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THE EFFECT OF DISTURBANCE ON THE REPRODUCTION AND MANAGEMENT OF CAPTIVE CRANES[1]

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Abstract: A retrospective analysis of egg laying histories and observations of crane pairs at the International Crane Foundation and the Patuxent Wildlife Research Center indicates that disturbance associated with captivity has adverse impacts on captive breeding. Females on public display laid significantly fewer eggs than those off display ($P < 0.05$). Crane pairs moved to other pens (other than adjacent pens) or between facilities laid slightly fewer eggs than those birds which were not moved, although the results were not statistically significant ($P = 0.188$). Pen design and construction also appeared to have adverse impacts on breeding. In addition, human activities, intraspecific interactions, and rearing methods influence a bird's response to disturbance, and, therefore, these factors must also be considered in an effective crane management program. Modifying procedures to minimize disturbance, timing necessary disturbances after the breeding and molt seasons, and carefully monitoring birds for signs of stress can result in increased reproductive potential for captive, endangered cranes.

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Key words: behavior, disturbance, reproduction, cranes, *Grus*.

From the inception of propagation programs at the International Crane Foundation (ICF) and the Patuxent Wildlife Research Center (Patuxent Center), captive breeding was accepted as a technique that could prevent extinction and contribute to the recovery of certain species by providing a controlled protective captive environment, fostering coordinated research, and providing stock for bolstering or re-establishing wild populations (Archibald 1974, Derrickson and Carpenter 1981). To develop propagation and reintroduction techniques for endangered cranes, ICF maintains 110 individuals of all 15 species of cranes with emphasis on the endangered species, including Siberian (*Grus leucogeranus*), red-crowned (*G. japonensis*), white-naped (*G. vipio*), hooded (*G. monachus*), wattled (*Bugeranus carunculatus*), and black-necked (*G. nigricollis*) cranes. The Patuxent Center maintains 275 individuals including whooping (*G. americana*), Mississippi sandhill (*G. canadensis pulla*), greater sandhill (*G. c. tabida*), and Florida sandhill (*G. c. pratensis*) cranes.

Maintaining birds in captivity for breeding purposes requires considerable knowledge of their reproductive biology and behavior. For example, it is known that the stimulus that initiates the breeding cycle in birds is a complex combination of innate physiological rhythms and environmental stimuli (Gee 1983). Most of these external stimuli, e.g., photoperiod, light intensity, temperature, rainfall, humidity, nutrition, presence of a mate, territory, and nesting material, have been identified and their influence varies among species. Less is known, however, about factors such as stress (i.e., disturbance) which may have an adverse influence on the breeding season.

Stress is the effect of physical, physiological, or emotional factors (stressors) that induce an alteration in an animal's homeostasis or adaptive state (Anonymous 1987). Stress responses often involve changes in the neuroendocrinologic function, autonomic nervous system, and mental state of the animal, as well as its behavior. If stressors are short-term, an animal's response usually will not result in long-term harmful effects. Prolonged or excessive distress may result in harmful responses, such as abnormal feeding and social behavior and inefficient reproduction.

However, the ability to correlate a stressor with a specific effect can be very difficult. Failure to establish an acceptable clinical measure of stress results from the (1) inability to determine which biological value is the best measure of stress, (2) lack of nonspecific stress response that characterizes all types of stressors, and (3) failure to establish a correlation between stress measures and a meaningful impact on the animal's well-being (Moberg 1987). In addition, finding a measure of that stressor is further complicated by inter-animal variability in stress response. The biological responses depend on a variety of factors, such as prior experience, genetics, age, or physiological state (Moberg 1987). The role that stress plays in preventing apparently healthy birds from breeding in captivity is poorly understood (Cooper 1978), although stress has been shown to affect reproductive success in birds by altering hormone

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levels (Gee 1983, Stoskopf 1983).

The purpose of this paper is to retrospectively evaluate the effects of disturbance associated with public display, pen transfers, pen design, and construction on egg production in captive cranes. Based in part on these findings or observations, management recommendations are presented to reduce the impact of disturbance on crane breeding. Recommendations are also made for managing human activities, neighboring cranes, and rearing methods to increase crane reproduction in captivity.

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METHODS

Public Display and Pen Transfers

Cranes at ICF are housed in 1 of 2 facilities. One facility is on public display, whereas the second facility is off display in an isolated area in which visitors are generally not permitted. Pen transfers include the movement of pairs within the same facility or between facilities; it does not include the movement of birds to adjacent pens for disease management.

To evaluate the effects of disturbance on reproduction, we examined the laying histories of cranes at ICF in relation to the effects of public display and pen transfers. Nine of 21 females were selected for study of their individual transfer history and egg laying history because they (1) had a history of pen transfers, (2) produced eggs for at least 2 seasons between 1974 and 1987, and (3) were managed for optimum reproduction. Data were analyzed starting with the female's first year of egg production and ending with her 1987 laying season, death, or shipment from ICF. Total number of eggs laid was selected as the most suitable measure of productivity.

Egg production during years in which pairs were on display was compared with production during years in which the same cranes were off display. Because pen transfers could confound the effects of public display, the data were analyzed separately for years in which the birds were moved or were not moved. A move year was one in which a pen transfer occurred between the date on which the last egg was laid in the previous season and the first egg of the following season. A non-move year was designated when there were no pen transfers during the selected time period. Years in which cranes were moved to adjacent pens were not included in the data set.

To evaluate the effects of pen transfers, we compared egg production during years in which pairs were moved with production during years in which cranes were not moved. The data were separated for years in which the birds were on display or were off display to correct for confounding effects of the cranes' display status. All analyses used the Wilcoxon signed rank test, a nonparametric test, with a 1-sided alternative (Hollander and Wolfe 1973). Significance levels of $P < 0.05$ were considered sufficient to reject statistical hypotheses.

Pen Design and Construction

By examining records at both ICF and the Patuxent Center, we identified a number of cases where disturbance associated with pen design or facility construction appeared to have an impact on crane breeding. Two examples of these disturbances were examined.

RESULTS

Public Display and Pen Transfers

Annual egg production at ICF in relation to public display and pen transfers is presented in Table 1. Six of the 9 females in the sample that were maintained both on and off display consistently produced more eggs while off display, independent of pen transfer effects. Females which were moved to other pens produced more eggs while off display than while on display ($P = 0.016$; see columns 1 and 3, Table 1). Females which were not moved also produced more eggs while off display than while on display ($P = 0.031$; see columns 2 and 4, Table 1).

Analysis of the data for birds off public display indicates that females not moved produced slightly more eggs than females which were moved, although the results were not statistically significant ($P = 0.188$; see columns 1 and 2, Table 1). The data were insufficient to compare egg production by cranes on public display during years in which they were moved and not moved (see columns 3 and 4, Table 1).

Pen design and Construction

Disturbance Associated with Pen Design.—At ICF, 4 pairs of cranes with prior laying histories were placed in a new exhibit area. The birds appeared healthy and displayed normal behaviors but did not lay eggs. The exhibit was equipped with a variety of features to promote breeding. such as visual barriers between pairs, photoperiod control, and sprinkler systems. By closely observing the birds and examining the pen design, human disturbance appeared to

Table 1. Effect of public display and pen transfers[a] on mean egg production (production years) of female cranes at the International Crane Foundation, 1974-87.

	Off display		On display	
Female	Bird moved	Bird not moved	Bird moved	Bird not moved
A	3.5 (2)	5.8 (5)		
B	15.0 (1)	12.7 (3)	0.0 (1)	0.0 (1)
C	2.0 (1)	10.0 (2)		
D	9.5 (2)	9.5 (2)	4.0 (1)	6.5 (2)
E	10.0 (1)	13.7 (7)	9.0 (1)	
F	2.0 (1)	2.0 (4)	0.3 (3)	0.0 (1)
G	2.0 (1)	2.5 (4)	0.0 (1)	0.0 (1)
H	5.0 (2)	3.0 (1)	0.0 (2)	0.0 (1)
I	0.0 (1)	1.2 (5)		
$\bar{x}$	5.6(12)	6.9(33)	1.5 (9)	2.2 (6)

[a] Includes transfer of birds within or between facilities; does not include production years in which birds were moved between adjacent pens.

cause the lack of reproduction. The individual enclosures were designed for public viewing from 1 end and access for bird care and maintenance from the other. Although the aviculturists only entered the pens briefly in the morning, the birds were effectively disturbed from both ends of their pen, causing disruption of territorial security. Consequently, the interior shelter was sealed off and the birds were fed and watered from the public entrance. This consolidated all disturbance at 1 location and provided the birds with a secure nesting site. As a result, 3 females which had been on display for several years and never laid began laying. Another female just reaching sexual maturity laid her first eggs under this management.

Disturbance Associated with Construction.—In October 1979, the Patuxent Center initiated the construction of a new perimeter fence around the crane breeding facility that required 4 to 5 workers and the use of heavy equipment. Because of inclement weather, the construction was intermittent and not completed until late winter. Construction activities occurred within 25 m of the whooping crane breeding pens. As an apparent response to the construction-related disturbance, a marked decrease in production occurred. Four whooping crane pairs produced 21 eggs in 1979, whereas only 2 whooping crane pairs produced 6 eggs in 1980.

In 1985, 24 chain-link breeding pens were constructed at the Patuxent Center to replace a pen complex built as a temporary structure in the early 1970's. Construction and associated disturbance at the new whooping crane breeding complex, timed to interfere as little as possible with either the 1985 or 1986 breeding season, was initiated at the end of the 1985 breeding season and was not completed until late October. In early July 1985, prior to the initiation of the construction, whooping crane pairs were moved approximately 50 m to a complex housing sandhill crane pairs. The initial phase of construction consisted of a team of 7 to 8 workers supported by heavy equipment. The cranes were moved to their new pen complex in early November 1985. However, minor disturbances, such as installation of visual barriers, filling in holes, and installation of gate guards, continued until early January. Although 3 pairs of whooping cranes bred in 1985, producing a total of 13 eggs, none of the pairs was productive in 1986. This decrease in productivity can probably be attributed to a combination of disturbance and the movement of the cranes to smaller pens. In 1987, the 3 previously productive pairs of whooping cranes and 2 new pairs came into production.

DISCUSSION

It is known that wild sandhill cranes will abandon their territories and fail to breed if they are repeatedly disturbed during the breeding season (Derrickson and Carpenter 1981). Similarly, frequent disturbance can significantly alter the breeding behavior of captive pairs and can ultimately result in reproductive failure (Derrickson and Carpenter 1981). Unless captive birds have adapted to consistently high levels of disturbance, it is important to prevent and reduce disturbance during the breeding season to enhance breeding success.

Although disturbance is not the only stress that may interfere with reproduction in cranes, disturbance does appear to have been instrumental in reducing the productivity of cranes at ICF and the Patuxent Center. Unfortunately, it is difficult to quantify the impact because other sources of stress and factors such as weather, fright, subclinical disease, lack of territorial integrity, and changes in animal care personnel also influence reproduction. The impact of more subtle disturbances on a bird's behavior and productivity is even more difficult to evaluate. However, based on an analysis of bird moves versus breeding results at ICF, and observations at both ICF and the Patuxent Center on the adverse effects that disturbance appears to have on egg production, it does appear that certain types or levels of disturbance can affect crane breeding. Therefore, the following management procedures are recommended to reduce disturbance to cranes.

Display

The evaluation of the data indicates that captive cranes

produce fewer eggs while on display. Therefore, it is desirable to maintain valuable breeding birds off display. Unfortunately, this option does not exist for many zoos involved in breeding programs. These zoos, therefore, should consider constructing off-exhibit enclosures for breeding. Cranes could then be rotated between areas based on breeding priorities. Subadults, nonbreeders, or well-represented pairs make up a significant portion of a captive population and are generally suitable for display.

If it is necessary to maintain breeding cranes on display, facilities and management practices should be designed to promote breeding. The presence of other species in the exhibit should be carefully considered. Species should be selected that are not aggressive to cranes, that solicit minimal aggression from cranes, and that are unlikely to disturb nesting sites.

Pen Transfers

Analysis of the egg production data suggests that moving birds to other pens, other than adjacent pens, or facilities has a slight negative effect on egg production. Although the data in this comparison are limited and not statistically significant, differences of even 1 to 2 eggs per year can be important in the preservation of genetic diversity in small captive populations. Therefore, efforts should be made to place pairs in suitable breeding pens and to minimize transfers as long as reproduction is desired. If a pair does not breed in a particular pen, the pair should be closely observed to determine if environmental or behavioral disturbances are affecting dominance or territorial security. The status of the pair bond should be evaluated by observations for proximity, synchronized maintenance activities, guard and unison calls, synchronized display, male defense of the female and territory, and aggression between pair members (Mirande and Archibald 1990). Attempts should be made to minimize disturbance. If efforts are unsuccessful, transfer to a different enclosure should be considered.

Although it is better to minimize disturbance by moving cranes within a complex, pen transfers to new areas will periodically be necessary. For example, old facilities may need to be replaced or birds may need to be moved because of pair incompatibility or to establish new pair bonds after the death of a mate.

Facility Design

Optimally, crane pairs should be housed in units, each containing 2 pens (each minimally 15 × 18 m) that are generally arranged in a linear series (Archibald 1974, Archibald and Veiss 1979, Carpenter 1986). Isolation for breeding pairs and disease management can be ensured or facilitated by allowing only 1 compartment to be occupied at a given time so that each pair is flanked by empty pens. In effect, this provides a psychological territory that is 3 times as large as the occupied pen. Ideally, buffer zones (approximately 9 m) should be placed between rows of pens.

Visual barriers should be provided along fences to define territorial borders and to provide cover for easily stressed birds (Mirande and Archibald 1990). The provision of small buildings (4.3 × 3–4 m) is desirable because birds can be locked in familiar enclosures during severe weather or in case of illness or injury. If the cranes are fed and watered from the shelters, the birds can be serviced with minimal disturbance.

Facilities should be designed to provide a secure, undisturbed section in each pen for nesting. Entry into these areas should be avoided. If birds must be handled, they should be herded and caught in other areas of the pen.

Construction

All unavoidable or planned disturbances, such as major construction projects, should take into account the ability of the crane pair to tolerate stress, their proximity to disturbance, and their physiological stage in the annual breeding cycle. Necessary disturbances should be timed to occur in the fall after parent-reared chicks are several months old and molt is completed. In addition,, these activities should be completed as far as possible in advance of the next breeding season.

Other Recommendations

In addition to the sources of disturbance previously discussed in this paper, other captive management activities should be evaluated to minimize disturbance effects on birds.

Human Activities.—Disturbance can be reduced by acclimating pairs to necessary activities before breeding commences to minimize potential stress effects. This can be accomplished largely by restricting access to breeding areas to essential personnel only and by completing all routine husbandry and propagation activities, i.e., nest checking, egg collecting, feeding, and artificial insemination, on a regular daily schedule (Derrickson and Carpenter 1981). Regular contact, however, by personnel who care for the birds (i.e., aviculturists) can be advantageous because contact is less stressful when it is necessary.

It is important to maintain permanent, experienced staff in captive breeding programs because cranes easily recognize individuals and adjust more easily to the presence of familiar people. In addition, aviculturists who are familiar with crane

behavior and the likely reactions of individual birds to various stimuli or stressors are the most qualified to work with, and be a minimal disturbance to, the birds. The ability of aviculturists to identify sources of stress can influence management decisions designed to eliminate or reduce these sources.

Although procedures have been developed to minimize stress in birds, individuals vary in their response to human activities, and procedures may need to be modified for these birds. For example, artificial insemination procedures are generally initiated 2–4 weeks prior to expected egg laying to condition the birds to handling procedures. However, observations at the Patuxent Center on a compatible pair of whooping cranes during the 1981 breeding season revealed that normal pair activities were disrupted for several hours following routine capture and handling for artificial insemination (Derrickson and Carpenter 1987). Because both birds were extremely stressed following handling, all attempts at artificial insemination were halted. Although the pair resumed normal behavior and progressed to nest building, the female did not lay. The following year the pair was not captured or handled for artificial insemination early in the breeding season, and the problem was avoided. Stress-related behavior was not observed, and the birds came into breeding condition rapidly. Semen collection from the male and artificial insemination of the female were resumed after the laying of their first egg without apparent ill-effect, and the female subsequently produced an additional 4 fertile eggs (Derrickson and Carpenter 1987).

A similar pattern was observed in a pair of common cranes (*G. grus*) at ICF. Attempts at artificial insemination early in the breeding season resulted in extreme stress and the disruption of normal behaviors. After attempts were ceased, the birds gradually reestablished their dominance and laid. Artificial insemination was resumed after the laying of the first egg without any apparent adverse effects.

Intraspecific Interactions.—Crane pairs are highly territorial and are bred most successfully in isolated pens. Cranes in adjacent pens can inhibit breeding because pair members, especially males, often spend much of their time along bordering fences trying to drive off the "intruding" birds. This has several negative effects, including (1) involvement of the male in aggressive display to the degree that normal pair interactions are inhibited, (2) compromise of territorial security, and (3) injuries resulting in physiological stress. Therefore, it is important to provide buffer zones or visual barriers between aggressive birds. It is also important to observe pairs closely when new neighbors are introduced. Occasionally males are stimulated to such high levels of aggression that they displace their aggression and kill their mates (Mirande and Archibald 1990). Pairs should be watched very closely for an increase in submissive behavior by the female and members may need to be separated temporarily to avoid injury to the female.

Rearing Method.—The response of cranes to disturbance will vary greatly with their rearing history. Wild-caught cranes are the most sensitive to disturbance. Gradually conditioning these birds to the presence of people and encouragement of the expression of dominant behavior toward people are important to promotion of breeding and reducing the risk of injury. Aviculturists can minimize stress by assuming submissive posture around the birds, by avoiding direct eye contact, and by making soft sounds to let the birds know when they are approaching and where they are working. Daily offerings of small amounts of choice food items such as corn can also help to tame birds and reduce disturbance effects. Parent-reared birds are generally very wary and exhibit behavior similar to wild-caught cranes. There is a greater risk of these birds injuring themselves as a result of disturbance than with hand-reared birds. Conditioning these birds to the presence of humans is also very important. Hand-reared birds are generally very tolerant of people and, if not severely imprinted on humans, breed very well in captivity. These individuals are the least affected by handling and breed more readily on display than cranes reared by other methods.

Rearing method should be carefully selected based on the management goals for each individual crane. Cranes reared for captive management should either be hand-reared by methods to reduce imprinting or parent-reared but exposed to people to reduce inhibition of breeding from human-related stress later in life (Mirande and Archibald 1990).

CONCLUSIONS

A retrospective analysis of egg laying histories and observations of crane pairs at ICF and the Patuxent Center indicates that disturbance associated with captivity has an adverse impact on captive breeding. Females on public display laid significantly fewer eggs than those off display ($P < 0.05$), independent of crane moves. Crane pairs moved to other pens (other than adjacent pens) or between facilities laid slightly fewer eggs than those birds that were not moved, although the results were not statistically significant. Therefore, to promote reproduction and maximize the success of captive propagation programs, aviculturists should maintain valuable crane pairs off display whenever possible. Pairs on display should be managed to minimize disturbance. Until more data are obtained, pen transfers should be minimized or timed to reduce possible impact on breeding goals for genetic management, although some pen transfers may be beneficial if birds are moved to less disturbed pens.

Facilities should be designed to promote dominance and territorial security, provide a secure nesting area, and minimize aggression toward neighbors. Disturbance levels in the captive environment should be reduced as much as possible in advance of the breeding season (Cooper 1978, Carpenter and Gabel 1984, Derrickson and Carpenter 1987). Necessary disturbances, such as pen construction, should be timed shortly after the molt season or when parent-reared chicks are several months old to minimize disturbance effects. In addition, human activities, intraspecific interactions, and rearing methods influence a bird's response to disturbance, and, therefore, these factors must also be considered in an effective crane management program.

Captive pairs should be monitored throughout the breeding season for changes in behavior such as frequent pacing, excessive preening, decreased frequency of precopulatory behavior or unison calling, and egg breaking, which indicate stress. When such behavioral changes are noted, propagation procedures should be immediately re-evaluated and modified (Derrickson and Carpenter 1987).

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