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Abstract: The U.S. Fish and Wildlife Service (USFWS) began building a captive whooping crane (*Grus americana*) colony at Patuxent Wildlife Research Center (Patuxent), Maryland, in 1966. From 1976 to 1984, 73 eggs from this colony and 216 eggs from Wood Buffalo National Park (Wood Buffalo), Canada, nests were placed in sandhill crane (*G. canadensis*) nests at Grays Lake National Wildlife Refuge (Grays Lake), Idaho, the site of the first whooping crane reintroduction attempt. Although 84 chicks fledged from the 289 eggs, the egg transfer program has been discontinued because of inordinately high mortality (only ca. 13 birds remain in the wild in 1991) and lack of breeding in survivors. In recent decades new methods have emerged for introducing captive-produced offspring to the wild. Surrogate studies with sandhill cranes, particularly the endangered Mississippi sandhill cranes (*G. c. pulla*), have shown that young cranes, raised either by captive, conspecific foster parents, or by costumed humans and in close association with live cranes and lifelike crane taxidermic dummies, have high post-release survival rates. These techniques will likely be used in future whooping crane reintroduction programs. Current recovery objectives for the whooping crane include expansion of the 2 captive colonies, establishment of a third captive colony in Canada, and reintroduction of 2 additional wild populations. The Kissimmee Prairie in central Florida has been selected for the next release experiment. Evaluation of this site began in 1984, and risk assessment is expected to begin in 1992 with the transfer and monitoring of a group of captive-reared, juvenile whooping cranes. These "tests of the environment" will, if results are favorable, be followed by a full-scale reintroduction effort of at least 20 birds/year beginning in 1994 or 1995.

Key Words: captive breeding, *Grus americana*, *Grus canadensis*, recovery, sandhill crane, whooping crane

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Of the 15 species of cranes worldwide, 6 species and 2 subspecies are listed as endangered (U.S. Fish and Wildlife Service 1988). All 15 species have been bred in captivity, and during the last 20 years, several reintroduction projects have been initiated. Herein, we relate past and potential efforts for recovery of the whooping crane.

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WHOOPING CRANE POPULATION DECLINE

Historically, the breeding range of the whooping crane extended from Illinois northwest through Iowa, Minnesota, and North Dakota into southern Manitoba, Saskatchewan, and Alberta (Allen 1952) with a disjunct population nesting in the Great Slave Lake region (U.S. Fish and Wildlife Service 1986). In 1939, a small, widely disjunct population was also found breeding in the marshes north of White Lake, Louisiana (Lynch 1984). Breeding may have also occurred at other locations, but information is limited. Wintering populations ranged from the Rio Grande delta eastward along the Gulf Coast to Florida and along the Atlantic Coast as far north as New Jersey (Allen 1952). In the 1800's, a combination of habitat destruction, human disturbance, hunting, and egg and specimen collection for museums and private collectors contributed to a rapid population decline. By 1870, fewer than 1,400 individuals remained (Allen 1952). In 1945, the population consisted of 2 disjunct flocks totaling about 21 birds (Fig. 1) (U.S. Fish and Wildlife Service 1986); only 3 birds remained of the small (soon to be extinct) sedentary flock in Louisiana. The remaining 18 birds comprised a flock that wintered at Aransas along the Texas Gulf Coast and nested in Wood Buffalo, Northwest Territories, Canada (Allen 1956) (Fig. 1). Following this nadir, the whooping crane population began its slow increase.

PATUXENT'S CAPTIVE COLONY

The ponderous expansion of the whooping crane population beginning in the late 1940's (Fig. 1) prompted a search for management schemes to bolster the wild population. Captive breeding was attempted for many years with isolated pairs at Audubon Park Zoo in New Orleans (1948–66), in confinement at Aransas (1948–51), and at the San Antonio Zoo (1967 to present) (McNulty

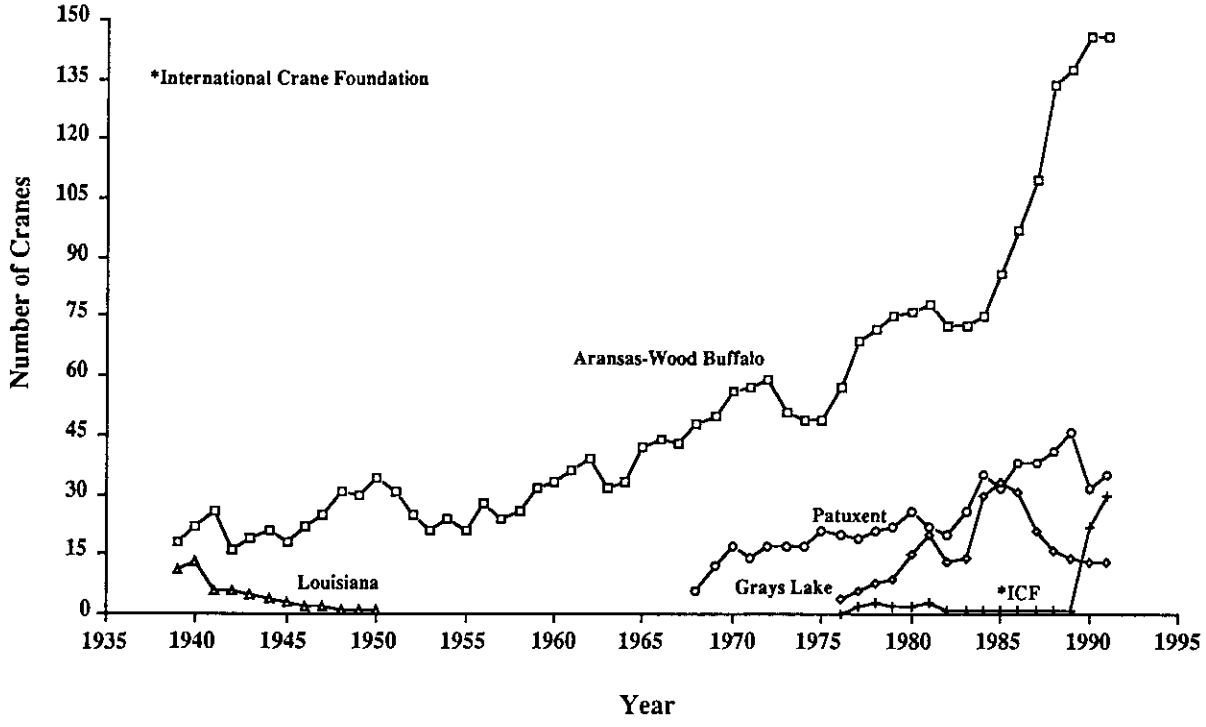

Fig. 1. Whooping crane populations, 1939–91. Captive colony counts are for 1 January. All others are peak winter counts. Each peak winter count (e.g., 1978–79) is reported for January of the latter year (e.g., 1979).

1966, U.S. Fish and Wildlife Service, unpubl. data). The notion of establishing a sizable captive flock by removing young whooping cranes from the Aransas-Wood Buffalo population was first proposed by Lynch (1956). Theoretically, whooping cranes produced by the captive flock could be released to augment the wild population as a hedge against catastrophic loss of the wild population. Hyde (1957) noted that sandhill cranes and whooping cranes usually lay 2 eggs but rarely raise 2 young. He suggested that a captive flock could be established without detriment to the wild population by removing 1 egg from each clutch. Erickson (1968) recommended first developing a surrogate flock of nonendangered sandhill cranes. In 1961, the USFWS established a captive flock of sandhill cranes at Monte Vista National Wildlife Refuge in Colorado to develop crane husbandry and propagation techniques. In 1966, the surrogate flock and a flightless male whooping crane recovered in Canada in 1964 were moved to Patuxent. In 1967, the second eggs from 6 nests in Wood Buffalo were taken to Patuxent. Egg taking has continued sporadically ever since (Table 1), with eggs sent either to Patuxent, to Grays Lake, Idaho, or, more recently, to the International Crane Foundation (ICF), Baraboo, Wisconsin. Management agencies and researchers generally believe that this egg harvest has not adversely affected, and may have actually increased, the number of chicks fledged each fall in Canada (Kuyt 1987; F. G. Cooch, pers. commun.).

During the colony's first decade at Patuxent, many disease and nutritional problems that initially impaired survival of whooping cranes in captivity were resolved (Erickson 1975, Carpenter 1977, Carpenter and Derrickson 1982, Serafin 1981). It then became possible to address more subtle problems such as failure of neonatal young to feed, failure of pairs to bond and breed, and sexual imprinting of chicks on human caretakers (Kepler 1977). In 1975, the first fertile eggs were produced by a captive female at Patuxent. As problems with artificial insemination, incubation, and chick rearing were addressed, annual productivity increased (Archibald 1974, Kepler 1977, Gee 1979). The first chick fledged in 1976. Between 1975 and 1991, the Patuxent flock produced 255 eggs, of which 73 (61 known to be fertile) were transferred in an attempt to establish a second wild flock at Grays Lake. The captive population slowly expanded (Fig. 2), although it occasionally suffered major declines, as in 1984, when a major epizootic, eastern equine encephalitis (EEE), killed 2 males and 5 females. This outbreak and 2 other epizootics led to the decision to establish a second captive breeding flock at a site remote from Patuxent. In November 1989,

Table 1. Destination and fate of whooping crane eggs taken from Wood Buffalo National Park, 1967–91.

Year	No. of eggs collected	Patuxent Wildlife Research Center		Grays Lake National Wildlife Refuge	
		No. of eggs received	No. of young fledged	No. of eggs received[a]	No. of young fledged[a]
1967	6	6	4	0	0
1968	11	11	6	0	0
1969	14	14	6	0	0
1970	7 (5 viable)	5	0	0	0
1971	10	10	2	0	0
1972	0	0	0	0	0
1973	0	0	0	0	0
1974	13 (11 viable)	11	4	0	0
1975	14	0	0	14	5
1976	15	0	0	15	4
1977	16	0	0	16	4
1978	13	0	0	13	3
1979	19	0	0	19	6
1980	13	0	0	13	4
1981	12	0	0	12	0
1982	16	2	1	14	3
1983	18	2	2	16	11
1984	25	3	1	22	10
1985	25 (23 viable)	2	1	23	11
1986	24 (24 viable)	9	2	15	2
1987	19	7	5	12	2
1988	26	14	7	12	2
1989	9 (3 viable)	9	3	0	0
1990	12[b](11 viable)	0	0	0	0
1991	16 (9 viable)	16	4	0	0
Totals	341 (320 viable)	121	48	216	67

[a] An additional 73 eggs (61 fertile from which 17 young fledged) from Patuxent were transferred to Grays Lake from 1976 to 1984.
[b] All 12 eggs were sent to ICF. Eleven hatched; 8 chicks fledged.

22 birds representing all families in the captive flock were transferred to the ICF.

The following factors compound the difficulty of propagating whooping cranes in numbers sufficient to build 3 captive colonies while supporting future reintroduction projects: (1) delayed sexual maturity (i.e., captive females at Patuxent first laid at 5 [2 females], 6 [2], 7 [3], 8 [3], 9 [2], 10 [1], 11 [1], and 18 [1] years of age: only 2/3 laid eggs by 8 years of age, Fig. 3), (2) moderate fertility levels (only 3/4 of captive-produced eggs are fertile), (3) moderate hatchability rates (only 3/4 of the fertile eggs hatch), (4) low fledging success (only 3/5 of the chicks fledge), and (5) demographic anomalies characteristic of small populations (e.g., unequal sex ratios and differential mortality). From these demographic factors, in Fig. 3 we project the size of the future captive population. However, unforeseen infusions of eggs from Canada and/or major mortality events can drastically alter these predictions.

REINTRODUCTION ATTEMPTS

The Translocation of a Single Bird

By 1947, only 1 wild bird remained in the marshes near White Lake, Louisiana (Fig. 1) (McNulty 1966, Doughty 1989). In an effort to retain the genetic contribution of this bird, the crane was captured by helicopter on

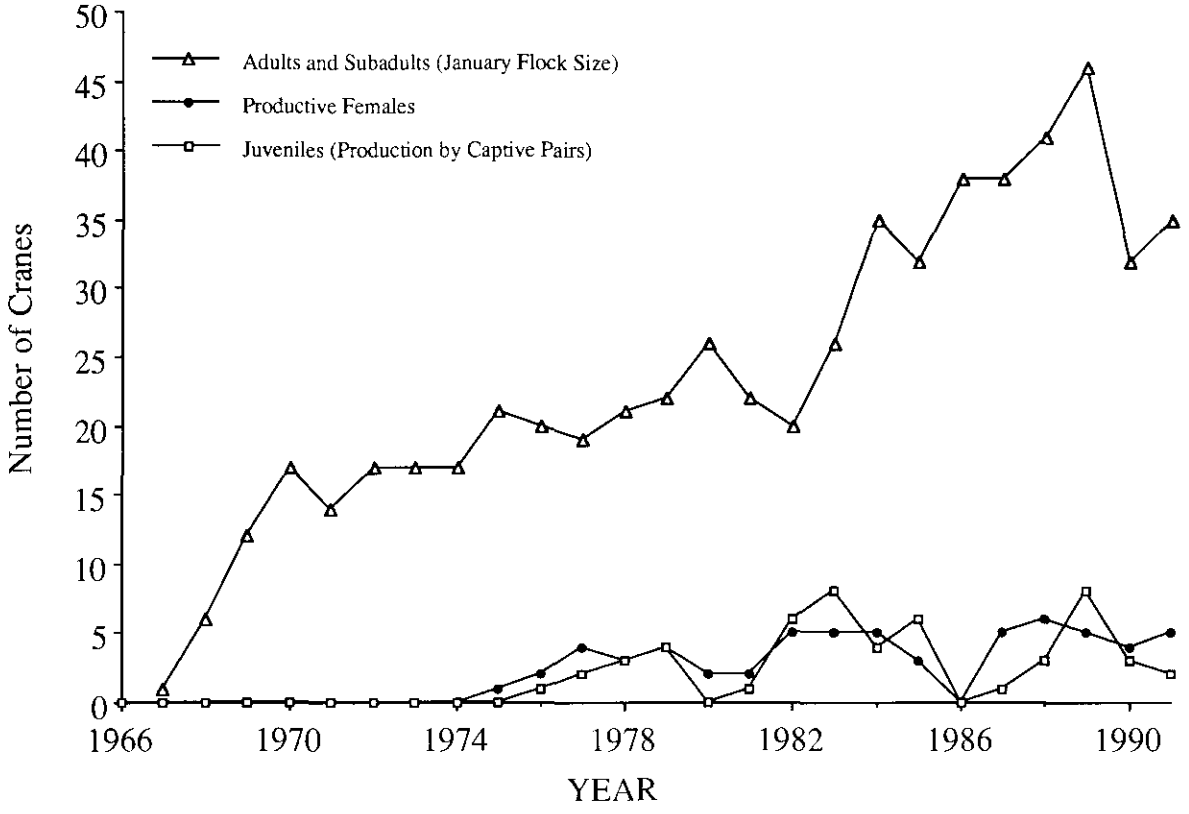

Fig. 2. Size of the captive whooping crane flock at Patuxent Wildlife Research Center, 1966–91.

11 March 1950 and translocated by truck to join the Aransas-Wood Buffalo flock. On arrival, the dangerously weakened crane was penned and force fed for 2 days, then released into a freshwater marsh; later, it was attacked by 2 wild cranes. It was recaptured, fed, and released at a freshwater lake some distance from other whooping cranes. It survived through the spring and summer but was found dead in September. If nothing else, this attempt demonstrated some of the problems inherent in translocating adult cranes.

The Grays Lake Experiment

The only reintroduction effort thus far attempted consisted of placing nearly 300 whooping crane eggs in greater sandhill crane (*G. c. tabida*) nests at Grays Lake. This experiment was designed to create a disjunct population of whooping cranes that, like their sandhill crane foster parents, would nest in Idaho and winter along the Rio Grande in west-central New Mexico (Drewien and Bizeau 1978). Beginning in 1975, each egg from Patuxent or Wood Buffalo was placed alone in nests of greater sandhill cranes.

According to plan, the sandhill crane foster parents incubated the eggs and reared the young whooping cranes that hatched. The chicks also accepted their foster parents and followed them on migration. However, only 209 (72%) of the 289 whooping crane eggs transferred to Grays Lake hatched, and only 84 chicks (40% of the 209 that hatched or 29% of the original 289 eggs) fledged. High egg and chick mortality rates were associated with inclement weather and coyote (*Canis latrans*) predation (Drewien and Bizeau 1978, Drewien et al. 1985). Most cranes that managed to fledge died from powerline and other wire strikes (Brown et al. 1987) or from avian tuberculosis (Doughty 1989). Recruitment has not kept pace with mortality, and the Grays Lake whooping crane flock declined from a high of 33 birds in 1984–85 to 13 birds in 1991 (Drewien et al. 1989, Lewis 1990).

Low survival rates in young birds at Grays Lake were accompanied by the failure of surviving whooping cranes to form pair bonds and breed. Among breeding-age birds a preponderance of males caused by differences in male and female mortality contributed to this failure. More importantly, the few females that reached breeding age failed to pair with males on the wintering ground or the

spring staging areas and then scattered on northward migration, thereby further diminishing their chances of finding mates. Yearly attempts were made to capture these wandering females and transport them back to pair with wild males at Grays Lake. Because no pairing occurred naturally, 2 Patuxent-reared females were introduced to males at Grays Lake in 1981 and 1989 to see if cross-fostered males would pair normally. Both females seemed to form temporary pair bonds with wild males, but neither pairing resulted in eggs or in pairs that migrated south together (Drewien et al. 1989).

From projections of conservative values for age-specific mortality rates at Grays Lake, Garton et al. (1989) concluded that at best only 6 pairs of whooping cranes would be breeding after infusions of 30 eggs per year for 50 years. The future of the project had been under question since the mid-1980's. In March 1990, a decision was made to deemphasize the Grays Lake experiment. The last egg transfer was in 1988, and no further transfers of captive-reared females are anticipated. Because of fear of transmitting avian tuberculosis to other flocks, captive or wild, there is little likelihood that any of the surviving birds in the Grays Lake flock will be added to any existing captive colony. Some or all could go to a separate facility. The 13 birds remain under study in hopes of learning as much as possible for future experiments, and a decision concerning their fate is expected late in 1991. The Grays Lake population will either languish, then disappear, or be removed.

CHOOSING THE NEXT EXPERIMENTAL REINTRODUCTION SITE

Factors such as high mortality rates during migration (which may account for about 80% of the losses for birds in the Aransas-Wood Buffalo flock [U.S. Fish and Wildlife Service 1986]), disease hazards, and demographics, all recommend that the next reintroduction site have the following characteristics: (1) extensive suitable habitat, (2) geographical isolation from other wild populations (to limit effects of a single catastrophic mortality event [oil spill, storm, epizootic]), (3) a southern location that would discourage migration (and thereby limit migration related mortality and negate the need to teach birds to migrate), and (4) a location within the historic range of the species. Using these criteria, an obvious choice for the next reintroduction of a sedentary population would be the marshes north of White Lake in southern Louisiana. It seems logical to return the birds to the wild where they most recently lived. The creation of a nonmigratory population is also preferred because of risks noted during migration in the Grays Lake experiment.

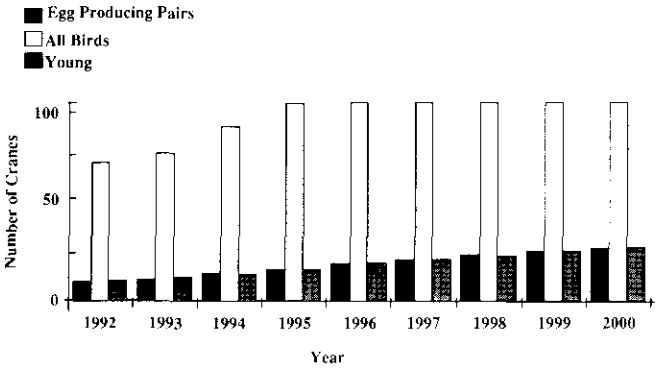

Fig. 3. Projected number of whooping cranes in captive colonies, 1992–2000. Values are based on 5% post-fledging annual mortality; age of first egg production, 8 years; 1 young fledged per producing female per year; 50:50 sex ratio in offspring; and 110 birds as maximum pooled size for all 3 colonies.

In recent decades White Lake appeared to be unavailable as a reintroduction site because state and federal wildlife management agencies had strong reservations (Gomez 1992). The state feared that the declaration of critical habitat would impair waterfowl hunting and other forms of wildlife use. Federal agents feared that local customs, especially wildlife harvesting practices, would endanger any released birds. As a consequence, 3 other sites were evaluated from 1984 to 1987 (McMillen et al., in press): (1) the Upper Peninsula of Michigan (McMillen 1988), (2) Okefenokee Swamp in southern Georgia (Bennett, in press; Bennett and Bennett, in press), and (3) the Kissimmee Prairie region in central Florida (Bishop, in press). All areas have extensive wetlands, are somewhat removed from urban areas, and currently support sizable sandhill crane populations. Whooping crane breeding, however, has never been documented for any of the 3 areas, although Allen (1952) and Nesbitt (1982, 1988) report evidence that the species occurred and perhaps summered in Florida even into the present century.

In 1988, the USFWS decided to proceed with a whooping crane introduction experiment in Florida. Reasons favoring the Kissimmee Prairie include the extent of wetland habitat, the potential for establishing a nonmigratory flock, the high degree of state and local support for the project, favorable land use practices, and favorable human demographics.

Unfortunately, the Kissimmee Prairie poses risks of Venezuelan equine encephalitis and avian tuberculosis; an EEE zone is also nearby. Although EEE outbreaks have been reported for southwestern Michigan, Carpenter et al. (1989) concluded that of the 3 areas being evaluated, the risk of contact with EEE was least likely for birds breeding in northern Michigan. Cranes breeding there would

probably visit southern regions only in winter, when EEE transmission is less likely because of reduced activity of the mosquito vector.

REINTRODUCTION TECHNIQUES

Reintroduction techniques for fledged cranes were described by Konrad (1976), Derrickson and Carpenter (1983), Horwich (1986, 1989), Horwich et al. (in press), Bizeau et al. (1987), Ellis et al. (1992), and Urbanek and Bookhout (1992). The techniques most likely to be employed in future whooping crane introduction attempts are listed below.

High survival rates have been achieved in releases of parent-reared Mississippi sandhill cranes. Two-thirds of the birds released from 1981 to 1989 survived for at least 1 year (McMillen et al. 1987, Zwank and Wilson 1987, Ellis et al. 1992). During the past 5 years, at least 13 captive-reared Mississippi sandhill cranes have paired or bred in the wild.

Although various attempts have been made to release hand-reared birds, until the mid-1980's hand-reared birds generally proved unsuitable. For example, none of 14 hand-reared birds released without acclimation near Lake Okeechobee, Florida, integrated into the wild flock, and within a few months all had died (Nesbitt 1979). In recent experiments, sandhill crane chicks have been reared in relative isolation from humans. In addition, some chicks are penned in visual and auditory (but not physical) contact with adult cranes. These chicks are handled by costumed caretakers, are taught to feed using either a puppet head (ICF) or a taxidermic mount crane head (Patuxent), and are brooded by a taxidermic brooder mount. From these rearing regimes fledged birds released in Wisconsin, Michigan, and Mississippi have survived well, and many birds have paired with wild cranes (Urbanek 1990, unpubl. data; Archibald and Archibald, in press; Ellis et al. 1992; G. W. Archibald, pers. commun.). It is, of course, important for release birds to have an extended on-site acclimation period (ca. 1 month is recommended for birds transferred from an off-site captive-rearing center) if they are to survive well. Even parent-reared birds survive poorly if released without acclimation (Drewien et al. 1982).

FUTURE RECOVERY GOALS AND SCHEDULE

The USFWS and Canadian Wildlife Service (CWS) have separately published recovery plans for the whooping crane (U.S. Fish and Wildlife Service 1986, Cooch et al. 1988). Common goals in the recovery plans are increases in the size of current wild and captive flocks and establishment of at least 2 additional, disjunct, wild flocks in the near future. The 2 agencies also operate under a 1990 Memorandum of Understanding (MOU) that dictates cooperative decision-making in the day-to-day management of captive and wild whooping crane populations.

Increasing the Size of the Aransas-Wood Buffalo Flock

Both USFWS and CWS recovery plans agree on the need to increase the Aransas-Wood Buffalo flock. Because increases in the wild flock depend primarily on natural recruitment, recovery plans stress the need to reduce mortality. Specific concerns include identifying and evaluating disturbances and developing contingency plans for rapid containment of hazards such as oil spills, disease, and human or "pest" disturbances. Plans also call for identifying and preserving essential habitat for use in winter, during migration, and during the breeding season.

Although extraordinary efforts have been made to build captive whooping crane colonies and to create a wild flock at Grays Lake, we emphasize that the expansion of the Aransas-Wood Buffalo flock (Fig. 1) has been due entirely to endogenous production. Not 1 egg or crane has come from the captive colonies. This statement is not meant to demean human efforts in the crane's behalf; for surely, without intensive efforts to create refuges and to educate hunters along the flyway, the population would not have grown to its present number (about 140 birds) (Fig. 1). Furthermore, beginning in 1984, the second fertile eggs from many nests in Canada were moved to nests where pairs were incubating infertile eggs. This type of manipulation should result in more pairs fledging chicks than would have occurred naturally (F.G. Cooch, pers. commun.).

Captive Populations

Recovery goals to be achieved by 1995 include increasing the size of captive breeding flocks to 15 breeding pairs at Patuxent and 10 breeding pairs at the ICF and establishing an additional captive flock at the Calgary Zoo in Alberta, Canada. Pen construction began at Calgary in 1991 and will be completed by summer 1992. The staff will work with sandhill cranes in 1992 and will probably receive their first whooping crane eggs from Patuxent, ICF, or perhaps Wood Buffalo in 1993.

Recovery plans also emphasize maximizing genetic diversity in the captive flocks by selectively harvesting eggs from the Wood Buffalo flock and utilizing other genetic management techniques. The plans also call for research to enhance captive reproduction by further refining incuba-

tion, hatching, and rearing procedures, and by behavioral management of pairs.

Establishing Additional Wild Flocks

Long-term survival of whooping cranes can be ensured by establishing disjunct captive and wild populations. Before the bird is "down listed" from endangered to threatened status, the USFWS recovery plan calls for at least 2 additional wild flocks (each flock with a minimum of 25 nesting pairs) (U.S. Fish and Wildlife Service 1986). "Delisting" could occur as even more flocks are established.

After the decision was made to discontinue the Grays Lake experiment, it became urgent to choose alternate destinations for the eggs from Wood Buffalo. In 1989–90, most of the second eggs in each clutch were sent to the captive colonies although a few clutches were left with 2 eggs. Another likely use of these eggs is to establish new wild flocks. In 1988, the USFWS, with the concurrence of the CWS, agreed on the Kissimmee Prairie for the next whooping crane reintroduction experiment. Additional reintroduction experiments are also likely in Canada during the present decade.

Long-term survival of any reintroduced wild flock depends on the same factors that Griffith et al. (1989) associated with successful translocation of other avian groups: (1) large founder populations, (2) suitable habitat, and (3) high fecundity. These conditions can be only partially met in any whooping crane release.

PROJECTIONS, GOALS, AND CONCLUSIONS

With the expansion of the Aransas-Wood Buffalo population to over 140 birds, the growth of the Patuxent flock to about 40 birds, the establishment of the ICF flock with 30 birds, and the construction of a new propagation facility at the Calgary Zoo in Alberta, we are optimistic about whooping crane recovery. This optimism is reflected in the previously mentioned MOU signed in April 1990 by the USFWS and the CWS calling for joint cooperation in (1) enhancing and preserving habitat, (2) increasing bird survival rates, (3) improving bird and egg transfer practices, (4) establishing new captive flocks and wild populations, (5) determining disposition of specimens and handicapped birds, and (6) deciding on the best uses for wild and captive-produced birds and eggs.

The USFWS recovery plan (U.S. Fish and Wildlife Service 1986) calls for expansion of the Aransas-Wood Buffalo population to 40 breeding pairs by the turn of the century and the establishment of 2 additional wild populations by 2020. The CWS (Cooch et al. 1988) calls for a separate population of 25 pairs in the United States and another population of at least 5 pairs in Canada by 2010.

A recent draft appendix to the CWS plan (F.G. Cooch, pers. commun.) provides a 5-year action plan governing the fate of eggs from Canada and the captive flocks. The young surviving from eggs harvested in Canada in 1992 and from captive production are to be transferred to Florida to begin reintroduction experiments. The 1991 and 1993 eggs from Canada are to be used to help build the captive flocks. Beginning in 1994, captive colonies are to provide 20 young each year for 10 years to establish a wild flock in Florida. Some eggs from Canada may provide chicks to supplement the early Florida releases. A new 5-year action plan will be developed for the 1995–2000 period. If all proceeds satisfactorily, another release may begin in Canada in the late 1990's while the Florida release is still underway.

As in the past, all increases in the Aransas-Wood Buffalo population will be from natural reproduction and recruitment. Although no eggs or birds are to go to Wood Buffalo from captive flocks, fertile eggs in the nests in Wood Buffalo will be distributed so that nesting pairs have at least 1 viable egg.

In the 1940's, the whooping crane teetered on the brink of extinction; fewer than 30 birds remained in the world. In the intervening 5 decades, the wild population has expanded 7-fold, while sustaining a massive effusion of 349 eggs to build the Grays Lake flock and captive flocks. The recovery of the whooping crane, although not yet complete, stands as a singular marvel in the annals of wildlife conservation.

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