Overview: PSA Test Case for Selected California Fisheries

California Ocean Science Trust contracted with MRAG Americas (MRAG) to conduct a Productivity-Susceptibility Analysis (PSA) on twelve California fisheries to better understand the role this tool can play in setting objectives for fisheries management. PSA is a tool for identifying and prioritizing a fishery stock's vulnerability to overfishing. PSA can be conducted alone or as part of a series of data analysis (e.g. PSA is the second step in the Ecological Risk Assessment Framework for Effects of Fishing used in Australia where each step moves from qualitative to more quantitative approaches).

The PSA method is based on relative scores derived from life-history characteristics - "productivity," and species' responses to fishing pressure - "susceptibility." Productivity represents the potential for rapid stock growth and is ranked semi-quantitatively from low to high, while susceptibility scores are based on indices that can make a stock more or less vulnerable to fishing effort. Outputs from a PSA do not indicate or consider the status of a stock, risks to the wider marine ecosystem, specify harvest guidelines, or consider climate change variables; rather, it is a tool that estimates overexploitation risk from direct impacts of fishing only. PSA outputs may vary depending on the quality of data inputs and the methodologies applied.

PSA methodology can be modified and tailored to address the needs and characteristics of specific fisheries management frameworks. To demonstrate how methodologies can affect results, the analyses presented in the following report by MRAG were conducted using 1) a methodology adapted by MRAG in 2009 that was adjusted for US fisheries by an expert working group, and 2) the methodology employed by Marine Stewardship Council (MSC) as part of their certification. Both methods were adapted from Hobday et al. 2007. Although this test case did not consider it, there is a separate methodology developed by NOAA for use on federally managed fisheries.

As an additional demonstration of the information available from PSA, for relevant species, this report evaluated fish both the entire stock and the portion fished within California waters. This separation in the analysis provides a comparison and opportunity for managers and decision makers to decide where California management action can have the biggest benefit. Management measures at the State level will have differing degrees of success when imposed on a stock completely under California control than in situations where exploitation occurs primarily elsewhere. By evaluating both the vulnerability of the entire stock and the California portion managers can better understand and prioritize fisheries for which State level management measures will be most beneficial.

Interpreting PSA Plots

A PSA plot (Figure 1) illustrates the relative vulnerability of the unit of analysis (stock or assemblage), determined by the combination of productivity (x-axis) and susceptibility (y-axis). The productivity and susceptibility rankings are given a score (1 to 3 for high to low productivity, respectively; and 1-3 for low to high susceptibility, respectively). The colored contour lines divide regions of equal risk and group units of similar risk level (e.g. hypothetical points A and B would be considered equal risk).

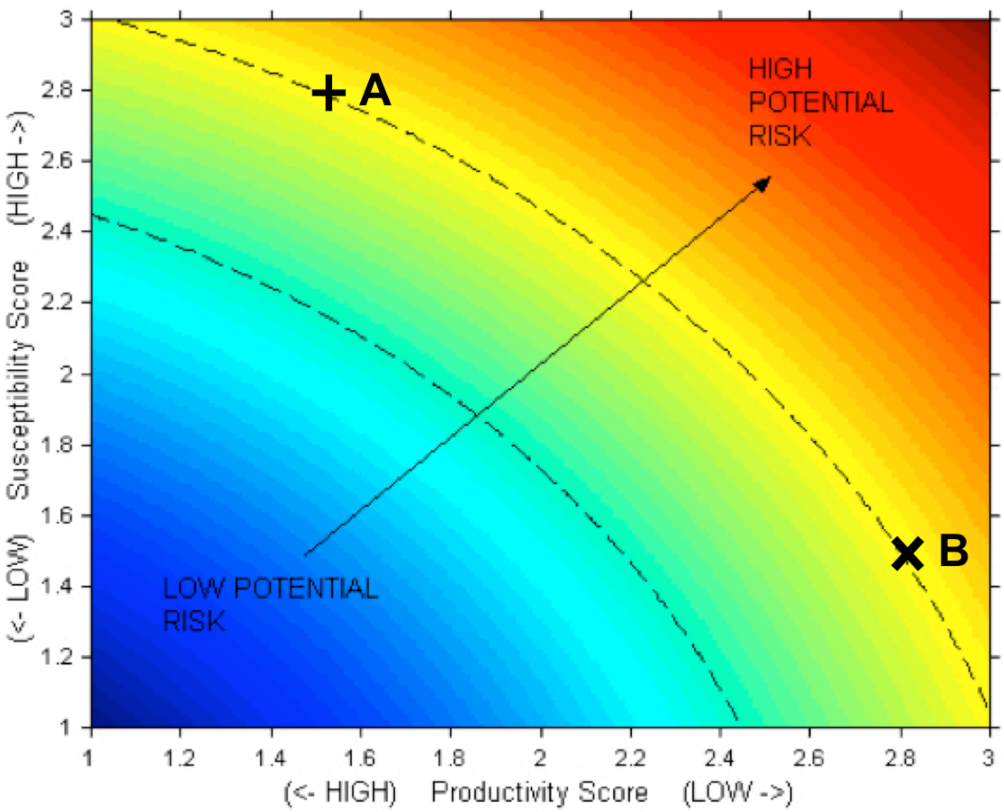

Figure 1. The output is graphed to produce a PSA plot.

Summary Results

One of the most important findings and demonstrations of the MRAG analyses is the differences in results based on the structure of two PSAs applied. These results highlight the importance of tailoring a PSA to the specific needs of researchers or managers and inherent properties of the region and fisheries under consideration. Some structural differences that can alter the outcome for a given fishery include:

- The particular productivity and susceptibility attributes selected to include in the PSA for a suite of fisheries can be added or deleted (e.g., NOAA also considers management context in their PSA)
- Scoring can be either additive or multiplicative, thus affecting the overall risk score (MRAG considered the additive calculation method as precautionary)
- Attributes can be weighted
- Upper and lower limits of bins (cutoff scores) within attributes can vary, i.e. a score of "5" could fall into the low risk bin in one PSA and the moderate risk bin in another
- Uncertainty in data sources can be added and later evaluated in the model (as the NOAA PSA does)

The structure of a particular PSA is set by decisions made by relevant experts, taking into account factors such as how precautionary a model the user desires, the types of information widely available for the suite of fisheries assessed, and the types of interpretations that will be drawn from the results. For example, the NOAA PSA includes an extra component evaluating data uncertainty, which allows users to further investigate attributes where better data or research may make a difference in overall risk score. PSA is inherently precautionary, especially when an attribute is scored with unreliable data or information borrowed from a similar species, in some cases, obtaining more specific data may change the overall risk score for a given species.

Interpreting Results

MRAG has made several suggestions how to best utilize the results of PSA. In addition to understanding the potential vulnerability of a fishery to overfishing, results can help managers and decision makers prioritize their focus for status determinations or management actions on fisheries with the highest needs. PSA results can be used in conjunction with other scientific knowledge and management context to make decisions on how to:

- Group species into prioritization categories. For example:
    - Species with low vulnerability may therefore be a low priority for further evaluation of management changes or stock status evaluations
    - Species for which management decisions can be deferred
    - High risk species that likely need to move on to the next phase of evaluation with either data rich or data poor methodologies
- Manage similar risk species together
- Identify targeted data and research needs
    - For instances where PSA indicates high vulnerability based on limited data, MRAG proposed several data deficient models appropriate to assess such stocks (see pp. 36; many also listed in OST's spreadsheet).

Considering Next Steps

As noted, this report constitutes a test case; the fisheries were chosen to align with other projects rather than out of an imminent interest in altering their management. The goal was to gain a better understanding of PSA as a tool. In order to properly utilize PSA and its results, California should identify or tailor a PSA appropriate for the state's specific needs and metrics. Additionally, model input needs to be carefully vetted with researchers, managers, and other stakeholders for each fishery. This process is important since many of the attributes analyzed are not fixed data such age at maturity, but require a deeper knowledge of metrics not easily measured, such as fishermen behavior or spatial analysis of fishing grounds.

In Summary, PSA is one of many tools available that can address both data poor and data rich species within the same analysis. The test case provides us with insight into how this approach may be beneficial to California fisheries management and identifies several areas and issues that need to be addressed prior to implementation of the methodology.

Productivity and Susceptibility Analysis

with Next Step Recommendations

Test Cases for Selected California Fisheries

Report to

California Ocean Science Trust

April 16, 2014

MRAG Americas, Inc.

www.mragamericas.com

Contents

1 Introduction

Vulnerability analysis based on a comprehensive screening of risk provides a precautionary evaluation of vulnerability of fishery resources to overexploitation. These assessments identify gaps and uncertainties in science and management measures leading to an inability to accurately estimate Maximum Sustainable Yield (MSY). Stocks are more vulnerable if their productivity is low because of slow reproduction rates or other factors in the life history of the species, and/or they have high susceptibility to impacts from fishing effort due to factors such as: (1) direct capture by the fishing gear, (2) impacts from the fishing gear on their essential fish habitat, and/or (3) an already reduced population size. Understanding a stock's vulnerability can be a key piece of information for managing for uncertainty. One tool available for vulnerability assessments is a Productivity and Susceptibility Analysis (PSA), which is a method for ranking of the relative vulnerability of differing fish populations by mapping the populations in a chart that reflects both susceptibility and productivity scores.

The Ocean Science Trust seeks a better understanding of the abilities of PSA and the role it can play in setting objectives for fisheries management. From this test case analysis we seek to understand the level of effort involved in conducting PSA, the types of conclusions that can be drawn from its results, and recommended next steps after completing a PSA. MRAG Americas (MRAG) has conducted PSA on twelve California fisheries with separate analyses for each gear type and fishery (commercial or recreational), including consideration of the fisheries impact on localized California populations or stock wide fishing activities. Analyses were conducted using a methodology adapted by MRAG in 2009 that was adjusted for US fisheries by an expert working group and the Marine Stewardship Council (MSC) employed methodology; detail on each approach provided below.

2 Overview of the Productivity Susceptibility Approach

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 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 method is applied here as a means of assessing a fishery species or stock based on a comprehensive screening of risk for a set of predetermined measurable attributes. The PSA methodologies employed were adapted by the Marine Stewardship Council (MSC) from Hobday *et al.* (2007)[1]. For this report, MRAG used the MSC description of the details of the approach in the Risk-based Framework[2] of the

[1] 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.

[2] Marine Stewardship Council. 2013. MSC Certification Requirements Version 1.3, 14 January 2013. Available online: http://www.msc.org/documents/scheme-documents/msc-scheme-requirements/msc-certification-requirements/view

Fishery Certification Requirements v1.3. The results of the PSA measure risk from direct impacts of fishing only.

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**).

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. 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 (Figure 1). 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 scores[3] serve to break the range of attribute values for a stock into the high – medium – low risk bins.

	Attributes
Productivity	Average age at maturity
	Average maximum age
	Fecundity
	Average maximum size
	Average size at maturity
	Reproductive strategy
	Trophic Level

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

Figure 1: Productivity and susceptibility attributes utilized to score the risk to a unit.

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, 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.

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 2) that illustrates the relative vulnerability of the unit of analysis. Stock status and harvest strategies are not factors in the PSA. Overall risk scores computed by the attributes result in a range of scores where values < 2.64 is low risk, values above 3.18 is high risk and moderate risk values fall within.

[3] Provided in Appendix A for MRAG and MSC methods used.

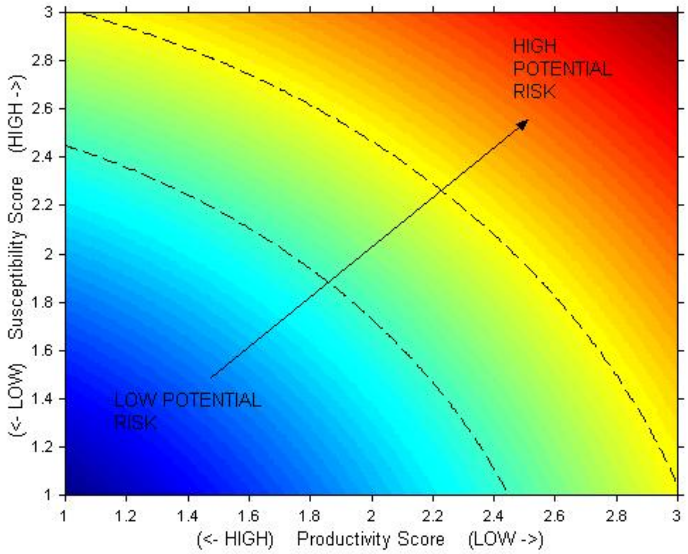

Figure 2: The axes on which risk to the ecological units is plotted. The *x*-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The *y*-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. 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).

2.1 Data Acquisition

Species and fishery specific information was obtained though multiple sources. A number of common references were used to obtain information, both due to the credibility of the source and to lend consistency in data used. The Ocean Sciences Trust provided species specific productivity data based on recently conducted rapid assessments[4], and fishery and gear specific information for susceptibility attributes. Subsequently MRAG relied on fisheries status reports from the California Department of Fish and Wildlife[5], life history data from Fishbase[6], California fishery specific value for 2012 from the CA DFW[7] and federal value from NMFS Annual Landings Statistics[8], along with fishery and species specific reports from multiple sources. PSAs were conducted under each approach (MRAG and MSC methods) for each California fishery and sector separately along with assessing the impact from composite gear use (grouping all fisheries and gears by defaulting to the highest susceptibility score for any attribute).

[4] California Ocean Science Trust. 2013. Rapid Assessments for Selected California Fisheries. California Ocean Science Trust. Oakland, California, USA. August 2013. Available online: http://calost.org/science-initiatives/?page=rapid-assessments

[5] Multiple years available online: http://www.dfg.ca.gov/marine/status/

[6] Froese, R. and D. Pauly. Editors. 2013. FishBase. World Wide Web electronic publication. www.fishbase.org, version (12/2013).

[7] CA DFW Final 2012 California Commercial Landings: http://www.dfg.ca.gov/marine/landings/landings12.asp

[8] NMFS Annual Commercial Landings by Gear Type: http://www.st.nmfs.noaa.gov/st1/commercial/landings/gear_landings.html

2.2 MRAG PSA Method

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.

The MRAG methodology was adapted in a working group in 2009[9][10], with input from workshop participants including members of the NFMS Vulnerability Work Group[11]. The following list summarizes changes adopted by the MRAG methodology, with specific cutoff scores and susceptibility attributes provided in Appendix A.

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

3 Findings

Productivity and susceptibility analyses (PSA) were conducted California fisheries of twelve different species. A species susceptibility to a gear type depends in part on the selectivity of the gear and the species ability to escape when it encounters the gear; therefore, PSA were conducted for each gear type individually along with a composite view that considered the wider range of the stock and the impact of gears collectively. For stocks entirely within California waters, the PSA results represent the total risk to the stocks. However, several stocks ranged far beyond California, so the PSA results provide the total stock-wide risk and the contribution from California. Available information for each species and fishery varied, though we were able to fill in all attributes for each species with data or reasonable assumptions;

[9] MRAG Americas. 2009a. Use of Productivity-Suscetibility Analysis (PSA) in Setting Annual Catch Limits for US Fisheries: An Overview. March 2009. Available online: http://www.mragamericas.com/wp-content/uploads/2010/04/PSA_methodology.4.09.pdf

[10] MRAG Americas. 2009b. Use of Productivity susceptibility Analysis (PSA) in Setting Annual Catch Limits for US Fisheries: A Workshop Report. A report for the Lenfest Ocean Program. May 2009. Available online: http://www.mragamericas.com/wp-content/uploads/2010/04/PSA_Workshop-Report_May-09_MRAG-FINAL.pdf

[11] Overview and technical reports available online: http://www.nmfs.noaa.gov/msa2007/vulnerability.htm

further, the fisheries have been evaluated through different means in recent years, including rapid assessments, fishery status reports, and MSC certifications (Table 1).

Table 1: Fisheries assessed in this report.

Common Name	Species name	Fishery	Gear	CA FMP	PFMC FMP	OST RA	MSC Cert
White Seabass	*Atractoscion nobilis*	Commercial	Small Mesh Drift Gill Net Hook and line	x		x	
Market Squid	*Loligo (Doryteuthis) opalescens*	Commercial	Purse and drum seine Brail (dip net)	x	x	x	
Dungeness Crab	*Metacarcinus magister*	Commercial	Trap			x	x (OR)
		Recreational	Trap			x	
California Halibut	*Paralichthys californicus*	Commercial	Trawl Gill net Hook and line			x	
		Recreational	Hook and line				
Pacific Herring	*Clupea pallasi*	Commercial	Gill net			x	
Albacore Tuna	*Thunnus alalunga*	Commercial	Pole and line Troll and jig		x	x	x
Pacific Sardine	*Sardinops sagax*	Commercial	Purse seine		x	x	
Pink (Ocean) Shrimp	*Pandalus jordani*	Commercial	Otter trawl			x	x (OR)
Sablefish	*Anoplopoma fimbria*	Commercial	Trawl Longline Trap		x	x	
Spiny Lobster	*Panulirus interruptus*	Commercial	Trap	In devel		x	
Swordfish	*Xiphias gladius*	Commercial	Harpoon		x	x	
Red and purple urchins	Red urchin (*Strongylocentrotus franciscanus*), Purple urchins (*S. purpuratus*)	Commercial	Hand collected				

CA FMP - Fishery is management under a CA state Fishery Management Plan.
PFMC FMP - Fishery is managed federally by a Pacific Fishery Management Council Plan.
OST RA - Rapid Assessment was conducted by OST for the fishery in July 2013.
MSC Cert - Fishery is certified by the Marine Stewardship Council.

In the subsequent sections we provide findings from the analyses with brief fishery summaries[12], an important difference to consider is the MRAG approach modified productivity scores to align more with life histories more commonly seen in the species of US fisheries, though susceptibility scoring is not gear specific and the score is additive. In contract the MSC susceptibility attributes provide a more direct measure of the specific gear, though scoring is multiplicative. In multiplicative the values are multiplied, thereby a low score in the string will reduce the overall score. This often results in lower scores compared with an additive approach; the MRAG method considered it precautionary to use an additive calculation for the overall susceptibility scores.

[12] Detailed fishery information is available from the OST Rapid Assessments (http:/calost.org) and CA DFW Status of Fisheries Reports (http://www.dfg.ca.gov/marine/status/).

3.1 Summary

All PSAs were conducted to provide a measure of fishery vulnerability by a specific gear type in the California fishery, with additional analyses provided for a composite measure to consider the broader impact on the stock given a larger distribution, multiple gears and in some cases multiple nations contributing to the fishing pressure. Management of the fisheries in California varies considerably as does the level of information and monitoring on a fishery. The PSAs for the California fisheries, not including the composite analyses, are provided in Figure 3, **Error! Reference source not found.**, Figure 5 and Figure 6. These figures provide the general overview of how the fisheries vulnerabilities related to one another. Individual fishery analyses with composite impacts are provided in the following sections. In review of these results, it is important to keep in mind that high productivity equals low risk and high susceptibility equals high risk. Given that these are rapid analyses, further refinement of the approach and information use would benefit from stakeholder consultation, particularly to refine understanding of the susceptibility attributes.

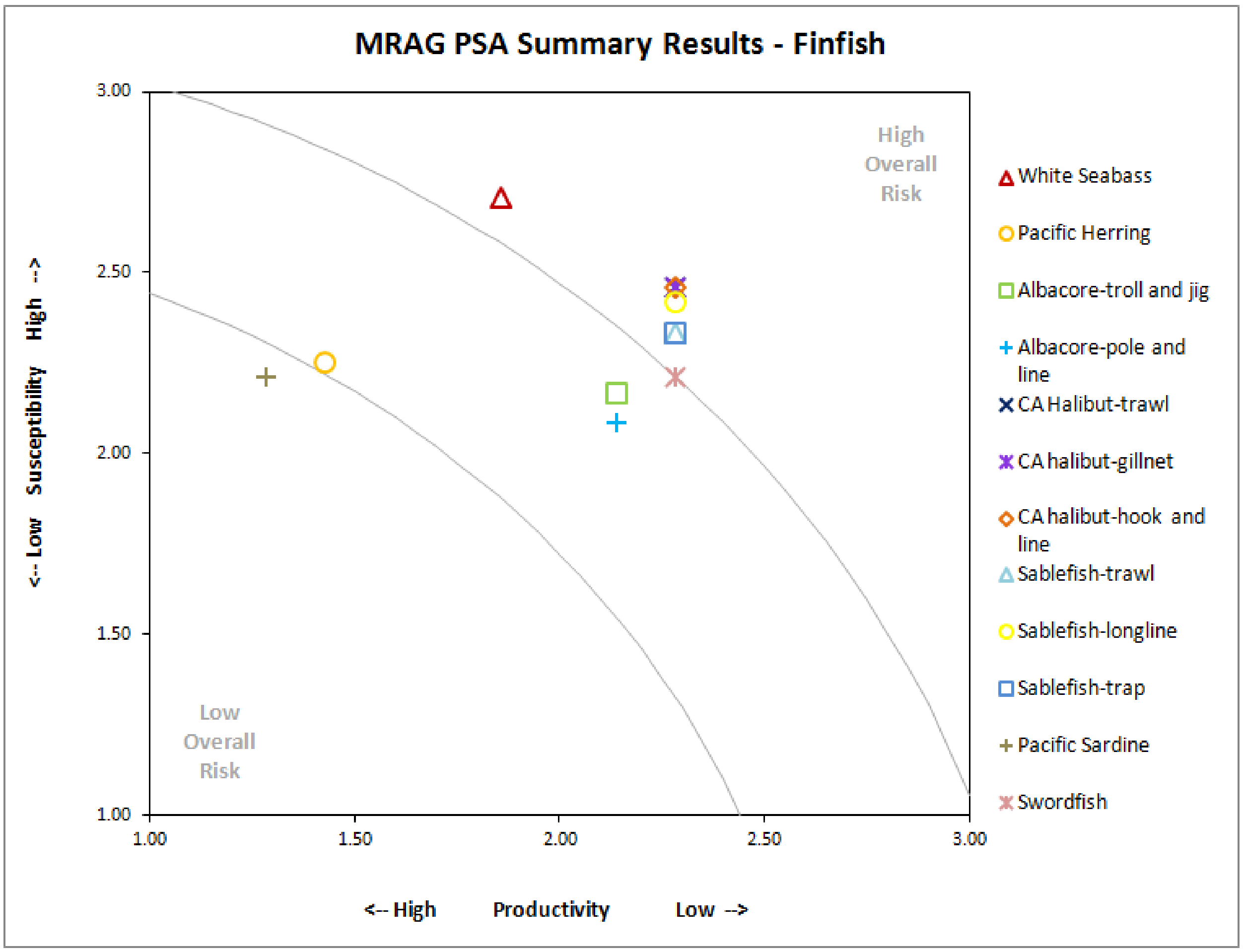

Figure 3: MRAG PSA Analyses for California Finfish Fisheries.

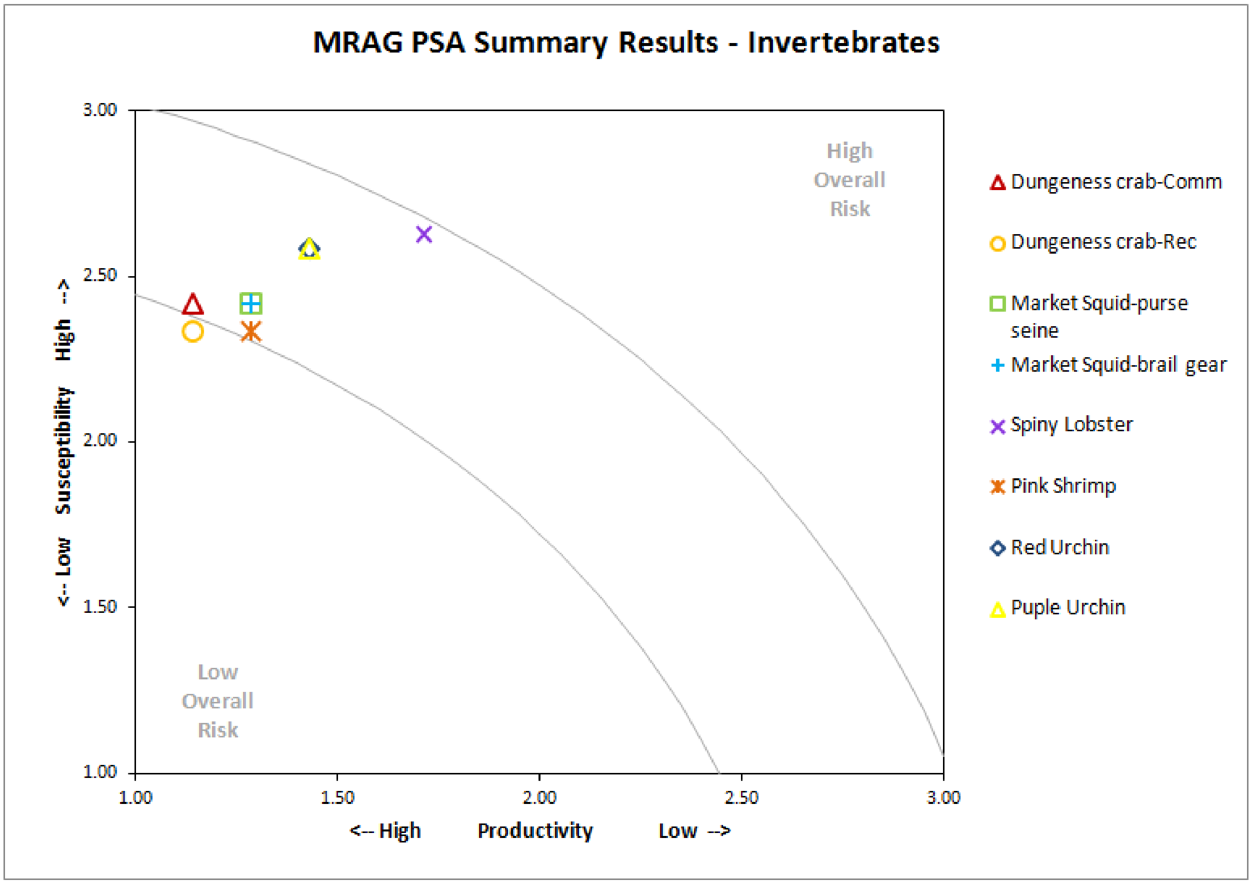

Figure 4: MRAG PSA Analysis for California Invertebrate Fisheries.

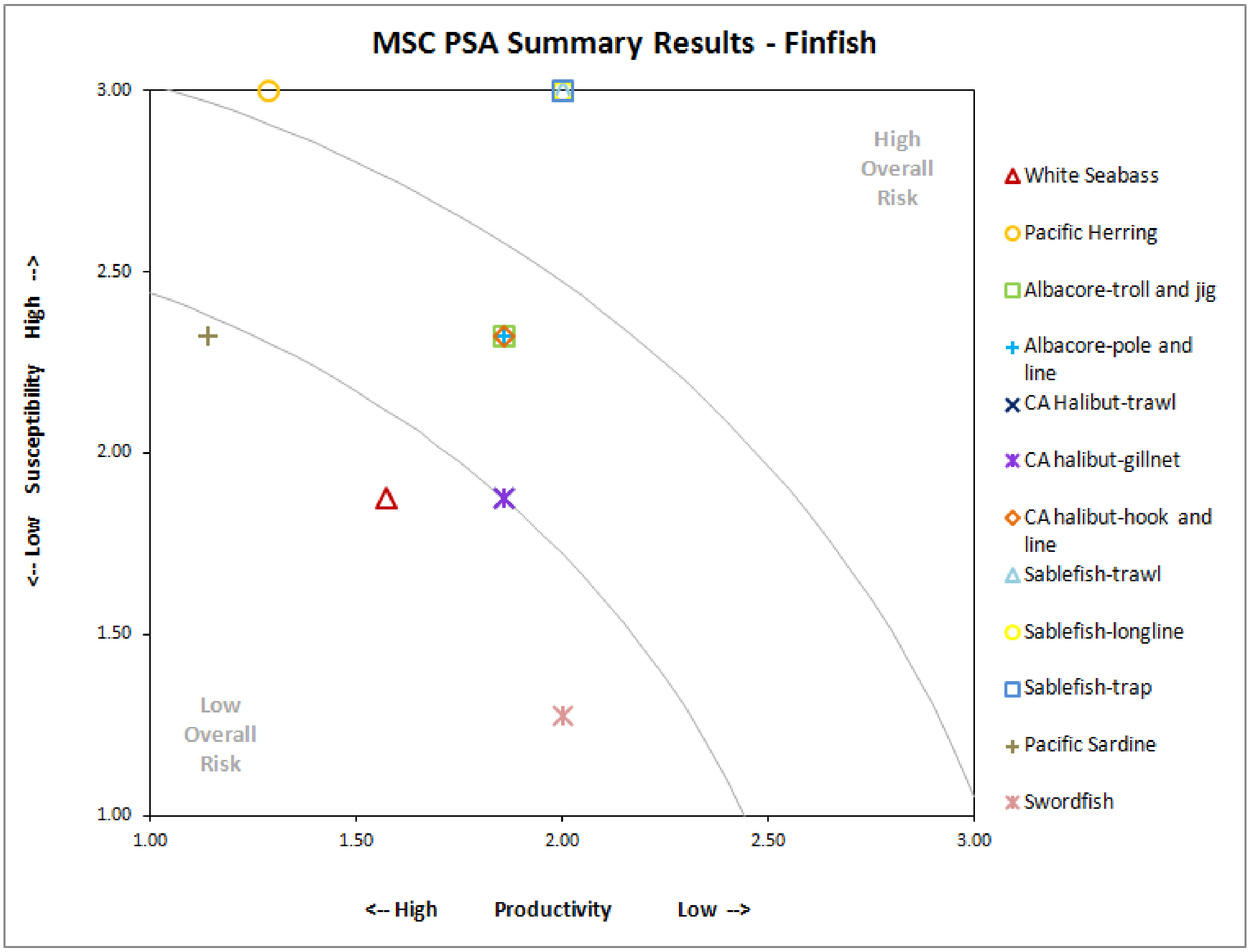

Figure 5: MSC PSA Analyses for California Finfish Fisheries.

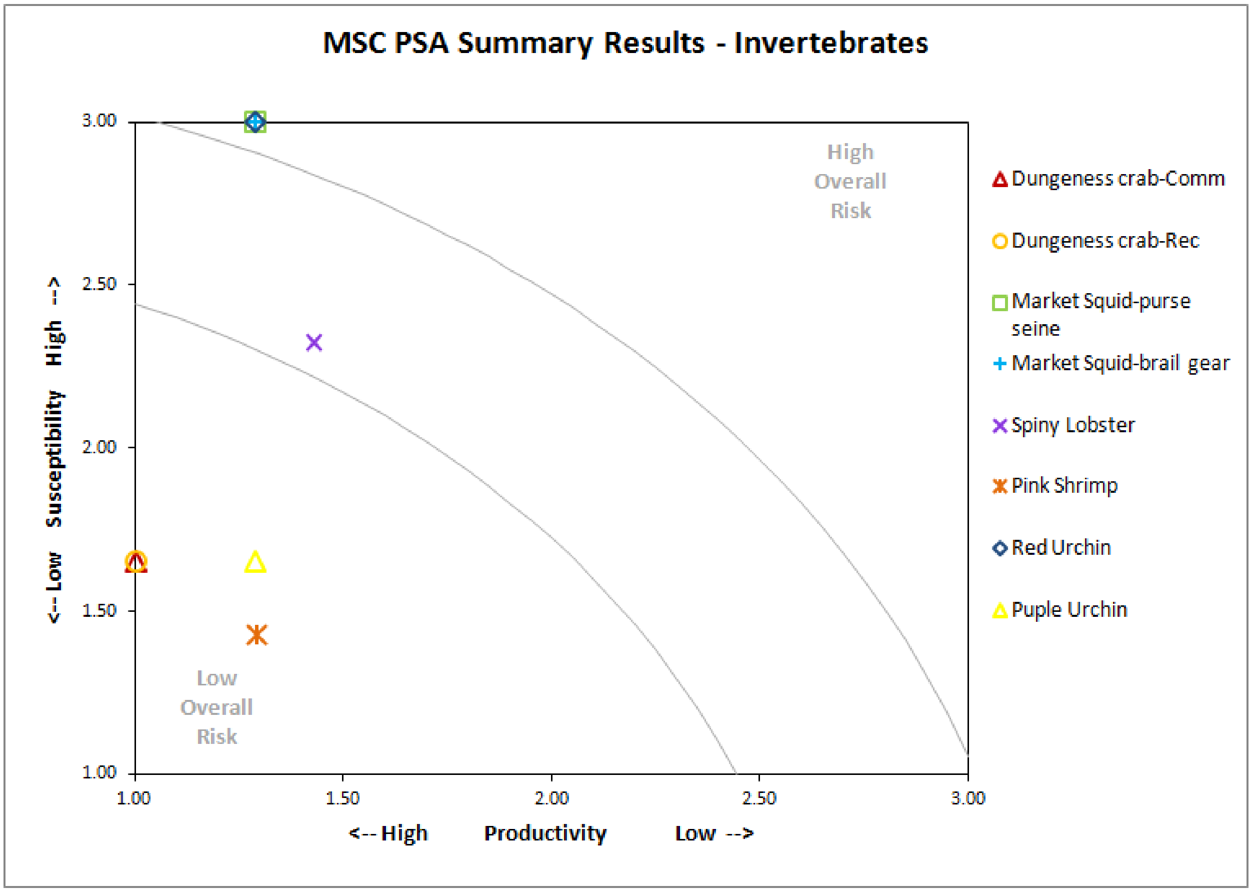

Figure 6: MSC PSA Analyses for California Invertebrate Fisheries.

3.2 White Seabass

In California, white seabass (*Atractoscion nobilis*) are fished commercially using gillnet. There are also a very active recreational fishery in California and a commercial fishery in Mexico; though the CA commercial fishery is the primary focus of the analysis. The species generally exhibits high productivity but are also susceptible to fishing impacts given their habitat and fishing methods employed. The species undertakes schooling behavior and is generally found over rocky bottoms and kelp beds and has a limited distribution ranging from Magdelena Bay, Baja California, Mexico to the San Francisco area; fishery has been concentrated in southern California, south of Point Conception. The California Fish and Game Commission adopted the White Seabass Fishery Management Plan (WSFMP) in June 2002[13].

White seabass have high productivity but are highly vulnerable to fishing activities as measured by the MRAG PSA susceptibility scores; note that a higher productivity score equals lower risk that resulted from different cut-off scores used by the MRAG method. Table 2 details the PSA scores, which are plotted in Figure 7.

[13] Available online: http://www.dfg.ca.gov/marine/wsfmp/index.asp

Table 2: White Seabass PSA attribute risk scores.

Species: *Atractoscion nobilis* Fishery and gear: Commercial – Small Mesh Drift Gill Net			White Seabass				
			MRAG			MSC	
			Gill net	Stock wide		Gill net	Stock wide
Productivity	Age at maturity		med	med		low	low
Productivity	Size at maturity		med	med		med	med
Productivity	Maximum age		med	med		med	med
Productivity	Maximum size		high	high		med	med
Productivity	Fecundity		low	low		low	low
Productivity	Repro strategy		low	low		low	low
Productivity	Trophic level		med	med		med	med
Productivity Score			1.86	1.86		1.57	1.57
Susceptibility	Availability	Glob Dist	high	high	Areal overlap	med	high
Susceptibility	Availability	Behavior	high	high			
Susceptibility	Encounterability	Habitat	high	high	Vertical overlap	med	med
Susceptibility	Encounterability	Bathymetry	high	high			
Susceptibility	Selectivity	Size at mat	med	med	Gear selectivity	high	high
Susceptibility	Selectivity	Max size	high	high			
Susceptibility	Selectivity	Desirability	med	med			
Susceptibility	Post capture mortality		high	high	PCM	high	high
Susceptibility Score			2.71	2.71		1.88	2.33
Overall Risk Score			3.28	3.28		2.45	2.81
Risk Ranking			High	High		Low	Med
Stock Status			No assessment available, increased population and landings over past two decades				
Note: Status from OST 2013. Composite (stock wide) considers federal revenue beyond the state fishery, stock wide distribution and impact of recreational and Mexican fisheries.							

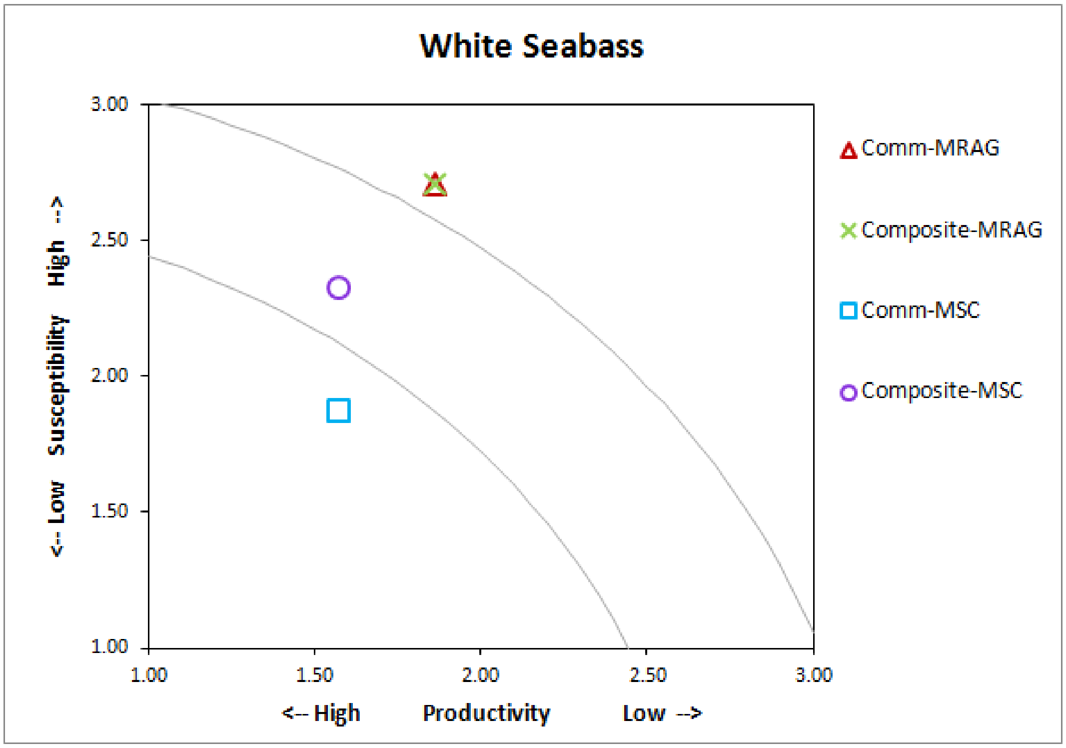

Figure 7: White Seabass PSA Plot.

3.3 Market Squid

In California, market squid (*Loligo (Doryteuthis) opalescens*) are one of the most important commercial fisheries by volume and value. The fishery is managed under a federal fishery management plan by the Pacific Fishery Management Council and by the state using consistent management guidelines. The commercial fishery uses purse and drum seine and brail nets accompanied by attracting lights to target inshore spawning aggregations and populations exhibit some site fidelity with seasonal return to recruitment locations.

As an invertebrate, squid are highly productive (low risk) and highly susceptible (high risk). Productivity attributes of size at maturity and trophic level are not specifically known, though given other life history characteristics it is reasonable to assume that these attributes should have low risk scores; typically a PSA would score high risk in the absence of data. Table 3 details the PSA scores, which are plotted in Figure 8.

Table 3: Market squid PSA attribute risk scores.

Species: *Loligo (Doryteuthis) opalescens* **Fishery and gear:** Commercial - Purse and drum seine, Brail gear (dip net)			**Market Squid**						
			MRAG				**MSC**		
			Comm Purse Seine	Comm Brail Gear	Stock wide		Comm Purse Seine	Comm Brail Gear	Stock wide
Productivity	Age at maturity		low	low	low		low	low	low
Productivity	Size at maturity		low	low	low		low	low	low
Productivity	Maximum age		low	low	low		low	low	low
Productivity	Maximum size		low	low	low		low	low	low
Productivity	Fecundity		med	med	med		med	med	med
Productivity	Repro strategy		med	med	med		med	med	med
Productivity	Trophic level		low	low	low		low	low	low
Productivity Score			1.29	1.29	1.29		1.29	1.29	1.29
Susceptibility	Availability	Glob Dist	high	high	high	Areal overlap	high	high	high
Susceptibility	Availability	Behavior	high	high	high				
Susceptibility	Encounterability	Habitat	low	low	low	Vertical overlap	high	high	high
Susceptibility	Encounterability	Bathymetry	high	high	high				
Susceptibility	Selectivity	Size at mat	low	low	low	Gear selectivity	high	high	high
Susceptibility	Selectivity	Max size	low	low	low				
Susceptibility	Selectivity	Desirability	high	high	high				
Susceptibility	Post capture mortality		high	high	high	PCM	high	high	high
Susceptibility Score			2.42	2.42	2.42		3.00	3.00	3.00
Overall Risk Score			2.74	2.74	2.74		3.26	3.26	3.26
Risk Ranking			Med	Med	Med		High	High	High
Stock Status			Status in California not well known, population fluctuates annually in response to environmental factors.						

Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact of purse seine and brail gears.

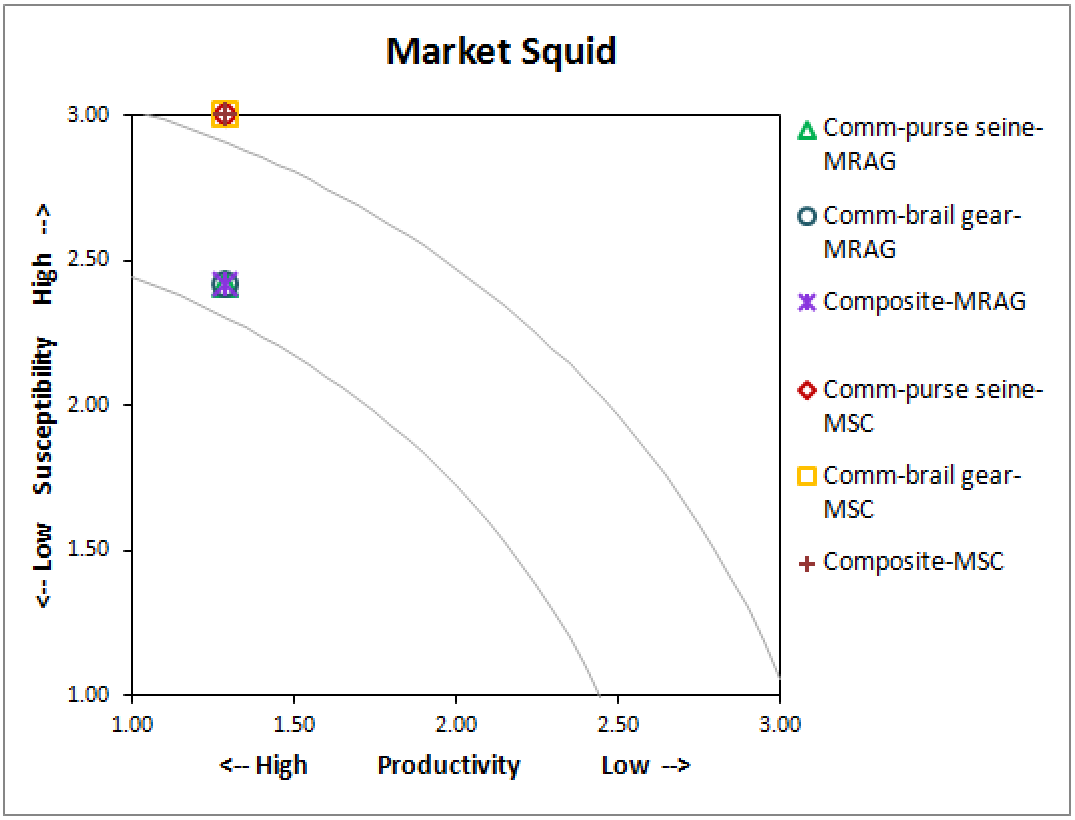

Figure 8: Market Squid PSA Plot.

3.4 Dungeness Crab

Dungeness crab (*Metacarcinus magister*) was the highest value fishery in California in the 2011-2012 fishing year. Dungeness crab are managed by restricting sex, size and season – the "3-S" principle; however, there is no formal fishery management plan. Management is coordinated among California, Washington and Oregon fisheries. There are established commercial and recreational fisheries that use traps. The California fishery operates in two main areas: northern and central California, divided at the Sonoma-Mendocino border.

Dungeness crab are a highly productive (low risk) benthic species with populations that respond to oceanic conditions and environmental variations. In the absence of stock assessments, regulations protecting mature and spawning females are believed sufficient to sustain the population. Productivity attributes of size at maturity and trophic level are not specifically known, though given other life history characteristics it is reasonable to assume that these attributes should have low risk scores; typically a PSA would score high risk in the absence of data. Table 4 details the PSA scores, which are plotted in Figure 9.

Table 4: Dungeness Crab PSA attribute risk scores.

Species: *Metacarcinus magister* **Fishery and gear:** Commercial - Trap Recreational - Trap			**Dungeness Crab**						
			MRAG				**MSC**		
			Comm Trap	Rec Trap	Stock wide		Comm Trap	Rec Trap	Stock wide
Productivity	Age at maturity		med	med	med		low	low	low
	Size at maturity		low	low	low		low	low	low
	Maximum age		low	low	low		low	low	low
	Maximum size		low	low	low		low	low	low
	Fecundity		low	low	low		low	low	low
	Repro strategy		low	low	low		low	low	low
	Trophic level		low	low	low		low	low	low
Productivity Score			1.14	1.14	1.14		1.00	1.00	1.00
Susceptibility	Availability	Glob Dist	high	high	high	Areal overlap	low	low	high
		Behavior	med	med	med				
	Encounterability	Habitat	high	high	high	Vertical overlap	high	high	med
		Bathymetry	med	med	med				
	Selectivity	Size at mat	med	med	med	Gear selectivity	high	high	high
		Max size	low	low	low				
		Desirability	high	med	high				
	Post capture mortality		high	high	high	PCM	high	high	high
Susceptibility Score			2.42	2.33	2.42		1.65	1.65	3.00
Overall Risk Score			2.67	2.60	2.67		1.93	1.93	3.16
Risk Ranking			Med	Low	Med		Low	Low	Med
Stock Status			In CA, current population abundance and overfishing status are unknown, and biological reference points are not designated for this fishery.						
Note: Status from OST 2013. Composite (stock wide) considers federal fishery value beyond the state fishery, stock wide distribution and impact of recreational and commercial fisheries coast wide.									

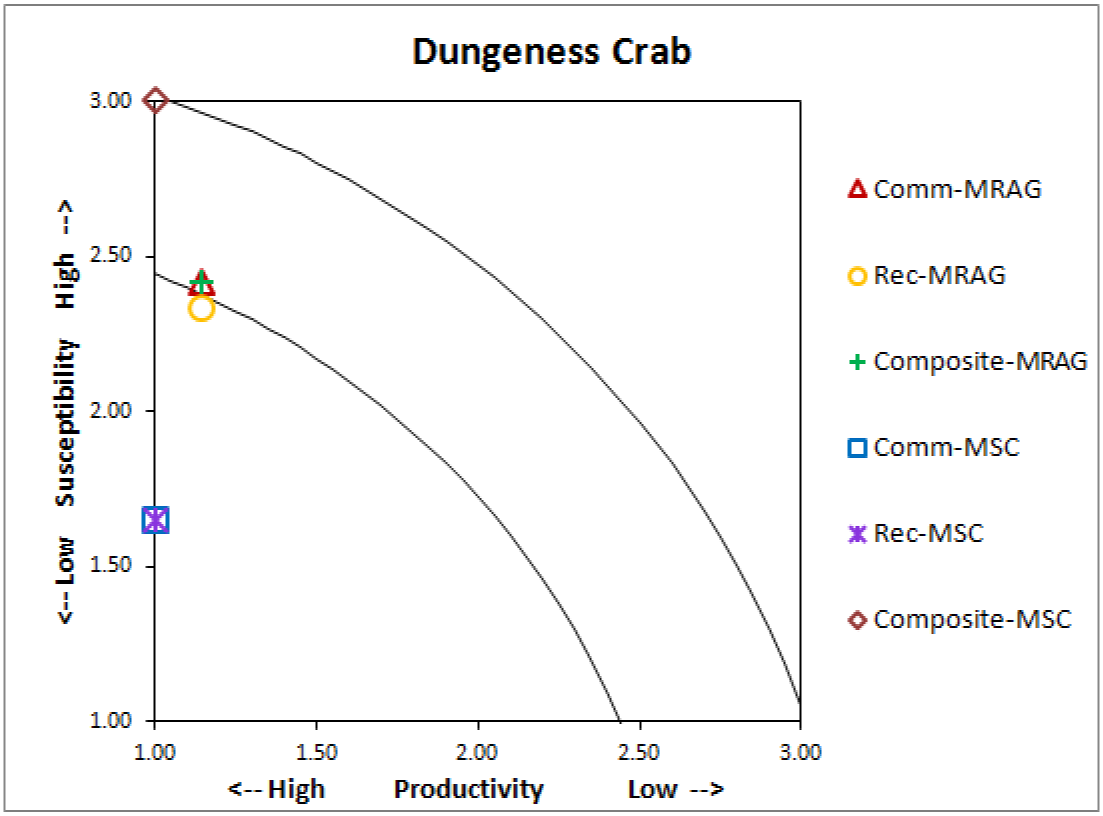

Figure 9: Dungeness Crab PSA Plot.

3.5 California Halibut

The California halibut (*Paralichthys californicus*) population has a southern and central California stock, fished with trawl, set gill nets and hook and line. The commercial fisheries have caught California halibut using trawl, set gillnets, and hook-and-line. Bottom gillnets historically accounted for a significant portion of the catch, but their use has declined due to the banning of this gear in several areas along the California coast. Trawl and bottom gillnets are the primary gears used in southern California, while mostly trawl and hook-and-line gear are used in central California. There is no fishery management plan for the fishery and a 2011 stock assessment found the southern stock to be depleted to about 14% of its unexploited spawning stock biomass level with increasing biomass in the central stock.

Depending on the risk scores selected, California halibut exhibit low to moderate productivity (moderate to high risk). There are sex-specific differences in age, size, maturity, and distribution. California halibut females live longer, grow larger, mature later and appear to be more common or more easily captured than males. The analysis considered maximum and mature sizes and ages for females. Table 5 details the PSA scores, which are plotted in Figure 10.

Table 5: California halibut PSA attribute risk scores.

Species: *Paralichthys californicus* Fishery and gear: Commercial - Trawl, Gillnet, Hook and Line Recreational - Hook and Line			California Halibut										
			MRAG						MSC				
			Trawl	Gillnet	Hook & line	Rec, Hook & Line	Stock wide		Trawl	Gillnet	Hook & line	Rec, Hook & Line	Stock wide
Productivity	Age at maturity		high	high	high	high	high		low	low	low	low	low
Productivity	Size at maturity		med	med	med	med	med		med	med	med	med	med
Productivity	Maximum age		high	high	high	high	high		high	high	high	high	high
Productivity	Maximum size		med	med	med	med	med		med	med	med	med	med
Productivity	Fecundity		low	low	low	low	low		low	low	low	low	low
Productivity	Repro strategy		low	low	low	low	low		low	low	low	low	low
Productivity	Trophic level		high	high	high	high	high		high	high	high	high	high
Productivity Score			2.29	2.29	2.29	2.29	2.29		1.86	1.86	1.86	1.86	1.86
Susceptibility	Availability	Glob Dist	med	med	med	med	med	Areal overlap	med	med	med	med	high
Susceptibility	Availability	Behavior	med	med	med	med	med						
Susceptibility	Encounterability	Habitat	med	med	med	med	med	Vertical overlap	high	high	high	high	high
Susceptibility	Encounterability	Bathymetry	high	high	high	high	med						
Susceptibility	Selectivity	Size at mat	med	med	med	med	med	Gear selectivity	med	med	high	high	high
Susceptibility	Selectivity	Max size	med	med	med	med	med						
Susceptibility	Selectivity	Desirability	med	med	med	med	med						
Susceptibility	Post capture mortality		high	high	high	high	high	PCM	high	high	high	high	high
Susceptibility Score			2.46	2.46	2.46	2.46	2.46		1.88	1.88	2.33	2.33	2.33
Overall Risk Score			3.36	3.36	3.36	3.36	3.36		2.64	2.64	2.98	2.98	2.98
Risk Ranking			High	High	High	High	High		Low	Low	Med	Med	Med
Stock Status			The southern CA stock (primarily trawl and gillnet used) is estimated to be depleted to about 14% of its unexploited spawning biomass level while the central stock (primarily trawl and hook and line) healthy and has been increasing since 1995.										
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact gears across commercial and recreational fisheries.													

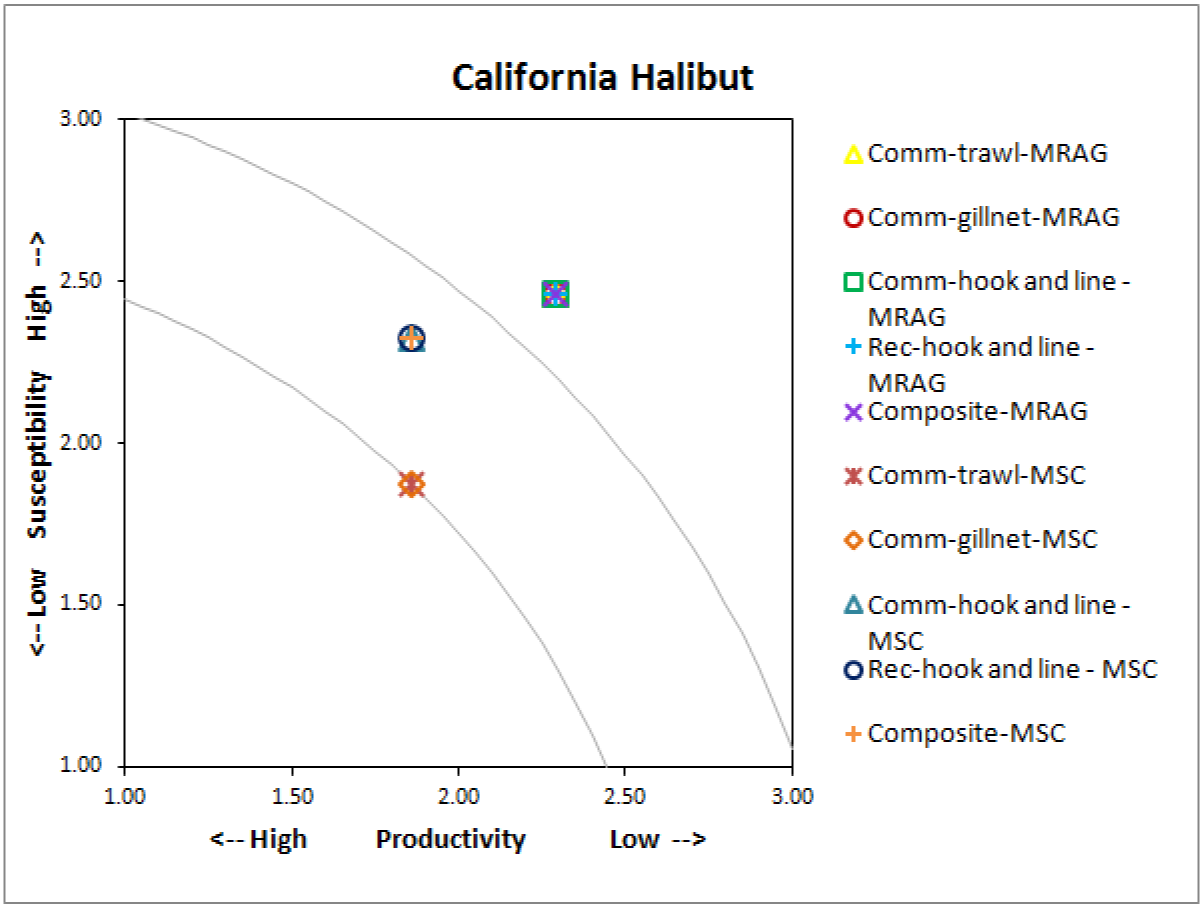

Figure 10: California Halibut PSA Plot.

3.6 Pacific Herring

There are three components to the Pacific herring (*Clupea pallasi*) fishery in California: (1) the sac-roe fishery using gillnet gear, (2) a live herring fishery also using gillnet, and (3) hand-collected roe on kelp (HOEK) using SCUBA. Of the three, the sac-roe fishery is the largest and receives the highest allocation of quota. All three components occur in San Francisco Bay. The herring fishery is regulated through a variety of mechanisms, including an annual spawning biomass assessment to set quotas, limited entry permitting, seasonal closures, separation of the fishery into platoons, and gear restrictions.

Herring form breeding aggregations, and fishing is permitted at aggregations. Mature adults migrate inshore, entering estuaries to breed. Herring range from north Baja California to Alaska and Russia; we consider each spawning area as a separate stock that needs specific management, as depletion from overharvest of a spawning site would likely take a long time to recover. Because the primary fishery (roe) occurs on spawning fish with high site fidelity, the analysis considers that fishery completely overlaps the (spawning) stock range (during the fishery period). Table 6 details the PSA scores, which are plotted in Figure 11.

Table 6: Pacific herring attribute risk scores.

Species: *Clupea pallasi* **Fishery and gear:** Gill net –Sac Roe fishery (highest allocation) Gill net – Live herring fishery Scuba - Herring roe on Kelp (Hoek)			Pacific Herring								
			MRAG					MSC			
			Sac-Roe	Live Fishery	Kelp Roe	Stock wide		Sac-Roe	Live Fishery	Kelp Roe	Stock wide
Productivity	Age at maturity		med	med	med	med		low	low	low	low
	Size at maturity		low	low	low	low		low	low	low	low
	Maximum age		med	med	med	med		med	med	med	med
	Maximum size		low	low	low	low		low	low	low	low
	Fecundity		low	low	low	low		low	low	low	low
	Repro strategy		low	low	low	low		low	low	low	low
	Trophic level		med	med	med	med		med	med	med	med
Productivity Score			1.43	1.43	1.43	1.43		1.29	1.29	1.29	1.29
Susceptibility	Availability	Glob Dist	high	high	high	high	Areal overlap	high	high	high	high
		Behavior	high	high	high	high					
	Encounterability	Habitat	low	low	low	low	Vertical overlap	high	high	low	High
		Bathymetry	high	high	high	high					
	Selectivity	Size at mat	low	low	low	low	Gear selectivity	high	high	low	high
		Max size	low	low	low	low					
		Desirability	low	low	low	low					
	Post capture mortality		high	high	high	high	PCM	high	high	high	high
Susceptibility Score			2.25	2.25	2.25	2.25		3.00	3.00	1.20	3.00
Overall Risk Score			2.67	2.67	2.67	2.67		3.26	3.26	1.76	3.26
Risk Ranking			Med	Med	Med	Med		High	High	Low	High
Stock Status			Stock status in California is assessed annually only in San Francisco Bay. Abundance fluctuates widely due to variable recruitment; the population has been increasing over the past four surveys.								

Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution, fishery value and collective impact of gears.

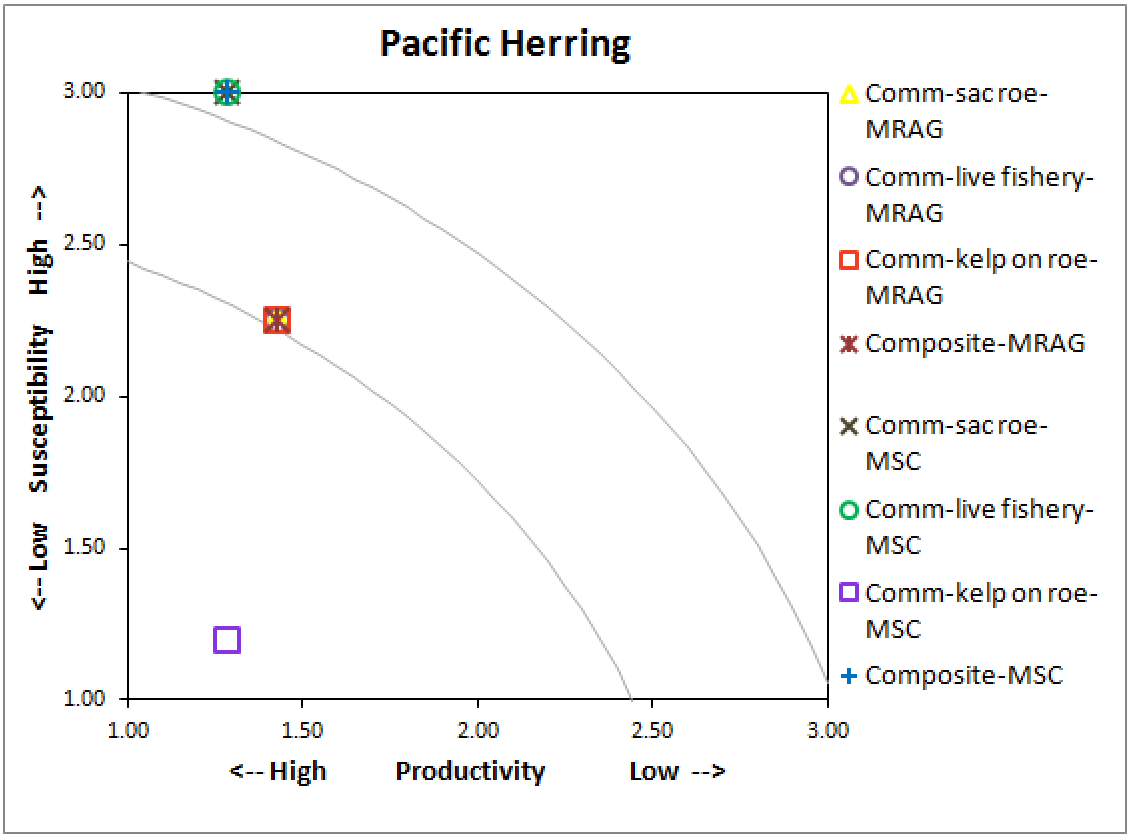

Figure 11: Pacific Herring PSA Plot.

3.7 North and South Pacific Albacore Tuna

Albacore tuna (*Thunnus alalunga*) are a highly migratory species with a wide distribution; the fishery in California targets seasonally migrating albacore in nearshore ocean waters off southern California. Given their range, Albacore are managed jointly by the Inter-American Tropical Tuna Commission (IATTC) for waters east of 150˚ W longitude, and the Western and Central Pacific Fisheries Commission (WCPFC) for waters west of 150˚ W longitude. Along the US West Coast, albacore tuna are managed under the Pacific Fishery Management Council's Highly Migratory Species Fishery Management Plan.

In US waters the commercial fishery uses pole and line and troll gear, the species is also a prized recreational catch. The population is regularly assessed and in 2011 was considered to be healthy with recruitment sufficient to sustain current levels of fishing mortality. With variable fishing pressure from multiple nations, the fishery is well monitored with a precautionary harvest strategy. Management measures applied to the stock are adopted by both the IATTC and WCPFC and passed to member countries to implement. In the North Pacific, the American Albacore Fishing Association has been MSC certified for pole and line and troll and jig gear since August 2007[14] and the American Western Fish Boat Owners Association (WFOA) member countries to implement. In the North Pacific, the American

[14] More information available online: http://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific/aafa-pacific-albacore-tuna-north/unit-of-certification

Albacore Fishing Association has been MSC certified for pole and line and troll and jig gear since March 2010[15]. Table 7 details the PSA scores, which are plotted in Figure 12.

Table 7: Albacore tuna PSA attribute scores.

Species: *Thunnus alalunga* **Fishery and gear:** Commercial – Poll and Line, Troll and jig			Albacore Tuna						
			MRAG				**MSC**		
			Troll & jig	Pole & line	Stock wide		Troll & jig	Pole & line	Stock wide
Productivity	Age at maturity		high	high	high		med	med	med
Productivity	Size at maturity		high	high	high		med	med	med
Productivity	Maximum age		med	med	med		med	med	med
Productivity	Maximum size		med	med	med		med	med	med
Productivity	Fecundity		low	low	low		low	low	low
Productivity	Repro strategy		low	low	low		low	low	low
Productivity	Trophic level		high	high	high		high	high	high
Productivity Score			2.14	2.14	2.14		1.86	1.86	1.86
Susceptibility	Availability	Glob Dist	low	low	low	Areal overlap	med	med	high
Susceptibility	Availability	Behavior	med	med	med				
Susceptibility	Encounterability	Habitat	low	low	low	Vertical overlap	high	high	high
Susceptibility	Encounterability	Bathymetry	med	med	med				
Susceptibility	Selectivity	Size at mat	high	high	high	Gear selectivity	high	high	high
Susceptibility	Selectivity	Max size	med	med	med				
Susceptibility	Selectivity	Desirability	med	med	high				
Susceptibility	Post capture mortality		high	high	high	PCM	high	high	high
Susceptibility Score			2.17	2.08	2.17		2.33	2.33	3.00
Overall Risk Score			3.05	2.99	3.05		2.98	2.98	3.53
Risk Ranking			Med	Med	Med		Med	Med	High
Stock Status			The north Pacific albacore stock is considered to be healthy at current levels of recruitment and fishing mortality (June 2011).						
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact of gears.									

[15] More information available online: http://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific/WFOA-North-Pacific-Albacore-Tuna/fishery-name

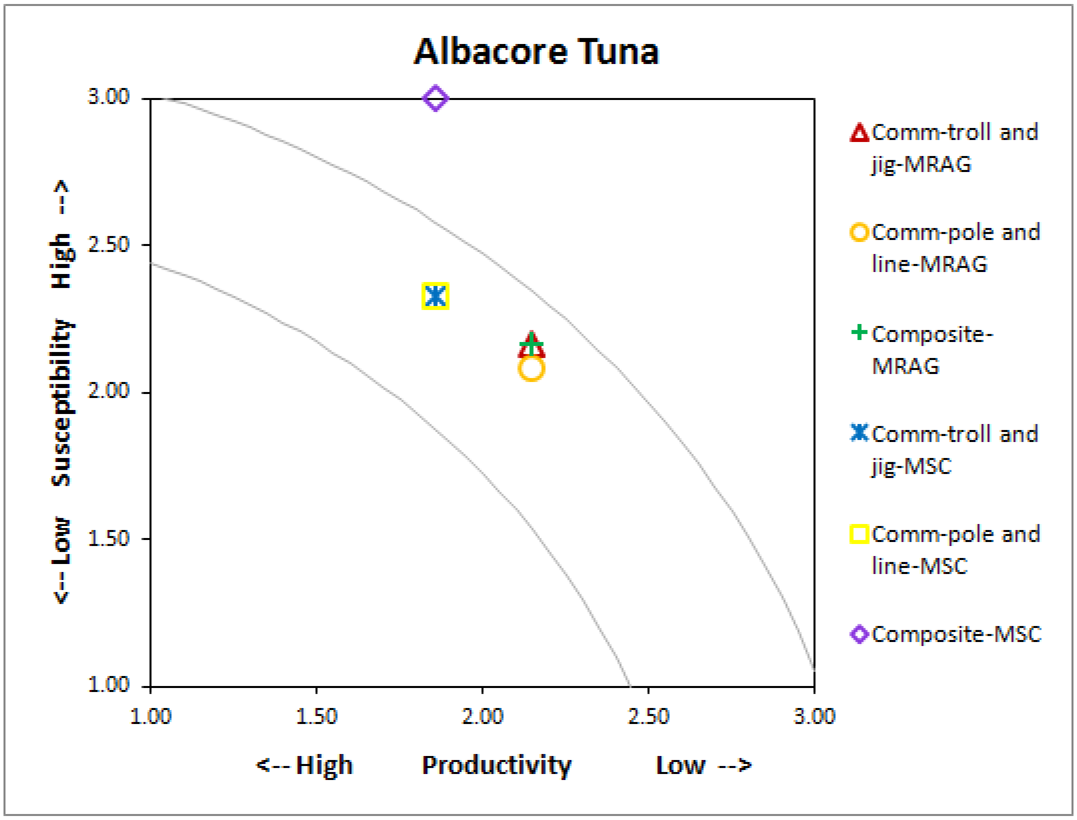

Figure 12: Albacore Tuna PSA Plot.

3.8 Pacific Sardine

Pacific sardine (*Sardinops sagax*) is fished commercially in California using round haul gear such as: purse seines, drum seines, and lampara nets; which surround aggregates so that there is little opportunity for escape. Pacific sardine are an abundant forage fish ranging from Baja California to British Columbia, there are established fisheries along its range. There are no formal management arrangements between the three countries, though an annual meeting of the Trinational Sardine Forum collaborates on improving the coast-wide stock assessments and improved understanding of the fishery. In the US, sardine is managed by the Pacific Fishery Management Council through the Coastal Pelagic Species Fisheries Management Plan since 2000. The FMP uses a harvest guideline based on biomass estimates and divides the allocation into three seasons. Population biomass has recently been declining, US exploitation rate has been declining and populations are considered healthy. Table 8 details the PSA scores, which are plotted in Figure 13.

Table 8: Pacific sardine PSA attribute scores.

Species: *Sardinops sagax* Fishery and gear: Commercial – Purse Seine			Pacific Sardine				
			MRAG			MSC	
			Purse seine	Stock wide		Purse seine	Stock wide
Productivity	Age at maturity		med	med		low	low
	Size at maturity		low	low		low	low
	Maximum age		med	med		med	med
	Maximum size		low	low		low	low
	Fecundity		low	low		low	low
	Repro strategy		low	low		low	low
	Trophic level		low	low		low	low
Productivity Score			1.29	1.29		1.14	1.14
Susceptibility	Availability	Glob Dist	med	med	Areal overlap	med	high
		Behavior	high	high			
	Encounterability	Habitat	low	low	Vertical overlap	high	high
		Bathymetry	high	high			
	Selectivity	Size at mat	low	low	Gear selectivity	high	high
		Max size	low	low			
		Desirability	med	high			
	Post capture mortality		high	high	PCM	high	high
Susceptibility Score			2.21	2.29		2.33	3.00
Overall Risk Score			2.56	2.63		2.59	3.21
Risk Ranking			Low	Low		Low	High
Stock Status			Biomass have been declining since 2006, though populations are still considered healthy. U.S. exploitation rate has been declining since 2002, although total (MX, UX, CAN) exploitation rate has increased in recent years.				
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and value and impacts of CAN and MX fisheries.							

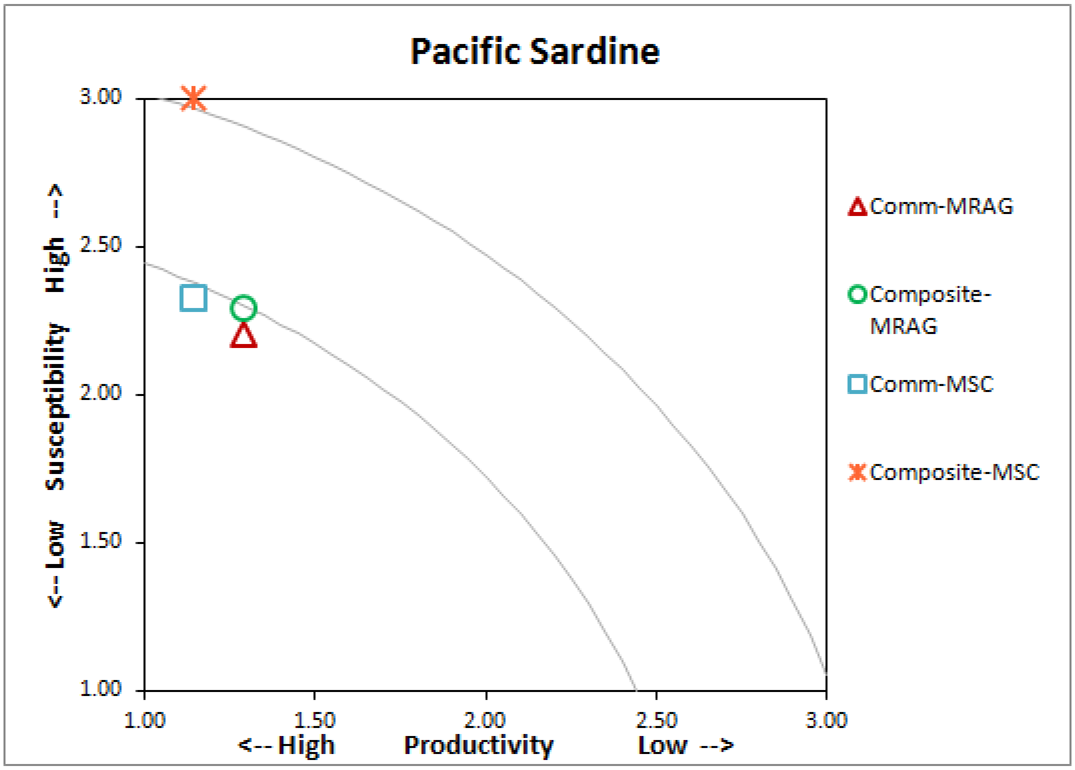

Figure 13: Pacific Sardine PSA Plot.

3.9 Pink Ocean Shrimp

The West Coast pink shrimp (*Pandalus jordani*) stock ranges from Unalaska to San Diego, California at depths of 36 to 457 m and is usually found over a green mud, or mixed mud and sand bottom. Populations of this species appear to be largely influenced by environmental conditions and less so by fishing pressure. There are large variations in seasonal abundance. Throughout the range, beds with commercial concentrations, in depths of about 100 to 200 m, support fisheries from Vancouver, British Columbia, Canada south to Point Arguello, California. Oregon, being the center of distribution, has historically yielded over 80% of US landings.

The stock in California is primarily managed through the following regulations: closure of various state and federal waters to trawling, use of bycatch reduction devices (BRDs), closed season, maximum count-per-pound, minimum mesh size, and incidental catch limits.

The importance of environmental factors on ocean shrimp recruitment and distribution suggests fishing pressure may have relatively less influence on stock status. Population surveys and mathematical models were used in the 1960's and 1970's, but no further attempts have been made to estimate abundance in California. However, annual landings have been exceptionally low since 2003.

Pink ocean shrimp have high productivity; however, the susceptibility attributes range from medium to high-risk given that commercial trawling is widespread over the species distribution, even if the gear appears to have low selectivity. As of 2007, the Oregon Pink (Ocean) Shrimp Trawl Fishery has been certified sustainable by the Marine Stewardship Council (MSC). Table 9 details the PSA scores, which are plotted in Figure 14.

Table 9: Pink (ocean) shrimp attribute risk scores.

Species: *Pandalus jordani* Fishery and gear: Commercial – Otter Trawl			Pink Ocean Shrimp				
			MRAG			MSC	
			Otter trawl	Stock wide		Otter trawl	Stock wide
Productivity	Age at maturity		low	low		low	low
	Size at maturity		low	low		low	low
	Maximum age		low	low		low	low
	Maximum size		low	low		low	low
	Fecundity		med	med		med	med
	Repro strategy		med	med		med	med
	Trophic level		low	low		low	low
Productivity Score			1.29	1.29		1.29	1.29
Susceptibility	Availability	Glob	high	high	Areal overlap	med	high
		Beha	med	med			
	Encounterability	Habit	high	high	Vertical overlap	high	high
		Bathy	med	med			
	Selectivity	Size a	low	low	Gear selectivity	low	low
		Max s	low	low			
		Desir	med	med			
	Post capture mortality		high	high	PCM	high	high
Susceptibility Score			2.33	2.33		1.43	1.65
Overall Risk Score			2.66	2.66		1.92	2.09
Risk Ranking			Med	Med		Low	Low
Stock Status			No stock assessment has been completed for the entire west coast. Population abundance is highly variable seasonally, difficult to estimate stock biomass.				
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact of fisheries in WA, OR and BC, CAN.							

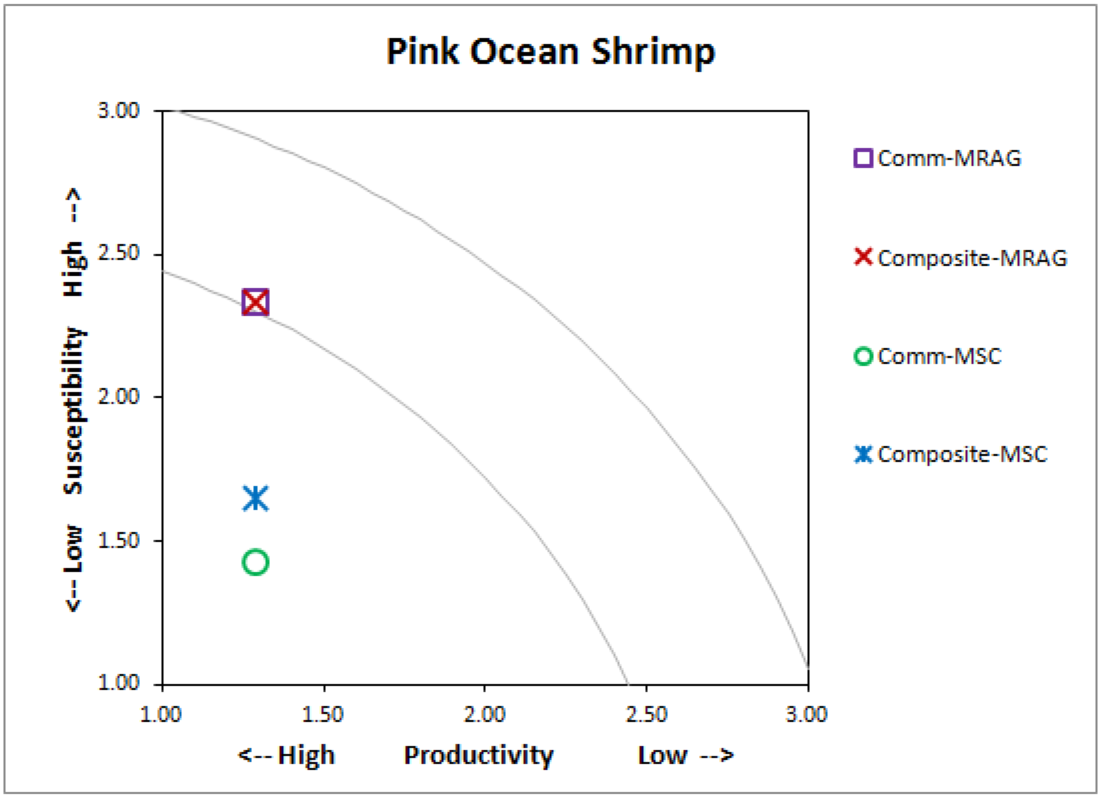

Figure 14: Pink (Ocean) Shrimp PSA Plot.

3.10 Sablefish

Sablefish (*Anoplopoma fimbria*) are a demersal species managed by the Pacific Fishery management Council under the West Coast Groundfish Individual Fishing Quota (IFQ) Program. Sablefish range from southern Baja California, Mexico to the northern stretches of the Bering Sea and Japan and are fished throughout their range. On the West Coast, the commercial fishery can utilize trawl, longline and trap gear to target sablefish, and in recent years some long-time trawl fishermen switched to fixed gear (especially traps) to harvest sablefish because of the higher market price for sablefish caught with fixed gear, compared to trawl-caught sablefish.

In addition to closely monitored individual quota allocations, the fishery is managed with limited entry, depth limits, gear restrictions and area closures. As of 2011, the relative spawning biomass for the West Coast sablefish stock was at 34% of unfished levels, suggesting that the stock is not overfished. However, the stock is in the precautionary level with biomass between the healthy level of 40% unfished biomass and of the overfished level of 25%. The West Coast limited entry groundfish trawl fishery is currently undergoing MSC assessment, which includes the IFQ sector. Table 10 details the PSA scores, which are plotted in Figure 15.

Table 10: Sablefish attribute risk scores.

Species: *Anoplopoma fimbria* **Fishery and gear:** Commercial – Trawl, Trap and Longline			Sablefish								
			MRAG					MSC			
			Trawl	Longline	Trap	Stock wide		Trawl	Longline	Trap	Stock wide
Productivity	Age at maturity		high	high	high	high		med	med	med	med
Productivity	Size at maturity		high	high	high	high		med	med	med	med
Productivity	Maximum age		high	high	high	high		high	high	high	high
Productivity	Maximum size		med	med	med	med		med	med	med	med
Productivity	Fecundity		low	low	low	low		low	low	low	low
Productivity	Repro strategy		low	low	low	low		low	low	low	low
Productivity	Trophic level		high	high	high	high		high	high	high	high
Productivity Score			2.29	2.29	2.29	2.29		2.00	2.00	2.00	2.00
Susceptibility	Availability	Glob Dist	med	med	med	med	Areal overlap	high	high	high	high
Susceptibility	Availability	Behavior	med	med	med	med					
Susceptibility	Encounterability	Habitat	high	high	high	high	Vertical overlap	high	high	high	high
Susceptibility	Encounterability	Bathymetry	med	med	med	med					
Susceptibility	Selectivity	Size at mat	high	high	high	high	Gear selectivity	high	high	high	high
Susceptibility	Selectivity	Max size	med	med	med	med					
Susceptibility	Selectivity	Desirability	med	high	med	high					
Susceptibility	Post capture mortality		high	high	high	high	PCM	high	high	high	high
Susceptibility Score			2.33	2.42	2.33	2.42		3.00	3.00	3.00	3.00
Overall Risk Score			3.27	3.33	3.27	3.33		3.61	3.61	3.61	3.61
Risk Ranking			High	High	High	High		High	High	High	High
Stock Status			The 2011 West Coast sablefish stock assessment indicates that the stock is in decline. Although not considered overfished, it is in the precautionary zone which causes more restrictive harvest levels to be implemented.								
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact of gears.											

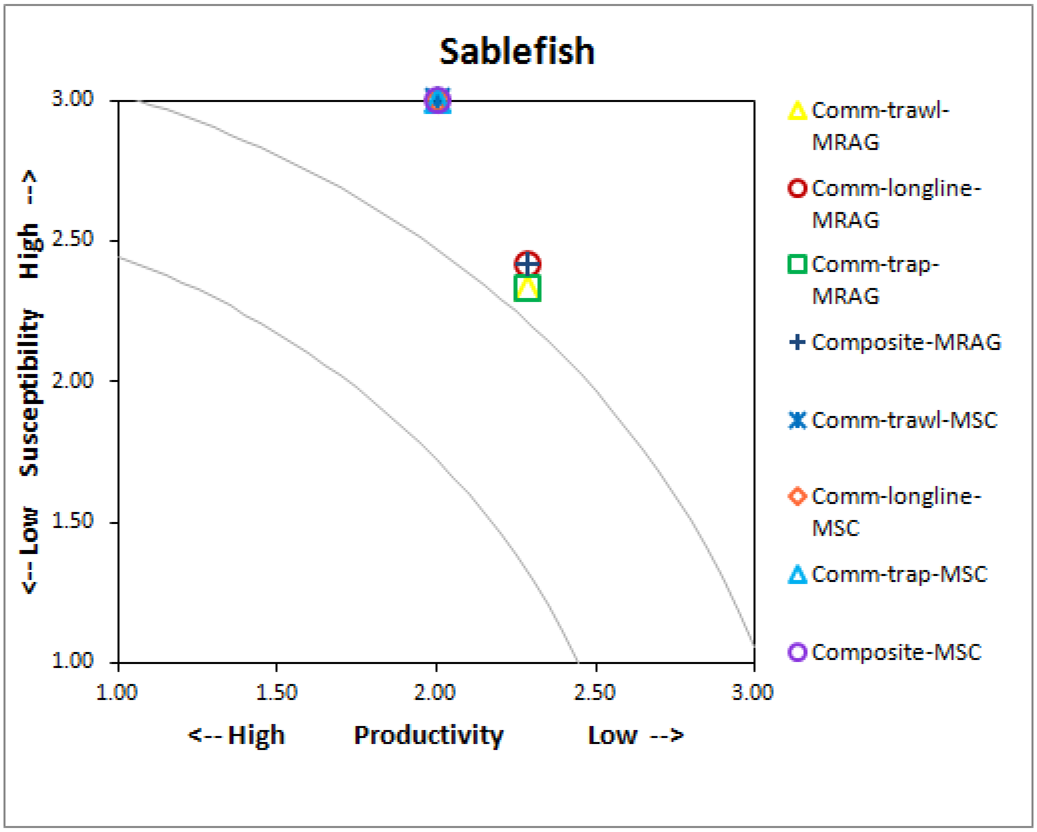

Figure 15: Sablefish PSA Plot.

3.11 Spiny Lobster

The California spiny lobster (*Panulirus interruptus*) is found along the west coast of California from Monterey to Bahía Magdalena, Baja California, Mexico, with a small isolated population in the northwest corner of the Gulf of California. The California fishery for spiny lobster takes place south of Point Conception, California to the California-Mexico border. It is managed by the Fish and Game Commission and the California Department of Fish and Wildlife via a limited access program (limit on number of permits issued), seasonal closure, and gear and size restrictions. A 2011 stock assessment indicates that the spiny lobster population off southern California is stable.

There are two fisheries, a commercial, and a recreational one, that represents approximately 34% of the total landings. Lobster traps are the main gear used in the commercial fishery. Recreational fishermen are allowed to catch lobster by hand when skin or scuba diving, or by using hoop nets.

In Mexico *Panulirus interruptus* is fished commercially in an area from the border with the US to Margarita Island. However, the main portion of the stock is between Cedros Island and Punta Abreojos. Most of this area is part of the Vizcaíno Biosphere Reserve. The fishery was certified as sustainable by the Marine Stewardship Council in April 2004 and completed reassessment in June 2011[16]. Imports from Mexico to the US are twice the California production. Table 11 details the PSA scores, which are plotted in Figure 16.

Table 11: Spiny lobster attribute risk scores.

Species: *Panulirus interruptus* **Fishery and gear:** Commercial – Trap			Spiny Lobster				
			MRAG			MSC	
			Trap	Stock wide		Trap	Stock wide
Productivity	Age at maturity		high	high		med	med
	Size at maturity		low	low		low	low
	Maximum age		med	med		med	med
	Maximum size		med	med		low	low
	Fecundity		low	low		low	low
	Repro strategy		med	med		med	med
	Trophic level		low	low		low	low
Productivity Score			1.71	1.71		1.43	1.43
Susceptibility	Availability	Glob Dist	high	high	Areal overlap	med	med
		Behavior	med	med			
	Encounterability	Habitat	high	high	Vertical overlap	high	high
		Bathymetry	high	high			
	Selectivity	Size at mat	low	low	Gear selectivity	high	high
		Max size	med	med			
		Desirability	high	high			
	Post capture mortality		high	high	PCM	high	high
Susceptibility Score			2.63	2.63		2.33	2.33
Overall Risk Score			3.14	3.14		2.73	2.73
Risk Ranking			Med	Med		Med	Med
Stock Status			Based on the 2011 stock assessment, the spiny lobster population off southern California appears to be stable with a large and robust sub-legal population. Harvest rates have been stable.				
Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and impact of the recreational and commercial US and MX fisheries.							

[16] Chet Chaffee (March 21, 2004). "An MSC Assessment of the Red Rock Lobster Fishery, Baja California, Mexico" (PDF). Marine Stewardship Council. http://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific/mexico-baja-california-red-rock-lobster/assessment-downloads-1/Final_Report_Red_Rock_Lobster_21March04.pdf

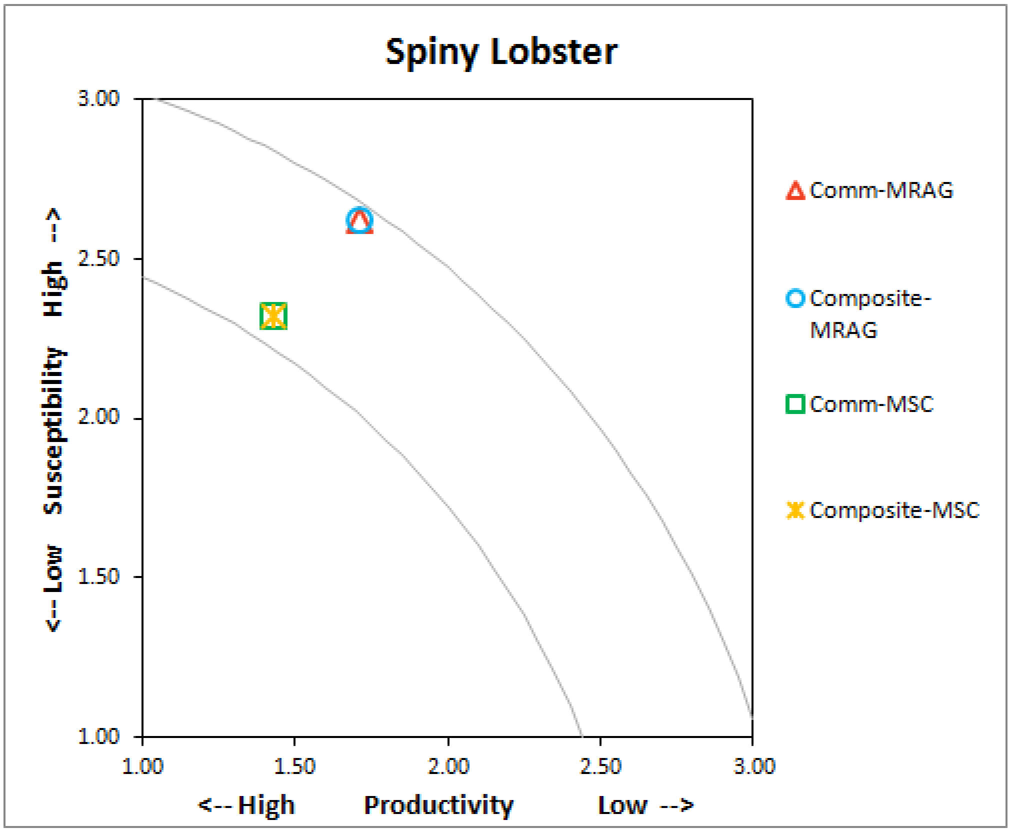

Figure 16: Spiny Lobster PSA Plot.

3.12 Swordfish

Swordfish (*Xiphias gladius*) are a highly migratory species with a wide distribution. The fishery in California uses harpoon, gillnet and longline gears; harpoon is the most selective but smallest component of the overall commercial fishery. Harpoon gear was the primary focus of the PSA, the analysis also considered the impacts of the total fishery on the vulnerability of the stock. In 2012, only nine vessels participated in the harpoon fishery, declining from recent years. Fishing effort was concentrated in coastal waters off San Diego and in the Southern California Bight; only 158 swordfish were landed in 2010 by harpoon.

In the US swordfish are managed by the Pacific Fishery Management Council's Highly Migratory Species Fishery Management Plan (HMS FMP), which uses data from international stock assessments to inform management decisions. The PFMC employs gear, permit, season, and area restrictions. Catch of swordfish by US West Coast fisheries constitutes about 5.8 percent of the Eastern Pacific-wide catch. Stocks are considered healthy and above the biomass level that would produce maximum sustainable yield. Table 12 details the PSA scores, which are plotted in Figure 17.

Table 12: Swordfish attribute risk scores.

<table>
<tr><td colspan="3" rowspan="3">**Species:** *Xiphias gladius*
Fishery and gear:
Commercial – Harpoon</td><td colspan="5">**Swordfish**</td></tr>
<tr><td colspan="2">**MRAG**</td><td rowspan="2"></td><td colspan="2">**MSC**</td></tr>
<tr><td>Harpoon</td><td>Stock wide</td><td>Harpoon</td><td>Stock wide</td></tr>
<tr><td rowspan="7">Productivity</td><td colspan="2">Age at maturity</td><td>high</td><td>high</td><td rowspan="8"></td><td>low</td><td>low</td></tr>
<tr><td colspan="2">Size at maturity</td><td>high</td><td>high</td><td>high</td><td>high</td></tr>
<tr><td colspan="2">Maximum age</td><td>med</td><td>med</td><td>med</td><td>med</td></tr>
<tr><td colspan="2">Maximum size</td><td>high</td><td>high</td><td>high</td><td>high</td></tr>
<tr><td colspan="2">Fecundity</td><td>low</td><td>low</td><td>low</td><td>low</td></tr>
<tr><td colspan="2">Repro strategy</td><td>low</td><td>low</td><td>low</td><td>low</td></tr>
<tr><td colspan="2">Trophic level</td><td>high</td><td>high</td><td>high</td><td>high</td></tr>
<tr><td colspan="3">Productivity Score</td><td>2.29</td><td>2.29</td><td>2.00</td><td>2.00</td></tr>
<tr><td rowspan="8">Susceptibility</td><td rowspan="2">Availability</td><td>Glob Dist</td><td>low</td><td>low</td><td rowspan="2">Areal overlap</td><td rowspan="2">low</td><td rowspan="2">low</td></tr>
<tr><td>Behavior</td><td>med</td><td>med</td></tr>
<tr><td rowspan="2">Encounterability</td><td>Habitat</td><td>low</td><td>low</td><td rowspan="2">Vertical overlap</td><td rowspan="2">med</td><td rowspan="2">high</td></tr>
<tr><td>Bathymetry</td><td>high</td><td>high</td></tr>
<tr><td rowspan="3">Selectivity</td><td>Size at mat</td><td>high</td><td>high</td><td rowspan="3">Gear selectivity</td><td rowspan="3">med</td><td rowspan="3">high</td></tr>
<tr><td>Max size</td><td>high</td><td>high</td></tr>
<tr><td>Desirability</td><td>med</td><td>med</td></tr>
<tr><td colspan="2">Post capture mortality</td><td>high</td><td>high</td><td>PCM</td><td>high</td><td>high</td></tr>
<tr><td colspan="3">Susceptibility Score</td><td>2.21</td><td>2.21</td><td rowspan="3"></td><td>2.18</td><td>1.65</td></tr>
<tr><td colspan="3">Overall Risk Score</td><td>3.18</td><td>3.18</td><td>2.37</td><td>2.59</td></tr>
<tr><td colspan="3">Risk Ranking</td><td>Med</td><td>med</td><td>Low</td><td>Low</td></tr>
<tr><td colspan="3">Stock Status</td><td colspan="5">Stocks of Western and Central N Pacific and Eastern N Pacific are considered healthy and above the level required to sustain recent catches. Biomass is above B_{MSY}.</td></tr>
<tr><td colspan="8">Note: Status from OST 2013. Composite (stock wide) considers stock wide distribution and collective impact of fisheries in the North Pacific using harpoon, gillnet anf longline gears.</td></tr>
</table>

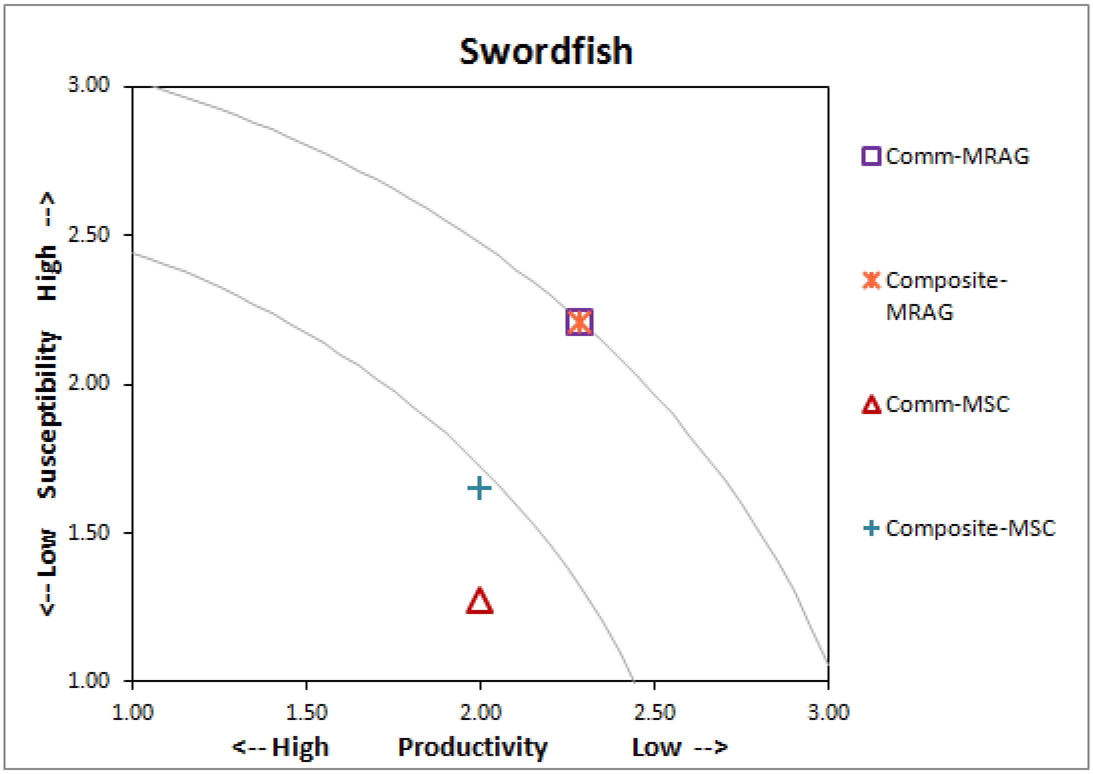

Figure 17: Swordfish PSA Plot.

3.13 Red and Purple Urchins

The red and purple sea urchins range from Alaska to Baja California, inhabiting depths of up to 150 meters. The commercial fishery for the red sea urchin has been very valuable in California for more than a decade, and caters largely to the Japanese export market. The gonads of both male and female urchins are the object of the fishery and are referred to as "roe", or "uni" in Japanese. Sea urchins are collected by divers operating in near shore waters. Divers are size-selective, and check gonad quality while fishing to ensure marketability. The price paid to fishermen for gonads is based on quality.

In the last few years, the red urchin fishery has become fully exploited throughout its range in northern and southern California. Because of predation by sea otters, sea urchin stocks in central California occur at densities too low to sustain a commercial fishery. The purple sea urchin, which occurs over a similar geographical range as the red sea urchin, is also harvested in California on a limited basis; the fishery for purple urchin is also smaller because this species is smaller, yields less roe, requires more effort to harvest and process than red sea urchins, and has a lower value in the Japanese market. Larval production and settlement rates indicate that the status of the purple sea urchin appears to be stable.

The general biology of red and purple sea urchin is very similar, with similar habitats, reproduction, and feeding habits. The major difference is that that purple urchins are much smaller, rarely attaining a body or "test" diameter of over 10 centimeters, while red sea urchins can be greater than 20 centimeters in diameter. An important life-history trait is the longevity of both species, with red urchins living up to 200 years and purple urchins up to 70 years. This productivity attribute can increase the risk significantly. In addition, both species are hand-captured by divers at depths below 100 feet, which increases their susceptibility and vulnerability, as the encounter rates and selectivity are high. Table 13 details the PSA scores, which are plotted in Figure 18.

Table 13: Red and Purple sea urchin attribute risk scores.

Species: Red (*Strongylocentrotus franciscanus*); Purple (*Strongylocentrotus purpuratus*) **Fishery and gear:** Commercial – Hand collected			**Red Urchin**		**Purple Urchin**			**Red Urchin**		**Purple Urchin**	
			MRAG					**MSC**			
			Hand	Stock wide	Hand	Stock wide		Hand	Stock wide	Hand	Stock wide
Productivity	Age at maturity		med	med	med	med		low	low	low	low
	Size at maturity		low	low	low	low		low	low	low	low
	Maximum age		high	high	high	high		high	high	high	high
	Maximum size		low	low	low	low		low	low	low	low
	Fecundity		low	low	low	low		low	low	low	low
	Repro strategy		low	low	low	low		low	low	low	low
	Trophic level		low	low	low	low		low	low	low	low
Productivity Score			1.43	1.43	1.43	1.43		1.29	1.29	1.29	1.29
Susceptibility	Availability	Glob Dist	high	high	high	high	Areal overlap	high	high	low	low
		Behavior	high	high	high	high					
	Encounterability	Habitat	high	high	high	high	Vertical overlap	high	high	high	high
		Bathymetry	high	high	high	high					
	Selectivity	Size at mat	low	low	low	low	Gear selectivity	high	high	high	high
		Max size	low	low	low	low					
		Desirability	med	med	med	med					
	Post capture mortality		high	high	high	high	PCM	high	high	high	high
Susceptibility Score			2.58	2.58	2.58	2.58		3.00	3.00	1.65	1.65
Overall Risk Score			2.95	2.95	2.95	2.95		3.26	3.26	2.09	2.09
Risk Ranking			Med	Med	Med	Med		High	High	Low	Low
Stock Status			In southern CA, harvestable stocks of red sea urchin have been in decline since 1990. Larval production and settlement patterns in Purple sea urchin indicates stable status for the species.								
Note: Status from CA-DFW, 2003. Composite (stock wide) considers stock wide distribution and fishey impact over its range.											

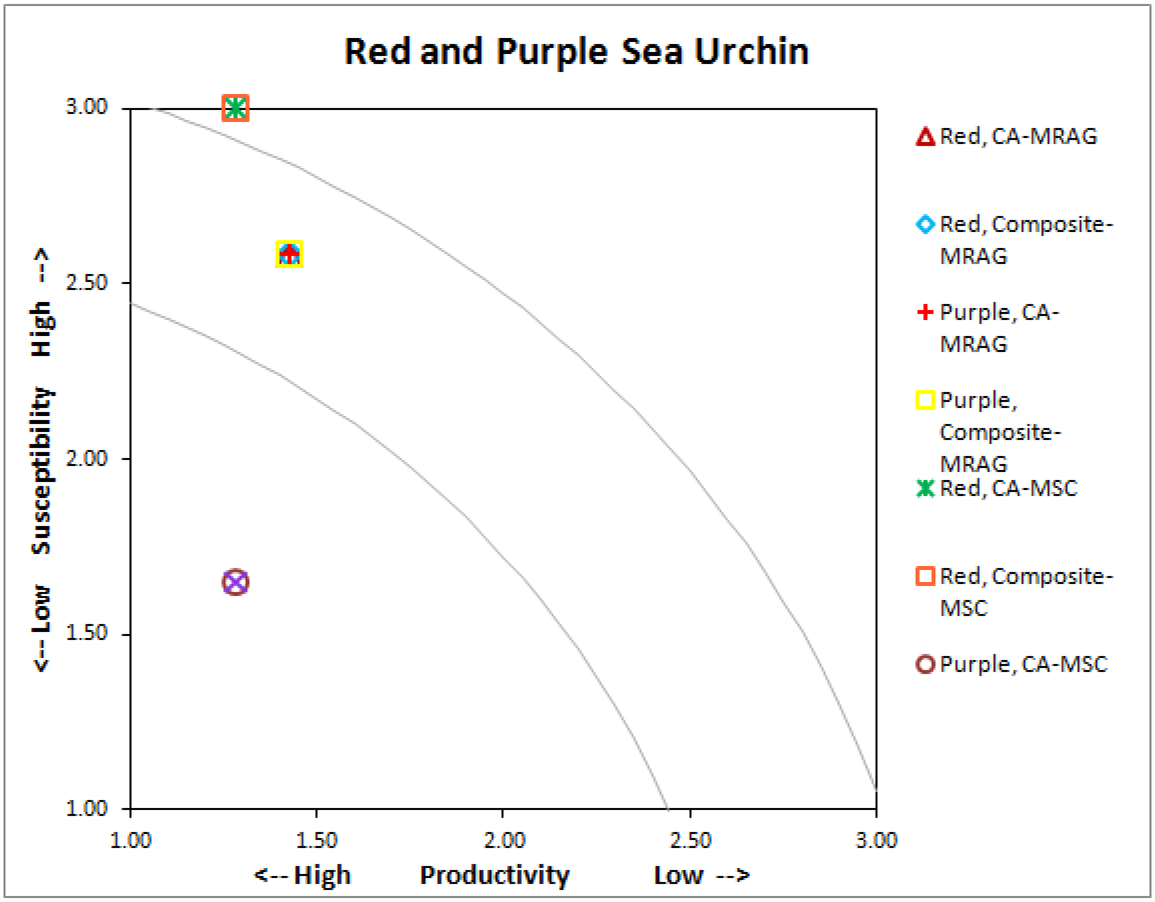

Figure 18: Red and Purple Sea Urchin PSA Plot.

4 Next Steps and Recommendations

4.1 Utilization of PSA Results

The development of PSA, as part of the Australian Environmental Risk Assessment for the Effects of Fishing (ERAEF)[17], allowed scientists, managers, and stakeholders to quickly and efficiently filter fisheries into those that had minimal environmental risks, and those with risk high enough to warrant a more detailed look. 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 results of the PSA measure risk from direct impacts of fishing only.

In an era of reduced funding for fishery management and environmental review, sorting the highest risk fisheries offers an opportunity to expend limited funds on the highest needs. This sorting of fisheries by risk remains one of the highest uses of PSA. PSA provides a tool for rapidly assessing the vulnerability of a stock prior to status determinations or management actions. For a very limited expenditure, an array of fisheries can be sorted by risk, and managers can use the results for allocating science and management funds to better understand management needs and make management improvements

[17] Hobday *et al*. 2007

necessary to improve sustainability of fisheries. 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.

In many cases, fisheries identified as high risk by PSA may already have comprehensive management that keeps harvests at sustainable levels; conversely, fisheries identified as low risk may have peculiar features that put stress on stocks. Therefore, conducting follow up reviews by knowledgeable persons is critical for ground-truthing the situation.

Although PSA primarily serves as filtering mechanism to assess potential risk, and alone cannot identify management deficiencies, PSA can provide insights in combination with other information for developing precautionary management measures. The terms of reference that guided the MRAG PSA activities (MRAG 2009a, b)[18] also identified the value of PSA in management of data deficient fisheries. Section 104 (a)(15) of the 2007 MSA reauthorization 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.” Magnuson-Stevens Act National Guideline 1 required that NMFS set overfishing levels (OFLs), annual catch limits (ACLs), annual catch targets (ACTs), and accountability measures (AMs) for federally managed species, such that ***OFL > ACL ≥ ACT***. Rosenberg *et al*. (2007)[19] proposed a precautionary procedure for setting ACLs based on requirements of the MSA, using uncertainty, risk of overfishing, and vulnerability of stocks to set buffers between the OFL and ACL or ACT. Designed to increase the probability that overfishing doesn’t occur and that rebuilding proceeds as needed, the buffers are designed to determine how far the ACL should be set below the OFL to account for the various sources of scientific and management uncertainty. As scientific and management uncertainty increases, the precautionary approach requires setting larger buffers. The risk level determined through PSA offers a mechanism for setting buffers: each PSA risk level could have an associated proportional increase in buffer.

Currently in several US Regional Fishery Management Councils, species are combined into management groups with one or more indicator species. Rosenberg *et al.* (2007) point out that species from the same or similar families may have quite different vulnerabilities. A large difference in vulnerability of any species from the indicator could have serious management consequences, leading to potential overharvest if the risk is underestimated or overly severe restrictions if the vulnerability is overestimated. While considering species individually for management action is the preferred course, grouping species by vulnerability through PSA rather than taxonomically could lead to a more precise group with the most appropriate indicator species.

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[18] MRAG Americas. 2009a, 2009b.

[19] 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.

The MSC (2013) further suggests that susceptibility scores can provide the basis for management actions to reduce risk from fishing. If a PSA shows a fishery has high susceptibility scores, for example through a high areal or vertical overlap with the stock, increased precaution could result from actions that reduce the overlap. Such actions as closed areas (to reduce areal overlap), or gear modifications or temporal closures (to reduce the vertical overlap) would reduce the susceptibility scores. Of course, these actions do not occur in a vacuum and may have unintended consequences for other species or fisheries. But it is clear that reducing susceptibility scores will reduce risk. The other part of PSA, productivity, is inherent to the fisheries, and fishing practices cannot change the scores of the attributes. However, in cases where productivity scores are defaulted to high risk because of insufficient information, research to fill the gap could reveal that the risks are lower.

4.2 Next Steps

The determination of PSA for all California species would provide an opportunity for a comprehensive risk assessment and subsequent sorting of fisheries by risk categories. This could lead to proactive decisions for deferring management measures for some fisheries, selecting others for more management scrutiny, or increasing research needed for effective management of others. In many jurisdictions, inaction occurs from lack of decision rather than through conscious decision. Once sorting by PSA occurs, further sorting could occur to rationally decide not to implement further action for a subset of (low risk) fisheries, to apply data deficient methods to another subset, to start targeted research for others, and to continue current management for yet others. This could lead to a long range plan based on risk and projections of budgets.

We envision that the PSA work would take place through a working group or workshop. The limited time for gathering data for the preliminary PSA results reported in this report likely led to use of incomplete data. A working group or workshop consisting of experts on the biology and fisheries of the species would have the best available information for populating the PSA spreadsheets, leading to the most accurate results. Consensus strengthens the conclusions. The working group could also supplement the PSA results with additional fishery specific information, such as incorporating the status of the stocks into the risk evaluations, using (where known) such information as whether overfished and overfishing occurring. During the completion of the PSA results for each fishery, the MRAG team had numerous conversations on the interpretations of the information leading to scores; this illustrates that to obtain scoring consistency, the analysts must have experience with using the PSA. In particular, it is necessary to have expert discussions on the productivity and susceptibility attributes and changes with the development of each fishery, as this information was not always readily available to the MRAG analysts. We suggest that a facilitator experienced with PSA assist any work group or workshop in the interpretation of data and the determination of scores.

The PSA calculations for various fisheries were conducted at the sector level, to avoid masking vulnerability factors for particular fisheries. In some cases, the stock of a fishery occurred only in California, and in other cases the California segment of the fisheries represented only a small portion of the stock as a whole. This detailed breakout provides policy makers and managers an opportunity to decide where California management action can have the biggest benefit, and what types of management action are most appropriate. The management measures take on different importance whether placed on a stock completely under California control or a small portion of the stock for which exploitation occurs primarily elsewhere. California policy makers and managers can use this information to make decisions most appropriate for the State.

4.3 Data Deficient Methods

Once sorting of fisheries with PSA results has occurred, some will likely be categorized as needing management but not having sufficient information. In these cases, data deficient methodologies may be appropriate; experts charged with applying the methods must determine which of the methods best fits the fisheries in question. We have identified four methods, which are summarized below. NOAA Fisheries has developed an online toolbox to provide a suite of biological modeling software programs that can be used in fisheries stock assessments (http://nft.nefsc.noaa.gov/index.html), and most of the methods come from the NMFS toolbox. In general, the main biological processes for the majority of the species analyzed in this report have been studied. This includes growth, longevity, reproduction and survival either in California or in the general distribution of each species, or for closely related species. It is likely that most of these models could be applied, with the appropriate growth parameters, size of full recruitment into the fishery, and average length (size) of the captured species over a few years, and catch data.

Recent work by Caruthers *et al.* (2012[20] and 2014[21]) identifies the need for extensive testing of data limited methods. In the former paper, the authors evaluated the reliability of two commonly used catch-based stock assessment methods: the surplus production and delay-difference models. These methods are used to classify stock status with only fisheries catch data available. The findings suggest that the methods could not be reliably used to assess the status of exploited fish stocks.

The 2014 paper expanded the analysis to evaluate methods currently in use in US fishery management plans, alternative methods described in literature and other methods for use in setting catch limits in data-limited fisheries. The analysis revealed that only those methods that dynamically accounted for changes in abundance and/or depletion performed well at low stock sizes. Close review of this research or undertaking similar studies to examine the application and performance of potential methods against California fisheries stocks would be a useful coupling with PSA analyses.

[20] Carruthers, T. R., C. J. Walters, & M.K. McAllister. 2012. Evaluating methods that classify fisheries stock status using only fisheries catch data. Fisheries Research, 119, 66-79.

[21] Carruthers, T. R., A.E. Punt, C.J. Walters, A. MacCall, M.K. McAllister, E.J. Dick, & J. Cope. 2014. Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research, 153, 48-68. Available online: http://swfsc.noaa.gov/publications/FED/01286.pdf

4.3.1 *Depletion-Corrected Average Catch (DCAC)[22] and Depletion-based Stock Reduction Analysis (DB-SRA)*

Among the models offered in the NMFS toolbox is the **Depletion-Corrected Average Catch** (DCAC) method for estimating sustainable yields for data-poor fisheries on long-lived species. Based on the idea that the average catch has been sustainable if abundance has not changed, DCAC makes a correction to that average if abundance has increased or decreased. The magnitude of the correction depends on the approximate natural mortality rate. Uncertainty is recognized in all of the parameters in the model, and is reflected in the output probability distribution.

Given the difficulty in estimating MSY, data-poor fishery analysis may only be able to estimate a yield that is likely to be sustainable. Here, the problem is to identify a moderately high yield that is sustainable, while having a low chance that the estimated yield level greatly exceeds MSY. DCAC is a simple method for estimating sustainable catch levels when the data available are a little more than a time series of catch. The method needs extensive testing.

Input information includes the sum of catches and associated number of years (ideally 10 years or more), the relative reduction in biomass during that period, the natural mortality rate (M, which should be <0.2 $year^{-1}$ to apply this model), and the assumed ratio of F_{MSY} to M. These input values are expected to be approximate, and their uncertainty can be integrated by Monte Carlo exploration of DCAC values. Simple methods to estimate input parameters are provided in the DCAC methodology, such as approximation of M with Pauly's (1980)[23] and Hoenig's (1983)[24] methods, and the ratio between F_{MSY} and M with Restrepo *et al.* (1998)[25] method. DCAC outputs include point estimates of the different parameters and a frequency distribution of sustainable yield (MacCall 2009)[26].

This method is most useful for species with low natural mortality rates; stocks with low mortality rates tend to pose the most serious difficulties in rebuilding from an overfished condition. The relationship between F_{MSY} and M may vary among taxonomic groups of fishes and among geographic regions, and an evaluation of the relationship would be a good candidate for meta-analysis. Uncertainty in parameter values can be represented by probability distributions. A Monte Carlo sampling system such as WinBUGS can easily estimate the output probability distribution resulting from specified distributions of the inputs.

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[22] NOAA Fisheries Toolbox: Depleted Corrected Average Catch (DCAC), Version 2.1.1, October 2012. Available online: http://nft.nefsc.noaa.gov/DCAC.html

[23] Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(2):175-192

[24] Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. CIEM 39(2):175-192

[25] Restrepo, V.R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade and J. F. Witzig. 1998. Technical Guidance on the Use of Precautionary Approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum. Available online: http://www.nmfs.noaa.gov/sfa/NSGtkgd.pdf

[26] MacCall, A. D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. – ICES Journal of Marine Science, 66: 000–000.

This approach has been updated to a more robust method, the **Depletion-based Stock Reduction Analysis** (DB-SRA)[27]. DB-SRA combines DCAC with a probability analysis to more closely link stock production with biomass and evaluate potential changes in abundance over time. The method uses estimates of historical annual catches, approximate natural mortality rate and age at maturity for determining reasonable yield and management reference points for data-poor fisheries in cases where approximate catches are known from the beginning of exploitation. In the DB-SRA, a production function is specified based on general fishery knowledge of the relative location of maximum productivity and the relationship of MSY fishing rate to the natural mortality rate. The probability analysis added here increases the reliability and decreases uncertainties associated with historical biomass estimates generated from DCAC.

In 2010, the DB-SRA and DCAC methods were used to update overfishing limit (OFL) distributions and estimate sustainable yields for unassessed stocks in the Pacific Coast Groundfish FMP. DB-SRA was used for 42 of the 50 unassessed stocks, the remaining 8 stocks were not accessible to DB-SRA and the DCAC method was employed. The results provided the basis for setting ACLs for 50 data-poor stocks; the approach was recommended by the Council's Statistical and Scientific Committee and the results adopted by the Council in April 2010 as part of the basis for OFLs in the 2011-2012 harvest specification process.[28]

4.3.2 Survival Estimation in Non-Equilibrium situations (SEINE)[29]

The Survival Estimates in Non-Equilibrium situations (SEINE) model calculates mortality rates from changes in the mean lengths. The model is a variant of the equilibrium Beverton and Holt (1956, 1957)[30] annual mortality estimator. Gedamke and Hoenig (2006)[31] developed the SEINE model for application in non-equilibrium conditions and to allow the mortality rate to change over time, where the observed mean length reflects the mortality rate at any given time.

The data requirements are: von Bertalanffy parameters, the length at full vulnerability, and a series of annual observations of mean length over time. The model estimates mortality rates and the years in which they changed.

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[27] Dick, E. J., & A.D. MacCall. 2011. Depletion-based stock reduction analysis: a catch-based method for determining sustainable yields for data-poor fish stocks. Fisheries Research, 110(2), 331-341.

[28] Dick, E. J., & A.D. MacCall. 2010. Estimates of Sustainable Yield for 50 Data-Poor Stocks in the Pacific Coast Groundfish Fishery Management Plan. NOAA-TM-NMFS-SWFSC-460. June 2010. Available online: http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-460.pdf

[29] NOAA Fisheries Toolbox: Survival Estimation in Non-Equilibrium situations (SEINE), Version 1.3, September 2008. Available online: http://nft.nefsc.noaa.gov/SEINE.html

[30] Beverton, R. J. H., and S. J. Holt. 1956. A review of methods for estimating mortality rates in fish populations, with special reference to sources of bias in catch sampling. Rapports et Proce`s-verbaux des Re´unions, Conseil International pour l'Exploration de la Mer 140:67–83. *AND* Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigations Series II, Marine Fisheries, Great Britain Ministry of Agriculture, Fisheries and Food 19.

[31] Gedamke, T., and J. M. Hoenig. 2006. Estimating mortality from mean length data in nonequilibrium situations, with application to the assessment of goosefish. Transactions of the American Fisheries Society 135:476–487. Available online: http://www.sefsc.noaa.gov/sedar/download/S14RD27%20Gedamke_HoenigTrans%20Z%20.pdf?id=DOCUMENT

4.3.3 *Productivity-Susceptibility Analysis (PSA) (NMFS)*[32]

The NOAA version of the PSA (for relevant papers see Patrick *et al*. 2010[33] and Cope *et al*. 2011[34]), as the other versions (MSC, MRAG) discussed in this report is a semi-quantitative and rapid risk assessment tool that relies on the life history characteristics of a stock and its susceptibility to a fishery. Similar to the other methods, the productivity and susceptibility of a stock are determined by providing a score ranging from 1 (low) to 3 (high) for a set of attributes related to each index (productivity = 10; susceptibility = 12). In this version the analyst can also assess the data quality associated with each attribute score, and customize the analysis by weighting these attributes. As with other PSAs, stocks with low productivity and high susceptibility are considered to be at a high risk of becoming depleted, while stocks with high productivity and low susceptibility scores are considered to be at low risk of becoming depleted.

The NOAA PSA methodology[35] contains several modifications to previously published examples, including: (1) expanding the number of attributes scored from 13 to 22 to consider both direct and indirect impacts; (2) redefining the attribute scoring bins to align with life history characteristics of fish species found in US waters; (3) developing an attribute weighting system that allows users to customize the analysis for a particular fishery; (4) developing a data quality index based on five tiers of data quality, ranging from best data to no data, to provide an estimate of information uncertainty; and (5) developing a protocol for addressing stocks captured by different sectors of a fishery (e.g., different gear types, different regions)[36].

The current version can assess the vulnerability of US fish stocks from becoming overfished ($B_{CURRENT} < ½B_{MSY}$) or undergoing overfishing ($F_{CURRENT} > F_{MSY}$), with an emphasis on assessing data-poor stocks. Where, vulnerability has been identified by NOAA-Fisheries as a useful measure for: (1) identifying stocks that should be managed and protected under a fishery management plan, (2) grouping data-poor stocks into relevant management complexes, and (3) developing precautionary harvest control rules. In addition, scoring of the data quality used to define vulnerability may help in determining species of interest for further data collection and particular data gaps across species.

The Terms of Reference for this report did not include use of the NOAA PSA.

4.3.4 *Length-based SPR*

A new form of size-based stock assessment uses information about well-studied species for the assessment of poorly studied species. This opens up the way for most poorly studied species to be assessed on the basis of just the two simplest studies already required by stock assessment; size of

[32] NOAA Fisheries Toolbox: Productivity and Susceptibility Analysis (PSA), Version 1.4, March 2010. Available online: http://nft.nefsc.noaa.gov/PSA.html

[33] Patrick, W.S., P. Spencer, J. Link, J. Cope, J.Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortés, O. Ormseth, K. Bigelow & W. Overholtz. 2010. Fishery Bulletin, 108(3).

[34] Cope, J. M., J. DeVore, E.J. Dick, K. Ames, J. Budrick, D.L. Erickson, J. Grebel, G. Hanshew, R. Jones, L. Mattes, C. Niles & S. Williams. 2011. An approach to defining stock complexes for US West Coast groundfishes using vulnerabilities and ecological distributions. North American Journal of Fisheries Management, 31(4), 589-604

[35] See: Patrick *et al.* 2010 and Cope *et al.* 2011.

[36] http://spo.nmfs.noaa.gov/tm/TM101.pdf

maturity and adult size composition. The simplicity of the new approach and its use of size data will make it possible for industry organizations to start taking responsibility for their own data collection and assessment processes. This could empower industry to buy in to a collaborative role with government in stock assessment and in seeking cost savings. The David & Lucille Packard Foundation has provided funding the via the Marine Stewardship Council (MSC) to complete the development, establish the scientific basis, and begin implementation trials, with the ultimate aim of establishing a new global standard for certifying data-poor fisheries for MSC. Tests of the methodology are underway at the MSC and showing promising preliminary results (Nicolas Gutierrez, MSC, pers. com.)

The assessment methodology developed analytical models for the relationship between M/k and the von Bertalanffy growth curve, and demonstrated the link between the life history ratios and yield- and spawning-per-recruit. It further developed the previously recognized relationship between M/k and yield- and spawning-per-recruit by using information on L_m/L_∞, knife-edge selectivity (L_c/L_∞), and the ratio of fishing to natural mortality (F/M), to demonstrate the link between an exploited stock's expected length composition, and its spawning potential ratio (SPR), an internationally recognized measurement of stock status. Variation in length-at-age and logistic selectivity patterns were incorporated in the model to demonstrate how SPR can be calculated from the observed size composition of the catch.

The SPR-Length assessment extends an old principal of fisheries call Life History Invariants, which recognizes that two ratios; the rate of natural mortality (M) divided by the rate of growth (*k)*, and the size of maturity (L_m) and average maximum size (L_∞), are predictably correlated across species, size ranges and life-spans. Stock assessors already use these principals to specify stock assessment for species in which the basic biology has not been studied.

These two ratios also predict the size composition of unfished populations. This is valuable information because it gives a base-line against which current size composition can be compared. Previously that information had to come from studies done before, or around the beginning of the fishery. This method opens up the way to a new way of assessing fish stocks, based on the size composition of the adult part of the stock, which we have taken advantage of to develop new assessment software. This new form of assessment can be applied flexibility to estimate rates of spawning in a stock, as well as an index of fishing pressure, both of which can be used within harvest strategies to estimate the adjustments needed to manage a stock to agreed management targets.

A broad analysis of the international literature that shows these two ratios vary predictably across groups of the species and so can be predicted for an unstudied species by its relationship to well-studied species. For many species, which have not been studied, these ratios can be predicted precisely enough from the literature on related studied species to let us apply our size-based assessment.

5 Appendix A: PSA Cut-off Tables

5.1 MRAG Cut-off Scores

Table 14: MRAG Productivity scores.

MRAG Method: PRODUCTIVITY SCORES			
Adjusted scoring bins in working group according to stocks in US fisheries			
	Low productivity (high risk, 3)	Medium productivity (moderate risk, 2)	High productivity (Low risk, 1)
Average age at maturity	> 4 years	2-4 years	<2 years
Average maximum age	>30 years	10-30 years	<10 years
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

For the MRAG susceptibility analysis, each susceptibility aspect (Availability, Encounterability, Selectivity, and Post Capture Mortality) score is calculated as averages of composite attributes and the overall susceptibility score is additive of the aspects. The breakdown of the aspects and their composite attributes are provided in Table 15; cut-off scores are provided in Table 16, Table 17, Table 18 and Table 19. The attributes of average size at maturity and maximum size, within the Selectivity aspect, use their productivity scores.

Table 15: MRAG Susceptibility attributes.

	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

Table 16: MRAG Selectivity scores.

MRAG Method: SELECTIVITY				
Includes Productivity measures of Average Size at Maturity and Average Max Age				
		Low (1)	Moderate (2)	High (3)
Commercial	$/lb	< $1.00	$1.00 - $2.25	> $2.25
	Annual Landings Value	< $500,000	$500,000 - $10,000,000	> $10,000,000
Recreational	% Retention	<33%	34-66%	>66%

Table 17: MRAG Availability scores.

MRAG Method: AVAILABILITY			
Distribution			
Global distribution	**Description**	**Risk Category**	**Risk Score**
Worldwide	both hemispheres	L	1
US Waters	single hemisphere	M	2
Regional	isolated, regional distribution	H	3

Stock Structure Proxy: Special Behavioral Characteristics

Stock likelihood scores and rationale types for reviewing availability risk scores for species without detailed distributional maps. Examples are in italic.

Rationale: Type of barrier to dispersal	Score = Low risk (L) (low chance of local stocks)	Score = Medium risk (M) (medium chance of local stocks)	Score = High risk (H) (high risk of local stocks)
Rationale 1. Geographic barriers	**1L**	**1M**	**1H**
	Deepsea, >650 m: Semi-global water mass - Some depth barriers, too shallow:	*Pelagic and upper slope: Depth and water temperature barriers -mode water.*	*Restricted to estuaries and or embayments on the shelf: Combination of lat, long, depth, coastal, water temperature barriers*
Rational 2. Temporal barriers	**2L**	**2M**	**2H**
	No seasonal peaks in feeding, mating, spawning.	*Some seasonal peaks but breeding not restricted to a particular season. E.g. batch spawning teleosts, some dogfishes*	*Species forms breeding colonies or breeding aggregations. Fishing is permitted at or near breeding or feeding aggregations*
Rationale 3. Ecological barriers (habitat requirements or feeding)	**3L**	**3M**	**3H**
	Occupiable habitat is dispersed through a species range. E.g. pelagics	*Bycatch species has a preference for a particular type of habitat but habitat occurs across 50% or the range of a fishery. Habitat is different to the habitat of the target species and therefore not targeted*	*Site fidelity: Occupiable habitat is restricted by food availability or bottom topography (reefs, canyons etc). Fishing occurs near restricted habitat*
Rationale 4. Behavioral barriers	**4L**	**4M**	**4H**
	No behavior. E.g. algae	*No social behaviour e.g. sunfish*	*Schooling: Fish/sealion returns to birth place to spawn. Birds remain near rookery to rear chicks. Migrating populations targeted by fishing activity; gonochoristic hermaphrodites*
Rationale 5. Life history barriers	**5L**	**5M**	**5H**
	Adult highly migratory, larvae pelagic and dispersed easily, spawning and feeding are dispersed in space and time.	*Few restrictions to dispersal. E.g. Adult fish species is dispersed through the worlds oceans, female has one million eggs, larvae pelagic, but adults only spawn in the Sargasso Sea; utilize inshore nursary grounds*	*Species can not complete its life history. e.g. salmon returns to spawn in the estuary where it hatched. River mouth is fished annually*

Table 18: MRAG Encounterability scores.

MRAG Method: ENCOUNTERABILITY			
Habitat/water column attribute			
HABITAT/WATER COLUMN	DESCRIPTION	ALL RISK	Risk Score
air	air breathers: seabirds, mammals, reptiles	H	3
demersal, soft bottom	bottom: sand, mud	H	3
demersal,hard bottom	bottom: rocky, reefs	H	3
epipelagic	surface	L	1
benthopelagic	bottom and midwater	M	2
mesopelagic	midwater	L	1
Bathymetry attribute			
BOTTOM DEPTH	CODE	ALL RISK	Risk Score
0-110	1	H	3
110-250	2	H	3
250-565	3	M	2
565-820	4	M	2
820-1100	5	M	2
1100-3000	6	L	1

Table 19: MRAG Post Capture Mortality Scores.

MRAG Method: POST CAPTURE MORTALITY			
Role in fishery	**Includes**	**Risk Category**	**Risk Score**
Target	retained therefore dead	H	3
Byproduct	usually retained may sometimes be discarded alive or dead	H	3
Discards other than TEP	discarded alive or dead	M	2
TEP	likely to be dead	H	3
TEP Chondrichthyans	discarded alive or dead	M	2
TEP	discarded alive or dead	M	2
TEP	discarded alive or dead	H	3
TEP teloest - Syngnathidae	likely to be dead	L	1
TEP invertebrates (if any?)		L	1

5.2 MSC Cut-off Scores

Table 20: MSC Productivity scores.

MSC Method: PRODUCTIVITY SCORES			
	Low productivity (high risk, 3)	Medium productivity (medium risk, 2)	High productivity (low risk, 1)
Average age at maturity	> 15 years	5-15 years	<5 years
Average maximum age	>25 years	10-25 years	<10 years
Fecundity	<100 eggs per year	100-20,000 eggs per year	>20,000 eggs per year
Average maximum size	>300 cm	100-300 cm	<100 cm
Average size at maturity	>200 cm	40-200 cm	<40 cm
Reproductive strategy	Live bearer	Demersal egg layer	Broadcast spawner
Trophic Level	>3.25	2.75-3.25	<2.75

Table 21: MSC Susceptibility scores

MSC Method: SUSCEPTIBILITY			
	Low risk (1)	Medium risk (2)	High Risk (3)
Areal Overlap Overlap of the fishing effort with a species distribution of the stock.	<10% overlap	10-30% overlap	>30 % overlap
Vertical Overlap The position of the stock/species within the water column relative to the fishing gear.	Low overlap with fishing gear	medium overlap with fishing gear	High overlap with fishing gear
Selectivity for set gillnets Selectivity is the potential of gear to capture or retain the species	Length at maturity < mesh size, or >5 m in length	Length at maturity is 1-2 times mesh size or 4-5 m in length	Length at maturity >2 times mesh size, to say, 4 m in length
Selectivity for hooks Defined by typical weights of the species caught relative to the breaking strain of the snood, the gaffing method used in the fishery, and by diet of potential species	a. Does not eat bait (e.g. diet specialist), filter feeder (e.g. basking shark), small mouth (e.g. sea horse). Most robust scoring attribute.	a. Large species, with adults rarely caught, but juveniles captured by hooks.	a. Bait used in the fishery is selected for this type of species, and is a known diet preference (e.g. squid bait used for swordfish), or important in wild diet.
Scores for hook susceptibility may be assigned using the categories to the right. If there are conflicting answers, e.g. Low on point 1 but medium on point 2, the higher risk score shall be used.	b. Species with capacity to break line when hooked (e.g. large toothed whales, and sharks).	b. Species with capacity to break snood when being landed.	b. Species unable to break snood when being landed
	c. Selectivity known to be low from selectivity analysis/experiment (e.g. <33% of fish encountering gear are selected)	c. Selectivity known to be medium from selectivity analysis/experiment (e.g. 33-66% of fish encountering gear are selected).	c. Selectivity known to be high from selectivity analysis/experiment (e.g. >66% of fish encountering gear are selected)
Selectivity for Traps/Pots Scores for trap susceptibility may be assigned using the categories to the right. If there are conflicting answers, e.g. Low on point 1 but medium on point 2, the higher risk score shall be used.	a. Cannot physically enter the trap (e.g. too big for openings, sessile species, wrong shape, etc).	a. Can enter and easily escape from the trap, but is attracted to the trap (e.g. does eat the bait, or trap is attractive as habitat)	a. Can enter, but cannot easily escape from the trap, and is attracted to either the bait, or the habitat provided by the trap.
	b. Can enter and easily escape from the trap, and no incentive to enter the trap (does not eat bait, trap is not attractive as habitat, etc.)	b. Can enter, but cannot easily escape from the trap, and no incentive to enter the trap (does not eat bait, trap is not attractive as habitat, etc.)	b. Species regularly found in the trap
		c. Species occasionally found in the trap.	
Post-capture mortality(PCM) The chance that, if captured, a species would be released in condition that would permit subsequent survival	Evidence of post-capture release and survival	Released alive	Retained species, or majority dead when released