ASSESSMENT OF OIL SPILL RISK TO BIRDS

by

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TABLE OF CONTENTS

SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objective of this project was to develop a procedure for ranking areas with respect to the relative risk of oil spills to resident and visiting bird populations. Our methods were based on the assumption that the prospect theory of Daniel Kahneman and Amos Tversky (1979) is the most appropriate descriptive model of the way individuals respond to questions concerning decisions about environmental risk.

We found that breeding bird populations were singled out as the most important group to protect, and that respondents showed little inclination to rank moulting, migratory or wintering populations separately from one another. Birds that are about to commence or that have begun breeding have a higher reproductive value than birds that will not breed again for several months or more. Thus this result focuses on the importance of expected reproductive value.

We also compared preferences for avoiding putting various species groups at risk of losing some fraction of their population. We found, not surprisingly, that respondents were least willing to risk populations of species defined as having low reproductive rates, and conversely, species with high reproductive rates were seen as of lesser concern. Alcids were accorded high levels of concern, as were swans. While the alcids fit the category of species with low reproductive rates, swans may not. Possibly small population size, true especially of Trumpeter Swans (*Olor buccinator*), was a factor, or possibly more emotional/aesthetic considerations influenced the high degree of protection sought for them.

We found that respondents tended not to differentiate between our bird-groups when the local population put at risk was equal to or less than 10% of the world population, or when the local population was equal to or greater than 50% of the world population of the bird-groups in question. The biological interpretation of this result is that below 10% of the world population, the risk to each species as a whole is small enough that no one species category was singled out as of greater concern. On the other hand, when there is a potential loss of 50% or more of the world population, all species again tend to be of equal concern. A loss of that magnitude would apparently makes any species immediately equivalent to a threatened, if not an endangered, species. These results can be summarized as saying that our respondents would vote to protect preferentially areas where birds breed and areas with bird populations having low reproductive rates.

Our results complement the King and Sanger (1979) Oil Vulnerability Index (OVI) in several ways. First, the high level of agreement between the rankings obtained by our method and one based on the OVI is evidence that biologists do compare birds in a measurable and consistent way. Second, the relatively small number of categories used with success in our study suggests that when risk is being evaluated, differentiation of birds into species is redundant because reproductive potential is the factor attended to most. Third, our data demonstrate the feasibility of obtaining an interval scale of risk, a level of measurement necessary if comparisons between combinations of species or groups of species are to be made. The OVI, being a ordinal scale, cannot be used in this way.

Our findings that respondents' behavior was consistent with prospect theory (Kahneman and Tversky 1979) means that evaluations of risk to birds may be dependent on the manner in which questions concerning that risk are posed.

For example, options described in terms of saving birds may receive different responses than options described in terms of bird losses - as in our questionnaire - even if the expected risks are exactly the same in both cases (Thaler 1980, Tversky and Kahneman 1981). Even if the rank orderings were to remain constant, changes in the relative value of species might result, affecting the overall evaluation of several species taken together. If synthesis meetings for lease areas, or questionnaires are expected to provide consistent information, the possible effects of different ways of presenting the available options should be taken into account.

INTRODUCTION

The prospect of oil exploration, extraction and associated hazards over much of the outer continental shelf of the United States has prompted a program of baseline studies of this region. Included in this program have been a variety of studies of the distribution, abundance, reproductive biology and food habits of marine birds. These studies have successfully identified the places where high concentrations of birds are found, and when they are likely to be there. While there remains much to be learned about these avian populations, we now have for several regions sufficient data to allow preliminary predictions about where and when birds might encounter oil.

We have also made a start on addressing the question of which species are most likely to become oiled if an oil spill should occur in a specific area. The Oil Vulnerability Index (OVI) of King and Sanger (1979) includes 6 factors (Marine Orientation, Roosting, Foraging, Escape, Flocking on Water, History of Oiling) out of 20 that specifically relate to the likelihood that a member of a given species will become oiled. Additional field work addressing the behavior of marine birds when they encounter floating oil is in progress in southern California (Varoujean, pers. comm.).

A second question that needs to be addressed is the relative value of the individual birds that might become oiled. The loss of an individual from the population of an endangered species is clearly of greater significance to its population than is the loss of an individual of a species that has a large, widely dispersed population. The OVI of King and Sanger (1979) addresses this second question by including a number of factors related to species range, population size, productivity, mortality unrelated to oil, and seasonal changes in distributions. Their index is designed for the northeast Pacific region as a whole, and it is useful for assessing the relative impact of a spill on two or more different species. It is more difficult to apply their index when comparing the risk of an oil spill in two or more small adjacent areas. If each area contains several species, how should the index scores for the different species be combined into a measure which allows inter-area comparison?

A third question is therefore, how should the relevant evidence be evaluated when choosing between alternative oil lease-sale plans. This question includes not only the likelihood of birds present in the area being oiled, but also an assessment of the seriousness of the loss and possibly other factors, not directly linked to biology, that may influence a decision. The decisions as to how to weight the available data clearly go beyond a strictly biological context.

Ideally, one would like to have a scale, derived from biological considerations, that would allow an assessment of the overall risk to birds within a segment of a lease-sale and the ability to compare this assessment to that of any other area. If such a scaling method were at hand, and if all the required data were available, then a panel of experts would have an objective basis for decision making. Additionally , if the decision procedure itself were also known, managers and others would have much greater success at using the expert's choices in their own decisions.

The need for information about how to rank various options became painfully obvious to us during the St. George Synthesis meeting (BLM 1981) held in Anchorage in April 1981. After careful review of the available data on distribution, abundance and status of birds throughout the area of the lease-sale, we were faced with making recommendations on a variety of lease-sale options. These included the extremes of no sale, selling all nominated tracts or recommending deletions of tracts that would either protect the colonies on the Pribilofs or protect the lagoons of the north side of the Alaska Peninsula, important migratory rest stops and foraging areas for waterfowl. We knew what species were present, how long they were present and what they were doing. We did not have an objective guideline for ranking the two intermediate options and we had to rely on intuition and experience.

These perceived needs led to the project summarized here. When we set out, we had as our main objective the development of a method whereby the choices of experts evaluating risky alternatives for avifauna could be simulated for the purposes of ranking oil lease-areas. In this we have been partially successful. We have obtained by means of a questionnaire rankings for several groups of bird species that agree substantially with the ranks predicted by the OVI. However, unlike the OVI, the scale which ranks our groups of species also provides information about the distance between groups so that the relative value of combinations of groups or species can be compared. We have been only partially successful because, within the scope of this study, relative values for groups of species at all levels of risk could not be obtained. Our evaluation of the risk levels for which we have data suggests our procedures can be used in a way beneficial to both biologists and managers.

METHODS

In order to obtain data about individual choices among risky alternatives, we designed a questionnaire patterned after past research in decision theory (Allais 1953, Kahneman and Tversky 1979, Thaler 1980, Tversky and Kahneman 1981). These other efforts were concerned mostly with fairly simple situations, so our first task was to construct similar questions in terms of birds and their environments.

Questions used in this study were of two types:

1) "Within a specified area, assume endangered species will suffer 0% losses with probability .50 and 100% losses with probability .50. What certain % loss for a species of large birds would you accept as an equivalent substitute?"*

2) "Within a specified area, assume a species with a high reproductive rate will suffer 0% losses with probability .50 and 100% losses with probability .50. What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

- a. 1% of the world population? _____
- b. 5% of the world population? _____
- c. 10% of the world population? _____
- d. 25% of the world population? _____
- e. over 50% of the world population? _____ ".

Thirteen bird groups (Table 1) were compared using 3 levels of risk (.25, .50, .75) and 5 levels of local population (1%, 5%, 10%, over 50% of the world population). In addition, 4 types of habitat (migratory, wintering, breeding, moulting) were considered. Included in each questionnaire was a glossary

*The complete questionnaire can be found in Appendix A defining the bird group labels and habitat names used, along with a lengthy introduction explaining gambles and their expected value. Approximately 35 individuals and organizations were asked to fill out a questionnaire (Table 2); of about 15 replies, 7 were judged suitably complete to be included in our analysis.

Ranking of Bird Groups

Rankings for the thirteen bird groups were obtained from each individual's responses as follows. Consider first type (1) questions. According to prospect theory (see references cited above) many people will over-weight a sure loss relative to gambles having the same expected value. For example, given a choice between a gamble with an expected value of 50% losses for an endangered species and a sure loss of 50% for the same species, most people prefer the gamble, implying the certain loss has the greater negative value. This in turn implies the gamble would be judged equivalent to a certain loss smaller than 50%, say 45%. It follows that if the same gamble is judged equivalent to a certain loss for another species of only 40%, then the latter species must be more valuable than the species involved in the gamble. Similarly, if the same gamble is judged equivalent to a certain loss for another species that is greater than 45% then the second species must be less valuable than the endangered species. In this manner, using the same gamble, equivalent sure losses for all groups of species can be obtained and transformed into ranks. Gambles involving three levels of risk - .25, .50, .75 probability of 100% losses - to an endangered species were compared to equivalent sure losses for the other twelve groups of birds.

Type (2) questions were used to derive rankings when world populations were taken into account. If the procedures described above were repeated

Table 1

Bird Group Codes *

0	Endangered Species
1	Large Birds
2	Small Birds
3	Game Birds
4	Subsistence Birds
5	Alcids
6	Shore Birds
7	Gulls
8	Swans
9	Ducks
10	Tubenoses
11	Birds with high reproduction rates
12	Birds with low reproduction rates

* Brief explanations of these categories are in the glossary of Appendix A

Table 2
Individuals and organizations contacted

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for all five local population levels our questionnaire would have been prohibitively long, so we ranked each bird group by the magnitude of its equivalent loss. We assumed that for any particular gamble, the more valuable a species, the smaller the corresponding equivalent loss. When bird groups or habitats were judged to have the same rank, each was assigned the average of the ranks they would have been assigned had no ties occurred (Siegal 1956).

The question of how well people agree on their bird group preferences is important for managers because strong agreement suggests a strong concensus of opinion is possible, and it is important for biologists because strong agreement suggests the concept of value may have a substantive basis. To test the level of agreement, individual rank-orderings of the bird groups were compared across risk levels and different population proportions using to Kendall coefficient of concordance. If this statistic was significantly large, we could assume each individual had an underlying rank ordering of the bird groups which we could estimate as suggested by Kendall (1948). Using the same statistic, these individual rankings were compared and tested for a single ranking aggregated across subjects. Rankings based on the Oil Vulnerability Index and our methods were compared using the Kendall rank correlation coefficient τau.

Habitats were compared at each level of risk by counting the number of subjects that ranked birds in one kind of habitat as more or less valuable than birds in another. For example, if a subject indicated a 30% sure loss for birds in a breeding area was equivalent to a .25 chance at 100% losses in a breeding area, but the same gamble was equivalent to a 40% sure loss in a migratory route, then we assumed that subject valued birds in a breeding area more than birds in a migratory route.

Table 3

Equivalent sure losses for endangered species within a breeding area.

	Gambles*		
Subj .	(-100%, .25)	(-loo%, .50)	(-loo%, 675)
A	-.85	-.95	-.98
B**	-.10	-.05	-.05
C	-.75	-.85	-.90
D	-.125	-,25	-.50
E	-.60	-.70	-.80
F	-.30	-.80	-.90
G	-.10	-.10	-.10
Expected Value	-.25	-.50	-*75

$X^2 = 8.33$, $p < 0.016$ (N = 6)

*(-100%,X) represents the gamble; an x chance of 100% losses and an l-x chance at 0% losses.

**not included in the chi-square test, see text page 13.

RESULTS

Table 3 gives our respondents' sure losses for gambles involving endangered species in a breeding area; subject A indicated a sure loss of 85% was equivalent to a .25 chance at 100% losses. This table was derived from the first set of questions asked. These questions were the least complex of all the questions and were designed to both familiarize the subject with the form of the questionnaire and to test our assumption that risk was evaluated in a manner consistent with prospect theory. If, contrary to prospect theory, subjects compute the expected value of risky choices, in the present context they should tend to evaluate a .25 chance of 100% losses of an endangered species as close to a certain loss of 25%. The data in Table 3 and throughout our study do not support this assumption. Table 3 does offer evidence that our subjects understand the questions to the extent that larger equivalent losses are associated with greater risk ($\chi^2 = 8.33$); as the size of the expected loss (risk level) increases, more birds would be given up to avoid the gamble. (An exception is subject B, but this individual does not repeat the pattern seen in Table 3 in the rest of the questionnaire.)

Table 4(A) shows that 6 of the 7 respondents valued birds in a breeding area over each of the other three habitats when comparisons were made based on a .25 chance at 100% losses. At the same level of risk, 3 subjects valued birds in a migratory route over birds in a moulting area, 3 subjects valued moulting over migratory and 1 subject was indifferent between these two habitats, and so on. The exhibited preference of breeding to other habitats has a multinominal probability of less than 0.01 of being due to chance. For the .5 gamble, the only significant preference was breeding over moulting, and at the .75 level of risk, no significant preferences are evident.

Table 4(B) further illustrated the homogenizing effect of increasing risk. At each level of risk, three comparisons were made, breeding against migratory, breeding against moulting, and breeding against wintering. Each habitat could receive a maximum score of 7 (i.e. 7 subjects showed a preference for one over the other) in each comparison for a total of 21. The preference exhibited by our subjects for birds in a breeding ground clearly is reduced as risk increases.

Rank Ordering of Bird Groups

Table 5 summarizes the ranks assigned to the thirteen bird groups based on the equivalent losses indicated by respondant A for three different gambles, as in the type (1) question described earlier. The first row corresponds to the gamble where an endangered species has a .25 probability of suffering 100% losses, the second row to a .50 probability of 100% losses, and the third row to a .75 probability of 100% losses. For example, at the .25 level of risk, Subject A indicated bird groups coded 8 and 10 were more valued than any other bird group but equal to each other, thus each received a rank of 1.5. The Kendall coefficient of concordance for this table is sufficiently large (W=.874) to justify the assumption that this subject's ranking of the bird groups is independent of the risk level, and to accept as the best estimate of the underlying 'ranking the column sums given in row 4 (Kendall 1948).

Two rankings of the bird groups were obtained from type (1) questions (i.e., those questions not mentioning world populations). First, a ranking across gambles was obtained for each subject as in Table 5. Table 6 gives these rankings with the derived overall ranking in the last row. The second ranking was obtained by deriving a ranking for each gamble across subjects and then summarizing across gambles. Table 7 gives the derivation for the .25 gamble and Table 8 the summary rank order.

Type (2) questions were used to construct a third ranking of the bird

Table 4(A)

Habitat Preference by Subject
The number of respondents ranking the row category over the column category

Risk Level (gamble)		Br	Mi	Mo	Wn
	Br/		6*	6*	6*
.25	Mi/	1		3.5	4*5
	Mo/	1	3.5		4
	Wn/	1	2.5	3	
		Br	Mi	Mo	Wn
	Br/		4	5*	4
,50	Mi /	3		4	4
	Mo/	2	3		3.5
	Nr/	3	3	3.5	
		Br	Mi	Mo	Wn
	Br/		3.5	3.5	3.5
.75	Mi/	3.5		4	3
	Mo/	3.5	3		2.5
	Wn/	3.5	4	4.5	

Key Br = Breeding
Mi = Migratory
Mo = Moulting
Wn = Wintering

*p < .01

**p < .05

Table 4(B)

Habitat Preference by Subject
Breeding Area Against All Others

		Breeding Area	Other Areas
	.25	18	10.5
Risk Level (gamble)	.50	13	10.5
	.75	10.5	10.5

$p < .05$, $df = 2$ ($\chi^2 = 5.952$)

Table 5

Subject A Rankings

Bird Group Code*

		0	1	2	3	4	5	6	7	8	9	10	11	12
	.25	3	7.5	12.5	7.5	7.5	7.5	7.5	7.5	1.5	7.5	1.5	1.2.5	7.5
	.50	1	8	12.5	8	8	8	8	8	3	8	3	12.5	3
Risk	.75	2.5	9.5	12.5	9.5	9.5	6	6	2.5	2.5	6	2.5	12.5	9.5
	Col Sum	6.5	25	37.5	25	25	21.5	21.5	18	7	21.5	7	37.5	20
	Rank	1	10	12.5	10	10	7	7	4	2.5	7	2.5	12.5	5

$W = .874$**, $\chi^2 = 31.45$, $df = 12$, $p < .01$

*See Table 1 for explanations of bird-group codes

**Kendall coefficient of concordance

groups. Only when the local population at risk totaled 25% of the world population did subjects exhibit consistent rankings for each type of gamble. At the 25% population level all subjects except F (this person inverted ranks unintentionally) gave consistent rankings so we removed F from this particular analysis and proceeded as in Tables 7 and 8. Table 9 gives the rankings obtained.

Comparison to the Oil Vulnerability Index

Table 10 compares the rankings we obtained in Tables 6, 8 and 9 to one based on the King and Sanger OVI (1979). This OVI based ranking was constructed by categorizing all the species considered by King and Sanger into our species groups, calculating the average OVI score for each species group, and ranking the averages. The overall agreement between the four rankings is very high ($W=.748$), so an aggregate ranking was estimated as before and placed in the last column. Table 11 gives the same four rankings rearranged into order of vulnerability. Notice that the two rankings having the greatest degree of association (Kendall's τau) are W_1 and W_2 ($\tau=.929$) while the smallest τau is between the OVI ranking and W_3 ($\tau=.258$).

DISCUSSION

The relatively small proportion of responses obtained in this study can be attributed not only to an inclination on the part of many biologists to avoid value judgments, but also to difficulties inherent in the nature of the study.* The amount of information necessary for this kind of analysis is best obtained by repeated interviews, but unfortunately this was not possible. Our only alternative was to make use of a questionnaire which

*See Appendix B for some comments by respondents.

Table 6

Bird Group Ranks Across Subjects*

	Bird Group Code**												
SUBJECT	0	1	2	3	4	5	6	7	8	9	10	11	12
A	1	10	12.5	10	10	7	7	4	2.5	7	2.5	12.5	5
B	13	5	5	11	9.5	5	5	5	1.5	9.5	8	12	1.5
C	13	6	6	6	6	3	10	12	1.5	6	10	10	1.5
D	13	7	7	7	7	7	7	7	7	7	7	7	1
E	1	8.5	12	6.5	4	2.5	11	5	2.5	2.5	6.5	13	10
F	1	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	12	2.5	13	2.5
G	6	4	9.5	9.5	5	1	11.5	13	7	8	3	11.5	2
Sum	48	48	59.5	57.5	49	33	59	53*5	29.5	58	39.5	79	23.5
Rank	5.5	5.5	12	8	7	3	10	11	2	9	4	13	1

W = .349***, $\chi^2 = 29.30$, df = 12, $p < .01$

*derived from type (1) questions

**See Table 1

***Kendall coefficient of concordance

Table 7

Bird Group Ranks across Subjects at .25 Risk Level

Bird Group Codes*

SUBJECT	0	1	2	3	4	5	6	7	8	9	10	11	12
A	3	7.5	12.5	7.5	7.5	7.5	7.5	7.5	1.5	7.5	1.5	12.5	7.5
B	12	5.5	5.5	12	9.5	5.5	5.5	5.5	1.5	9.5	5.5	12	1.5
C	10.5	6	6	6	6	7	10.5	13	2	6	10.5	10.5	2
D	13	7	7	7	7	7	7	7	7	7	7	7	1
E	1	8	11.5	8	3.5	3.5	11.5	3.5	3.5	8	8	13	8
F	1	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	12.5	6.5	12.5	6.5
G	3	3	8.5	8.5	6	3	12.8	13	8.5	8.5	3	12.5	3
Sum	43.5	43.5	57.7	55.5	46	35	61	56	30.5	59	42	80	29.5
Rank	5.5	5.5	12	8	7	3	10	11	2	9	4	13	1

$w = .354^{**}$, $\chi^2 = 29.77$, $df = 12$, $p < .01$

*See Table 7

**Kendall coefficient of concordance

Table 8

Bird Group Ranks across Subjects and Risk Levels

Bird Group Code*

RISK	0	1	2	3	4	5	6	7	8	9	10	11	12	W	p(χ^2)
.25	5.5	5.5	10	8	7	3	12	9	2	11	4	13	1	.354	<.01
.50	7	6	11	8	4	3	9	11	1	11	5	13	2	.283	<.05
.75	7	5	12	9.5	8	4	11	9.5	2	6	3	13	1	* 309	<.02
Sum	19.5	16.5	33	25.5	19	10	32	29.5	5	28	12	39	4		
Rank	7	5	12	8	6	3	11	10	2	9	4	13	1		

W = ,923**, χ^2 = 33.23, df = 12, p <.001

*See Table 1

**Kendall coefficient of concordance

Table 9

Bird Group Ranks at the .25 population level*

Bird Group Code*

RISK	0	1	2	3	4	5	6	7	8	9	10	11	12
.25	9	6.5	6.5	11	11	2	6.5	3	4	11	6.5	13	1
.50	10	5	3	11.5	9	2	7	5	5	11.5	8	13	1
.75	9	6	6	11	11	2	6	6	3	11	6	13	1
Sum	28	17.5	15.5	33.5	31	6	19.5	14	12	33.5	20.5	39	3
Rank	9	6	5	11.5	10	2	7	4	3	11.5	8	13	1

$W = .959$, $\chi^2 = 34.54$, $df = 12$, $p < .001$

*See Table 1

**N = 6

Table 10

Comparison of Derived Ranks to Oil Vulnerability Index

Ranking by different criteria

Species Group	OVI *	W_1^{**}	W_2^{***}	W3	****Aggregate Rank
Endangered Species	1	5.5	7	9	5.5
Large Birds	6	5*5	5	6	5.5
Small Birds	9	12	12	5	10
Game Birds	12	8	8	11.5	11
Subsistence Birds	8	7	6	10	7
Alcids	2	3	3	2	2
Shore Birds	3	10	11	7	12
Gulls	11	11	10	4	8
Swans	5	2	2	3	3
Ducks	7	9	9	11.5	9
Tubenoses	4	4	4	8	4
Birds with high reproduction rates	10	13	13	13	13
Birds with low reproduction rates	3	1	1	1	1

OVI* : Ranks based on Oil Vulnerability Index;

W_1^{**} : Ranks based on table 6;

W_2^{***} : Ranks based on table 8;

W_3^{****} : Ranks based on table 9.

Table 11

Bird Groups In Order of Vulnerability*

	OVI	W_1	W_2	W_2	Aggregate Rank
High 1	Endangered Birds	Birds with low reproduction rates	Birds with low reproduction rates	Birds with low reproduction rates	Birds with low reproduction rates
2	Alcids	Swans	Swans	Alcids	Alcids
3	Birds with low reproduction rates	Alcids	Alcids	Swans	Swans
4	Tubenoses	Tubenoses	Tubenoses	Gulls	Tubenoses
5	Swans	Endangered Species	Large Birds	Small Birds	Endangered Species
6	Large Birds	Large Birds	Subsistence Birds	Large Birds	Large Birds
7	Ducks	Subsistence Birds	Endangered Species	Shore Birds	Subsistence Birds
8	Subsistence Birds	Game Birds	Game Birds	Tubenoses	Gulls
9	Small Birds	Ducks	Ducks	Endangered Species	Ducks
10	Birds with high reproduction rates	Shore Birds	Gulls	Subsistence Birds	Small Birds
11	Gulls	Gulls	Shore Birds	Ducks	Game Birds
12	Game Birds	Small Birds	Small Birds	Game Birds	Shore Birds
Low 13	Shore Birds	Birds with high reproduction rates	Birds with high reproduction rates	Birds with high reproduction rates	Birds with high reproduction rates

$\tau(W_1, W_2) = .929$, $P(z=4.42)<.001$
$\tau(OVI, W_1) = .568$, $P(z=2.70)<.003$
$\tau(OVI, W_2) = .538$, $P(z=2.56)<.006$
$\tau(W_2, W_3)=.452$, $P(z=2.15)<.015$
$\tau(W_1, W_3)=.429$, $P(z=2.04)<.02$
$\tau(OVI, W_3)=.258$, $P(z=1.22)>.10$

*Rankings defined in Table 10

was necessarily very long and complex, and to limit our formal analysis to order statistics. Nevertheless, we have some substantive results to report.

Comparing Rankings. First of all, the rankings of our bird groups were obtained in a way very different from that used by King and Sanger to construct their OVI, and yet the results of both methods are similar (Tables 10 and 11). This is reassuring because it is evidence that biologists evaluate risk to birds in a reliable manner. It also suggests both ways of measuring vulnerability are sensitive to the same factors. Our results have shed some light on the nature of these factors.

The data in Tables 10 and 11 support our contention that risk is evaluated primarily on the basis of features closely related to reproduction rates. Species having high reproductive rates tend to be ranked as least vulnerable while species with low reproductive rates tend to be ranked as most vulnerable. The large concordance statistic associated with the four rankings ($W=.748$) suggests all four have the same underlying rank order with the observed differences accounted for mostly by a confounding of the notions of risk and the meaning of a species being "endangered".

If vulnerability is mostly a function of reproductive ability, then as more birds are put at risk the class of endangered species will tend to contain additional species so that the property of being endangered can no longer be used to discriminate between species. The rank of an endangered species is therefore likely to drop as risk increases, and this is what we see in Tables 10 and 11.

The strongest pair-wise relationship in Table 11 is between rankings W_1 and W_2 which were constructed from answers to questions that did not draw attention to the size of the local bird population put at risk, relative to the world population of the same species. The weakest association is that between the OVI derived ranking and W_3. The W_3 ranking is based on answers to questions that drew the respondents attention to the size of the local population at risk relative to the world population, increasing the absolute level of risk. What is most obvious about these different rankings is the movement of the rank assigned to endangered species. The OVI automatically forces any endangered species - a category defined almost exclusively in terms of numbers of birds - to be ranked as most vulnerable. Our method on the other hand, did not prejudge the relative importance of any particular species, whether or not it was endangered, and we have found a decreasing relative preference for endangered species as perceived risk increases.

Utilizing Ranks. The ordered rankings we have constructed and the OVI of King and Sanger can be used for management decisions when the distance between ranks is not important. This would be the case, for instance, if all the species in one lease-area were ranked lower than all the species in another area, and the higher ranked species were in numbers at least as great as the lower ranked species. It is true that population size is one of the factors in the King and Sanger index but this does not allow one to claim that an OVI score of 80 is twice as large as an OVI score of 40, and this is what is essential if combinations of species with different size local populations are to be compared.

If a selected group of individuals were made available for repeated testing, the methods used in this study would provide an interval scale of vulnerability. Several estimates of the equivalent losses used in our analysis could be used to calculate the distance between ranks so that any combination of ranks and populations could be compared to any other combination. To illustrate, if for a given gamble the sample estimate of the equivalent loss for species with a high reproduction rate was .6 and the sample estimate of the equivalent loss for species with a low reproduction rate was .2 then we could say the latter was rated as three times as vulnerable as the former, i.e. are individual was equivalent to three individuals of the other type.

Several levels of complexity are available with this procedure. We have so far discussed rank order aggregated across subjects and the corresponding interval scales. Management decisions could be made at a lower level of aggregation by using the individual interval scales of each subject to "vote" on alternatives. Each individual, as represented by his or her scale, would indicate yes or no and management could then use the total vote count as an indication of general preference.

A still lower level of aggregation is also available. Our work so far indicates that the way individuals rank order species is fairly constant - except for endangered species - over different gambles, but between rank distances may change and this would affect the evaluation of combinations of species. This problem would be reduced if several scales were constructed for each individual, each scale corresponding to a particular level of risk. If the format of our study were used, every respondent would have three scales of vulnerability, one for each gamble (.25, .50, .75 probability of total loss). Management could then take a vote on alternatives as described in the previous paragraph, using the appropriate scale for individual voters.

Prospect Theory. If management chooses to solicit opinions with questionnaires or especially in an open forum such as a synthesis meeting, they should be aware that "Individuals who face a decisive problem and have a definite preference (i) might have a different preference in a different framing of the same problem (ii) are normally unaware of alternate frames and their potential effects on the relative attractiveness of options, (iii) would wish their preferences to be independent of frame, but (iv) are often uncertain how to resolve detected inconsistencies" (Slovic and Tversky 1974).

The following generic problems (Tversky and Kahneman 1981) illustrate the inconsistencies which may arise when framing effects are not paid attention to (the proportion of respondents preferring each alternative is given in brackets).

Problem 1. [N=152]

Imagine that the U.S. is preparing for the outbreak of a rare Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the program are as follows:

If program A is adopted, 200 people will be saved [72%].

If program B is adopted, there is a 1/3 probability that 600 people will be saved and a 2/3 probability that no people will be saved [28%].

Which of the two programs would you favor?

Problem 2. Same cover story [N=155].

If program C is adopted, 400 people will die [22%].

If program D is adopted there is a 1/3 probability that nobody will die and a 2/3 probability that 600 people will die [78%].

Notice that programs A and C have identical outcomes (400 dead) and programs B and D have identical expected values (400 dead). The only difference in the two problems is the wording of the options and yet the majority of people in the study reversed preference. People tend to value the "sure thing" over a gamble having an expected value equal to the "sure thing". Program A is seen as a <u>gain</u> of 200 lives and is therefore preferred to program B. Program C is seen as a <u>loss</u> of 400 lives and this has a <u>more negative</u> value than the preferred option program D. Frames of reference that interpret as gains or losses can affect preferences.

Another source of difficulty is the tendency to group the costs and benefits associated with an object. "Imagine you are about to buy a jacket for $125 and a calculator for $15. The calculator salesman tells you that the calculator you want to buy is on sale for $10 at the other branch of the store, a 20-minute drive away. Would you make the drive? (Kahneman and Tversky 1982)" The majority of people who answered this question said they would make the trip. However, when another group of respondents were given a similar problem with the cost of the jacket changed to $15 and the cost of the calculator changed to $125 and $120 in the other store, most people said they would not make the trip. In both cases the costs and benefits were the same but a reduction from $15 to $10 was seen as more valuable than a reduction from $125 to $120.

The point we are making with these examples is that carefully worded questions are mandatory if reliably consistent preferences are to be obtained. The questionnaire used in this study was constructed with these considerations in mind and a number of individuals were able to understand the questions and give sensible answers without prompting from us other than the written introduction and directions. We would expect open discussions such as those conducted at synthesis meetings to have little chance at producing a reliable concensus of opinion if a comparable level of attention is not paid to the structure of options.

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PREFACE

George Hunt and I are working on an application of decision theory to the problem of rank-ordering different geographical regions in terms of their environmental sensitivity. We intend to develop a decision rule that incorporates both the best available quantitative field work and the subjective expertise of knowledgeable persons. The enclosed questionnaire is our first attempt at designing a quantitative measure of ecological risk. The answers supplied by yourself and others will provide data necessary for the derivation of a preference structure in the context of bird ecology. This project, funded by the Bureau of Land Management through the National Oceanic and Atmospheric Administration, is primarily concerned with analyzing the risk to Alaska seabirds associated with oil spills, but we believe our methodology can be adapted for applications in other natural situations.

The mathematical details of our methodology will be made available to respondents or other interested parties as requested. In brief, we propose to derive a set of mathematical functions which approximate individual preferences for risky situations. These functions will be combined into a single decision rule and this, in turn, used to rank-order potentially hazardous situations for seabirds. We acknowledge the fact that preferences implied by a group decision are not necessarily identical to those based on any particular individual's preferences, and consequently the particular method used to obtain group choices is likely to be somewhat controversial. We would be most happy to reply to any comments or suggestions you might have concerning this matter. We, of course, are solely responsible for any short-comings of our methodology and do not presume to speak for any person generous enough to contribute to our effort.

INTRODUCTION

As we mentioned previously, our goal is to devise a rule whereby any number of geographical regions can be compared and ranked in terms of their ecological value. To do this we have selected a particular method of quantifying your judgments of relative value that requires a series of choices between hypothetical future events, which can occur for certain, and alternative gambles--or lotteries as they are sometimes called--in which the ultimate outcomes are generally uncertain. This method, as we have interpreted it in the context of bird ecology, is based on research done by Howard Raiffa, Duncan Lute, Amos Tversky, Daniel Kahneman, and others, in the fields of decision theory and the psychology of choice.

To illustrate the ideas underlying our approach, consider first the situation where each possible consequence of an oil spill within a specified region is assigned a cost in dollars and a probability of occurrence so that the sum of all the probabilities equals 1.0. Under these circumstances, one way to rank-order regions is to simply compute the expected dollar cost associated with each region (the cost of each consequence multiplied by its probability, summed over each region) and assign preferences based on the assumption that smaller expected costs are more valued than larger expected costs.

One immediate objection to this scheme is the observation that expected costs do not reflect the full range of consequences of a choice. For example, a region with a 75% chance of a moderate oil spill (estimated cost = $50,000.00) and a 25% chance of a small spill (estimated cost = $30,000.00) would have the same value as a region with a 50% chance of little oil damage ($10,000.00) and a 50% chance of considerable damage ($80,000.00); the expected cost in each region is $45,000.00. It is not unreasonable to suggest some people might consider the latter region to be more risky, especially if $80,000.00 were an intolerable, or unrecoverable loss. Expected value schemes do not take into account factors such as threshold conditions. In fact, when individuals are asked to make real choices with risk involved, they typically do not make their choice based on expected values. This result cannot be interpreted merely as irrational or inconsistent behavior. It is evidence that external factors are commonly taken into account when a choice must be made between risky alternatives. This point of view has led researchers such as those mentioned above to expend considerable effort in perfecting methods for determining mathematical descriptions of the choices people actually make when ranking hypothetical risky outcomes. Their findings (e.g., Schlaifer 1969) form the basis upon which our questionnaire is structured.

Since we are dealing in a context where money is not a direct consideration, we have selected as the unit of analysis individual birds rather than dollars. In an effort to capture some of the complexity of an ecological system, we have included questions which are intended to reveal relationships between different categories of birds and different types of bird habitats. The particular hazardous event we had in mind when constructing the questions is an oil spill which impacts a finite region for a finite amount of time. The consequences of this event are always given as potential levels of bird mortality, in terms of either classifications of birds or classifications of habitat. What we ask is that you place a value on each of the risky sets of consequences we describe.

The complication is that the values you indicate must be in terms of proportions of birds lost, either when the birds are those typically found in the region being considered or when the birds are all members of a particular category. All the questions you will see are composed of two parts, a description of a gamble having two possible consequences and a request for the "sure thing" alternative consequence you judge to be an equivalent substitute for the gamble. With consequences in terms of proportion of birds lost, the gamble in a typical question is phrased thusly: "Suppose within a region x there is a .25 probability of 0% mortality for birds of Type Y and a .75 probability of 100% mortality for birds of Type Y." The value you place on this gamble is the "certain" loss--i.e., a proportional loss with probability I.O--that you would be willing to substitute for the gamble.

1. Given a colony/breeding ground, assume birds of an endangered species will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this endangered species would you accept as an equivalent substitute for the above gamble?

answer ______________

2. Given a colony/breeding ground, assume an endangered species will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this endangered species would you accept as an equivalent substitute for the above gamble?

answer ______________

3. Given a colony/breeding ground assume an endangered species will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this endangered species would you accept as an equivalent substitute for the above gamble?

answer ______________

4. Assume 0% bird losses will occur in a colony/breeding ground with probability 1.0.

Given the same size population in a moulting area, what certain % loss for birds typical of this area would you accept as a substitute?

answer ______________

5. Assume 0% bird losses will occur in a colony /breeding ground with probability 1.0.

Given the same size population in a migratory route, what certain % loss for birds typical of this region would you accept as a substitute?

answer ______________

6. Assume 0% bird losses will occur in a colony/breeding ground with probability 1.0.

Given the same size population in a wintering ground, what certain % loss for birds typical of this area would you accept as a substitute?

answer ______________

7. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .75 and 100% bird losses will occur with probability .25.

Given the same size population in a moulting area, what certain % bird loss would you accept as equivalent to the above gamble?

answer ______________

8. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .75 and 100% bird losses will occur with probability .25.

Given the same size population in a migratory route , what certain % bird loss would you accept as equivalent to the above gamble?

answer ______________

9. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .75 and 100% bird losses will occur with probability .25.

Given the same size population in a wintering ground, what certain % bird loss would you accept as equivalent to the above gamble?

answer ______________

10. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .50 and 100% bird losses will occur with probability .50.

Given the same size bird population in a moulting ground, what certain % loss would you accept as equivalent to the gamble?

answer ______________

11. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .50 and 100% bird losses will occur with probability .50.

Given the same size bird population in a migratory route, what certain % loss would you accept as equivalent to the gamble?

answer ______________

12. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .50 and 100% bird losses will occur with probability .50.

Given the same size bird population in a wintering ground, what certain % loss would you accept as equivalent to the gamble?

answer ______________

13. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .25 and 100% bird losses will occur with probability .75.

Given the same size bird population in a moulting ground, what certain % loss would you accept as equivalent to the gamble?

answer ______________

14. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .25 and 100% bird losses will occur with probability .75.

Given the same size bird population in a migratory route, what certain % loss would you accept as equivalent to the gamble?

answer ______________

15. Assume, at a colony/breeding ground, 0% bird losses will occur with probability .25 and 100% bird losses will occur with probability .75.

Given the same size bird population in a wintering ground, what certain % loss would you accept as equivalent to the gamble?

answer ______________

16. Within a specified area, assume 0% losses for an endangered species has probability 1.0.

a. What certain % loss for a species of large birds would you accept as an equivalent substitute?

answer ______________

b. What certain % loss for a species of small birds would you accept as an equivalent substitute?

answer ______________

c. What certain % loss for a species of game birds would you accept as an equivalent substitute?

answer ______________

d. What certain % loss for a species of subsistence birds would you accept as an equivalent substitute?

answer ______________

e. What certain % loss for a species of Alcids would you accept as an equivalent substitute?

answer ______________

f. What certain % loss for a species of shore birds would you accept as an equivalent substitute?

answer ______________

g. What certain % loss for a species of gulls would you accept as an equivalent substitute?

answer ______________

h. What certain % loss for a species of swans would you accept as an equivalent substitute?

answer ______________

i. What certain % loss for a species of ducks would you accept as an equivalent substitute?

answer ______________

j. What certain % loss for a species of tubenoses would you accept as an equivalent substitute?

answer ______________

k. What certain % loss for a species with a high reproductive rate would you accept as an equivalent substitute?

answer ______________

l. What certain % loss for a species with a low reproductive rate would you accept as an equivalent substitute?

answer ______________

17. Within a specified area, assume endangered species will suffer 0% losses with probabiltiy .75 and 100% losses with probability .25.

a. What certain % loss for a species of large birds would you accept as an equivalent substitute?

answer ______________

b. What certain % loss for a species of small birds would you accept as an equivalent substitute?

answer ______________

c. What certain % loss for a species of game birds would you accept as an equivalent substitute?

answer ______________

d. What certain % loss for a species of subsistence birds would you accept as an equivalent substitute?

answer ______________

e. What certain % loss for a species of Alcids would you accept as an equivalent substitute?

answer ______________

f. What certain % loss for a species of shore birds would you accept as an equivalent substitute?

answer ______________

g. What certain % loss for a species of gulls would you accept as an equivalent substitute?

answer ______________

h. What certain % loss for a species of swans would you accept as an equivalent substitute?

answer ______________

i. What certain % loss for a species of ducks would you accept as an equivalent substitute?

answer ______________

j. What certain % loss for a species of tubenoses would you accept as an equivalent substitute?

answer ______________

k. What certain % loss for a species with a high reproductive rate would you accept as an equivalent substitute?

answer ______________

l. What certain % loss for a species with a low reproductive rate would you accept as an equivalent substitute?

answer ______________

18. Within a specified area, assume an endangered species will suffer 0% losses with probability .50 and 100% losses with probability .50.

a. What certain % loss for a species of large birds would you accept as an equivalent substitute?

answer ________________

b. What certain % loss for a species of small birds would you accept as an equivalent substitute?

answer ________________

c. What certain % loss for a species of game birds would you accept as an equivalent substitute?

answer ________________

d. What certain % loss for a species of subsistence birds would you accept as an equivalent substitute?

answer ________________

e. What certain % loss for a species of Alcids would you accept as an equivalent substitute?

answer ________________

f. What certain % loss for a species of shore birds would you accept as an equivalent substitute?

answer ________________

g. What certain % loss for a species of gulls would you accept as an equivalent substitute?

answer ______________

h. What certain % loss for a species of swans would you accept as an equivalent substitute?

answer ______________

i. What certain % loss for a species of ducks would you accept as an equivalent substitute?

answer ______________

j. What certain % loss for a species of tubenoses would you accept as an equivalent substitute?

answer ______________

k. What certain % loss for a species with a high reproductive rate would you accept as an equivalent substitute?

answer ______________

l. What certain % loss for a species with a low reproductive rate would you accept as an equivalent substitute?

answer ______________

19. Within a specified area, assume an endangered species will suffer 0% losses with probability .25 and 100% losses with probability .75.

a. What certain % loss for a species of large birds would you accept as an equivalent substitute?

answer ______________

b. What certain % loss for a species of small birds would you accept as an equivalent substitute?

answer ______________

c. What certain % loss for a species of game birds would you accept as an equivalent substitute?

answer ______________

d. What certain % loss for a species of subsistence birds would you accept as an equivalent substitute?

answer ______________

e. What certain % loss for a species of Alcids would you accept as an equivalent substitute?

answer ______________

f. What certain % loss for a species of shore birds would you accept as an equivalent substitute?

answer ______________

g. What certain % loss for a species of gulls would you accept as an equivalent substitute?

answer ______________

h. What certain % loss for a species of swans would you accept as an equivalent substitute?

answer ______________

i. What certain % loss for a species of ducks would you accept as an equivalent substitute?

answer ______________

j. What certain % loss for a species of tubenoses would you accept as an equivalent substitute?

answer ______________

k. What certain % loss for a species with a high reproductive rate would you accept as an equivalent substitute?

answer ______________

l. What certain % loss for a species with a low reproductive rate would you accept as an equivalent substitute?

answer ______________

20. Within a specified area, assume large birds will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c. 10% ______________
d. 25% ______________
e. over 50% ______________

21. Within a specified area, assume large birds will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c. 10% ______________
d. 25% ______________
e. over 50% ______________

22. Within a specified area, assume large birds will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______
b. 5% ______
c. 10% ______
d. 25% ______
e. over 50% ______

23. Within a specified area, assume small birds will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______
b. 5% ______
c. 10% ______
d. 25% ______
e. over 50% ______

24. Within a specified area, assume <u>small birds</u> will suffer 0% losses with probability .50 and 100% losses with probability .50.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

25. Within a specified area, assume <u>small birds</u> will suffer 0% losses with probability .25 and 100% losses with probability .75.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

26. Within a specified area, assume <u>game birds</u> will suffer 0% losses with probability .75 and 100% losses with probability .25.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

27. Within a specified area, assume <u>game birds</u> will suffer 0% losses with probability .50 and 100% losses with probability .50.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

28. Within a specified area, assume game birds will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

29. Within a specified area, assume subsistence birds will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

30. Within a specified area, assume subsistence birds will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c. 10% ______________
d. 25% ______________
e. over 50% ______________

31. Within a specified area, assume subsistence birds will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c. 10% ______________
d. 25% ______________
e. over 50% ______________

32. Within a specified area, assume Alcids will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

33. Within a specified area, assume Alcids will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

34. Within a specified area, assume <u>Alcids</u> will suffer 0% losses with probability .25 and 100% losses with probability .75.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

35. Within a specified area, assume <u>shore birds</u> will suffer 0% losses with probability .75 and 100% losses with probability .25.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

36. Within a specified area, assume shore birds will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

37. Within a specified area, assume shore birds will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________

b. 5% ____________

c. 10% ____________

d. 25% ____________

e. over 50% ____________

38. Within a specified area, assume <u>gulls</u> will suffer 0% losses with probability .75 and 100% losses with probability .25.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c* 10% ______________
d. 25% ______________
e. over 50% ______________

39. Within a specified area, assume <u>gulls</u> will suffer 0% losses with probability .50 and 100% losses with probability .50.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______________
b. 5% ______________
c. 10% ______________
d. 25% ______________
e. over 50% ______________

40. Within a specified area, assume gulls will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

41. Within a specified area, assume swans will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

42. Within a specified area, assume swans will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

43. Within a specified area, assume swans will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

44. Within a specified area, assume ducks will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

45. Within a specified area, assume ducks will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

46. Within a specified area, assume ducks will suffer O% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

47. Within a specified area, assume tubenoses will suffer O% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
de 25% ____________
e. over 50% ____________

48. Within a specified area, assume tubenoses will suffer 0% losses with probability .50 and 100% losses with probability ,50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

49. Within a specified area, assume tubenoses will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
. over 50% ____________

50. Within a specified area, assume a species with a <u>high reproductive rate</u> will suffer 0% losses with probability .75 and 100% losses with probability .25.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______
b. 5% ______
c. 10% ______
d. 25% ______
e. over 50% ______

51. Within a specified area, assume a species with a <u>high reproductive rate</u> will suffer 0% losses with probability .50 and 100% losses with probability .50.

What <u>certain % loss</u> for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ______
b. 5% ______
c. 10% ______
d. 25% ______
e. over 50% ______

52. Within a specified area, assume a species with a high reproductive rate will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

53. Within a specified area, assume a species with a low reproductive rate will suffer 0% losses with probability .75 and 100% losses with probability .25.

What certain % loss for this species would you accept as an equivalent substitute? if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

54. Within a specified area, assume a species with a low reproductive rate will suffer 0% losses with probability .50 and 100% losses with probability .50.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

55. Within a specified area, assume a species with a low reproductive rate will suffer 0% losses with probability .25 and 100% losses with probability .75.

What certain % loss for this species would you accept as an equivalent substitute, if the local population totaled:

a. 1% of the world population? ____________
b. 5% ____________
c. 10% ____________
d. 25% ____________
e. over 50% ____________

Appendix B

Selected comments of respondents

"Although I hate to make value judgments in these hypothetical situations, I agree with you that it is better to make the value judgments on biological bases rather than let developers and oil companies make them on other bases."

"Sorry - I just don't have time to do this justice - if that is, indeed, possible. I'd be happy to comment on specific cases but I can't deal with these questions biologically - there are too many uncertainties. I would suggest, however, that our concern, as a nation, with 'endangered species' hasn't done us or wildlife much good."

*'I feel very uneasy about my responses . . . . Are you asking which species are more highly valued - large, small, alcids, swans, etc.? If one believes in equality of species, no such judgments are appropriate."

". ..Also, transfixation of attention on large oil spills is a totally unrealistic view of reality, when the chronic, low level pollution is far more important. The questionnaire cannot be generalized; it would be easier if the real situation was presented and more valid, too."

"My experience in real life has been that survival of any individual bird is secondary to the protection of habitat and salmonid habitat in particular... I accepted a much more dangerous gamble for expanding species (Trumpeter Swans, Brandts, Cormorants, Glaucous-winged Gulls) and for boom-bust reproductive strategists such as game birds and shore birds . ..theoretical species identity changed as I progressed through the lists of increasing percent of the world's population."

"'I accept that these are the questions you have to ask yourself when the crunch comes, but I don't see much point in asking them in the abstract, in advance. Theyhave to be asked about an actual situation, even if they have to be asked in a hurry. I'm always saying this to people who draw up elaborate contingency plans for emergency oil spill operations - they're of very little use in practice because no oil spill yet, to my knowledge, has ever been quite like any preceding one."