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Cover: A Western Snowy Plover from Rancho Guadalupe Dunes Preserve County Park. Photo courtesy of Alex Mandel.

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Incorporating Stakeholder Preferences into Transboundary Conservation Planning: A Case Study from the Korean Demilitarized Zone

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Abstract

We present a framework for conservation planning near international borders where military activity has created a refugium for wildlife, which is illustrated by analyzing the Demilitarized Zone (DMZ) between North and South Korea. The DMZ has seen no significant land development since 1953 and now has exceptional biodiversity including 11 Red List species, such as the red-crowned crane (*Grus japonensis*), which has only 1100-1450 individuals left in the wild. This study assumes that after Korean reunification part of the DMZ will be opened for agricultural and commercial use and therefore prioritizes a fraction of the remaining sites to serve as a UNESCO Biosphere Reserve. A focus group study was conducted to incorporate the preferences of South Korean stakeholders into the conservation plan. The main finding of the focus group was that rice farmers have opposed the establishment of a Biosphere Reserve in the past because they were concerned that it would harm their livelihoods.

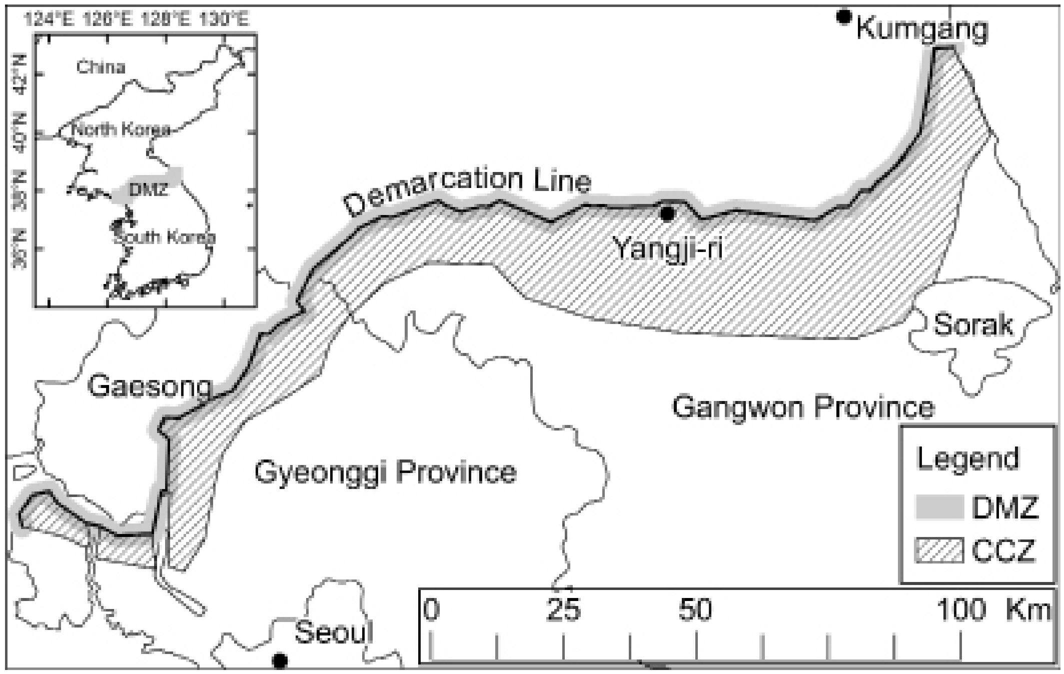
Introduction

Transboundary planning is a specialized branch of conservation planning concerned with the management of biodiversity on or near international borders. Armed conflict sometimes creates refuges in transboundary regions in which the intactness of natural habitat is significantly higher than in surrounding regions (Dudley et al. 2002). A framework for conservation planning in transboundary regions in general and transboundary refugia in particular is needed for several reasons. First, the IUCN Draft Code for Transboundary Protected Areas includes provisions regarding the management of protected areas after armed conflict and recommends that priority be given to the ecological restoration of habitats of rare, threatened, and endemic species (Sandwith et al. 2001). Given that resources for the acquisition and management of conservation areas are limited, putting the habitat of all rare, threatened, and endemic species under a conservation plan may not be feasible. It would be useful to have a framework for prioritizing as much of such habitat as possible without violating budgetary constraints.

Second, transboundary conservation areas have not been implemented in the former Yugoslav Republic of Macedonia and the Red Sea due to conflicts among stakeholders involved in the planning process (Catsadorakis and Malakou 1997; Portman 2007). Stakeholders are defined here as people with the

Figure 1.

Study region in the DMZ and CCZ of South Korea showing the Gyeonggi and Gangwon provinces of South Korea and the Gaesong industrial region of North Korea. Yangji-ri, site of the focus group study, is located in CCZ near the DMZ in western Gangwon province. Also shown are Sorak National Park of South Korea and the Kumgang Mountain area in North Korea. No polygon of the boundaries of Kumgang National Park is available in the World Database on Protected Areas. Inset: location of the study region on the Korean Peninsula. For this and the subsequent map, the projection is UTM Zone 52N and is the absolute scale is 1: 836 074.



authority to enact conservation plans, people affected by the plan, people with expertise about the planning region, and groups who may contribute funding for the implementation of the plan (Margules and Sarkar 2007). In addition, proposals for a Biosphere Reserve in the Korean DMZ have not moved forward due to opposition by stakeholders in rural South Korea (see below). Because attaining conservation goals requires the assent of stakeholders a framework that incorporates stakeholder preferences into transboundary conservation would be to useful to conservation management success. Increased stakeholder involvement is likely to increase the commitment of the stakeholders to the successful completion of the plan.

The objective of this study is to develop a systematic area prioritization framework for biodiversity conservation in a transboundary region where species' occurrence data is scarce and stakeholder groups initially oppose the establishment of conservation areas. The framework consists of modeling species' ecological niches, prioritizing areas for biodiversity conservation, and using criteria elicited from local stakeholders to refine the prioritized areas. The framework can then be incorporated into a comprehensive conservation plan for the Korean DMZ border area by considering a wider range of issues including economic feasibility, military activities, and legal and political systems. The contribution of this study is to develop a technique for incorporating the preferences of local stakeholders into the prioritization of biodiversity conservation areas when access to the stakeholders is limited. In addition, this study reports the results of a focus group interview with local farmers in the Civilian Control Zone (CCZ) , which is a buffer zone in northern South Korea near the DMZ. These stakeholders have driven the opposition to conservation efforts in the DMZ region since 2000 but there has been no previous systematic analysis of their views.

Methods

Study Area: The Korean War began on 25 June 1950 and ended with the 27 July 1953 Armistice Agreement that established the DMZ, a 4 km wide, 248 km

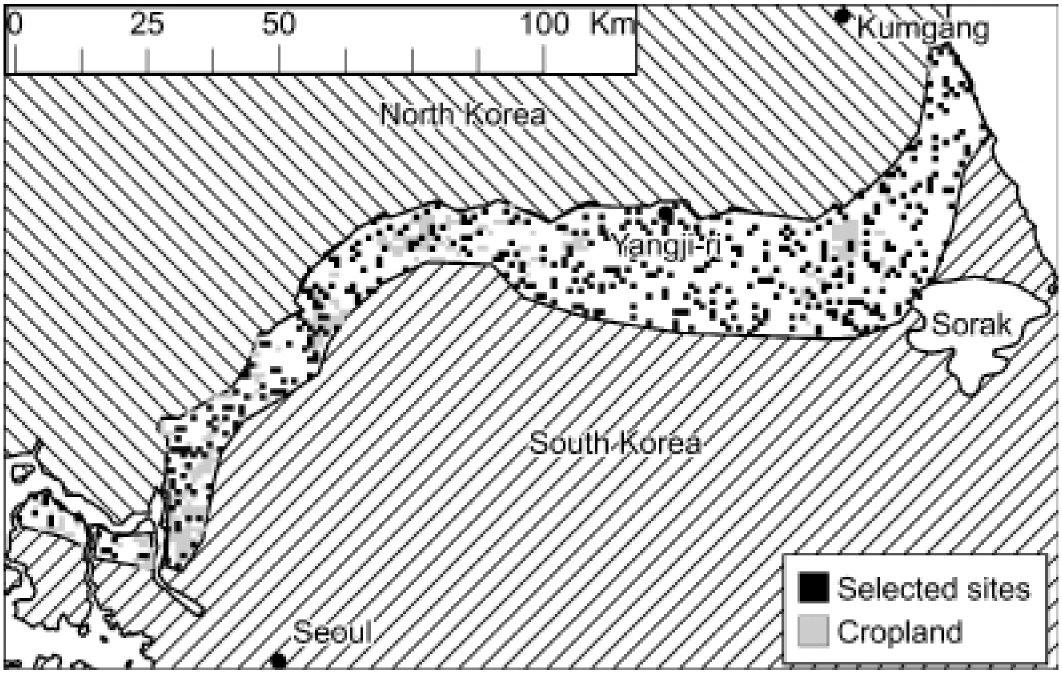


Figure 2.

Conservation plan that contains minimal cropland. The amount of cropland in the 10 000 optimal solutions to the area prioritization model ranged from 41 to 70 km2. The map shows the set of sites selected as conservation areas in the solution that contains the least cropland and the set of sites with cropland in the CCZ and DMZ.

along the Military Demarcation Line at latitude 38°N (Higuchi et al. 1996). Established in 1967, the CCZ is a 5- to 20-km wide buffer zone south of the DMZ in South Korea comprised primarily of irrigated agricultural fields and forest lands (Lee and Mjelde 2007). The present analysis defines the CCZ using a polygon provided by the Ministry of Environment of South Korea, according to which the area is 3223 km2 in size (Figure 1). In South Korea, approximately 90% of the farmer population of the CCZ is involved in rice-paddy agriculture as South Korean law currently restricts land use in the CCZ to agriculture (Ministry of Environment 2007). The DMZ is completely inaccessible for security reasons and travel in the CCZ in South Korea is highly restricted.

Since military restrictions preclude extensive biological surveys, estimates of the DMZ's biodiversity are based primarily on remote-sensed observations such as returns from satellite-collared animals. These data indicate that the rice-paddy plains in the CCZ are an important wintering area for migratory birds, including two crane species of conservation concern, the red-crowned crane (*Grus japonensis*) and the white-naped crane (*Grus vipio*), which feed on surplus grain from the agricultural fields of the CCZ after harvest (Higuchi et al. 1996). The red-crowned crane, which has only 1100-1450 individuals left in the wild, breeds in Japan, North Korea, eastern Russia, and China, then migrates 900 km south to wintering grounds in the DMZ, where it roosts at night and forages in the CCZ during the day (Higuchi et al. 1998). Other IUCN Red List species of the DMZ include two birds, the Chinese egret (*Egretta eulophotes*) and the fairy pitta (*Pitta nympha*), and a bovid, the Chinese goral (*Naemorhedus caudatus*).

Species' Niche Modeling And Area Prioritization: The niche modeling and area prioritization are described in more detail in the supporting information available from http://fullertl.bol.ucla.edu. In summary, models of the ecological niches of species were constructed using occurrence data collected by the South Korean Ministry of Environment from 2004 to 2006 comprising 2960 occurrence points that represented a total of 131 species (eleven species of mammals, 48 birds, three reptiles, three amphibians, twelve insects, 34 plants, two invertebrates, and 18 fishes). A database comprised of 23 environmental variables including ecoregion type, elevation, slope, land cover, and climate data was assembled to predict potential habitat for these species. Using these data, models of species' distributions in the CCZ and DMZ at the 1 km resolution were constructed with the software package Maxent. Sufficiently accurate models could be constructed for 46 of these species (Table 1). For the criteria used to assess model accuracy, see "*Species' Ecological Niche Models*" in the Results.

Next, an optimization model was used to select sites to be included in a Biosphere Reserve in the CCZ and DMZ. The objective of the model was to protect the habitat of as many species as possible subject to a constraint on the amount of land that could be set aside for the Reserve. In the CCZ and DMZ, such a constraint is appropriate because the establishment of a Reserve must compete with agricultural and commercial development and the use of land for security purposes by the military and state police (Westing 1992). To incorporate social criteria into the area prioritization process, 10 000 solutions to the model were found using the explicit exclusion algorithm of Arthur et al. (1997). All of the solutions covered the same number of species but the solutions differed with respect to which sites were selected to be in the Reserve. As a result, the solutions also differed with respect to social and economic criteria important to stakeholders in South Korea. After the 10 000 solutions were generated, the MultCSync software package was used to find a subset of the solutions that were "non-dominated", that is, better than all of the other solutions with respect to at least one criterion and no worse than the other solutions with respect to the other criteria (Moffett et al. 2006).

Incorporation Of Stakeholder Preferences: Since 2000 the South Korean Ministry of Environment has advocated a UNESCO Transboundary Biosphere Reserve in the DMZ and has commissioned an environmental zoning plan and sponsored scientific meetings in support of its establishment (Han and Kim 2004). In connection with these efforts, the Ministry proposed designation of a UNESCO Biosphere Reserve near the village of Yangji-ri in Cholwon County, Gangwon province, South Korea to protect the wintering grounds of the red-crowned crane and the white-naped crane. However, local governments and farmers in Cholwon County vehemently opposed the Biosphere Reserve. Although the source of local residents' hostility has not previously been investigated by any academic researcher, the South Korean press reported that they objected to the Biosphere Reserve because it included a great deal of cropland.

To elucidate the basis of the stakeholders' opposition to the Biosphere Reserve in the CCZ, a focus group study was conducted with rice farmers in Yangji-ri. Focus group studies have been increasingly adopted as a useful research method for understanding the public's perception of environmental issues (Fisher and Young 2007). It was hoped that the focus group study could provide data on stakeholder preferences that could be used to refine the area prioritization, as well as information on any potential impediments to the establishment of a transboundary conservation area in the CCZ and the DMZ. Yangji-ri village was selected because it was more accessible than others in the CCZ due to the promotion of ecotour-

Table 1

Scientific name	Common name	Samples	AUC	Test	TPR
Birds					
Anas formosa Georgi, 1775b	Baikal teal	6	0.996	2	1
Anser fabalis Latham, 1787	bean goose	23	0.772	4	0.8
Charadrius placidus Gray & Gray, 1863	long-billed plover	57	0.772	10	0.857
Cygnus columbianus Ord, 1815	tundra swan	10	0.984	10	1
Cygnus cygnus Linnaeus, 1758	whooper swan	16	0.96	9	1
Dryocopus martius Linnaeus, 1758	black woodpecker	31	0.831	8	0.857
Egretta eulophotes Swinhoe, 1860b,d	Chinese egret	14	0.815	1	0.667
Grus japonensis Müller, 1776a	red-crowned crane	52	0.945	11	0.923
Grus vipio Pallas, 1811b,e	white-naped crane	5	0.996	5	1
Pandion haliaetus Linnaeus, 1758	osprey	12	0.905	4	1
Pernis ptilorhynchus Temminck, 1821	Oriental honey-buzzard	12	0.848	1	1
Pitta nympha Temminck & Schlegel, 1850b	fairy pitta	10	0.889	2	1
Strix aluco Linnaeus, 1758	tawny owl	27	0.83	8	1
Terpsiphone atrocaudata Eyton, 1839c	Japanese paradise-flycatcher	27	0.77	6	1
Fishes					
Acheilognathus signifier Berg, 1907	Korean bittering	85	0.971	11	0.952
Acheilognathus somjinensis Kim & Kim, 1991	Seomjin bittering	5	0.962	2	1
Cottus hangiongensis Mori, 1930	Tumen River sculpin	16	0.995	11	1
Cottus poecilopus Heckel, 1837	alpine bullhead	84	0.828	11	0.762
Gobiobotia macrocephala Mori, 1935	big-headed gudgeon	24	0.806	3	1
Gobiobotia naktongensis Mori, 1935	Nakdong gudgeon	24	0.987	11	1
Iksookimia choii Kim & Son, 1984	Choi's spiny loach	5	0.993	2	1
Koreocobitis naktongensis Kim, Park, & Nalbant, 2000	none	4	1	8	1
Lampetra reissneri Dybowski, 1869	Far Eastern brook lamprey	31	0.819	8	1
Microphysogobio koreensis Mori, 1935	gudgeon	14	0.933	8	1
Pseudobagrus brevicorpus Mori, 1936d	Korean stumpy bullhead	10	0.92	8	1
Pseudopungtungia nigra Mori, 1935d	black shiner	56	0.976	11	1
Pseudopungtungia tenuicorpus Jeon & Choi, 1980	slender shiner	77	0.919	11	1
Pungitius kaibarae Tanaka, 1915	short nine-spined stickleback	39	0.846	9	1

Fishes (continued)					
Pungitius sinensis Guichenot, 1869	Chinese nine-spined stickleback	5	0.993	3	1
Insects					
Copris tripartitus Waterhouse, 1875	dung beetle	8	0.852	6	1
Fabriciana nerippe C. & R. Felder, 1862	none	13	0.805	1	1
Mammals					
Martes flavigula Pocock, 1936	yellow-throated marten	81	0.785	11	0.75
Naemorhedus caudatus Milne-Edwards, 1867b,d	Chinese goral	29	0.987	11	1
Prionailurus bengalensis Kerr, 1792	leopard cat	480	0.75	11	1
Pteromys volans Linnaeus, 1758	Siberian flying squirrel	30	0.955	10	1
Ursus thibetanus ussuricus Heude, 1901b,d	Asiatic black bear	8	0.955	6	1
Plants					
Aconitum austrokoreense Koidz. Lee, 1980	none	12	0.962	8	1
Berchemia berchemiaefolia (Makino) Koidz., 1935	none	29	0.88	11	0.857
Corylopsis gotoana Makino, 1988	none	25	0.964	11	0.833
Hylotelephium ussuriense (Komarov) H. Ohba, 1977	none	8	0.987	7	1
Iris odaesanensis Y. N. Lee, 1974	none	26	0.959	11	1
Leontice microrhyncha S. Moore, 1879	none	6	0.999	8	1
Lilium cernuum Komarov, 1901	cernuous lily	20	0.856	10	1
Paeonia obovata Maxim., 1859	Chinese peony	22	0.901	11	1
Smilacina bicolor Nakai, 1914	none	16	0.999	11	1
Reptile					
Chinemys reevesii Gray, 1831a	Chinese pond turtle	18	0.775	3	0.75

ism and was known to be one of the most vocal in opposing the Biosphere Reserve proposal. A focus group discussion was conducted for two hours with eight participants most of whom settled in Yangji-ri in 1970s and 1980s for rice agriculture in the CCZ. The first author moderated the discussion, transcribed a recording of the discussion, and translated Korean to English. Spoken phrases in the transcript were coded into "nodes", which are objects that represent something to which the focus group participants referred, according to standard protocols using NVivo 7 (Auld et al. 2007). The nodes were analyzed to infer the preferences of farmers for alternative conservation plans. The objective of the content analysis was to clarify topics that may not have been clear in the middle of the discussion.

Results

Species' Ecological Niche Models: The Maxent models were considered accurate if the AUC was ≥ 0.75 and at least one binomial test of omission was significant at $\alpha = 0.05$. The Maxent models for 46 species met these two criteria: 14 birds, 15 fishes, 2 insects, 5 mammals, 9 plants, and 1 reptile. Only these 46 species were included in the prioritization of conservation areas. 11 of these species are listed in the IUCN Red List, the South Korean Red List, or both (Table 1). The mean true positive rate for these 46 species was 93.6%. The true positive rate is the probability that Maxent will classify a site in the test set as suitable habitat for the species given that the species actually occurs in the site. In particular, the true positive rate for the red-crowned crane was 94.5%. A previous study constructed a crane habitat model using logistic regression and achieved a true positive rate of 71.2% (Li et al. 1999). The Maxent model presented here provides substantial improvement in accuracy for predicting potential crane habitat.

Criteria Important To Stakeholders: The topics most frequently referred to by the farmers were cropland and the red crowned crane. As such, we viewed these two issues to be of principal importance. Contrary to reports that farmers in the CCZ are hostile toward the red-crowned crane (John et al. 2003), the focus group demonstrated that the attitudes of rural stakeholders toward the crane are nuanced. One participant stated that the "crane is good to us … [t]hanks to the crane, the rice produced in Cholwon maintains the highest value in the nation." South Korean consumers believe that the red-crowned crane only lives in a clean environment. Since the largest number of crane in Korean Peninsula winters in Cholwon County, where Yangji-ri is located, rice from Yangji-ri is seen as high quality. Thus, the farmers view the crane as beneficial for advertising their rice. This provides substance to the claim that stakeholders in the CCZ do not oppose crane conservation.

During the focus group interview, one participant stated that: "[n]obody here opposes biodiversity conservation, but what matters is how it would affect residents in the village." Another participant stated that "[i]f the use of farmland were further restricted by conservation, our agriculture would be significantly obstructed." On the basis of these and other similar statements in the focus group interview transcript, it was inferred that the stakeholders are receptive to protecting the red-crowned crane's habitat contingent upon the magnitude of the economic loss that would result from such protection. For a complete transcript of the focus group interview, see Kim (2008).

Area Prioritization Results: Each optimal solution to the area prioritization model included all 46 species by selecting 494 sites as conservation areas. Two criteria were measured on each of the 10 000 different solutions: the amount of cropland and the representation of red-crowned crane habitat in the selected sites. The first criterion was included because it is important to farmers in the CCZ according to the focus group study. The second criterion was included because of the crane's endangered status and declining population trend. All 10 000 solutions included at least 10% of the crane's habitat (81.6 km2). However, some of the solutions contained up to 133.73 km2, which is approximately 16% of the crane habitat in the CCZ and DMZ. Of the 10 000 solutions, 23 were non-dominated. Each solution recommended that some cropland be designated for inclusion in the Biosphere Reserve. Since the amount of cropland affected by the conservation plan was particularly important to the farmers in CCZ, the non-dominated solutions were analyzed to find the solution that selected the minimum amount of cropland to be converted into protected land (Figure 2).

Discussion

Implications Of The Present Analysis For The Implementation Of A Conservation Plan In The CCZ And DMZ: The focus group study pinpointed three factors that may complicate the implementation of a conservation plan in the CCZ and DMZ and suggested remedies for these impediments. First, the farmers in Yangji-ri feel that they do not benefit economically from conservation efforts. The farmers reported that a business from outside Yangji-ri profits from ecotourism in their village and that they are concerned that if conservation areas are established on their cropland, then the value of their land will decrease significantly. The focus group participants stated that they would be more receptive to conservation activities by environmental groups, the local Cholwon government, and the central government if the activities facilitate economic benefits to the residents of the village (Kim 2008). Second, the farmers felt that they had been consulted insufficiently during previous conservation planning efforts. For example, residents of Yangji-ri opposed the attempted designation of a national monument to protect their village's natural springs, called "saemtong" on the grounds that the monuments' boundaries were drawn incorrectly by scientists from outside the region based on a map that was rarely ground-truthed. After this episode, the farmers became less receptive to meeting with academics and government scientists. The farmers in Yangji-ri reported that they have had a few opportunities to share their views with ecologists. However, the farmers were aggravated that scientists visit their village then never return. This could be remedied if conservation planners hold several meetings with stakeholders in Yangji-ri and provide updates about how these consultations inform decision-making by the South Korean government. Third, the focus group disclosed that farmers in Yangji-ri are frustrated about restrictions on culling wildlife, which they perceive to be part of the government's conservation policy. Decreasing restrictions on the culling of non-listed species such as the wild boar may make the farmers in Yangji-ri more receptive toward the conservation of Red List species.

Shortcomings Of The Analysis And Areas For Future Research: Since the focus group participants were not selected at random due to severe restrictions on travel, their views may not have been representative of all residents of the CCZ. In general, it is recommended that multiple focus group studies should be conducted consisting of different types of stakeholders including the military, conservation planners, environmental groups, and officials from the local and central government. The focus group study confirmed that the farmers' principal reasons for opposing the Biosphere Reserve were that they were concerned that the Reserve would be established on their land and that it would decrease the value of their property. Although the cranes' presence in Yangji-ri increases farmers' incomes by making their rice more attractive to consumers, the prevailing opinion among the focus group participants was that the decrease in property value and further constraints on their agricultural activity due to the establishment of the Reserve on what is currently cropland outweigh the potential gain in income due to the preservation of crane habitat. More work is needed to quantify the economic impact of crane conservation on agriculture in the CCZ. The main contribution of the focus group study was to provide details about the farmers' opposition that can be used to develop more successful conservation policies for the CCZ and DMZ in the future. Another shortcoming of the analysis is that stakeholders in North Korea were not included in the focus group. A consensus has emerged that successfully implementing a transboundary conservation plan requires a minimum amount of cooperation between the participating countries, including person-to-person communication (Zbicz 2003). Thus, the eventual inclusion of North Korean stakeholders in planning for the DMZ is essential.

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Plover: a Subpopulation-Based Model of the Effects of Management on Western Snowy Plovers

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Abstract.
Plover is a program written in VB.net to model a subpopulation of Western Snowy Plovers (*Charadrius alexandrinus nivosus*). The model is based on data and observations in scientific literature. It was intended to assist managers in understanding how management decisions could potentially affect a local population. The results of this model underscore the need to protect Western Snowy Plovers from human impacts.

Keywords: Western Snowy Plover; Charadrius alexandrinus nivosus; model

Introduction

The Western Snowy Plover (*Charadrius alexandrinus nivosus*) is small shorebird that was federally listed in 1993 as threatened under the Endangered Species Act. These birds make their homes on sandy beaches often near natural water outfalls, such as river mouths, on the west coast of North America from Washington State, USA, to Baja California, Mexico (Page et al. 1995). Parental care is mainly the responsibility of the male. Females leave the nest shortly after the eggs hatch to start a new nest with a new male (Warriner et al. 1986). Unfortunately, their breeding grounds are frequently places humans use for recreation, and development often grows around these areas. Human activities lead to destruction of the Western Snowy Plovers' habitat and an increase in predation on adults and nests by creating larger edge areas and introducing predatory species, such as house pets (Ruhlen et al. 2003).

Western Snowy Plovers have specific habitat requirements, especially during the breeding season. They need a sandy beach with limited vegetation, minimal disturbance by humans, and an adequate food source. Invasive species have reduced the quality of some habitat by vegetating once open areas (USFWS 2001). The beach should also be broad enough to accommodate their habit of nesting at least 100 meters from the high water line (USFWS 2001). Western Snowy Plovers hunt for invertebrates that hide in kelp washed up on the shore, so beaches without beach wrack are unsuitable (Lafferty 2000). Because they nest directly in the sand, foot and vehicle traffic need to be at a minimum to prevent crushing of the birds or their eggs (Ruhlen et al. 2003).

A variety of approaches have been taken in the past to increase the numbers of Western Snowy Plovers. Limiting human access to occupied beaches, restricting dogs and other pets, as well as fencing off breeding grounds and predator removal are common management tools (Lafferty 2000). A common belief expressed in Western Snowy Plover literature is that seemingly small management actions could make a dramatic difference in the size of a subpopulation. Lafferty (2000) articulates this directly and Sandoval (2004) quantifies this, to an extent, with data showing that numbers of adult birds and fledglings increase quickly after management efforts are taken to protect breeding areas from foot traffic.

Deciding which threat to manage is difficult. Management of human behavior in Western Snowy Plover habitat may be the most important factor in their recovery. Lafferty (2000) and Ruhlen et al. (2003) point out that Western Snowy Plover breeding success seems to be inversely proportional to the amount of human use of their habitat. A study by , Neuman et al. (2004) shows that mammalian predators can negatively impact the number of eggs a male Western Snowy Plover can hatch. Observations from this study also suggest that avian predators can significantly reduce the number of chicks surviving to become adults.

Western Snowy Plover research is far from complete. Several researchers have quantified the birds' fecundity (USFWS 2001, Neuman et al. 2004, Powell 1996), effects of human interaction (Ruhlen et al. 2003), and predation (Neuman et al. 2004), but no one has combined all these important factors to determine their collective effect on a population. There seems to be a need for a population growth model on a small spatial scale that incorporates the effects of human decisions.

Only one paper has applied a population model of any kind to Western Snowy Plovers. Nur et al. (2001) developed a population viability model for the entire subspecies of Snowy Plovers (from Washington State, USA, to Baja California, Mexico). This model employed six metapopulations and took a spatial approach. The model used was

A Western Snowy Plover at Rancho Guadalupe Dunes Preserve County Park. Photo credit: Alex Mandel a commercially available program that specializes in metapopulations in which the authors set various parameters to produce an estimate of the population size after 100 years. Each metapopulation covered at least one county but some contained several counties. Both the temporal and spatial scale of this model is not applicable to a management situation.

Because management decisions are often made on a local scale, a model focusing on one nesting site could be useful to managers.

Model Parameters

Plover is a model written in VB.net that represents a subpopulation, the birds present at a single stretch of beach, of Western Snowy Plovers at any habitat location. The size of the subpopulation depends on the size of the available breeding habitat, and whether the subpopulation is protected from predation and human disturbance. The spatial scale is small – limited to one habitat area – since management decisions are made at this scale. The temporal scale is also somewhat limited because of the lack of availability of long-range data for comparison to the model results.

Each subpopulation has distinct characteristics and is likely to have different optimal plans. This model was built to test management alternatives before they are put into action to avoid potentially detrimental experimentation with this threatened subspecies. Given the model output, managers should be able identify the best strategy when several combinations of options are available. Since some management choices are controversial, like restricting human beach access, better compliance and less dissent might be gained by describing the potential outcomes of such decisions.

The user must enter four pieces of information before running the model - the initial number of breeding males, the size of the breeding habitat, whether the subpopulation should be protected from predation or human disturbance. The average number of nests per male can also be changed by the user. The number of eggs laid per breeding male, however, is hardwired into the code because females lay three eggs per nest fairly consistently and the number of eggs laid is not affected by human influence (Warriner et al. 1986).

Plover is a stage-based population model (see figure 1), similar in some respects to Wemmer et al.'s (2001) model of a Piping Plover (Charadrius melodus) population. Rather than calculating the number of individuals in each age class from birth to death (up to fifteen years, in the case of the Western Snowy Plover; Page et al. 1995), the model has four life stages: adults, eggs, hatchlings, and juveniles. These life stages have no specific units with respect to time in Plover because the output happens after each year. The life stages happen in succession, but do not require a particular length of time. For each year the model calculates the number of individuals in each stage based on the number of individuals in the stage before. For example, the number of eggs laid depends on the number of reproductive adults present and the number of eggs laid will partly determine the number of hatchlings in the next stage. The model tracks only reproductive males because males tend the nest and females leave shortly after the chicks hatch to start new nests with a different male (Warriner et al. 1986).

Calculations for each stage are determined by three factors. The first, as mentioned above, is the number of individuals present in the previous time step. The second is the rate of survivorship between each stage for non-adults and between each year for adults. The third is comprised of human-introduced circumstances that have some capacity to limit Western Snowy Plover survivorship. These are regulating factors.

Dispersal, another regulating factor, affects the juvenile and adult stages but not the other two. About twenty five percent of juveniles disperse to other beaches (Nur et al. 2001). Juveniles that dispersed from other beaches to the population in the model immigrate as adults in the next year. The amount of emigration and immigration to the adult pool is also affected by the size of the habitat and the number of humans using the habitat area for recreation. In observational studies, as the breeding area decreases in size or the number of people increases, the rate of Western Snowy Plovers emigration increases (Powell 1996). If conditions improved (i.e. more habitat area or fewer people) individuals from other areas will immigrate into the subpopulation. The dispersal factors reflect these observations in the model. The amount of human interaction and the size of the habitat remain static in each model run but some simulation of dynamics in these factors can be achieved by changing the inputs on separate model runs.

The majority of the parameters were found in literature about Western Snowy Plover studies that sought to quantify some aspect of their life history (see table 1) but two elements were calibrated. The affects of human disturbance was calibrated to reflect Powell's (1996) observations that where humans are present, Western Snowy Plovers are not. In the interface, there is an option to either protect the population from humans or not. When the box on the interface to protect the birds from human presence is not checked, the model increases the rate of emigration to between 85 and 95 per cent of the adults present in the model population and immigration is limited (Nur et al. 2001). The general immigration rate was taken from Nur et al. (2001), but if the subpopulation drops to zero in one year, one or two adults will appear in the next year. This was done to incorporate the fact that one or two pairs seem to try to nest at a location even if a subpopulation was unsuccessful in previous years (Sandoval 2004 and Powell 1996).

Results

Plover's output (see figure 2 for example output) shows that a subpopulation of Western Snowy Plovers can only successfully breed when humans and predators are kept at a minimum. When the birds are unprotected, the population in the model drops rapidly and inevitably disappears regardless of the size of the starting population. This is consistent with field observations (Sandoval 2004). Beaches with high rates of human use and no protection from predators have few or no Plovers in spite of the high suitability of the habitat (Powell 1996). No Snowy Plovers are found in areas where human activity has increased. Observations show, however, that on sites with few breeding pairs, numbers rapidly increase when a portion of the nesting area is protected (Sandoval 2004). Plover also has the same result.

Plover was tested against the brief population data available from Sandoval (2004). These data were ideal because they span a period in which a highly effective management plan was enacted that dramatically reduced the amount of human interaction with the birds and protected nests from both avian and mammalian predation, although they only provides specific counts for a few years. The quality of the site was otherwise high so the study resulted in good information for comparison. The output from Plover is very similar to the observed data that show the population increasing rapidly when no threats were present in the breeding area. Unfortunately, longer term data were unavailable at the time of writing so the plausibility of later model predictions for the combined management strategies cannot be confirmed, however, the results of the Plover model do make ecological sense: growth in the population slows and fluctuates below the maximum nesting density. The effects of no management on the subpopulation in both the model and the observations match. Without management, few adults will be present at a site and those that are present will have very low reproductive success.

The optimal management strategy for a subpopulation of Western Snowy Plovers with average life history parameters (i.e. three eggs per nest, average survivorship between life stages, etc.) is to protect the subpopulation from both predation and human interference (see figure 2). Employing both options significantly increases the number of adults at a site more than simply protecting the birds from humans. Excluding humans from the nesting area is a good option, however, if only one action can be selected for a site. A subpopulation that only receives protection from predation, according to the model, will not survive. In the model, this is due to the stipulation that when humans are present, the majority of the birds leave in spite of any increased fledging success from the protective predator exclosures. Subpopulations receiving no protection will also fail.

Limitations of Plover

Plover's limitations stem mainly from a lack of research on its subject species. At this time the model cannot take into account the amount of human activity on a beach or the number of predators present because data on the effects of these factors does not exist in a form that is useful for a model like Plover. Because only short-term data is available, the long-range predictions the model can make cannot be substantiated and therefore the model should not be used for such predictions. The results can only be applied to the number of adults because some of the regulating factors have not been developed completely in the model. For example, human activity only affects immigration and emigration rates but not hatching success and predation only affects hatching and not the rates of fledging, juvenile survival, and adult survival.

Another important aspect of Western Snowy Plover ecology was intentionally left out of this model. While beach grooming plays a large role in determining how much food is available for nesting birds, not enough is known about Western Snowy Plover energetics at this time to include it in this model. One paper (Tucker & Powell 1999) describes and quantifies their diet, but little is known about how food availability limits the number of birds. Powell's (1996) study of southern California beaches showed that Western Snowy Plovers are unlikely to be found on raked beaches. Until more is known about their energetics, it is unnecessary to include beach grooming in a model like Plover because it can be assumed that raked beaches cannot support a breeding population of Western Snowy Plovers.

Conclusion

More information is needed before Plover can fulfill its ultimate objective of being a tool that weighs management options against one another, however, the current results have important implications for the management of this threatened subspecies of shorebird. Western Snowy Plovers must be protected in some fashion. At the very least their interactions with humans must be limited, but combining this strategy with reducing predation is the most effective.

In the future, Plover will be able to predict the implications of more specific goals. The number of encounters with humans and the number and type of predators around the breeding habitat will be included in the model to give a more complete picture of how a subpopulation will grow or decline. Plover also has the potential to expand to encompass the entire population of Western Snowy Plovers by connecting various subpopulations with each other, each with their own set of management strategies, to see how the birds move between different beaches.

Obtaining the Program

Plover is licensed under Creative Commons Attribution-Share Alike 3.0 United States License, making it free and open source. Contact the author for the program.

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Report from the Field:

Monitoring Ocelot Dispersal with Satellite Telemetry

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The total number of ocelots (*Leopardus pardalis*) remaining in the U.S. has been estimated at 36-78 individuals (Haines et al. 2005; Janečka et al. 2008) in two Texas populations which are isolated from each other and from the nearest population in Mexico (Janečka 2006). Many aspects of ocelot ecology and behavior may be altered in these populations, which are relying on scarce, highly fragmented habitat patches (Haines et al. 2006) and have experienced severe reductions in genetic diversity (Janečka 2006). For example, juvenile dispersal movements of Texas ocelots tend to be circular rather than uni-directional, as lack of habitat frustrates attempts to leave the natal area (Laack 1991). Studies of nearby healthy populations in northeastern Mexico will be valuable in many respects for informing attempts to restore the ocelot to its proper place in Texas ecosystems. For instance, dispersal is a particularly important aspect of metapopulation recovery because it genetically links separate sub-populations, and information on dispersal distances can help guide managers' decisions on site choice for population establishment. However, dispersal is difficult to study in species able to travel long distances. As part of a long-term study of ocelot ecology in Tamaulipas, Mexico (Caso 1994), I conducted a pilot study of the utility of satellite telemetry for monitoring ocelot dispersal in this region.

A male ocelot weighing 7kg and estimated to be 1 year old was captured in a box trap on May 19, 2005 on Los Ebanos ranch, which is located on the Gulf coast approximately 250 km south of the Texas border. He was fitted with a 190g radio-collar (Sirtrack Ltd., Havelock North, New Zealand) equipped with both a VHF transmitter and a transmitter utilizing the Argos satellite tracking system (Service Argos, Inc., Largo, MD). The satellite transmitter was programmed to transmit for 6 hours every third day (from 0200 to 0800 local time) and was manufactured to have a lifespan of approximately 2 years. The VHF transmitter ran continuously and was expected to last approximately 17 months. The transmitter package also contained an activity monitor which kept track of the number of times the collar had changed orientation in the previous 24 hours. All satellite data transmissions contained this activity count as well as location information.

The ocelot was monitored with both types of telemetry through June 21, 2005, after which data transmissions from the satellite transmitter ceased, apparently due to a malfunction. VHF monitoring continued through August 3, 2005, after which the signal was no longer picked up in the study area. Satellite data transmissions resumed on November 24, 2005 and indicated that the ocelot was near Barra del Tordo, approximately 50km south of the capture site. Transmissions continued through May 8, 2006, at which point they ceased permanently.

Transmitter locations calculated by the Argos system are given precision codes to enable users to judge their reliability. During the 5 months of post-dispersal

Ocelot. Photo credit: Cathy Burkey and the Dallas Zoological Society.

monitoring (11/24/05-5/8/06), only 4 locations (out of 54 total) with <1000m estimated error were received. They covered a 3-month period and were all within 4km of each other southwest of Barra del Tordo, approximately 10km from the coast. This suggests that the ocelot had established a home range at that site. The activity counts obtained during the post-dispersal monitoring (3307-5480 movements/24h) were similar to those obtained during the first month of transmissions (3407-4643), confirming that the ocelot was still alive and wearing the collar.

Data on ocelot dispersal distance are scarce, but several studies have documented males moving 10-15km from their natal ranges to adult ranges (Ludlow and Sunquist 1987; Laack 1991; Crawshaw 1995; Jacob 2002). In addition, a male in Brazil that was captured on a farm and translocated to a state park traveled 30km through a primarily agricultural landscape to return to the capture site (Jacob 2002). The 50km dispersal documented here is the longest ocelot movement yet reported, but without satellite telemetry, the farther an animal travels from the initial study site, the less likely it is to be found again. Male ocelots have been recorded moving up to 7.3km (linear distance) in a single day (Crawshaw 1995), so long-distance movements could be accomplished very quickly.

The Argos system's ability to acquire locations is best at high latitudes. The combination of low latitude and the dense forest preferred by ocelots was most likely responsible for the low precision of most of the locations recorded in this study. Satellite telemetry alone does not seem to be a cost-effective tool for monitoring dispersal of ocelots. Further elucidation of this aspect of ocelot ecology will be greatly facilitated by the development of combined GPS/Argos transmitter packages small enough to be put on this species.

Despite its limitations, the Argos system revealed a long-distance dispersal event which would not otherwise have been discovered. The distance traveled by this young male ocelot is encouraging because it demonstrates functional connectivity among the scattered patches of forest remaining in coastal Tamaulipas. It also suggests that if habitat corridors are created between remnant Texas populations, ocelots' natural dispersal capabilities should be sufficient to maintain gene flow within the metapopulation.

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A history of dramatic successes at protecting endangered sea turtle nests by removing predators

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Five species of sea turtle, all listed on the IUCN Red List as endangered or critically endangered (IUCN, 2004), nest on Florida beaches. The nesting aggregation of loggerhead turtles is of global significance as it is the second largest nesting aggregation in the world, with the largest concentration in a middle-eastern region vulnerable to the effects of war, political upheaval, and severe oil spills (Meylan et al. 1995). The highest productivity for sea turtle nesting in Florida takes place on beaches protected as Florida State Parks or National Wildlife Refuges. Unfortunately, reproductive success is greatly hindered by nest predation, making human intervention necessary to insure sea turtle conservation.

Racoons (*Procyon lotor*) are the most destructive of a wide variety of sea turtle nest predators in Florida (e.g., Stancyk 1982, Engeman et al., 2003, 2005, Garmestani and Percival 2005). A diverse assortment of other animals, mostly invasive predators, join raccoons as destructors of sea turtle nests (e.g., Lewis et al. 1994, 1996, Woolard et al. 2004, Martin et al. 2005, Helmstetter and Atencio 1997, Northwest Florida Partnership 2000). Nevertheless, the pervasiveness and severity of raccoon predation on sea turtle nests in Florida prompted a leading sea turtle conservation organization to identify raccoons as the single greatest source of sea turtle mortality in Florida (Caribbean Conservation Corporation/Sea Turtle Survival League, N.D.). Coastal development has greatly reduced sea turtle nesting habitat, but raccoon populations thrive at artificially high abundances in association with human development (e.g., Smith and Engeman 2002), reaching astounding densities as great as 238 raccoons/km^2. Predation is a critical threat to many endangered or even locally rare species (Hecht and Nickerson 1999) and its deleterious impact is compounded through habitat loss and altered predator communities (Reynolds and Tapper 1996), such as artificially high raccoon populations and invasive predators. Reduction of nest predator populations has been widely recommended (Bain et al., 1997, Mroziak et al. 2000), and widely-practiced, to protect sea turtle nests (Stancyk 1982, U.S. Fish and Wildlife Service and National Marine Fisheries Service 1991, U.S. Fish and Wildlife Service 2000, Engeman et al. 2003, 2005, Garmestani and Percival 2005).

If imperiled sea turtles are to successfully reproduce on Florida beaches, nest predation must be at low levels. Effective programs to remove nest predators have been highly successful at accomplishing this. One of the most outstanding and well-documented examples has taken place on the high-density nesting beach on Jupiter Island within the protected confines of Hobe Sound National Wildlife Refuge and St. Lucie Inlet Preserve State Park. Along this 5.3 km stretch of beach the number of sea turtle nests deposited each year can range to nearly 2000, with the usual number around 1500. Historically, as many as 95% of the nests on the beach had been depredated, primarily by raccoons, but more recently also by invasive armadillos (*Dasypus novemcinctus*). Some predator removal reduced depredation to around 50%, but the implementation of an agreement with predator management experts and the use of predator monitoring to optimize the timing and placement of management efforts reduced nest predation to under 28% (Engeman et al. 2003). Further application and improvement of the monitoring methods brought nest predation under 10% (Engeman et al. 2005). The net result of these low predation figures was the production of many tens of thousands of additional hatchling sea turtles each year. However, the destructive influence of predators was demonstrated in a later year when a funding shortfall caused a reduction in predator management during turtle nesting season, resulting in an immediate rise in nest predation (Engeman et al. 2006).

Similar results have taken place in Florida's panhandle where the removal of raccoons as well as invasive coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*) and feral swine (*Sus scrofa*) have not only greatly improved turtle nesting results, but also improved nesting results for listed shorebirds and the survival of beach mice (Northwest Florida Partnership 2000, Lewis et al. 1994, 1996). On Cayo Costa Island on Florida's west coast there was a dramatic upturn in sea turtle nesting success as well as nesting success for listed shorebirds resulting from the removal of raccoons and invasive feral swine (Florida Dept. Environmental Protection and USDA/Wildlife Services unpublished data). During the same time span, neighboring similar islands had turtle and shorebird nesting success remain at or near zero. Subsequent raccoon removal at nearby islands motivated by this success also resulted in dramatically improved nesting success.

There are few practical alternatives to removing predators if sea turtles are to successfully nest. The translocation or release of invasive species in Florida is illegal (multiple violations, Chap. 39 F.A.C.), and the translocation of native species is similarly prohibited. In particular, translocation of raccoons can be particularly harmful when one considers its potential role in rabies transmission among high-density raccoons, which has been a periodic problem in Florida and along the rest of the east coast of the U.S. (Winkler and Jenkins

A green sea turtle. Photo credit: U.S. Fish and Wildlife Services.

1991). An alternative, such as nest caging to place a barrier between predator and nest is not only impractical on high density nesting beaches, but often does not reduce predation, and may even facilitate raccoon depredation of nests in some situations (Mroziak et al. 2000). Moreover, an extensive economic analysis was conducted for predator removal strategies for the Jupiter Island beach and found that the predator removal methods applied had extraordinary, but conservatively calculated monetary benefit-cost ratios accruing from over $8 million in benefits for producing approximately 84,000 additional hatchling turtles in a year from predator removal costing under $10,000 (Engeman et al. 2002). Given the seriousness of the need to assist nesting success of endangered sea turtles and the efficacy and economical practicality from predator removal, we have to ask ourselves, how can we not afford to remove predators when necessary to protect the turtle nests?

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Opinion: The Evolution-Conservation Interface

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It is increasingly recognized that a species' decline is often brought about by adverse effects that are mediated by behavior (e.g., Somers and Gusset 2009). Correspondingly, an increase in conservation-oriented behavioral research can be observed, focusing on topics such as mate choice (Gusset et al. 2006), adoption (McNutt et al. 2008), cooperative hunting (Rasmussen et al. 2008), or Allee effects (Somers et al. 2008). There is no framework available, however, to help conservation biologists identify the specific cases when they should be worried about behavior, nor which behaviors they should be concerned about. Furthermore, the practicalities of incorporating behavioral considerations into decision-making often remain unclear. Conservation biologists thus continue to have difficulties recognizing how behavioral knowledge can help tackle real-world conservation challenges.

Here, I argue that a fundamental understanding of evolutionary ecology can resolve some of these problems. Often species become a conservation concern as a result of the evolutionary novelty of human-altered landscapes. Evolutionary theory stresses the importance of gaining inclusive fitness benefits, and evolution thus provides an overarching paradigm that enables conservation biologists to identify cases in which these benefits are threatened. Accordingly, conservation biologists can develop measures to increase individual fitness. I exemplify my viewpoint by two recently published studies, which are among the first to explicitly make use of knowledge at the interface between evolution and behavior to enhance endangered species recovery programs.

(1) Sex allocation theory predicts that maternal condition influences offspring sex ratios. Attempts to increase breeding success in the endangered kakapo (*Strigops habroptilus*) using supplementary feeding inadvertently resulted in highly male-biased offspring sex ratios, with detrimental consequences on mating behavior. Robertson et al. (2006) applied sex allocation theory to identify and remedy this conservation dilemma. Offspring sex ratios were subsequently rectified by altering maternal condition through a modified supplementary feeding regime.

(2) Group augmentation theory provides a framework for the evolution of cooperative breeding when individual fitness is positively related to group size, independent of relatedness. For cooperatively breeding species relying on a critical number of helpers for raising their young, this suggests that groups could be artificially augmented to increase breeding success. Graf et al. (2006) implemented this conservation strategy in endangered African wild dogs (*Lycaon pictus*), which demonstrated that reintroduction success can be enhanced by augmenting existing packs that are below threshold size with unrelated individuals prior to release.

Considering individual fitness as

the currency of success, conservation interventions can be evaluated against an evolutionary background or explicitly designed based upon evolutionary considerations. Moreover, the two studies demonstrate how findings from conservation practice can add to our understanding of evolutionary processes: in the respective cases the evolution of skewed sex ratios and cooperative breeding. I thus advocate a more evolutionary sophisticated approach to conservation biology, encouraging the advancement of what Ashley et al. (2003) termed "evolutionary enlightened management."

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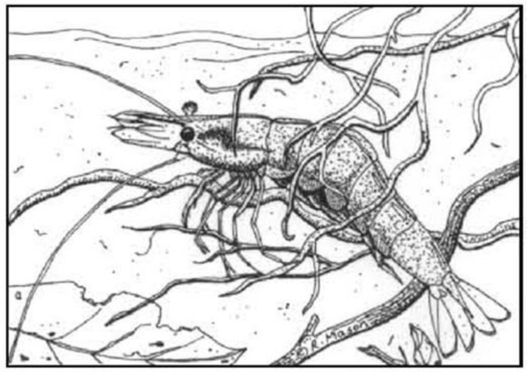

Hidden in a tangle of submerged tree roots a two-inch, nearly transparent **CALIFORNIA FRESHWATER SHRIMP** (*Syncaris pacifica*) busily dines on nutritious detritus gleaned with her small claws. As approaching salmon fry search for food the shrimp freezes and changes color to match the dark, undercut stream bank. Non-native fishes are not easily fooled by this camouflage and search vegetation more carefully. When caught, the shrimp's only defense is to quickly jab her unicorn-like rostral spine into the roof of the fish's mouth and hope to be spit out, which usually isn't the case. Ironically, when these perennial streams dry up from California's long, dry summers, doomed fish trapped in remnant pools eventually become the shrimp's feast. After danger passes, she resumes feeding while carrying her new clutch of nearly a hundred eggs due to hatch in nine months. *Artwork and text by Rochelle Mason* *© 2006 www.Rmasonfinearts.com*

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