USE OF PRODUCTIVITY-SUSCEPTIBILITY ANALYSIS (PSA) IN SETTING ANNUAL CATCH LIMITS FOR U.S. FISHERIES: An Overview

A Report From MRAG Americas, Inc.

With support from Expert Working Group participants*

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1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1976 and the 1996 Amendments made progress toward recovery of depleted stocks and sustaining stock health, but many stocks remain overexploited or have not been rebuilt (NOAA, 2007; Rosenberg *et al*., 2006). As a result, the 2007 amendments to the M-S act are designed to improve accountability in management to prevent overfishing and rebuild stocks to levels that will support maximum sustainable yield.

Section 104 (a)(15) of the 2007 Magnuson-Stevens Reauthorization Act (MSRA) establishes "a mechanism for specifying annual catch limits in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability." Annual catch limits are the amount of each type of fish allowed to be caught in a year. Congress has set a "no fail" deadline to establish catch limits for all fisheries experiencing overfishing by 2010, and 2011 for all other fisheries.

In January 2009, the National Marine Fisheries Service (NMFS) published a final rule to implement the new MSRA requirements and amend the guidelines for NS1, including overfishing levels (OFLs), annual catch limits (ACLs), annual catch targets (ACTs), and accountability measures (AMs) Regional fishery management councils will be responsible for developing ACL amendments for each fishery management plan. For many fisheries, no data exist to conduct traditional analyses sufficient to determine current status of the stocks or whether overfishing occurs. Without a means to objectively determine overfishing levels and a fishing mortality at or below overfishing, regional management councils will likely set ACLs using conservative best guesses. Rosenberg *et al*. (2007) developed a straightforward process for establishing sustainable catch limits for all species, including those that lack sufficient scientific data; this included procedures for estimating catch levels in data poor situations.

Rosenberg *et al*. (2007) proposed a precautionary procedure for setting ACLs based on requirements of the M-S Act:

- ***As a default or starting point, preventing overfishing applies to ALL stocks, therefore, so should ACLs.***
- ***To successfully end and prevent overfishing, OFL > ABC ≥ ACL.***
- ***ACLs should account for uncertainty in stock status and risk of overfishing for each stock.***
- ***Consideration of risk must include some evaluation of the vulnerability of a stock to the fishery.***
- ***The buffer or distance between the ACL and the OFL should be greater when the risk of overfishing is higher (i.e., when uncertainty is greater or the consequences of overfishing as expressed by vulnerability of the resource is higher).***

Central to this process is determining the "buffer" needed between the OFL and the ACL to increase the probability that overfishing doesn't occur and that rebuilding proceeds as needed. That is, the process is designed to determine how far the ACL should be set below the OFL to account for the various sources of uncertainty referred to in the principles above. In general, buffers need to increase as risk of overfishing increases and amount of information decreases; conversely, low risk and more information allow a smaller buffer. This process will require a risk-based assessment using the procedure of Hobday *et al*. (2007) for all species.

1.1 The Risk Based Assessment

In July and August 2007, MRAG Americas convened a working group of experts (The ACL Working Group) in fisheries science and management to discuss applying the ACL and AM requirements to all species caught in U.S. waters. The ACL Working Group found that the framework developed by a recent joint Australian Commonwealth Scientific and Research Organization (CSIRO) and Fisheries Management Authority (AFMA) project (Hobday *et al*., 2006) for Ecological Risk Assessment for the Effects of Fishing (ERAEF) provides a good basis for a precautionary evaluation of vulnerability of fishery resources.

The Working Group recommended Level 2 of the ERA, the Productivity and Susceptibility Analysis (PSA), for this purpose. The Marine Stewardship Council (MSC) also uses the PSA (plus the level 1 Scale Intensity Consequence Analysis) in a pilot program to assess sustainability of data deficient stocks (Hobday, 2007).

The PSA approach is a method of assessing a fishery species or stock based on a comprehensive screening of risk for a set of predetermined measurable attributes. The PSA methodology employed here was adapted from Hobday *et al.*, 2007. The results of the PSA measure risk from direct impacts of fishing only. In this case it is intended to illuminate if management complexes and regulations are appropriate for a given group of stocks and aid in the development of annual catch limits as mandated by the Magnuson-Stevens Reauthorization Act (MSRA).

The PSA approach is based on the assumption that the risk to a species will depend on two characteristics: (1) the productivity of the unit, which will determine the rate at which the unit can sustain fishing pressure or recover from depletion or other impacts due to the fishery; and (2) the susceptibility of the unit to fishing activities. The PSA analysis essentially measures the relative risk or the vulnerability of the resource to the potential for fishery impacts. This approach is especially useful as it allows for a baseline comparison between many species with varying levels of available information. In the stocks discussed below, there are cases where full assessments have been regularly conducted, while for other stocks little is known other than distribution or life history characteristics.

The PSA approach examines attributes of each unit (stock or assemblage) with respect to productivity or susceptibility to provide a relative measure of risk to the unit. Productivity is measured by averaging the seven attributes outlined in Table 1. Susceptibility is estimated as the product of four independent aspects; Availability, Encounterability, Selectivity and Post-capture Mortality (PCM); these aspect values are composed of attributes.

Table 1. Productivity and susceptibility attributed utilized to score the risk to a unit.

	Attribute
Productivity	Average age at maturity
	Average size at maturity
	Average maximum age
	Average maximum size
	Fecundity
	Reproductive strategy
	Trophic level
Susceptibility	Availability considers overlap of fishing effort with a species distribution and takes into account species specific behaviors
	Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species
	Selectivity considers the potential of the gear to capture or retain species
	Post capture mortality considers the condition and subsequent survival of a species that is captured and released (or discarded)

The productivity and susceptibility rankings determine the relative vulnerability of the unit of analysis (stock or assemblage) and are given a score (1 to 3 for high to low productivity, respectively; and 1-3 for low to high susceptibility, respectively). The output is graphed to produce a PSA plot (Figure 1). Overall risk scores are classified as follows: High (> 3.18), Medium (2.64 – 3.18) and Low (< 2.64) (Hobday *et al.,* 2007).

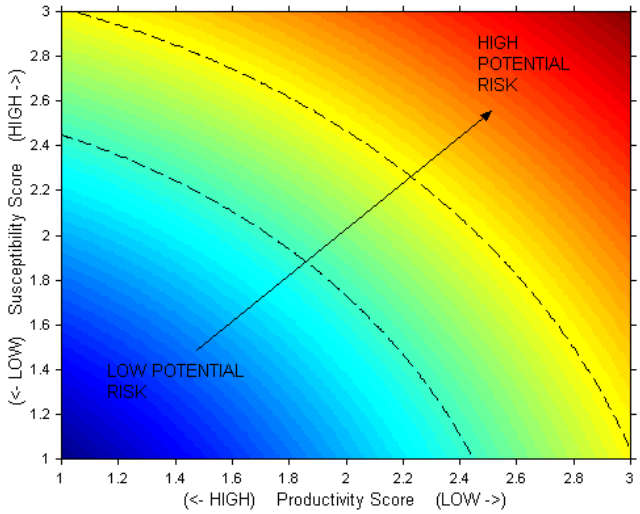

Figure 1. The axes on which risk to the ecological units is plotted. The *x*-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The *y*-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The combination of susceptibility and productivity determines the relative risk to a unit, i.e. units with high susceptibility and low productivity are at highest risk, while units with low susceptibility and high productivity are at lowest risk. The contour lines divide regions of equal risk and group units of similar risk levels (Hobday *et a*l., 2007).

1.2 Information Collection

Productivity and susceptibility analyses (PSA) were conducted for fishery stocks from the Atlantic HMS Division, Northeast, Mid-Atlantic, South Atlantic, Gulf of Mexico and Pacific[1]. All stocks are managed through federal fishery management plans and many have been the subject of stock assessments. Considerable time was spent collecting regionally specific information, where available for each unit. Reports and scientific publications were often consulted for the most recent and accurate information, along with stock assessments, FMPs, NMFS and other fishery management (i.e. State Fish and Wildlife Departments) websites for species specific information. When regionally specific information was unavailable, more generic species-level information was used (e.g., from Fish Base http://www.fishbase.org). All collected values for use in the PSA are sourced. In the absence of information, an attribute was given a default high risk score, in accordance with the CSIRO's treatment of uncertainty in their ERAEF methodology. Those units that were given a high score due to uncertainty in at least one attribute are indicted by open symbols on the resulting PSA plots (provided for groups of stocks in each region). Subsequently, attribute values assigned for each species were reviewed by experts for accuracy. Expert opinion provides access to additional information to add to the vulnerability assessment based on intimate knowledge of the species and fishery that would have been otherwise unavailable for our analyses. The resulting productivity and susceptibility scores for each species were plotted on a PSA graph; regional results are provided as appendices to this report.

1.3 A Note about our Productivity Susceptibility Analysis Methodology

The PSA methodology is a powerful tool that allows stakeholders and regulators to gain perspective on the inherent risk of a fishery stock to fishing activities. It also allows scientists to clarify specifically where information is lacking and where to focus resources to collect more information, since attributes weigh differently on risk. The methodology employed here was adopted from the CSIRO method as adjusted for the Marine Stewardship Council. MRAG made appropriate adjustments with respect to scoring guidelines for each attribute for US stocks. These analyses were limited by the timeframe for the study, but provide a powerful evaluation of vulnerability. They could be strengthened by stakeholder consultations and increased fishery specific information, to fine-tuning the determinations in the future. Additionally, this method does not weigh the status of the stock into the risk evaluations, which is undoubtedly critical. We have identified stock status, where known, for each species. Consistent with the definitions used by NOAA Fisheries as described in the MSA, overfishing is occurring when the fishing mortality rate has exceeded F_{MSY} (the fishing mortality rate that maximizes catch biomass in the long term), and a stock is overfished when the current biomass is less than the sustainable target (typically the minimum stock size threshold set below B_{MSY}). Councils, NMFS, and other management activities should incorporate some measure of stock status, if available, into a final assessment of overall risk score.

MRAG adjusted the scoring guidelines utilized for US stocks for interim productivity susceptibility analyses. The provisional changes represented a first cut at developing suitable scoring guidelines for all US fisheries; and as noted by the Annual Catch Limits Working Group (Rosenberg *et al*., 2007) a peer review workshop is necessary to evaluate the guidelines.

2 PSA Working Group

The Productivity Susceptibility Analysis (PSA) Work Group (WG) was convened in January 2009, in Boston, MA. The group was composed of participants from the scientific (including one of the authors of the ERAEF PSA process), NGO, and management communities (a full list of attendees is provided in the Working Group Report). Members of the workgroup reviewed the methodology conducted by MRAG Americas and the recommendations developed by the NMFS Vulnerability

[1] Regional results are provided as attachments to this report. PSA for Gulf of Mexico species will not be provided, contact The Ocean Conservancy for those results.

Evaluation Work Group (VEWG) (select members were also in attendance at the PSA WG) in consideration of changes to be made to the existing Productivity and Susceptibility analyses. Details of the Working Groups discussions and recommendations are provided in the Work Group report.

Briefly, the PSA WG was tasked to

1) Establish the specific details of a methodology for conducting Productivity and Susceptibility Analysis (PSA) for all U.S. fishery stocks that will be applicable for use by U.S. Fishery Management Councils. Including:
   a) the development of appropriate scoring guidelines that serve as risk cut-off scores for attributes, and address the potential applicability of alternate scoring guidelines for divergent resources
   b) selection of the appropriate type and number of Productivity and Susceptibility Attributes to use in the vulnerability assessment of fishery stocks
   c) development of a risk score threshold appropriate to increase resolution and deal with uncertainty
2) Develop a method to incorporate vulnerability assessments into setting catch limits for data-poor stocks based on a model to simulate the performance of a specific Annual Catch Limit (ACL) with various buffers (i.e. different proportions of ACL) developed by MRAG Americas
3) Promote a method for use in calculating PSA for stock complexes (multiple species or populations group for management purposes).
4) Provide a consistent set of guidelines for future PSA analyses. This will inform the current work of the National Marine Fishery Service (NMFS) and Councils about how to deal with a very large number of stocks were data are limited.

With regard to the analyses conducted and the results provided herein, item (1) from above reflects specifically on the methodology. The WG recommendations included adjusting the PSA to include attributes and scoring guidelines developed by the NMFS VEWG. The NMFS VEWG spent considerable time determining the appropriate attributes that most related to vulnerability (susceptibility and productivity). Once a suite of attributes was determined, they selected risk bins based on expert opinion to serve as cut-off scores for the various attributes. The appropriateness of the chosen attributes was tested by conducting the PSA on case study fisheries. There was considerable overlap in the attributes by Hobday *et al.* (2007) and those chosen by the NMFS VEWG; however the NMFS VEWG did not utilize a nested approach to score susceptibility (where aspects of susceptibility are composed of attributes). Their process was designed so that the attribute tables used in scoring vulnerability would be populated by expert opinion. This differs considerably from the information collection conducted by MRAG Americas, which relied on generally available information. For this reason it is not appropriate to directly apply their suite of attributes to the MRAG methodology (by Hobday et al. and modified) as recommended by the WG. However, the updated PSA methodology was adjusted according to the WG recommendations that appropriately fit within the boundaries and continuity of the analyses. This did include application of a number of the NMFS VEWG findings.

The summary of changes is provided below, and tables illustrate the changes to the cutoff scores and susceptibility attributes.

- The seven productivity attributes utilized in the interim analyses were maintained, but cut-off scores were adjusted as determined by the NMFS VEWG (Table 2).
- The aspects of susceptibility (Availability, Encounterability, Selectivity, and Post Capture Mortality) were maintained (Table 3).
- Fishery desirability, measured as commercial catch value of the fishery in lbs/$, was added as a susceptibility attribute incorporated into selectivity. Where catch was less than 10 tons, fishery was assumed undesirable and scored low risk (Table 4).
- Each aspect (Availability, Encounterability, Selectivity, and Post Capture Mortality) score is now calculated as averages of composite attributes and the susceptibility score is additive of the aspects (Table 5).

- Charted results use different symbols to differentiate when a vulnerability score includes lack of information (precautionary high risk) versus those that are fully informative.
- The WG agreed that PSAs should be conducted at the fishery level; the results provided here represent updates to the interim assessments and are therefore maintained as stock level PSAs.

Table 2. Cut-off scores for productivity attributes.

	Low productivity (high risk, score=3)	Moderate productivity (medium risk, score=2)	High productivity (Low risk, score=1)
Average age at maturity	>4 years	2-4 years	<2 years
Average maximum age	>30 years	10-30 years	<10 years
Annual Fecundity	<1,000 eggs per year	1,000-20,000 eggs per year	>20,000 eggs per year
Average size at maturity	>50 cm	30-50 cm	<30 cm
Average maximum size	>150 cm	60-150 cm	<60 cm
Reproductive strategy	Live bearer	Demersal egg layer	Broadcast spawner
Trophic Level	>3.5	2.5-3.5	<2.5

Table 3. Susceptibility aspects.

	Aspect	Desription
Susceptibility	**Availability**	Overlap of fishing effort with a species distribution and takes into account species specific behaviors
	Encounterability	The likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species
	Selectivity	The potential of the gear to capture or retain species and the desirability (value) of the fishery
	Post Capture Mortality	The condition and subsequent survival of a species that is captured and released (or discarded)

Table 4. Desirability cut off scores, adapted from the NMFS VEWG.

Description	Risk Score
stock is not highly valued or desired by the fishery (< $1/lb; or annual catch < 10 tons)	L
stock is moderately valued or desired by the fishery ($1 - $2.25/lb)	M
stock is highly valued or desired by the fishery (> $2.25/lb)	H

Table 5. Susceptibility aspects with component attributes.

	Aspect	Attribute
Susceptibility	Availability	Global Distribution
		Behavioral characteristics that would impact susceptibility
	Encounterability	Habitat
		Bathymetry
	Selectivity	Size at Maturity
		Maximum Size
		Desirability
	Post Capture Mortality	Post Capture Mortality

3 Summary of Regional PSA Results

One hundred and forty-three stocks in Federal fishery management regions were selected by the Lenfest Ocean Program for review, belonging to five regions including the NMFS Atlantic HMS Division; an additional 26 Gulf of Mexico stocks were also assessed. Table 6 below provides a summary of the number of stocks from each region where analyses resulted in low, medium and high overall risk scores. The majority of stocks evaluated have high risk scores (Figure 2).

Table 6. Summary of overall risk scores by region for the full 169 stocks evaluated (results include Gulf of Mexico stocks).

	Overall Risk Score		
	Low	Medium	High
HMS (50)		2	48
Northeast (14)		7	7
Mid Atlantic (4)		3	1
South Atlantic (73)	4	25	44
Gulf of Mexico (26)		8	18
Western Pacific (2)		1	1
Total	4	46	119

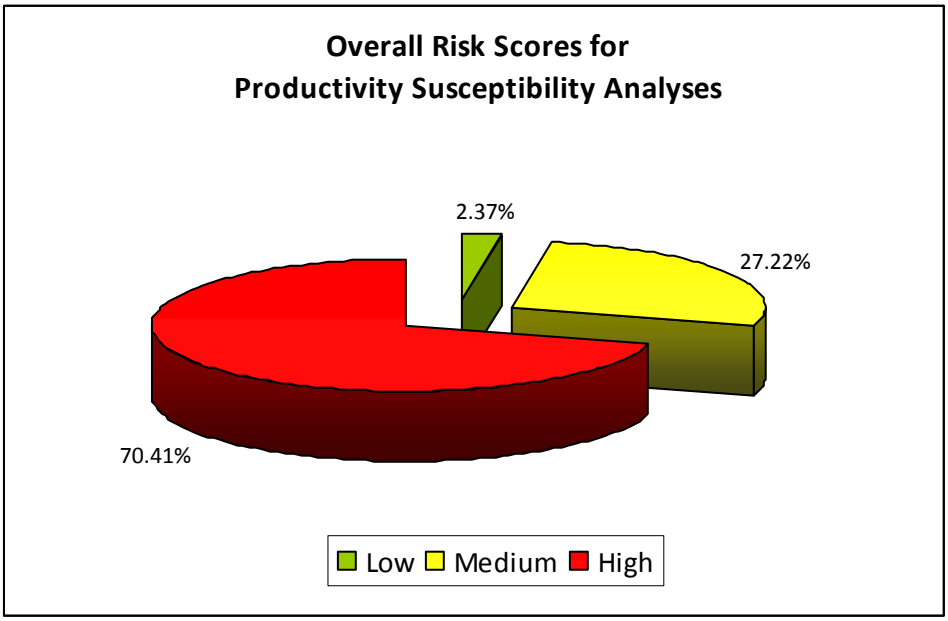

Figure 2. Percentage of high, medium and low overall risk scores from PSA analyses for 169 stocks in 6 regions.

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