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PROGRESS IN SATELLITE TRACKING CRANES

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Abstract: We review the history of tracking cranes with satellite telemetry and identify some of the difficulties in designing satellite transmitters and harnesses for cranes. Miniaturization of these transmitters and a plethora of harnessing experiments since 1989 allow us to recommend limited application of this technology to all species of cranes. We are still uncertain, however, if cranes harnessed with satellite telemetry devices are able to reproduce after migration. Because of this uncertainty, we urge caution in the use of this technology, especially with breeding adults in severely endangered populations. This manuscript also describes continuing research needs.

Key Words: crane, migration, satellite, telemetry

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Conservation of migratory cranes requires information on long-distance movements and knowledge of important staging, stopover, and wintering areas. Migration studies also identify essential wetlands for conservation and may suggest important mortality factors. To determine migration routes of most cranes, specialized equipment and procedures that permit tracking of individuals over long distances are required. For projects involving very few birds crossing sensitive international borders, tracking via satellite is often the most practical and reliable means for this task.

We acknowledge the International Crane Foundation for its primary role in facilitating our field testing of satellite telemetry techniques in Asia. W. S. Seegar has been important in encouraging development of a bird-borne satellite transmitter. P. W. Howey of Microwave Telemetry (mention of trade names or products does not imply endorsement by the U.S. Fish and Wildlife Service or Wild Bird Society of Japan), J. French of Mariner Radar, and P. Goriup of the Nature Conservation Bureau (U.K.) worked closely with us in applying satellite telemetry technology to cranes. We thank the aviculture staff at the Patuxent Wildlife Research Center (Patuxent) for handling and observing our instrumented cranes in every kind of weather. L. J. Miller and S. S. Klugman were especially helpful in recording data and planning crane harnessing sessions. We deeply appreciate the time and efforts of W. Howard, a silversmith in Stoughton, Wisconsin, in manufacturing dummy satellite transmitters. M. Childress and C. Ellis helped greatly in manuscript preparation.

HISTORY OF SATELLITE TRACKING EFFORTS WITH WILDLIFE

Although monitoring animal movement and behavior by satellite was contemplated in the early 1960's, this was not accomplished until 1970 when an elk (*Cervus elaphus*) was instrumented at the National Elk Refuge in Wyoming (Craighead et al. 1972). The large size of early transmitter packages restricted their use to very large animals (e.g., black bears [*Ursus americanus*] [Craighead et al. 1971], and basking sharks [*Cetorhinus maximus*] [Priede 1982]). Miniaturization of electronic components in the 1980's allowed application of satellite telemetry to smaller birds (Fuller et al. 1984, Strikwerda et al. 1985, French 1986, Strikwerda et al. 1986, Priede 1988, Tomkiewicz 1989, Harris et al. 1990). Platform transmitter terminals (PTT's: the technical name of devices that are monitored by the Argos satellite network) weighing less than 150 g are now commercially available.

Dramatic weight reduction was quickly followed by tests of a variety of transmitter shapes on captive birds. Research on attachment methods and bird behavioral responses to conventional radio tags helped in selecting those methods least likely to elicit adverse behavior (Snyder et al. 1989, Olsen et al. 1992). Wind tunnel experiments were conducted to produce more aerodynamically efficient PTT designs (Obrecht et al. 1988). Also, biomechanical models were used to determine the effects of PTT mass and aerodynamic drag on bird flight (Pennycuick and Fuller 1987, Pennycuick et al. 1988, Pennycuick et al. 1989). Beginning in 1990, tests at Patuxent have concentrated on direct observations of the short-term effects of harnesses and satellite backpacks on free flying cranes and the long-term effects on penned cranes (Olsen et al. 1992 and unpubl. data).

In the wild, PTT's have been tested with mixed results on tundra swans (*Cygnus columbianus*), bald eagles (*Haliaeetus leucocephalus*), giant petrels (*Macronectes giganteus*) (Higuchi et al. 1991, Strikwerda et al. 1986), whooper swans (*C. cygnus*), mute swans (*C. olor*) (Priede 1988), and houbara bustards (*Chlamydotis undulata*) (Goriup 1988). The utility of satellite tracking has been demonstrated in studies with wandering albatrosses (*Diomedea exulans*) in the southwestern Indian Ocean (Jouventin and Weimerskirch 1990), migrating Bewick's swans (*C. columbianus bewickii*) in northern Europe (Nowak et al. 1990), a bald eagle (Strikwerda et al. 1986), and a golden eagle (*Aquila chrysaetos*) (McIntyre et al. 1991). To date, the smallest bird to be instrumented and tracked was an adult female gyrfalcon (*Falco rusticolus*) in Greenland (P. W. Howey, M. R. Fuller, and W. S. Seegar, unpubl. data).

Satellite telemetry provided information that was previously unavailable on bird movements in remote locations and over long distances. The value of this information often justifies the high costs associated with PTT purchase ($2,000–3,000 U.S.) and use of the satellite system ($11–22 U.S. per PTT reception day). Difficulties in attaching relatively large PTT's are being overcome on a species by species basis and PTT reliability has improved until, today, this technology deserves serious consideration for the study of long distance movements of birds over 1,500 g in mass.

SATELLITE TRACKING OF CRANES

Because of the great distances involved, the remoteness of the areas traversed, the crossing of restricted political boundaries, and the duration of migratory flights, satellite telemetry is the only reasonable means of tracking birds such as the Siberian crane (*Grus leucogeranus*). A great deal was learned from more than 15 years of experience attaching conventional radio tags to cranes (Nesbitt 1976, Melvin and Temple 1987). In 1987, a solar-powered PTT was tested on captive sandhill cranes (*G. canadensis*) at Patuxent, but feathers covered the solar panel and prevented recharging. Later, S. A. Nesbitt (Florida Game and Fresh Water Fish Commission) and S. E. Landfried worked to design a battery-powered PTT specifically for cranes, and in April 1989, Mariner Radar dummy packs, originally designed for houbara bustards, were attached to captive cranes at Patuxent. In June 1989, Landfried and W. Howard produced the first PTT prototype specifically designed for cranes. These early attempts revealed problems with the houbara necklace harness and resulted in a shift to a backpack design. In July 1989, a Landfried prototype was placed on a Siberian crane at the International Crane Foundation to determine if the shape was compatible with the birds' anatomy. By fall 1989, Mariner Radar had redesigned the bustard PTT for cranes. Patuxent expanded crane harnessing experiments in the spring of 1990 to include 4 different brands of PTT's. To date, PTT attachment tests have been made using over 20 penned and 8 free-flying cranes (Olsen et al. 1992 and unpubl. data).

Two preliminary studies demonstrated the feasibility of tracking cranes by satellite. In Florida during spring 1989, S. A. Nesbitt harnessed a greater sandhill crane (*G. c. tabida*) with a ca. 160-g solar-powered, Telonics PTT (Nagendran 1992). The bird was tracked flying north from its wintering grounds for 20 days until its signal was lost in Michigan. In 1990, 3 Eurasian cranes (*G. grus*) were fitted with Telonics (ca. 156-g) backpacks on the breeding grounds in northwestern Siberia (Ellis et al. 1992). One crane migrated over 3,300 km to winter in Iran. The other 2 birds carried their PTT's 700–1,000 km before signals were lost. Although the lightest (weight) of these 3 birds is known to have survived 8 months while her backpack continued to transmit, it is uncertain that any of these 3 birds survived to breed in 1991.

Research Topics

Design and implementation of satellite tracking techniques for cranes involve several overlapping phases: first, designing harnesses and testing satellite telemetry hardware on captive surrogate (i.e., non-endangered) cranes; later, field testing PTT systems with wild surrogate species; and finally, if a system proves reliable and noninjurious, applying the technique to endangered species. We need to know whether PTT attachment impairs survival or reproductive performance. If flight speed or efficiency is altered, mortality rates may rise or reproductive rates may fall.

Designing PTT's Specifically for Cranes.—Research had led to reduction in mass, optimizing power, and complex programming to increase PTT longevity. Concurrent work involved fitting the transmitter to the crane (i.e., adjusting PTT size and configuration, and antenna orientation and location). At present, 3 brands of PTT's are available and certified (i.e., approved for commercial use) by Service Argos, the agency that manages satellite data, in sizes suitable for cranes (up to ca. 200 g): (1) ca. 160 g from Telonics (battery and solar-powered), (2) 65–85 g from Microwave Telemetry, and (3) 55–85 g Nippon

Telephone and Telegram (NTT) (marketed by Toyocom). Mariner Radar may soon have Argos certification for a streamlined PTT weighing under 100 g and NTT is developing a short-lived PTT weighing less than 50 g.

Longevity is largely a function of duty cycle. Microwave Telemetry units have functioned longer than any other type and can be programmed for infrequent transmission, allowing for a life expectancy of 1 to 2 years. Other manufacturers also forecast long life through infrequent transmission: results are pending.

One objective during the design phase was to create aerodynamic shapes appropriate for crane anatomy. Patuxent worked with Clairson Industries to design, manufacture, and test a feather guard for the Telonics solar-powered PTT. This device was designed to promote laminar air flow over the crane's dorsum while preventing feathers from covering the solar panel. The feather guard proved reliable when the PTT was on sandhill cranes, but when applied to a hand-reared Siberian crane, it did not prevent feathers from partly covering the solar array.

Developing Harnesses and Attachment Techniques.—Non-endangered captive cranes were used to test various harnessing materials and configurations. Practical concerns involved finding the optimum material (nylon, velcro, teflon, or plastic cord) for attaching the PTT to the crane. In early backpack harnesses, Nesbitt (1976) used latex (surgical) tubing. We initially harnessed captive cranes at Patuxent using neoprene cord. Although tough and durable, neoprene is less flexible than teflon ribbon and caused abrasions and minor skin lacerations. Nearly all of our latest tests have been with teflon ribbon.

Our 4-strap design uses 1.3-cm wide ribbons joined at the breast (Olsen et al. 1992). We are also experimenting at Patuxent with 2 new attachment methods. A leg band borne PTT adapting a 60-g Microwave Telemetry PTT is still in the earliest phases of testing. Patuxent's new backpack harness consists of a teflon ribbon double loop that falls free if the continuous loop is severed at any point. The teflon ribbon passes through the front left attachment on the PTT, across the breast to the right rear attachment, through the PTT, out the left rear attachment, and across the breast to the front right attachment. The ends of the loop are sewn together and the seam is covered by a brass or copper ferrule which is flattened and crimped over the seam. In early trials, the continuous loop harness took from 0.5 to 2.5 hours to fall free when using 1.3-cm wide teflon ribbon. The backpack fell free in only 4 seconds when narrow 7-mm wide ribbon was used. Although the backpack is free to move left and right, it is maintained middorsally by the scapular feathers lying along each side. Because the device is self-aligning, we were able to reduce the attachment time from 30 to 45 minutes required for the 4-strap harness to about 8 minutes for the continuous loop. Both harness types were adjusted so that 3 or 4 fingers lying side by side could slide snugly beneath the PTT front and rear.

In 1990, the Wild Bird Society of Japan tested epoxy resin to attach NTT PTT's to the back feathers of captive cranes. When initial attempts in Japan proved successful, Patuxent made 1 test of the technique, but the crane tore the PTT, and attaching feathers, free in 5 days. Subsequently, the Wild Bird Society also abandoned the technique in favor of Patuxent's teflon ribbon harness.

Olsen et al. (1992) summarized behavioral responses of captive cranes with 4-strap teflon ribbon harnesses and dummy PTT's at Patuxent. After an initial 2-day adjustment period, no adverse behavior was noted. Surprisingly, there was no significant increase in preening. Physical wear was generally as follows: skin abrasion was negligible even after months of attachment, but the contour feathers below and immediately adjacent to the PTT's were frayed and broken by the preening of the cranes or by direct wear. Downy feathers remained intact. Moderate wear to the harness was sometimes noted for backpacks remaining on the cranes for several months. We saw little or no evidence of thickening or discoloration of integument beneath the PTT, antenna wear (important only for early versions of the Mariner Radar PTT), abrasion or other damage to the PTT housing, or damage to the underside of the PTT.

The continuous loop and 4-strap harnesses were tested with cranes trained to fly free at Patuxent. Both designs ride without bouncing, even during flapping flight.

Transmitter Tests.—A few live PTT's of various designs were fitted to captive non-endangered cranes to assess battery life, programming accuracy, and power requirements. One Microwave Telemetry PTT (113 g with harness) functioned for 14 months at Patuxent. Other Microwave Telemetry units designed to last 4–6 months have functioned for the planned intervals. Some solar-powered units have also been tested on captive cranes but with mixed results.

Field Trials.—Several field tests of PTT's on wild cranes have been conducted. The first tests involved the greater sandhill crane migrating from Florida (Nagendran 1992) and the 3 Eurasian cranes from Siberia (Ellis et al. 1992). In 1991, a Telonics solar PTT was attached to a hand-reared juvenile Siberian crane in northwestern Siberia. Later this was exchanged for an NTT PTT, but the bird and its 2 companions failed to migrate. Also in 1991, research expanded into southcentral Siberia where a white-naped crane (*G. vipio*) was outfitted with an NTT PTT. It migrated south to Poyang Lake in southeastern China (Anon. 1992). Another test involving Eurasian cranes was conducted in Finland in 1992, however, results are not yet available (Juhani Rinne, Masala, Finland, pers. commun.).

Tests should also determine whether PTT attachment disrupts reproduction. In the single test to date, 1 pair of captive sandhill cranes, both outfitted with PTT's, successfully incubated 2 eggs full term at Patuxent. We also observed a pair of Eurasian cranes with 3-day old chicks in northwestern Siberia. The adult male in this pair was captured and instrumented during hatching (Ellis and Markin 1991). We have no data concerning the reproductive performance of any crane that completed a migration while carrying a PTT.

Finally, although we obtained good estimates of crane migratory locations and have identified routes of travel and important wetlands (see Ellis et al. 1992, Nagendran 1992), pinpointing locations is often a problem. To minimize weight, sacrifices have been made in battery size and wattage. These changes reduce energy output and result in less precise geographical fixes. Because the satellite determines location as a function of distance between satellite and PTT, elevation and altitude of PTT may greatly influence readings. Accuracy is also a function of the number of transmissions received by the satellite. Keating et al. (1991) determined that accuracy is greatest when PTT elevations change little. This is an important consideration when a crane is flying. Major topographic features may cause misidentification of location or interfere with signal reception (Stewart et al. 1989, Keating et al. 1991). Sampling frequency, and thus accuracy, varies greatly with latitude. Because the satellites are in polar orbits, PTT's closer to the poles are subject to more passes (and thus yield more data) than PTT's near the equator (Service Argos 1987, Fancy et al. 1988, Keating et al. 1991). Thus for cranes migrating in a north-south direction, locations of fixes are most accurate and data receptions are most frequent for the northern leg of migration.

Recommended Experiments

Although much has been accomplished, work is still needed to make PTT's more aerodynamic. Further miniaturization, especially of batteries, is also needed. Future field work will determine if cranes, after migrating with PTT's: (1) survive well, (2) can fertilize eggs, (3) can incubate effectively, and (4) can rear chicks. Comparisons of survival rates and reproductive performance would be most useful if enough cranes (ca. 15 birds) were instrumented with PTT's (or dummies) and compared with a similar-sized control group. Both groups should be monitored using only conventional radiotelemetry (leg band attachments). Ideally, both groups would be instrumented for 2 or more months prior to the breeding attempt.

CONCLUSIONS

This and other publications in this volume (Ellis et al. 1992, Nagendran 1992, Olsen et al. 1992) reveal that much work has been done to apply satellite telemetry technology to cranes. With PTT's now available in the 50- to 100-g range and with harnessing procedures now available (both 4-strap and fall free), we encourage limited application of these techniques to projects involving long distance movements of all cranes. Species by species adaptations may be necessary, especially for smaller cranes. Once the final questions are answered affirmatively concerning the ability of instrumented birds to survive, migrate, and breed, the techniques may be applied even to breeding pairs of endangered cranes.

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