Whooping Crane Recovery: A Case Study in Public and Private Cooperation in the Conservation of Endangered Species

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Abstract: *I describe three theoretical approaches to endangered species conservation: public-sector models, private-sector models, and mixed models. Criteria to consider in evaluating these models are scientific, economic, legal, ethical, and administrative. The history of conservation efforts on behalf of the endangered Whooping Crane (*Grus americana*) is used as an example of a mixed-model approach (one that involves both public- and private-sector organizations and individuals) to the conservation of endangered species. Evaluation of Whooping Crane conservation efforts, using the specified criteria, suggests that this mixed model gets relatively high marks in all areas. My recommendations for endangered species conservation activities include (1) ensuring that all potential sources of scientific expertise and "caring" are included, (2) developing a robust national funding mechanism for endangered species conservation efforts, and (3) creating streamlined administrative structures and operating procedures tailored to the unique needs of each endangered species conservation team. Broader implications of the Whooping Crane story for conservation biology as a profession and for conservation biologists as individuals include (1) being inclusive rather than exclusive in conservation planning and implementation, (2) recognizing the power of individual initiative and commitment, (3) collecting basic data over an extended period of time, and (4) emphasizing the importance of communication, cooperation, and coordination.*

Recuperación de la Grulla Americana: Un caso de estudio sobre la cooperación pública y privada en la conservación de especies en peligro de extinción

Resumen: *Se describen tres métodos teóricos para la conservación de las especies en peligro de extinción: los modelos del sector público, los modelos del sector privado y los modelos mixtos. Los criterios considerados en la evaluación de estos modelos incluyen criterios científicos, criterios económicos, criterios legales, criterios, éticos y criterios administrativos. Se emplea el historial de los esfuerzos de conservación en beneficio de la grulla americana (*Grus americana*), que está en peligro de extinción, como un ejemplo del método denominado "modelo mixto" (es decir, el que comprende organizaciones tanto del sector público como del sector privado e individuos) para la conservación de las especies en peligro de extinción. La evaluación de los esfuerzos para la conservación de la grulla americana, mediante el empleo de los criterios especificados, sugiere que este tipo de modelo mixto recibe una calificación relativamente buena en todas las áreas. Mis recomendaciones para las actividades de conservación de especies en peligro de extinción incluyen: (1) garantizar que se incluyan todas las fuentes posibles de experiencia y "cuidado," (2) desarrollar un mecanismo robusto de financiamiento nacional para los esfuerzos de conservación de las especies en peligro de extinción y (3) crear estructuras administrativas y procedimientos operativos eficientes diseñados para servir las necesidades exclusivas de cada equipo de conservación de especies en peligro. Las implicaciones más amplias de las historia de la grulla americana para la biología de la conservación como una profesión y para los biólogos de las conservación como individuos, incluyen: (1) adoptar un enfoque inclusivo en lugar de exclusivo*

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en cuanto a la planificación y aplicación de la conservación, (2) reconocer el poder de la iniciativa y el compromiso individuales, (3) recolectar información básica a lo largo de un período extenso de tiempo y (4) recalcar la importancia de la comunicación, cooperación y coordinación.

Introduction

A majority of people in the United States favors protecting the environment, preserving biodiversity, and preventing species extinctions (Mann & Plummer 1995; Thompson 1995; Wexler 1995). The problems arise when deciding how this should be done, who is going to pay for it, and who wins and who loses in the process.

There are three major types of solutions to the problem of conserving endangered species: private- and public-sector models and mixed models.

The line of reasoning behind private-sector models suggests that those who care about endangered species should take on the entire job of conservation. For-profit organizations such as pharmaceutical companies would invest in a certain amount of species protection, and nonprofit organizations such as The Nature Conservancy and the National Audubon Society would protect the rest to the extent that their funds permit. Contributions to these organizations would be an index of how much the public is willing to spend on endangered species conservation. In addition, individual land owners, scientists, and volunteers would contribute to endangered species conservation committing their individual time and resources.

In public-sector models, conservation of endangered species is a public good (such as national security) that can be provided adequately only by government intervention. Within this category are two major subtypes of models that differ according to the methods that government might use to accomplish endangered species conservation. Method A is a command-and-control strategy in which the government issues regulations to protect endangered species and the public must comply, and method B is an incentive strategy in which the government provides economic rewards to encourage conservation.

The third category, mixed models, is a hybrid of the public and private model types. In the ideal mixed model, government would work with private organizations and individuals to maximize conservation benefits by using the best aspects of both the private and public approaches.

In evaluating these models of endangered species conservation, several categories of selection criteria should be considered: scientific, economic, legal, ethical, and administrative.

Scientific criteria include quantitative and qualitative indices of endangered species conservation. These measures might consider the number or percentage of endangered species that are enabled to survive over a period of time, the amount of genetic diversity preserved in species that are declining, or the representativeness of the types of ecosystems being protected. Economic criteria include the questions, "Is it worth it?" (benefit/cost analysis) and "Where do we get the most for our conservation dollar?" (cost-effectiveness analysis). Legal criteria involve assessing the different approaches to endangered species conservation in terms of their compatibility with the U.S. Constitution (in particular, the Bill of Rights), statutes, regulations, and common law. Ethical criteria focus on issues of right and wrong in terms of equity and justice. Conservation involves ethical questions regarding human beings and other living organisms. Administrative criteria consider the practicalities of implementing the endangered species conservation measures. Various approaches must be assessed in terms of the potential effectiveness of their administrative structures and procedures.

The Whooping Crane Story

The Whooping Crane (*Grus americana*) is a symbol of public concern for endangered species in the United States. For more than 100 years, at least some people have been concerned about the rarity and declining populations of this magnificent bird. I present a brief summary of the natural history of the Whooping Crane and then consider both the private and public efforts that have been made to conserve this highly endangered species. I also assess Whooping Crane conservation efforts using the criteria described above and offer recommendations concerning future endangered species conservation activities. Finally, I suggest some broader implications of the Whooping Crane story for conservation biology as a profession and for conservation biologists as individuals.

Robert Porter Allen estimated that the total population of Whooping Cranes as of 1869 was approximately 1300 birds (Allen 1952). Two other estimates put the 1870 population at between 500 and 700 birds (U.S. Fish and Wildlife Service 1994). Habitat loss and hunting decimated this population so that, by 1937, only two small breeding populations survived: a nonmigratory group of about 10 to 15 birds in southwestern Louisiana and a flock of about 20 birds that migrated between coastal Texas and a (at that time unknown) location in northern

Table 1. Population size of the Texas-Canada migratory flock of Whooping Cranes since 1940.*

Year	*Adults*	*Young*	*Total*	*Change*
1940	15	7	22	—
1945	15	3	18	−4
1950	30	4	34	+16
1955	21	0	21	−13
1960	31	2	33	+12
1965	32	10	42	+9
1970	48	8	56	+14
1975	47	2	49	−7
1980	70	6	76	+27
1985	71	15	86	+10
1990	126	20	146	+60
1995	125	7	132	−14

**Source: U.S. Fish and Wildlife Service 1994.*

Canada. A hurricane killed half of the Louisiana birds in 1940, and the last individual from that group was taken into captivity in 1950. Table 1 shows the population numbers of the Texas-Canada migratory flock every 5 years since 1940 (U.S. Fish and Wildlife Service 1994).

The historical range of the Whooping Crane extended from the Arctic coast to central Mexico and from Utah to the Atlantic coast. Currently, the one natural wild flock migrates from the vicinity of Aransas National Wildlife Refuge on the coast of Texas to Wood Buffalo National Park on the border of Alberta and the Northwest Territories of Canada (U.S. Fish and Wildlife Service 1994).

Whooping Cranes require isolated marsh and wet prairie habitat, where they feed on crustaceans, fish, small vertebrates, insects, small mammals, roots, berries, and grain (Ehrlich et al. 1988). On their wintering grounds they experience competition for food from humans, raccoons, and other birds. In their nesting area they face a variety of vertebrate competitors for food (James Lewis, personal communication). Predation generally affects only young and sickly birds and eggs (except for illegal hunting by humans). Predators include bobcats, wolves, black bears, coyotes, and raptors (Edwards et al. 1994).

Whooping Cranes are monogamous and will find a new mate only if their first mate dies. In their nesting habitat (Wood Buffalo National Park in Canada) the pair builds a shallow nest of soft grass on a mound of coarse grass, reeds, or sod. The nest is always near or surrounded by water (Kuyt 1995). The average nesting territory, which the pair defends, is 4.1 km^2 (Edwards et al. 1994). Ninety percent of Whooping Crane clutches contain two eggs, 8% contain one egg, and 2% contain three eggs (Edwards et al. 1994). Both parents incubate the eggs (29–31 days), and both parents feed and guard the young. The young are precocial, able to walk and swim within a few hours of hatching. They follow their parents around on foot and in the water for 80 to 90 days before they are able to fly.

The cranes migrate south beginning in September, traveling in family groups or in small groups of juveniles and unattached birds. When they arrive at their winter habitat (Aransas National Wildlife Refuge in Texas), the family groups establish winter territories that average about 117 ha (U.S. Fish and Wildlife Service 1994). The juveniles and unattached birds move around on the outskirts of the established family territories.

The Whooping Crane is the most endangered of the world's 15 species of crane. This bird was listed as "threatened with extinction" by the U.S. Congress in 1967. It was listed as endangered in 1970, and critical habitat was designated in 1978. Recovery efforts on behalf of the Whooping Crane are currently implemented cooperatively by the U.S. and Canada (Edwards et al. 1994; U.S. Fish and Wildlife Service 1994).

Private and Public Efforts in Whooping Crane Conservation

In the early 1900s individuals and organizations (such as the National Audubon Society) followed the plight of declining wildlife populations. One individual, Dr. Myron Swenk, published spring and fall counts of migrating Whooping Cranes sighted in Nebraska from 1912 to 1934. Unfortunately, Swenk's counts were highly inflated by erroneous sightings (e.g., of Sandhill Cranes [*Grus canadensis*], White Pelicans [*Pelecanus erythrorhynochos*], and Snow Geese [*Chen caerulescens*]) which led to false optimism about the status of Whooping Cranes. Based on Swenk's data, the American Ornithologists' Union reported in 1941 that there were about 300 Whooping Cranes surviving (McNulty 1966). In retrospect, the best estimate of the 1941 total world population of Whooping Cranes was 22 birds (U.S. Fish and Wildlife Service 1980).

The U. S. government's first involvement with Whooping Cranes (other than the Migratory Bird Treaty of 1916, which mandated a 10-year closed hunting season on Whooping Cranes and other declining species) came in 1936 when biologists from the Bureau of Biological Survey (forerunner of the U.S. Fish and Wildlife Service) visited the Aransas area on the Gulf Coast of Texas. In the flurry of New Deal spending, Congress had provided money for wildlife conservation (via the Duck Stamp Act of 1934), and the biologists were surveying possible sites for wildlife sanctuaries (McNulty 1966). The biologists found a great abundance of wildlife, including Whooping Cranes, in the vicinity of Blackjack Peninsula in Aransas Bay, and they recommended the purchase of this area as a waterfowl refuge. As McNulty (1966:41) relates the story, " . . . it was a crucial moment in whooping-crane history when the bureau decided to purchase the Blackjack Peninsula. There is no reason to doubt that the whooping cranes would otherwise have vanished years ago. The bureau bought [18,904 ha] for $463,500."

The private-sector footnote to this public-sector initia-

tive was that the seller of the land retained mineral rights that allowed oil exploration and drilling anywhere on the property. It should be noted here that the present holder of the mineral rights, Conoco Oil Company, has been very cooperative with the refuge staff by not drilling in the marshes, by not conducting seismic activities when the cranes are present, and by supporting crane research and management projects.

To illustrate the sometimes contradictory purposes of government programs, the next government initiative to affect the Whooping Cranes occurred when the U.S. Army Corps of Engineers decided in 1940 to dredge the Gulf Intracoastal Waterway right through the Aransas refuge. This single government decision represents, to this day, one of the gravest dangers to the continued survival of the cranes (Tom Stehn, personal communication). Another government initiative that affected the cranes was the establishment in 1942 of a U.S. Army Air Corps bombing range on Matagorda Island adjacent to the Aransas National Wildlife Refuge.

By the early 1940s, the combination of private concern and government action for waterfowl protection had resulted in the establishment of a winter refuge for the Whooping Cranes. In addition, the combination of private and public interests had also led to a situation in which the environment around the wintering cranes could be described by McNulty (1966:51) as follows:". . . bombing and machine-gun ranges established by the Army Air Corps on the barrier islands; target-shooting boatmen riding through the refuge on the Intracoastal Waterway; exploration for oil on the refuge; the drilling of oil wells in the waters of the bay."

It was economic necessity that forced the creation of the first truly mixed model for Whooping Crane conservation. In 1945 the U.S. Fish and Wildlife Service had no money to pursue research on the cranes, so the National Audubon Society joined forces with the U.S. Fish and Wildlife Service and the Saskatchewan Museum of Natural History to begin the Cooperative Whooping Crane Project. Since that time, conservation efforts on behalf of the Whooping Crane have been a product of a wide range of individuals, private organizations, governments, and the media. The following are a few illustrations of the variety of players and activities that have been a part of the Whooping Crane story (McNulty 1966; U.S. Fish and Wildlife Service 1980, 1986, 1994).

1946. Robert Porter Allen, working for the National Audubon Society, took direction of the Cooperative Whooping Crane Project. Allen became the single most knowledgeable and dedicated champion of the crane in the history of Whooping Crane conservation efforts. He conducted the original detailed biological studies of the birds (Allen 1952, 1956) and worked tirelessly for their survival until his death in 1963.

1950. First Whooping Crane hatched in captivity at Aransas National Wildlife Refuge, owned and operated by the U.S. Federal Government. The mother was a captive crane on loan from the New Orleans City Zoo, and the biologist in charge was Robert Porter Allen from the National Audubon Society.

1952. The wild flock was down to 21 birds. A massive publicity campaign was launched to educate hunters about Whooping Cranes in hopes that the number lost during migration could be limited. In addition to the U.S. and Canadian news media, campaign participants included state and provincial fish and game departments, the U.S. and Canadian Wildlife Services, and the National Audubon Society. Result: all 21 birds and 3 young returned to Aransas in the fall.

1954. Cooperation between the Canadian Wildlife Service, the U.S. Fish and Wildlife Service, and the National Audubon Society led to the discovery of the summer nesting grounds of the Whooping Cranes in Wood Buffalo National Park. Wood Buffalo had been designated a National Park for bison by the Canadian Government in 1922.

1955. The U.S. Air Force planned to practice photoflash bombing on Matagorda Island adjacent to Aransas National Wildlife Refuge. Canadian news media mounted a strong protest, and the Canadian Government made a formal request to the U.S. State Department to stop this imminent threat to the cranes. U.S. Secretary of State John Foster Dulles got the U.S. Department of Defense to cancel the proposed bombing plan.

1959. The Canadian Audubon Society lobbied to stop a proposed railroad through Wood Buffalo National Park, the cranes' nesting grounds. The controversy raged for 2 years, and then the Canadian prime minister asked the Canadian parliament to mandate an alternate (and more expensive) route for the railroad.

1960. The National Audubon Society leased 1601 ha of Matagorda Island for the use of Whooping Cranes. In 1961 the Society leased an additional 687 ha for the same purpose. The U.S. Fish and Wildlife Service approved a Sandhill Crane hunting season in Texas and New Mexico. The National Audubon Society was furious, believing that the hunting of Sandhill Cranes would markedly increase the chances of Whooping Cranes being shot.

1961. A standing committee of the private International Wild Waterfowl Association became an independent organization called the Whooping Crane Conservation Association. This worldwide membership group continues to support Whooping Crane conservation.

1964. The Canadian Wildlife Service gave in to pressure from hunters and farmers (complaining about crop depredation) and approved a Sandhill Crane hunting season in Saskatchewan. The U.S. Fish and Wildlife Service made no objections.

1965. Senator Karl Mundt of South Dakota pushed an amendment to an appropriations bill that allotted money to the U.S. Fish and Wildlife Service for captive breeding facilities at Patuxent Wildlife Research Center in Laurel,

Maryland. This was the beginning of the Rare and Endangered Project that has led to the extensive captive breeding of Whooping Cranes and other endangered species.

1966. The Canadian Wildlife Service published extensive information on the nest sites and breeding behavior of the cranes, based on studies conducted at Wood Buffalo National Park (Novakowski 1966). The Canadian Wildlife Service has conducted annual breeding ground surveys since this time.

1967. The Canadian Wildlife Service and the U.S. Fish and Wildlife Service began removing surplus eggs from Whooping Crane nests at Wood Buffalo National Park to help build the captive flock at Patuxent Wildlife Research Center.

1970. The Whooping Crane was listed as an endangered species in the United States. The National Audubon Society sponsored a study of the cranes' behavior and habitat at Aransas National Wildlife Refuge, under a cooperative agreement with the U.S. Fish and Wildlife Service.

1972. The International Crane Trust (later the International Crane Foundation) was founded in Baraboo, Wisconsin. This private organization is dedicated to the worldwide conservation of all 15 species of cranes. Texas A & M University conducted a study of the environmental effects of oyster shell dredging in San Antonio Bay adjacent to Aransas National Wildlife Refuge. The conclusion of the study was that shell dredging did not appear to have adverse effects on the refuge (U.S. Fish and Wildlife Service 1986).

1973. The U.S. Congress passed the Endangered Species Act.

1975. The first International Crane Workshop was held to provide a forum for sharing research and management strategies among all parties interested in crane research and conservation.

1976. The U.S. Whooping Crane Recovery Team was established.

1977. The Canadian Wildlife Service, in cooperation with the U.S. Fish and Wildlife Service, began capturing and color-marking prefledged young Whooping Cranes at Wood Buffalo National Park so that the behavior of specific birds of known age could be studied. The National Audubon Society organized a reporting network, in coordination with the U.S. and Canadian Wildlife Services, to provide data on Whooping Crane migration patterns. State and provincial wildlife agencies also joined this monitoring and protection effort.

1978. Critical habitat for the Whooping Crane, including the wintering grounds in Texas and important migration stopover points, was designated in the United States. The Platte River Whooping Crane Habitat Maintenance Trust was formed to protect and restore critical migration habitat. The U.S. Fish and Wildlife Service assumed control of the former U.S. Air Force bombing range on Matagorda Island adjacent to the refuge.

1980. The first Whooping Crane Recovery Plan was published by the U.S. Fish and Wildlife Service.

1981. The U.S. Fish and Wildlife Service, the Canadian Wildlife Service, and the National Audubon Society began a program of radio-tracking Whooping Cranes in the wild flock in order to gather detailed information on migration behavior (Howe 1983).

1983. The State of Texas Parks and Wildlife Department assumed control of the refuge on Matagorda Island in order to consolidate management of the public land on the island.

1984. The U.S. Fish and Wildlife Service created the position of Whooping Crane Coordinator to coordinate international, national, state, and private conservation activities.

1985. The Canadian Wildlife Service and the U.S. Fish and Wildlife Service signed a formal Memorandum of Understanding detailing procedures for joint activities related to Whooping Crane conservation. This agreement was renewed in 1990 and 1995. The U.S. Fish and Wildlife Service and 13 state governments on the crane migration route signed an agreement detailing procedures for cooperative protection of Whooping Cranes.

1987. The Canadian Wildlife Service and several provincial governments signed an agreement similar to that between the U.S. Fish and Wildlife Service and the 13 state governments mentioned above.

1988. The North American Crane Working Group was established to bring together managers, researchers, teachers, aviculturalists, biologists, and others interested in the conservation of cranes and their habitat in North America (James Lewis, personal communication).

1989. Twenty-two captive Whooping Cranes were shipped from Patuxent Wildlife Research Center in Maryland to the International Crane Foundation in Wisconsin. This splitting up of the captive flock was done to reduce the risk of disease outbreaks decimating the entire captive population. The National Wildlife Federation, a private conservation organization, provided financial support for the Whooping Crane pens and chick-rearing facility established at the International Crane Foundation (James Lewis, personal communication).

1991. The U.S. Fish and Wildlife Service contracted the Conservation Breeding Specialist Group of the World Conservation Union to convene a Whooping Crane Conservation Viability Assessment workshop, involving crane experts from both public and private organizations.

1992. The National Wildlife Health Research Center (part of the U.S. Fish and Wildlife Service at the time) and the International Crane Foundation cosponsored a Whooping Crane health management workshop to organize information on crane diseases and to establish standard protocols for disease monitoring and management in both captive and wild flocks. Calgary Zoo, under the auspices of the Canadian Wildlife Service, was approved

as the breeding site for the first captive flock of Whooping Cranes in Canada.

1993. Students from Texas A & M University, supported by the U.S. Fish and Wildlife Service, studied the available quantity and nutritive composition of the winter foods that cranes consume at Aransas National Wildlife Refuge (Nelson 1995). The U.S. Army Corps of Engineers began to "armor" shoreline along the section of the Gulf Intracoastal Waterway that passes through Aransas National Wildlife Refuge. This process will continue until habitat loss from shoreline erosion has been controlled. The Florida Game and Fresh Water Fish Commission and the U.S. Fish and Wildlife Service released 14 captive-reared Whooping Cranes in Kissimmee Prairie, Florida. This marked the beginning of an ongoing project to establish a nonmigratory wild flock of Whooping Cranes. Birds for this project are being "isolation-reared"—to avoid imprinting on humans—at Patuxent Wildlife Research Center (now known as Patuxent Environmental Science Center) and at the International Crane Foundation.

1994. The U.S. Fish and Wildlife Service, the Whooping Crane Conservation Association, and the World Wildlife Fund of Canada funded research on teaching young Whooping Cranes to migrate by having captive-reared birds adopted by adult Whooping Cranes in the Rocky Mountain experimental flock. Conoco Oil Company proposed to conduct a seismic survey on 14,800 ha of Aransas National Wildlife Refuge. Under Texas state law Conoco's ownership of the mineral rights under the refuge gives them trespass and mining rights anywhere on the refuge land. Again, it should be noted that Conoco has been very cooperative with the refuge and has continually endeavored to conduct its operations in an environmentally sound manner (James Lewis, personal communication).

1995. As of June 1995 the total world population of Whooping Cranes was 340 birds. There were 166 birds in the natural wild flock, 28 birds in experimental wild flocks, and 146 birds in captivity (James Lewis, personal communication).

Assessing the Mixed Model

Considered as a whole, the history of Whooping Crane conservation efforts represents a mixed-model solution to an endangered species problem. The relative success or failure of this particular model can be assessed by considering how the Whooping Crane recovery efforts stack up against the evaluation criteria I have presented.

In terms of scientific criteria, the number of Whooping Cranes has increased from 21 in 1944 to 340 in 1995 (U.S. Fish and Wildlife Service 1994; James Lewis, personal communication). Varying degrees of habitat protection have been provided: 21,932 ha in Texas, 4800 ha in Nebraska (for migration stopovers), and 4,428,800 ha in Canada (Mann & Plummer 1995). Computer models estimate that 87% of the genetic diversity that existed in the wild flock in 1938 has been preserved (Mirande et al. 1991). In addition, it is estimated that captive-hatched birds have retained about 96% of the genetic diversity found in the wild flock. Finally, a population viability assessment has concluded that the probability of extinction of the Whooping Crane over the next 100 years is less than 1% (Mirande et al. 1991). Of course these projections are based on numerous assumptions and changes in habitat carrying capacity or various mortality risks (disease or chemical spills) could radically change the extinction probability.

Regarding economic criteria, it is difficult to muster adequate financial data for the 60-year history of Whooping Crane conservation efforts. Dozens of individuals, private organizations, and government agencies (local, state, provincial, territorial, and federal) have spent money on Whooping Crane conservation. For the U.S. Fish and Wildlife Service alone, present proposed budgets for Whooping Crane conservation range from $2.5 million to $2 million per year, with a total projected cost of $48 million to achieve the recovery plan goal of downlisting the species from endangered to threatened (U.S. Fish and Wildlife Service 1994).

Some examples of specific economic benefits related to Whooping Crane conservation include the following:

- The city of Rockport Texas (near Aransas National Wildlife Refuge) estimates that wildlife-related tourism and other activities benefit the local economy by about $6 million annually (U.S. Fish and Wildlife Service 1994).
- Wildlife tourism in the Platte River area of Nebraska (migration stopover for Whooping Cranes) generates about $15 million annually in revenue for local communities (Lingle 1987).
- The communities surrounding Bosque del Apache National Wildlife Refuge in New Mexico and Alamosa/Monte Vista National Wildlife Refuge in Colorado gain significant additional revenue from tourism related to the presence of Whooping Cranes (U.S. Fish and Wildlife Service 1994).
- Over 30,000 people per year visit the International Crane Foundation in Baraboo, Wisconsin, generating revenue for the Foundation and for the surrounding communities (George Archibald, personal communication).

Added to the usual difficulties involved in estimating benefits is the problem that the Whooping Crane is the "flagship species" (Dietz et al. 1994) of North American endangered species conservation. That is, many other species have benefited from efforts undertaken on behalf of the Whooping Crane. For example, much of the

money from the U.S. Fish and Wildlife Service is spent on refining the science of captive breeding. The results of these investments have benefited, and will continue to benefit, many other species of birds, including subspecies of the Sandhill Crane, the California Condor (*Gymnogyes californianus*), the Peregrine Falcon (*Falco peregrinus*), and the Masked Bobwhite (*Colinus virginianus*), as well as a number of mammal species such as the red wolf (*Canis rufus*), black bear (*Ursus americanus*), Florida panther (*Felis concolor coryi*) and black-footed ferret (*Mustela nigripes*).

One question that could be asked about costs and benefits is whether it is worth $48 million to achieve downlisting of the Whooping Crane from endangered to threatened. It is quite different to ask whether it is worth $48 million to advance the science of captive breeding to the point where animals in danger can be bred successfully in captivity, trained to re-enter their natural habitats, and reintroduced to the wild with a high probability of survival. If one compares the benefits of saving the Whooping Crane and advancing the science of captive breeding with the benefits of purchasing one additional military aircraft, most biologists (and, perhaps, even the general public) would have little trouble making a choice. On the other hand, there would be much disagreement among scientists and the general public if the question were how $48 million should be spent to achieve the maximum amount of endangered species conservation. In order to analyze this question, "endangered species conservation" would need to be defined in specific terms such as numbers of species conserved for specific periods of time or numbers of acres of critical habitat protected. Then, policy initiatives would have to be compared in terms of their potential impact on these specific conservation indicators. In this process of specifying both goals and policy options, there would be a great deal of room for disagreement.

What is clear from the history of Whooping Crane conservation expenditures is that the mixed-model approach has resulted in the spreading of costs across "those who care" and the general citizenry of both the United States and Canada.

In terms of legal criteria, the people who have implemented Whooping Crane conservation efforts have made an extreme effort to avoid infringing on the rights of private citizens. In fact, some would argue that considerations for the property rights of private citizens and corporations have significantly increased the risk of extinction for the cranes. Particularly in Texas, the rights of landowners, oil and natural gas companies, and fishermen have been respected to the point where their activities could threaten the continued survival of the cranes. On the migration route, the high wires of electrical utility companies are a significant source of Whooping Crane mortality. In this case the Government initially acted with force (in the early 1980s) but more recently has proceeded by enlisting the cooperation of utility companies in installing warning devices on their wires and by joining with the industry and the National Audubon Society to establish the Avian Power Line Interaction Committee (James Lewis, personal communication).

The habitat protection components of Whooping Crane recovery efforts have relied on the purchase of land from willing sellers (with the sellers retaining mineral rights in Texas) rather than on "takings." If anything, the only potential legal challenge to the Whooping Crane conservation program could come from conservation interests that could argue that the cranes have not received the full protection required by the Endangered Species Act. In particular, the cranes are "harassed" at Aransas National Wildlife Refuge as a result of a myriad of human activities in the vicinity of their wintering grounds. One can only surmise that the government's hesitancy to be more aggressively protective of the cranes is a combination of trying to "get along" with disparate interest groups in rural Texas (fishermen, tourboat operators, oil interests, etc.) and realizing that the cranes would be extremely vulnerable if they were perceived to be a threat to the livelihoods of local citizens.

From an ethical framework that considers the "balancing of goods" (Mann & Plummer 1995), the history of Whooping Crane conservation efforts must be viewed as successful as of 1995. The facts are that the species has survived, the costs have been spread among a large number of people, and a minimum restriction of human activity has been required to achieve this result. On the other hand, from an ethical framework that is more biocentric—asserting equal rights for all organisms—than anthropocentric, our history with the Whooping Crane has been and continues to be an ethical disaster. We destroyed the bird's habitat, we hunted the population to near extinction, and all we can muster in recompense are two refuges that are tiny in comparison to the bird's original range, one of which is surrounded by so many hazards that the word refuge is arguably a misnomer. Certainly in today's political and ethical climate, the more pragmatic balancing framework is the one that is likely to be applied in evaluating approaches to the conservation of endangered species.

Historically, the greatest weaknesses of Whooping Crane conservation efforts have been in the administrative area. With a huge cast of characters ranging from individuals to private organizations to units of government at all levels in two different sovereign nations, the problem of communication—let alone coordination—becomes practically insurmountable. At one point in the 1950s, the director of the New Orleans Audubon Park Zoo arrived in a truck at Aransas National Wildlife Refuge and demanded the return of "his Josephine" (the only captive breeding female at the time) (McNulty

1966). Today, the U.S. Fish and Wildlife Service and the Canadian Wildlife Service operate cooperatively under a Memorandum of Understanding, and the two country coordinators participate actively in a wide variety of forums in order to ensure coordination of conservation activities on behalf of the Whooping Crane. It is to the great credit of the dedicated individuals involved in Whooping Crane conservation that activities have been as coordinated as they have been and that so much progress has been made during the past 60 years.

From an administrative point of view, a single organizational structure with clear lines of authority and responsibility would be ideal for an endangered species conservation program. This operational efficiency must be weighed, however, against the benefits of the mixed model, in which opportunities exist for innovations and contributions from a wide variety of individuals and organizations.

Limitations and Recommendations

This analysis was based on a consideration of the conservation history of only one species; a species probably not typical of the majority of endangered and threatened species—particularly the less charismatic. Some general recommendations can be derived from this analysis, however. First, because the conservation of endangered species depends on continuing developments in conservation science, input from concerned and knowledgable parties should be encouraged at all points in a conservation program. Species recovery teams and higher-level, cross-species advisory groups should include private individuals with a particular interest in the species as well as representatives from government, private conservation organizations, and communities that may be affected by conservation activities.

Second, a robust funding mechanism needs to be developed to support endangered species conservation efforts. Mann and Plummer (1995) suggest a "national biodiversity trust" that would permit flexibility in using funds to provide incentives for conservation. I suggest expanding trust fund functions to include the subsidization of individual and organizational scientific initiatives on behalf of particular species or groups of species. This approach would put some funding behind the kinds of synergistic activities among concerned parties that have occurred with Whooping Crane conservation activities. An alternative way to support creative scientific initiatives of individuals and private organizations would be to fund endangered species research as part of the programs of an independent, nonregulatory National Institute for the Environment, as recently described by Denis Hayes (1995).

It is not necessary to create a new bureaucracy to administer the national biodiversity trust fund and its associated endangered species conservation activities. The U.S. Fish and Wildlife Service, the National Science Foundation, or the National Fish and Wildlife Foundation could manage this fund if they were provided with adequate staffing and appropriate authority.

In terms of overall funding mechanisms, Mann and Plummer (1995) propose that the budget for a national biodiversity trust should be established by the U.S. Congress in the same manner that federal agency budgets are established. I propose a somewhat more "sacred" status for this trust fund so that annual appropriations from Congress are not required. Funds could be directed to the trust through several mechanisms. A basic level of funding could be provided through automatic deductions from the paychecks of all employed citizens. Thus, a certain base level of support would be guaranteed without the annual budget agony faced by most federal agency programs.

Additional funds could be derived from creative tradeoffs and mitigation agreements with developers and other economic interests. For example, timber interests in the Pacific Northwest might contribute to the trust in return for receiving some carefully designed "sustainable use rights" in less-critical forest habitats, thereby generating funds that could be used to protect more-critical habitats or species in more extreme danger of extinction. (An independent scientific body would need to be involved in determinations about which habitats are less and more critical). This approach would be to establish "win-win" negotiations that involved government, conservation interests, and economic development interests. Government agencies would need to be flexible in terms of relaxing regulations on a case-by-case basis; conservation interests would need to be willing to give in some areas in order to gain in others; and business and industry would need to view conservation contributions as a necessary and reasonable cost of doing business. The Environmental Defense Fund and The Nature Conservancy are currently developing these types of agreements in order to persuade business and industry to further conservation objectives (Environmental Defense Fund letter, 7 May 1995, "Creating Incentives to Conserve Wildlife Habitat"; Steven Burns, personal communication).

My final recommendation is that each species recovery team and higher-level advisory group create its own simple administrative structure and basic operating procedures. Each administrative system would be uniquely designed to serve the functions and the particular parties involved in each working group. The goal would be to establish functional methods of communication and coordination without generating unwieldy bureaucratic structures. With relatively smooth communication and coordination of activities, the advantages of the mixed model could be maximized.

Broader Implications for Conservation Biology

The Whooping Crane story provides some broader implications for conservation biology as a profession and for conservation biologists as individuals. The story illustrates the efficacy of including in conservation efforts all potential sources of knowledge, innovation, and financial support. It would be a worthwhile standard procedure in any conservation activity to ask whether all possible stakeholders and sources of effectiveness have been involved in the effort and whether some other person or group might suggest a different approach to this problem.

At key points in the history of Whooping Crane conservation, one person or a few individuals made contributions to the recovery effort that may have made the difference between extinction and survival for this magnificent species (Doughty 1989). As individual conservation biologists, we may sometimes feel overwhelmed or immobilized by the enormity of conservation challenges. But as Margaret Mead so eloquently stated, "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has" (Petras & Petras 1995).

The 60-year history of research and data collection on the Whooping Crane is a good reminder that collecting basic data over a long period of time provides the critical information needed to gain a clear understanding of the history, present dynamics, and future prospects of a species or a larger system. In the case of the Whooping Crane, there seems to be a regular boom-and-bust cycle in population numbers that would not have become apparent without the consistent collection of basic demographic data over an extended period (Binkley & Miller 1983; Boyce & Miller 1985; Nedelman et al. 1987).

Finally, the Whooping Crane story clearly illustrates that, especially for migratory and widely-dispersed species, communication, cooperation, and coordination across territorial and jurisdictional boundaries are absolutely essential for species conservation. Long before there were any formal written international agreements or published recovery plans, Canadians and U.S. citizens, government employees, and private individuals were communicating, cooperating, and coordinating activities with the common, simple purpose of saving the Whooping Crane from extinction (McNulty 1966; Doughty 1989; Edwards et al. 1994; U.S. Fish and Wildlife Service 1994).

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