Title: Assessing Vulnerability - NMFS Vulnerability Evaluation Work Group Results.

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Assessing Vulnerability

The National Marine Fisheries Service (NMFS) created the Vulnerability Evaluation Work Group (VEWG) to provide a methodology for determining the vulnerability of a stock. The vulnerability of a stock to becoming overfished is defined in the National Standard 1 (NS1) guidelines as a function of its productivity ("the capacity of the stock to produce MSY and to recover if the population is depleted") and its susceptibility to the fishery ("the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery"). The guidelines note that the "vulnerability" of fish stocks should be considered when: 1) differentiating between stocks "in the fishery" and "ecosystem components"; 2) assembling and managing stock complexes; and 3) creating management control rules.

The Approach

Tasked with providing a tool that is flexible in its use and comparable across fisheries and regions, the VEWG reviewed several risk assessment methods to determine which approach was best suited for the NS1 guidelines use of the term vulnerability. While quantitative modeling provides the most rigorous method for determining whether a stock is vulnerable to becoming overfished or is currently experiencing overfishing, insufficient data exists to perform such modeling for many of the stocks managed by NMFS. Therefore, the VEWG focused on developing a flexible semi-quantitative methodology that could be used in many fisheries and regions. The Productivity and Susceptibility Assessment (PSA) was selected as the best approach for examining the vulnerability of stocks, because it can be based on qualitative data, has a history of use in other fisheries, and is recommended by several organizations and work groups as a reasonable approach for determining risk.

The PSA was originally developed to classify differences in bycatch sustainability of the Australian prawn fishery by evaluating the productivity of a stock to its susceptibility to the fishery (Stobutzki et al. 2001). The productivity and susceptibility of a stock was determined by providing a score ranging from 1 to 3 for a standardized set of attributes (N=13) related to each factor. The scores were then calculated for each factor and graphically displayed on an x-y scatter plot (Figure 1). Stocks that received a low productivity score and a high susceptibility score were considered to be the least sustainable (i.e., high vulnerability), while stocks with a

high productivity score and low susceptibility score were considered to be the most sustainable (i.e., low vulnerability).

Modifications to the Original PSA Methodology

While the VEWG agreed that the PSA was an appropriate model in which to base their vulnerability evaluation, the work group began meeting in January 2008 to revise the methodology based on the proposed revisions of Hobday et al. (2004) and Rosenberg et al. (2007), as well as making additional revisions to provide more flexibility for its use in diverse U.S. fisheries.

Revisions include:

- Selecting an appropriate number of Productivity and Susceptibility attributes (Table 1 and Table 2);
- Redefining the scoring matrix to provide break points related to US fisheries;
- Developing a universal weighting system;
- Developing a Data Quality Index (Table 3; Figure 2); and
- Addressing different sectors and gear.

Example Applications

The VEWG selected seven fisheries (Northeast Multispecies Groundfish, Atlantic Shark Complexes, South Atlantic/Gulf of Mexico Snapper-Grouper Longline Fishery, California Coastal Pelagics, California Nearshore Groundfish, Bering Sea/Aleutian Island Skate Complex, and the Hawaiian Pelagic Longline Fishery) to evaluate the effectiveness of its vulnerability evaluation. Overall 166 stocks were examined, and the results provided some interesting trends in vulnerability scores (Figure 1). The work group finished its report in March 2009 (Patrick et al. 2009), and resources for conducting a vulnerability analysis can be found at http://www.nmfs.noaa.gov/msa2007/vulnerability.htm.

Literature Cited

Hobday, A. J., A. Smith, and I. Stobutzki. 2004. Ecological risk assessment for Australian Commonwealth fisheries. Final Report Stage 1. Hazard identification and preliminary risk assessment. Report Number R01/0934, CSIRO Marine Research.

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Stobutzki, I., M. Miller, and D. Brewer. 2001b. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation 28: 167-181.

Tables and Figures

Table 1. Productivity attributes and rankings.

Productivity attribute	Definition	Ranking		
		High (3)	Moderate (2)	Low (1)
r	The intrinsic rate of population growth or maximum population growth that would occur in the absence of fishing at the lowest population size.	> 0.5	0.16 - 0.5	< 0.16
Maximum age	Maximum age is a direct indication of the natural mortality rate (*M*) , where low levels of *M* are negatively correlated with high maximum ages.	< 10 years	10 - 30 years	> 30 years
Maximum size	Maximum size is correlated with productivity, with large fish tending to have lower levels of productivity, though this relationship tends to degrade at higher taxonomic levels.	< 60 cm	60 - 150 cm	> 150 cm
von Bertalanffy growth coefficient (*k*)	The von Bertalanffy growth coefficient measures how rapidly a fish reaches its maximum size, where long-lived, low-productivity stocks tend to have low values of *k*.	> 0.25	0.15 - 0.25	< 0.15
Estimated natural mortality (*M*)	Natural mortality rate directly reflects population productivity, as stocks with high rates of natural mortality will require high levels of production in order to maintain population levels.	> 0.40	0.20 - 0.40	< 0.20
Measured fecundity	Fecundity (i.e., the number of eggs produced by a female for a given spawning event or period) and is measured here at the age of first maturity.	> 10e4	10e2 - 10e3	< 10e2
Breeding strategy	The breeding strategy of a stock provides an indication of the level of mortality that might be expected for the offspring in the first stages of life.	0	1 - 3	≥4
Recruitment pattern	Stocks with sporadic and infrequent recruitment success often are long-lived and thus might be expected to have lower levels of productivity.	Highly frequent recruitment success (> 75% of year classes are successful).	Moderately frequent recruitment success (between 10% and 75% of year classes are successful).	Infrequent recruitment success (< 10% of year classes are successful).
Age at maturity	Age at maturity tends to be positively related with maximum age (*tmax*), as long-lived, lower productivity stocks will have higher ages at maturity relative to short-lived stocks.	< 2 year	2 - 4 years	> 4 years
Mean Trophic Level	The position of a stock within the larger fish community can be used to infer stock productivity, with lower-trophic-level stocks generally being more productive than higher-trophic-level stocks.	< 2.5	2.5 - 3.5	> 3.5

Table 2. Susceptibility attributes and rankings.

Susceptibility attribute	Definition	Ranking		
		Low (1)	Moderate (2)	High (3)
Areal overlap	The extent of geographic overlap between the known distribution of a stock and the distribution of the fishery.	< 25% of stock occurs in the area fished.	Between 25% and 50% of the stock occurs in the area fished.	> 50% of stock occurs in the area fished.
Geographic concentration	Geographical concentration is the extent to which the stock is concentrated into small areas.	Stock is distributed in > 50% of its total range	Stock is distributed in 25% to 50% of its total range	Stock is distributed in < 25% of its total range.
Vertical overlap	The position of the stock within the water column (i.e., demersal or pelagic) relative to the fishing gear.	< 25% of stock occurs in the depths fished.	Between 25% and 50% of the stock occurs in the depths fished.	> 50% of stock occurs in the depths fished
Seasonal migrations	Seasonal migrations either to or from the fishery area (i.e. spawning or feeding migrations) could affect the overlap between the stock and the fishery.	Seasonal migrations decrease overlap with the fishery.	Seasonal migrations do not substantially affect the overlap with the fishery.	Seasonal migrations increase overlap with the fishery.
Schooling/Aggregation and other behavioral responses	Behavioral responses of both individual fish and the stock in response to fishing.	Behavioral responses decrease the catchability of the gear.	Behavioral responses do not substantially affect the catchability of the gear.	Behavioral responses increase the catchability of the gear (i.e., hyperstability of CPUE with schooling behavior).
Morphology affecting capture	The ability of the fishing gear to capture fish based on their morphological characteristics (e.g., body shape, spiny versus soft rayed fins, etc.).	Species shows low selectivity to the fishing gear.	Species shows moderate selectivity to the fishing gear.	Species shows high selectivity to the fishing gear.
Desirability/Value of the fishery	Assumes that highly valued fish stocks are more susceptible to overfishing or becoming overfished by recreational or commercial fishermen due to increased effort.	Stock is not highly valued or desired by the fishery (< $1/lb; < $500K/yr landed; < 33% retention).	Stock is moderately valued or desired by the fishery ($1 - $2.25/lb; $500k - $10,000K/yr landed; 33-66% retention).	Stock is highly valued or desired by the fishery (> $2.25/lb; > $10,000K/yr landed; > 66% retention).
Management strategy	The susceptibility of a stock to overfishing may largely depend on the effectiveness of fishery management procedures used to control catch.	Targeted stocks have catch limits and proactive accountability measures; non-target stocks are closely monitored.	Targeted stocks have catch limits and reactive accountability measures.	Targeted stocks do not have catch limits or accountability measures; non-target stocks are not closely monitored.
Fishing rate relative to M	As a conservative rule of thumb, it is recommended that M should be the upper limit of F so as to conserve the reproductive potential of a stock.	< 0.5	0.5 - 1.0	> 1
Biomass of spawners (SSB) or other proxies	The extent to which fishing has depleted the biomass of a stock relative to expected unfished levels offers information on realized susceptibility.	B is > 40% of B_0 (or maximum observed from time series of biomass estimates).	B is between 25% and 40% of B_0 (or maximum observed from time series of biomass estimates).	B is < 25% of B_0 (or maximum observed from time series of biomass estimates).
Survival after capture and release	Fish survival after capture and release varies by species, region, and gear type or even market conditions, and thus can affect the susceptibility of the stock.	Probability of survival > 67%	33% < probability of survival < 67%	Probability of survival < 33%
Fishery impact to EFH or habitat in general for non-targets	A fishery may have an indirect effect on a species via adverse impacts on habitat.	Adverse effects absent, minimal or temporary.	Adverse effects more than minimal or temporary but are mitigated.	Adverse effects more than minimal or temporary and are not mitigated.

Table 3. The five tiers of data quality used when evaluating the productivity and susceptibility of an individual stock.

Data quality score	Description	Example
1	(Best data) Information is based on collected data for the stock and area of interest that is established and substantial.	Data rich stock assessment, published literature that uses multiple methods, etc.
2	(Adequate data) Information with limited coverage and corroboration, or for some other reason deemed not as reliable as Tier 1 data	Limited temporal or spatial data, relatively old information, etc
3	(Limited data) Estimates with high variation and limited confidence and may be based on similar taxa or life history strategy.	Similar genus or family, etc.
4	(Very limited data) Expert opinion or based on general literature review from wide range of species, or outside of region	General data – not referenced
5	(No data) No information to base score on – not included in the PSA, but included in the DQI score.	

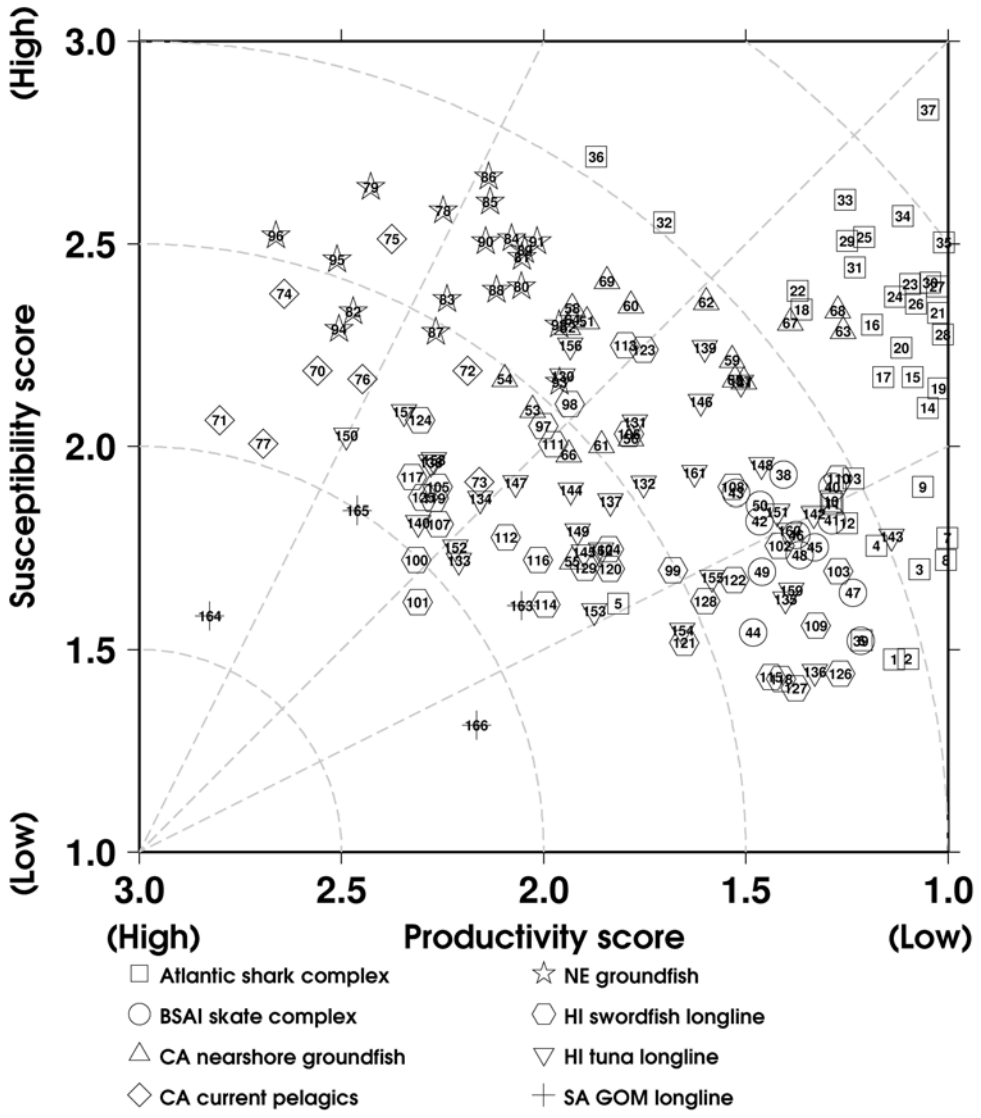

Figure 1. Overall distribution of productivity and susceptibility x–y plot for the 166 stocks evaluated in this study, differentiated by fishery (see Patrick et al. 2009 for reference IDs).

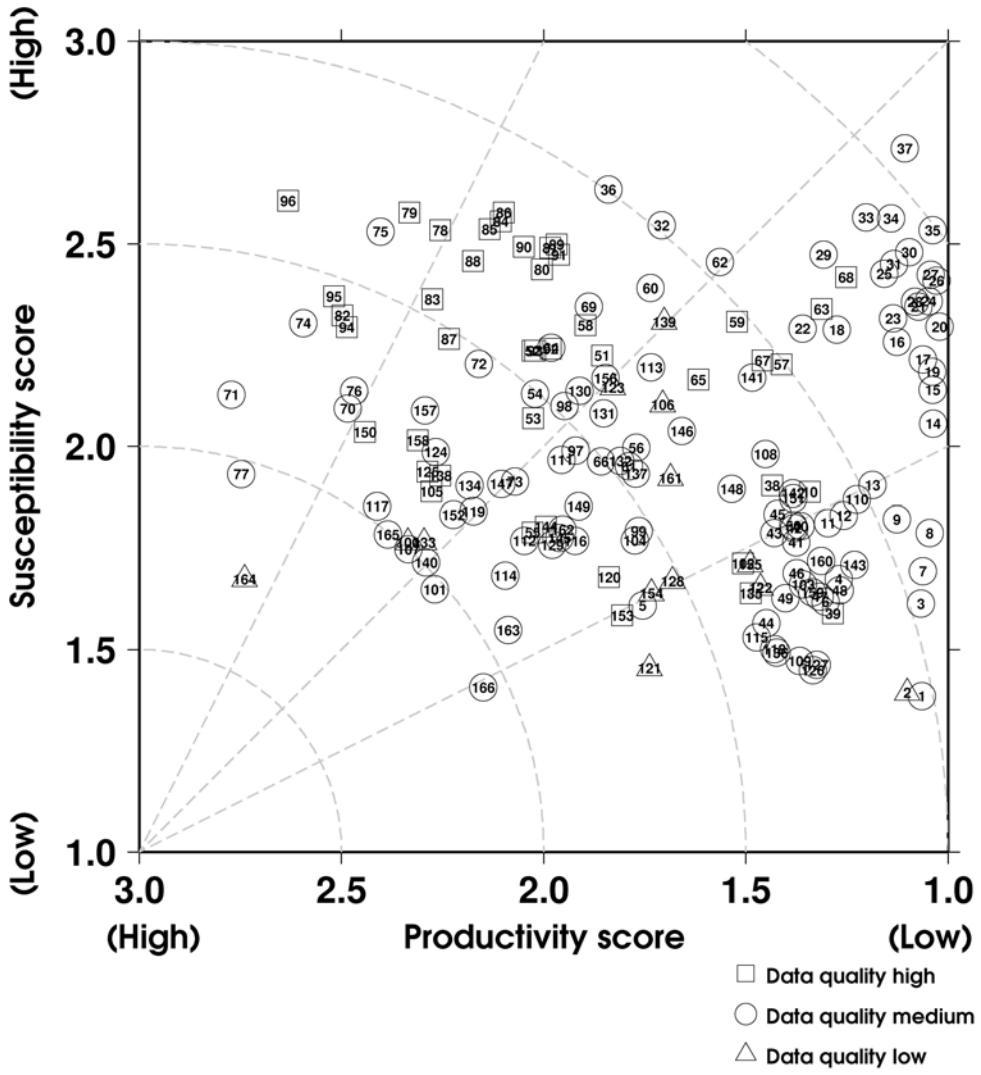

Figure 2. Overall distribution of data quality scores for the productivity and susceptibility factors (see Patrick et al. 2009 for reference IDs).