

SATELLITE RADIOTELEMETRY AND BIRD STUDIES IN NATIONAL PARKS AND PRESERVES

provides alternative for studies of wide-ranging wildlife

By MICHAEL W. BRITTEN, CAROL L. MCINTYRE, AND MARY KRALOVEC

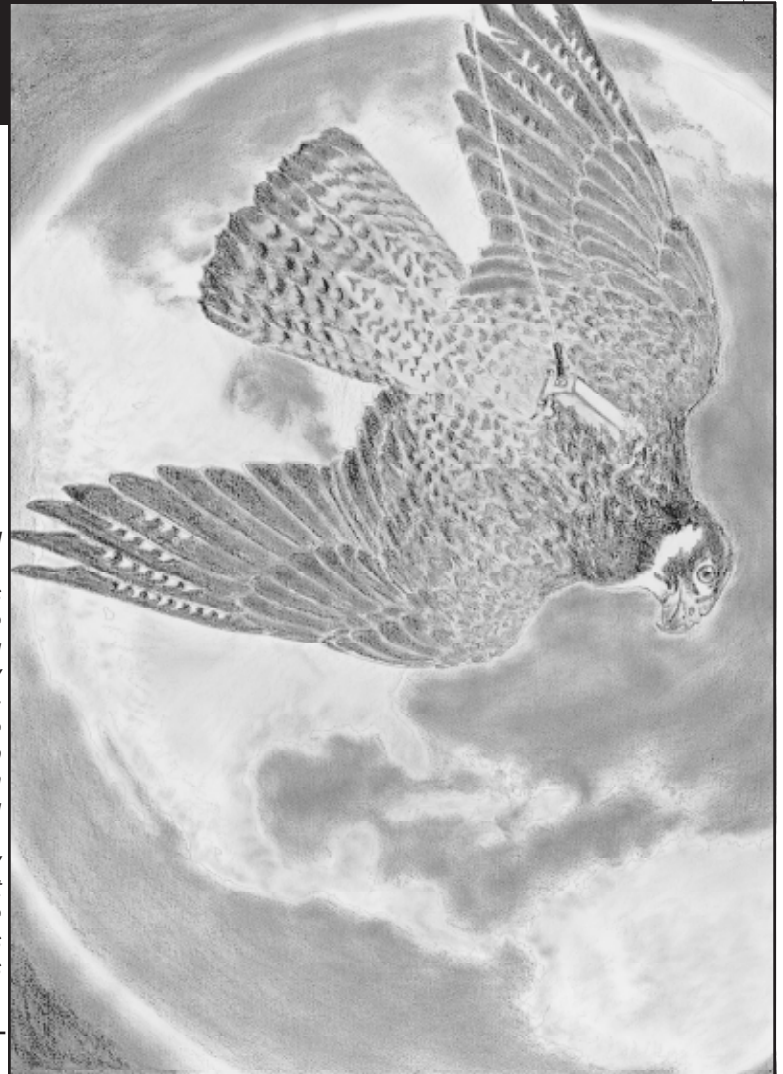
RADIOTELEMETRY HAS REVOLUTIONIZED wildlife study allowing researchers to identify and locate individual animals remotely. Wildlife scientists have used telemetry for many purposes, including estimating population size and demographic parameters, identifying habitat use, and documenting daily activities and migration and dispersal patterns.

Until recently, most telemetric studies relied on very high frequency (VHF) radios and required ground or aircraft tracking. This conventional radiotelemetric technique is only possible when the transmitter and receiver are close together, usually within about 30 km (19 mi), and nothing, such as a topographic feature, obstructs signal transmission. For animals that move long distances or inhabit remote areas, the high cost of locating radio-tagged individuals limits sample size and, consequently, research results. In these cases, a relatively new research tool, satellite radiotelemetry, may be more appropriate.

SATELLITE RADIOTELEMETRY FOR TRACKING WILDLIFE

Satellite radiotelemetry tracking uses special transmitters or platform transmitter terminals (PTTs) worn by wildlife (fig. 1) and receivers on board polar orbiting satellites. The PTTs are located using the Doppler effect, a shift in the frequency of radio waves caused by changes in the relative velocity of the transmitter and receiver as the satellite orbits the earth.

Figure 1. Small, lightweight, and sophisticated, radio transmitters now communicate with orbiting satellites to relay locations of wide-ranging wildlife species to researchers in their offices. Using this technology, scientists recently learned that Alaskan peregrine falcons winter as far away as Argentina.



NPS ILLUSTRATION BY PHILIP THYS

This technique is a cooperative effort between the user, the National Oceanographic and Atmospheric Administration (NOAA), and Service Argos, Inc. Argos, established in a 1978 agreement between NOAA, the National Aeronautics and Space Administration, and the French Space Agency, is a global satellite-based location and data collection system dedicated to environmental applications. Argos receives, processes, and transfers data to the user via electronic mail (including NPS CC:Mail), telephone modem, and fax.

HOW SATELLITE TELEMETRY WORKS

All PTTs transmit a unique code within their 401.65 MHz signal. As the orbiting satellite "rises" and comes into "view" of a

PTT, the satellite picks up the signal and identifies the transmitter. The Doppler effect increases the received frequency as the satellite approaches. Once the satellite is directly overhead, its velocity relative to the transmitter is zero and the Doppler effect is absent. As the satellite moves away from the PTT, the frequency shifts lower. Argos determines the PTT location by solving the simple relationship between the Doppler effect and the angle between the PTT and the satellite several times during one satellite pass.

Location accuracy depends on several factors including oscillator (frequency generator) stability, accuracy of the estimated satellite location in space, PTT elevation, and satellite pass duration. Argos classifies the data as class one, two, or three corre-

sponding to locations within 1,000, 350, or 150 m (1,094, 383, and 164 yd, respectively) of true location. Accuracy suffers whenever assumptions used to determine the transmitter location (e.g., that the carrier frequency is really 401.65 MHz) are violated. In wildlife satellite telemetry the transmitters are small and batteries are weak resulting in poor signal quality and inaccurate locations. For many locations, Argos gives no estimate of accuracy; however, all wildlife locations are classified indicating reasons for the inaccuracies. Fancy et al. (1988) assessed the accuracy of satellite-determined locations for PTTs at known locations (some attached to captive animals) and found a mean error of 829 m (907 yd) and a maximum error of 8.8 km (5.5 mi). In their assessment, 90% of the reported locations were within 1.7 km (1 mi) of the true location. Clark (1988) measured location accuracy of PTTs in Wyoming and Montana and found one standard deviation of 541-645 m (592-705 yd, respectively).

PAST USES OF SATELLITE RADIOTELEMETRY

The Argos system has been most heavily used by oceanographers, meteorologists, and hydrologists for applications such as tracking both water and wind currents and oil spills and relaying hydrologic data from remote watersheds. The first successful applications in wildlife research involved heavy, bulky instruments designed for tracking oceanographic buoys and weather balloons (Fancy et al. 1988). An 11.3 kg (25 lb) satellite radio collar was used to track an adult female elk (*Cervus canadensis*) for 29 days in Wyoming in April 1970 (Craighead et al. 1972). Craighead et al. (1971) monitored temperature and light intensity in the winter den of a black bear (*Ursus americanus*) with a satellite transmitter (powered by automobile batteries) placed outside the den. In March 1977, Lentfer and DeMaster (1982) used 5.6 kg (12.3 lb) transmitters to track polar bears (*Ursus maritimus*) by satellite.

Early PTTs were too heavy for tracking birds. Gradually lighter and smaller PTTs were developed and used to track larger birds such as bald and golden eagles (*Haliaeetus leucocephalus* and *Aquila*

chrysaetos) (James D. Fraser. 1994. Virginia Polytechnic and State University. Blacksburg, Virginia. Personal communication), swans (*Cygnus columbianus*) (Higuchi 1991), cranes (*Grus vipio* and *G. monacha*) (Higuchi 1992), storks (*Ciconia ciconia*) (Berthold 1992), and albatrosses (*Diomedea exulans*) (Weimerskirch 1993).

Scientists have also studied marine species using satellite telemetry, including loggerhead sea turtles (*Caretta caretta*), dolphins (*Stenella attenuata*), and basking sharks (*Cetorhinus maximus*) (Fancy et al. 1988). Unfortunately, both conventional and satellite telemetry are limited for marine animal studies because water rapidly attenuates radio signals. Some researchers have attached satellite transmitters to floats trailing behind and above the study animal to solve this problem.

LIMITATIONS

Satellite radiotelemetry is not currently appropriate when the scale of the movements being studied is small (e.g., habitat use or home range size). The smallest satellite transmitters currently available weigh between 25-30 g (0.9-1.1 oz), limiting their use for small birds (less than 1,000 g or 35 oz) or other small animals. Data can be delayed 20 minutes to 3 hours before being processed by Argos and relayed to the user. Because the satellites are in polar orbit, there are more frequent data collection periods near the poles than near the equator. For example, at 65° north latitude (approximately the latitude of our peregrine falcon studies) the satellite passed overhead an average of 22 times each day, whereas at 30° north the average dropped to nine overpasses per 24 hour period, and at the

for the peregrine falcon study, we programmed the PTTs to transmit 8 hours every other day during fall migration and 8 hours every 2 weeks during winter to conserve the expected 500 hours of battery life.

COSTS

Satellite telemetry is expensive, with each transmitter costing between \$1,800-\$3,500 (the PTTs used in our studies cost \$2,700 each). We paid Argos approximately \$1,000 per PTT for 500 hours of data transmission. By comparison, conventional telemetry is also costly. VHF transmitters cost \$150-\$350 each, and a receiving system (receiver, antennae, and optional scanner) costs \$750-\$3,500. Ground tracking requires at least one observer or automated tracking stations, and associated costs. Costs increase dramatically as the study area increases. If large, aerial tracking and associated aircraft, pilot, and fuel costs, becomes necessary. Aerial tracking is also risky for the observer and pilot, as reported in the last issue of *Park Science*, and is a cost that should always be considered. Furthermore, studies of highly mobile species require scientists to mark and track more animals, due to emigration.

Sometimes, satellite telemetry is a cheaper research alternative. No ground observer, tracking vehicle, receiver, aircraft, or pilot is required. Data entry costs nothing and produces no transcription errors (data are received in ASCII text files). Unlike conventional telemetry, satellite radiotracking costs do not increase with the size of the study area and the chances of "losing" animals that leave the tracking area are minimal. Kralovec (1994) found that the cost of locating one bald eagle per day

...Only satellite telemetry provides a means to document entire migratory routes—from Alaska to Argentina and all points in between

equator only seven per day. Finally, PTTs cannot be located by researchers using conventional telemetry, making removal and recovery of transmitters difficult. Battery power also limits the use of small transmitters; however, the PTTs can be programmed to transmit at specified target intervals to extend battery life. For example,

in southeast Alaska was lower using satellite telemetry (\$19.39 per location) than conventional telemetry (\$33.32 per location).

Continued on page 22

Compared to mark-recapture techniques, satellite telemetry is more efficient. In bird banding studies, for example, recapture rates are very low, often less than 1%, requiring that many animals be marked to achieve adequate sample size. Using satellite telemetry, barring transmitter and harness difficulties, all marked animals can be remotely located and identified. For example, in our study of the migration routes of adult female peregrine falcons, we successfully tracked 11 of 15 marked birds during fall migration and nine of the 15 to their wintering sites. In three cases the birds appeared to have removed the transmitters.

Satellite telemetry is not subject to the same bias as mark-recapture and conventional telemetry methods; once an animal is marked a researcher can relocate it almost anywhere. Researchers have little difficulty discriminating between mortality and emigration.

TRACKING BIRDS USING SATELLITE TELEMETRY

JUVENILE GOLDEN EAGLES IN DENALI NATIONAL PARK, ALASKA

In 1987, the National Park Service began a study of the nesting ecology of golden eagles in Denali National Park, Alaska. One objective was to determine the migratory routes and wintering areas of juvenile birds. Toward this end, we banded juvenile eagles and tagged three nearly fledged golden eagles (one in 1990 and two in 1992) with 90 g (3.2 oz) PTTs using a backpack-style harness. We successfully determined the autumn migration routes and wintering area for two of the young eagles.

In 1990, the first study eagle left the park on September 23 and moved along the northern edge of the Alaska Range until it turned south near Whitehorse, Yukon Territory, Canada. From October 1-17, the bird continued south through interior British Columbia and into east-central Idaho. Between September 23 and October 17, it moved 2,530 km (1,569 mi) from its Denali nest (an average of 97.5 km or 60 mi per day). The eagle remained in east-central Idaho on the western side of the Bitterroot Mountains from October 17, 1990, through February 18, 1991, the last transmission date.

In 1992, a second study eagle left the park on September 27 following nearly the same route as the 1990 bird. However, it crossed the Canadian Rockies and turned southward near Lesser Slave Lake in Alberta. By October 16, the bird passed Saskatoon, Saskatchewan, and on October 22, crossed into northeastern Montana. The eagle remained there until the last transmission on January 18, 1993.

Most golden eagles in interior and northern Alaska are migratory. While these birds may spend as much as 5 months (October through March) away from their breeding grounds, they follow unknown migration routes and winter in unknown locations. Mike Kochert of the Bureau of Land Management in Boise, Idaho, commented in a 1994 conversation that some researchers feel that winter food supplies may be an important factor determining reproductive success of golden eagles. Determining the wintering locations of golden eagles from Denali, therefore, has become an important objective of the current nesting ecology study. Our data, collected by satellite telemetry and banding during this study, provide the only data on migratory pathways and wintering areas of juvenile golden eagles from Alaska.

BALD EAGLES IN GLACIER BAY, ALASKA

In 1991, Glacier Bay National Park and Preserve and the U.S. Fish and Wildlife Service (FWS) began monitoring the long distance movements of bald eagles using satellite telemetry. The park asked us to determine the movements of adult and fledgling eagles from Glacier Bay, identify their wintering sites, and evaluate the feasibility of using satellites to monitor the movements of free-ranging eagles.

We tagged three adult bald eagles with PTTs in October and November, 1991, and also tagged three and four 8-10 week old nestlings in August 1991 and July 1992, respectively. We attached the 76-157 g (2.7-5.5 oz) PTTs, with an estimated battery life of 12 months, using a backpack harness. We also attached 18 g (0.6 oz) tail-mounted conventional VHF transmitters to the adult eagles to confirm the satellite determined locations.

Adult bald eagles remained near their nests on a year-round basis with short forays to salmon streams inside and outside the park. Two of the three adults traveled

to the Chilkat Bald Eagle Preserve, over 60 km (36 mi) northeast of Glacier Bay, for 1-2 months. Using conventional telemetry at the Chilkat River, we found and visually confirmed locations of the adults obtained by satellite. After visiting the bald eagle preserve, both eagles returned to their nest sites in Glacier Bay where we again verified their presence using conventional telemetry.

Fledgling bald eagles left Glacier Bay for a longer period and moved away from the park in a southeasterly direction. Six of the seven fledglings left the boundaries of the national park and preserve and were not located there again. Within 4-6 weeks of fledging, four of the fledglings traveled to the bald eagle preserve where they remained for 1-3 months before leaving in a southeasterly direction. We subsequently located the four fledglings throughout southeast Alaska, with one traveling to Prince Rupert, British Columbia, a distance of over 430 km (267 mi) from its natal territory in Glacier Bay. One fledgling eagle appeared to remain in Glacier Bay throughout the winter and early spring. This young eagle moved between its natal territory and various salmon streams in and near the national park.

By using satellite-monitored transmitters, we recorded the movements of both adult and fledgling eagles as they moved within and outside the park. These patterns were similar to those seen in other bald eagles studies in southeast Alaska. We determined that Glacier Bay bald eagles are not year-round residents and identified the areas outside the park that they used. Bald eagle management must transcend park boundaries and include not only regional, but also national and international concerns.

GYRFALCONS ON THE CENTRAL SEWARD PENINSULA, ALASKA

In 1992, the National Park Service began a study of the autumn and winter movements of juvenile gyrfalcons (*Falco rusticolus*) from the Seward Peninsula in western Alaska as part of the shared Beringian heritage program. In 1992, we tagged two gyrfalcons with 45 g (1.6 oz) PTTs in a pilot study to determine if these birds could be tracked by satellite. The 1992 results were successful and in 1993, we continued the work by tagging seven juvenile gyrfalcons from three nests. This time we used 30 g (1.1 oz) PTTs attached with backpack harnesses. We observed the fal-

cons carefully after attaching the PTTs and found that birds appeared to fly normally with no noticeable negative effects from the PTT or harness.

We are very excited by the results from this research as they are the first to document regular movements of gyrfalcons between Alaska and Russia. Four of the nine radio-tagged birds crossed the Bering Strait and moved into eastern Russia within 4 weeks of fledging; three of the four eventually returned to winter in Alaska. One bird, however, moved over 3,500 km (2,170 mi) along the southern coast of Russia and wintered in the Shantar Island region in the Sea of Okhotsk (fig. 2). Although banding data documented a similar long distance movement of a juvenile gyrfalcon from the Seward Peninsula to the Kamchatka Peninsula in 1971, only satellite telemetry provides a means to document the entire migratory route.

Other new or noteworthy observations included the lack of directionality in the movements of the juvenile gyrfalcons from the natal area, the independence of sibling movements, movements of juvenile gyrfalcons corresponding to changes in the abundance of prey, long distance movements of juvenile gyrfalcons within 3 months of fledging and the tendency of juvenile gyrfalcons to use coastal and riparian areas, where prey may be more abundant, in autumn and winter.

These results provide the most current information on the movements of juvenile gyrfalcons in Alaska. Of the nearly 500 gyrfalcons banded in Alaska only five have been recovered away from their original banding site (Swem et al. 1994). While these recoveries provide important data on the movements of Alaskan gyrfalcons, the logistical costs associated with banding 500 gyrfalcons over 20 years are staggering. Results from the current study show that satellite radiotelemetry is a cost efficient and effective research tool for studying the movements of large birds in remote areas.

PEREGRINES IN YUKON-CHARLEY RIVERS NATIONAL PRESERVE AND GLEN CANYON NATIONAL RECREATION AREA

In 1993, the National Park Service and the U.S. Fish and Wildlife Service began a cooperative study of the autumn and winter movements of adult female peregrine falcons (*Falco peregrinus anatum*) that breed

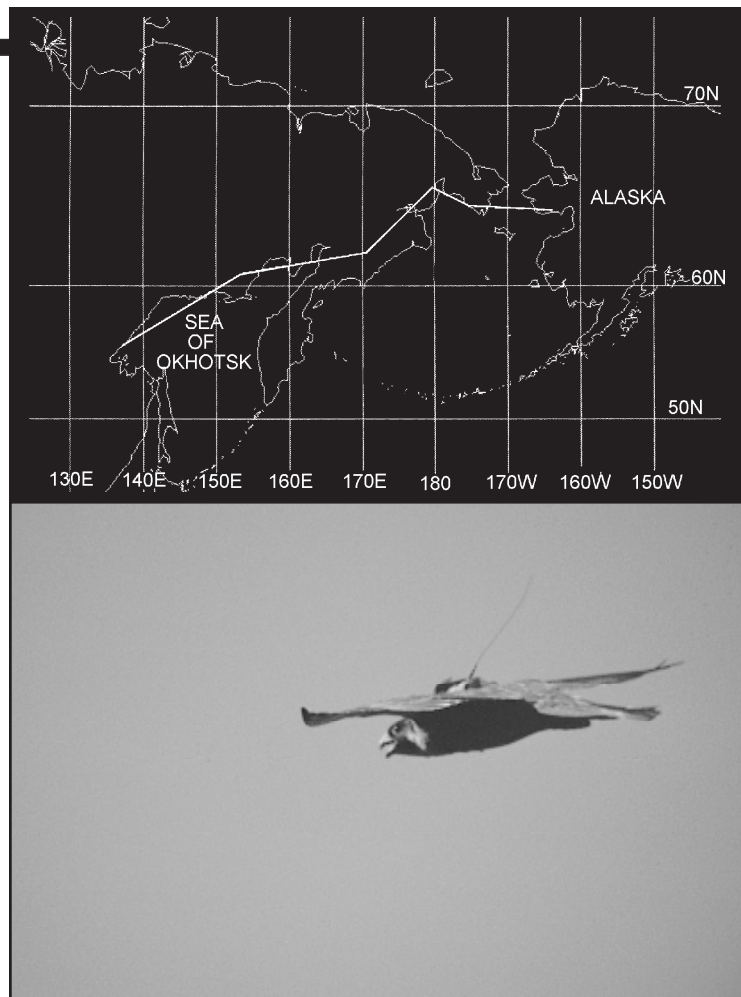


Figure 2. Movements of a juvenile gyrfalcon from Seward Peninsula, Alaska, to Shantar Island, Russia, September to October 1993.



Figure 3. Peregrines in the Alaska and Glen Canyon studies flew without signs of discomfort or hindrance while wearing the satellite transmitters.

in Yukon Charley Rivers National Preserve, Alaska, and Glen Canyon National Recreation Area, Utah and Arizona. In 1993, we tagged two birds from each breeding area with 25-30 g (0.9-1.1 oz) PTTs after the breeding season in a pilot effort to determine if satellite telemetry was feasible to study their migration. Upon release, the birds appeared to fly and hunt normally and seemed unaffected by the transmitter and harness (fig. 3).

Figure 4 on page 24 shows the migration routes of the study peregrines. We tracked the birds through the fall and winter and found that one of the Alaska birds departed in late August and migrated through central North America to southwest Florida where it wintered. The other Yukon-Charley falcon also departed in late August and migrated through central North America, continuing through Mexico to its wintering site in eastern Honduras. In September, the first Glen Canyon bird migrated to the west coast of Mexico, and in early October, we lost its signal. The other Alaskan falcon also departed in September and

spent several weeks on the west coast of Mexico before continuing to its wintering site in Nicaragua.

Three of the four pilot study peregrines returned to their territories to breed the following spring and summer. Two were still wearing their PTTs, batteries exhausted, which we removed upon recapturing the birds. The birds appeared healthy and showed no signs of wear or ill effects from the harness or PTT. The fourth bird, identified by its coded color band, had dropped its PTT. We refurbished the recovered transmitters with new batteries (at a cost of \$100) for future use.

We initiated the full study following the success of the initial tracking efforts with additional funding provided by the Air Force through the Department of Defense Legacy Resource Management Program. The objectives of the ongoing research are to document the autumn migration routes, any important stopover sites, and wintering areas of peregrines from the two study areas. We will also document and compare differences in migratory patterns and be-

Continued on page 24

havior between the high latitude breeding population in Yukon-Charley and the temperate latitude population in Glen Canyon.

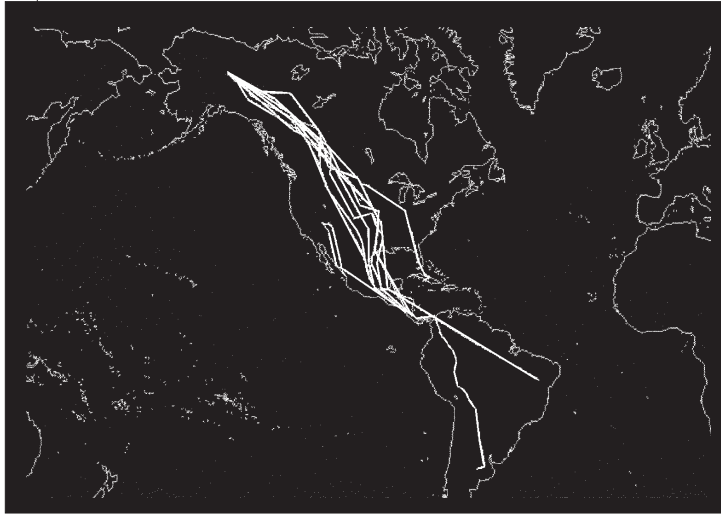


Figure 4. Migratory routes and wintering sites of adult female peregrine falcons from Yukon-Charley Rivers National Park and Preserve and Glen Canyon National Recreation Area. Routes from the pilot fall 1993 to winter 1993-94 study are labeled; all other routes are from peregrines studied the following autumn and winter.

In July 1994, we deployed PTTs on 11 adult female peregrines in Yukon-Charley. Three of the birds appeared to drop their transmitters in the park before migrating. The others left the area in late August, with one traveling to British Columbia before we lost its signal. The remaining seven birds migrated to their wintering areas in Cuba, southern Mexico (two birds), El Salvador, Costa Rica, Brazil, and Argentina (fig. 4).

Results of this study indicate that the wintering range of Yukon-Charley peregrines is larger than suggested by band recoveries; more birds winter in Central America and the Caribbean than previously known, and at least some of the Glen Canyon peregrines migrate and leave the United States in the fall and winter. The only previous data, four band recoveries, give no indication that peregrines in the southwest leave the country in winter. Our results shed light on the risks of pesticide contamination to peregrines along their migration routes and on wintering grounds, areas where the use of dangerous pesticides is not regulated as strictly as in the United States. This infor-

mation bears directly on consideration of proposals to reclassify the peregrine falcon under the Endangered Species Act.

CONCLUSIONS

Satellite radiotelemetry proved to be the most efficient research tool available for these projects and will be extremely useful to other researchers interested in the broad-scale movements of larger birds and mammals. The equipment and data costs are high, but the cost per location may often be less than conventional VHF telemetry. The relative cost depends on the species involved and the size, terrain, and remoteness of the study area. Satellite telemetry allows researchers to follow animals almost anywhere regardless of ecological conditions and political boundaries and reduces the

number of animals that must be marked to answer most research questions.

Technological advances are also making satellite telemetry more useful. Recently, satellite transmitters have been coupled with global positioning system units to allow extremely accurate locations to be relayed automatically by satellite. In the near future, smaller (20 g or 0.7 oz) PTTs and lightweight solar powered transmitters will be available, including ones with additional sensors (e.g., altitude). Finally, as demand increases, PTTs and satellite telemetry will become less expensive and more important as a tool for wildlife studies.



LITERATURE CITED

- Berthold, P., E. Nowak, and U. Querner. 1990. Tracking white storks on migration through Europe to Africa. *Argos Newsletter* 43:1-3.
- Clark, D.D. 1988. Use of Argos for animal tracking in the Rocky Mountain Region of North America. *Acte du Colloque International: Suivi des vertebres terrestres par radiotelemetrie*. Principaute de Monaco. 12-13 December, 1988.
- Craighead, F.C., Jr., J.J. Craighead, C.E. Cote, and H.K. Buechner. 1972. Satellite and ground radio tracking of elk. Pages 99-111 in S.R. Galler, K. Schmidt-Koenig,

G.J. Jacobs, R.E. Belleville, editors. *Animal Orientation and Navigation—a symposium*. NASA Special Publication 262. 608 pp.

- Craighead, J.J., F.C. Craighead, Jr., J.R. Varney, and C.E. Cote. 1971. Satellite monitoring of black bear. *Bioscience* 21:1206-1211.
- Fancy, S.G., L.F. Pank, D.C. Douglas, C.H. Curby, G.W. Garner, S.C. Amstrup, and W.L. Regelin. 1988. *Satellite telemetry: a new tool for wildlife research and management*. USDA Fish and Wildlife Service Resource Publication no. 172. Washington, D.C.
- Higuchi, H., K. Ozaki, G. Fujita, M. Soma, N. Kanmuri, and M. Ueta. 1992. Satellite tracking of the migration routes of cranes from southern Japan. *Strix* 11:1-20.
- Higuchi, H., F. Sato, S. Matsui, M. Soma, and N. Kanmuri. 1991. Satellite tracking of the migration routes of whistling swans (*Cygnus columbianus*). *J. Yamashina Institute of Ornithology* 23:6-12.
- Kralovec, M.A. 1994. Bald eagle home range size and movements from Glacier Bay National Park and Preserve, Alaska: with an analysis of satellite radio telemetry. M.S. Thesis. Virginia Polytechnic and State University. Blacksburg, Virginia.
- Lentfer, J.W., and D. DeMaster. 1982. Satellite radio tracking of polar bears. Pages 52-53 in C. Cote, R. Taylor, and E. Gilbert, editors. *Nimbus-6 random access measurement system applications experiment*. NASA Special Publication 457, Washington, D.C. 99 pp.
- Swem, T., C. McInnyre, R.J. Ritchie, P.J. Bente and D.G. Roseneau. 1994. Pages 437-444 in B.U. Meyburg and R.D. Chancellor, editors. *Raptor Conservation Today: Proceedings of the IV World Conference on Birds of Prey and Owls*. Berlin, Germany, 10-17 May, 1992. Pica Press.
- Weimerskirch H., M. Salamolard, F. Sarrazin, and P. Jouventin. 1993. Foraging strategy of wandering albatrosses through the breeding season: a study using satellite telemetry. *Auk* 110(2):325-342.

Mike Britten is a Wildlife Biologist with the NPS Rocky Mountain Regional Office. His address is P.O. Box 25287, Denver, CO 80225, and his phone number is (303) 969-6705. Carol McIntyre is a Wildlife Biologist with the NPS Alaska Regional Office at 2525 Gambell Street, Anchorage, AK 99503. Mary Kralovec is a Wildlife Biologist and can be reached by writing 1809 North Locust, Appleton, WI 54914.

Skip Ambrose of the FWS Fairbanks office initiated the peregrine, gyrfalcon and golden eagle studies. Layne Adams with the NPS Alaska Regional Office participated in the gyrfalcon and golden eagle studies. James Fraser of Virginia Polytechnic and State University helped with the golden eagle study, and Dr. Patricia Kennedy of Colorado State University assisted in the peregrine study.