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REPORT OF THE FIRST AD HOC FINFISH STOCK ASSESSMENT PANEL

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Abbreviations Used in This Document

F — Refers to an instantaneous rate of fishing mortality. This is often written with a subscript to indicate the fishing mortality rate at a given biological reference point, e.g.;

- $F_{0.1}$ — The fishing mortality rate where the slope of the yield curve has theoretically dropped to 10% of the slope at the origin.
- F_{msy} — The fishing mortality rate that theoretically produces maximum sustainable yield.
- F_{max} — The fishing mortality rate that theoretically produces maximum yield-per-recruit. Note: this is NOT the same point as F_{msy}.
- $F=M$ — The fishing mortality rate is theoretically equal to natural mortality.

FMP — Fishery Management Plan

MFMT — Maximum fishing mortality threshold (an MSY control law component)

MSST — Minimum stock size threshold (an MSY control law component)

MSY — Maximum sustainable yield

OY — Optimum yield

SPR — Spawning Potential per Recruit - the average reproductive capacity of a female recruit under exploitation as a proportion of the reproductive capacity in the absence of fishing.

OR

Spawning Potential Ratio - the average reproductive capacity or spawning stock biomass of a stock under exploitation relative to the reproductive capacity of spawning stock biomass in the absence of fishing. There are two basic types of SPR values:

- Transitional SPR — This is the SPR value at a given point in time, and may be suitable for use as a proxy for biomass levels in MSY control laws.
- Static SPR — This is the SPR that will eventually be reached if fishing mortality and all other parameters that affect SPR are held constant. This may be suitable for use as a proxy for fishing mortality rates in MSY control laws. (Also called Equilibrium SPR)

SSB — Spawning stock biomass

SSBR — Spawning stock biomass per recruit, or spawning stock biomass ratio, as a proportion of the SSB in the absence of fishing (see SPR, second definition)

Panel Members Present

Dr. James Cowan, Jr. (Chair)	University of South Alabama
Mr. Joseph Shepard (Vice-Chair)	Louisiana Dept. Of Wildlife and Fisheries
Dr. Jerald Ault	Univeristy of Miami/RSMAS
Mr. Douglas Gregory	University of Florida/Monroe County
Mr. Mike Murphy	Florida Marine Research Institute
Dr. Clay Porch	NMFS/SEFSC

Others present

Vernon Minton - Gulf Council Member
Bob Shipp - Gulf Council Member
Wayne Swingle - Gulf Council staff
Rick Leard - Gulf Council staff
Steven Atran - Gulf Council Staff
Pete Eldridge - NMFS/SERO
Chris Legault - NMFS/SEFSC
Victor Restrepo - NMFS/SEFSC
Stephen Turner - NMFS/SEFSC

INTRODUCTION

At the direction of the Gulf of Mexico Fishery Management Council (Council), the Ad Hoc Finfish Stock Assessment Panel (Panel) met in Miami, Florida on June 22-25, 1998 to review available information and provide guidance to the Council for defining appropriate maximum sustainable yield (MSY) levels or MSY proxies for finfish that could be used in setting definitions for overfished and overfishing thresholds. The Panel Also discussed control law strategies for recovery when a stock falls below defined thresholds of overfished or overfishing.

Under the Sustainable Fisheries Act of 1996, the Regional Management Councils and NMFS are required to develop new definitions of what constitutes overfishing and overfished exploited stocks, and optimum yield targets. These new definitions are to be submitted to NMFS for review and approval by October 1998. The Magnuson-Stevens Fishery Conservation and Management Act contains several points relevant to developing these new definitions:

- The terms “overfishing” and “overfished” mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the MSY on a continuing basis.
- National Standard 1 of the Magnuson-Stevens Act requires that conservation and management measures prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.
- The term “optimum”, with respect to the yield from a fishery, means the amount of fish which : (A) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; (B) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and (C) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.

On May 1, 1998, NMFS published revised guidelines for several of the Magnuson-Stevens Act National Standards, including Standard 1. These guidelines called for overfishing and overfished thresholds to be defined in terms of a maximum fishing mortality threshold (MFMT) and a minimum stock size threshold (MSST), or reasonable proxies thereof. They also require the establishment of a MSY control rule that would be expected to result in a long-term average catch approximating MSY. The MFMT would be the level of fishing mortality associated with the specific MSY control rule for that stock. A fishing mortality rate in excess of the MFMT threshold for a period of 1 year or more would constitute overfishing. The MSST would be the stock size (biomass) threshold that is the greater of: 1) one half the MSY stock size, or 2) the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years.

Additional guidelines are being prepared by NMFS to assist the Councils with development of MSY control rules. These additional guidelines were not finalized in time for the Panel meeting; however, NMFS staff involved in development of these guidelines (Victor Restrepo and Clay Porch) were present at the meeting to assist the Panel in interpreting the requirements.

RATIONALE FOR SELECTION OF SPR PROXY FOR MSY

The Panel reviewed SPRs corresponding to a fish stock's life history, population dynamics, and fishing mortality rates corresponding to various biological reference points that potentially could serve as proxies for F_{MSY}. Mace (1994) reported that F_{max} always exceeds F_{msy} for a Beverton-Holt stock/recruitment function, and generally when using other functions (e.g., a Ricker function). She concluded that F_{max} was usually too high to serve as a reliable proxy for F_{MSY}, although it may be useful as a MFMT overfishing threshold. Consequently, the Panel rejected SPR corresponding to F_{max} as an F_{MSY} proxy, and discussed SPR at $F_{0.1}$ as a potentially better proxy for F_{MSY}. Although it was noted that $F_{0.1}$ was originally derived as an indicator of optimum economic yield with little attention to its biological function, the SPRs associated with $F_{0.1}$ are generally much more conservative than those for F_{max}. Additionally, Mace (1994) stated that $F_{0.1}$ often corresponded with $F_{35\%SPR}$. The third scenario for an MSY proxy reviewed by the Panel was the SPR associated with F=M. The Panel noted that at F=M, fishing rates usually correspond to static SPR levels above 40%. Since Mace (1994) recommended $F_{40\%\,SPR}$ as a surrogate for F_{msy}, the Panel concluded that this level was probably most conservative and, perhaps, could be the best estimate of F_{OY}.

Consequently, the Panel determined that static SPRs associated with either $F_{0.1}$ or F=M were acceptable proxies for F_{MSY}. At the Panel's disposal were the necessary life history and population dynamics information to estimate these values for a number of the species in the region. These were examined during the exploratory simulations described below. Ideally, a stock-recruitment function linked to information on stock age and size structure could be used to directly estimate MSY; however, adequate data for this type of analysis are not available for the majority of the stocks examined by the Panel. The proxies chosen by the Panel have a firm basis in the scientific literature. Deriso (1987) showed that an F equal to $F_{0.1}$, as estimated from equilibrium yield-per-recruit analyses, provided a catch that was close to MSY. There is also compelling evidence that MSY is attained for most stocks when fishing mortality equals natural mortality (F=M) (Gulland 1970). **Consequently, the Panel concluded that the**

most likely SPR corresponding with F_{MSY} would be somewhere between a SPR at F_{max} and a SPR at F=M, but perhaps closer to SPR at $F_{0.1}$.

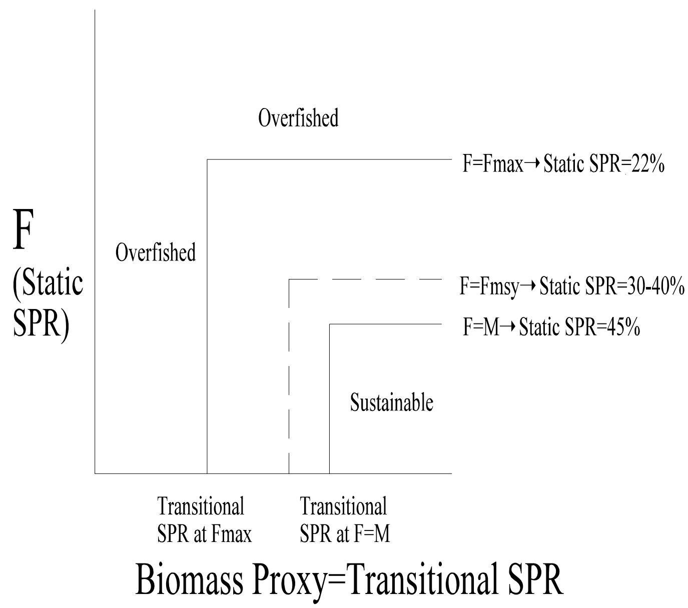

Figure 1. Theoretical argument and SPR equivalent estimates of F_{max}, F=M, and F_{msy} based upon our exploratory simulations.

The Panel used data generated in the stock simulation exercise described above to provide advice to the Council in two ways. Given that previous literature reviews on stock dynamics have led several others (e.g., Clark 1993, Mace et al.1996) to conclude that fishing mortality (F) rates consistent with static SPR values of 30-40% are good proxies for F_{msy}, The Panel first focused on learning whether or not data for several Gulf of Mexico stocks produced results consistent with these findings. While SPR estimates are highly dependent on the specific set of selectivities used to generate Table 1, the Panel could find no compelling argument to recommend a F value resulting in an SPR < 30% as a good proxy for F_{msy} for any species. The argument is summarized in Figure 1. Theory and experience from previous analyses (e.g., Deriso 1987) suggest that F_{msy} should fall between F_{max} and F=M which, based upon this simple analysis for several Gulf of Mexico stocks, corresponds to static SPR values of approximately 22% to 45% SPR, respectively (Table 1).

Table 1. Selected population characteristics used to determine the range of possible SPR values that approximate MSY. The F values and corresponding SPRs were calculated using the analytical yield model described in Ault et al. 1998.

Species	$F_{0.1}$	F_{max}	F = M	M	K	t-lambda	M/K
Red Drum	30%	11%	30%	0.2	0.367	40	0.55
Red Snapper	37%	20%	37%	0.10	0.16	50	0.63
King Mackerel	36%	22%	42%	0.20	0.17	17	1.18
Spanish Mackerel	43%	30%	39%	0.30	0.27	12	1.11
Red Grouper	42%	25%	47%	0.18	0.153	17	1.18
Gag	30%	16%	35%	0.20	0.15	13	1.34
White Grunt	43%	26%	43%	0.375	0.186	8	2.01
Vermilion Snapper	35%	18%	36%	0.23	0.206	10	1.11
Nassau Grouper	45%	19%	60%	0.18	0.145	17	1.24
Greater Amberjack				0.20	0.250		0.80
Bay Anchovy				2.53	0.22		11.5
Northern Anchovy				0.43	0.32	7	1.43

Data for white grunt and Nassau grouper is from Ault et al. 1998, for bay anchovy from Wang 1998, for northern anchovy from Ault and Olsen 1996, and for the remaining species from the appropriate stock assessments.

The fishing mortality rate, F_{max}, has been demonstrated for many stocks to exceed F_{msy}, and it is considered by the Panel to be risk prone, implying that the SPR corresponding to F_{msy} should exceed 21% (the average F_{max} SPR for those species summarized) by a significant margin. In addition, there is strong support in the literature (Deriso 1987, Clark 1993, Mace et al. 1996) for choosing either $F_{0.1}$ or F=M as acceptable proxies for F_{msy}. The Panel was divided as to which proxy was the most appropriate. Some members argued that F=M was a more conservative approach, providing a greater buffer for the stock against environmental variability. Other Panel members suggested that $F_{0.1}$ was nearly as conservative, but allowed for some additional harvest that would not be realized at F=M. For the stocks considered in Table 1, the lowest value of SPR expected at $F_{0.1}$ is 30%, and the mean SPR is approximately 38%, implying that, while 30% to 40% SPR may be an appropriate range for MSY proxies: 1) SPR at $F_{30\%SPR}$ (F_{MFMT}; see Control Rule section below) may be a reasonable proxy for SPR at F_{msy} for some species; 2) fishing mortality rates in excess of $F_{30\%SPR}$ most likely will exceed F_{msy}; and, 3) fishing mortality rates resulting in SPRs much higher than 30%, i.e., at F=M, may be appropriate for some species. It should be noted that these findings for the Gulf of Mexico are entirely consistent with those of Clark (1993), Mace et al. (1996) and others mentioned above.

Nevertheless, while the Panel recommends that SPR at $F_{30\%SPR}$ is a good minimum proxy for SPR at F_{msy} for some species, it may be risk prone for those species with less compensatory reserve and a lower potential for producing population biomass. Consequently, to scale this potential for the species in Table 1, the Panel calculated the index M/K (natural mortality rate/von Bertalanffy growth coefficient). Species with low values of M/K (high growth with respect to natural mortality) are expected, and have been shown, to be able to sustain higher yields as a fraction of spawning stock biomass than those with high M/K (high natural mortality with respect to growth) (Deriso 1987). This is largely due to the presence of multiple age classes from which spawning potential can be realized for those long-lived species with low natural mortality rates. This index is easy to calculate, and can be done so with relative confidence given knowledge of age, growth, and longevity estimates based upon otoliths, and knowledge of the relationship between natural mortality rates and longevity.

MSY PROXY RECOMMENDATIONS

The Panel suggests that for species with $M/K < 1.0$, e.g., red drum, red snapper, greater amberjack, the SPR at $F_{30\%SPR}$ probably is a good proxy for SPR at F_{msy}. However, for species with M/K ratios >1.0, e.g., vermilion snapper, king mackerel, Spanish mackerel, red grouper, fishing mortality rates corresponding to $F_{30\%SPR}$ may exceed F_{msy} and thus the SPR proxies should be increased to values corresponding to SPR at $F_{35\%SPR}$. For those species where $M/K>1.5$, e.g., gag and white grunt, SPRs corresponding to $F_{40\%SPR}$ (or higher) may be the best proxies of SPR at F_{msy}.

To further clarify this approach, the Panel added M/K ratios for Chesapeake Bay bay anchovy and southern California Bight northern anchovy to Table 1. While high yields have been obtained, or can be expected, from each of these stocks, high M/K ratios imply that there is risk in reducing the SPR level below 40% given the relatively few age classes available to produce eggs (only 1 or 2 for bay anchovy). Historically, the northern anchovy stock has been able to sustain only modest fishing pressure ($\sim F=0.1$ to 0.3) before dropping to stock levels at which recruitment success became highly susceptible to adverse environmental fluctuations, leading to recruitment failures and collapse of the fishery. Simulations of fishing on bay anchovy produced similar results (Wang 1998). **It should be noted, however, that estimates of M and K are not without error (in fact estimates vary widely for many species, especially with regard to M). Some Panel members noted that, in general, stocks with high M values are usually more resilient than those with low M values. The Panel noted that the M/K ratios should be used in conjunction with all other information about life history characteristics that may help to define a stocks compensatory reserve.**

CONTROL RULE FOR STOCK REBUILDING

Each fishery management plan (FMP) is mandated to specify overfishing criteria that include: (1) a maximum fishing mortality threshold (MFMT) that may not exceed the level associated with the proxy for F_{MSY} and (2) a minimum stock size threshold (MSST). The MSST is defined in the National Standard guidelines as the greater of "one-half the MSY stock size or the minimum biomass at which rebuilding to the MSY level would be expected to occur within 10 years if the stock were exploited at the maximum fishing mortality threshold ...". The ideal value of MSST depends on the resiliency of the stock, which in the case of the stocks examined in this report is not well established. The Panel believes that the most appropriate strategy to address this issue would be through analyses by the respective stock assessment panels for each FMP. In the interim, the Panel recommends that MSST be set equal to the stock size associated with the maximum fishing mortality threshold (B_{MFMT}) multiplied by the greater of 1 minus the natural mortality rate (M) or 0.5. With this definition the overfishing criteria (MFMT and MSST) appear as illustrated in Figure 2. Such a rule of thumb for MSST is intuitively appealing because one would expect stocks with a higher M to recover faster, on average, than stocks with a lower M.

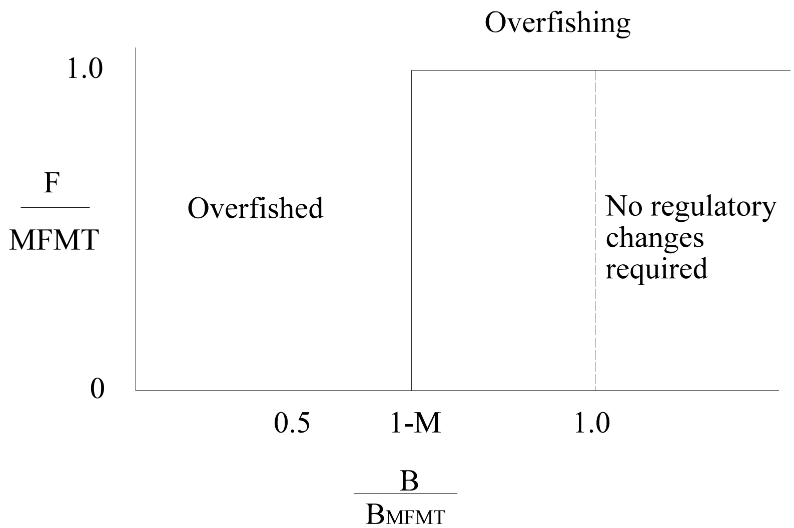

Figure 2. Hypothetical example showing the relationship between Maximum Stock Size Threshold (solid vertical line) and the Maximum Fishing Mortality Threshold (solid horizontal line) using the 1-M rule of thumb. Overfishing occurs whenever the fishing mortality rate (F) or stock size (B) is above or to the left of the solid lines. The dotted vertical line corresponds to the long-term average stock size that would be achieved by fishing at the MFMT (B_{MFMT}). Note that both F (vertical) and B (horizontal) axes are scaled by the values at F=MFMT.

Given these overfishing criteria, each FMP must also specify a rebuilding plan should the stock size fall below the MSST. This rebuilding plan will also depend on the resiliency of the stock in question. A default limit control rule that has been suggested in the past is to reduce the fishing mortality rate in proportion to the amount that the current stock size is below the MSST. Mathematically this can be expressed as:

$$F = C*MFMT \qquad (1)$$

where C= B/MSST if B < MSST © = 1 otherwise) and MSST = (1-M)B_{MFMT}. This idea is illustrated in Figure 3. To the extent that a stock fished at F = MFMT is expected to fluctuate about B_{MFMT} on a scale related to M, this control rule would generally accommodate the timetables required under the guidelines for implementing National Standard 1 of the Magnuson-Stevens Act. Ideally, of course, the control rule should be tailored to the unique life history characteristics and level of depletion of the stock. Such detailed analyses were not possible within the time frame available to the Panel, but are strongly recommended for the future.

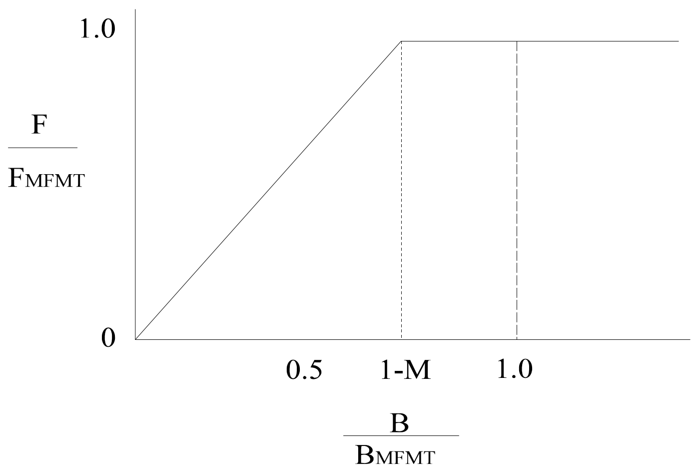

Figure 3. An example of a default limit control rule, based on the formula in Equation 1.

In practice, the fishing mortality rate will tend to occasionally deviate above the MFMT even when the MFMT control law is prosecuted effectively, owing to the randomness of the fishing process itself. Likewise, stock size will tend to occasionally deviate below B_{MFMT} about half of the time, owing to natural fluctuations in recruitment and natural mortality. (Results of computer simulations often show that constant F_{msy} policies can cause the stock to fall well below MSY (Jerry Ault. personal communication). A more conservative "precautionary" control law that has been recommended is to set a target F at 75 percent of MFMT and reduce F in proportion to the extent the current stock size is below MSST:

$$F = C*0.75*MFMT \qquad (2)$$

where C= B/MSST if B < MSST © = 1 otherwise) and MSST = (1-M)B_{MFMT}. If the stock is severely overfished (B << MSST), a more drastic reduction in F may be necessary to meet the rebuilding time requirements. This "precautionary" control law is contrasted with the earlier "limit" control law (equation 1) in Figure 4. Interestingly, simulation studies by Mace (1994) and others suggest that 75% F_{msy} generally would result in long-term yields of 94% MSY or higher while the long-term biomass levels would exceed 125% of the biomass at MSY. Thus, the use of the more precautionary control rule trades a small sacrifice in yield for a large gain in biomass.

The Panel suggests that the default limit control law (equation 1) with MFMT = F_{msy} be used to satisfy the legal requirements of the FMP and the "precautionary" control rule (equation 2) be applied operationally (Figure 4).

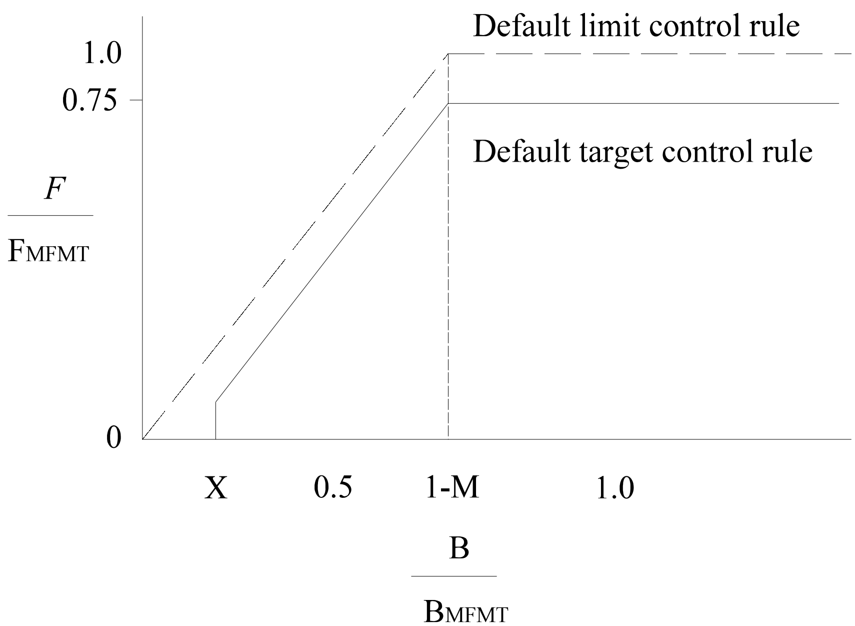

Figure 4. The recommended default "precautionary" control rule (solid lines) contrasted with the default "limit" control rule defined earlier (dashed lines). The vertical dotted line is the default MSST. The value of X is the fraction below B_{MFMT} at which no fishing will be allowed, which may or may not be below 0.5 at the Councils discretion. The default limit control rule could be submitted to satisfy the legal requirements for the overfishing criteria, whereas the precautionary control law could be used to avoid frequent excursions outside the limit control rule (which would necessitate equally frequent regulatory actions by the Council).

APPROPRIATE MSY PROXIES (SPR, SSB, SSBR)

The Council asked the Panel to consider whether spawning stock biomass per recruit (SSBR) or spawning stock biomass (SSB) is more appropriate than the use of SPR to gauge stock status. The Panel assumed that the Council was requesting guidance as to the most appropriate measure of a stocks ability to replenish itself over time.

First, the Panel wishes to clarify that SPR is simply a general term that refers to the proportion of a spawning stock remaining under fished conditions to that of an unfished stock. Ideally annual egg production should be used in the calculation of SPR. However, egg production is not always available, and thus biomass of mature females is often used as a proxy. The use of biomass in the calculation of SPR was historically referred to as SSBR. Currently, either the use of eggs or biomass is referred to as SPR.

Spawning stock biomass (SSB) measures the magnitude in weight of the mature component of the stock. Trends in SSB are driven by recruitment, fluctuations in natural mortality and growth rates, and fishing mortality rates, and do not necessarily reflect regulatory actions. A SSB management criterion would seek to maintain spawning biomass above some estimated level that would insure the population's ability to sustain itself. If a stock undergoes a period of low recruitment, then management measures to reduce fishing mortality must be implemented to maintain SSB at or above the specified critical level. In contrast, the simplest interpretation that SPR is driven by fishing mortality rates alone suggests that it directly reflects measures taken to manage a stock. Under this scenario, fluctuations in recruitment are not a factor; only the proportion of the population remaining after fishing that resulted from those recruitment levels is considered.

At this time, the Panel cannot recommend one method over another. It should be the purview of the stock assessment panels to decide the best method used based upon the available data. However, if the Council wishes to adopt a method that best reflects management measures imposed, we feel that the use of SPR is the appropriate measure to use.

The Panel also was asked to consider whether recruitment indices were appropriate for setting total allowable catch (TAC) of red snapper. There was consensus among Panel members that estimates of the magnitude of recruitment (and recruitment indices), while apparently somewhat easy to obtain, are fraught with estimation error and provide little or no information with respect to stock dynamics and fishing mortality rate. Thus, the Panel concluded that they are not appropriate for setting TACs, especially given the inherent observed variability in stock recruitment relationships.

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