. Bycatches of age 0 and 1 Spanish mackerel in the Gulf of Mexico are also significant.

Cobia are also evaluated using VPA's from 1984 to the present. Size sampling as been very sparse and indices of abundance used to calibrate the VPA's are limited in scope. Catches of cobia in both the Atlantic and Gulf of Mexico are largely recreational. However, there is a significant bycatch of age 0 fish in the Gulf of Mexico shrimp trawls.

Current stock status:

Restrictive management measures for king mackerel were imposed beginning in the 1985-86 period through a system of quotas, bag limits and allocations to different user groups. The result has been that the Gulf of Mexico king mackerel have begun recovery from an overfished state. Current estimates of static %SPR and transitional SPR for Gulf king mackerel are not available at this time, due to the need for further data analysis before the 1996 stock assessment can be completed. The Atlantic king mackerel have not been so severely exploited and are believed to be near optimum conditions (both static and transitional SPR are about 32%).

A management system of quotas, bag limits and allocations for Spanish mackerel was imposed in 1987 at which time the status of both Atlantic and Gulf of Mexico Spanish mackerel was considered overfished. These restrictions, along with a ban on entangling gear in Florida beginning in June 1995, have allowed the Gulf and Atlantic groups to recover from the overfished status. Current estimates of static %SPR and transitional SPR for Gulf and Atlantic Spanish mackerel are all slightly higher than 20%.

Assessments indicate that neither the Gulf nor Atlantic cobia should be considered overfished at this time. There has been no trend in catches, indices of abundance or size frequencies during the period of the data.

Recommendations

The status of king and Spanish mackerel stocks should incorporate measures of both the overfished condition and the act of overfishing (see Section IV), whereas cobia should be evaluated based on a measure of overfishing only.

For the coastal pelagics, the SPR Committee felt that the overfishing definition should be consistent with the reef fish definition. For king and Spanish mackerel, this would result in a decrease in the threshold (static and transitional) SPR from 30% to

20%. The SPR Committee felt this was reasonable since there is no reason to believe that the two species of mackerel are any more or less resilient than reef fish (they are shorter-lived and faster-growing), or than the "average" finfish. However, the Committee recommended that the current rebuilding strategy be continued until the 30% level (which may be close to an appropriate OY or MSY target) is attained.

Red Drum FMP

Definition of Optimum Yield (from Red Drum Amendment 2, March 1988)

OY is defined as:

1. All red drum recreationally and commercially harvested from state waters landed consistent with state laws and regulations under a goal of allowing 30 percent escapement of the juvenile population.

2. All red drum commercially or recreationally harvested from the Primary Area of the EEZ under the TAC level and allocations specified under the provisions of the FMP, and a zero retention level from the Secondary Areas of the EEZ.

Definition of Overfishing (from Red Drum Amendment 2 - footnote on page 6, March 1988)

Overfishing is defined as a fishing mortality that prohibits attaining the spawning stock goal or threshold which is currently set at a 20 percent SSBR ratio.

Red drum

Background: Red drum in the Gulf of Mexico mature early (3-5 years of age), grow rapidly during this subadult phase, and live upwards of 40 years of age. The subadult phase is spent principally in estuarine areas, moving out of these areas with the onset of maturity, forming offshore schools of adult red drum. Spawning occurs in the fall in the passes. Recreational fishing has occurred historically in the inshore areas on subadults, with little or no fishing pressure on mature adults prior to the mid-1980s. Fishing pressure on the subadults increased during the mid-to late 1970s to very high levels of fishing mortality. Beginning in the mid-1980s, a large increase in fishing mortality occurred on the adults (via purse seines). A moratorium on fishing in the EEZ occurred after 1986. Overfishing was defined as the fishing mortality resulting in transitional SPR below 20%, and measured by escapement through age 3, initially set at 20% of unfished stock, but later increased to 30% to be "conservative."

Data Availability: The catch matrix (ages 0-35+, and years 1979-1991, Goodyear 1993) for VPA analysis included commercial and recreational reported landings and sampling for size (fecundity data from C. Wilson (LSU); age-length data from C. Wilson (LSU), M. Murphy (FDEP), Gulf Coast Research Laboratory, TPWD, and Pearson (1929); adult age structure from C. Wilson (LSU) and M. Murphy (FDEP); mark-recapture data from TPWD, LDWF, M. Claverie (LA GCCA), Gulf Coast Research Laboratory, ADMRD and ADCNR, and FDEP; various indices of recruitment including bag-seine samples from TPWD, and LDWF, gill-net samples from TPWD, LDWF, and Gulf Coast Research Laboratory, and trammel-net samples from LA DWF). The gill-net samples from Texas PWD and Louisiana DWF were used to tune the VPA.

Analytic Approaches: VPA techniques were used to estimate fishing mortality rates. Relative escapement through age 3 was estimated from these fishing mortality rates for 1979-1991. Estimates of transitional SPR were made for 1979-1991 and projected through 1997.

Current Status: Estimates of escapement through age 3 averaged about 10% in the early 1980s to about 1% in 1986/1987, increasing to above 40% in 1991. The transitional SPR was estimated to be about 10% in 1992, but is projected to reach 20% by 1997 under existing regulations. The 1992 estimate of static %SPR for red drum was about 44%. The median fishing mortality rate based on stock-recruitment estimates is higher than either $F_{30\%}$ or $F_{20\%}$ (Figure 7), suggesting that the stock will increase in size if fishing mortality can be reduced below $F_{20\%}$.

Recommendations

The current overfishing definition for red drum should be replaced with the SPR Committee's suggested overfishing definition given in Recommendation 16 in Section IV. The status of the red drum stock should be evaluated using the Preferred Definition.

The Council should recognize that, due to the selectivity patterns exhibited by red drum fisheries (high fishing mortality on juveniles), MSY is considerably lower than might otherwise be the case.

SECTION IV: RECOMMENDATIONS FOR FUTURE DEVELOPMENT OF OY AND OVERFISHING DEFINITIONS

The following recommendations were reached by Committee consensus.

Definitions and Interpretation

1. The following standardized terminology should be adopted and used consistently:

Target: the word, *target*, refers to the management target, OY, which may incorporate biological, economic, social and other relevant factors. (The SPR Committee only considered the biological components of targets)..

Threshold: the word, *threshold*, refers to the biological reference points that delimit the act of *overfishing* and/or the *overfished* condition and/or a *depleted* stock condition. The *threshold* delimiting the act of *overfishing* essentially refers to the current fishing mortality rate (or, more correctly, the current fishing mortality vector); the *threshold* delimiting the *overfished* condition refers to the extent of stock depletion due to fishing; the *threshold* delimiting a *depleted* stock condition refers to the size of the recruited biomass relative to optimum or historical levels. In contrast to management *targets*, *thresholds* are based only on biological considerations.

Overfishing: the word, *overfishing*, refers to an unacceptably high fishing mortality rate that exceeds a *threshold* fishing mortality rate.

Overfished: the word, *overfished*, refers to an unacceptably poor stock condition due to past *overfishing* resulting in a stock condition that is below the *threshold overfished* level.

Depleted: the word, *depleted*, refers to a stock biomass that is low relative to optimum or historical levels (due either to fishing or environmental factors or both).

Static SPR: a spawning per recruit analysis, analogous to yield per recruit, that assumes fishing mortality and all other inputs except recruitment are constant.

Transitional SPR: spawning production per recruit in year t relative to that which would have been produced in year t if there had been no fishing on the cohorts that existed in year t (SPR2 in Powers MS). Transitional SPR may also be called the *unweighted transitional SPR*, in cases where there is a need to differentiate it from the *weighted transitional SPR*.

Weighted transitional SPR: spawning production in year t relative to that which would have been produced in year t if there had been no fishing on the cohorts that existed in year t (SPR1 in Powers MS).

2. *Thresholds* should be treated as limits which the stock or fishery should never cross (unless the stock is already beyond the *threshold*), whereas *targets* should be treated as reference points about which the stock or fishery is expected to fluctuate (provided the fluctuations are of sufficiently low magnitude that they do not cross the *thresholds*).

3. The definitions of overfishing required for each FMP should incorporate definitions of both the degree of *overfishing* (i.e. the current fishing mortality rate) and the *overfished* condition (i.e. measures of the effects of fishing on stock condition). Since a stock can be *depleted* (due to environmental factors) without being *overfished*, biomass *thresholds* should also be considered for incorporation into overfishing definitions, particularly in cases where there is a need to define a minimum stock size below which fishing activities should cease or be severely curtailed (e.g. restricted to bycatch only). Biomass *thresholds* can be expressed in terms of absolute or relative measures of stock biomass (e.g. VPA estimates, commercial CPUE, research survey catch rates). However, it is often difficult to define biomass *thresholds* because reference biomass levels corresponding to the optimum (e.g. B_{msy}), or the maximum (i.e. the unfished biomass), or the level below which the probability of stock collapse becomes unacceptably high, may be unknown. One common method of specifying a biomass *threshold* is to examine or fit stock-recruitment data and determine a lower limit of biomass on the left-hand limb of the stock-recruitment relationship that corresponds to a "significant" reduction in recruitment compared to maximum levels (e.g. the biomass corresponding to a recruitment equal to 50% of the estimated maximum recruitment; NMFS Overfishing Review Panel, 1994). However, if there are few or no observations at sufficiently low spawning biomass, there is little general guidance about the levels of biomass that should be chosen to represent a *depleted* stock condition. The SPR Committee recommends that individual Stock Assessment Panels should evaluate the potential for specifying biomass *thresholds* on a stock by stock basis.

4. The SPR Committee did not consider individual OY definitions in detail, since Committee members did not have the expertise to integrate economic, social, and other relevant concerns with biological targets. However, the Committee did agree that certain characteristics should be essential components of valid definitions of OY:

   - OY should be based on the biological target of MSY (or associated reference points such as F_{msy} or B_{msy}), modified appropriately by economic, social, and other relevant factors.

   - when MSY cannot be calculated reliably, as is generally the case, it is suggested that static %SPR levels in the range 30-40% be used as surrogates for F_{msy}. This range is based on values in the scientific literature; e.g. Clark (1991, 1993) conducted several analyses that suggested $F_{35\%}$ as a reasonable surrogate for F_{msy} over a wide range of life history characteristics. In general, the low end of the range should be used for resilient species and the high end for species that have low fecundity and/or are slow-growing, late-maturing, or long-lived.

- the definition of OY should be operational (i.e. measurable).

- OY (the *target*) should be sufficiently distinct from the *threshold* that there is a low probability that the *threshold* will be crossed.

- OY should be sufficiently distinct from the *threshold* that the difference between the two is measurable.

5. The SPR Committee did not consider individual rebuilding plans in detail, due to time constraints. However, the Committee did agree that certain characteristics should be essential components of rebuilding plans:

- The ultimate goal of a rebuilding strategy should be to restore the stock to a specified target level (e.g. the level associated with OY); i.e. the rebuilding plan should not be abandoned as soon as the stock is barely restored to the correct side of the *threshold*, as there may be a high probability that the stock will soon revert to an *overfished* or *depleted* condition.

- Rebuilding plans should include a reasonable time horizon for recovery (specified by the Council), and should be designed to make consistent progress towards recovery. Consistent progress means that there is no grace period before a rebuilding plan is implemented, and that there should be milestones along the way related to improvements in the quantities used to define the degree of *overfishing* or the *overfished* status.

<u>Analytical Considerations</u>

6. The static %SPR (which, for a given selectivity pattern, corresponds to a unique fishing mortality rate) should be used as a measure of the extent of *overfishing*. The (unweighted) transitional SPR (SPR2 in Powers MS) should be used as a measure of the *overfished* condition. Absolute or relative measures of stock biomass should be used to index stock *depletion*, but the determination of whether to use biomass *thresholds* and how to calculate them if used should be referred to individual Stock Assessment Panels.

7. Pending further evaluation of alternative measures of transitional SPR, a single, unique definition should be used for all evaluations conducted for U.S. stocks. Currently, there are at least two different measures that have been used for Gulf of Mexico stocks: the weighted and unweighted transitional SPR (see Section II). Based on the conclusions of the NMFS Overfishing Supplemental Review, the unweighted

transitional SPR (SPR2 in Powers MS) should be preferred.

8. Definitions of static %SPR and transitional SPR should be presented as part of the overfishing definition, both as written statements and mathematical equations, either as explicit components of the overfishing definition, or else as part of the surrounding explanatory text.

9. Ongoing research into methods for identifying and dealing with bias and uncertainty in the estimation of SPR should be encouraged.

10. In most cases, it appears that there is no need for special considerations for protogynous species. As long as sperm is not limiting, the protogynous life history is likely to enhance stock resilience. One situation where special consideration might be required is the case where the sex transition is age dependent, because in this case it is possible that the population could lose all of its males.

11. For species where per capita reproductive output increases non-linearly with fish weight (e.g. species that increase the frequency of spawning with weight), the units of SPR should be eggs per recruit or some other appropriate measure of reproductive output per recruit, rather than spawning biomass per recruit.

12. Special considerations for warm water vs. temperate species: the SPR Committee could not identify any factors that would *a priori* lead to the conclusion that warm water species are generally any more or less resilient than temperate species. In order to determine the relative degree of resilience of Gulf finfish stocks, it is necessary to estimate survival ratios (Recruits/Spawning units) and to compare reference points based on survival ratios (e.g. the median survival ratio or replacement levels of fishing mortality[1]) with similar reference points for temperate species. For Gulf finfish species, the amount of stock-recruitment data is generally inadequate to support definitive conclusions.

13. Stock-recruitment data should be graphed along with appropriate biological reference points such as F_{med}, $F_{20\%}$ and other levels of $F_{\%}$. Even though the time series of S-R data may be insufficient to provide reliable estimates of some reference points, they may nevertheless provide potentially useful auxiliary information about stock status. As the reliability and length of the time series improves, such estimates can be used to modify the estimates of *thresholds*.

14. If life history, environmental or other "ancillary" information is considered relevant to the definition of overfishing, appropriate models should be developed to investigate the consequences of such "ancillary" information and this should be incorporated

[1] these quantities may change markedly as data accumulate

directly into the overfishing definition in an operational manner.

Structure of Overfishing Definitions

15. The SPR Committee recommends that all of the overfishing definitions it was charged to investigate should be revised. The purpose of re-writing the definitions is to ensure: (i) consistency between FMP's in the overfishing definitions, (ii) that the definitions have separate components that distinguish between the act of *overfishing* and the *overfished* (and/or *depleted*) stock condition (where sufficient information exists to specify these components), (iii) explicit and unambiguous descriptions of the quantities used to determine the act of *overfishing* and the *overfished* and/or *depleted* condition (e.g. whether SPR refers to the static %SPR or the unweighted or weighted transitional SPR), and (iv) a system that provides alternative definitions depending on the amount or quality of data available.

16. The SPR Committee recommends adoption of the following overfishing definition for all FMP's considered:

PREFERRED DEFINITION: (to use when there is sufficient information to determine whether the stock is *overfished*)

"A [reef fish, mackerel, cobia, red drum] stock or stock complex is considered to be *overfished* when the transitional SPR is below a *threshold* level that may vary by fish species or stock. The default *threshold* transitional SPR is 20% unless otherwise specified explicitly below. If the stock is *overfished*, a rebuilding program that makes *consistent progress* towards restoring stock condition must be implemented and continued until the stock is restored beyond the *overfished* condition, and should be continued until the stock is restored to the management target [e.g. MSY, as modified by relevant factors]. The rebuilding program must be designed to achieve recovery within an acceptable time frame, as specified by the Council.

"When a [reef fish, mackerel, cobia, red drum] stock or stock complex is not *overfished*, *overfishing* is defined as a fishing mortality rate in excess of the fishing mortality rate corresponding to the *threshold* static %SPR. The default *threshold* static %SPR is 20% (i.e. $F_{20\%}$) unless otherwise specified explicitly below. If fishing mortality rates that exceed the level associated with the static %SPR *threshold* are maintained, the stock may become *overfished*. Therefore, if *overfishing* is occurring, a program to reduce fishing mortality rates towards management target levels will be implemented, even if the stock is not in an *overfished* condition.

"The determination of whether to use biomass *thresholds* as measures indexing unacceptable levels of stock *depletion*, and how to calculate them if used, will be deferred to individual Stock Assessment Panels, which will also develop a rebuilding plan if stock biomass falls below any such biomass *threshold*.

"[For reef fish, coastal pelagics and red drum] there are currently no exceptions to the default *threshold* static %SPR (20%) or the default *threshold* transitional SPR (20%) specified in the preferred overfishing definition. However, should sufficient stock-recruitment data become available, stock-specific static and transitional SPR *thresholds* associated with the degree of *overfishing* and the *overfished* condition may be calculated."

ALTERNATIVE DEFINITION (to use when there is sufficient information to calculate the static %SPR, but insufficient information to determine whether or not the stock is *overfished*)

"When there is insufficient information to determine whether a [reef fish, mackerel, cobia, red drum] stock or stock complex is *overfished*, *overfishing* is defined as a fishing mortality rate in excess of the fishing mortality rate corresponding to a default *threshold* static %SPR of 30% (i.e. $F_{30\%}$), unless an alternative level is specified explicitly below. If *overfishing* is occurring, a program to reduce fishing mortality rates to at least the level corresponding to management target levels will be implemented."

"[For reef fish, coastal pelagics and red drum] The only exceptions to the default *threshold* static %SPR (30%) specified in the overfishing definition are:

> red grouper [alternative definition]: *overfishing* is defined as a fishing mortality rate in excess of $F_{20\%}$."

Justification

The justification for choosing the 20% level as the default *threshold* for the definition of *overfishing* (as measured by the static %SPR) and the *overfished* condition (as measured by the transitional SPR) for the Preferred Definition is that it is supported by scientific research conducted in recent years. Goodyear (1993 and in earlier papers) has shown that the 20% level is a reasonable default *threshold* on both theoretical and empirical grounds. Mace and Sissenwine (1993) surveyed stock assessment results for 83 stocks and concluded that 20% was an appropriate default *threshold* for finfish stocks with "average" resilience. They and others have shown that the 20% level tends to be close to F_{max} (unless there is a large difference between recruitment and maturity schedules). There is no reason to believe that the 20% level is either overly conservative or overly risky for defining *thresholds*, provided there are sufficient data to determine stock status relative to this reference point.

The rationale for choosing $F_{30\%}$ as the default *threshold* for the definition of *overfishing* in the second tier is that the second tier is used for data poor species or stocks for which there is much uncertainty about stock status. Therefore, there is a need for greater caution in the application of the definition. A static %SPR of 30% is the 80th percentile of the estimates of replacement %SPR calculated in the study by Mace and Sissenwine (1993).

The reasons that red grouper is singled out as an exception to the default *threshold* in the Alternative Definition and assigned a less-cautious *threshold* of 20% are that (i) despite problems with VPA analyses, these and other preliminary stock assessment runs lead to a high degree of confidence that the stock is not currently *overfished*, suggesting that the current fishing mortality rate may be sustainable, (ii) examination of static yield per recruit and spawning per recruit results shows that $F_{20\%}$ is not unreasonably high compared to other reference points (e.g. $F_{current}$ and F_{max}) (Figure 4), (iii) in contrast to some other protogynous species, red grouper do not appear to have exhibited any detectable decline in the relative proportion of males over the last 30 or so years, and (iv) females mature at a small size and the stock may therefore have relatively high compensatory reserve.

The reasons that the Committee did not also assign a lower %SPR to gag are that (i) there is greater uncertainty about current stock status, and therefore about the sustainability of the current fishing mortality rate, (ii) examination of static yield per recruit and spawning per recruit results (Figure 6) shows that $F_{20\%}$ is about 3-4 times higher than $F_{current}$, and also considerably higher than F_{max}, and (iii) there is a possibility that the proportion of males in the stocks may have declined to very low levels in recent years.

17. The overfishing definition should be included as part of a control law, which is a diagram specifying fishing targets (e.g. OY), overfishing *thresholds*, and the management actions that are required depending on stock status relative to determinations of *overfished* and *overfishing* (an example schematic control law is illustrated in Figure 1).

18. Lists of fish stocks or species with different *thresholds* and maximum fishing mortality rates from those specified as default *thresholds* in the overfishing definition should be included as an integral part of the definition.

Additional Recommendations for Individual FMP'S and Species

19. For reef fish only: The definition of OY for reef fish should not be the same as the definition of overfishing, as is currently the case. However, any change that is made should specify OY in measurable terms.

20. For reef fish, red snapper is the only species for which the overfishing definition can be evaluated using the Preferred Definition; the status of all other species in the FMP should be evaluated using the Alternative Definition.

21. For red snapper, a static %SPR of 20% is appropriate (see the justification given under recommendation 16). There is no reason to believe that red snapper is any more or less resilient than an "average" finfish, for which it has been repeatedly suggested in the scientific literature that a static %SPR of 20% is a reasonable *overfishing threshold*.

22. For the coastal pelagics, the status of king and Spanish mackerel stocks should currently be evaluated using the Preferred Definition, whereas cobia should be evaluated using the Alternative Definition.

23. For the coastal pelagics, the Committee felt that the overfishing definition should be consistent with the reef fish definition. For king and Spanish mackerel, this would result in a decrease in the *threshold* transitional SPR from 30% to 20%. The Committee felt this was reasonable since there is no reason to believe that the two species of mackerel are any more or less resilient than reef fish (they are shorter-lived and faster-growing), or than the "average" finfish. However, as per Recommendation 5, the Committee recommended that the current rebuilding strategy be continued until the 30% level (which may be an appropriate target) is attained.

24. The current overfishing definition for red drum should be replaced with the SPR Committee's suggested overfishing definition given in Recommendation 16. The status of the red drum stock should be evaluated using the Preferred Definition.

25. The Council should recognize that, due to the selectivity patterns exhibited by red drum fisheries (high fishing mortality on juveniles), MSY is considerably lower than might otherwise be the case.

26. The definition of OY for red drum should be extended to include fish in the EEZ.

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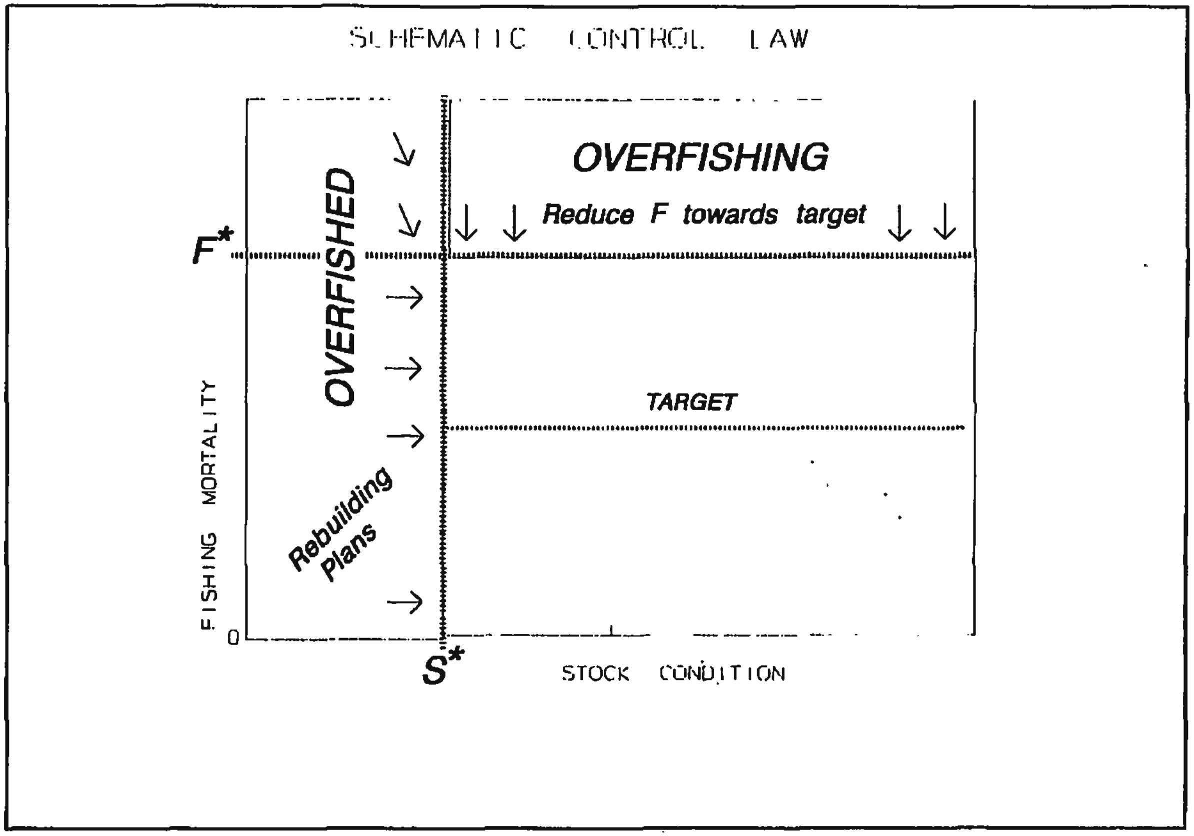

Figure 1. Schematic fisheries control law. The management objective is to regulate the fishery so that it fluctuates around the target, with the constraint that fishing mortality must not exceed F^* and stock condition must not fall below S^*. If fishing mortality exceeds F^*, immediate action must be taken to reduce fishing mortality. If stock condition falls below S^*, a rebuilding plan must be developed and implemented.

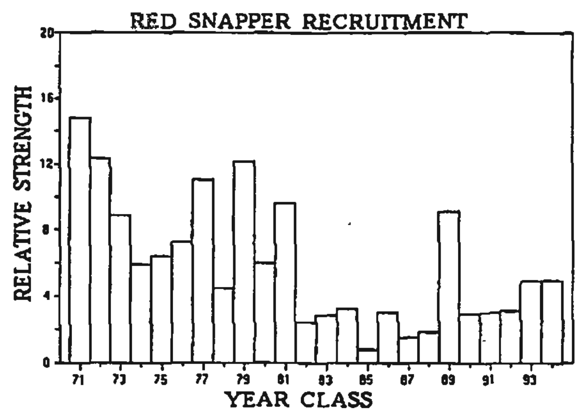

Figure 2. Year class strength estimate for red snapper 1971-1994. (Figure 33 from Goodyear 1995).

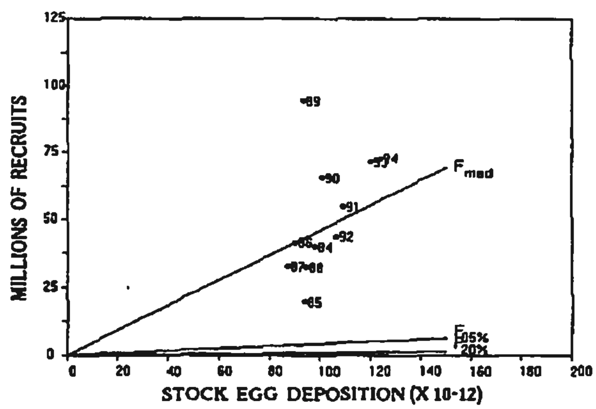

Figure 3. Scattergram of stock and recruitment data for red snapper (based on data from Goodyear 1995).

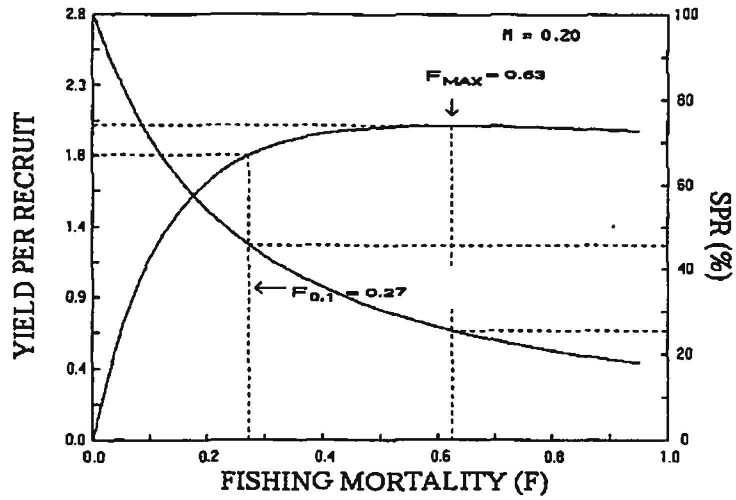

Figure 4. Estimates of $F_{0.1}$, F_{max} and SPR for red grouper assuming 1991-1992 average vulnerabilities at age and a 20 inch minimum size. (Figure 59 from Goodyear and Schirripa 1993).

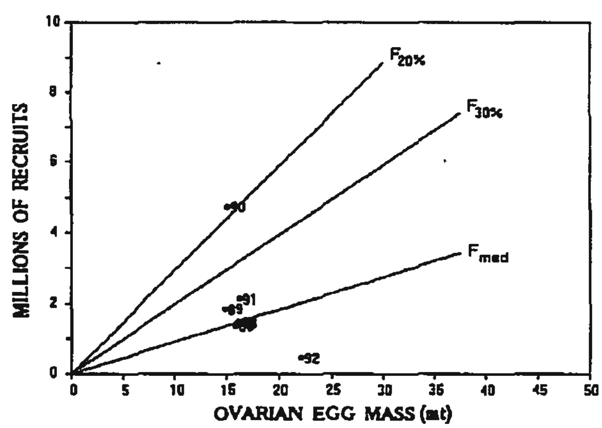

Figure 5. Scattergram of stock and recruitment data for Gulf of Mexico gag (based on data from Schirripa and Goodyear 1994).

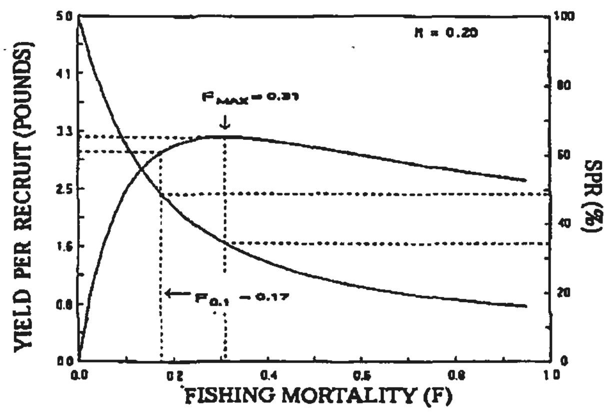

Figure 6. Estimates of $F_{0.1}$, F_{max} and SPR for gag assuming 1991 vulnerabilities at age, a 20 inch minimum size, and a 33% discard mortality. (Figure 58 from Schirripa and Goodyear 1994).

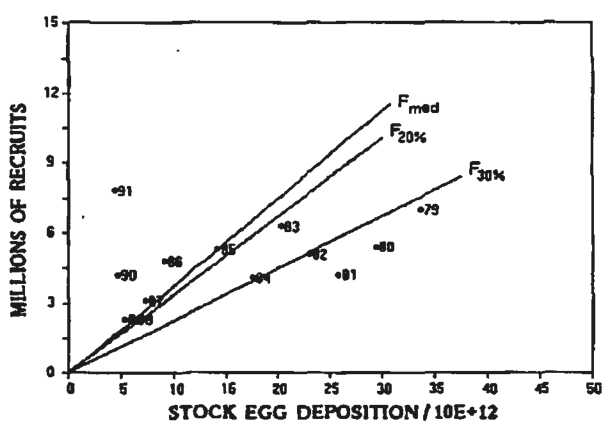

Figure 7. Scattergram of stock and recruitment data for Gulf of Mexico red drum (based on data from Goodyear 1993).