Satellite telemetry and wildlife studies in India: Advantages, options and challenges

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Greater spatial coverage, accuracy and non-invasiveness of satellite technology make it one of the best tools to track long-distance migrants, which is otherwise difficult using conventional radio telemetry. In this article, we review the evolution of satellite telemetry and its application. We provide examples of three recent studies in India that have demonstrated and created a widespread appreciation of the use and benefits of satellite telemetry among biologists and managers. We also discuss the future prospects of this technology *vis-à-vis* benefits and challenges in the Indian subcontinent.

ANIMAL movement and migration studies have made significant progress with the use of radio telemetry. Conventional radio telemetry has been used in numerous studies in different regions. However, the use of this technology is generally restricted to a limited area or to species with a limited range of movement. It is difficult to apply radio telemetry to study long-distance migrants, unless observers are able to stay within several kilometres of the animals. Some of the other challenges to radio telemetry are hilly terrain or dense vegetation, where getting signals and following animals often become major constraints. These problems and the need to track long-distance migrants, particularly birds, led to the development of other technologies with greater spatial coverage, accuracy and ease in tracking. Satellite telemetry has overcome many of these problems and has become a useful tool, particularly where animals traverse trans-border or remote areas. Recently, there is a greater recognition of the use and benefits of this technology among biologists, managers and various conservation organizations.

Satellite-tracking technology has been used with growing regularity in the Western Hemisphere since 1970. However, the use of this technology in the Indian subcontinent was limited to one study in 1994, when three Eurasian cranes (*Grus grus*) were fitted with satellite transmitters or platform terminal transmitters (PTTs) in Keoladeo National Park (KNP), Bharatpur and tracked to their Siberian breeding grounds[1]. In 1998–1999, the first long-term project using satellite tracking in India was started on cranes (Higuchi *et al.*, unpublished data). More recently, the application of the technology was demonstrated in a workshop[2] with the capture of bar-headed geese (*Anser indicus*)[3]. In this article we present satellite telemetry as a tool for the purpose of wildlife conservation.

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Background

What is satellite tracking? The essence of satellite telemetry is to attach ultra-high frequency (UHF) radio transmitters to wildlife that are subsequently tracked by weather satellites orbiting the earth, and then these locations are sent to users. These locations are in the form of latitude and longitude, and allow tracking the movements of the animals that are carrying the UHF transmitters. Transmitters may also provide other data such as altitude, ambient temperature and activity. Satellite telemetry is extremely useful for tracking organisms that are difficult to track via conventional radio-telemetry that uses conventional very high frequency (VHF) radio transmitters. Satellite-tracking locations can be superimposed on habitat information gathered via remote sensing, to develop a more complete picture of the animal's long-distance movements, an aspect of its ecology that is especially important for conservation of species and their habitats. Satellite tracking of long-distance migrants has allowed scientists to identify migration routes and important staging and stopover sites, across several thousand kilometres. Such information is critical for implementing conservation activities along flyways that include many countries offering numerous political challenges, and across formidable geographic terrain[1,3–7]. Analysis of important habitats used by cranes that were satellite-tracked has provided valuable information for habitat management and conservation[5,8].

Conservation of long-distance migrants requires basic information about movement patterns, migration routes, stopover and staging areas. The absence of such information makes it difficult to implement conservation plans effectively. The highly endangered Siberian crane (*Grus* *leucogeranus*) that spends the winter in India, has declined from nearly 200 individuals in the late 1950s to just two birds, a decrease that might have been prevented with detailed information on its long-distance movements. With current state-of-the-art technology such as satellite telemetry, remote sensing, and GIS (Geographic Information Systems), it is possible to quickly, efficiently and accurately compile critical habitat information for conservation of species. However, it is important to be able to deploy satellite transmitters on animals if we are to move from the realm of 'hypothetical' habitat use to real-time information, the latter being of greatest value for conservation.

Evolution of satellite telemetry

Satellite transmitters

Satellite-tracking technology in wildlife studies was identified as an important tool as early as in 1970, when an elk (*Cervus elaphus)* was marked and tracked in Wyoming[9]. The technology became more popular in the last decade largely due to reduction in weight, refinement in shape, size and harness methods. The first bird-borne PTT was developed in 1986[10]. Since the deployment of a 160 g transmitter on a sandhill crane in 1989, the technology has made substantial progress[11]. Mita and Kanmuri[12] developed a 25 g PTT in 1994, but the current generation of transmitters weighs as little as 15 g.

Development of satellite transmitters or PTTs has continued towards manufacturing smaller transmitters[13]. This has resulted in the use of satellite tracking on different groups of birds, such as seabirds[14], bald eagles (*Haliaeetus leucocephalus*), Eurasian cranes[1], white-naped cranes (*Grus vipio*), hooded cranes (*Grus monacha*)[15,16], demoiselle cranes[7], Japanese red-crowned cranes[17] European white storks[18], Oriental white storks[6,17] lesser spotted eagles[19] and several other species. As the weight of PTTs decreased, studies were initiated on smaller species in groups such as seabirds, waterfowl and shorebirds, including northern pintail (*Anas acuta*) (Miller *et al*., unpublished data) and the far eastern curlew (*Numenius madagascariensis*) (Ueta *et al*., unpublished data).

Harnessing

There are several methods to deploy a transmitter on a bird. Transmitters may be attached to a leg band and the leg band is then put on the bird. Another method of attachment is to fit a backpack harness with variations in the backpack attachment[20,21]. For cranes, the harness material is a ribbon-coated with Teflon. The ends of the Teflon ribbon are sewn together with absorbable surgical suture, to allow the transmitter to be released from the bird once the battery of the PTT has been expended[21]. PTTs may be attached to neck collars and the neck collar is fitted on the bird's neck. The neck collar-type of deployment is primarily used on geese, and is not suitable for long-necked birds such as cranes and storks. Another method of deployment is surgical implantation, which has been used in species such as diving ducks or in geese.

Data service provider and data acquisition

The signals transmitted by the PTTs are received by the US National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites, which are at an altitude of 850 km and circle the earth around every 100 min. The French aerospace affiliate, Service Argos (Toulouse, France), estimates the PTT locations from Doppler shifts in frequency. The locations are subsequently relayed to ground stations in USA and France, and users can either retrieve their data directly from Service Argos website via electronic mail. These data may be further analysed and processed by users, with the aid of customized computer programs. There is a range of location accuracies that Argos provides (Argos, Inc., 1996). Location class 3, (LC 3) is the most accurate, with an estimated range of radius of 150 m. LC 2 has a radius range of 350 m, LC 1 has a range of 1000 m, and LC 0 is > 1000 m. No accuracy ratings have been ascribed to LC A, B and Z.

Datasets are processed[22] and spatial interpretation of locations is often carried out using ArcInfo and ArcView geographic information system software (ESRI Inc., Redlands, CA, USA), Landsat satellite images (USGS, EROS Data Center, Sioux Falls, SD, USA) and digital thematic maps. With each location, Service Argos provides a signal quality index.

Financial and logistical considerations

At first, satellite telemetry seems to be prohibitively expensive. In reality, it is extremely cost-effective. Conventional radio telemetry using VHF radios is more cost-effective when it is necessary to study local movements of animals in terrain that does not interfere with signal reception. Satellite telemetry, on the other hand, is the only choice if one needs to document long-distance movements, stopover and staging sites, movement across formidable geographic terrain such as mountains and oceans, and for transborder movement. Satellite telemetry has been useful in the conservation of species and their habitats, because much of the information is not available from other methods.

Satellite transmitters for avian species range from US$2100 to 5000 depending on the manufacturer and the number of PTTs ordered. The list of manufacturers of PTTs can be found in the Service Argos newsletters. Currently, PTTs may be ordered from companies such as Microwave Telemetry Inc. (Maryland, USA) and Nippon

Telegraph and Telecommunication (NTT, Japan) to track avian species. Once the PTTs are purchased, they need to be registered with Service Argos, and an agreement needs to be signed with Service Argos as well. For each PTT that is to be deployed, there is an associated Argos tariff per PTT year, i.e. 365 days. This Argos tariff is US $3700 per PTT year for nations that are signatory to the Joint Tariff Agreement (JTA). Non-JTA nations pay a significantly higher Argos Tariff rate. In India, the National Institute of Oceanography (NIO), Goa under Department of Ocean Development (DOD) is the JTA representative, and future satellite-tracking programmes in India can avail of this benefit through NIO. Additionally, there are costs associated with data retrieval. This amount is based on kilobytes of information, i.e. data received from Service Argos, and the amount is paid to Service Argos.

Satellite telemetry studies in India

Satellite technology has been used extensively to study migratory birds across many regions through the 1990s. However, in the Indian subcontinent, the use of this technology has been limited. As mentioned earlier, satellite telemetry was first used in India on migratory birds when three Eurasian cranes were fitted with PTTs in 1994 at KNP[1]. Almost six years passed before a new international collaborative project was undertaken in India on large wetland birds, in 1998–1999. Under this project, Eurasian cranes were marked with PTTs in Kutch, Gujarat (Higuchi *et al.*, unpublished data). In the winter of 1999–2000, two bar-headed geese were fitted with PTTs and one of them was tracked to its probable breeding grounds in Tibet[2] (Figure 1).

Scope of satellite telemetry studies

India is home to several hundred birds species, especially during the winter months. The behavioural ecology of many of these migrants is different on their wintering grounds compared to their breeding areas. For example, capturing a crane on its breeding grounds is extremely challenging. Cranes on their breeding territories are wary, range far apart, and their territories are generally located in remote areas, far from human dwellings. The opposite behaviour is displayed on their wintering areas. Cranes are gregarious and found in large flocks on their wintering areas, often foraging in agricultural fields. This behavioral aspect of cranes makes it significantly easier to capture and deploy transmitters on them on their wintering areas, offering a more efficient use of funds with an opportunity to increase sample size. A more comprehensive approach to conservation of cranes would be to document all aspects of their ecology, and satellite telemetry is a useful tool for this purpose. If there are differences in migration routes between fall and spring migration, then it is often necessary to deploy transmitters on the breeding grounds as well as the wintering areas, especially since most transmitters do not frequently have a battery that lasts through both fall and spring migrations. Migratory behaviour also differs between fall and spring migrations, and this is also important for the conservation of species[23].

Innumerable species winter in India, and very little is known about these species in terms of their breeding areas, migration routes, and several other aspects of the biology. Satellite telemetry has been used extensively over the last two decades to document hitherto unknown migration routes of species in North America, Russia, Europe and Australia. If species could be satellite-tracked from India, this would aid enormously in conservation efforts of numerous species.

Understanding trans-Himalayan migration

India is a winter terminus for several species of birds in central Asia[24,25]. For many species breeding in northern areas and travelling to the south during winter, the Himalayan mountain range is a formidable barrier to migration[3]. Satellite-telemetry studies have shown that the houbara (*Chlamydotis undulata*) migrates around the range and spends summer in different areas[26], but such a circular route greatly increases the distance and duration of its migration compared with a trans-Himalayan route. However, the presence of several different species of birds has been observed, flying at elevations well above 5000 m, to cross over the Himalayas[27–29].

Satellite telemetry workshop and deployment on bar-headed geese

Efforts were made for more than ten years, to demonstrate the use of satellite-telemetry technology in India to biologists, managers and government officials. Indian biologists have been collaborating with their colleagues overseas for several decades, but some of the aspects of technological advancement in techniques appeared to elude the decision-makers in India. This finally culminated in a workshop on satellite-telemetry technology transfer held in India, primarily for participants from India and neighbouring countries, including wildlife research and management personnel. The workshop sessions focused on satellite-technology transfer and development of species-priority lists, collaborating individuals and agencies, networking and potential project ideas, and funding opportunities. The initial plan was to demonstrate the use of this technology to three different interest groups, turtles, elephants and migratory birds, all of which range over large areas, and often difficult terrain. However, because of logistics, the technique was demonstrated on birds, and recently on turtles.

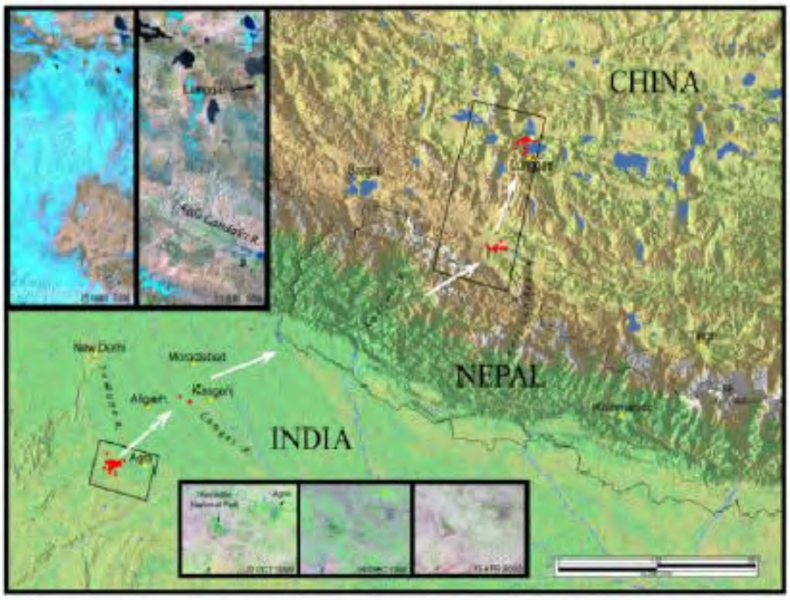

Figure 1. Map showing migration of satellite-tracked, bar-headed geese from Keoladeo National Park to their summer and potential breeding areas in Tibet. (Source: Javed *et al.*[4].)

Bar-headed geese were chosen as the candidate species for field demonstration of satellite telemetry, due to several reasons. They are known to fly over the Himalayas and have been seen or heard by individuals scaling Mount Everest (> 9000 m). While bar-headed geese are known to winter in India, and some of their breeding areas are also known (areas in Ladakh and Tibet), their migration routes between wintering and breeding areas were not documented. Very little information was available on the ecology of the species. They have also been listed as near-threatened[30]. Bar-headed geese are familiar to those visiting KNP, making the species a good candidate for the education of visitors. Since the species is not listed as endangered or threatened, getting government permission to capture the birds and deploy the transmitters was far less cumbersome than would have been with some of the other species. For all these aforementioned reasons, bar-headed geese became the ideal candidates to satellite track during the technology transfer workshop[2].

Promises of satellite telemetry

Satellite telemetry has come of age in India. While few satellite tracking studies have been conducted in India, the three carried out to date on avian species clearly indicate the need to continue with such studies. The information obtained from the three tracking efforts has added greatly to our understanding of the respective species tracked, and helped identify important stopover and staging areas of the species during migration.

Satellite-tracking bar-headed geese was the first attempt to apply satellite-telemetry technology to study waterfowl migration in India[3]. This was a pilot effort. The project served as a hypothesis-generating exercise to further examine the ecology of bar-headed geese. A logical follow-up study would be to examine a larger sample of marked individuals, captured in the major wintering areas of India. From such a study, we might obtain better information about different migration routes, timing, distinct breeding and wintering populations. Recently, the Indian and Russian governments have agreed to use satellite telemetry on nearly 20 migratory species, which include cranes, geese and raptors. This is likely to provide the much needed momentum. Ongoing advances in satellite transmitters[2], including hourly geographic positioning system (GPS) locations and altitude sensors will provide tools needed to describe the exact migration flight-patterns of the bar-headed goose. These advances in technology should lead to improved conservation for many species. The successful tracking of bar-headed geese and Eurasian cranes has ushered in a new beginning in wildlife tracking studies in India. We hope that in future projects this technology will be utilized, offering unlimited opportunities for studying migratory behaviour of species, where it has not been possible to use standard radio telemetry.

Challenges and options for satellite-telemetry studies in India

For all satellite telemetry studies (for that matter for any telemetry study), it is imperative to capture organisms, since they need to be fitted with transmitters. For a species that is not listed as a Schedule-I species in the Wildlife (Protection) Act of 1972, clearance may be obtained from the state government. For species listed under Schedule-I, central government approval is mandatory before applying to the state government for permission. Getting approval from the central government has been a formidable challenge. However, Gujarat, Rajasthan and more recently, Orissa (for turtles) and their respective Forest Departments have been cooperative. If satellite telemetry were to become an important conservation tool, it would be valuable to simplify the application process for its use.

Conclusion

Satellite telemetry has unlimited application potential in the Indian subcontinent. This has been demonstrated by three separate studies. These studies have provided invaluable exposure of the use and benefits of the technology for understanding the behaviour of long-distant migrants. We have embraced many modern research techniques to study wildlife in India, and it is only appropriate that we include cutting-edge technology such as satellite telemetry to our bag of tools. With numerous species being on the verge of extinction, we need to be on par with our international colleagues in our efforts to conserve and protect biodiversity. Satellite telemetry offers a powerful tool in these conservation efforts, especially when it is combined with Landsat image analysis of habitats utilized by the wildlife species that are tracked. Latest cutting-edge technologies such as these not only provide academic incentives to users, but also bring in other benefits as well. The ease, efficiency and spatial coverage not only unravel mysteries of migration and movement, but also allow us to chart strategies for conservation of species, some of which may be critically endangered.

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