Tab B, No. 15
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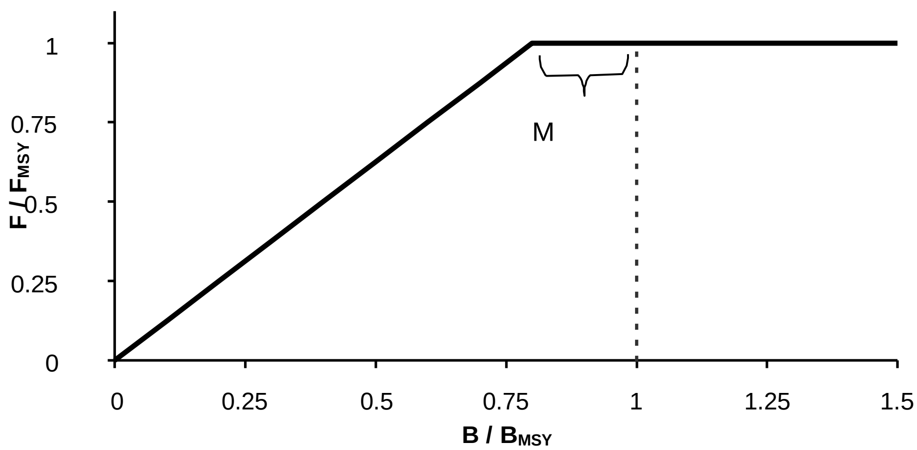
Minimum Stock Size Threshold (MSST) for Reef Fish Stocks



Options Paper for Draft Amendment 44

to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico

August 2016

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ENVIRONMENTAL ASSESSMENT COVER SHEET

Name of Action

Draft Amendment 44 to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico: Minimum Stock Size Threshold (MSST) for Reef Fish Stocks

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Type of Action

( ) Administrative ( ) Legislative
(X) Draft ( ) Final

Summary/Abstract

To be completed

ABBREVIATIONS USED IN THIS DOCUMENT

B_{MSY}	stock biomass level capable of producing an equilibrium yield of MSY
Council	Gulf of Mexico Fishery Management Council
F	instantaneous rate of fishing mortality
FMP	Fishery Management Plan
GMFMC	Gulf of Mexico Fishery Management Council
Gulf	Gulf of Mexico
IPT	Interdisciplinary Planning Team
M	instantaneous rate of natural mortality
MFMT	maximum fishing mortality threshold
MSST	minimum stock size threshold
MSY	maximum sustainable yield
NMFS	National Marine Fisheries Service
NS1	National Standard 1 guidelines
OY	optimum yield
SDC	status determination criteria
SEDAR	Southeast Data, Assessment and Review
SEFSC	Southeast Fisheries Science Center
SPR	spawning potential ratio
SSB	spawning stock biomass
SSC	Scientific Statistical Committee

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CHAPTER 1. INTRODUCTION

1.1 Background

The Sustainable Fisheries Act of 1996 and the subsequent revisions to the National Standard 1 (NS1) guidelines required Councils to establish new definitions of overfishing (maximum fishing mortality threshold – MFMT), overfished (minimum stock size threshold –MSST), and estimates of maximum sustainable yield (MSY) or proxy for managed stocks. Collectively, these are referred to as status determination criteria. In 1999, the Gulf of Mexico Fishery Management Council (Council) submitted the Sustainable Fisheries Act Amendment (GMFMC 1999) to comply with these requirements. All of the MFMT criteria and proxies for MSY were in terms of percent spawning potential ratio (SPR), while the proposed MSST criteria were deferred until further evaluations of the stocks could occur. NMFS accepted most of the MFMT definitions, but rejected all of the definitions for MSY and other biomass reference points on the basis that MSY is not biomass-based and is therefore not an acceptable proxy for MSY or MSST.

The Council subsequently established status determination criteria (SDC) on a species-by-species basis as stock assessments were conducted. However, SDC were only defined if a stock was in need of rebuilding, as part of the parameters of the rebuilding plan. Of the 31 species currently in the Reef Fish Fishery Management Plan (FMP), 14 have had stock assessments conducted (Table 2.1), but only 6 have had MSST and MSY proxies defined (Table 1.2), leaving 25 reef fish stocks with undefined MSY and MSST. All of the reef fish stock have MFMT defined since those were accepted in the Sustainable Fisheries Act Amendment, although in some cases the MFMT was redefined in a later amendment.

For most stocks, the overfished status has been evaluated using the formula:

$$(1\text{-}M) * B_{MSY}\text{, or 50\% of } B_{MSY}\text{, whichever is less}$$

In the above equation, M is the natural mortality rate and B_{MSY} (sometimes referred to as SSB_{MSY}) is the stock biomass or spawning stock biomass level that allows the stock to produce MSY (or its proxy) on a continuing basis. 50% of B_{MSY} is the lowest level of MSST allowed under the National Standard guidelines. As noted above, the MSST and MSY proxy has only been formally defined on an as needed basis, so for most stocks the overfished status determination has been an informal determination. One purpose of this amendment is to adopt official definitions of MSST and MSY proxies for all reef fish stocks in order to bring the Reef Fish FMP into compliance with the NS1 guidelines.

For some stocks that have a very low natural mortality rate, the above formula results in an MSST that is very close to the B_{MSY} biomass level. For example, red snapper is a moderately long-lived fish that has a natural mortality rate of about 0.1. Using the above formula, this results in a MSST at 90% of B_{MSY}. In such situations it can be difficult to determine if a stock is actually below MSST due to imprecision and accuracy of the data. In addition, natural fluctuations in stock biomass levels around the B_{MSY} level may temporarily drop the spawning stock biomass below MSST. Setting a wider buffer between B_{MSY} (or proxy) and MSST can avoid these issues.

Setting MSST at a lower level reduces the likelihood of a stock being declared overfished, and may reduce the time needed for an overfished stock to rebuild back above the MSST. However, while rebuilding to above the MSST allows a stock to be re-characterized from overfished to rebuilding, it does not relieve the requirement that the stock be rebuilt to B_{MSY} within a specified time period.

This Amendment to the Reef Fish FMP proposes to set MSST at a certain minimum distance from B_{MSY} regardless of the natural mortality rate for all stock in the Reef Fish FMP.

Gulf of Mexico Fishery Management Council

- Responsible for conservation and management of fish stocks
- Consists of 17 voting members, 11 of whom are appointed by the Secretary of Commerce, the National Marine Fisheries Service Regional Administrator, and 1 representative from each of the 5 Gulf states marine resource agencies
- Responsible for developing fishery management plans and amendments, and for recommending actions to National Marine Fisheries Service for implementation

National Marine Fisheries Service

- Responsible for conservation and management of fish stocks
- Responsible for compliance with federal, state, and local laws
- Approves, disapproves, or partially approves Council recommendations
- Implements regulations

1.2 Purpose and Need

The purpose for the action is to set MSST for reef fish stocks taking into consideration natural mortality rates, and to establish MSST for all stocks in the reef fish fishery management unit.

The need for the proposed action is to comply with the NS1 guidelines requiring that stocks have an MSST, while giving consideration to preventing reef fish stocks with low natural mortality rates from alternating between overfished and non-overfished conditions.

1.3 History of Management

Following passage of the Sustainable Fisheries Act of 1996, the National Marine Fisheries Service (NMFS) published updated National Standard Guidelines that included the introduction of status determination criteria. The updated guidelines for NS1 described MFMT to determine when overfishing is occurring, and MSST to determine when a stock is overfished. The NS1 guidelines further required that each FMP must specify, to the extent possible, objective and measurable status determination criteria for each stock or stock complex covered by that FMP and provide an analysis of how the status determination criteria were chosen and how they relate to reproductive potential.

In 1999, the Council submitted its Generic Sustainable Fisheries Act Amendment (GMFMC 1999), in which it attempted to define MFMT along with other biological reference points of MSY and optimum yield (OY) for stocks under management. All of the definitions were based on static[1] SPR. For reef fish stocks, the amendment proposed the following MFMT MSY, OY, and MSST definitions (Table 1.1).

[1] SPR is a measure of reproductive capability, but is measured in two different ways. Static SPR is a measure of spawning-per-recruit relative to the level of spawning-per recruit that would occur in the absence of fishing. It is analogous to yield-per-recruit and is the level of spawning that would occur at equilibrium if fishing occurred at the same rate and selectivity pattern. Transitional SPR is a measure of spawning production per recruit in a given year relative to the spawning production that would have occurred in that year if there had been no fishing. Static SPR is directly related to fishing mortality and can be used as a measure of overfishing. Transitional SPR can be used to indicate how close the age structure of a stock is to being rebuilt, but does not necessarily correlate to absolute biomass levels (GMFMC 1996). Although these terms have fallen out of common use, phrases such as “a mortality rate of 30% SPR” or “yield when fishing at 30% SPR” refer to static SPR.

Table. 1.1. Proposed MSY, OY, MFMT, and MSST definitions in the Generic Sustainable Fisheries Amendment. The MFMT definitions were approved except for red snapper (which was defined in a later amendment), but all SPR-based biomass reference points (MSY, OY, and MSST) were disapproved.

Stock	MSY (proposed, not approved)	OY (proposed, not approved)	MFMT (approved)	MSST
Goliath grouper	50% static SPR	50% static SPR	$F_{50\%\ SPR}$	To be implemented by framework measure as estimates of B_{MSY} and MSST are developed by NMFS, the Reef Fish Stock Assessment Panel, and the Council.
Red snapper	26% static SPR	36% static SPR	$F_{26\%\ SPR}$	
All other reef fish stocks	30% static SPR	40% static SPR	$F_{30\%\ SPR}$	

On November 17, 1999, NMFS notified the Council that, while it approved the definitions of MFMT based on static SPR, it disapproved all SPRs submitted as proxies for MSY, OY and MSST because SPR is not biomass-based and is not an acceptable proxy for biomass reference points.

All stocks have an MFMT from the Generic Sustainable Fisheries Act Amendment or as later modified. Other status determination criteria and biological reference points were adopted on a stock-by-stock basis as stocks were assessed, but only if the stock was determined to be in need of a rebuilding plan. Stocks for which MSST has been adopted are shown in Table 2.1.

Table 1.2. Stocks with status determination criteria assigned.

Stock	MFMT	MSST	MSY	Source
Gag	F_{MAX}	(1-M)*femaleSSB_{MAX} (M = 0.15)	Yield at SSB_{MAX}	Amendment 30B (GMFMC 2008a)
Red grouper	$F_{30\%\ SPR}$	(1-M)* SSfemale gonad wt_{MSY} (M = 0.2)	Yield at $SSB_{30\%\ SPR}$ measured in terms of female gonad weight	Secretarial Amendment 1 (GMFMC 2004a)
Red snapper	$F_{26\%\ SPR}$	(1-M)*B_{MSY} (M = 0.094277)	Yield at $F_{26\%\ SPR}$	Amendment 27 (GMFMC 2007)
Vermilion snapper	F_{MSY} (no proxy)	(1-M)*B_{MSY} (M = 0.25)	Yield at F_{MSY}	Amendment 23 (GMFMC 2004b)
Gray triggerfish	$F_{30\%\ SPR}$	(1-M)*egg$SSB_{30\%\ SPR}$ (M = 0.27)	Yield at $SSB_{30\%\ SPR}$ measured in terms of female egg production	Amendment 30A (GMFMC 2008b)
Greater amberjack	$F_{30\%\ SPR}$	(1-M)*B_{MSY} (M = 0.25)	Yield at $F_{30\%\ SPR}$	Secretarial Amendment 2 (GMFMC 2002)
Hogfish (proposed)	$F_{30\%\ SPR}$	0.75*$SSB_{30\%\ SPR}$	Yield at $SSB_{30\%\ SPR}$	Amendment 43 (in development)

Note: Amendment 23 did not define an MSY proxy for vermilion snapper. It specified that SDC were to be based on the actual MSY estimate. The proxy SEDAR 9 and SEDAR 9 update assessments, however, used a proxy based on the yield when fishing at $F_{30\%\ SPR}$.

Several other reef fish species have had stock assessments, but were not in need of rebuilding plans (or in the case of goliath grouper, harvest was already prohibited), and therefore were not assigned status determination criteria. These stocks include mutton snapper, lane snapper, yellowedge grouper, goliath grouper, black grouper, tilefish, and hogfish.

CHAPTER 2. MANAGEMENT ALTERNATIVES

2.1 Action 1 – Minimum Stock Size Threshold for Species in the Reef Fish Fishery Management Unit

Alternative 1: No Action. MSST for species that have a defined specification will not be changed. MSST will remain undefined for species that do not have a definition specified.

Alternative 2: MSST = (1-M)*B_{MSY} (or proxy)

Alternative 3: MSST = (1-M)*B_{MSY} (or proxy) or 0.75*B_{MSY} (or proxy), whichever is less.

Alternative 4: MSST = 0.75*B_{MSY} (or proxy), for all stocks.

Alternative 5: MSST = 0.50*B_{MSY} (or proxy), for all stocks.

Discussion:

Stocks with a low natural mortality rate can end up with a minimum stock size threshold (MSST) that is only slightly below the B_{MSY} (or proxy) spawning stock biomass level. In such situations it can be difficult to determine if a stock is actually below MSST due to imprecision and accuracy of the data. In addition, natural fluctuations in stock biomass levels around the B_{MSY} level may temporarily drop the spawning stock biomass below MSST, although analysis from the Southeast Fisheries Science Center (SEFSC) suggests that this is unlikely except at very low natural mortality rates (see below). Setting a wider buffer between B_{MSY} (or proxy) and MSST can avoid these issues. In addition, setting a wider buffer can allow a greater opportunity for management to end a decline in a stock that is approaching an overfished condition and rebuild the stock without the constraints imposed by a rebuilding plan that is required if the stock drops below MSST and is declared overfished. However, if a stock does drop below MSST and is declared overfished, a more restrictive rebuilding plan may be needed than if there were a narrower buffer between B_{MSY} and MSST. Thus, the decision of where to set MSST requires a balance between conservation and management flexibility.

Under **Alternative 1**, only six of the 31 stocks in the Reef fish Fishery Management Plan (FMP) currently have MSST defined. Those stocks are: gag, red grouper, red snapper, vermilion snapper, gray triggerfish, and greater amberjack (Table 1.2) For each of these stocks, MSST = (1-M)*B_{MSY} (or proxy). The natural mortality rate (M) for these stocks ranges from 0.09 to 0.25, so the resulting MSST values range from 75% to 91% of the B_{MSY} proxy. For the remaining 25 stocks, MSST is undefined and would need to be established on a case by case basis.

Alternative 2 sets MSST for all stocks at (1-M)*B_{MSY} (or proxy). This is often the de facto MSST used to determine overfished status, but has been formally adopted in an FMP amendment only for stocks in need of a rebuilding plan. Stock that have not been assessed, and stock that have been assessed and found not to be in need of a rebuilding plan, have not had the MSST established. Natural mortality rates have been estimated for 14 of the 31 reef fish stocks in the Gulf of Mexico (Gulf) (Table 2.1). These estimates range from a low of 0.073 (yellowedge grouper) to a high of 0.28 (greater amberjack), so the resulting MSST values range from 72% to 91% of the B_{MSY} (or proxy). An additional 14 stocks have natural mortality estimates from other regions, either in the published literature or in Southeast Data, Assessment and Review (SEDAR) assessments done for South Atlantic stocks (Table 2.2). The SEFSC and the Scientific and Statistical Committee (SSC) would need to determine if these estimates are applicable to the Gulf stocks or if separate Gulf estimates are needed. Three stocks have no published estimates of natural mortality (Table 2.2).

Alternative 3 sets MSST at 0.75*B_{MSY} (or proxy) for all stocks that have M = 0.25 or less. Stocks with M greater than 0.25 would use the (1-M)*B_{MSY} formula, which would result in a wider buffer between B_{MSY} and MSST for those stocks with M greater than 0.25.

Mutton snapper (M=0.11)	Vermilion snapper (M=0.25)	Black grouper (M=0.136)
Red snapper (M=0.094)	Yellowedge grouper (M=0.073)	Gag (M-0.134)
Lane snapper (M=0.11-0.24)	Goliath grouper (M=0.12)	Tilefish (M=0.13)
Yellowtail snapper (M=0.194)	Red grouper (M=0.14)	Hogfish (M=0.179)

In addition, there are 14 reef fish stocks that have natural mortality rates estimated from regions other than the Gulf and 3 stocks that have no estimate of natural mortality (Table 2.2). Until estimates of natural mortality for the Gulf are available, these stocks will be considered to have an unknown mortality in this region and will be included in the low mortality category. These stocks include:

Queen snapper (M=0.33-0.843)	Speckled hind (M=0.15-0.20)	Goldface tilefish (M=n/a)
Blackfin snapper (M=0.23-0.73)	Warsaw grouper (M=0.08)	Blueline tilefish (M=0.10)
Cubera snapper (M=0.15)	Snowy grouper (M-0.12)	Lessor amberjack (M=n/a)
Gray snapper (M=0.18-0.43)	Yellowmouth grouper (M=0.14-0.24)	Almaco jack (M=n/a)
Silk snapper (M=0.19-0.86)	Scamp (M=0.14-0.15)	Banded rudderfish (M=0.41)
Wenchman (M=0.44)	Yellowfin grouper (M=0.20)	

All of the above stocks (29 of 31) would have MSST = 0.75*B_{MSY} (or proxy). The only stocks not subject to this level are gray triggerfish (M=0.27) and greater amberjack (M-0.28). For these stocks, MSST would be equal to 0.73*B_{MSY} and 0.72*B_{MSY} respectively.

Alternative 4 sets MSST 0.75*B_{MSY} (or proxy) for all reef fish stocks. This would set MSST at the 0.75 level for all 31 stocks in the FMP including gray triggerfish and greater amberjack.

Alternative 5 sets MSST 0.50*B_{MSY} (or proxy) for all reef fish stocks. This would set MSST at the 0.50 level for all 31 stocks in the FMP.

If any species are added to the management unit, or if the estimate of M is changed in a peer-review report or SEDAR assessment for any existing species in the management unit, the intent of this action is that MSST will be set based on the most recent estimate of M and the preferred alternative specified in this action.

Evaluation of the Likelihood of Stocks Falling Below MSST Due to Natural Fluctuations

The SEFSC evaluated the probability that spawning stock will fall below the MSST in the absence of overfishing when MSST = (1-M)*B_{MFMT} versus other MSST reference points (Appendix A). This analysis was requested by the interdisciplinary planning team (IPT) during preparation of this amendment. The analysis modeled three stocks using different proxies for MFMT (F_{MSY} for bluefin tuna, F_{MAX} for vermilion snapper and $F_{30\% SPR}$ for gray triggerfish). For these stocks, estimated natural mortality (M) ranged from 0.14 to 0.27. In the model, abundance was varied randomly while the stock was fished at MFMT. Results showed that fewer than 5% of the model runs resulted in spawning stock levels below MSST at either (1-M)*B_{MFMT} or 0.75*B_{MSY}. None of the model runs resulted in spawning stock levels below MSST at 0.50*B_{MSY}. These results indicate that for the stocks examined, (1-M)*B_{MFMT} appears to be a sufficient buffer against stocks dropping below MSST due to natural fluctuations. However, lower values of M did result in higher probabilities of the stock dropping below MSST despite not experiencing overfishing. As a result, the relationship may breakdown for very small levels of M less than 0.1, in which case adopting an MSST of at least 0.9*B_{MFMT} may be appropriate for stocks with M less than 0.1.

Table 2.1. Reef fish species with natural mortality estimates from stock assessments for the Gulf of Mexico stock.

Common Name	Scientific Name	M	Source
Snappers			
Mutton snapper	*Lutjanus analis*	0.11	SEDAR 15A (2008)
Red snapper	*Lutjanus campechanus*	0.094277	SEDAR 31 (2013)
Lane snapper*	*Lutjanus synagris*	0.30 0.11-0.24	Ault et al. (2005) Johnson et al. (1995)
Yellowtail snapper	*Ocyurus chrysurus*	0.194	O'Hop et al. (2012)
Vermilion snapper	*Rhomboplites aurorubens*	0.25	SEDAR 9 (2006a)
Groupers			
Yellowedge grouper	*Hyporthodus flavolimbatus*	0.073	SEDAR 22 (2011a)
Goliath grouper	*Epinephelus itajara*	0.12	SEDAR 23 (2011b)
Red grouper	*Epinephelus morio*	0.14	SEDAR 12 (2007)
Black grouper	*Mycteroperca bonaci*	0.136	SEDAR 19 (2010)
Gag	*Mycteroperca microlepis*	0.134	SEDAR 33 (2014a)
Tilefishes			
Tilefish	*Lopholatilus chamaeleonticeps*	0.13	SEDAR 22 (2011c)
Other Species			
Hogfish	*Lachnolaimus maximus*	0.179	Cooper et al. (2013)
Greater amberjack	*Seriola dumerili*	0.28	SEDAR 33 (2014b)
Gray triggerfish	*Balistes capriscus*	0.27	SEDAR 9 (2006b)

* Lane snapper: Ault et al. (2005) estimated M=0.30 for lane snapper in the Florida Keys. Johnson et al. (1995) reported a range of M estimates from 0.11 to 0.24 for lane snapper from the northern Gulf of Mexico.

Table 2.2. Reef fish species with no estimate of Gulf of Mexico natural mortality. Natural mortality estimates, where shown, are for stocks from other regions, primarily the Florida Keys, U.S. south Atlantic, or Caribbean.

Common Name	Scientific Name	M	Source
		Snappers	
Queen snapper	*Etelis oculatus*	0.843 0.33-0.76	Murray and Moore (1992) Bryan et al. (2011)
Blackfin snapper	*Lutjanus buccanella*	0.23 0.73	Ault et al. (1998) Tabash and Sierra (1996)
Cubera snapper	*Lutjanus cyanopterus*	0.15	Ault et al. (1998)
Gray (mangrove) snapper	*Lutjanus griseus*	0.25 0.18-0.43	Ault et al. (2005) Burton (2000)
Silk snapper	*Lutjanus vivanus*	0.23 0.19-0.86 0.86	Ault et al. (1998) Bryan et al. (2011) Tabash and Sierra (1996)
Wenchman	*Pristipomoides aquilonaris*	0.44	Froese and Pauly (2014a)
		Groupers	
Speckled hind	*Epinephelus drummondhayi*	0.20 0.15	Ault et al. (1998) Ziskin (2008)
Warsaw grouper	*Hyporthodus nigritus*	0.08	Ault et al. (1998)
Snowy grouper	*Hyporthodus niveatus*	0.12	SEDAR 36 (2013)
Yellowmouth grouper	*Mycteroperca interstitialis*	0.14-0.24*	Burton et al. (2014)
Scamp	*Mycteroperca phenax*	0.15 0.14	Potts and Brennan (2001) Ault et al. (2005)
Yellowfin grouper	*Mycteroperca venenosa*	0.20	Ault et al. (2005)
		Tilefishes	
Goldface tilefish	*Caulolatilus chrysops*	n/a	
Blueline tilefish	*Caulolatilus microps*	0.10	SEDAR 32 (2013)
		Jacks	
Lesser amberjack	*Seriola fasciata*	n/a	
Almaco jack	*Seriola rivoliana*	n/a	
Banded rudderfish	*Seriola zonata*	0.41	Froese and Pauly (2014b)

* For Yellowmouth grouper, Burton et al. (2013) gave age specific natural mortality rates calculated three ways, but did not provide an average. The values in this table are the range of average values for each method for the adult age groups (ages 3 to 31).

APPENDIX D – ANALYSIS OF NATURAL FLUCTUATIONS

A Preliminary Analysis of the Probability that the Spawning Stock will Fall Below the Minimum Stock Size Threshold in the Absence of Overfishing

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The Interdisciplinary Planning Team charged with developing a Minimum Stock Size Threshold amendment to the Reef Fish FMP requested an analysis be conducted to determine the likelihood of stock biomass levels falling below the minimum stock size threshold (MSST) for reasons other than overfishing. This document presents the results of preliminary analyses based on the assessments of three stocks with very different life history strategies: vermilion snapper, gray triggerfish and western Atlantic Bluefin tuna. These stocks were chosen because the forecasting software used in those assessments was easily modified to accommodate the request, however more species will be analyzed as time permits.

The basic approach to quantifying the probability that a stock would fall below a prescribed level of MSST without undergoing overfishing involves stochastic projections of the long-term abundance of the stock when it is subject to fishing at the maximum fishing mortality threshold (MFMT) used to define the overfishing limit (F_{MSY} for Bluefin, F_{MAX} for vermilion snapper and $F_{30\%}$ for gray triggerfish). Stochasticity was introduced by incorporating estimates of parameter uncertainty and lognormally-distributed random deviations in recruitment as specified in the assessment documents referenced below. Populations were found to reach a dynamic equilibrium within 150 years, therefore it was safe to assume that any transient effects resulting from the stock starting somewhere above or below MSST would be negligible by the final year of the projection. The fraction of the projections where the biomass in the final year falls below the biomass at MSY (or proxy) was then tabulated in the form of cumulative frequency distributions (Figure 1).

In all three examples fewer than 5% of the runs resulted in spawning stock levels below the fraction (1-M) of the long-term spawning biomass level associated with MFMT (B_{MFMT}). In these examples M ranges between 0.14 and 0.27, so it was also true that 5% or fewer of the runs resulted in spawning stock levels below 0.75*B_{MFMT}. None of the runs resulted in spawning stock levels below 0.5*B_{MFMT}.

The probability of classifying a stock as overfished when MSST is defined as (1-M)* B_{MFMT} appears to change inversely with M. For example, if the value of M assumed for vermilion snapper is increased from 0.25 to 0.5, the probability that the stock would be classified as overfished decreased from 4% to near zero (Figure 2). Conversely, if the value of M assumed for vermilion snapper is decreased from 0.25 to 0.05, the probability that the stock would be classified as overfished increased to 37%.

In conclusion, the MSST definition (1-M)* B_{MFMT} appears to be a sufficient buffer against classifying any of the three stocks examined as overfished merely as a consequence of natural fluctuations in year-class strength. Only a small percentage of the projections resulted in levels of spawning biomass below this level. The reason for this is that the extent to which year-class fluctuations result in fluctuations in spawning biomass generally decreases with the number of year classes in the population, and the number of year-classes in the population in turn generally increases with decreasing M. This relationship may breakdown for very small levels of $M < 0.1$, in which case one might wish to adopt a definition for MSST that does not exceed 0.9*B_{MFMT}, e.g.,

$$MSST = MIN[1-M, 0.9]*B_{MFMT} .$$

The present analysis could be expanded to allow for fluctuations in the natural mortality rate, growth and other population parameters, in which case it might be expected that the probability of dipping below any given level of MSST due to natural fluctuations would increase. This implies that a somewhat larger buffer might be appropriate. The levels mentioned during the IPT discussions included 0.75*B_{MFMT} and 0.5*B_{MFMT} (the latter being the lowest level allowed under the current NS1 guidelines). While further analyses are needed to indicate the level of natural variability required to support buffers as low as 0.5*B_{MFMT} in general, the current work suggests that at least for longer-lived stocks (low M) the degree of uncertainty would need to increase a great deal for such a low threshold to be appropriate. Ortiz et al. (2010) point out that setting a limit well below B_{MFMT}, while having the desirable quality of increased statistical power for detecting whether a stock has been overexploited, also carries with it the danger of extended time periods for management actions required for rebuilding. The current requirement under Magnuson-Stevens Fishery Conservation and Management Act to take immediate actions to stop overfishing should mitigate against this danger of falling too far below B_{MFMT}, or to put it another way, causes buffers as low as 0.5*B_{MFMT} to have no meaningful effect on the management of long-lived animals

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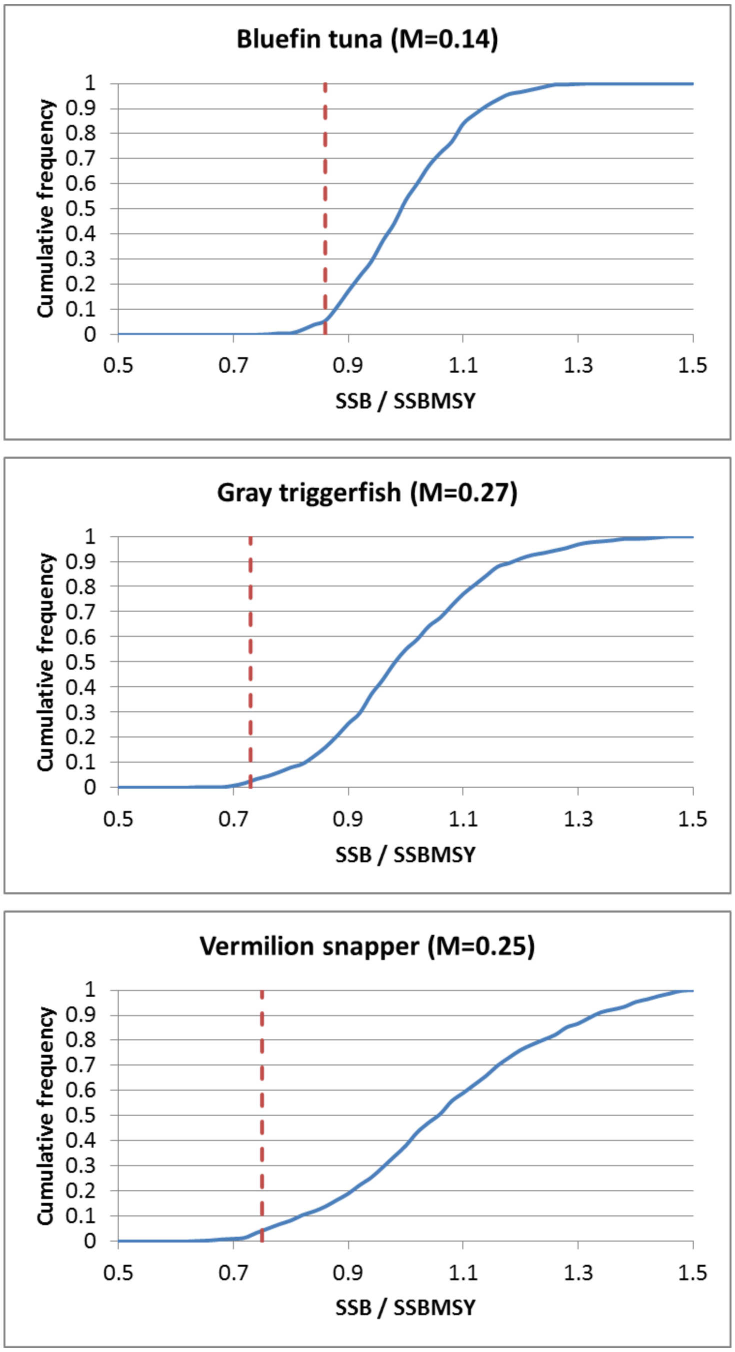

Figure 1 (Appendix D). Cumulative probability distributions of the spawning biomass in the last year of the projection relative to the equilibrium spawning biomass associated with MFMT for each of the three species. The dashed vertical line represents the quantity 1-M.

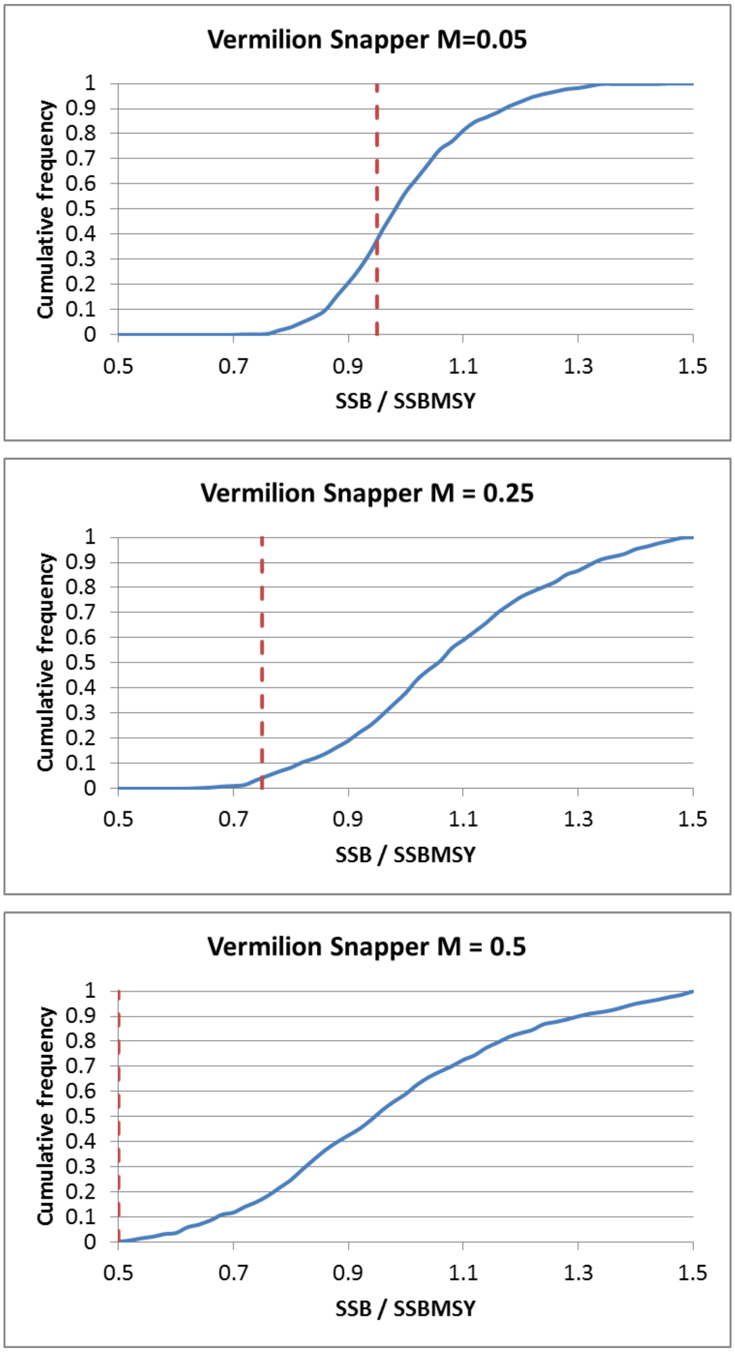

Figure 2 (Appendix D). Cumulative probability distributions of the spawning biomass in the last year of the projection relative to the equilibrium spawning biomass associated with MFMT for vermilion snapper assuming 3 different levels of M. The dashed vertical line represents the quantity 1-M.