



United States Department of the Interior

NATIONAL PARK SERVICE

Gulf Islands National Seashore

3500 Park Road

Ocean Springs, Mississippi 39564

IN REPLY REFER TO:

NH 1988-36

N22 GUIS-MS

25 January, 1988

Memorandum

To: Superintendent *JH*
Chief Ranger *CRC*
Management Assistant
FL Interpretation
FL District Ranger
MS Interpretation
MS District Ranger

From: Research Biologist, Gulf Islands National Seashore

Subject: Eagle Project

Attached for your information is a manuscript I have recently submitted to American Scientist. It provides an overview of the eagle project to date, and a rationale for future efforts. Please let me know if you have any questions or comments.

Ted Simons
Research Biologist

ISLAND EYRIES (Nests of Birds of Prey)

Ted Simons

Steve K. Sherrod

Michael W. Collopy

M. Alan Jenkins

A blend of ancient falconry techniques, animal husbandry, and modern ecological theory are aiding the recovery of the bald eagle.

Despite Benjamin Franklin's persistent lobbying on behalf of the wild turkey, our founding fathers chose the bald eagle (Haliaeetus leucocephalus) as our national symbol. At the time a common resident throughout much of North America, bald eagles were viewed as symbols of strength, courage, beauty, and freedom. Over the past two centuries their populations have plummeted, so that today they also symbolize the effects of environmental contaminants, habitat loss, human persecution of wildlife, and the impending free-fall of world wide biological diversity (Lewin 1986). Since the banning of DDT in 1972 (Grier 1982) populations have shown encouraging signs of recovery, but today over 90% of the remaining nesting pairs are confined to relict populations centered in Florida, the Chesapeake Bay area, Maine, the Great Lakes, and the Pacific Northwest (Green 1985).

Over the last 15 years nationwide conservation efforts have been focused on restoring the bald eagle to portions of its former range. For the most part, these efforts have involved the reintroduction of

birds into the islands of suitable habitat that remain. Often these habitat islands are imbedded in a landscape highly modified by man's activities, and where without direct intervention there would be little likelihood of natural recolonization.

The ancient falconry technique known as hacking (Sherrod et al. 1981) is the foundation of most reintroduction projects. The method, originally used with great success for restoring peregrine falcon populations (Falco peregrinus) has more recently been applied to bald eagles (Cade and Temple 1977, Nye 1987). Centuries ago falconers discovered the fact that most birds of prey are philopatric, that is they form an attachment to the place where they are born, and tend to return to that location when they are ready to breed. Thus, young bald eagles released into suitable but unoccupied habitat will tend to return to that habitat to nest when they reach adulthood at five to six years of age. The irony of this philopatric tendency is that it makes wild birds less likely to recolonize vacant habitats. For example, although over 2500 bald eagles migrate from the northern U.S. and Canada to winter in southeastern states, few if any stay to breed. Even with this large yearly influx of birds, there are currently only about 120 active Bald Eagle nests in the Southeastern U.S. outside of the state of Florida (Bagley 1987). This population is estimated to be about one third of its historic size (Fig. 1). Hacking has proven to be an effective wildlife management tool because it not only establishes birds in the scattered islands of remaining suitable habitat, but also because it overcomes the population inertia that results from phylopatry.

The goals for the restoration of the species are determined by the U.S. Fish and Wildlife Service and outlined in a document call the recovery plan (Murphy 1984). The plan has established a goal of 90 new nests in the southeast, which would increase the regional nesting population to approximately 40% of its estimated historic level. At that point the population would no longer be viewed as in danger of extinction, and consideration would be give to changing its status from endangered to threatened. Although most of the fourteen eagle hacking projects underway in the U.S. are in their early stages, the results have been encouraging, and to date at least seven new nesting territories have been established by hacked birds (Nye 1987).

Finding a suitable source of birds for reintroduction is an obstacle for all hacking projects. Bald eagle hacking projects in the Northern U.S. have been able to use chicks removed from healthy populations in Canada and Alaska. However, southern bald eagles are thought by many to be a distinct sub-species (King 1981). They show several unique adaptations to their environment, all of which are believed to have some genetic basis. Southern birds are smaller (presumably an adaptation to the warmer climate) less migratory as adults, and in contrast to their northern counterparts, winter breeders. Our work, a large cooperative project involving the Sutton Avian Research Center, the states of Florida, Georgia, Alabama, Mississippi, Oklahoma, and North Carolina, the University of Florida, and the National Park Service, is an effort to develop a restoration program that takes into account the unique characteristics of southern bald eagles. The first

and most important stage of this project was an attempt to determine if we could use the relict Florida population, which contains over 80% of the birds remaining in the southeast, as a renewable source of eagles by employing a technique called egg-recycling.

EGG RECYCLING

The technique relies on a female bird's ability to lay a replacement clutch of eggs (recycle). This ability, presumably an adaptation to the loss of eggs to predators, storms etc., had been demonstrated in related species such as Ospreys (Pandion haliaetus) and falcons, but not in wild bald eagles (Kennedy 1977, Morrison and Walton 1980). If Florida bald eagles could be induced to recycle, and if they could do it without a significant reduction in their breeding success, our plan was to use that surplus production as a source of birds for hacking projects throughout the southeast.

We set out to examine this question in 1985 with four objectives; (1) to determine if recycling occurs in southern bald eagles, (2) to determine how egg removal affected subsequent nesting success and productivity, (3) to determine how the timing of clutch removal influenced recycling, and (4) to determine any differences between the behavior or survival of late fledging eagles from donor nests, and fledglings from undisturbed control nests.

Donor and control nests were located in two areas of north-central Florida, Alachua and Marion counties, and the Ocala National Forest,

where there are large numbers of nesting bald eagles (Fig. 1). Aerial surveys during the 1985 - 1987 breeding seasons were initiated prior to egg-laying (October/November) and flown approximately weekly until nearly all eggs hatched (mid-March). From mid-March until the eaglets fledged, surveys were conducted approximately once every two weeks to monitor chronology and productivity at all nests.

Locating accessible nests for egg collecting and obtaining permission from landowners to visit the nests required a substantial amount of time and persuasion. A total of 42 suitable donor nests were eventually located, and 87 eggs were removed over three breeding seasons. One egg collecting trip was made in 1985, and two in 1986 and 1987. Eggs are removed from the nests by climbers and quickly dispatched to the Sutton Center in Oklahoma (Fig. 2).

Egg recycling rates ranged from 70.6% in 1987 to 100% in 1985, averaging 78.6% (Table 1). Although none of the adult birds we studied were marked or banded, we feel confident about our estimates of recycling, which were based on the chronology of egg laying, the proximity of alternate nests, and the history of eagle nesting in the area. Of the 32 birds that recycled over the three years, 21 did so in their original nest, and 12 in nearby alternate nests.

The age of an egg at the time of collection was estimated by subtracting the 35 day incubation period from the hatching date (Bent 1937).

During the three years of the study, the ages of the eggs when collected varied widely, but averaged 15.9, 16.2, and 15.8 days old,

respectively. Although our sample sizes are small, it does appear that the probability of recycling decreases as the nesting season progresses.

Recycling intervals (the number of days between egg removal and subsequent relaying) averaged nearly 30 days (Table 1), ranging from 20 days to 57 days. Overall there was no relationship between the age of the clutch when removed and the recycling interval.

The ultimate impact of removing eggs was judged by comparing the productivity of donor and control nests (Table 1). We found no significant differences between these two groups in the percentage of nests fledging young, or in the number of young fledged per active nest. Thus, we feel that if precautions are taken to collect eggs early in the season, Florida bald eagles will recycle readily, and produce young at normal rates.

CAPTIVE PROPAGATION

Preparations for the captive propagation phase of the project began at the Sutton Center a full year before any eggs were collected. A chick raising lab, and facilities for food production, preparation, and storage were built. Specialized equipment such as the cannisters for holding eggs in the field, portable field incubators, and a motorhome/field lab also had to be built and tested. Redundancy, backup, and monitoring capabilities were incorporated into each phase of the project, to insure against the inevitable problems caused by bad weather, power outages, equipment malfunction, and human error.

Once eggs are removed from a nest they are put into a protective cannister, lowered to the ground, and placed in a portable field incubator. This incubator, powered by a portable generator, is fitted inside with netting to cradle the eggs and protect them from vibration and shock. It was designed to maintain internal temperatures within $\pm .25^{\circ}\text{C}$ in the face of ambient temperatures that range between freezing and 27°C . From there, the eggs are taken to the motorhome field lab and placed in a larger incubator that has also been specially cushioned against road vibration and equipped with back up power and temperature alarms. It takes about two days to obtain the twenty or so eggs normally taken during a collecting trip. During that period, and the non-stop 33 hour ride back to the Sutton Center, the eggs are carefully monitored and turned by hand every three hours around the clock.

At the Sutton Center the eggs are placed under special Cochin sitting hens. These hens which are kept "broody" by exposure to long photoperiods, make excellent surrogate parents, and their attention greatly increases hatching success. Prior to hatching, at about 35 days of age, the eggs are transferred back to an incubator to minimize the possibility of disease in the newly hatched chicks.

After hatching, chicks are brooded on "K-pads" (thermostatically controlled hot water bottles) until they are able to thermoregulate at about three and one half weeks of age. For the first several weeks chicks are fed with a latex eagle head puppet to insure the proper

stimulus for imprinting (Fig. 3). By three weeks they are able to feed themselves from trays of ground up food left in their individual artificial nests, and by six weeks they are capable of tearing up whole food on their own. After chicks are a week old and their vision begins to sharpen, all feeding is done from behind one-way mirror dividers. From that point until they are ready to fledge great precautions are taken to minimize the chick's awareness of their human caretakers. This is done to insure that the birds do not imprint on their foster parents and lose the instincts necessary for survival in the wild.

Coturnix quail are raised year round at the center to provide the staple of the young eagle's diet. Eagle chicks, which hatch at about 85 grams, weigh 3.5 to 5 kilograms some eight weeks later, and consume the equivalent of 800 quail in the interval. Only about half that number are fed to each bird, however, with the balance of their diet made up of venison, rabbits, chicken, rats and a supplement of multiple vitamins.

Sibling aggression, a common behavior in birds of prey, must be controlled in captive reared birds. During the first month of development, chicks must be physically separated to prevent them from attacking and killing each other. This must be done while keeping them in sight of their nest mates to permit proper imprinting (Fig. 4). Called the "Cain and Abel" conflict (Stinson 1979) siblicide appears to be an adaptation to eliminate competition in the nest during periods of food shortage. It persists until chicks are about a month old, and until that time, the mere presence of a dominant sibling close by may

inhibit a subordinate chick's feeding and development. In the wild this behavior often means that fewer chicks survive to fledging than actually hatch. By controlling siblicide in the laboratory, and providing optimum conditions for hatching, chick nutrition, and development, we have achieved productivities up to 60% greater than that normally attained by wild birds (Tables 1 and 2).

At six weeks of age chicks are nearly fully grown and they are moved from the temperature controlled chick lab to a "hardening yard" where they are acclimated to ambient temperatures. After about two weeks of acclimation they are sexed, banded, and distributed to the hack sites.

HACKING

There are currently four hack sites in the program, and a fifth, North Carolina, will be added in 1988 (Fig. 1). The criteria for selecting a site are illustrated by the Horn Island hack site located 15 km off the Mississippi Coast. Historic data indicate that the bald eagle was once a fairly common breeder on the barrier islands and adjacent coastal areas (Burleigh 1945). The birds were extirpated by the early 1950's, and today only a single coastal nest can be found along the Northern Gulf Coast. Thus, the Horn Island site will serve to reconnect the relict populations in Louisiana and Florida. This strategy, a basic tenet of conservation biology, will promote genetic exchange between the sub-populations and reduce the probability of local population extinctions (Wilcove et al. 1986). Additional evidence of the area's suitability for eagles is provided by the abundance of osprey, an ecologically similar

species. And finally, protected public lands, such as Gulf Islands National Seashore and nearby Bon Secour National Wildlife Refuge, insure the long term preservation of those habitats. These characteristics: evidence of historic nesting, high quality, protected habitat, and the potential to reconnect relict populations, are shared by all of the release sites.

The hack tower itself consists of a 30' high platform upon which are built cages and artificial nests, and a room from which the birds can be observed and fed undetected (Fig. 5). Great care is taken in designing the towers to insure, as in the earlier stages of the program, that the birds have no direct contact with people.

Nearly full grown when they are placed in the hacking tower the birds require two to three pounds of fresh whole fish, rabbits, or other meat a day. Regular observations are stepped up when the eaglets reach ten weeks of age in order to pinpoint the best time for release. Nestlings become noticeably more restless just prior to fledging, and it is important that they not develop an aversion to the hack tower by being confined too long. Before release, each bird is fitted with a lightweight transmitter attached with a backpack style harness made of tubular teflon ribbon. The device, which falls off within a year, allows us to monitor the birds for about six months. If released properly young eagles usually return to the tower to feed within 72 hours, and continue to do so for up to three months as they sharpen their hunting and flying skills. This gradual transition to independence is probably crucial to their survival, especially in light of recent evidence that most

fledglings embark on a long non-stop northward migration when they are about six months old (see below). Hacked birds are not expected to establish breeding territories until they are four to six years old. Nevertheless we already have two records of hacked birds returning to their release sites a year or more after release, one in Oklahoma, and one in Alabama.

THE FUTURE

Having demonstrated the viability of a restoration program based on egg-recycling, we were faced with developing a management strategy that addressed the recovery plan objectives. This was not a simple matter, due in large part to a lack of good demographic data. The current state of our knowledge about bald eagles illustrates that wildlife management today is an imprecise science at best. Although they are one of the most conspicuous and intensively studied of all North American birds, and in spite of the fact that they have received special attention as our national symbol and an endangered species, we still know very little about the population biology of bald eagles. Rates of fecundity (reproductive success) and survival determine the characteristics of a population. However, almost all of what we know about bald eagles comes from studies conducted during the breeding season. As a result we have a fair understanding of fecundity in these birds, but we can only make rough estimates of juvenile and adult survival rates, and only guess at the percentage of adult birds that attempt to breed each year (Newton 1979).

One approach to these shortcomings has been the use of stochastic population models to determine the most sensitive aspects of a species' life history. These models, which incorporate random fluctuations in life history parameters, have been used recently to better understand the population dynamics of several endangered birds including:

California condors (Gymnogyps californianus) (Mertz 1971), bald eagles (Grier 1980) and dark-rumped petrels (Pterodroma phaeopygia) (Simons 1984). The patterns for each of these "k-selected" (long-lived low productivity) birds are similar (Mac Arthur and Wilson 1967).

Populations of these and many other endangered species are extremely sensitive to changes in adult survival rates (Grier 1980), less sensitive to changes in juvenile survival, and rather tolerant of variations in reproductive success. In addition, their low intrinsic rate of population increase subjects small populations of these species to high extinction probabilities (Fig. 6). When applied to the conservation of bald eagles, several take home lessons are evident; (1) even under optimum conditions, population recovery will require several decades, (2) founder populations established by hacking should be fairly large (at least 30 birds) to minimize the chances that random events will send a population to extinction, and (3) future conservation efforts must be based on a better understanding of survival rates, because unless adult survival rates exceed 85%, efforts that focus on fecundity, such as hacking, may be futile.

Our plans for future work have been shaped by the results of this modeling, the egg-recycling, captive propagation, and hacking work,

the recovery plan objectives, and the need for better information on survival rates.

The egg-recycling results indicate that the Florida eagle population can comfortably withstand a harvest of 100 eggs per year. Several factors suggest that the optimal way to hack birds would be as one large group. First of all, population modeling predicts, that hacking many birds at once will, on average, yield the same results as hacking smaller numbers of birds over many years. This is attractive because the economics of hacking strongly favor larger releases. In addition, it is reasonable to assume that birds released into vacant habitats as part of a single large cohort will be more likely than birds in small cohorts to find a mate when they reach breeding age. On the other hand, caution argues that putting all of ones eagle eggs in one basket may be risky given the uncontrollable effects of weather and food supplies on survival. Finally, modeling, captive propagation results, and the success of hacking efforts to date (Nye 1987) indicate that about 20% of the eggs we collect in Florida will produce breeding adult birds. Our plan for the management phase of this program is an attempt to strike a balance between all of these factors. Called the target state release program it will run for five years and involve release sites in five states (Fig. 1). Each year, beginning in 1989, one site will conduct a large-cohort release of up to 75 birds, with the remaining birds distributed among the other four sites. This effort should realize the recovery plan goal of 50 new nests in the five target states, a little better than half of the regional objective. Assuming the results are

favorable, the program will then be shifted to the remaining southeastern states and continued for another four or five years.

Coupled with the expanded restoration program, new field studies have been undertaken to broaden our understanding of bald eagle biology. The work will continue the close monitoring of donor nests in Florida, and initiate a long term population study aimed at determining the dispersal patterns and survival rates of wild birds. Radio telemetry will be a valuable tool for much of this work.

Recent advances in battery, miniaturization, and solar cell technology have made radio telemetry studies of eagles feasible and affordable (Kenward 1980). Miniature battery powered transmitters weighing less than 30 grams and capable of air to air ranges of up to 100 km are now available at a reasonable cost, as are slightly heavier solar assisted transmitters with life spans of several years or more. Studies begun as part of this program have documented the dispersal and survival patterns of hacked eagles in Oklahoma, and fledglings from donor and control nests in Florida. Ten Florida chicks were radio-tagged in 1987 and tracked for several months. Preliminary data indicate that there is no difference between the age at which nestlings disperse from control (128 days) versus donor (131 days) nests, and several fledglings were relocated after migrations to the Chesapeake Bay area. Oklahoma birds have been also been relocated after migrating to Northern Wisconsin and Minnesota. One of us (AJ) using a combination of ground and aerial tracking, followed a bird dispersing from the Oklahoma hack site on a continuous 11 day migration to southern Canada in 1987 (Fig. 7).

Surprisingly, the bird did not feed or follow rivers or other natural features during migration as we expected. It flew due north (even over downtown Omaha) only varying from that course as a result of the strong westerly winds it encountered enroute.

The development of light weight satellite telemetry transmitters holds the greatest promise for understanding the population biology of eagles. Employed for almost a decade on a variety of larger animals including caribou, sea turtles, whales, and grizzly bears, the transmitters work with a Doppler positioning system carried aboard the National Oceanic and Atmospheric Administration's TIROS-N satellites. Researchers from the Applied Physics Laboratory at Johns Hopkins University were the first to refine the technology to the point where it could be applied to large free-fly birds (Strickwerda et al. 1985, 1986). They attached a 170 gram prototype transmitter to a sub-adult male bald eagle in July 1984 and tracked the bird for almost eight months over a distance of 4554 km. (Fig. 7). The results provided an unprecedented record of movement patterns and habitat selection in a free-flying eagle, and a glimpse of the technology's potential. To be practical for large scale applications, the weight of the transmitters will have to be reduced by about 50%, but this is thought to be feasible, and commercially produced transmitters are expected to become available within the next two years (Tomkiewicz and Beaty 1987). When they are, and we begin to understand the movement patterns and survival rates of bald eagles, we will be able for the first time, to direct the limited resources available for the conservation of these and other wide-ranging wildlife species, where they will do the most good.

TRICKLE DOWN CONSERVATION

Conservation programs targeted at species like the bald eagle can be extremely effective as direct mechanisms for preserving biological diversity. This occurs through the acquisition and preservation of breeding and wintering habitats and the untold species that piggyback on the process.

In addition to these direct benefits, there are many others more intangible. In some ways this project is as symbolic as the birds it is attempting to conserve. Bald eagles are not on the verge of extinction, and when viewed in the context of global conservation needs, and other critically endangered species, the attention may seem misplaced. In fact, it is the symbolic nature of widespread species like the bald eagle, with their ability to capture the imagination of the public, that make them such worthwhile conservation investments. As symbols of wilderness and the freedom wilderness represents, they have the unique capacity to inspire people and foster a sympathetic attitude towards the needs of other threatened species and related environmental issues such as habitat destruction and water quality. Clearly, without that attitude, and the political will it engenders, the needs of more obscure species will go unmet. It may be trickle-down conservation, but in light of the ever increasing pressure of global resources, it may prove to be one of the more fruitful conservation strategies available in the years ahead.

BIOGRAPHICAL NOTE

Ted Simons (B.S., wildlife biology, University of Wisconsin, 1975; M.S., Ph.D. wildlife biology, University of Washington, 1979, 1983) is a research biologist with the National Park Service. Address: Gulf Islands National Seashore, Ocean Springs, Mississippi 39564. Steve K. Sherrod (B.S., zoology, University of Oklahoma, 1971; M.S., zoology, Brigham Young University, 1974; Ph.D., biology, Cornell, 1982) is director of the Sutton Avian Research Center, a private non-profit organization established in 1983 for the conservation of rare and endangered birds. Address: Box 2007, Bartlesville, Oklahoma 74005. Michael W. Collopy (B.S., biology, University of California Santa Barbara, 1972; M.S., Wildlife Management, Humboldt State University, 1975, Ph.D., natural resources, University of Michigan, 1980) is chairman and associate professor in the Department of Wildlife and Range Science, University of Florida. Address: 118 Newins-Ziegler Hall, Gainesville, Florida 32611. M. Alan Jenkins (B.S., zoology, Utah State University, 1966, M.S., zoology, Brigham Young University, 1974) is assistant director of the Sutton Avian Research Center.

LITERATURE CITED

Bagley, F.M. 1987. Summary of 1986-1987 southern bald eagle nesting success. Unpublished report. U.S. Fish and Wildlife Service field office, Jackson, Mississippi.

Bent, A.C. 1937. Life histories of North American birds of prey, Order Falconiformes. Part I. U.S. National Museum Bulletin no. 167. Washington, D.C.

Burleigh, T.D. 1945. The bird life of the Gulf Coast region of Mississippi. Occ. Papers Mus. Zool., No. 20: 331-490. Louisiana State University, Baton Rouge.

Cade, T.J. and S.A. Temple. 1977. The Cornell University falcon programme, pp. 353-369. In: R.D. Chancellor (ed.) Report of proceedings, world conference on birds of prey, Vienna, 1975. Int. Council for Bird Preservation, London.

Green, N. 1985. The bald eagle, pp. 508-531. In: R.L. Di Silvestro (ed.), Audubon Wildlife Report 1985. National Audubon Society, New York.

Grier, J.W. 1980a. Ecology: a simulation model for small populations of animals. Creative Computing 6: 116-121.

_____ 1980b. Modeling approaches to bald eagle population dynamics. Wildl. Soc. Bull. 8: 316-322.

_____ 1982. Ban on DDT and subsequent recovery of reproduction in bald eagles. Science 218: 1232-1235.

Kennedy, R.S. 1977. A method for increasing Osprey. In: J.C. Ogden (ed.) Transactions of the North American osprey research conference. National Park Service Trans. and Proc. Ser. no. 2, Washington, D.C.

Kenward, R. 1980. Radio-monitoring birds of prey, pp. 97-104. In: C.J. Amlaner and D.W. Macdonald (eds.) A handbook on biotelemetry and radio tracking. Pergamon Press, Oxford and New York.

King, W.B. 1981. Endangered birds of the world. Smithsonian Institution Press, Washington, D.C.

Lewin, R. 1986. A mass extinction without asteroids. Science 234: 14-15.

Mac Arthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey.

Mertz, D.B. 1971. The mathematical demography of the California condor population. Am. Nat. 105: 437-453.

Morrison, M.L., and B.J. Walton. 1980. The laying of replacement clutches by falconiforms and strigiforms in North America. *Raptor Res.* 14: 79-85.

Murphy, T.M. 1984. Southeastern states bald eagle recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota.

Nye, P.E. in press. A review of bald eagle hacking projects and early results in North America. In: D. Garcelon (ed.) Proceedings of the international symposium on raptor reintroduction. Raptor Research Foundation.

Sherrod, S.K., W.R. Heinrich, W.A. Burnham, J.H. Barclay, and T.J. Cade. 1982. Hacking: a method for releasing peregrine falcons and other birds of prey. The Peregrine Fund, Ithaca, N.Y.

Sherrod, S.K., M.A. Jenkins, G. McKee, S. Tatom, and D. Wolfe. in press. Using wild eggs for production of bald eagles for reintroduction into the Southeastern United States. In: R. Odom (ed.) Proceedings of the third non-game and endangered wildlife symposium. Georgia Department of Natural Resources. Social Circle, Georgia.

Simons, T.R. 1984. A population model of the endangered Hawaiian dark-rumped petrel. *J. Wildl. Manage.* 48: 1065-1076.

Stinson, C.H. 1979. On the selective advantage of fratricide in raptors. *Evolution* 33: 1219-1225.

Strikwerda, T.E., H.D. Black, N. Levanon, and P.E. Howey. 1985. The bird-borne transmitter. *Johns Hopkins APL Technical Digest* 6: 60-67.

Strikwerda, T.E., M.R. Fuller, W.S. Seegar, P.W. Howey, and H.D. Black. 1986. Bird-borne satellite transmitter and location program. *Johns Hopkins APL Technical Digest* 7: 203-207.

Tomkiewicz, S.M. and D.W. Beaty. 1987. Wildlife satellite telemetry - a progress report 1987. Paper presented at the 1987 Argos Users Conference, September 15-17, Washington, D.C.

Wilcove, D.S., C.H. McLellan, and A.P. Dobson. 1986. Habitat fragmentation in the temperate zone, pp. 237-256. In: M.E. Soule (ed.) *Conservation biology*. Sinauer Associates Inc., Sunderland, Massachusetts.

TABLE 1. SUMMARY OF RECYCLING DATA FOR SOUTHERN BALD EAGLE NESTS 1985 - 1987.

Year	Status	n	n Recycled	% Recycled	Recycling Interval (days)		Percent Nests Fledging Young	Number of young Fledged per Active Nest
					Mean	SD		
1985	Donor	9	9	100.0	32.4	11.4	77.8	1.22
	Control	31	-	-	-	-	71.0	1.19
1986	Donor	16	12	75.0	31.0	8.5	56.2	1.0
	Control	47	-	-	-	-	66.0	0.98
1987	Donor	17	12	70.6	26.2	3.9	70.6	1.24
	Control	54	-	-	-	-	68.5	1.17
OVERALL	Donor	42	33	78.6	29.9	8.4	66.7	1.14
	Control	132	-	-	-	-	68.2	1.11

TABLE 2. RESULTS OF SOUTHERN BALD EAGLE CAPTIVE REARING AND HACKING EFFORTS 1985 - 1987.

	Year			Total or (Mean)	Total or (Mean)
	84-85	85-86	86-87	84-86	84-87*
# EGGS COLLECTED	18	34	35	52	87
# VIABLE**	17	33	32	50	82
% VIABLE	94.4	97.1	91.4	(96.2)	(94.3)
# HATCHED	17	30	24	47	71
% VIABLE EGGS HATCHED	100.0	90.9	75.0	(94.0)	(86.6)
# CHICKS REARED TO HACKING AGE	13	28	20	41	61
% CHICKS HATCHED REARED TO HACKING AGE	76.5	93.3	83.3	(87.2)	(85.9)
# CHICKS SUCCESSFULLY HACKED	12	28	19	40	59
% CHICKS HATCHED SUCCESSFULLY HACKED	70.6	93.3	79.2	(85.1)	(83.1)
% VIABLE EGGS RESULTING IN HACKED BIRDS	70.5	84.4	59.4	(80.0)	(72.0)
% EGGS COLLECTED RESULTING IN HACKED BIRDS	66.7	82.4	54.3	(76.9)	(67.8)

* 1987 was an atypical breeding season in Florida due to unusually warm, wet weather during the incubation period. These conditions apparently fostered the growth of bacteria in the birds' nests and the infection of many developing embryos (Sherrod et al. in press). The result was an abnormally low hatching success in both wild and captive reared eggs. We feel that the 84-86 statistics are more typical of the results that can be obtained under average conditions.

** Viable eggs are fertile eggs that showed some sign of development.

LEGENDS FOR FIGURES

Figure 1 The historic distribution of the southern bald eagle stretched from east Texas to the Carolinas. The population has declined from an estimated 1500 breeding pairs to about 500 pairs today. Over 80% of the remaining birds are concentrated in central and southern Florida. The restoration program seeks to reestablish breeding birds across the southeast through a combination of egg recycling, captive propagation and hacking at strategic sites in five states.

Figure 2 Eggs are collected by climbers who wear surgical gloves and masks to protect the eggs from contamination. The overhanging nest edge can make access to nest precarious, but most clutches are removed in fifteen to twenty minutes. (M.A. Jenkins)

Figure 3 A latex bald eagle puppet is used to feed a three week old eaglet. Birds are kept isolated from human contact to prevent imprinting and observed through one way mirrors. (Sutton Avian Research Center)

Figure 4

Four week old eagle chicks in the chick rearing barn at the Sutton Avian Research Center. Eaglets are separated from their siblings to prevent siblicide, a common source of mortality in wild chicks. This behavioral manipulation and the provision of optimal conditions from incubation to fledging resulted in productivities that averaged .68 chicks fledged/foster-reared egg compared with .52 chicks fledged/wild egg. Refined techniques should permit laboratory success rates above .80 chicks fledged/egg in the future. (G. McKee)

Figure 5

Hacking tower on Horn Island, Mississippi. Towers are placed in isolated patches of vacant habitat in an effort to reconnect the relict populations remaining in the southeast. Cages containing artificial nests surround a central observation room from which the birds can be fed and observed without knowledge of their human caretakers. (T. Simons)

Figure 6

A summary of population modeling results. The figure on the left depicts the probability of population extinction given declining rates of fecundity and survival. Simulations assume average and maximum rates derived from field studies in Florida (Table 1) population models (Grier 1980b), and a founder

population of 50 birds. Lines depict the relative effect on extinction probability as each parameter is decreased from its maximum rate, while the other two parameters are held at their average rate. See Grier (1980a, 1980b) and Simons (1984) for details of the model. The figure on the right depicts the probability of population extinction within one generation assuming various founder population sizes. The simulations assume average rates of fecundity and survival.

Figure 7

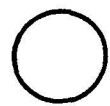
An better understanding of movement patterns and survival rates is essential for the effective conservation and management of bald eagles and other wide ranging species. (A) Conventional telemetry techniques allowed us to track a young eagle on its initial northern migration from the Oklahoma hack site in 1987, but the process is difficult, time consuming, and expensive. In the near future satellite telemetry will provide the potential for continuously monitoring many birds for extended periods of time. (B) Strikwerda et al. (1985, 1986) pioneered the use of satellite transmitters on birds. They tracked a juvenile bald eagle by satellite from 21 July 1984 to 19 March 1985 (used with permission). ✕

(Cover)

An eleven week old bald eagle fledgling returns to the hacking tower for the first time. Reliance on food provided at the tower for the first one to three months of independence is probably crucial to the young bird's survival. The characteristic white head and tail of adult birds will not appear until they are three to five years old. (T. Simons)



Historic Breeding Range
(1500 pairs)



Current Active Nests
(500 pairs)

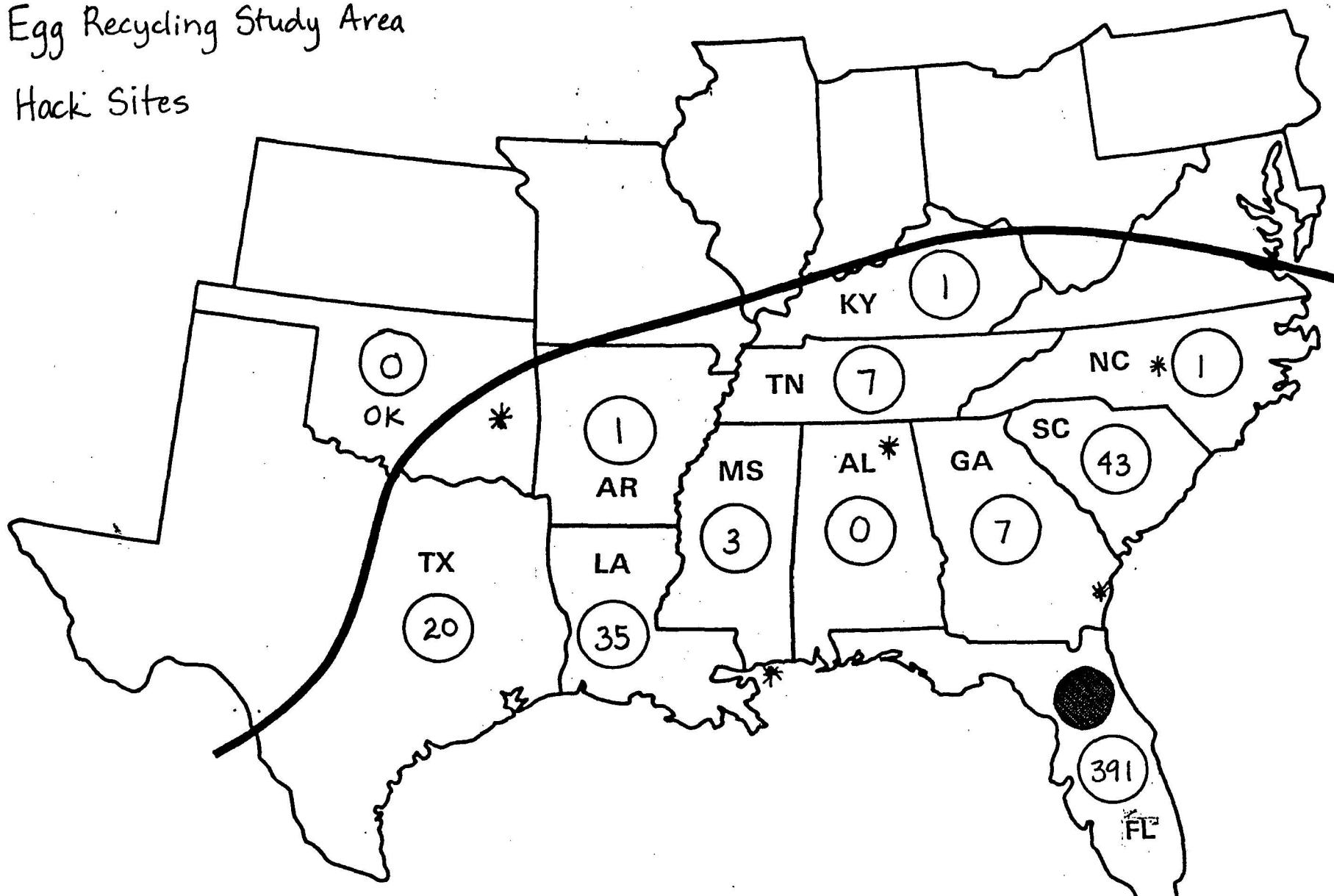


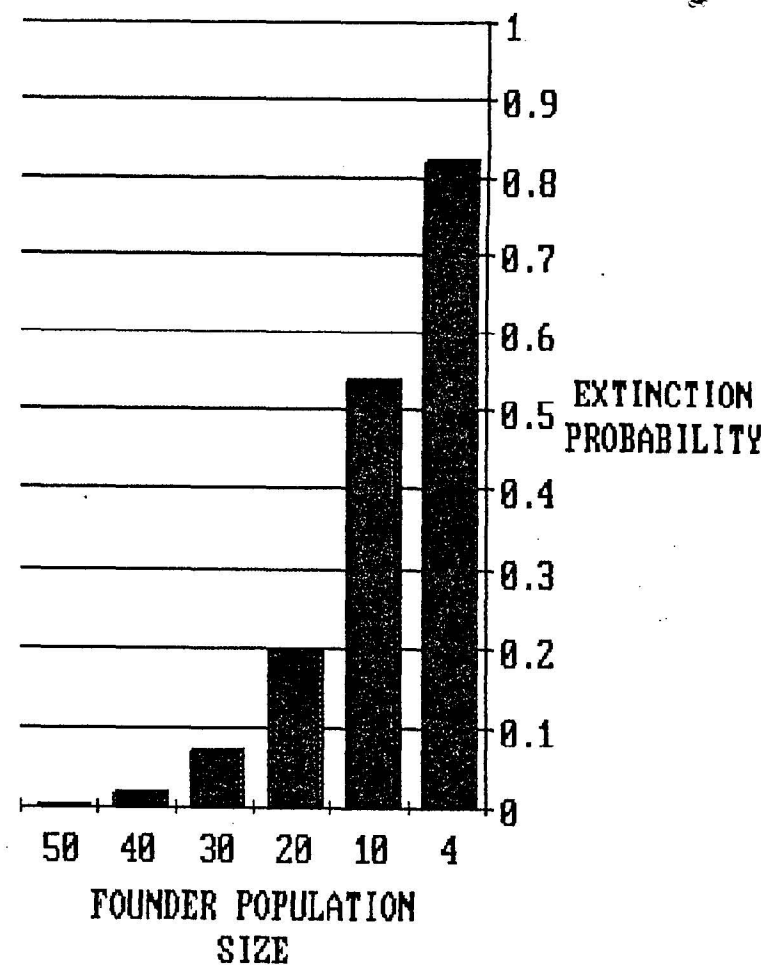
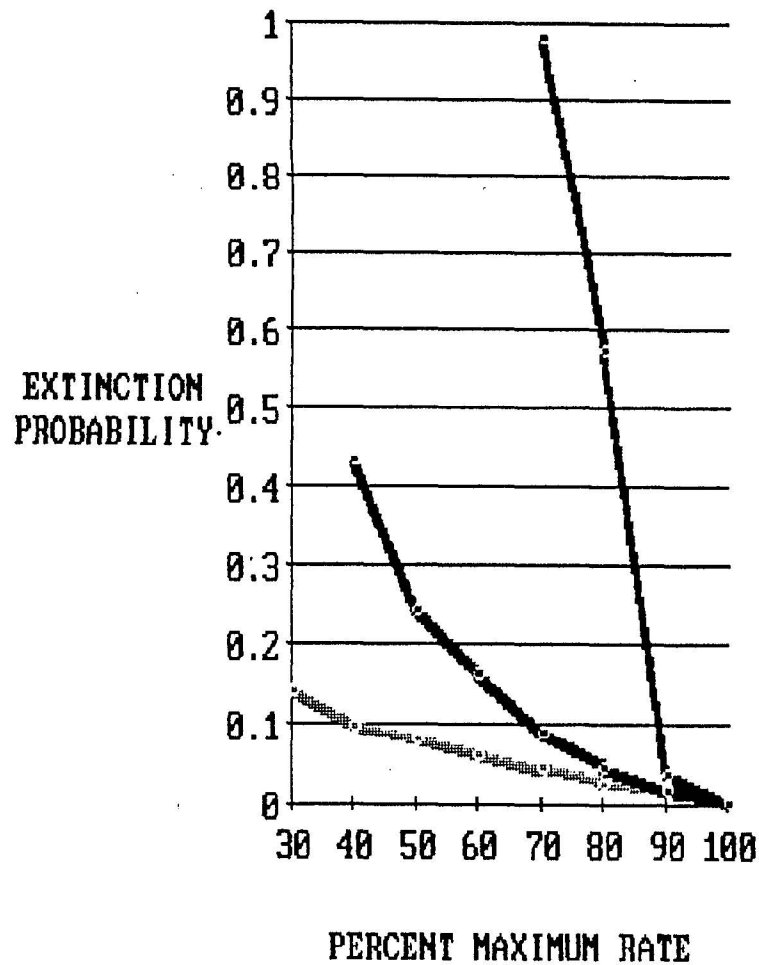
Egg Recycling Study Area



Hack Sites

Fig. 1



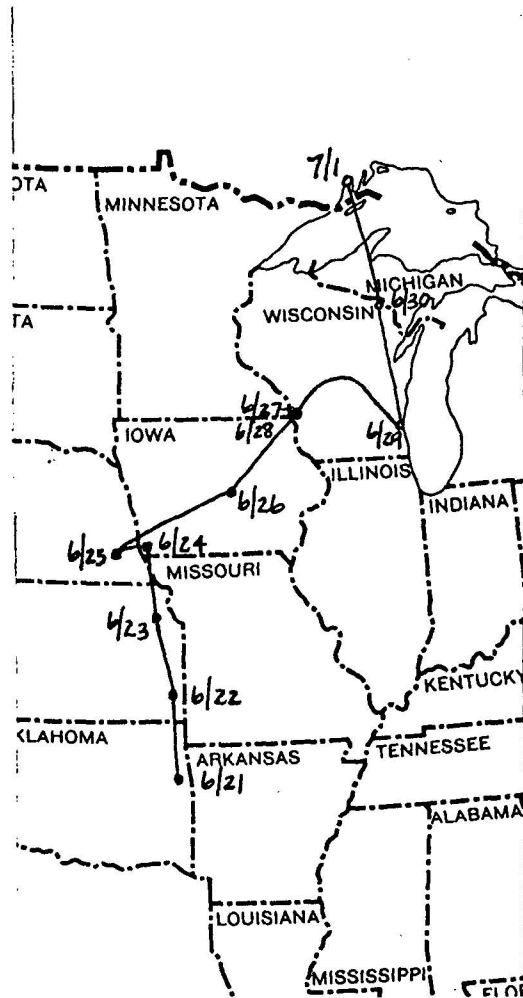


PARAMETER	AVERAGE RATE	MAXIMUM RATE
Fecundity	1.1 young/nest	1.5 young/nest
Juvenile* Survival	60% - 90%	70% - 90%
Adult** Survival	90%	95%

* Annual survival in birds 1 - 4 years old
 ** Annual survival in birds 5 years and older

Fig. 6

A



B

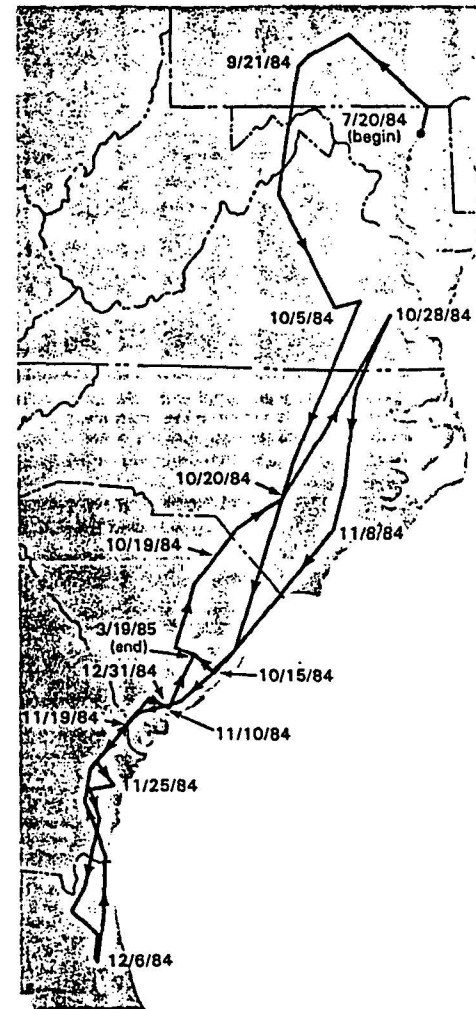


Fig. 7