

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

Working Group Participants:

Andrew A. Rosenberg, Department of Natural Resources,
Institute for the Study of Earth, Oceans and Space, University of New Hampshire

Alejandro Acosta, Florida Fish and Wildlife Conservation Commission

Elizabeth Babcock, Rosenstiel School of Marine and Atmospheric Science, University of Miami

Jennie Harrington, MRAG Americas, Inc.

Alistair Hobday, Australian Commonwealth Scientific Industrial Research Organization

Charlotte B. Mogensen, International Fisheries, Ministry of Food, Agriculture and Fisheries, Denmark

Robert O'Boyle, Beta Scientific Consulting, Canada

Douglas Rader, Environmental Defense

Jill H. Swasey, MRAG Americas, Inc.

Robert J. Trumble, MRAG Americas, Inc.

Robert C. Wakeford, MRAG Americas, Inc.



MAY 2009

A report supported by



LENFEST
OCEAN
PROGRAM

Table of Contents

1	Introduction	2
1.1	Premise	2
1.2	Overview of the Productivity Susceptibility Analysis.....	3
1.3	Workshop Goals.....	4
1.4	Process recommended by the PSA Workshop.....	5
2	PSA Methodology	6
2.1	Regional Results	8
3	ACLs for Data-Poor Stocks.....	9
4	Stock Complexes and Other Uses of PSA	12
5	Guidelines for Conducting PSA	13
6	Next Steps	14
7	References.....	16
8	Appendix A – Useful Terms	17
9	Appendix B – Additional Participants and Observers	18

Acknowledgements

MRAG Americas would like to thank Alejandro Acosta (FL Fish and Wildlife Conservation Commission), Molly Lutcavage (University of New Hampshire), Doug Rader and Sarah Hagedorn (Environmental Defense), Charlotte Mogensen (Denmark Ministry of Food, Agriculture and Fisheries) and Bob O'Boyle (Beta Scientific Consulting) for reviewing the PSA input information. Their expert opinion was invaluable in providing access to additional sources of information, given their intimate knowledge of the science, species and fisheries, for these analyses.

1 Introduction

This report provides guidance on the use of risk-based assessments in setting annual catch limits for US fisheries based on the recommendations of a workshop of national and international fisheries experts convened by the Lenfest Ocean Program. Staff from NOAA Fisheries participated in the workshop as technical advisors. The purpose of the workshop was to develop recommendations on methodology for vulnerability assessments (productivity and susceptibility analyses (PSA)) that would apply to all US fisheries for use in setting annual catch limits as mandated by the Magnuson Stevens Reauthorization Act (MSRA) of 2007.

The PSA Workshop participants (Andrew Rosenberg, Alejandro Acosta, Elizabeth Babcock, Jennie Harrington, Alistair Hobday, Charlotte Mogensen, Robert O'Boyle, Douglas Rader, Jill Swasey, Robert Trumble and Robert Wakeford) were chosen for their expertise in fisheries science and management. They served as individuals, not representatives of any organization, and the report presented here is the consensus view of these independent experts. The Workshop members brought experience and perspectives from many fisheries around the world to the meetings held in January 2009 in Boston, with MRAG Americas, Inc. providing staff support. A number of additional participants proved invaluable during the workshop; a list of these participants is provided in Appendix B.

1.1 Premise

As a consequence of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) of 1976 and the 1996 Amendments, progress has been made towards the recovery of depleted stocks and sustaining stock health. However, many stocks remain overexploited or have not been rebuilt (NOAA, 2007; Rosenberg *et al.*, 2006). As a result, the 2007 amendments reauthorizing the MSA are designed to improve accountability in management to prevent overfishing and rebuild stocks to levels that will support maximum sustainable yield. The Lenfest Ocean Program convened an annual catch limits (ACL) working group of national and international fisheries experts, with participation by NOAA Fisheries as technical advisors to the working group, in the summer of 2007 to assess the Magnuson-Stevens Reauthorization Act (MSRA) requirements for ACLs and to recommend a procedure for determining them. The report (Rosenberg *et al.* 2007) laid the groundwork for the subsequent work that is reported herein.

In January 2009, the National Marine Fisheries Service (NMFS) published a final rule to implement the new MSRA requirements and amend the guidelines for National Standard One (NS1), including overfishing levels (OFLs), annual catch limits (ACLs), annual catch targets (ACTs), and accountability measures (AMs). Regional fishery management councils are now responsible for developing ACLs and AMs for each fishery management plan. For many fisheries, data are too limited to permit traditional analyses on the determination of current stock or overfishing status. Rosenberg *et al.* (2007) recommended a straightforward process, guided by the following principles, for establishing sustainable catch limits for all stocks, including those that lack sufficient scientific data:

- **Preventing overfishing applies to ALL stocks, therefore, so should ACLs.**
- **To successfully end and prevent overfishing, $OFL > ABC \geq ACL$.**
 - *Overfishing level (OFL); Acceptable Biological Catch (ABC); Annual Catch Limit (ACL)*
- **ACLs should account for uncertainty in stock status and risk of overfishing for each stock.**
- **Consideration of risk must include an 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 the precautionary approach for setting ACLs proposed by Rosenberg *et al.* (2007) is determination of the "buffer" needed between the OFL and the ACL designed to increase the probability that overfishing doesn't occur and that rebuilding proceeds as planned. That is, the process is designed to determine how far the ACL should be set below the OFL to account for sources of scientific and management uncertainty. In general, buffer size needs to increase as risk of overfishing increases and

amount of information decreases; conversely, low risk and more information allow for a smaller buffer. Risk-based assessments provide a method that can apply to all stocks, including those considered data deficient. The ACL Working Group found that the framework developed by a recent joint Australian CSIRO/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 work of the ACL working group outlined the theoretical foundations of a risk-based approach to the determination of control rule buffers but did not explore practical application which may result in refinements to the approach. The ACL working group suggested that application of PSA to data rich situations could provide case studies which would inform buffer determination in data poor situations. The work of the PSA workshop was undertaken to test the earlier theoretical work through case studies on a range of data availability situations.

1.2 Overview of the Productivity Susceptibility Analysis¹

The Productivity and Susceptibility Analysis (PSA) is a method of assessment which allows all units within any of the ecological components to be effectively and comprehensively screened for risk to human impact. The PSA is based on the assumption that the risk to an ecological component (fishery stock in this case) will depend on two characteristics of the component units: (1) the **Productivity** of the unit, which will determine the rate at which the unit can recover after potential depletion and (2) the extent of the impact due to the fishing activity, which will be determined by the susceptibility of the unit to the fishing activities (**Susceptibility**). Each attribute is scored 1 for low risk, 2 for medium risk, and 3 for high risk. These risk scores are determined based on cut-off scores for each attribute that are consistent across fisheries. The cut-off scores² serve to break the range of attribute values for a stock into the high-medium-low risk bins. It is important to note that the PSA analysis essentially measures potential for risk. A fully quantitative measure of risk requires some direct measure of abundance or mortality rate for the unit in question (and hence measures of fishing effort), the uncertainty in status as well as management efficacy and the specification of a loss function giving the consequence of stock decline. This information is generally lacking for data-deficient species and fisheries. During the PSA assessment, each unit of analysis is scored for risk with regard to attributes for productivity and susceptibility and the output graphed to produce a PSA plot (Figure 1) that illustrates the relative vulnerability of the unit of analysis.

¹ For greater detail on the PSA methodology, refer to "MRAG Americas. 2009. Use of Productivity-Susceptibility Analysis (PSA) in Setting Annual Catch Limits for the Federal Fisheries of the United States. Report to the Lenfest Ocean Program. March 18, 2009." A copy of that report can be obtained by contacting Lenfest (http://www.lenfestocean.org/PSA_methodology.4.09.pdf). For greater detail on the Ecological Risk Assessment for the Effects of Fishing (ERAEF), refer to Hobday *et al.* 2007.

² Cut-off scores used by MRAG to break the range of attribute values into risk bins are provided in the PSA methodology report identified above.

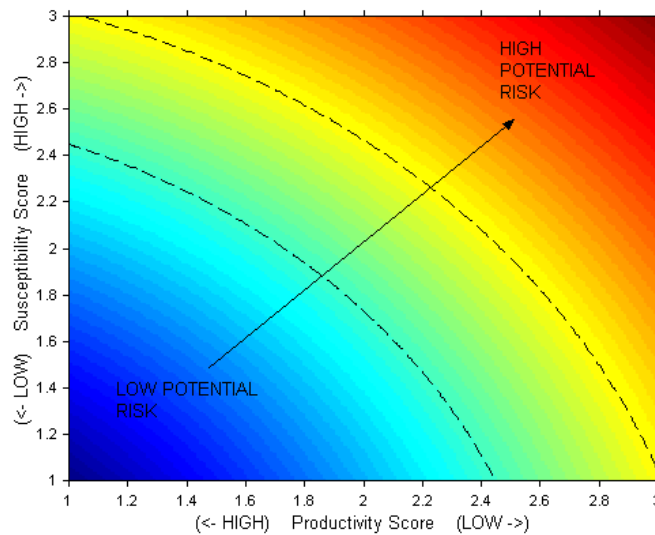


Figure 1. The PSA plot. The x-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The y-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The combination of susceptibility and productivity 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 al.*, 2007).

1.3 Workshop Goals

MRAG Americas conducted PSA assessments for a range of fish stocks from multiple regions; these assessments provided insight on the vulnerability of a given stock and degree of data availability. Subsequent to completing PSAs for each region, external reviewers evaluated the productivity and susceptibility attribute scores of each stock. It was recognized that while the PSA methodology can provide a sound basis for the evaluation of the vulnerability of stocks to fishing, there remain issues to be resolved for the approach to be fully accepted by a scientific community and applicable to management. Thus, MRAG Americas convened a workshop of regional and international science and management experts, including Dr. A. Hobday, who was one of the originators of the PSA, to evaluate the methodology and aid in its further development. NOAA Fisheries staff in attendance provided additional technical expertise. The goals that guided the workshop were:

- A. Establish the specific details of a methodology for conducting Productivity and Susceptibility Analysis (PSA) for all U.S. fishery stocks which will be applicable for use by U.S. Fishery Management Councils. The current method is based on Australian fisheries so the PSA Workshop may need to modify it for U.S. fisheries.
- B. Develop a method to incorporate vulnerability assessments into setting catch limits for data-poor stocks.
- C. Promote a method for use in calculating PSA for stock complexes (multiple species or populations group for management purposes). This follows the Lenfest Annual Catch Limits Working Group recommendation that managers not lump stocks together to determine their overfishing risks and that PSA should be performed on each stock individually.
- D. Provide a consistent set of guidelines for future PSA analyses. This will inform the current work of NOAA Fisheries and the Fishery Management Councils about how to deal with a very large number of stocks where data are limited.

In the following section, a summation of the Workshop discussions of each goal and the resulting recommendations is provided.

1.4 Process recommended by the PSA Workshop

The process recommended by the PSA Workshop for evaluating stock vulnerability includes the following steps:

1. Productivity – Susceptibility Analyses, based on the work by Hobday *et al.* (2007), should be conducted by fishery sector to accurately reflect vulnerability on all stocks (data rich and data poor).
 - Stock productivity is determined as the average risk score of the following attributes (Table 1): (1) average age at maturity, (2) average size at maturity, (3) average maximum age, (4) average maximum size, (5) fecundity, (6) reproductive strategy and (7) trophic level. Scores for each attribute are based on cut-off scores as deemed appropriate for US fisheries by the Workshop. In the absence of data, an attribute is given a precautionary high risk score.
 - Next, stock susceptibility is determined as the average of the following aspects (Table 1): (1) Availability (global distribution and behavioral characteristics that would impact susceptibility), (2) Encounterability (habitat and bathymetry), (3) Selectivity (size at maturity, maximum size and desirability), and (4) Post Capture Mortality (condition and subsequent survival of a species that is caught). The score of each aspect is averaged from composite attributes within an aspect. Scores for each attribute are based on cut-off scores as deemed appropriate for US fisheries by the PSA Workshop. In the absence of data, an attribute is given a precautionary high risk score.
2. Plotting of Productivity and Susceptibility scores and determination of overall risk score as determined by Euclidean distance³ from the plot's origin.
3. Application of the risk scores along with scientific and management uncertainty, in estimation of the OFL – ACL buffer.

Table 1. Productivity is the average of seven attributes, while Susceptibility is the average of four aspects (derived from eight attributes).

		Attribute	
Productivity			Average age at maturity
			Average size at maturity
			Average maximum age
			Average maximum size
			Fecundity
			Reproductive Strategy
			Trophic Level
		Aspects of Susceptibility	Attribute
Susceptibility	Availability	Global distribution	
		Behavioral characteristics	
	Encounterability	Habitat	
		Bathymetry	
	Selectivity	Average size at maturity	
		Average maximum size	
		Desirability	
	Post Capture Mortality	Survival after capture and release	

³ The **Euclidean distance** is the "ordinary" distance between two points that one would measure with a ruler, which can be proven by repeated application of the Pythagorean Theorem. This is $\sqrt{(P_1 - P_2)^2 + (S_1 - S_2)^2}$, where P_2 and S_2 are at 0,0.

2 PSA Methodology

Goal: Establish the specific details of a methodology for conducting Productivity and Susceptibility Analysis (PSA) for all U.S. fishery stocks which will be applicable for use by U.S. Fishery Management Councils. The current method is based on Australian fisheries so the Working Group may need to modify it for U.S. fisheries.

In Australia, all fisheries must be deemed ecologically sustainable. Where more data and resources exist, a fishery may exploit a species at closer to a presumed maximum sustainable yield (MSY). However, less information requires management to be more precautionary and the fishery to be prosecuted further from MSY. Ecological risk assessments, developed by Australia's Commonwealth Scientific Industrial Research Organization (CSIRO), evolved from the need to increase the risk landscape to increase confidence in the fishery. By operationalizing risk, a management strategy can be implemented to decrease the risk. The Productivity – Susceptibility Analyses, which is the second level of a three level Ecological Risk Assessment for the Effects of Fishing (ERAEF), is based on an exposure-effect risk model (vs a likelihood-consequence model) and hence measures the exposure of the fishery to activity (susceptibility) and the effect, how the fishery will respond (productivity) (Hobday *et al.* 2007).

The PSA methodology developed by Australia's CSIRO is semi-quantitative using observed values for attributes that are assigned a risk score. They developed a list of 70+ productivity attributes, from which they identified the seven for which data most commonly exist. Seven appeared to serve as an appropriate number; above this each attribute contributed too little to the mean productivity score (each attribute contributes 1/7th of the average score); fewer attributes produce scores that are less robust to uncertainty. For this reason it was also important that they chose to treat uncertainty with precaution, and the absence of information is given a default high risk score. The susceptibility score is composed of four aspects, each of which is scored based on its component attributes. The methodology developed by CSIRO and adapted for US fisheries by MRAG was the focus of this Goal. The Workshop spent considerable time deliberating the components of the process and how they should be applied to US fisheries. In consideration of the PSA approach, the Workshop considered the work done by the NOAA Fisheries Vulnerability Evaluation Working Group (VEWG), members of which were present at the meeting.

The PSA Workshop considered the VEWG process for determining the appropriate attributes that most related to vulnerability and data poor situations. Under the VEWG process, once the suite of attributes was determined, risk bins to serve as cut-off scores for high, medium, and low risk of the various attributes were selected based on expert opinion for susceptibility scoring combined with analysis of variance (ANOVA). The appropriateness of the chosen attributes and the risk bin values was tested by conducting the PSA on case study fisheries (those that VEWG members were intimately knowledgeable on). This process was designed so that the attribute tables would be populated and scored based on best available data by a group of experts, where available, or by expert opinion. The VEWG chose to add a data quality index component to their analyses as a means to treat uncertainty.

This approach differs considerably from the information collection conducted by MRAG, which used the CSIRO approach. The CSIRO approach treats uncertainty with precaution and scores the absence of data as high risk (i.e. a "3"). Under the CSIRO model, gathering additional data cannot increase the risk score but could decrease it. MRAG followed the CSIRO model, and used peer review to validate the attribute values.

The number and type of attributes employed along with how they are treated are of particular concern. The potential of weighting the attributes, especially those that compose the productivity score, was discussed by the group, as this would also affect the precautionary treatment of uncertainty. It was concluded that while all attributes may not equally weigh on a species' productivity, there would need to be a consistent means of assigning weights (i.e. as determined through simulation modeling). Until this is available, all attributes should be treated with equal weight allowing for the precautionary treatment of data poor situations as high risk. The Workshop participants agreed to maintain the seven productivity

attributes identified in Hobday *et al.* (2007) and adapted the cut-off scores in combination with those developed by the VEWG to apply to all US fisheries. The Workshop considered that the nature of the species subject to fishing in the US is sufficiently different from Australian species that the limits to the categories for scoring (cut-offs) needed to be adjusted.

There were discussions regarding normalizing length at maturity to maximum length; however, it was concluded that there is no sound basis for the length normalizations (i.e. initial tests found the same resulting risk score for a tuna and a sardine). MRAG continued the PSA analyses with both length-at-maturity and maximum-length as independent attributes. Given the results by Hobday *et al.* (2007) it did not appear to be advantageous to remove either attribute.

The susceptibility component of the PSA allows for inclusion of multiple factors that would impact a stock's vulnerability. The Workshop reviewed those used by Hobday *et al.* (2007) and the VEWG and considered additional ones. A list of nine attributes, comprising four aspects of susceptibility, was agreed. Subsequent to the workshop, it was discovered that two attributes (areal overlap and % unavailable to gear) did not readily lend themselves to rapid information collection, and thus they were omitted from the current PSA methodology (Table 2). Notwithstanding this, these attributes warrant further consideration and efforts should be made to address how they might be scored.

Table 2. Susceptibility aspects and their associated attributes.

		Composite Attributes
Susceptibility Aspects	Availability	Global distribution
		Behavioral characteristics
	Encounterability	Habitat
		Bathymetry
	Selectivity	Morphology Affecting Capture
		Desirability
	Post capture mortality	Survival After Capture and Release

The treatment of missing information has direct impact on the overall risk score. Treating missing information as high risk inflates the overall score and can lead to a falsely inflated estimate of potential risk. However, a precautionary treatment of risk allows the addition of science and management to reduce the estimated risk. The appearance of a high risk score with a flag is more alarming than a flagged low risk score; given an incentive to acquire more information to reduce the risk, rather than the initial reaction of taking no action when faced with a low risk score. The VEWG chose to highlight missing data points and rather than treating the absence of information as high risk, they added a data quality index score that reflected the confidence in the data. While the PSA workshop agreed to continue to treat missing information as high risk, it was decided that scores that included missing information must be differentiated (for example, visually on the PSA plot) from other scores derived from data. Additionally, the issue of data quality could be represented in the scientific uncertainty aspect of the buffer estimation, where improving data quality would result in a smaller buffer.

The goal of the PSA is to provide a tool for rapidly assessing the vulnerability of a stock prior to status determinations or management actions. PSA results can be directly factored into the estimation of the buffers between the overfishing limit (OFL), the Annual Catch Limit (ACL) and the Annual Catch Target (ACT). Scientific and management uncertainty factor into this buffer as well.

The PSA is plotted on a 2D chart, with productivity versus susceptibility. In Australia, the process allows for the addition of a third management axis that accounts for some management and status variables. The VEWG also included components of management into their susceptibility attributes. The Workshop agreed that some aspects of management were already captured in the susceptibility attributes (e.g., spatial controls) without the need to add attributes; the addition of a third axis may further complicate the process. Further, the exploitation status of a stock should be considered separately in any ACL determinations and should not be masked by inclusion in the PSA.

Based on the discussions during and subsequent to the workshop, the participants chose to adopt the following recommendations for conducting PSA analyses⁴:

- *Vulnerability assessments are a valuable tool not intended to replace stock assessments.*
- *The vulnerability assessments must be a transparent process that can be understood by the scientific, management and stakeholder communities.*
- *Exploitation status should not be incorporated into the PSA analyses; it warrants separate consideration, not to be masked by vulnerability score and should be discriminated separately.*
- *Mixing observed and derived parameters in the PSA attributes should be avoided. The use of observed parameters streamlines the process and builds stakeholder confidence.*
- *The assessment should use a precautionary treatment of uncertainty, so that the addition of information and management will reduce the risk.*
- *PSA plots need to highlight where overall risk scores result from missing information.*
- *PSAs should be conducted for all stocks at the fishery sector level, so as not to mask important vulnerability factors for particular fisheries. This also complements the fishery specific determination of ACLs that will be developed by regional Fishery Management Councils.*
- *The PSA scoring should utilize three risk thresholds (High, Medium, Low) until analysis can determine an appropriate method for increasing the number of risk thresholds.*
- *The methodology should employ at least seven productivity attributes. The overall productivity score should be additive of the component attributes.*
 - *Average age at maturity, Average maximum age, Fecundity, Average size at maturity, Average maximum size, Reproductive strategy and Trophic level.*
- *Cut-off scores should be applicable to all US fisheries and were derived in combination of the cut-off developed by the NOAA Fisheries VEWG and Hobday et al. (2007).*
- *The susceptibility score should be additive of the 4 aspects, and aspect scores are averaged from composite attributes. This is in accordance with the scoring guidelines developed by the VEWG.*
- *A consistent set of rules must apply to both productivity and susceptibility attributes.*

2.1 Regional Results

Provided below is a summary of PSA results using the methodology recommended by the Workshop participants (Table 3 and Figure 2). An overwhelming 70% of stocks were scored high risk by the PSA; however, 49.8% of those high scores are missing information for at least one attribute and 19.3% are missing information for three or more attributes. It is important to note this lack of basic life history information for many species and that the quality of any assessment will depend on the quality of the baseline information.

⁴ For greater detail on the PSA methodology, refer to "MRAG Americas. 2009. Use of Productivity-Susceptibility Analysis (PSA) in Setting Annual Catch Limits for the Federal Fisheries of the United States. Report to the Lenfest Ocean Program. March 18, 2009." A copy of that report can be obtained by contacting Lenfest.

Table 3. 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

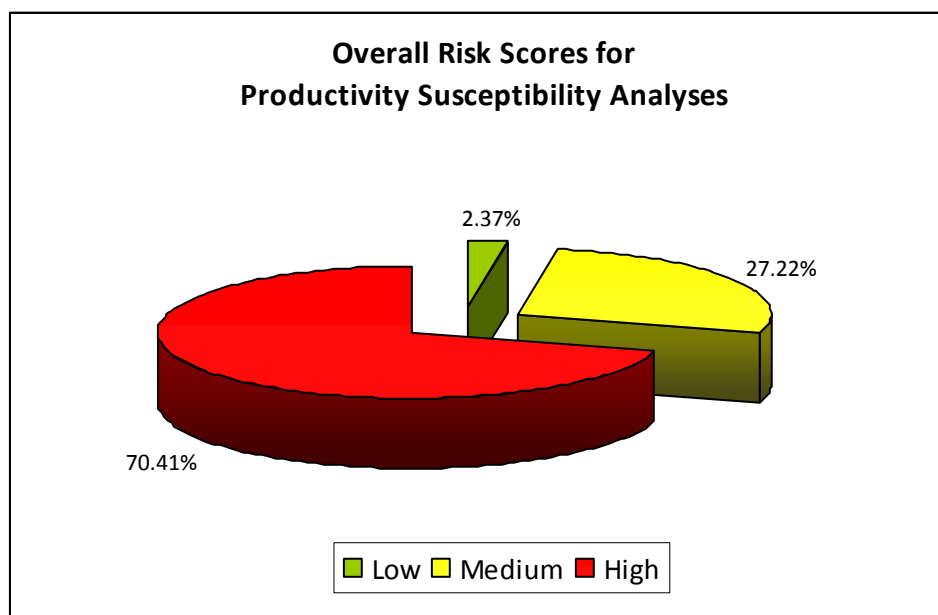


Figure 2. Percentage of high, medium and low overall risk scores from PSA analyses for 169 stocks in 6 regions.

3 ACLs for Data-Poor Stocks

Goal: Develop a method to incorporate vulnerability assessments into setting catch limits for data-poor stocks.

A number of issues were highlighted by the Workshop in response to the latest NOAA National Standard Guidelines 1 on setting ACLs (DOC 2009). The Guidelines indicate that while ACLs will remain as the limit reference point to fishing opportunities, a new Annual Catch Target (ACT) will be adopted at a value less than or equal to the ACL, depending on the buffer size required by each fishery to prevent overfishing (i.e., management uncertainty). For example, a fishery that exhibits low management uncertainty could have a small buffer that results in an ACT very close to or equal to the ACL, whereas a fishery with high management uncertainty could require a considerably larger buffer size. The ACT value is intended to serve as an accountability measure to ensure that ACLs are not exceeded. In addition, the level of scientific uncertainty or risk, determines the Overfishing Level (OFL) and Acceptable Biological

Catch (ABC), which in turn are used to calculate the ACL and ACT values. If the OFL were determined with a high level of uncertainty, the ABC value would be expected to be lower (e.g., large buffer) than if an OFL value were determined with a low level of risk (small buffer size). The development of buffers and the relationship between scientific uncertainty and management uncertainty as part of a 2-step process are summarized in Figure 3 below.

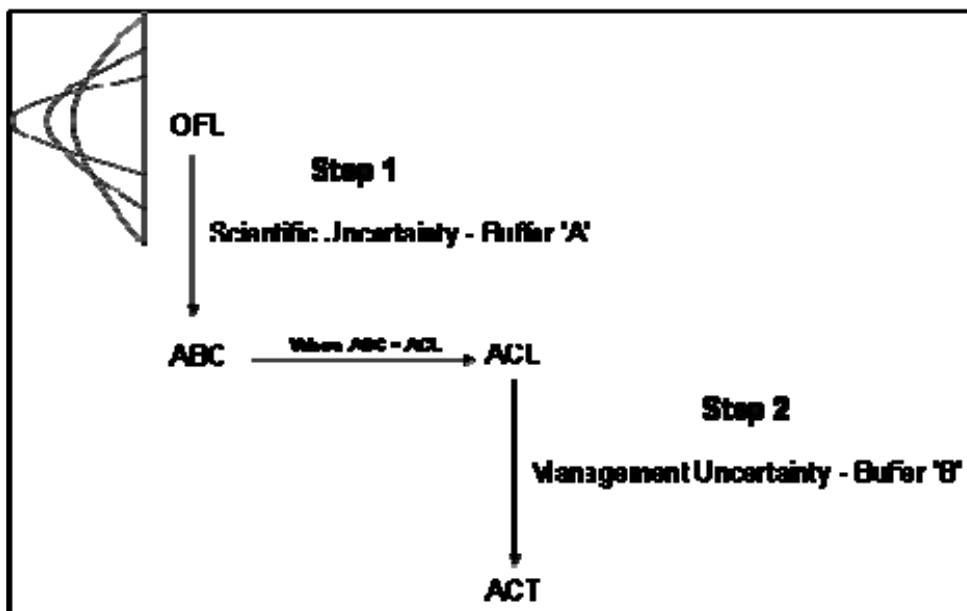


Figure 3. Schematic diagram to show the relationship between scientific uncertainty and management uncertainty in the development of OFL, ABC, ACL and ACT.

The size of each buffer (A and B; Figure 3) is expected to change according to the level of both scientific uncertainty and management uncertainty (Table 4). While Table 4 suggests a single overall buffer size to encompass both scientific and management uncertainty, buffer calculations should remain separate for both sources of uncertainty. It is likely, for example, that a regional Scientific and Statistical Committee (SSC) would be responsible for developing the scientific uncertainty buffer 'A' whereas the regional Fishery Management Council would consider the size of the management uncertainty buffer 'B'.

MRAG Americas is presently exploring a population-fishery model to simulate the performance of ACLs with various buffers (i.e. different proportions of ACL) for several data-rich stocks in the Gulf of Mexico⁵ associated with different levels of uncertainty to develop a basis for relating the size of the buffer to uncertainty and species vulnerability, calculated from PSA scores using the methodology discussed in section 2 (Figure 3). This pattern, which should include stocks across a range of different vulnerabilities, will then inform the setting of ACLs for data poor stocks. The concept for the model was based on the recommendations of Rosenberg *et al.* (2007). In this simulation model, consideration was given to the level of complexity to determine the level of scientific uncertainty. However, it was argued that bias and uncertainty may be similar across all assessment platforms.

⁵ Data available from NMFS SEDAR reports: Red Grouper, Red Snapper, King Mackerel, Gag Grouper, Greater Amberjack

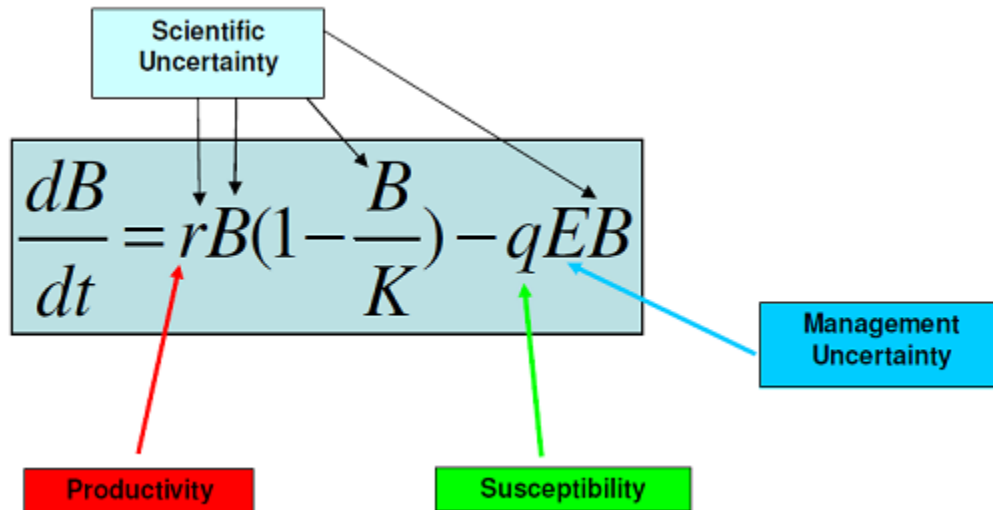


Figure 4. The PSA is designed to allow assessment of ecological risk without abundance estimates. Productivity attributes are life history characteristics that correlate with the intrinsic rate of increase (r) while susceptibility attributes correlate with the elements of the susceptibility term (q) in the equation based on the logistic growth equation with a removal term (qEB). The illustration denotes where scientific and management uncertainty factor into the equation.

Table 4. Expected changes in buffer size with changes in scientific uncertainty and management uncertainty.

		Scientific Uncertainty		
		Low	Medium	High
Management Uncertainty	Low	Small buffer size		
	Medium		Medium buffer size	
	High			Large buffer size

Scientific uncertainty includes model, process and observation error; the Workshop devoted considerable discussion to the issues and aspects of uncertainty (i.e. retrospective bias in the assessment, frequency of assessment and life history traits for the species concerned) to be included in a simulation model. It was generally agreed however, that adjustment for the retrospective patterns should be done by the assessment team and relayed to the SSC for inclusion in the scientific uncertainty buffer. The status of the stock and the requirement of rebuilding programs are also expected to have an impact on buffer size, but due to time constraints would not be considered at this time.

The level of risk within management uncertainty contains a number of elements including: enforcement, accountability, latent effort, other fishery catches, effectiveness and precision. The Workshop agreed that it would be important to try and quantify these elements within each fishery for inclusion in a simulation model.

The Workshop discussed the benefits of including PSA results into the 2-step process, and it was agreed that species vulnerability should help inform the size of the scientific buffer 'A'. Thus, a species with low

vulnerability should have a smaller buffer size than a species with high vulnerability. The PSA score could therefore be used to modify the OFL value to obtain the ABC (i.e., $ABC = OFL * PSA$).

Based on the discussions during the meeting and follow-up correspondence, the Workshop chose to adopt the following recommendations:

- *To develop a 2-step simulation model to include both scientific and management uncertainty separately.*
- *The PSA contains components associated with the scientific uncertainty; therefore use PSA to inform scientific uncertainty rather than management uncertainty for both data rich and data poor species.*
- *Keep buffer sizes separate between scientific and management uncertainty.*
- *Simulate management uncertainty around the ACT and evaluate it against both the ACL and OFL.*
- *Use input controls (total fishing mortality) to simulate scientific uncertainty and output controls (total catch) to simulate management uncertainty.*

4 Stock Complexes and Other Uses of PSA

Goal: Promote a method for use in calculating PSA for stock complexes (multiple species or populations grouped for management purposes). This follows the Lenfest Annual Catch Limits Working Group recommendation that managers not lump stocks together to determine their overfishing risks and that PSA should be performed on each stock individually.

National Standard 1 allows for the management of fisheries consisting of multiple species (complexes). The NS 1 guidelines recommend that the sum of individual target levels be less than the fishery-wide optimum yield (OY); however, if individual OYs are not specified, then harvest could disproportionately affect one or a few unproductive stocks and overfishing would occur. Rosenberg *et al.* (2007) noted that species grouped into a complex for the purposes of setting OFLs and ABCs may not all have similar characteristics with respect to vulnerability or uncertainty. In consequence, the more vulnerable stocks will be at greater risk of depletion or even extirpation if exploitation limits are set based on the less vulnerable stocks.

The identification and grouping of species into complexes is not typically based on vulnerability, and indicator species that are generally more information rich are often used as the basis of management decisions. Complexes have often been defined on a taxonomic basis and management issues arise when prohibited species are grouped into complexes with commercial stocks. Rosenberg *et al.* (2007) advised against using complexes, but if they are being used, the complexes should be considered in light of vulnerability assessments. The PSA serves to identify varying risk scores for similar species and can be used to discriminate where species have been inappropriately grouped. The PSA Workshop upheld this recommendation and agreed that vulnerability assessments would be valuable for use with developing fisheries (e.g., frontier species and unfished ecosystems such as deepwater). The utility of this tool for use with frontier species would demonstrate the power of this approach. The precautionary treatment of uncertainty will provide incentive to reduce the risk, which is a very important factor in the management of a new fishery. Managers will need specific guidance on how to develop buffers for complexes, if they are to be employed, though the Workshop did recommend that the weakest stock should guide the complex.

The use of indicator species, while a common practice, poses unique challenges for management. Management has no set protocol for dealing with stock complexes when effort shifts off of the indicator species and onto another stock within the complex. Management of stock complexes is more suitable for non-selective fisheries but less so if stocks can be separated into selective fisheries, because mixed vulnerabilities put the higher vulnerability stocks at higher risk. More selective fisheries may additionally alleviate some of the troubles with misidentification of catch, which is common in some regions.

Vulnerability assessments, as conducted through PSA, can be a valuable tool to aid in discriminating among the stocks within the stock categories that have been recently adopted by NMFS in the ACL guidelines. These include species that are managed individually, part of a complex, an ecosystem component (within a management unit) and outside of any management unit.

Based on the discussions during the meeting, the Workshop adopted the following recommendations for stock complexes and other uses for PSA:

- *The PSA vulnerability analysis be performed on all stocks individually to the extent possible and that creating management assemblages of fish with different levels of PSA scores be avoided.*
- *If stocks in a complex have a wide range of vulnerabilities, they should be rearranged such that a complex consists of species with similar vulnerability; management should be geared toward preventing overfishing of the more vulnerable stocks.*
- *Complexes are best suited for non-selective fisheries; for selective fisheries, management should break out complexes into individual species or smaller groups.*
- *The PSA should also be used to identify species not yet in a management unit that are vulnerable to fishing, and are beginning to be exploited.*
 - *Examples include the relatively new deep-drop fishery for barrellfish, blackbellied rosefish, sea bream, queen snapper and other deepwater reef fishes. Identifying these species early in the exploitation process can reduce the likelihood of collapse before effective management can be emplaced.*

5 Guidelines for Conducting PSA

Goal: Provide a consistent set of guidelines for future PSA analyses. This will inform the current work of the NOAA Fisheries and Councils about how to deal with a very large number of stocks where data are limited.

The PSA workshop brought together national and international fisheries experts with management professionals. A primary aim of the meeting was to provide a methodology and guidelines for using the PSA process in the fishery management setting, through the regional Council process. In light of the Magnuson-Stevens Reauthorization Act, all Councils will be required to develop ACLs for each fishery. MRAG conducted PSA for 169 stocks, which demonstrated the value of process in identifying stock vulnerabilities and disparate results for assumed species often managed together. With the ACL requirements, Council must confront the underlying issue of how to treat the overwhelming number of data poor stocks.

The Workshop explored the PSA methodology to derive the following guidelines for future PSA analysis.

Parallel to the recommendations for the PSA methodology, the Workshop recommended that:

- *Vulnerability assessments are a valuable tool not intended to replace stock assessments.*
- *The vulnerability assessments must be a transparent process that can be understood by the scientific, management and stakeholder communities.*
- *Exploitation status should not be incorporated into the PSAs. Stock status warrants separate consideration, where possible, not to be masked by vulnerability score and should be discriminated separately.*
- *Avoid mixing observed and derived parameters in the PSA attributes. The use of observed parameters streamlines the process and builds stakeholder confidence.*
- *The assessment should use a precautionary treatment of uncertainty, so that the addition of information and management will reduce the risk.*

Complementary recommendations include:

- *Vulnerability assessments should be conducted for all species at the fishery level (as defined by gear, area and species included), including data rich species with stock assessments.*
- *Productivity – Susceptibility Analyses*

- *Sensitivity analysis should be run on a suite of PSA analyses to determine the impact of missing attributes. If gathering data for a missing attribute does not change the risk category, it may not be cost effective to gather the data.*
- *Consider addition of a recruitment pattern attribute into the productivity score.*
- *Validation of productivity (r) & susceptibility (q) against the estimates produced from the PSA analysis*
- *Cumulative risk – need development of methods to allow the PSA results to be combined to allow cumulative risk from several fisheries to be combined for a single species.*
- *Identification of PSA unit guidelines*
 - *Test whether species with sequential hermaphroditism should be considered separately (i.e., males and females) in the PSA, and if these characteristics make these species particularly sensitive compared with other behavioral characteristics, such as schooling or spawning aggregation.*
- *All PSAs and simulations should be conducted at the fishery sector level.*
 - *Buffers would be developed for each fishery and should be additive.*
- *Consider the interactions and co-occurrence of PSA unit (e.g. the target species) with other protected species, and how/if that overlap should be captured in the vulnerability assessments. An alternative is to undertake PSA for protected species, as occurs in Australia.*

6 Next Steps

The PSA process has tremendous utility in fisheries management and broader applicability. Hobday *et al.* (2007) have also initiated applying the ERAEF method to habitats and ecological communities. To explore the full potential of the process, it will be valuable to apply the method to these non-species components of the ecosystem, as the Australian experience shows this to also be a useful tool in assessing habitat impact. Case studies on the recommended applicability of the method (i.e. developing fisheries) will be valuable.

The PSAs conducted prior to the meeting were updated based on the recommendations of the Workshop participants. There were distinctly different processes for the collection of information and analysis of risk scores by the VEWG compared with those conducted by MRAG Americas. MRAG completed a validation exercise comparing MRAG PSA results with those generated by the VEWG. There were 56 stocks done in common between the two exercises and the risk scores largely agreed. In select cases, the MRAG scores tended toward higher vulnerabilities due, in part, to the treatment of uncertainty as high risk, thus driving the system to collect more information to reduce that risk. The comparison results of these exercises can be found at www.lenfestoccean.org; www.mragamericas.com).

With the method developed and available for vulnerability assessments, it will be essential to ensure operational transfer. The PSA process has great potential for use with newly developing fisheries, and ERAEF methodology has great potential for units outside of fisheries (i.e. habitats).

The Workshop recommended the following next steps be taken to further strengthen the PSA process and facilitate its utility in setting ACLs, and beyond:

- *Expand the utility of the PSA to stock complexes, developing fisheries and unfished ecosystems (i.e. deepwater). Conduct case studies on example fisheries.*
- *Facilitate the operational transfer of the information. Potential vehicles include an educational component, workshops, an article for ICES, presentations to the regional Councils (particularly the Council Chairs meeting) and state and interstate fisheries commissions.*
- *Expand the utility of ERAEF to habitats; this would aid with identification of habitats of particular concern. Scope the possibility of applying the qualitative Scale Intensity Consequence Analysis (SICA, Level 1 of the ERAEF) to habitats.*
- *Accommodate for protected species and bycatch co-occurrence with target species in vulnerability assessments.*
- *Utilize the vulnerability assessments as a tool for exploration of research and monitoring needs.*

- *In the case studies already conducted, the assessments highlighted the importance of basic life history information, which was missing for many species.*
- *Develop and populate a database of information that can evolve as information becomes available and can be drawn from for vulnerability assessments.*

7 References

DOC. 2007. Magnuson-Stevens Fishery Conservation and Management Act Reauthorization.

DOC. 2009. Magnuson-Stevens Act Provisions; Annual Catch Limits; National Standard Guidelines. Federal Register. Vol. 74, No. 11. January 16, 2009.
http://www.nmfs.noaa.gov/msa2007/docs/acl_final_rule.pdf

Hobday, A.J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman and J. Dowdney. 2006. Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Hobday, A. J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, T. Walker. 2007. Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

NOAA Fisheries. 2007. 2007 Status of US Fisheries: Report to Congress.
<http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm>

Patrick, W. S., P. Spence, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortes, K. Bigelow, W. Overholtz, J. Link, and P. Lawson. In Review. Use of productivity and susceptibility indices to determine the vulnerability of a stock: with example applications to six U.S. fisheries. U.S. Department of Commerce, NOAA Technical Memorandum National Marine Fisheries Service - Alaska Fisheries Science Center.

Rosenberg, A.A., J.H. Swasey and M. Bowman. 2006. Rebuilding US Fisheries: progress and problems. *Front. Ecol. Environ.* 4 (6), 303-308.

Rosenberg, A., D. Agnew, E. Babcock, A. Cooper, C. Mogensen, R. O'Boyle, J. Powers, G. Stefánsson, and J. Swasey. 2007. Annual Catch Limits Report from the Lenfest Working Group. Lenfest Ocean Program.

8 Appendix A – Useful Terms

Most terms have been adapted from National Standard 1 and Annual Catch Limit

Terminology

Acceptable biological catch (ABC) is a level of annual total catch, including mortal discards, that may not exceed the amount corresponding to Flim translated into an amount of catch on an annual basis (see Overfishing Level). For overfished stocks, a rebuilding ABC must be set to reflect the annual catch that is consistent with the rebuilding mortality targets

Accountability measures (AMs) are management controls implemented such that overfishing is prevented, where possible, and corrected, if it occurs. They include definition of OY and establishment of an appropriate OY control rule such that OY is achieved and overfishing does not occur, measures to monitor progress of the fishery during the season and take action to prevent catch from exceeding the overfishing level, and corrective measures to respond to overages that may occur.

Annual catch limit (ACL) is a level of catch specified for a stock or stock complex each year, that is based on the OY control rule and that does not exceed the annual harvest level recommended by the Council's scientific and statistical committee (SSC).

Buffer zone is the area between a limit reference point and a threshold reference point (e.g. OFL and ABC). The size of the buffer is related to perceived risk and preventing overfishing.

MSY means the Maximum Sustainable Yield and is calculated as the largest long-term potential average catch or yield that can be taken from a core stock or stock assemblage under prevailing (e.g., generally current) ecological, environmental and fishery conditions while fishing according to a MSY control rule.

MSY stock size (Bmsy) means the long-term average stock abundance level of the core stock or stock assemblage, measured in terms of spawning biomass or other appropriate proxy, that would occur while fishing according to the MSY control rule. The MSY stock size is the target stock size to which overfished stocks must be rebuilt.

Overfished means a stock or stock assemblage whose biomass has been determined to be below its Blim. Determination of an overfished status triggers the requirement for development of a rebuilding plan.

Overfishing (to overfish) means to fish at a level that jeopardizes the capacity of the stock to produce MSY on a continuing basis.

Overfishing level (OFL) means the annual amount of total fishing mortality that corresponds to the estimate of Flim applied to annual biomass. Catch exceeding the OFL would indicate that overfishing is occurring.

OY (Optimum Yield): 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 MSY 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 MSY in such fishery.

Rebuilding means implementing measures that increase a fish stock to Bmsy or its proxy.

Stock assemblage means a group of stocks in an FMP that are sufficiently similar in geographic distribution, co-occurrence in fisheries, and life history so that SDC measured on an assemblage-wide basis or for an indicator stock will satisfy the Magnuson-Stevens Act requirements to achieve OY and prevent overfishing of a fishery. Not all stocks in an assemblage will have sufficient information to measure stock-specific status with respect to all reference points.

9 Appendix B – Additional Participants and Observers

NOAA Fisheries Staff that provided technical expertise

Galen Tromble NOAA Fisheries Headquarters, Domestic Fisheries Division Chief
Richard Methot NOAA Fisheries, Assessment and Monitoring Division
Wesley Patrick, NOAA Fisheries, Office of Sustainable Fisheries
Olav Ormseth, NOAA Fisheries Alaska Fisheries Science Center
Jason Cope, NOAA Fisheries, Northwest Fisheries Science Center

Ocean Conservancy

Chris Dorsett, Ocean Conservancy
Dennis Heinemann, Ocean Conservancy
Claudia Friess, Ocean Conservancy
Dana Wolfe, Ocean Conservancy

Lenfest Ocean Program

Charlotte Hudson, Lenfest Ocean Program

Pew Environment Group

Kate Semmens, Pew Environment Group
Chad Hanson, Pew Environment Group
Sera Drevenak, Pew Environment Group



LENFEST
OCEAN
PROGRAM

901 E Street NW, 10th Floor, Washington, DC 20004
ph: 202.552.2158 • fx: 202.552.2299
email: info@lenfestocean.org
www.lenfestocean.org