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Why do People Care about Sea Lions? A Fishing Game to Study the Value of Endangered Species

Min Gong · Geoffrey Heal

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Abstract Previous research proposes that human beings are motivated to protect endangered species for various reasons: consumptive use value, non-consumptive use value, non-use value, and intrinsic value. However, it has been difficult to tease apart these values at the behavioral level. Using an innovative fishing game, we study an important tradeoff between one kind of use value (monetary value) and one kind of non-use value (existence value) of the endangered Steller sea lion. In the fishing game, players make repeated decisions on how much pollock to harvest for profit in each period in a dynamic ecosystem. The population of the endangered sea lion depends on the population of pollock, which in turn depends on the harvesting behavior of humans. The data show that in general, people responded to the financial value (as a tourist resource), but not the existence value, of the sea lion by cutting down commercial fish harvesting to keep more sea lions in the ecosystem. However, not all people behaved the same regarding the existence value. Females displayed a higher existence value than males, as did people who reported stronger pro-environmental attitudes than those with weaker pro-environmental attitudes. Our findings have multiple implications on public opinion elicitation and public policy design.

Keywords Endangered species · Valuation · Behavior economics · Fishery game · Resource management

M. Gong
Altisource, 380 Knollwood Street, Winston Salem, NC 27103, USA

M. Gong (✉)
Columbia University, Center for Research on Environmental Decisions, 406 Schermerhorn Hall - MC 5501, 1190 Amsterdam Ave, New York, NY 10027, USA
e-mail: mingong@gmail.com

G. Heal
Columbia University, New York, NY, USA

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1 Introduction

Why do people value endangered species? Scientists have been arguing that endangered species matter to humans for two rather different classes of reason. One is that endangered species may have intrinsic value, value which is independent of its usefulness to us. Other species may be thought to have a right to exist whether or not they are helpful to the hegemonic species: they may be regarded as part of "the creation" and meriting conservation for this reason. This is the argument behind the US Endangered Species Act, which courts have interpreted as stating that species have a right to exist whatever the economic cost of conserving them (Callicot 2006).

The other is the instrumental value of endangered species: it has value to us and its existence increases our welfare. Economists have focused on the instrumental value of endangered species and categorized it into two classes, use and non-use values (Freeman AM 2003; Barbier 2011).Use values, including both consumptive and nonconsumptive use values, usually involve direct interactions with the species, while nonuse values do not. Typical use values are species harvesting, recreation values, and environmental functions such as erosion prevention. For example, Heal (2000) suggests multiple sources of usevalue for biodiversity, including inter alia: value as a source of genetic information (Simpson et al. 1996; Rausser and Small 2000), as in bioprospecting; value in increasing the resilience of natural ecosystems (Tilman et al. 1998; Naeem and Li 1997); value as an insurance against threats to an important food crop; and value in ecotourism. The two most frequently mentioned nonuse values are cultural heritage and existence value, the latter being defined as the benefit people receive from knowing that an endangered species exists (Barbier 2011).

That people recognize multiple reasons for protecting endangered species has been confirmed in public opinion surveys. For example, in a large-scale survey of 25,000 participants in the EU's 27 member states on stopping biodiversity loss (which includes protecting endangered species), 61 % of the participants agreed that it was a moral obligation to stop biodiversity loss. 55 % agreed that the conservation of biodiversity was important because biodiversity was indispensable for the production of food, fuel and medicines, or because biodiversity loss would probably have economic consequences for Europe (European Commission 2007).

In general, the conservation of endangered species has been promoted by conservation organizations mainly for its intrinsic value or non-use values, particularly existence value. They have argued for conservation on the grounds that other species, particularly charismatic ones such as whales and great cats, have a right to exist and are an intrinsically important part of our common heritage. We compiled a list of the largest conservation sites by scanning through the initial 10 pages of both Yahoo and Google search responses to "protect endangered species" and "protect biodiversity" and several informal online lists, as well as directory services such as Charity Navigator for any relevant organizations that the initial search may have missed. We identified 17 conservation organizations that have an annual avenue of $2 million or above, as listed in "Appendix 1". Out of the 17 sites, only one site mentioned use value on the front page. All 17 sites had pictures of charismatic species on their front pages, which implicitly invokes intrinsic or nonuse value. Six sites mentioned existence right or cultural heritage explicitly.

Although much research has been performed on economic role of endangered species from the perspective of use values (Swanson TM and Barbier EB 1992; Barbier et al. 1994), the argument that the endangered species matter to us because of its use value is not one that has been deployed widely in attempts to persuade the general public of the merits of conservation, as discussed in the previous paragraph. Yet from an economic perspective it appears that it should be a persuasive argument, capable of appealing even to those who have little empathy for the plights of other species, and no belief in their rights to exist. In short, it could be a more effective argument than an argument for conservation based on ethics or empathy. In this paper we test this idea: we investigate whether for a campus population at a north-eastern research university, a population that might be expected to be sympathetic to the rights of other species and of the environment in general,the use value or existence value arguments are more persuasive. We conclude unambiguously in favor of the former: use value clearly trumps existence value in influencing choices in a game that reproduces the tradeoffs between making profits and conserving endangered species. The relative importance of use versus existence values is shown to depend on demographic and psychological characteristics, but use values are always the more important. This has clear implications for the effectiveness of different ways of presenting the case for conservation of endangered species.

We test these ideas by allowing subjects in an experimental process to play a game. They assume the role of fishermen, fishing for pollock, a fish that is abundant in the Pacific Ocean. pollock are both a predator and a prey in their ecosystem: they eat smaller organisms and are themselves preyed on by Stellersea lions, a species recognized as endangered under the US Endangered Species Act. Fishermen compete with sealions for pollock, and are responsible for reducing the pool of food available to sea lions. This means that successful fishing reduces the population of a charismatic endangered species, and participants in the game are made aware of this competition by reading a single page article (included in Appendix 7) published by Oceana, an international organization focused solely on ocean conservation. We investigate the impact on fishing choices of various ways of highlighting the value of the endangered species, emphasizing either the use value or the existence value aspects.

2 Experimental Design

2.1 Game Design

Participants were given the ecosystem map shown in Fig. 1, based on the ecosystem of the Eastern Bering Sea (Finnoff and Tschirhart 2003; Finnoff and GongM 2012). The key species were the pollock that was commercially harvested for profit, and the Steller sea lion that preyed on pollock. The Steller sea lion was listed as endangered under the Endangered Species Act (1990). The population of the sea lion is a monotonically increasing function in the population of pollock. The pollock growth follows a logistic function in the pollock population, and is decreasing in the sea lion population.

Each participant decided how much pollock to harvest in each period of a 10-period game. Their final payoff for participating depended on the total profit they accumulated in the game. We used an experimental currency called Talers to represent the participants' profits. 10,000 Talers were exchangeable for $1 at the end of the study.

The study applied a 2 (with or without use value) $\times$ 2 (with or without existence value) between-subject design. The use value of the sea lion is measured by the monetary value generated from selling tickets for watching sea lions. The existence value is measured by donations made to the Alaska Sealife Center, an environmental organization devoted to protecting sea life. There were four treatments:

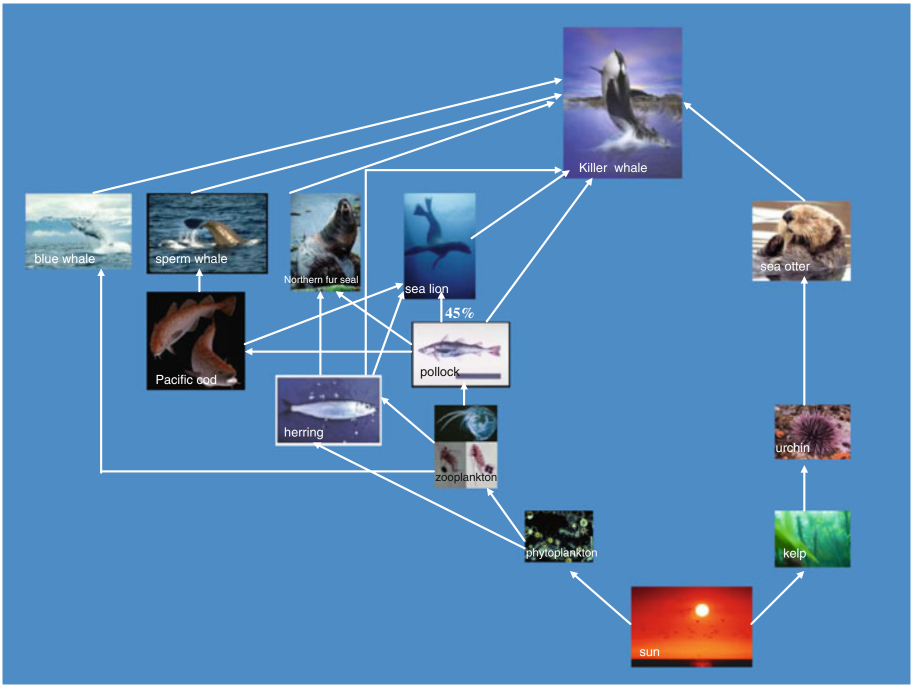

Fig. 1 The ecosystem map in the fishing game

Treatment 1 (Baseline): Participants profit from pollock harvesting. The profit is increasing in both the harvest level and the population of pollock[1]. An instruction sample for Treatment 1 is included in "Appendix 2".

Treatment 2 (Monetary Value of Sea Lions): Participants profit from pollock harvesting. The profit is increasing in both the harvest level and the population of pollock. In this case participants also profit from selling sea lion watching tickets. The sea lion profit is increasing and linear in the sea lion population. Each unit of sea lion yields 30 Talers in profit.

Treatment 3 (Existence Value of Sea Lions): Participants profit from pollock harvesting. Profit increases with both the harvest level and the population of pollock.The Alaska Sealife Center receives a donation that is increasing and linear in the sea lion population. Each unit of sea lion adds 30 Talers to the donation. Information on the endangered sea lion and the Alaska Sealife Center were provided together with the instruction sheet.

Treatment 4 (Monetary Value and Existence Value of Sea Lions): Participants profit from pollock harvesting. The profit is increasing in both the harvest level and the population of pollock. Participants also profit from selling sea lion watching tickets. The sea lion profit is increasing and linear in the sea lion population. Each unit of sea lion yields 15 Talers in profit.The Alaska Sealife Center receives a donation that is increasing and linear in the sea lion population. Each unit of sea lion yields 15 Talers in the donation.Information on the endangered sea lion and the Alaska Sealife Center were provided together with the instruction sheet.

Table 1 shows howthe financial and existence values of the sea lion and pollock are presented in each treatment.

[1] The profit is increasing in both the harvest level and the population of pollock so that the players will not deplete the stock in the last period. In addition the formulation chosen is concave in H, showing diminishing returns to within-period harvesting.

Table 1 Values in the four treatments

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Financial value of sea lion	No	Yes	No	Yes
Existence value of sea lion	No	No	Yes	Yes
Financial value of pollock	Yes	Yes	Yes	Yes
Existence value of pollock	No	No	No	No

2.2 Theoretical Solutions

Formally in the baseline (Treatment 1) problem, participants conceptually solved the following dynamic optimization problem (1).

$$\begin{aligned} &\underset{H_t}{Max} \textstyle\sum_{t=1}^{10} H_t(N_t - H_t) \\ &s.t. \\ &N_{t+1} = N_t + G_t - H_t \\ &S_t = 10\sqrt{N_t} \\ &G_t = 0.4N_t \left(1 - \tfrac{N_t}{300}\right) \Big/ \left(\tfrac{S_t}{100}\right) \\ &N_1 = 250 \\ &H_t \leq N_t \end{aligned} \tag{1}$$

Here N_t is the pollock population at time t; H_t is the harvesting amount at time t; G_t is the growth at time t; S_t is the sea lion population at time t; and the starting population of pollock at time 1 is 250 units. The dynamic design is similarto the predator-prey model in Allman and Rhodes (2004).

In the three treatments with sea lion value, participants conceptually solved the following problem (2) to maximize individual profit in Treatment 2 and maximize social welfare in Treatments 3 and 4. The term 30St represents the financial value of the sea lion and goes to the participant's profit in Treatment 2, and the existence value of the sea lion and goes to the Alaska Sealife Center in Treatment 3. In Treatment 4, the participant receives half of the sea lion value (15St), and the Alaska Sealife Center receives the other half. Mathematically, the total value takes the same form in Treatments 2, 3 and 4.

Note that in Treatments 3 and 4, if the participants do not maximize the social welfare, which is probably true for most people, then there is no explicit representation of existence value in the maximand: players choose a tradeoff between the existence value of sea lion and profits of harvesting pollock and selling sea lion watching tickets subjectively. Furthermore, if participants in Treatment 3 and 4 maximize their own profit instead of social welfare, they solve problem (1) instead in case 3 and problem (2) in case 4.

$$\begin{aligned} &\underset{H_t}{Max} \textstyle\sum_{t=1}^{10} H_t(N_t - H_t) + 30S_t \\ &s.t. \\ &N_{t+1} = N_t + G_t - H_t \\ &S_t = 10\sqrt{N_t} \\ &G_t = 0.4N_t \left(1 - \tfrac{N_t}{300}\right) \Big/ \left(\tfrac{S_t}{100}\right) \\ &N_1 = 250 \\ &H_t \leq N_t \end{aligned} \tag{2}$$

The maximum values in (1) and (2) are 50,972 Talers and 93,446 Talers, respectively. Figure 2 maps the optimal harvest paths over time.

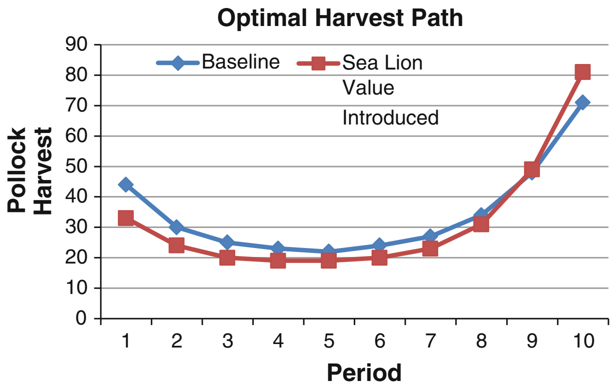

Fig. 2 Optimal harvest paths with and without sea lion value

2.3 Participants and Procedure

There were 115 participants in the study, of whom 62 % were females, and the majority of the participants were either between 18 and 24 (61 %) or between 25 and 34 (34 %). All were paid $6 for showingup plus the profit they accrued in the game.

The study was conducted in the behavioral labs of a Northeastern university. The game interface was coded in Java. Each player was provided with a personal computer in a separate cubicle to play the game. Each participant was probably aware of the existence of other participants, but not of the task that the other participants were performing. Conversations among participants were not allowed.

After reading the instructions, participants completed a set of quiz questions to ensure that they understood the game rules and how the ecosystem dynamics worked. No one reported difficulty finishing the quiz.Following the quiz, the participants were given an opportunity to practice the game. Some flexibility was allowed regarding the practice procedure. For example, scratch paper and pencils were provided. If someone wanted to use their own calculator, they were permitted to do so. During the practice mode, participants could practice as many times as they wished, and could quit in the middle of a practice game to start over. The scheduled length for the entire game (practice included) was 30 min. Most participants finished the task in approximately this time. In the cases where some participants spent more time practicing, extra time was allowed. All participants were required to finish at least one complete practice game (10 periods) before they could play the real game.

After playing the game, participants completed a short survey on their demographics and environmental attitudes. We used the New Ecological Paradigm (NEP) scale (Dunlap and LiereKD 2000) to measure participants' pro-environmental orientation.

At the end of the study, participants were paid for their profits and told that their donations to the Alaska Sealife Center would be made after the data collection was completed. A total donation of $187 was made on behalf of the participants 2 months later, and all participants received a notice about the donation.

2.4 Hypotheses Derived from Previous Literature

As reviewed in Sect. 1, based on previous literature on the biodiversity value, we hypothesized the following:

H1: People value endangered species—when sea lions have a positive value, participants will conserve more sea lions.
H1a: H1 is true when sea lions have a monetary value.
H1b: H1 is true when sea lions have an existence value.

Another set of hypotheses we tested in the current research are connected with individual characteristics related to a person's existence value for the endangered species. Previous research has found that an individual's environmental attitude can be partly predicted by his or her past experiences and background (Gifford et al. 1982). Females display higher environmental concerns in general (Zelezny et al. 2000). For example, females have a higher willingness to pay for an environmental good, such as a recycling service, than males (Gong and Aadland 2011). Past research also suggests that younger people and those who have a higher education level often are more concerned with environmental problems than older people and those who have a lower education level (Hunter et al. 2004; Rasinski et al. 1994).

Assuming that people's existence value of endangered species is correlated with their environmental attitude, we hypothesized the following.

H2: Donations to the Alaska Sea Life Center can be predicted by people's environmental attitudes and their demographic characteristics.
H2a: Donations are positively correlated with the NEP attitude measure.
H2b: Females donate more than Males.
H2c: Donations are negatively correlated with the age.

3 Results and Data Analyses

3.1 The Actual Harvest Path in the Game

Figure 3 shows the average harvest behavior in each period in the four treatments. Surprisingly, many participants were able to replicate the U-shape harvest path, the optimal solution in Fig. 2. Although this is not the focus of the current paper, we suspect that the practice experience contributed greatly to the learning process. The practice data is available upon request.

Note that, compared with the optimal harvest path in Fig. 2, players tended to over-fish in the middle periods resulting in a lower population (harvest) in the last period. This was true for both the baseline treatment and the three treatments with biodiversity value.

3.2 Do People Value Endangered Species?

To test H1, we regressed the sea lion population as the dependent variable on the following explanatory variables: whether there is a positive value on sea lions (No in Treatment 1, and Yes in others), Practice effort (number of periods the participants volunteered to practice), and Period # in which the harvest decision was made. Since each participant made 10 harvest decisions, a random effect variable was included to control for individual differences of the participants. The results are reported in Table 2.

Confirming H1, people conserved more sea lions when a positive value of the sea lion was introduced ($p = 0.025$, one tail t test). No significant effect was found on how many practice periods participants decided to use before playing the real game. The lack of the significance in the practice effort indicates that the difference in people's harvest behavior was not because of their difference in intelligence or learning process.

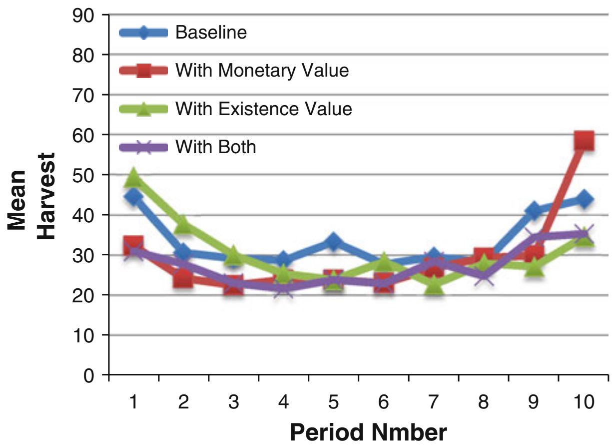

Fig. 3 The actual harvest path in the game

Table 2 Random effect regression on positive sea lion value

Variable	Coefficient	Standard error	t value	Pr(>|t|)
Dependent variables				
Sea lion population				
Independent variables				
Constant	143.8	4.61	31.17	0.00
Positive sea lion value	10.22	5.24	1.95	0.05
Practice effort	0.001	0.01	0.01	0.99
Fixed effects				
Period	−4.42	0.15	−29.29	0.00
Random effect				
Participant	Standard deviation =23.96			
Log likelihood	−4,913			
Sample size	1,150			

3.3 Why do People Value Endangered Species?

We tested two underlying motivations based on previous research: use value in the form of monetary value received from selling sea lion watching tickets, and existence value in the form of donations made to the Alaskan Sealife Center.

The random effect regression in Table 3 shows that people responded to the monetary value of sea lion by keeping more sea lions, confirming H1a ($p < 0.01$). However, this was not true for the existence value of the sea lion, resulting in a rejection of H1b.

Note that the rejection of H1b from the regression only shows that people on average did not adjust their harvesting levels when the existence value was introduced into the game. It does not imply that no participants held existence values. The survival and prosperity of numerous donation-dependent organizations devoted to animal protection indicate that many people put a positive value on the existence of other species. As will be discussed in Section 3.4, there were significant individual differences in terms of valuing the existence of sea lion.

Table 3 Random effect regression on monetaryand existence values

Variable	Coefficient	Standard error	t value	Pr(>|t|)
Dependent variable				
Sea lion population				
Independent variables				
Constant	143.8	4.53	31.70	0.00
Monetary value	0.58	0.20	02.86	0.00
Existence value	0.11	0.20	0.53	0.59
Practice effort	−0.001	0.01	−0.09	0.93
Fixed effects				
Period	−4.4	0.15	−29.29	0.00
Random effect				
Participant	Standard deviation = 23.53			
Log likelihood	−4,914			
Sample size	1,150			

3.4 Individual Behavior in the Game

3.4.1 Individual Differences in the Existence Value

To investigate the systematic individual differences in valuing the existence of endangered species, we regressed the donations in Treatments 3 and 4 on a list of demographics and NEP score. As shown in Table 4, donations were positively correlated with NEP score ($p = 0.05$ one-tail t test), confirming H2a. Also consistent with H2b, we found that females donated more than males ($p < 0.01$). However, H2c, the age hypothesis, was rejected. Moreover, the data indicates that the opposite of H2c was true. That is, the donation was positively correlated with age, instead of the negative relationship proposed in H2c. One possible reason for the rejection of H2c is because of the lack of age variance among participants. 61 % of participants were between 18 and 24 and 34 % of them were between 25 and 34. The positive correlation between age and donation may be the result of a more flexible budget held by

Table 4 Individual differences in existence value

Variable	Coefficient	Standard error	t value	Pr(>|t|)
Dependent variable				
Donation				
Independent variables				
Constant	21,216.09	3,464.91	6.12	0.00
NEP score	90.05	54.62	1.649	0.10
Gender	−6,931.95	908.7	−7.628	0.00
Age	4,302.74	821.77	5.236	0.00
Education	527.77	267.56	1.973	0.05
Income	−112.55	163.05	−0.69	0.49
Practice	−76.55	1.24	−6.809	0.00
Sample size	569			

the relatively older participants of a generally young sample. Note that participants in both Hunter et al. (2004) and Rasinski et al. (1994) who showed a negative relationship between age and pro-environmental attitudes were from the International Social Survey Program, and had a wide age range from early adulthood to octogenerian.

In the current design, the differences in donations between males and females might exist for two reasons. Females may have donated more than males because they valued the existence of the sea lion more, or because they were better at fishery management than males, or both. Similar reasoning applies to the donation differences between participants who had higher NEP scores and those who had lower scores. In the next section, we discuss the existence of individual differences in resource management.

3.4.2 Individual Behavior in Resource Management

The harvest paths of all participants are shown in "Appendixes 3–6". The green line represents the actual harvesting behavior and the red line shows the optimal. Each small graph represents the behavior of one participant. As shown in the 115 individual graphs, although the collective behavior of the participants in Fig. 3 is generally consistent with the theoretical U-Shaped optimal path in Fig. 2, there are large individual differences among participants.

For example, in the baseline treatment, Participant 13's strategy was very close to the optimal path, resulting in a high profit of 49,249 Talers. This participant practiced 90 periods before playing the real game. She said that her strategy was to "harvest moderately then harvest half the remaining pollock in round 10." On the other extreme, Participant 28 practiced 20 periods, and harvested too much in the beginning. Her profit was only 262 Talers. In her comments, she said "you should force more than one practice!" Note that the majority of the participants behaved more like Participant 13 than Participant 28. The second lowest profit in the baseline treatment was 26,676 Talers, and the average profit was 38,674 Talers. The maximum possible profit was 50,972 Talers.

To study the systematic individual differences in resource management efficiency, we analyzed the data from Treatments 1 and 2 where there was no existence value, and participants were inclined to maximize their profit from commercial pollock harvests and sea lion ticket sales.

Regression results in Table 5 show that there was no significant gender difference in terms of earning higher profits ($p > 0.05$), which indicates that the gender difference in donations was not a result of females being more efficient at resource management. However, profit was

Table 5 Individual difference in payoff maximization success

Variable	Coefficient	Standard error	t value	Pr(>|t|)
Dependent variable				
Donation				
Independent variables				
Constant	63,893.18	6,582.61	9.720	0.00
NEP score	240.09	115.72	2.075	0.04
Male	3,519.75	2,075.9	1.696	0.09
Age	−6,047.07	1,979.48	−3.055	0.00
Education	−3,447.57	608.42	−5.666	0.00
Income	309.22	366.96	0.843	0.40
Practice	167.01	21.81	7.659	0.00
Sample size	569			

positively correlated with the NEP score, which means that those who are more pro-NEP may have been better at the game, resulting in a higher donation. A possible explanation is that those pro-NEP people understood the complex nature of the ecosystem better and therefore developed a more useful strategy.That is, there are at least two reasons why the more pro-NEP people donated more than less pro-NEP people: pro-NEP people valuing the existence value of sea lion more, and being better at resource management.

Another interesting predictor of how well people did in maximizing their payoffs was the practice effort measured by the practice periods the participants decided to play. Not surprisingly, practice effort was positively correlated with the payoff. The more participants practiced, the better they did in the game. Age and education were negatively correlated with the payoff. However, given the lack of variety in age and education level in our sample, it is probably inappropriate to draw general conclusions on the age or education effect from these data.

4 Discussion and Conclusions

Previous research suggests that people are motivated to protect endangered species for a variety of reasons: non-consumptive use value, non-use value, and intrinsic value.The current research designs and implements an innovative fishing game to tease apart two kinds of values, use value and existence value, that underlying the seemingly altruistic behavior of humans to care about endangered species.

Our results show that (1) people do put a positive value on endangered species; (2) in general, people respond more to the use value than to the existence value; (3) there are systematic individual differences regarding the existence value. Females displayed a higher existence value than males, as did people who reported stronger pro-environmental attitudes than those with less pro-environmental attitudes.

Our findings have multiple implications for public opinion elicitation and public policy design.As mentioned in the introduction section, the conservation of endangered species has been promoted by conservation organizations mainly for its non-use or intrinsic values. Our findings suggest that it is important to highlight not only the existence right of the charismatic species, but also the use value of the endangered species to human beings. Furthermore, it is probably more efficient and effective to spend a limited budget to focus on the use value than the intrinsic or non-use value, when conservation organization market their causes, or when the government conducts a campaign to educate the public about value of endangered species.

As the first attempt to study values of the endangered species using incentive compatible games, the current study has much room for improvement for future research. First, we investigated only one kind of use value (monetary value) and one kind of non-use value (existence value). People may respond differently to other kinds of value. Second, the student sample lacks diversity in age and social-economic status. The fact that we found systematic individual differences even with such a relatively universal sample indicate the importance of running the study using a general public sample. All these can be interesting directions for future research.

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Appendix 1: List of 17 Largest Conservation Organizations

This list is meant to consist of the largest organizations devoted to biodiversity. The criterion for size of organization, was reporting annual revenue of more than $2 million. In some instances, environmental problems other than biodiversity are focused on as well by these groups, but biodiversity is a prime focus for all organizations included.

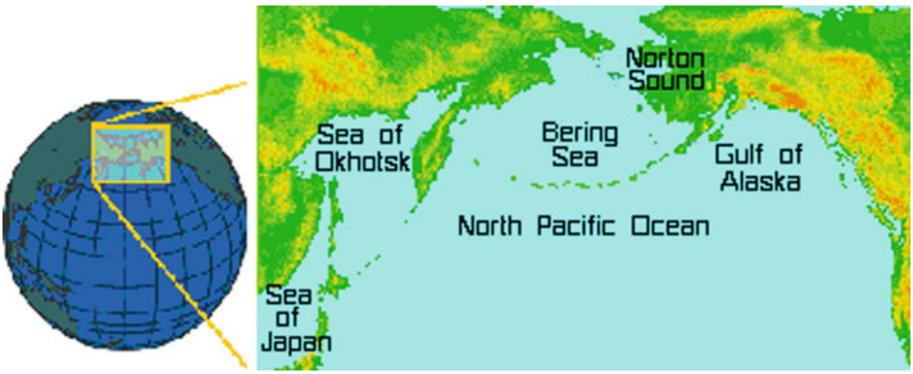
This list was compiled by first scanning through the initial 10 pages of both Yahoo and Google search responses to "protect endangered species" and "protect biodiversity." Second, several informal online lists, as well as directory services such as Charity Navigator, were looked over to find any relevant organizations that the initial search may have missed.

The list includes (in order of size):

1 The Nature Conservancy
2 Wildlife Conservation Society
3 World Wildlife Fund
4 The Royal Society for the Protection of Birds
5 National Wildlife Federation
6 International Union for Conservation of Nature
7 Conservation International
8 National Audubon Society
9 Defenders of Wildlife
10 African Wildlife Foundation
11 Oceana
12 Center for Biological Diversity
13 EcoHealth Alliance
14 Amazon Conservation Team
15 Fauna and Flora International
16 National Wildlife Refuge Association
17 World Land Trust—US

Appendix 2: Instructions

In this study, you will play a fisherman's game. As a fisherman in the Eastern Bering Sea, you have to make a decision on how much Pollock you will harvest in each period. The following maps show the location of the Eastern Bering Sea.



Each period, you earn units of an experimental currency called Talers by harvesting the Pollock. The game always lasts 10 periods. The Talers you earn in each period accumulate

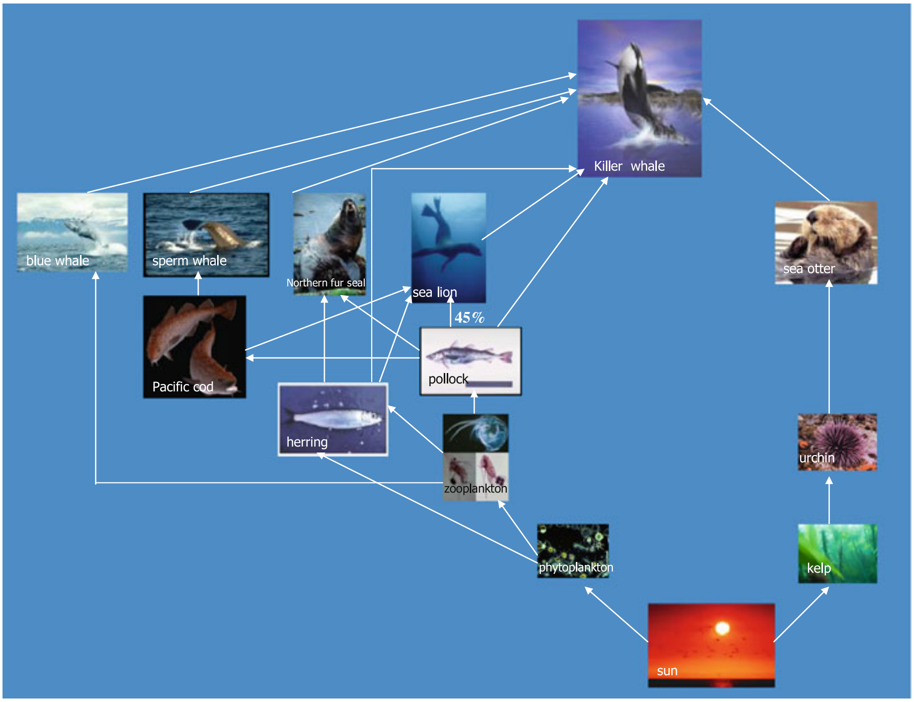


Fig. 4 The ecosystem in your territory

over time, and will determine your final payoff. 10,000 Talers are exchangeable for \$1. To illustrate, suppose at the end of the game, Participant 3 has 80,000 Talers and Participant 5 has 40,000 Talers. Participant 3 will be paid \$8 (80,000 Talers) + \$6 fee = \$14. Participant 5 will be paid \$4 (40,000 Talers) + \$6 fee = \$10.

Figure 4 presents an ecosystem map of your territory. There are 13 species in your fishing area. Arrows indicate predator-prey relationships. As shown in the map, Pollock preys on zooplankton, and is food to several marine mammals. For example, Pollock accounts for 45 % of a sea lion's diet. In each period, the population of sea lions is approximately half of the population of Pollock.

The Pollock population in the first period is 250 units. The growth of the Pollock in each period depends on both the current population of the Pollock and on that of its predator, sea lion. In general, the higher the Pollock population is, and the lower the sea lion population is, the faster the growth of the Pollock will be. But because the ecosystem has limited resource to sustain the Pollock growth, when the Pollock population is too high, the growth rate may slow down.

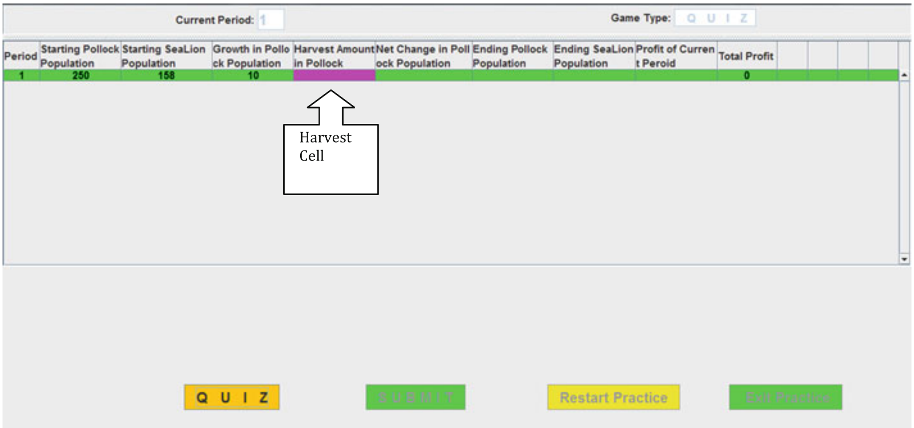
In period t, the Pollock's population equals to its population in the previous period (Period (t−1))+ Growth in Period (t−1))—your harvest in Period (t−1)). For example, suppose that the pollock population in Period 2 is 200, the growth is 19, the harvest is 30, then the population of Pollock in Period 3 = population of Pollock in Period 2 + growth in Period 2—harvest in Period 2 = 200 + 19−30 = 189.

The sea lion's population depends on that of its prey, the Pollock. The higher the Pollock population is, the higher the sen lion's population.

The mathematical growth formula of Pollock is presented in the "Appendix", if you are interested in the details.

In each period, the current status of the ecosystem will be presented on the screen, as shown on the next page. You will then make a decision on how much Pollock to harvest. Your profit depends on both how much you harvest and how large the Pollock population is: Profit = Harvest × (Population−Harvest). For example, if you harvest H units of Pollock in the 4th period, and the Pollock population in that period is 180 units, then your profit in the 4th period is H × (180−H) Talers.

To play the game, you will need to complete a few quiz questions. After the quiz, you will see the following decision page. You need to click the harvest cell, then hit ENTER to put in your desired harvest amount. To prevent accidental harvesting, in each period, you need to click SUBMIT at the bottom of the decision page to submit your harvest. That is, there are 3 steps: (1) type the amount in the harvest cell; (2) enter the number in the cell by hitting ENTER; (3) submit the number by clicking SUBMIT.



You can practice with the game before playing it for real to better understand how harvest impacts Pollock population, and how the ecosystem responds to your harvests. The current practice can be restarted anytime you click "Restart Practice." If you would like to quit practice and play the game for real, please click "Exit Practice". The Exit icon works only after you have completed the practice game at least once. Note that if you exit the practice mode and play the game for real, you cannot go back to the practice mode.

Please raise your hand if you have any question. Otherwise, please click Quiz to start the game.

The Growth Function of Pollock

Mathematically, the growth of Pollock follows the function below:

$$\text{PollockPopulation} = 100 \times 0.4 \times \text{PollockPopulation} \times \left(1 - \frac{\text{PollockPopulation}}{300}\right) \Big/ \text{SealionPopulation}$$

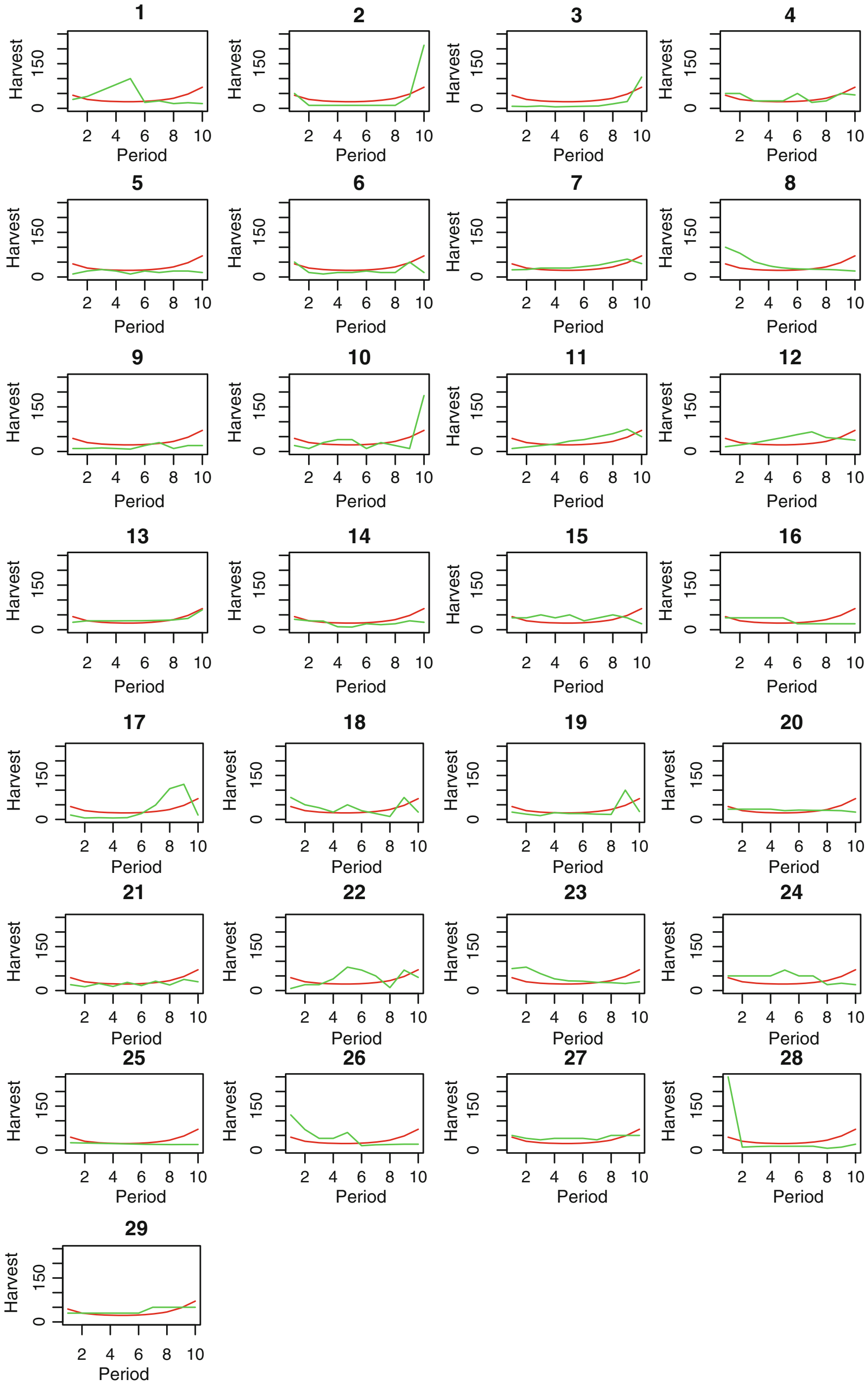
where

$$\text{SealionPopulation} = 10 \times \sqrt{\text{PollockPopulation}}$$

For example, suppose that the pollock population in Period 2 is 200, the population of sealion in Period 2 is $10 \times \sqrt[2]{200} = 141$, the growth of Pollock in Period 2 is $100 \times 200 \times (1 - \frac{200}{300})/141 = 19$.

Suppose you harvest 30 in period 2, then the Pollock population in Period 3 = population of Pollock in Period 2 + growth in Period 2—harvest in Period 2 = 200 + 19 − 30 = 189.

Appendix 3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Harvest
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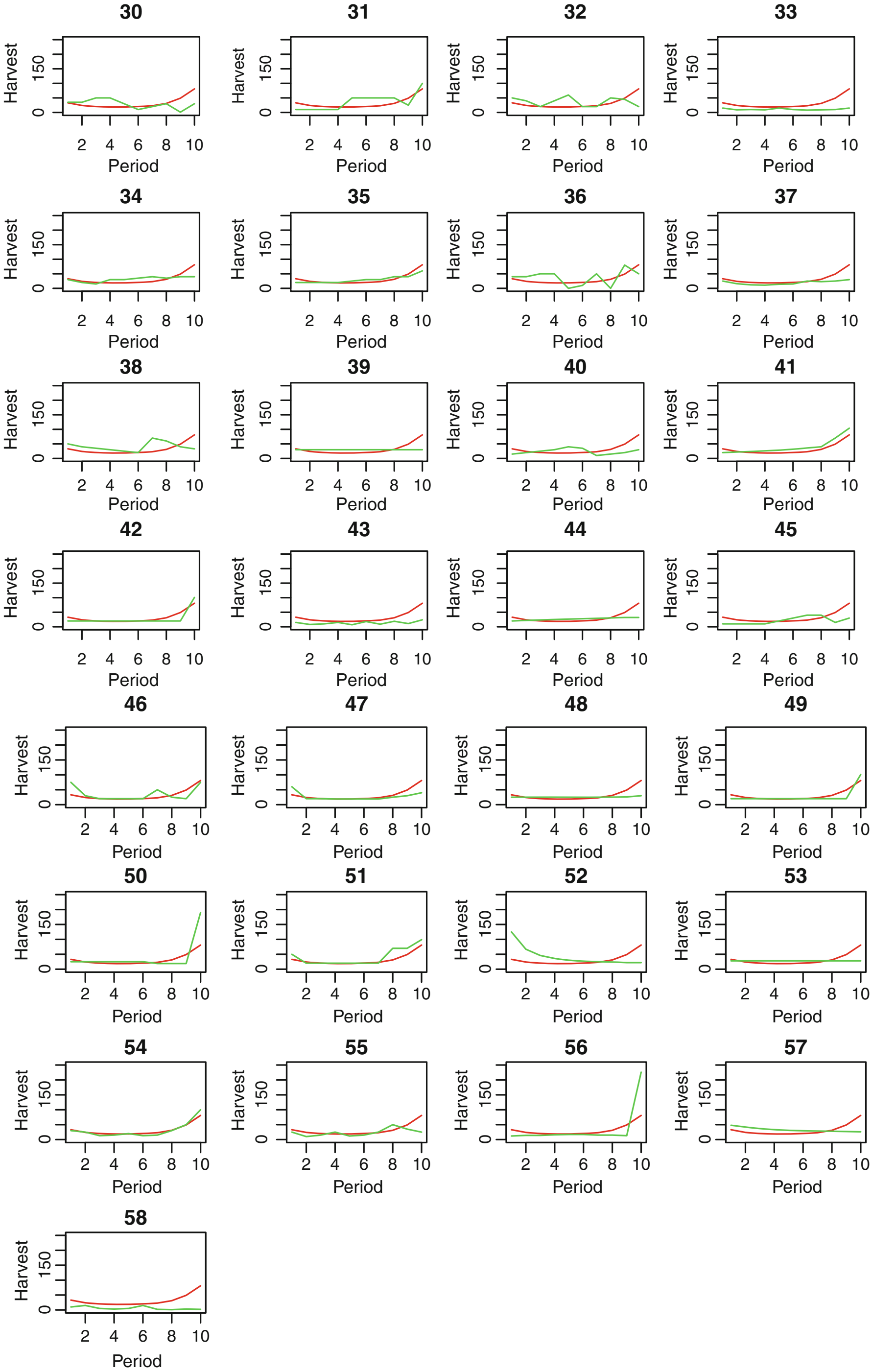
Appendix 4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Harvest
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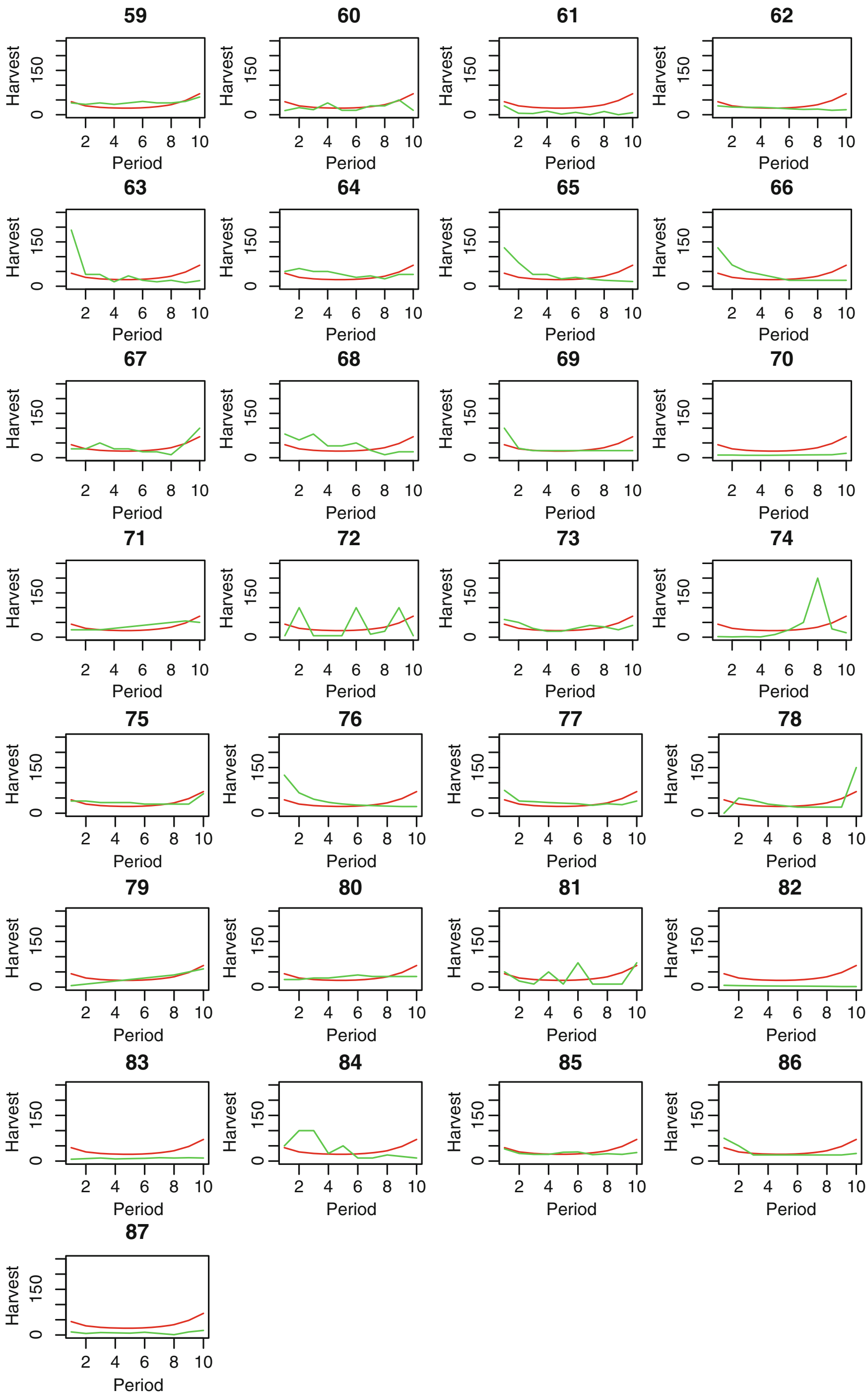
Appendix 5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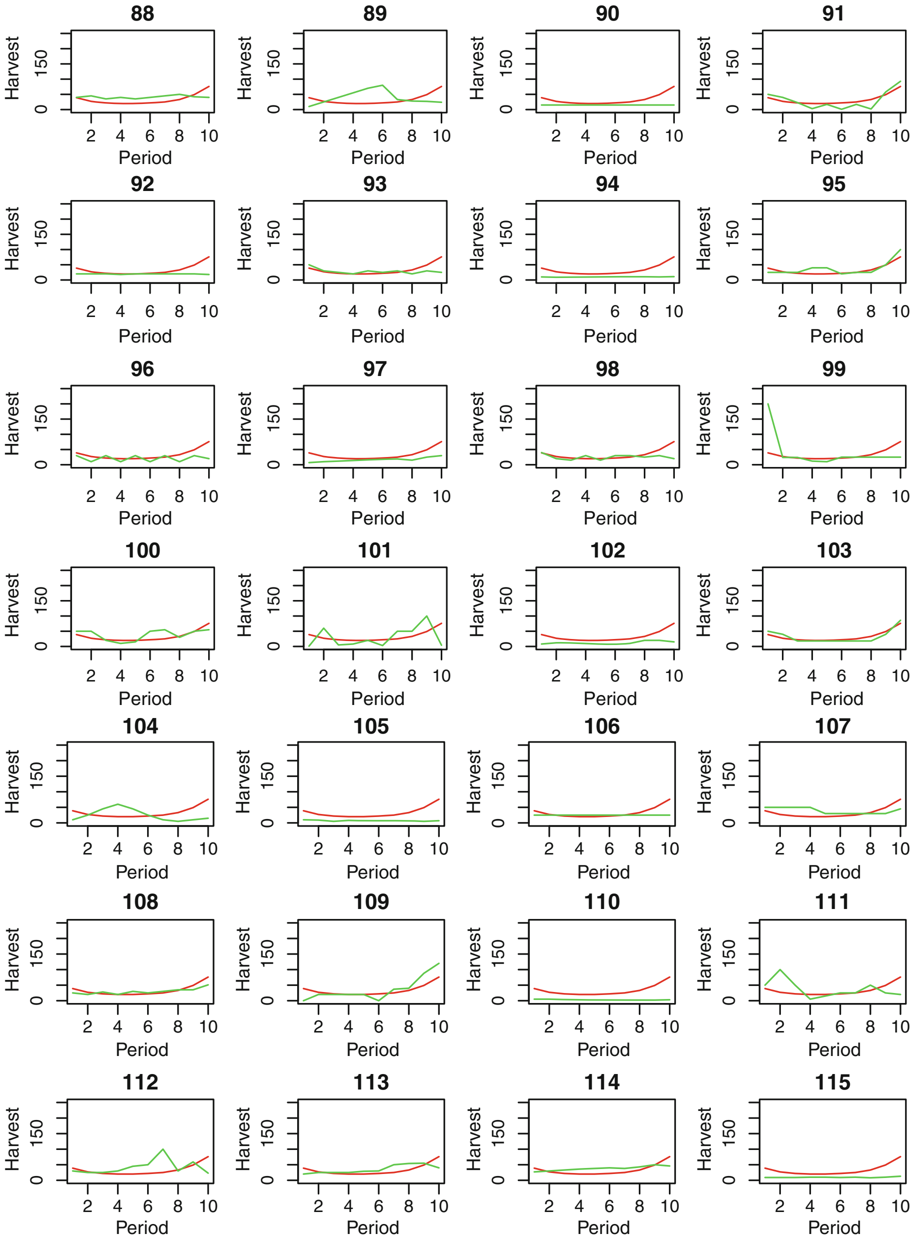
Appendix 6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Appendix 7

Stellar Sea Lions in Jeopardy

All Press Releases...

Oceana Calls for a Transparent Public Process and Release of Updated Biological Opinion

March 16, 2010

Contact: Michael LeVine (mlevine@oceana.org)

The National Marine Fisheries Service (NMFS) has delayed indefinitely the release of the latest Biological Opinion evaluating the impacts of commercial fishing on endangered Steller sea lions in Alaska. The Opinion was expected earlier this month and will evaluate whether current fishery management complies with the Endangered Species Act.

It is expected to show that the endangered western stock of Steller sea lions has continued to decline over portions of its range and is not meeting criteria set out in the agency's recovery plan. Oceana has called for the immediate release of the Biological Opinion and a transparent public process for addressing the competition between sea lions and commercial fisheries for important prey species, such as Atka mackerel.

"All of the available information shows that NMFS must do more to protect sea lions," said Michael LeVine, Pacific Senior Counsel for Oceana. "The agency should involve the public as it determines how best to comply with the Endangered Species Act while maintaining vibrant fisheries." Steller sea lions tell an important story about the health and resilience of the North Pacific marine ecosystems.

The species' decline and failure to recover are part of a larger, ongoing conversation among government, scientists, industry, communities, and conservation organizations about protecting the ecosystem and maintaining viable commercial fisheries in Alaska.

In a series of letters, Oceana requested that NMFS take action to protect sea lions, release the Biological Opinion, and establish a transparent public process that includes the opportunity for cooperation between all interested parties. "We know that business as usual cannot continue, and the best way forward is for NMFS to let us all be part of the solution," said LeVine. "It's time for us to have an open, public discussion about sea lions and fisheries."

4/19/2011 Donate to the ASLC

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Call the Development Office at (907) 224-6304 with any questions.

Thank You!

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alaskasealife.org/New/.../index.php?pa... 1/2

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