North Pacific Fisheries Management Council
Bering Sea / Aleutian Islands King and Tanner Crab Working Group

Working Group Membership:
NMFS: L. Rugolo [Co-Chair], J. Turnock
ADFG: S. Shareef [Co-Chair], J. Zheng

Draft Statement of Work

I. Scope of Responsibility of Working Group:

To revise and amend the Bering Sea / Aleutian Islands King and Tanner Crab Fishery Management Plan [FMP or Plan] of the NPFMC insuring that:

1. The revised Plan is in compliance with the Federal laws governing the management of these stocks - the Magnuson-Stevens Fishery Conservation and Management Act [MSFCMA], and the Sustainable Fisheries Act [SFA].
2. The underlying fisheries scientific and technical frameworks are consistent with the National Standards [NS] established by these Acts.
3. The specified conservation and management measures conform to the National Standard Guidelines [NSGs] - notably, to NSG1 and the adoption of precautionary management practices.
4. The fisheries scientific and technical frameworks that serve as the biological underpinning of management, represents the best scientific information available as required by NS2.

Revisions and amendments to the Plan are specified in two sections: **II. Revisions to the Plan**, and **III. Additional Technical Components to Implement in the Plan**. In each section, specific **Action Items** are identified for implementation. A brief overview precedes each item which provides the rationale for amending that Plan element. The value of each Action Item to the conservation and utilization of these stocks will be shown in the Environmental Assessment for the Plan amendment.

II. Revisions to the Plan:

Statement of Need:
For each stock under this Plan, the threshold definition of overfishing, the definition as to whether the stock is overfished, and the overfishing control rule require revision.

The SFA requires that status of overfishing determination criteria specify both a maximum fishing mortality threshold [MFMT], and a minimum stock size threshold [MSST] or reasonable proxies thereof. Stocks must be assessed according to whether the maximum fishing mortality threshold is exceeded, and whether the stock is below the minimum stock size threshold.

The NSGs require NOAA Fisheries to determine if the fishing mortality rate threshold is being exceeded and if the biomass is below the established threshold for each stock under the Plan. If the fishing mortality rate is above threshold, then overfishing is occurring. If the stock size is below the minimum threshold, then the stock is overfished. Remedial management action is required if either occurs. Where overfishing is occurring, fishing mortality must be reduced so that stocks can produce maximum sustainable yield [MSY] on a continuing basis. For stocks that are overfished, rebuilding plans with an acceptable likelihood of success must be implemented to rebuild stocks to the MSY level within an appropriate time frame.

The MSFCMA defines ten National Standards for fishery conservation and management. NS1 requires the adoption of conservation and management measures that prevent overfishing while providing optimum yield [OY] on a continuing basis from each stock. The advisory guidelines for NS1 state that the Councils should adopt a precautionary approach to specifying OY. The precautionary approach guidelines identify MSY as the minimum standard for defining management limits. The MSFCMA adopts this concept and constrains OY to be no greater than MSY.

A principle feature of the precautionary approach to management is the definition of ***limits*** to safeguard the long-term productivity of the stock. The NSGs define two limits for management that are required to insure stock conservation and yields close to MSY. These are the MFMT and MSST intended as benchmarks to gauge if a stock is being overfished or if it's in an overfished state. Another important feature of applying the precautionary approach is the specification of ***targets*** that are set safely below these limits. Target setting considers uncertainty and other management objectives. Criteria used to set limit and target levels should be explicitly ***risk averse***. Status determination criteria are used to evaluate the performance of limit and target reference point systems.

Pertinent Definitions:

I. ***Fishing Mortality Rate [F]*** refers to the full-selection instantaneous rate of fishing mortality that applies to fish of fully selected, or recruited sizes or ages. The terms *'full-selection F'* and *'fully-recruited F'* are synonymous.

ii. ***Overfishing*** is determined to be occurring when the fishing mortality rate F exceeds the MFMT rate required to produce the maximum sustainable yield on a continuing basis. It is defined in NS1 as *"a rate or level of fishing mortality that jeopardizes the capacity of a stock ... to produce the maximum sustainable yield on a continuing basis"*. The status determination of overfishing is based on the overfishing threshold [MFMT] specified in a Plan. Exceeding this threshold for a period of 1 year or more constitutes overfishing.

iii. ***Overfished*** stocks are those whose biomass is below the minimum stock size threshold expressed in terms of spawning biomass or other measures of reproductive capacity. The MSST should be set at the greater of one-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock were exploited at the full MFMT.

Should the stock size in a year fall below this threshold, the stock is considered overfished. The MSFCMA also uses "*overfished*" to describe a stock that is subject to an F in excess of the MFMT.

iv. The NS1 defines the following MSY-related concepts:

[a]. **MSY** is the largest long-term average catch or yield that can be taken from a stock under prevailing ecological and environmental conditions.

[b] **MSY Control Rule** is the harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY.

[c] **MSY Stock Size** is the equilibrium stock size under a constant fishing mortality MSY control rule - i.e., the long-term average stock size that would be achieved under an MSY control rule in which the fishing mortality rate was constant.

The Working Group will devise overfishing and overfished definitions, and MSY Control Rules for the stocks that are in compliance with governing Acts. The Amendment will specify thresholds to serve as standards for determining if a stock is being overfished or if it's in an overfished state. It will specify the MSY control rule that intrinsically links these threshold definitions for each stock.

☞ ***Action Item II.1. Overfishing Definition***:

1. A maximum fishing mortality rate [F] threshold [MFMT], or reasonable proxy thereof. Such a limit reference point, or F_{OFL}, will:

a. Represent the 'full-selection F' or the 'fully-recruited F' rate.

b. Encompass indirect losses to the stock as discards, and non-directed losses as bycatch from non-target fisheries.

c. Prescribe the F-based overfishing definition for the stock component exploited by the fishery - i.e., the exploitable stock biomass or its corollary, exploitable stock abundance.

d. Prescribe proxy overfishing definitions if required. Proxy definitions will be needed when the F_{MSY} cannot be estimated or when the estimated value is deemed unreliable [e.g., extremely low precision, insufficient contrast in the data, or inadequate models]. The choice among proxy measures must conform to the conservation requirements of the Acts in defining limits intended to safeguard the long-term productivity of the stock.

☞ ***Action Item II.2. Overfished Definition:***

2. A minimum stock size threshold MSST, or reasonable proxy thereof, expressed in terms of spawning biomass or other measures of reproductive capacity. The MSST should be the greater of either one-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock were exploited at the full MFMT. Formulation of this definition should satisfy:

a. The Act's conservation requirement of safeguarding the long-term productivity of the stock.

b. Where data allow, it would be derived in a structured modeling framework that reflects the species' essential biological and life-history characteristics, as well as its population and fishery dynamics.

c. Proxy overfished definitions should be scientifically defensible and supported by empirical evidence. Proxy definitions will be needed when the MSST cannot be estimated or when the estimated value is deemed unreliable [e.g., extremely low precision, insufficient contrast in the data, or inadequate models]. The choice among proxy measures must conform to the conservation requirements of the Acts in defining limits intended to safeguard the long-term productivity of the stock

☞ ***Action Item II.3. MSY Control Rule:***

3. In the National Standard Guidelines, the above two limit definitions are intrinsically linked through an MSY Control Rule that specifies how the F threshold should vary as a function of stock biomass in order to achieve yields close to MSY on a continuing basis. Control rules are pre-established plans for implementing management decisions without delay in response to changing status of the stock. The NSG1 states that the choice of a control rule should be guided by the characteristics of the fishery, the FMP's objectives and the best scientific information available. To minimize the occurrence of stock sizes for which rebuilding plans are required, the MSY Control Rule should afford *"built-in"* rebuilding as stock size declines below the MSY Stock Size.

Item III.7 and III.8 describes a method to intrinsically link the Plan's MSY Control Rule to an integrated *Tier System* and *Limit Reference Point System*. Item III.9 discusses desirable properties of control rules to achieve in this amendment.

III. Additional Technical Components to Implement in the Plan:

In addition to revising inadequately defined fisheries scientific and technical elements of the Plan, this Amendment will specify additional technical elements that are required to meet the responsibilities described in Items I.1 - I.4. The following is a list of key fisheries scientific and technical components of the Plan that require amending. Most have been described in the *Addendum to the Crab Plan Team Meeting Minutes of 22-24 September 2003* [Rugolo] submitted to the NPFMC in October 2003. Additional elements may be included in order to achieve compliance with the governing Acts, and with their attendant Standards and Guidelines.

1. Instantaneous Natural Mortality Rate [M]:

The rates of natural mortality used in stock assessment and harvest strategy modeling differ from those specified in the overfishing definitions of the Plan. For most stocks, the instantaneous rate of natural mortality [M] underlying the MSY Control Rule is decoupled from the applied harvest control rules. This results because the harvest strategy and population dynamic modeling frameworks are not analytically linked. In some cases, M is treated as a variable that is estimated annually in external model formulations whose

value represents total stock losses not attributed to direct fishery removals. As practiced, annual estimates of M can exceed that specified in the overfishing definition or MSY Control Rule without modification to the target or threshold fishing mortality rate definitions in the Plan.

There is a high degree of uncertainty whether the values of M specified in the Plan are consistent with the life-histories of the subject species. Current estimates are based on a method for estimating Z for lightly exploited stocks using observed oldest age [t_{MAX}] in the stock [Hoenig 1983]. Its formulation neither considered crustaceans nor virgin populations. Application of Hoenig [1983] is functionally equivalent to assuming that the 99th percentile of longevity [i.e, maximum attainable age in a virgin population] is known, and that this percentile is t_{MAX}. This is a risk-negative assumption, particularly in cases where age data are derived from exploited populations, and ages are inferred from indirect methods as for these crab species. By comparison, if the observed oldest ages [t_{MAX}] represent the 95th percentile, the Hoenig method provides M estimates that are approximately 40% higher across the range of modeled ages. When used to derive overfishing definitions, this difference provides substantially more risk-prone outcomes in terms of target or threshold F rates. This violates the intent of the NSGs in establishing target and limit reference points that are explicitly *risk averse* if the input value t_{MAX} is less than the 99th percentile of longevity.

Where empirically derived estimates of M are available for a stock, the Working Group may choose to co-opt these estimates for use in the amendment. Such estimates should preferably be the outcome of a directed research investigation designed to estimate M, in contrast to indirect methods using survey data in which the effects of indirect losses to the stock are not properly quantified. In such approaches, the instantaneous rate of total annual mortality Z is the quantity estimated, and M inferred by subtraction of an imposed F. The value of M specified in the Plan for any stock must be scientifically defensible. At a minimum, it must be consistent with the life-history of the species.

☞ ***Action Item III.1. Instantaneous Natural Mortality [M]:***

The Amendment will:

a. Describe the method that will be used to estimate M for each crab species subject to this Plan.

b. Describe how the rate M will be applied in the overfishing definition and in the MSY Control Rule for each stock.

2. <u>Plan Overfishing Definition and Z_{MSY}</u>:

The instantaneous rate of total annual mortality [Z] is defined as M+F. Most derived limit reference points [e.g., F_{MSY}] are outcomes of structured modeling frameworks whose value depends on the specified input M. While M may change inter-annually, or may be age or size-variant, empirical studies are commonly lacking to provide such understanding. The principle in the MSFCMA of fishing at F_{MSY} is that, given a specified value of M, the Plan will define conservation and management measures to maintain total annual losses from the stock at or below the sum of $F_{MSY}+M$. Hence, at or below $Z_{MSY}=F_{MSY}+M$. It's the

modeled Z_{MSY}, not F_{MSY}, that produces the measure of interest - the production of sustainable yields at the maximum [MSY], from a stock maintained at B_{MSY}, under and applied fishing rate F_{MSY}.

Heretofore in crab stock assessment and harvest strategy modeling, M has been estimated annually in excess of that specified in the overfishing threshold definitions for the stocks. Even in such instances, harvest goals are derived using the full value of F_{MSY}. Declines in abundance seen in the survey and not attributed to the retained catch, are assumed to result from inter-annual changes in natural mortality. Whether such declines result from true changes in M or from background bycatch or discard losses, the realized Z on exploited stocks has been allowed to exceed Z_{MSY} in practice without meeting the overfishing test standard of the Plan. Hence, without conforming to the intent of fishing below an overfishing threshold definition deemed appropriate for each stock.

☞ ***Action Item III.2. Plan Overfishing Definition and Z_{MSY}:***

The Amendment will:

a. Describe how Z_{MSY} will operate as a limit reference point for each stock.
b. Describe how Z_{MSY} will be applied in the overfishing definition and the MSY Control Rule for each stock.
c. Describe how Z_{MSY} will be applied in assessing the performance of the fisheries and the adopted conservation and management measures.

3. <u>Instantaneous Fishing Mortality Rate F and Annual Exploitation Rate [u]</u>:

The Plan fails to specify the proper use of F and u in devising conservation and management measures consistent with adopted overfishing definitions. In practice, F and u have been incorrectly used interchangeably in computational formulae that estimate preseason harvest levels. Where M and F compete for deaths during a fishery, or where losses from M occur between the time of the survey and the fishery opening, using the numerical value of F in place of the proper value of u results in overestimating the exploitation rate corresponding to that F. It also results in overestimating preseason harvest quotas.

The Plan also incorrectly uses the *"rate of utilization"* in place of exploitation rate as a status determination criterion for determining if overfishing is occurring. The utilization rate refers only to the retained catch and does not consider indirect losses from the stock from bycatch or discards. Exploitation rate is based on the fully-recruited F, fishery selectivities and natural mortality. Utilization rate underestimates exploitation rate if any indirect losses occur in the stock. If used as a status determination criterion, it provides more risk prone assessment outcomes.

☞ ***Action Item III.3. Instantaneous Fishing Mortality [F] and Exploitation Rate [u]:***

The Amendment will:

a. Describe how the fully-recruited F rate and fishery selectivity will be employed to derive the exploitation rate corresponding to the target or threshold F definitions in the Plan.

b. Prescribe what is the exploited component of each stock that is subject to the target or threshold Fs in the Plan.

4. Non-Directed Mortalities and Overfishing Definitions:
The Plan inadequately specifies the operational use of discard and bycatch mortalities in the formulation of target or threshold F rates, and in the estimation of preseason harvest goals. The lack of incorporation of these mortalities in the operational framework of the Plan results in estimating and applying F [or u] rates and catch quotas that exceed the overfishing definitions of the Plan.

☞ ***Action Item III.4. Non-Directed Mortalities and Overfishing Definitions:***
The Amendment will:

a. Describe how discard mortalities will be employed to derive the exploitation rate corresponding to the target and threshold F rates specified in the Plan.
b. Describe the approach to estimate the discard loss rates from the directed fishery for each stock, or the values of those rates.
c. Describes the approach to estimate the bycatch loss rates from the non-directed fisheries for each stock, or the values of those rates.

5. Biomass B_{MSY} and Sustainable Yield [SY]:
The Plan inadequately defines the equilibrium stock biomass [B_{MSY}] that will produce the maximum sustainable yield from each stock. The definitions of B_{MSY} may be underestimated for some stocks which would result in risk-prone outcomes in terms of judging stock health or stock recovery, or for assessing if the stock is overfished. This violates the intent of the NSGs in establishing reference values that are explicitly risk averse.

The Plan's B_{MSY} values for each stock are defined by the average survey estimate of total mature biomass [TMB] for the 15-years from 1983-97. The BS crab stocks were not in equilibrium during this period. Instead, they illustrated significantly varying trends in overall abundance. They were at levels of stock biomass that would not produce MSY on a continuing basis by definition. Computing B_{MSY} and MSST using data from this 15-year period may underestimate overfished definitions thereby specifying biomass standards that are artificially low.

The MSY Control Rule of the Plan specifies that the MFMT = F_{MSY} = M, where for *Chionoecetes* sp., M = 0.30, and for *Lithodes* sp., M = 0.20. Overfishing would occur if fishing mortality [F] exceeded the MFMT, F_{MSY}, in any year. Amendment #7 of the Plan defines MSY as "*the mature biomass of the stock ... exploited at a fishing mortality rate equal to a conservative estimate of natural mortality*". While the Environmental Assessment [EA] of Amendment #7 defines a status determination criterion for overfishing as the "*expected utilization rate as the projected guideline harvest level divided by the estimated legal male abundance*". Utilization rate is not equivalent to exploitation rate since it does not account for indirect losses due to bycatch or discards. Utilization rate underestimates

exploitation rate in such instances. This criterion is further lacking since it uses *"expected"*, not "realized" utilization rate, based on *"projected guideline harvest level"*, not the "realized catch". In practice, stock losses due to natural mortality from the time of the survey to the fishery have also been unaccounted for in harvest setting.

The status determination framework in the Plan does not require that this *"utilization rate"* be compared to the MFMTs based on the F_{MSY} specified in the MSY Control Rule or to any retrospectively derived estimate of fully-recruited F. A further complication is a description in the Executive Summary of the SAFE Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions and in Amendment #7 which defines a catch standard called sustainable yield [SY] = TMB*F_{MSY}. The SAFE report states that *"overfishing occurs if the harvest level exceeds the SY in one year"* - a definition that is not contained in Amendment #7. This latter definition is wholly lacking and theoretically inconsistent. For *C. opilio* in 2003, this definition would allow the removal of every male ≥ 4" cw, of every shell condition throughout the entire BS geographic range [i.e., u = 100%, F = ∞] without meeting the overfishing threshold standard. [see Item 13., p.5 of *Addendum to the Crab Plan Team Meeting Minutes of 22-24 September 2003* for the numerical illustration].

Sustainable yield as derived by TMB*F_{MSY} is not computed on the exploited portion of the stock. TMB includes mature female biomass which is not a component of landings. TMB also includes mature males of smaller size than the minimum size limits, and males of shell condition which are not targeted by the fishery or main component of yield. For some stocks, TMB includes components of the stock which are geographically not fished. The stock of *C. opilio* is noteworthy in this regard.

The sustainable yield that can be taken from a stock is meant to represent a measure of production which can be removed in excess of that necessary to provide stock replacement. It is often based on long-term dynamic equilibrium theory and results from a stock's inherent production characteristics. The Bering Sea crab stocks under this Plan have neither demonstrated the ability to replace total annual losses, nor the ability to maintain themselves in dynamic equilibrium. They have instead fallen and remained at exceedingly low levels of biomass. The inability of these stocks to respond to declines in abundance suggests that they have fallen to levels below their compensatory reserve.

A conceptual mismatch exists in the Plan concerning the stock component used to estimate harvest goals by the MSY Control Rule and the component of the stock exploited by the fishery. This application has led to exceedingly high rates of exploitation born by specific segments of the stock, and to localized depletions as exemplified by changes in the spatial distribution of *C. opilio* over time.

☞ ***Action Item III.5. Biomass B_{MSY} and Sustainable Yield [SY]:***

The Amendment will:

a. Describe the approach to estimate B_{MSY} or a proxy thereof.
b. Prescribe the exploitable abundance component of the stock to be used to estimate harvest goals.

c. Describe the approach to estimate catch standards using the exploitation rate corollary to the target F on the exploitable component of the stock.

6. Conservation Equivalency:

The MSY Control Rule of the Plan is not attentive to exceeding annual target F rates or specified overfishing definitions. No framework exists in the Plan for considering the consequences of such outcomes on stock biomass, or for safeguarding the long-term reproductive potential of the stock. The operational framework of the Plan provides no explicit control feedback to safeguard long-term stock productivity, or to insure stabilities in stock abundance or yield.

Harvest goals estimated for exploited stocks should include all direct and indirect stock removals, and relate directly to target or threshold fishing mortality rates specified in the Plan. The current crab Plan does not specify target fishing rates lower than the threshold limit reference points [F_{MSY}] as recommended by NSG 1. For these stocks, harvest control analyses estimate preseason harvest goals from survey-based estimates of stock biomass. Customarily, preseason harvest goals are exceeded by the fisheries - hence, the F rates on which the goals were based are also customarily exceeded.

Routinely exceeding threshold fishing mortality rates for most exploited fishery resources often leads to the erosion of stock biomass and to declines in the long-term productivity. The rates of such declines vary proportionally to the level of fully-recruited F in excess of threshold. Exceeding a target F rate would minimally result in a lower standing or spawning stock biomass in any year vs not having exceeded those rates. This practice is inconsistent with the intent of the NSGs in establishing biological reference points that are explicitly risk averse.

The concept of Conservation Equivalency as practiced or implemented in inter-jurisdictional State or Federal fishery management plans accounts for the outcome of exceeding target or threshold F rates. It provides for the maintenance of reproductive potential and stock biomass standards specified in the Plan. Requisite adjustments are made in the MSY Control Rule to reconstitute stock status resulting from over-achieving target fishing rates or harvest goals.

☞ ***Action Item III.6. Conservation Equivalency:***

The Amendment will:

a. Specify the approach of Conservation Equivalency which will serve to maintain stock biomass standards established in the Plan.
b. Identify the currency of measure for determining the equivalent conservation value used to adjust the MSY Control Rule in response to exceeding overfishing definitions in the Plan.
c. Describe the analytical framework to be applied in the Plan's MSY Control Rule for target rate setting that would achieve stock conservation equivalency and the specified stock biomass standards.

7. Tier System for Defining Overfishing Definitions:

Under the MSFCMA and the SFA, overfishing is defined as any amount of fishing in excess of the maximum fishing mortality threshold [MFMT]. In the NPFMC's BSAI and GOA Groundfish Fishery Management Plans, the MFMT or F_{OFL} is prescribed through a set of six tiers based on the level of information availability on the stocks. The BSAI King and Tanner Crab FMP contains a reduced tier system that is not fully implemented.

In the crab Plan, overfishing definitions for all stocks are derived under what would be lower tier standards for groundfish. Such overfishing definitions acknowledge incomplete or unreliable information and understanding of the stocks and the fisheries. In contrast, the current stock assessment and harvest strategy modeling rely on fully parameterized population dynamic models, such as stock-recruitment, to estimate stock abundance, guideline harvest levels, and target exploitation rates, or their corollary fishing mortality rates, corresponding to the overfishing thresholds [F_{OFL}]. Whether the available information and understanding for these stocks is sufficient for these purposes is at question.

A Tier System is needed in the crab Plan for prescribing the maximum fishing mortality threshold [MFMT] rates analogous to the groundfish Plans, with modification. The tiers would similarly correspond to orders of information availability on the stocks, and further explicitly address uncertainty in that information. The Tier System would reflect the annual status of stocks [SOS] - its understanding and uncertainty - as well the status of knowledge [SOK] per the groundfish Plans. This modified system would reflect the challenges faced in conducting analytical stock assessments on invertebrate fishery resources, and in formulating population dynamic models that provide meaningful output, such as target or limit biological reference points.

☞ ***Action Item III.7. Tier System for Defining Overfishing Definitions:***

The Amendment will:

a. Define a Tier System for prescribing the threshold overfishing definitions for each stock.
b. Formulate the system for setting F_{OFLs} that considers both the status of knowledge and its uncertainty, and the status of the stocks.
c. Describe the approach for formally integrating the Tier System and the Limit Reference Point System [see Item II.8] for prescribing target or threshold fishing mortality rates for each stock.

8. Limit Reference Point [LRP] System:

Caddy [1998] proposed a limit reference point system for gauging the annual health and status of the stocks. Limit reference points represent meaningful and measurable indices of stock health and status. These reference points are evaluated and used to derive an aggregate index of stock health that is implemented in a "*Traffic Light System*".

Caddy's diagnostic Traffic Light System is suitable to stocks for which uncertainty exists in quantifying reference points due to the lack of information or to low confidence in that information. The approach assesses stock and fishery status by a suite of non or semi-

quantitative multiple criteria. Its provides guidance as to the emphasis to be placed in applying the precautionary approach. Using a set of limit reference points to gauge the status of the stocks and the fisheries, the results indicate the management response requisite to achieving Plan goals. These responses are formulated in the MSY Control Rule for setting F_{OFLs} or target fishing mortality rates.

Several candidate LRPs are suitable to stocks under this Plan. These would include biomass [B], fishing rate [F], total annual mortality rate [Z], recruitment [R], trajectories in both stock biomass [B_T] and recruitment [R_T], and uncertainty in the estimates of any of these metrics [e.g., B_U, F_U, $Z_{U\ldots}$]. Other LRPs may also be suitable.

☞ ***Action Item III.8. Limit Reference Point System:***

The Amendment will:

a. Identify the suite of LRPs essential to gauging stock and fishery status.
b. Define a Traffic Light System for the status of stock and fishery assessment that is integrated in the MSY Control Rule.
c. Describe the method of enumerating annual SOS that would replace the current determination of stock biomass relative to threshold.
d. Define the limit reference point system and its use in a control rule that specifies the F Buffer Zone, F Target Zone and F Overfishing Zone.
e. Define the method to link the Limit Reference Point System and the Tier System for prescribing the maximum fishing mortality threshold or target F rates for each stock.
f. Prescribe how these combined systems would be used to set F_{OFL} values appropriate to the current status of the stock and fisheries.

9. <u>Projection Modeling Framework</u>:

The Plan lacks a suitably rigorous and informative modeling framework for evaluating the consequences of alternative fishery conservation and management measures on stock health. A general simulation framework is required for assessing how the stocks and fisheries would perform if fished at target or threshold Fs. Where specific outcomes are desired by a proposed management control [e.g., increase in stock biomass], this framework should provide quantified and reliable measures of achieving that outcome.

Restrepo et. al [1998] describe a fishery management strategy as *"the combination of data collection, stock assessment, control rules, and technical measures for implementing the harvest controls"*. In their review of stock assessment methods, the National Research Council stated *"Both harvesting strategies and decision rules for regulatory actions have to be evaluated simultaneously to determine their combined ability to sustain stocks"* [1998]. A flexible, generalized simulation modeling framework is required for evaluating management strategies for the BS crab stocks under this Plan. This includes specifying the performance criteria that will be examined in the evaluation process.

The NSG 1 describes the remedial action required to rebuild stocks once biomass has fallen below the MSST. The time frame for rebuilding depressed stocks is 10 years where

stock productivity characteristics allow, or some function of generation time when the expected time to rebuild under zero fishing is greater than 10 years. The intent of the MSFCMA is that overfished stocks be rebuilt quickly.

Where a stock is under a rebuilding plan, rebuilding trajectories of stock biomass given current population dynamic model formulations need to be compared to the rebuilding plan trajectories of stock biomass to evaluate the success of implemented management measures. In the current crab rebuilding plans, trajectories in expected stock biomass are not specified for the various management alternatives modeled. Restrepo et. al [1998] characterize a rebuilding plan as a strategy for selecting fishing mortality rates to achieve stock recovery within a specified time frame. Components of such plans include a *"rebuilding period"* and a *"rebuilding trajectory"* among others. A rebuilding Control Rule is specified that incorporates these components.

Even where stocks are not under rebuilding plans, a desirable property of any MSY control rule is that its application should always lead toward returning the stock to B_{MSY}. To guard against dramatic declines in stock biomass and the need to implement rebuilding plans, a desired property of an overfishing control rule would be to afford *"built-in"* rebuilding as stock size declines below the *MSY Stock Size*. In this manner, greater and more stable yields to the fisheries could be realized, as well as conferring stability to the reproductive potential of the stock. The MSY Control Rule of this Plan does not to provide these measures of protection to the stocks or to the fisheries.

☞ ***Action Item III.9. Projection Modeling Framework:***

The Amendment will:

a. Define a suitable analytical framework for examining the consequences of alternative conservation and management measures on stock status.
b. Specify the performance criteria that will be examined in the process of evaluating harvest strategies and decision rules.
c. Define a general simulation framework for developing rebuilding plans that achieve stock recovery in the requisite time frame. Plan components will specify both the rebuilding period and rebuilding trajectory.
d. Define a general simulation framework that would specify the rebuilding control rule for to each stock under a rebuilding plan.
e. Define an analytical framework that would prescribe the overfishing control rules for each stock.

10. <u>Sensitivity Analysis</u>:

As described under Action Items II.1 and II.2, this amendment will revise the overfishing and overfished definitions in the Plan, and specify status determination criteria for evaluating the performance of each fishery management system. These definitions will meet the conservation requirements of the Acts in safeguarding long-term stock productivity. They will also address the essential goal of formulating strategies and decision rules that are consistent with precautionary management practices.

Where data and understanding allow, limit reference points will be estimated within structured models that reflect the species essential biological and life-history characteristics, as well as their population and fishery dynamics. The suitability of such parameterized model structures for this purpose will depend on the validity of the input parameter values chosen to represent these essential processes.

For crab stocks under this Plan, key parameters belong to one of two main categories: [1] those related to the species itself [i.e., biological, life-history and population dynamics], and [2] those related to the fishery, and a lesser category related to the survey. Species-specific parameters include natural mortality, molt probability, growth increment, mating ratio, schedules of maturity and fecundity, weight @ size, longevity and recruitment. Fishery-specific parameters include the fishing season [duration and timing], discard mortality, bycatch mortality and the partial recruitment pattern. The latter reflects both crab *availability* [temporal and spatial distribution relative to the fishery] and the *selectivity* of crabs of different ages or sizes by the gears. Net selectivity is a key survey-specific parameter. Changes in these parameters due to natural variability or to changes in the fishery management system will affect estimates of reference points. To assess these affects and derive robust reference point values, sensitivity analyses will be performed.

Sensitivity analysis is of value in two broad respects. First, in instances where there is low confidence or poor understanding of a parameter value, the analysis can be configured with a restricted range of reasonable estimates of this parameter so as to examine the effects on model outcomes. Secondly, sensitivity analyses can be performed on the entire model structure and parameter space in order to provide understanding the relative contribution of parameters to model performance. The latter would be insightful in terms of identifying critical model dependencies which are important considerations in research planning aimed at meeting the essential information needs of the stocks. The formulation of effective fisheries conservation and management measures for these stocks indeed depends on such understanding. Sensitivity analyses conducted by the Working Group as part of this amendment will address both of these objectives.

☞ ***Action Item III.10. Sensitivity Analysis:***

The Amendment will:

a. Identify the important fishery and stock parameters whose variation would affect the overfishing and overfished threshold definitions.
b. Define an analytical framework that would be used to conduct sensitivity analyses of these reference points for each stock.
c. Define an analytical framework that would be used to select robust overfishing and overfished values based on sensitivity analyses.
d. Identify the critical information needs for management which would guide research planning for these stocks.