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The Impact of Falconry on Wild Raptor Populations Preface

ROBERT KENWARD. *Institute of Terrestrial Ecology, Furzebrook Road, Wareham, Dorset BH20 5AS U.K.*

At the 1986 annual conference of the Raptor Research Foundation held in Gainesville, Florida, Jim Mosher organized a mini-symposium to consider the impact of falconry on wild raptor populations, as the basis for a position statement. An ad-hoc committee including Jim Mosher (Chair), Jim Brett, Robert Kenward and Ian Newton prepared a draft position statement that was modified at the annual conference in St. Paul, Minnesota in 1988, and was then approved by a postal vote of the membership early in 1989. The six expanded abstracts that follow provide pointers to further literature on each of the main issues of the position statement.

A publication that is long in gestation risks being overtaken by events. Nevertheless, the conclusions of the position statement have so far been strengthened rather than contradicted. After three further years of data from a Prairie Falcon (*Falco mexicanus*) harvest study, D.E. Runde (pers. comm., see too Conway et al. 1995) was "comfortable that removal of 10–20% of nestlings is a safe sustainable yield." Radio-tagging has shown that banding can substantially overestimate first-yr mortality, and the resulting new models indicate that sustainable yields for some species could be more than 30% of the young (Kenward pp. 295–296). Three cases of hybrid falcons displacing normal peregrines breeding in Germany (H. Reilman pers. comm.) reinforce the position statement recommendation that such birds should at the least be imprinted on humans before being used in falconry.

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Controlled Harvest of Nestling Prairie Falcons: A Field Experiment

DOUGLAS E. RUNDE.[1] *Wyoming Cooperative Fishery and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming, Box 3166, University Station, Laramie, WY 82071 U.S.A.*

Raptors have been removed from the wild for use in falconry for centuries, but sustainable levels of harvest have not been clearly demonstrated. As the recreational demand for raptors focuses primarily on the younger age classes (nestlings and juveniles), standard models for estimating maximum sustainable yield (MSY) are inappropriate. The MSY concept is based on density-dependent population growth models, which typically require a reduction in population size well below carrying capacity in order to stimulate maximal population growth and allow maximal levels of harvest. For raptors, a more appropriate goal is to maintain stable populations near carrying capacity while allowing conservative harvests.

One approach to estimating a sustainable yield (SY) for a raptor population is based upon a comparison of reproductive success and mortality. For the Prairie Falcon (*Falco mexicanus*), mean productivity (from 15 studies spanning more than 20 years) is 2.5 young $pair^{-1}$ yr^{-1} (Runde 1987). A series of 15 survival schedules, derived from banding data, indicated that an average of 2.0 young $pair^{-1}$ yr^{-1} are needed to maintain stable populations through time (Runde 1987). Theoretically then, an average surplus of 0.5 nestlings is produced by each breeding pair each year.

From this, a SY for a local Prairie Falcon population is easily calculated by dividing the number of breeding pairs by 2. To do so requires an estimate of breeding population size. However, it may be impractical to survey the population each year and then set harvest levels. If an estimate of the number of breeding territories, or maximum number of breeding pairs is available, then average breeding population size can be calculated. A conservative estimate of occupancy rate (based on 9 field studies) is 65% (Runde 1987). If previous surveys indicate that 100 breeding territories are present, then 65 pairs are expected to occupy territories and 32.5 surplus nestlings will be produced in an average year. Due to normal fluctuations in populations, this approach will lead to recommended harvest levels that are above SY in some years and below SY in others.

My approach is based upon life-table estimates of survival rates from band return data. Such estimates are unavoidably suspect due to many potential sources of bias (Burnham and Anderson 1979). Thus, a field test of this approach was proposed and an experimentally-controlled harvest of nestling Prairie Falcons in southwestern Wyoming was begun in 1982. A 2420 km^2 study area was divided into a harvest area (with 20–26 breeding pairs) and an adjacent control area (with 45–55 pairs).

[1] Present address: Florida Game and Fresh Water Fish Commission, 620 South Meridian Street, Tallahassee, FL 32399 U.S.A.

Table 1. Summary of nestling Prairie Falcon removals in SW Wyoming, 1982–86.

YEAR	NUMBER REMOVED	HARVEST RATE (%)	PRODUCTIVITY AFTER REMOVALS[1]
1982	4	9	1.95
1983	0	—	1.55
1984	10	18	1.88
1985	15	27	1.90
1986	13	28	1.70
Totals	42	18	1.80

[1] Number of young per occupied breeding territory.

Experimental harvest involved removing enough nestling falcons to reduce breeding success to below 2 young pair^{-1} each year (Table 1). Nestlings were fostered into nests far removed from the study area (>225 km to the east), and hacked at an artificial nest site in southeastern Montana. None were removed in 1983 as natural nest success was very low.

If harvest exceeds SY, a decline in the population may eventually result. Excessive harvesting may lead to a decline in falcons available to fill vacant nest sites, in which case the number of occupied territories should decline. Therefore, breeding territories in the harvest and control areas were monitored each year to compare trends in territory occupancy. To avoid biases due to the discovery of additional nesting territories, occupancy rates were calculated from a subset of sites visited every year.

Although there was no evidence of a change in population size from 1982–86, it is too early to draw firm conclusions. Effects of the harvest will be detectable only after falcons fledged during the experiment dominate the breeding population. Trapping of breeding adults indicated that the recruitment of these cohorts began in 1985. As annual mortality of adults has been low (13–19%) (Runde 1987), recruitment will be slow. Complete turnover of the breeding population will require about eight yr.

Immigration may compensate for reduced breeding success and maintain the population even if SY has been exceeded. In an attempt to measure immigration into the harvest area, an extensive banding program has been conducted. More than 500 nestling and 100 adult falcons have been banded in or near the study area. If immigration is high and there is no decline in numbers of breeding pairs, a precise level of sustainable harvest will not have been demonstrated. However, the presence of a harvestable surplus will be shown and the approach taken may be applicable on a local scale.

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FALCONRY HARVEST IN THE UNITED STATES

JAMES A. MOSHER. *Savage River Consulting, 17811 Lappans Road, Fairplay MD 21733 U.S.A.*

Falconry, most simply defined, is the taking of game with the aid of a trained raptor. Many raptors used in falconry are birds taken from wild populations. There are numerous opinions about the sport or potential impacts on wild populations from this harvest. The purpose here is to present some data concerning raptor harvest, to put the harvest in perspective with regard to population numbers and to make some reasoned management recommendations. I believe that biologists and falconers alike will be drawn to similar conclusions by these data. The data came from two sources. First, an unpublished report by Brohn in 1986 for the International Association of Fish and Wildlife Agencies (IAFWA) Nongame Wildlife Committee included summaries of numbers of falconers and of raptors harvested, based on survey responses from 42 states. Second, I summarized falconers' annual reports for 23 states covering the 1- or 2-yr reporting periods ending in 1986. Copies of these reports were kindly provided by Walter Steiglitz, Assistant Director for Refuges and Wildlife of the United States Fish and Wildlife Service (USFWS). In order to protect the privacy of the individuals, much information was obscured in these reports. Where this resulted in a range of possible values, I used the high estimate for numbers harvested, and the low estimate for numbers returned to the wild. Because so many Peregrine Falcons (*Falco peregrinus*) and Harris' Hawks (*Parabuteo unicinctus*) were captive bred, and that information was obscured on most reports, I excluded those species from the USFWS data. They are, however, included in the IAFWA data.

Brohn reported that 2 776 falconers harvested 737 raptors of 15 species from the wild during 1986. Of these raptors, 367 were returned to the wild, either intentionally or accidentally, for an estimated net annual harvest of 370 birds. My review of USFWS data from 23 states yielded 350 birds harvested, 66 released and 118 accidentally lost, for a net harvest of 166 birds from wild populations. The IAFWA survey gave a net harvest rate of 8.8 birds state^{-1} yr^{-1}, while the USFWS reports gave a net harvest rate of 7.3 birds state^{-1} yr^{-1}. Further, the USFWS reports record that 330 young birds (6.9 state^{-1} yr^{-1}) were produced by captive propagators during the 1985 reporting year. Even allowing for no benefit from raptors returning to the wild from any source, the maximum annual harvest is estimated between 15.2 and 17.5 birds in each state.

Almost 56% of all raptors harvested were Red-tailed Hawks (*Buteo jamaicensis*) or Prairie Falcons (*Falco mexi-*

canus), species certainly not threatened or endangered. Regionally, California reported the highest harvest, with 128 birds taken and 118 returned to the wild, giving a net loss of 100 birds from the wild.

G.S. Butcher, M.R. Fuller and J.L. Ruos (unpubl. data) found significant increases from the early 1970s to the early 1980s in Christmas Bird Count (CBC) numbers of Northern Goshawks (*Accipiter gentilis*), Red-tailed Hawks, Merlins (*Falco columbarius*), Prairie Falcons and Gyrfalcons (*Falco rusticolus*), using the most conservative data. Their estimates of continental population numbers, extrapolated from CBSs for Red-tailed Hawks and Prairie Falcons are 80 000 and 13 000, respectively, for winter 1982–83.

My estimates of density of breeding raptors in the eastern forests, based on complete censuses of 32 km^2 study areas distributed from Maryland to Minnesota, approximate to 1 pair of Broad-winged Hawks (*Buteo platypterus*) in 5 km^2 and 1 pair each in 25 km^2 of Red-shouldered Hawks (*Buteo lineatus*), Red-tailed Hawks and Cooper's Hawks (*Accipiter cooperii*). In the northeastern U.S., where these study areas are located, there are approximately 575 000 km^2 of forested land. Some of it is certainly not suitable breeding habitat for one or more of these species. Likewise, portions of the areas I censused did not provide suitable breeding habitat. If only half of the available forest land is occupied, these data can be extrapolated to over 10 000 breeding pairs of the least dense species and almost 60 000 pairs of Broad-winged Hawks.

International trade in raptors is also dwarfed by these numbers. The annual report of the convention on International Trade in Endangered Species (CITES) of wild fauna and flora for 1986 reports 213 468 birds imported to the U.S.A. Only 36 individuals were raptors of falconry interest, and 9 of them were for falconry. For the same period, 5684 birds were exported, which included 16 raptors (15 hybrid falcons and 1 Peregrine Falcon reexported to Canada). The total number of imports, including species not covered by CITES (all raptors are covered) was estimated to be more than 700 000.

In the light of these data, I agree with the IAFWA that the harvest of wild raptors by falconers has no significant biological impact on the resource. It does not seem that substantial expenditures of time and money by state and federal regulatory agencies are needed to protect raptor populations from falconry harvest. In fact, when captive propagation by falconers is considered, the net effect may be a gain rather than a loss for some species in some areas. As noted by the IAFWA, there is scope for simplification of regulations and a reallocation of federal and state funding priorities. The limited funds available for management of raptor populations would be far better spent on regional and national monitoring programs and for research on the impacts of land use changes.

In particular, I note that in the U.S. it would be consistent with other managed migratory bird populations to remove state barriers to harvesting raptors. In 1986, Wisconsin required only a nonresident small game license to permit harvest by nonresident falconers. Reporting and banding requirements could be eliminated for all species except those of special concern. Internationally, experience in the U.S. supports the licensing of falconers based on demonstrated competency and experience, with possession limits based on the class of license. If standards of competency for falconers similar to the U.S. system were adopted internationally, noncommercial exchange of raptors might be permitted among licensed individuals of any countries adhering to such standards.

INFERRING SUSTAINABLE YIELDS FOR RAPTOR POPULATIONS

ROBERT E. KENWARD. *Institute of Terrestrial Ecology, Wareham, Dorset BH20 5AS U.K.*

Sustainable yield levels for raptors can be estimated in three main ways: (1) from data on populations harvested for falconry, (2) from data on stable populations in which a known proportion was killed by man and (3) by studying the dynamics of artificially depressed populations.

Ideally, harvest data should be obtained for at least 10 yr from populations where compensatory immigration can be discounted. The only such data are for Gyrfalcons (*Falco rusticolus*): records of nestlings which were taken from Iceland for four centuries would represent 25–50% of young from the present, saturated population (Cade 1968). More recently, an average 22% of Peregrine Falcon (*Falco peregrinus*) nestlings were taken from the Queen Charlotte Islands during five yr in the early 1960s (Blood 1968). There was no immediate marked population decline, but a slight downward trend would have been undetected in this short period. Similarly, the experimental 9–27% harvest of young Prairie Falcons (*Falco mexicanus*) in Wyoming seems to have caused no population decline (Runde 1987).

Although the proportion killed by man has ranged from 40–92% of recoveries in at least 27 banding studies (Newton 1979), this must partly reflect recovery bias: 47% of recovered Northern Goshawk (*Accipiter gentilis*) rings were from killed hawks on a Swedish island during 1975–85, but man caused only 36% of the deaths among 352 radio-tagged hawks in the same period (Kenward et al. 1993). To obtain a minimum estimate of man's impact, the number of birds killed can be expressed as a proportion of the number banded, and not just the recovered bands. In this case 14% of peregrines and 19–21% of goshawks were killed in Fennoscandia prior to 1962 (Nordstrom 1963, Höglund 1964), and 16% of North American Cooper's Hawks (*Accipiter cooperii*) during the 1930s (Henny and Wight 1972). The Fennoscandian goshawk population has remained large, with "best estimates" that about 30% were being killed in Finland (Haukioja and Haukioja 1970).

Data on increase rates for depressed raptor populations provide minimum estimates of sustainable yield, because the increase may stem from alleviation rather than removal of the depressive factors. Increase rates of 12% per annum in Britain and 16% in West Germany have been recorded for peregrines as a result of reduced persecution or pollution (Ratcliffe 1980, Newton 1988). In Holland, goshawk numbers increased by 19% annually during 1963–80 as organochlorine use was restricted (Marquiss 1981), and the reintroduced British goshawk population grew at an annual rate of 21% during 1964–80 (Thissen et al. 1981). The increases probably stemmed in part from breeding by birds which would not reproduce in saturated populations. Thus, 12% of goshawks bred in their first year in a German population where many adults were killed (Ziesemer 1983, Looft 1984), whereas none have in the Swedish island study (Kenward et al. 1991). If the German reproduction data are used in the Swedish population model, there is a 27% annual increase. Moreover, the Swedish females have a lower mortality than males, and thus a 1.67:1 excess in the adult population: removing 36% of young females would equalize the adult sex ratio.

These studies show that healthy peregrine and goshawk populations can sustain the removal of at least 10% of their young, and in some cases more than 20%. The same probably applies to many other raptor species. The impact of allotting native raptors for falconry is likely to be less than the gross take, because 50–93% may eventually be released or lost into the wild (Kenward 1974). This process can even benefit raptor conservation: it was a cheap and successful way to reestablish goshawks in Britain (Kenward et al. 1981, Marquiss 1981).

Healthy raptor populations can probably sustain at least a 10% harvest of juveniles, and in some cases perhaps more than 20%. The actual number of birds available from a given population would depend on the population's size, which should be monitored continuously to ensure that no decline results from the harvest. Since population monitoring is useful for raptor conservation, but costly, it may make more sense to encourage falconers to contribute to data collection, as the price for their harvest, than to channel their resources into the captive breeding of species which are unthreatened in the wild.

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COMMENTS ON HYBRIDIZATION IN RAPTORS

JIMMIE R. PARRISH[1] AND CLAYTON M. WHITE. *Department of Zoology, Brigham Young University, Provo, UT 84602 U.S.A.*

[1] Present address: Avocet Consulting, Inc., 1065 East Canyon Road, Avon, UT 84328 U.S.A.

The concept of hybrid raptors has interest to both the evolutionary biologists (systematist), because of the implications of hybridization to the understanding of phylogenetic relationships, and also to the falconer, because of the blending of characteristics that hybrids may manifest, some of which may be particularly desirable in the sport. At the writing of this paper, hybrids in many combinations of species are a major source of raptors for the falconer. As a group, falconers thus have specific interest in the phenomenon, in part because the concept of producing hybrids has come under question by some environmentalists, conservationists, biologists and others.

A basic understanding of taxonomic concepts, as well as criteria defining hybridization, is critical to adequately address hybridization involving raptors. We defined these concepts as pertaining to avian populations in general. We then defined the species using the classical and time honored characteristic notion of reproductive discontinuity (Mayr 1970, Bush 1975), as outlining the limits of a species, recognizing that such a definition may become obsolete as more and more data and analyses, especially molecular data, are available. Within this context, however, hybridization is the mixing of "alien" genes from one Mendelian population to another (Sibley 1957, Rising 1983) in both natural and artificial schemes. The hybrid is then the offspring of a cross between genetically dissimilar (at some level) individuals or populations. The word hybrid may conjure bad connotations (Cade 1983) while the word "purebred" gives good feelings. Purebreds, however, are nothing but channeled mixtures of genotypes. We used examples of hybrids that may occur in stable hybrid zones in the wild, among such nonraptorial birds as flickers (*Colaptes* spp.), jays (*Cyanocitta* spp.) and meadowlarks (*Sturnella* spp.) (Rising 1983). We further explored the influence of the natural spread of "alien" genes throughout the range of a species; for example, the Mallard (*Anas platyrhynchos*) is reproducing with and swamping out genes in related species such as the American Black Duck (*Anas rubripes*) (Ankney et al. 1986) and Pacific Black Duck (*Anas superciliosa*). Important questions, as they applied to the above nonraptorial species, but also the raptorial species discussed, include: what constitutes hybrid vigor (heterosis)? What is the effect of a hybrid swarm? How is fecundity of a given taxon affected by hybridization? What other effects should be considered when introduction of a hybrid occurs in a population? Is the question of hybridization among wild raptors an important one?

Most of these questions are not easily answered. At present, some cannot be. A relative paucity of data exists for evaluating effects of hybridization among wild raptor populations. Therefore, we discussed the kinds of data needed to formulate effective management questions involving hybrid raptors. An early record suggested the natural cross between a male Northern Goshawk (*Accipiter gentilis*) and a female Common Buzzard (*Buteo buteo*) (Gray 1958). Recently, there are at least five cases of intrageneric natural hybrids in raptors: *Otus asio* x *Otus kennicotti, Buteo jamaicensis* × *Buteo buteo, Falco tinnunculus* × *Falco naumanni, Accipiter fasciatus* × *Accipiter novaehollandiae, Milvus milvus* × *Milvus migrans* and *Falco peregrinus* × *Falco mexicanus* (Marshall 1967, Wobus and Creutz 1970, Sylven 1977, Hollands 1984, Olsen and Olsen 1985, Bjilsma 1988, Oliphant 1991). Two other natural hybrids have been suggested. Ellis (1995) speculated, based primarily on plumage, that the so-called Altay falcon (*Falco altaicus* or *Falco cherrug*?) of the mountains of central Asia resulted from hybridization of *Falco cherrug* × *Falco rusticolus.* Seibold et al. (1993), based on DNA sequence data showing two distinct mitochondrial hyplotypes within the currently recognized *Falco cherrug*, suggested that one of the hyplotypes may have resulted from hybridization of *Falco cherrug* × *Falco peregrinus.* Any special circumstances surrounding each of these examples is briefly discussed.

Some of the most interesting hybrids are those produced in captive breeding situations. The list of species that have been bred in captivity often with artificial insemination, is, of course, considerable. Of 83 species of diurnal raptors successfully bred in captivity as of 1985, 23 were falcons, eight buteos and seven accipiters (Cade 1986). Currently, hybrids are commonplace within the falconry community (Haak 1980). Certain combinations of falcons seem to be better for the sport than either of the parental types and indeed, some types of hybridization may confer a certain evolutionary fitness over either parental species (Grant and Grant 1992). We do not have good data on all the hybrid falcons that have been produced nor the combinations (either species involved or whether a tri- or more hybrid cross), and thus not much of an assessment can be made. Some of the karyotype and chromosomal differences in parental species within large native North American *Falco* were discussed (Schmutz and Oliphant 1987).

The inevitable question concerns the fate of such hybrid raptors if lost to the wild. Since we now live in habitats that are highly modified, a sort of hybrid environment, the question of what fits best into the environment is moot. Hundreds of "exotic" raptors have been lost into the environment without any discernable long-lasting affects. For example, Saker Falcons have bred with Peregines (Stevens 1972) and yet sakers lost to the wild in North America seem never to show up again; their genes certainly do not seem to be represented in wild breeding native populations of other North American *Falco* unless the haplotype situation mentioned above could be detected. Certainly, genes modifying morphology are not evident. Some intrageneric hybrids, where one of the parents is an exotic species, may be of concern, however. *Buteo jamaicensis*, an exotic in the U.K., has mated in the wild with *Buteo buteo* and this could pose a problem in the future as with the Mallard × black duck example.

As with most other management-oriented questions, the answers to questions surrounding hybridization are to be found within the natural realm only after some periods of observations. We can provide logical expectations on effects of artificial hybridization to wild raptor populations, and the affects seem to be of little consequence. In our discussion, particular emphasis was placed on taxa within the genus *Falco.*

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CONTRIBUTIONS OF REHABILITATION/EDUCATION PROGRAMS IN RAPTOR MANAGEMENT

PATRICK T. REDIG, GARY E. DUKE AND MARC MARTELL. *Raptor Research and Rehabilitation Program, 295 Animal Science/Veterinary Medicine Building, 1988 Fitch Avenue, St. Paul, MN 55108 U.S.A.*

The rise of rehabilitation of raptors has occurred concurrently with the increase in general efforts to manage and conserve raptors. Prior to the mid-1960s there was little evidence of rehabilitation being undertaken on any scale that might impact aspects of raptor management. Similarly, prior to 1970, there was a dearth of specific veterinary information available to be utilized in providing state-of-the-art medical care for raptors. Since then, a significant development in the number and scope of organizations for rehabilitating raptors and other wildlife has occurred among both lay and professional sectors. Many of these projects include public education and research, both basic and applied, among their objectives, so that the total impact of these efforts can potentially have a sizeable positive influence on the survival of raptors. Using data derived largely from the research and rehabilitation effort maintained at the University of Minnesota since 1974, we reached a number of conclusions. (1) Combined research and rehabilitation programs can provide effective means for detecting naturally occurring diseases and for assessing the importance of various causes of mortality among raptors. Fourteen years of data collected systematically show in general that the occurrence of natural disease is low in raptors, whereas the incidence of traumatic injuries from man-made factors constitutes the majority of the admissions. Among the latter, the greatest number of injuries arose from collisions with moving vehicles and powerlines. (2) Rehabilitation can result in complete recoveries with successful releases to the wild and subsequent survival. Data from banding records and telemetry studies show survival in excess of seven yr for some rehabilitated raptors and distances of more than 1000 miles traveled over the course of five mo following release. Data are also available which document successful nesting of released Bald Eagles (*Haliaeetus leucocephalus*), through the finding of color-marked feathers in and below occupied nests. The influence of these recovered birds on wild populations varies with the num-

bers involved, the number of wild birds present in a population and the effectiveness with which rehabilitated raptors are assimilated back into the wild. (3) Reintroduction and translocation projects for Bald Eagles and Peregrine Falcons (*Falco peregrinus*) have benefited by the rearing of young, and also through the assessment of health status and medical treatment of those that have become ill or injured during the release process. (4) Research into the utilization of crippled raptors for breeding purposes has produced positive results. Young of Bald Eagles and several owl species have been produced by crippled parents for release projects.

Other impacts of rehabilitation projects are farther reaching, but less measurable, than those mentioned above. Since 1980, 18 senior veterinary students have completed internships ranging from three wk to three mo at this program, and several have gone on to establish research and rehabilitation projects at other veterinary colleges. Additionally, raptor biologists from Spain, Mexico, France, England, Denmark, New Zealand and Israel have served internships during which they gained valuable experience in capture, restraint, blood sampling and other procedures that enhance their ability to gather field data about raptors. Further, the program now maintains an active list of more than 100 volunteers working in clinical, educational and public relations areas which not only further the immediate work of the program, but also provide the volunteers with lifetime experiences that will stimulate their understanding and make them effective communicators for raptor conservation in the future.

The most immeasurable thrust is in the area of public relations and education. Uncountable hundreds of thousands of people are being informed about the ongoing need for conservation of raptors and wildlife resources. Rehabilitation statistics indicate the effectiveness of such efforts. In the period 1972–75, 35% of the admissions to the program occurred due to projectile injuries; since 1981, 4% or fewer of admissions have come from projectile injuries. Additionally, public awareness of the need for eagle wintering habitat caused the reevaluation of an airport improvement project in St. Paul, MN that would have resulted in the felling or topping of trees on an island in the Mississippi that was used by Bald Eagles. This population of eagles was found by radio-tracking a rehabilitated bird that had recovered from a trap injury.

Influencing public policy and legislation are other arenas in which rehabilitation projects have had an impact. The current trend toward elimination of lead shot for waterfowl hunting has gained impetus from the realization that Bald Eagles are affected by lead poisoning, a fact that came to light from the admission of lead-poisoned eagles to rehabilitation facilities as well as the USFWS Health Laboratory in Madison. Additionally, several states in the Midwest have enacted legislation to eliminate the use of open-baited steel-jawed traps for small mammal trapping after recognizing the numbers of eagles admitted to rehabilitation projects that had been caught in traps.

The cost-effectiveness of rehabilitation is only measurable in terms of the number of benefits one is willing to apply against the actual medical costs of rehabilitation The Minnesota project computes a cost of about $75 per bird admitted to the clinic, amortized over a total admission of 4000 raptors in 14 yr. At an average release rate of 42%, the cost per released bird is about $150. Cost factors associated with other means of raptor management are not available, so direct comparisons cannot be made. However, given the wide array of benefits afforded raptors by the global efforts in conservation mediated through rehabilitation and education projects, we conclude that this area of endeavor is a viable and worthwhile tool for their management.

DEVELOPMENT OF CAPTIVE BREEDING AND RELEASE TECHNIQUES

TOM J. CADE AND MARTIN J. GILROY. *The Peregrine Fund, World Center for Birds of Prey, 5666 West Flying Hawk Lane, Boise ID 83709 U.S.A.*

Aldo Leopold (1933) began what can be called the "ecological tradition" in wildlife management, with its emphasis on habitat. Its principle is that the preservation and manipulation of all environmental factors that are necessary to support wildlife populations is more important than direct manipulation of the animals themselves. This approach has continued to the present date and is certainly the best policy whenever it can be pursued. The preservation of suitable habitats for birds of prey should be our paramount concern, as it is for all wildlife, since the more natural areas and ecosystems we can set aside and preserve in the unaltered state, the greater will be the abundance and diversity of raptors in the future. However, we all recognize that despite our best intentions and efforts, natural habitats of all sorts will continue to shrink in size and to deteriorate in their capacities to support a diversity of species, under the continuing influence of human population pressures and needs. Such passive preservation measures that aim to preserve the status quo are delaying actions at best, and alone will not suffice, simply because they will not occur on a large enough scale to take care of everything. Increasingly in the future, the strategy of biological conservation will need to combine strict habitat preservation with preservation of individual species, by using manipulative techniques (such as captive propagation and reintroduction) to help species to adjust and to survive in the increasingly human-dominated world.

PROPAGATION

It is curious that the captive propagation of raptors is a quite recent activity, given the long tradition of human involvement with these species in the sport of falconry and as tribal and national totems. The first Peregrine Falcon (*Falco peregrinus*) known to be raised from captive parents was produced as recently as 1942, and even as late as 1965 only about 23 species of diurnal raptors had successfully been bred in captivity, mostly on a casual basis.

The situation has changed markedly in the last two decades. When it became evident in the late 1960s that many raptor populations in north temperate regions had suffered major declines, owing to DDT and related pesticides or to other forms of environmental degradation, an interest emerged (particularly among falconers) to perfect techniques of captive breeding for some of these species, especially the peregrine. More than a quarter of all falconiform species have now been bred in captivity. At least 12 species have produced more than 100 progeny in captivity since 1975, some having produced thousands; the number of peregrines produced worldwide certainly exceeds 5000. It is probably safe to conclude that most, if not all, diurnal birds of prey can be bred in captivity given sufficient knowledge of their needs and sufficient resources to carry out the work.

Among the explanations for these breakthroughs is the zealous nature of raptor breeders. Most of them are falconers, building on 3000 years of knowledge about handling and training hawks and falcons. A second factor contributing to the success of these projects has been the rapid and free exchange of information among breeders through organizations such as the Raptor Research Foundation, North American Falconers Association, the Hawk and Owl Trust and the British Falconers' Club, to name a few. Finally, much is owed to the application of basic scientific information on avian reproductive physiology and breeding behavior and ecology. A quick example is the now well-known development of human-imprinted "semen donors" for artificial insemination, solving infertility problems owing to incompatibilities between mates. A thorough review of captive propagation is available in Cade (1986).

REINTRODUCTION

Raptor reintroduction programs, which are often technically "restocking" in that the original population is not truly extinct, have employed three general methods: (1) fostering captive-bred or harvested wild young into the nests of conspecific surrogates, (2) cross-fostering into the nests of other species and (3) hacking by modifications of the traditional falconers' methods. Details are available in Sherrod et al. (1981), Cade et al. (1988) and Barclay and Cade (1983). As these techniques have been refined, there has been a rapid increase in the number of reintroduction programs for raptors.

If a program is to be successful, its goals need to be specifically stated, based on reproductive and survival data from similar projects or from natural populations in other parts of the species' range so that accurate projections of the required commitment can be made, in terms of birds, work, time and money. Such projects should not be started merely because it is now comparatively easy to do so, or is good publicity, or makes an agency available for federal funding. Experience to date indicates that the establishment of self-sustaining populations in vacant range takes a lot of birds and a lot of time.

A concerted, cooperative, regional approach can maximize the return on species restoration efforts. Clustering release sites so as to saturate a region increases the likelihood of pair formation, and may be accomplished through cooperation of several states. Toward that end, an active, enthusiastic recovery team approach has worked well in the eastern peregrine reintroduction. Besides their role in coordinating the multitude of state and federal agencies that carry out this work, they have helped to expedite the regulatory burden and moderate the political aspects that accompany a large-scale program.

The cost of conducting raptor restoration programs in the coming decades will be high, since they are so labor intensive, especially when captive-produced birds are involved. Taking the Eastern Peregrine Recovery Program as a case in point, the Peregrine Fund has spent about \$2.8 million to propagate and release peregrines in the eastern states. Figuring in the expense of cooperating agencies probably brings this cost to about \$3.5 million, perhaps more, and this is but one of four regional recovery programs in the U.S. Though this may seem a staggering amount at first, it is not really that expensive relative to many of the other things people are willing to spend our public and private wealth to obtain. Compared to the \$10 million one individual recently paid for a single untrained racehorse, or the \$15 million purses of championship prize fights, or the billions of dollars spent on Star Wars technology, saving endangered species seems a bargain.

These costings underscore the need for sound economic projections in the planning stages of a reintroduction program, and the need for continued support for the duration of the program. Complete restoration may not be achieved until years after the initial enthusiasm of the program has waned. Moreover, the required support extends beyond money alone, to agency support. The success in establishing initial small populations can lead to an attitude of complacency, for example, so that states just entering a program become ineligible for the federal funds that got the program started. Government labs can become reluctant to analyze eggs to monitor the factors responsible for the species' original decline.

The involvement of the skilled private sector is one way of reducing some of the costs of reintroduction programs. Members of local bird clubs and individual falconers have helped survey and monitor falcons in the east. Many falconers have provided young for the peregrine recovery effort. Because of production problems at our facility in Boise in 1986, more than 15% of the birds released in the east were donated by private breeders. Others provided falcons for release in the Upper Mississippi region.

As natural environments become fragmented and degraded, it is up to those of us who care about these birds to convince the rest of humanity that they are worth the cost of saving. So long as people are willing to commit the necessary time, effort and money, the creative use of management techniques like captive breeding and reintroduction can be made to work for particular species of concern. The future is not bleak, as some pessimists would have us think; rather, it is a challenge.

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