MULTI-CRITERIA DECISION TOOL TO EVALUATE PROPOSED CHANGES IN STELLER SEA LION PROTECTION MEASURES IN ALASKAN GROUNDFISH FISHERIES USING THE ANALYTIC HIERARCHY PROCESS[1]

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ABSTRACT

Alaskan groundfish fisheries have been constrained to minimize impacts to the endangered Steller sea lion (SSL) since 1992. These management measures introduced inefficiencies and safety concerns for the fishing fleet. Recognizing the desire to optimize both the economic potential of fisheries in Alaska and the recovery of the endangered SSL, in 2006 the North Pacific Fishery Management Council (NPFMC) called for proposals to change the SSL protection measures. Following extensive review of scientific data and solicitation of public comment over a 16-month period, the SSL Mitigation Committee (SSLMC) developed a Proposal Ranking Tool (PRT) using the Analytic Hierarchy Process (AHP). The AHP enabled diverse individuals with various perspectives to use their expert knowledge in rating management measures relative to their expected impact to SSL. The PRT model output was used to select the best set of proposed management measures to move forward through the federal regulation process.

Keywords: fishery management, Steller sea lion, Analytic Hierarchy Process

1. Introduction

This paper describes the use of the Analytic Hierarchy Process (AHP; Saaty, 1999) to model fish harvest tactics, fishery management measures, and biological variables for their influence on the Steller sea lion (SSL) and its target prey field in the Gulf of Alaska and Bering Sea / Aleutian Islands. The modeling process facilitated the identification of those factors associated with Alaskan groundfish fisheries, acting in concert with biological variables, which affect the SSL. The intent of the modeling process is to assist knowledgeable decision-makers in forming consensus judgments about their perception of the problem, and their beliefs in the likely relative consequences of protection measures regarding the SSL and their prey field. (SSL protection measures are regulations that constrain fishing). Evaluating impacts from changes in protection measures is crucial to the continued economic viability and safety of the Alaskan groundfish fleet. This modeling process can be adapted to evaluate relative impacts from proposed regulation changes in other fisheries (hereafter referred to as proposals).

[1] Acknowledgements: The author facilitated initial development of the PRT and prepared a preliminary report in August 2006 from which much of the material in this paper is drawn (see www.fakr.noaa.gov/npfmc/current_issues/ssl/SSLMCranktool806.pdf). Revisions to the PRT and updated reports can be found at www.fakr.noaa.gov/sustainablefisheries/sslmc and are primarily due to the efforts of Larry Cotter (chairman), Bill Wilson (NPFMC staff), Dan Hennen (Alaska Sealife Center), Kristin Mabry and Melanie Brown (NMFS), and Sue Hills (UAF). The PRT was developed from discussion by the SSLMC in consultation with staff from the NMFS-AFSC and other scientists.

1.1 Background

Groundfish fisheries for pollock, Pacific cod and Atka mackerel in Alaskan waters contribute significantly to the Alaska, U.S. and world economies. Bering Sea pollock accounts for 15% of the world's total fish harvest, and 30% of total U.S. landings. The 2007 harvest for the fleet was approximately 1.4 million mt worth roughly $800 million annually. Pollock is processed into fillets, fish sticks and surimi. The 2007 harvest of Pacific cod was approximately 250,000 mt roughly valued at $150 million annually, and for Atka mackerel was 50,000 mt worth roughly $10 million annually (NMFS, 2007).

The range of the western population of SSL overlaps a large portion of the Alaskan groundfish fishery. The SSL consume groundfish as a large part of their diet in areas coincident with prime fishing areas. Beginning in the 1950's, counts of SSL declined in a core segment of their range by 80%, prompting listing of the SSL west of Cape Suckling as endangered, and those east of Cape Suckling as threatened under the Endangered Species Act (ESA). A Biological Opinion issued under the ESA concluded that the Alaskan groundfish fisheries for pollock, Pacific cod and Atka mackerel jeopardize the continued existence of the SSL and critical habitat by competing for and modifying the SSL's prey field. Because specific causes of the decline in SSL are not clearly understood, there is no clear linkage between fish harvest and SSL abundance. Nevertheless, acknowledging the assumption that fishing has a relationship with SSL abundance in the Biological Opinion, the North Pacific Fisheries Management Council (NPFMC) desired to minimize suspected fishing impacts to the endangered SSL. Thus, harvest constraints were instituted, in compliance with federal law. However, in 1998 a lawsuit brought against the National Marine Fisheries Service (NMFS) was successful in pointing out that NMFS had failed to consider cumulative impacts of all groundfish fisheries on the SSL, thereby involving the U.S. District Court, Western Washington, into fishery management. The court ruled that the existence of the SSL and its critical habitat shall not be jeopardized by fishery management measures. That is, decision-makers must institute SSL protection measures to avoid "jeopardy".

In striving to avoid "jeopardy", constraints were imposed on the Alaskan groundfish fishery thereby adversely impacting the socioeconomic welfare of the fleet. Recognizing the desire to optimize both the socioeconomic potential of fisheries in Alaska and the recovery of the endangered SSL, in 2006 the NPFMC called for proposals from the public to change SSL protection measures. A SSL mitigation committee (SSLMC) was appointed and charged with the review of proposals and development of a model called the Proposal Ranking Tool (PRT) using the AHP. The AHP enabled a diverse group of individuals with various perspectives to use their expert knowledge in judging how fisheries would be likely to affect the SSL. The PRT is intended for rating proposals relative to their expected impact to SSL, aiding in the selection of the best set of proposed management actions to move forward through the federal regulation process.

2. Development of the PRT

2.1 Approach

The PRT was developed from July 2006 to February 2007 in stages over a series of facilitated meetings with the SSLMC, who are comprised of 16 members representing federal, state and local governments, the fishing industry, native and environmental perspectives, academia, and private business. Advice and scientific information was provided by NMFS-Alaska Fisheries Science Center (AFSC) staff as well as members of the public. Scientific review of the PRT came from the Science and Statistical Committee (SSC) of the NPFMC.

The SSLMC exhaustively reviewed and debated a variety of references, data tables and other sources of information to define and rate elements of the PRT. For example, specialists on SSL abundance (Holmes and York, 2003), movement (Raum-Suryan et al., 2002), diet (Sinclair and Zeppelin, 2002), prey abundance (Ianelli et al., 2005), fishery effects (McDermott at el., 2005), behavior (Maniscalco et al., 2006) and other aspects of the problem provided papers or testimony at the meetings. The AHP was used to structure the problem and derive the interactions of its parts using available data in combination with expert judgment (Saaty, 1999). The AHP has been used extensively to address planning and prioritization in a variety of disciplines, and has recently been applied to fisheries research and management (Merritt and Criddle, 1993; Merritt, 1995, 2000 and 2001; Ridgley et al., 1997; Leung et al., 1998; Merritt and Quinn, 2000; Merritt and Skilbred, 2002; USFWS 2005; Mat-Su 2008). The AHP is a tool for facilitating decision-making by structuring the problem into levels comprising a hierarchy. Breaking a complex problem into levels permits decision makers to focus on smaller sets of decisions, improving their ability to make accurate judgments. Structuring also allows decision makers to think through a problem in a systematic and thorough manner. Decision support software was used interactively to structure the problem, depict the influence of weights, and derive the priority of elements.

2.2 Structure of the PRT

The PRT is structured in a top-down approach, where the first level is comprised of the goal and the second-third levels contain three questions for which reasonably reliable data are available to answer the questions.

The goal is:

- To develop a rational approach to evaluating proposed changes in fishing regulations for pollock Pacific cod and Atka mackerel in the Bering Sea/Aleutian Islands and Gulf of Alaska to optimize both the socioeconomic potential of those fisheries and the continued recovery of the endangered SSL.

The three questions are:

1. To what extent does fishing alter the prey field by season, putting the percentage of removal and duration of removal in the context of the status quo?
2. To what extent is the SSL sensitive to fishing activity, in relation to proximity to a given site type, and the percentage of sites affected in the region, and by season?
3. To what extent do the target species appear in the diet of SSL, by region and season?

The SSLMC packaged the three questions into two dimensions of the problem along which impacts can be measured,

- how fisheries affect the prey field of the SSL, and
- how fisheries affect the SSL.

The third through sixth levels of the hierarchy are comprised of variables (Table 1), which are components of proposed changes to fishing that can be regulated - quota, season dates, and spatial closures. When variables are included into the hierarchy, they become "children" of the dimensions and are scored as to their potential degree of impact, relative to their "parent" dimension. The SSLMC was tasked with discerning how variables associated with fishing regulation changes would be likely to impact the dimensions of the SSL and their prey. Ideally, the way to evaluate impacts of proposed changes in fishing is to know fish biomass in the harvest area, understand SSL nutritional needs at harvest time, and be able to predict with accuracy the amount and rate of harvest relative to fish biomass. However, this is a data-poor situation, so judgments must be made on the best available information.

Table 1. Variables in the PRT to evaluate proposals for relative impacts to the SSL and their prey.

Variable	Sub-units
1. Target fish species	a. Pacific cod b. pollock c. Atka mackerel d. Other prey items
2. Target species removals	a. a slight increase in amount harvested = 1 to 5% of the total seasonal TAC for all sectors in that fishery for the season. b. a moderate increase = 6 to10% increase in amount harvested c. a large increase is > 10% increase in amount harvested d. no change or a decrease in amount harvested
3. Fishing duration	a. a shorter fishing season relative to status quo b. a longer fishing season relative to status quo c. a fishing season of the same duration as status quo
4. Geographic regions	a. Eastern Gulf of Alaska (EGOA) b. Central Gulf of Alaska (CGOA) c. Western Gulf of Alaska (WGOA) d. Eastern Aleutian Islands (EAI; includes the Bering Sea) e. Central Aleutian Islands (CAI) f. Western Aleutian Islands (WAI) g. Pribilof Islands
5. Seasons	a. Summer (the SSL breeding season, defined as May-September) b. Winter (non-breeding season, October-April) c. Shifting fishing from winter to summer d. Shifting fishing from summer to winter
6. SSL site types – summer and winter for each type	a. Rookery b. Haulout c. other
7. Proximity zones to a SSL site	a. 0-3 nm b. 3-10 nm c. 10-20 nm d. 20+ nm in CH e. 20+ nm outside CH
8. The percentage of SSL sites affected in a region	a. 1-10% b. 11-25% c. 26-50% d. 51-75% e. 76-100%

Brief explanations of the variables and associated terms will help the reader to better understand their role in evaluating relative impacts of fishing to the SSL and their prey.

Status-quo: The current fishing regulatory situation in the context of each proposal.

Target fish species: Pollock, Pacific cod, and Atka mackerel occur frequently in the diet of SSL based on scat data, which may be the best proxy available for identification of SSL diet. Other prey species observed in high diet proportions comprise the "other" category. The relative importance of each fish species varies in relation to their proportion in the SSL diet in a given region and season.

Target species removals: Harvest for each fish species is considered as a percentage of the sum of all fishing sectors' seasonal Total Allowable Catch (TAC) for that species. Thus, if one fishing sector for Pacific cod proposed a change in harvest amount, the PRT would examine the overall effect for the entire Pacific cod fishery. This variable addresses seasonal shift in SSL prey.

Fishing duration: This term is related to intensity of fish harvest (amount and time) and addresses concerns about localized depletion of SSL prey. Less harvest in a longer time frame is judged less likely to result in localized prey depletion than would intense fishing in a pulse of time (3 to 10 days). The synergy of fishing duration and target species removals is intended to serve as a proxy for harvest rate.

Geographic regions: The regions relate to those cited in the SSL Recovery Plan and they are also where changes in fishing regulations are proposed. The seven regions include three in the Gulf of Alaska, three in the Aleutian Islands (which includes the Bering Sea), and the Pribilof Islands. Regions of the Gulf of Alaska and Aleutian Islands are all equally important because the SSL Recovery Plan requires an increasing trend of SSL for these regions. The Pribilof Islands are judged of slightly less importance to the overall recovery of SSL.

Seasons: Sensitivity to changes in the prey field from fishing differs according to SSL breeding behavior, where energy needs are high for pregnancy, nursing and weaning during the "summer" breeding season (May-September); thus, summer is judged to be a more sensitive time. Regulatory seasons for fishing partially overlap the breeding seasons; to develop the PRT, regulatory seasons were assigned to the breeding/non-breeding season based on timing of harvest.

SSL site types: Land use of SSL is characterized by activity, the number of animals counted and season into site types. The "other" category consists of sites where SSL are present, but do not meet criteria for designation as "rookery" or "haulout". The synergism between season, site type, proximity of fishing and percent of sites affected is important to judging which population segment at each site type is in critical need of protection measures.

Proximity zones: Potential impacts to prey in relation to distance fished from SSL sites is categorized into zones expressed in nautical miles (nm). The NMFS assumes that fishing in increasing proximity to a SSL site has an increasingly deleterious effect on SSL prey. The most critical habitat is 0 to 3 nm from SSL sites. This variable accounts for proximity of fishing in relation to site type and season.

Percentage of SSL sites affected: This concerns the percentage of SSL sites affected by fishing in a given proximity zone and season, where greater adverse impacts are judged to occur when fishing affects many sites at close proximity, compared to fishing affecting fewer sites at greater distance. To include the consideration of site type in this variable, the model can be run for precautionary management by assuming the most sensitive site type in the area is representative. An alternative assumption is that the majority site type is representative. A third option is to add the effects of site type together.

The entire hierarchy consists of one goal, two dimensions, eight variables containing a total of 40 sub-units, organized in six levels. For brevity, a schematic hierarchy is shown in Figure 1; the entire PRT consists of 260 elements. Some variable names are repeated to capture different aspects in relation to other variables, and to provide multiple scenarios, thus allowing flexibility in the scoring process. Reuse of variable names does not imply additional weight ("double counting"), rather, variables are clarified in the appropriate context.

2.3 Establishing Priorities

Following development of the hierarchy, priorities were assigned to elements of the hierarchy, with discussion about judging the degree of importance (degree of sensitivity to impact) of a group of elements in relation to their parent node - thus linking the elements in the lower levels to the upper levels of the hierarchy. A question such as the following was asked for each group of judgments, "Are all elements of this group of equal importance in assessing impacts, or is one element of more or less importance than another, in relation to its parent node?" A specific example follows: "Are all SSL site types (rookery, haulout, or other) of equal importance (sensitivity) to impact from fishing activity, or is one site type of more or less importance than another, in relation to a given season (winter or summer)?" In-depth discussion, with supporting data from NMFS staff and research updates followed each such question to establish a rationale for judging importance.

1st Level	2nd Level	3rd Level	4th Level	5th Level	6th Level
Goal	Dimension	Variable & *Sub-units*	Variable & *Sub-units*	Variable & *Sub-units*	Variable & *Sub-units*
Evaluate proposed changes in fishing regulations	Question #1: Effects of fishing on the prey field	Fishing season *Summer* *Winter* *Summer-winter* *Winter-summer*	Amount of prey removed by fishing (%TAC) *1-5%* *6-10%* *>10%* *No change*	Duration of fishing to remove prey *Shorter* *Longer* *Same*	
		Dimension			
	Effects of fishing on SSL	Question #2: Sensitivity of SSL in regards to site type and proximity of fishing	Site type by season *Summer rookery* *Summer haulout* *Summer other* *Winter rookery* *Winter haulout* *Winter other*	Proximity of fishing to site *0-3nm* *3-10nm* *10-20nm* *20+nmCH* *20+nm not CH*	% of SSL sites affected in Region *1-10%* *11-25%* *26-50%* *51-75%* *76-100%*
		Question #3: Appearance of prey in SSL scat, i.e., what they eat, when and where	Season *Summer* *Winter*	Region *EGOA* *CGOA* *WGOA* *EAI/BS* *CAI* *WAI* *Pribilofs*	Fish species *Cod* *Pollock* *Mackerel* *Other*

Figure 1. Schematic of the PRT hierarchy, showing the goal, dimensions, variables and sub-units.

The SSLMC used supporting data (when possible) and/or their expert judgment in individually assigning ratings of importance to elements. First, the relative importance of the dimensions was evaluated, then that of the variables within each dimension, and finally sub-units. Participants were given time to think and write down their ratings of importance before sharing and discussing their judgments. A modified positive ratio scale with associated verbal equivalents (after Saaty 1999) was used to rate importance, where numbers between those listed (e.g., 2, or 2.5, etc.) were used to interpolate meanings as a compromise:

Scale of Importance	Definition
9	Extreme importance
7	Very strong importance
5	Strong importance
3	Moderate importance
1	Slight importance

Elements judged of equal importance were given equal scores. Consensus was usually achieved. When disparity in judging importance occurred, discussion and debate was encouraged. Debates advanced the understanding of concepts and often resulted in a clearer definition of the dimension or variable. By seeking consensus the formation of a group solution was promoted.

Expert Choice software (www.expertchoice.com) was used interactively to depict the influence of weights and derive the priority of variables. Priorities approximate the strength of importance for each variable, adjusted to reflect the importance assigned to the dimension addressed by that variable. Mathematically, relative ratings of importance are entered into a vector and normalized. The values from the vector are then multiplied by the weight in the next highest level, and the result is the weight of importance for variables. The total score for each variable is then calculated by adding the weighted proportions over all variables within a dimension:

$$T_m = \sum_{k=1}^{d} W_k p_{k,m}$$

where

T_m = the total weighted score for variable *m,*
W_k = the weight for dimension k,
$p_{k,m}$ = the weighted proportion of the total score for variable m addressing dimension k
d = the number of variables.

2.4 Structural adjustment of the PRT

While approximate balance in a hierarchy is desired, complex problems do not always lend themselves to balance. Structural imbalance can lead to dilution of the weight of many variables, so adjustment is made to the priorities of the children, based on the total number of grandchildren. Structural adjustment must always be carefully examined to see if the results capture the intended proportion of weight and make sense. In a conceptual example, consider that if (A) has four grandchildren, and (B) has two grandchildren, then there are six grandchildren in all and structural adjusting multiplies A's priority by 4/6 and B's by 2/6, then normalizes. Thus, the overall priorities for A's grandchildren are not diluted simply because there are many of them.

2.5 Adjusted priorities

Adjusted priorities for the three questions, structured into two dimensions are:

- Dimension: effects of fishing on the prey field (0.250)
- Dimension: effects of fishing on the SSL (0.750)
  - Sensitivity of SSL in relation to site type and proximity of fishing (0.643)
  - Appearance of target species in SSL scat (0.107)

The higher priority given to "Effects of fishing on the SSL" results from concerns about space needed by the SSL in which to forage, access to prey, varying prey availability by season and region, and how many SSL sites may be potentially impacted in a region. Additionally, the number of scenarios for this dimension is roughly twice that of the other dimension, and greater weight is mathematically assigned to correct for dilution of intended importance.

Priorities relating to Question #1, effects of fishing on the prey field, result from characterizing removal amount in relation to the duration of removal by season (Figure 2).

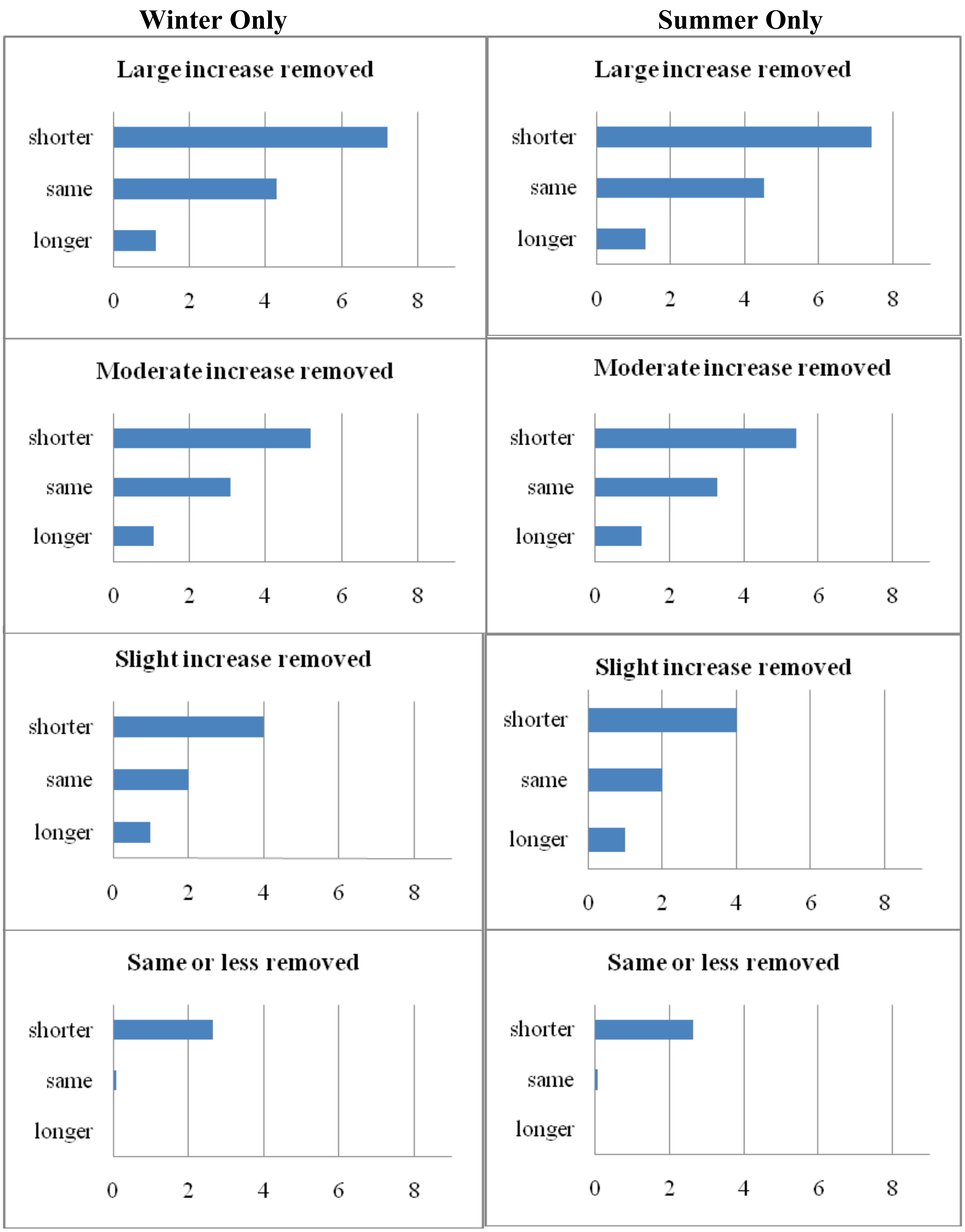

Figure 2. Judgments of potential impacts to the prey field resulting from three possible changes in fishing duration, in relation to a change in the amount harvested, for a given fishing season.

Priorities relating to Question #2, sensitivity of SSL in regards to site type and proximity of fishing, depend on how close fishing occurs to a site type in a given season (Figure 3). The impacts of fishing are judged to be highest when fishing affects a greater percentage of sites within the 0-3nm proximity zone.

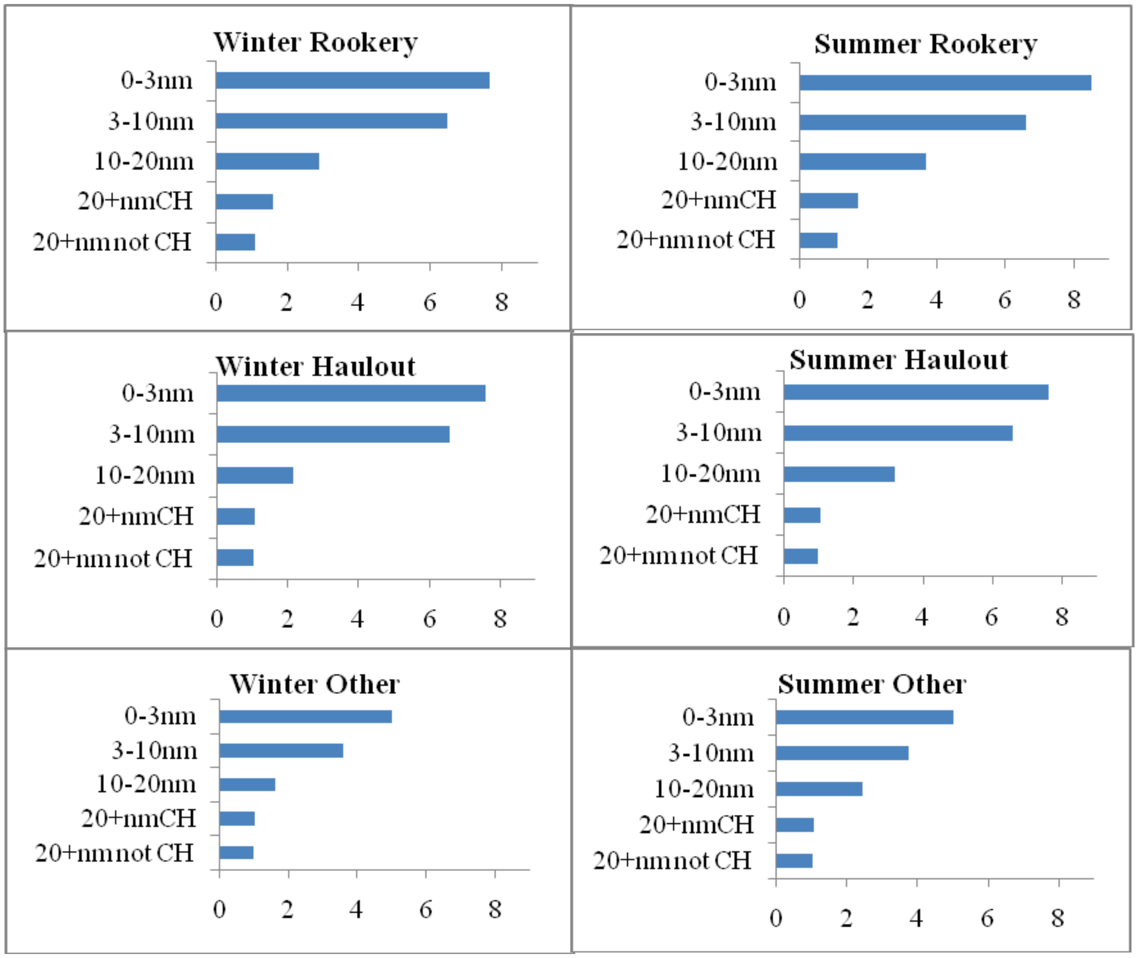

Figure 3. Judgments of the sensitivity of a SSL site type to proximity of fishing, by season.

Priorities relating to Question #3, appearance of prey in SSL scat, result from characterizing target fish species removals in a given region by season (Figure 4). A high score indicates high relative importance of that fish species in the SSL diet, in that region for that season.

2.6 Ratings of proposals in a data grid format

Although there are many advantages to pairwise comparison of elements using AHP, with a large number of fishery proposals to evaluate using a very large model, the number of pairwise comparisons becomes impractical. Therefore, to facilitate evaluation of proposals, variables in the hierarchy were transferred to a Data Grid format. A Data Grid format is appropriate for rating large numbers of alternatives (or in this situation, fishery regulation proposals) with respect to variables in the hierarchy.

3. Implementation and testing of the PRT

The PRT provides a relative rank for all proposals in terms of their adverse impacts to the SSL. And, the PRT provides a relative score for each proposal in relation to the status quo regulatory situation, thus enabling an assessment of potential impacts on a local scale. These scores provide a useful accounting of cumulative impacts from a suite of selected proposals. However, the PRT does not provide information about whether or not a proposal will result in "jeopardy" to the SSL or critical habitat. The role for determining "jeopardy" is reserved for the final Biological Opinion issued under jurisdiction of the ESA.

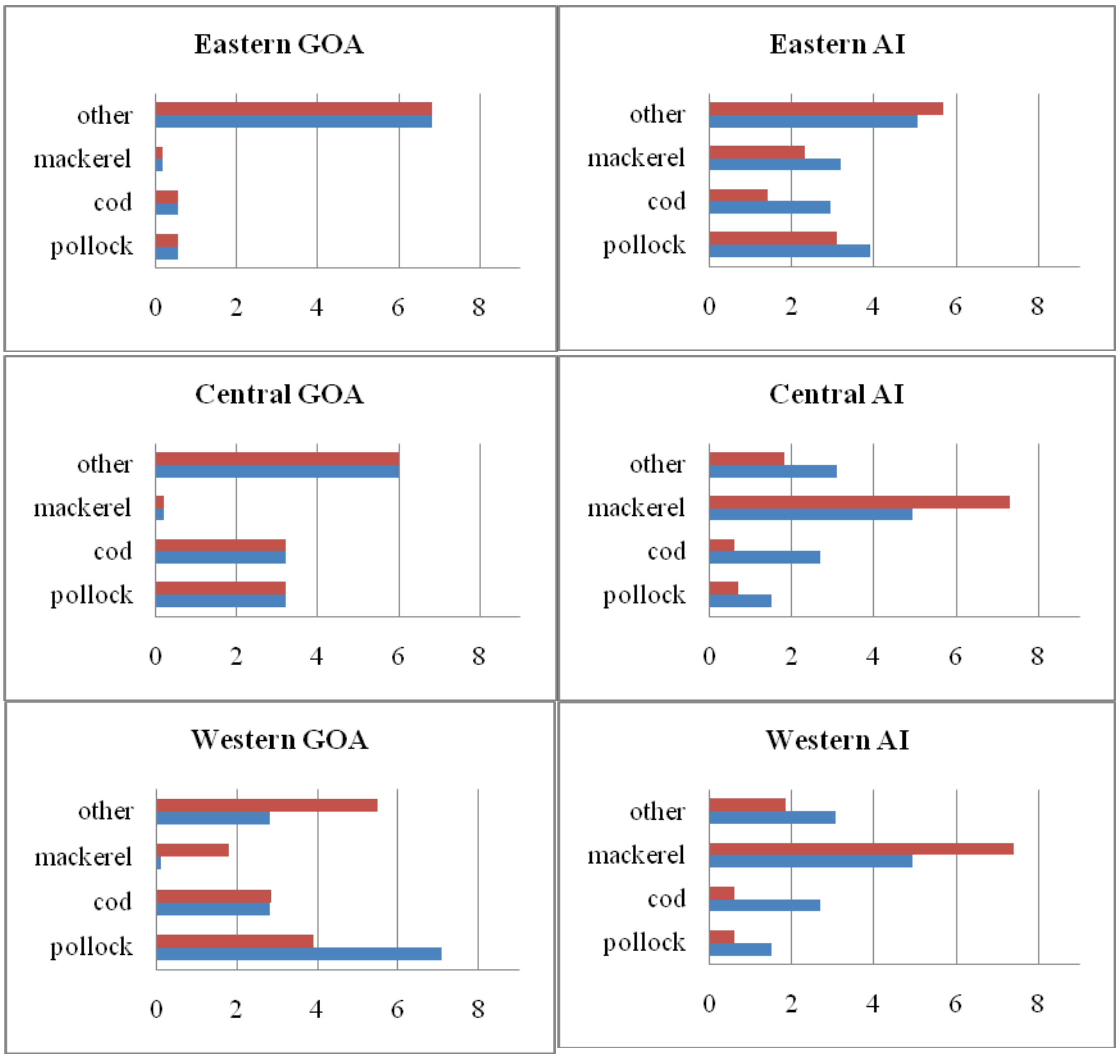

Figure 4. Ratings of importance for fish species by region and season; the blue horizontal bar represents winter and the red bar is summer.

3.1 Evaluation of the PRT using hypothetical proposals

An evaluation of model response was conducted by running two hypothetical proposals through the model, where a proposal with a higher score indicates greater expected impacts to the SSL and their prey field. First, sub-units in each hypothetical proposal were identified for variables of the model (Table 2a). Then, scores for each of the sub-units were assigned from priorities in the model using Data Grid, and summarized according to the three questions relating to how fishing impacts the SSL and their prey field (Table 2b).

Table 2a. The identification of sub-units in two hypothetical proposals.

Variables of the PRT	Sub-units for a hypothetical proposal with an expected high impact	Sub-units for a hypothetical proposal with an expected low impact
1. Target fish species	Atka mackerel	cod
2. Target species removals	A lot	slight
3. Fishing duration	shorter	longer
4. Geographic regions	WAI	CGOA
5. Seasons	summer	winter
6. SSL site types	rookery	other
7. Proximity zones to a site	0-3nm	20+nm
8. The percentage of SSL sites affected in a region	76-100%	1-10%

Table 2b. Summary scores of sub-units identified in two hypothetical proposals, by question in the PRT.

Questions in the PRT	Scores for sub-units in the hypothetical proposal with an expected high impact	Scores for sub-units in the hypothetical proposal with an expected low impact
Question #1: Effects of fishing on the prey field	.019	.002
Question #2: Sensitivity of SSL in regards to site type and proximity of fishing	.008	.003
Question #3: Appearance of prey in SSL scat, i.e., what they eat, when and where	.014	.0004
Total score	**.041**	**.005**

The hypothetical proposal with an expected high impact generated a much higher total score (0.041) than the hypothetical proposal with an expected low impact (0.005), thus proving that the PRT works – scores generated by the model reflect a common sense approach to categorizing impacts to SSL and their prey.

3.2 Sensitivity testing of the PRT

Two approaches were used to examine the sensitivity of the PRT. In one approach, different sub-units were selected in hypothetical proposals to see how the total score would change. For example, changing fishing duration from "shorter" to the "status quo" (current) regulatory situation resulted in a decreased total score, thus reflecting the preference for a longer temporal fishery to avoid SSL nutritional stress. In a second example, the fish species harvested was changed from "Atka mackerel" in the western Aleutian Islands to "Pacific cod", resulting in a decrease in total score, thus reflecting the importance of Atka mackerel in SSL scats in the western Aleutian Islands. In a third example, changing distance fished from a SSL rookery from "10 nm" to "3 nm" increased the total score, demonstrating higher expected impacts from fishing closer to the rookery. These results pleased the SSLMC, as the PRT is accurately representing the expert judgments of the SSLMC members who contributed to its development.

In the second approach, robustness in model performance was tested by changing priorities of the two dimensions. The model is deemed robust if rank order of variables in lower levels of the hierarchy are preserved following a 10% shift in priorities in the higher levels of the hierarchy. The SSLMC initially assigned priorities of 40:60 to dimensions #1 and #2, respectively. Following structural adjustment of the hierarchy, these priorities became 25:75 to preserve the intended weights of importance. A range of priorities were examined for their influence on variable sets in the lower levels of the hierarchy (see Table 3). It took a shift of greater than 10% in priorities of the dimensions to produce a change in rank order between variable sets "Target fish species" and "Fishing duration"; thus, the model may be characterized as fairly robust, according to the criterion stated above.

Table 3. Rank order of variable sets in the lower levels of the hierarchy as influenced by changes in priorities of the dimensions, located in the upper levels of the hierarchy.

Priorities of dimensions		**Rank order of selected lower level variables in the PRT resulting from changes in priorities for dimensions**		
Dimension #1: Effects of fishing on prey	**Dimension #2: Effects of fishing on the SSL**	**Rank order of: % SSL sites affected in a region**	**Rank order of: fish species**	**Rank order of: fishing duration**
15	85	1	2	3
20	80	1	2	3
25	75	1	2	3
30	70	1	2	3
35	65	1	3	2

3.3 Testing structural adjustment of the PRT

One question concerning the model framework is the effect of structural imbalance on the ranking of proposals. Structural imbalance can lead to dilution of the weight of many variables. Structural adjustment is an optional treatment for imbalance by restoring priorities to their respective proportion of weight. Structural adjustment can be made to the children of the current node, based on the number of grandchildren. To test whether adjusted weights truly reflect the relative weights intended by the SSLMC (and reflect common sense), the outcomes from testing hypothetical proposals in adjusted and unadjusted models were compared. To illustrate the effects of structural adjustment, a portion of the PRT appears below (Table 4a), along with the unadjusted priorities.

Table 4a. A portion of the PRT showing unadjusted priorities for each element.

<table>
<tr><th></th><th>Node</th><th></th><th>Children (x)</th><th></th><th>Grandchildren (y)</th></tr>
<tr><td rowspan="8">.600</td><td rowspan="8">Effects of fishing on SSL</td><td rowspan="2">.200</td><td rowspan="2">Appearance of species in scat (xa)</td><td>.112</td><td>Summer (ya)</td></tr>
<tr><td>.088</td><td>Winter (ya)</td></tr>
<tr><td rowspan="2">.400</td><td rowspan="2">Site sensitivity to proximity (xb)</td><td>.031</td><td>Winter other (yb)</td></tr>
<tr><td>.072</td><td>Winter haulout (yb)</td></tr>
<tr><td rowspan="4"></td><td rowspan="4"></td><td>.079</td><td>Winter rookery (yb)</td></tr>
<tr><td>.035</td><td>Summer other (yb)</td></tr>
<tr><td>.074</td><td>Summer haulout (yb)</td></tr>
<tr><td>.109</td><td>Summer rookery (yb)</td></tr>
</table>

Notice that there are two grandchildren for the child, "xa", whereas there are six grandchildren for the child, "xb". Adjusting for imbalance in the children will trickle down to the priorities at the bottom of the hierarchy. Adjustment is approximately made as follows:

Adjusted priority $Pa = (xa)\ (\Sigma ya)/\ \Sigma ya + \Sigma yb$ or $(.2)\ (2/8) = .05$, normalized to $.6 = .08$
Adjusted priority $Pb = (xb)\ (\Sigma yb)/\ \Sigma ya + \Sigma yb$ or $(.4)\ (6/8) = .30$, normalized to $.6 = .5$

The adjusted priorities as computed by the software are in Table 4b.

Table 4b. A portion of the PRT showing adjusted priorities for each element.

	Parent node		Children (x)		Grandchildren (y)
.600	Effects of fishing on SSL	.086	Appearance of species in scat (xa)	.048	Summer (ya)
				.038	Winter (ya)
		.514	Site sensitivity to proximity (xb)	.040	Winter other (yb)
				.093	Winter haulout (yb)
				.101	Winter rookery (yb)
				.045	Summer other (yb)
				.096	Summer haulout (yb)
				.140	Summer rookery (yb)

The effects of structural adjustment on summary scores of hypothetical proposals were then examined. The same hypothetical proposals used previously (Table 2a) were tested to determine model response to structural adjustment (Table 4c).

Table 4c. Comparison of summary scores reflecting expected impacts to SSL and their prey field from hypothetical proposals in the structurally unadjusted and adjusted model.

State of the PRT	**Hypothetical proposal with an expected high impact**	**Hypothetical proposal with an expected low impact**
Structurally unadjusted	.054	.009
Structurally adjusted	.056	.006

Structural adjustment slightly increased the distinction between the two hypothetical proposals (Table 4c). However, the rank order of proposals between the structurally adjusted and unadjusted models remains the same. The SSLMC was comfortable following testing of the model's performance because the output matched what they expected and made sense.

3.4 Interpreting scores of the PRT

Scores from the PRT are intended to create a ranking of proposals in a continuum, where proposals are rated against each other or the status quo fishing regulation situation, not as a direct measure of impact to the SSL. In other words, there is no absolute meaning of a specific score, no threshold below which relative impacts are "okay". Because of error sources associated with all modeling efforts, caution should be used when interpreting small differences in scores among proposals.

4. Discussion

To implement the proposal review process, each proposal was broken down into components that fit into the PRT and scored, while at the same time scoring the status quo regulatory situation pertaining to the proposal, thereby providing a metric against which the proposal was compared. Those proposals containing components that did not fit into the PRT were considered outside of the modeling process. In addition to the mathematical analysis offered by the PRT, evaluation of proposals was augmented by relevant data sources, as well as the common sense and expertise of the SSLMC. The outcome of the proposal review process was recommendations to the NPFMC that certain proposals should move forward through the federal regulation process. In consultation with Protected Resources Division, the final package of proposals constitute actions to avoid "jeopardy" (see the package of 34 proposals forwarded to the NPFMC dated May 2007 at www.fakr.noaa.gov/sustainablefisheries/sslmc).

At this time, the PRT is a tool for evaluating relative impacts of proposals – it does not consider biological or socioeconomic benefits offered by proposals. It is possible to use AHP in scoring benefits of proposals, thus modeling trade-off scenarios between impacts and benefits; however, the SSLMC decided to consider benefits outside of the modeling process for the time being.

The use of the AHP afforded several advantages to the development of the PRT. The problem involving Alaskan groundfish fisheries with the SSL and their prey is highly complex with incomplete and uncertain information, thus necessitating the use of expert judgment in problem-solving. For example, after exhaustive review of data sets (e.g., gear type, vessel size, number of vessels fishing, etc) and debate, the SSLMC concluded that no quantitative data set satisfactorily serves as an acceptable proxy for judging the effects of fishing on the prey field. Therefore, the only recourse for tackling this component of the problem was to use a qualitative means to judge the effects of fishing. The AHP easily lends itself to combining quantitative and qualitative information (Saaty 1999). Another advantage to using the AHP is that the PRT can be easily updated with new information, thus retaining flexibility to address new concerns or priorities.

The SSLMC was challenged to develop a rational tool for evaluating proposals with often insufficient information or in the presence of uncertainty. Thus, much of the development resulted from usually exhausting questioning and discussion with scientists and lengthy debates amongst the committee about available data and its meaning relevant to elements in the PRT. The dialogue proved an important strength of the PRT process, because SSLMC members and public observers became much more informed about the problem, thus increasing the accuracy of judgments. For example, following debate, conclusions of some committee members changed, thus altering their perspective of the problem and priorities. Creativity of ideas was encouraged and explored when alternative explanations were raised, thus refining variables and sub-units of the PRT, and their explanations.

The PRT provides an explicit representation of variables and their priorities that the SSLMC considers relevant to discriminating among proposals for relative impacts to SSL. This clarity and transparency facilitates review, which is expected to lead to greater refinements of the PRT.

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