

**Telemetry  
Studies with  
Special Reference  
to Bar-headed  
Goose: A Review**



## Abstract

Migration studies answer a great diversity of questions in a number of different fields, especially related to ecological, physiological and pathological aspects. Satellite telemetry studies have been conducted on waterbirds since the 1990s in Asia. Telemetry data have been subsequently utilized in a variety of applications, viz., determining stopover sites, migration routes and breeding and wintering sites, and in advanced uses such as determining habitat use, connectivity and physiological properties. Here, we have reviewed 30 telemetry-based studies and the articles published in relation to these on the Bar-headed Goose in Asia, one of the most widely distributed birds in the continent. Various interesting findings such as adaptations of the bird for flying at extreme heights, leap-frog migration, new breeding and wintering areas have expanded our knowledge about Bar-headed Goose ecology. In India, although telemetry studies started early, there have been very few studies on waterbirds. More studies need to be carried out to for development of conservation-based management strategies.

**Keywords:** Migration, stopover site, Himalaya, home range, wetland, avian influenza

## Introduction

Obtaining information about the pathways and habitat use of migratory bird species in different landscapes is very interesting to biologists, as this information is crucial for conservation and disease control. The Bar-headed Goose (BHG) (*Anser indicus*) belongs to the order Anseriformes and family Anatidae. It is one of the migratory birds of global significance owing to its close association with avian influenza. It is a large-range species, widely distributed in Afghanistan, Pakistan, Tajikistan, Russia, Bhutan, China, Mongolia, Nepal, Vietnam, Thailand, Uzbekistan and Kyrgyzstan (Figure 1) (BirdLife International 2012). In India, however, a breeding population has been documented from Ladakh (Gole 1982; Ali & Ripley 1987; Prins & Wieren 2004). Further, the BHG visits many protected and non-protected wetlands in different states of the country like Assam, Himachal Pradesh, Uttar Pradesh and Rajasthan, reviewed in (Ali & Ripley 1987). It is presently listed as a Least Concern species on The IUCN Red List of Threatened Species (Collar *et al.* 1994; BirdLife International 2000), but previously it was supposed to be a Near Threatened species (Collar & Andrew 1988). Javed *et al.* (2000) argued that an improvement in the method used for carrying out censuses could be a valid reason for the change in status. The total global population of the BHG is supposed to be <60,000 (Miyabayashi & Mundkur 1999).

Usually, the BHG prefers steppes, desert steppes, swamp meadows, saline meadows, alpine meadows and cropland habitat. Its preferred stopover sites in China are lakes, marshes and shallow wetlands (Zhang *et al.* 2011). In India, the BHG prefers low-altitude areas with shallow water habitats inside Keoladeo and agriculture land outside the park area, where it is a winter visitor (Javed *et al.* 2000). In winter, the BHG is gregarious and forms flocks; during the breeding season, it forms pairs. The sex ratio is different in semi-captive and wild geese. Semi-captive flocks consist of one male with one to five females, whereas a 1:1 ratio is maintained in wild geese. Further, wild geese form monogamous pairs (Lampercht 1989). Under natural conditions, BHG lay eggs between April and May, and the incubation period varies between 28 and 30 days (Ogilvie 1978).

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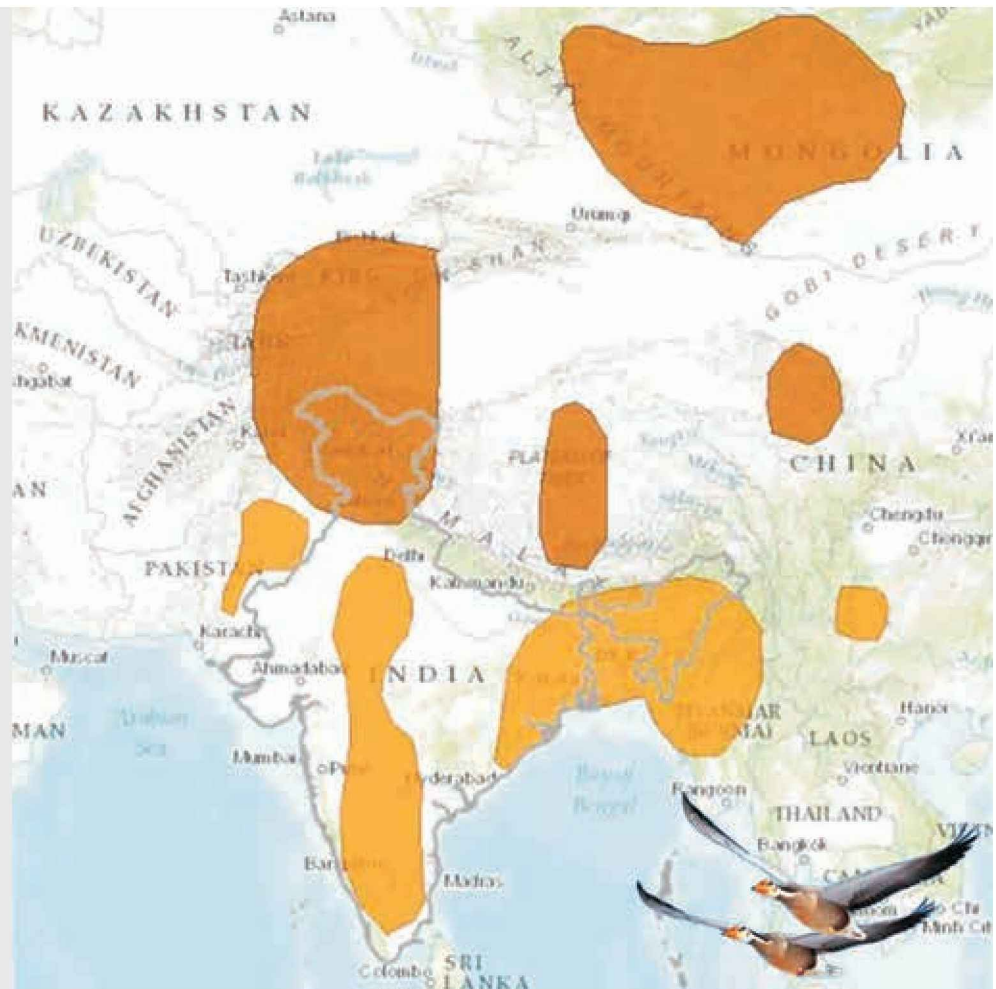
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Figure 1 : Distribution map of Bar-headed Goose (Source: <http://maps.iucnredlist.org/>)



Biologists have been always fascinated by waterbirds, especially the BHG, owing to its unique flight adaptability and susceptibility as HPVI carrier. Various studies have shown that BHG is adapted for rigorous flight over the Himalaya owing to its unique physiology (Ward *et al.* 2002; Scott & Milsom 2007; Lee *et al.* 2008). Further, it has been identified as a carrier of HPVI (Highly Pathogenic Viral Influenza) H5N1 (Chen *et al.* 2005; USGS 2005; Zhou *et al.* 2006; Bourouiba *et al.* 2010; Gaidet *et al.* 2010; Prosser *et al.* 2011). Thus indeed, satellite telemetry plays a vital role to know more about disease transmission mechanism.

### Methods

In this context, we have reviewed 30 peer reviewed publications, reports and articles related to the BHG from various sources and links. Of the approximately 400 articles found, we curtailed ourselves to 30 studies. Searches were carried out using Science Direct, Willey and Google Scholar with the search words “Bar-headed Goose”, “migration”, “movement pattern”, “home range” and “waterbirds”. Additionally, review papers on radio-telemetry were also reviewed to identify critiques and research gaps.

### Studies on Bar-Headed Goose: Global Scenario on Satellite Telemetry

In almost all the previous studies conducted on the BHG, ARGOS Platform Transmitter Terminal/Platform Terminal Transmitters (PTTs) were used (Table 1). Significant variations were found in the morphology and geography of different sub-populations with respect to the dynamics of leap-frog migration. According to a study, the BHG population from Mongolia covered the maximum distance, 3000 km, to India. Strong morphological characters were also found in Mongolian individuals compared with the sub-populations of China (larger tarsi and culmens; Takekawa *et al.* 2009). Subsequently, Koppen *et al.* (2010) reported that PTT-deployed geese in Kyrgyzstan migrated towards India and Pakistan. The distance covered during the winter migration was up to 1550 km, and wintering sites of the geese were found in the

**Table 1** : Global telemetry studies related to BHG

Reference	Type of Transmitter	Total Distance Covered (km)	Number of Individuals Tagged	Migration Route (Place)	Stop over Sites	Total Days of Movement	Type of Migration	Total Number of Locations
Javed <i>et al.</i> (2000)	PTT (Nippon Telegraph, T 2050)	780	2	India China	3	137	Autumn	192
Takekawa <i>et al.</i> (2009)	PTT (microwave, USA)	500-3000	60	China, India,	NA		Winter, fall, Spring, breeding, moult	93,009
Koppen <i>et al.</i> (2010)	PTT-100 Solar (microwave)	790-1550	4	Uzbekistan, Kyrgyzstan, Tajikistan, India Pakistan	4	1-53	Autumn and spring	5000
Guo-Gang <i>et al.</i> (2011)	PTT	1270-1470	10	China	4	50-90	Autumn	NA
Cui <i>et al.</i> (2011)	PTT-100 (microwave telemetry, USA)	17.89-404.41	21	China	NA	185-298	Moult, autumn and breeding	16,342
Prosser <i>et al.</i> (2010)	PTT	260-2303	15	China, India	7	1-154	Breeding and Spring	NA
Kalra <i>et al.</i> (2011)	PTT (Telonics)	870-1305	4	China, India	2	193-263	Winter	4663
Zhang <i>et al.</i> (2011)	PTT	1300-1500	11	China	5	73-83	Autumn	NA
Hawkes <i>et al.</i> (2012)	PTT-100 (microwave telemetry, USA)	3000	91	India China		135-1216		NA

floodplains of the Indus, Beas, Taunsa and Ravi in Lahore, Amritsar and Central Pakistan. Another concurrent study identified two migration routes of BHG, the first one in the Yarlong Zangbo valley and other parts of Tibet and the second one in Kohima (India), with an overall distance of 1270–1470 km being covered (Guo-Gang *et al.* 2011).

In contrast, Cui *et al.* (2011) reported that the native population of China covers the shortest migration distance, between Qinghai and other important wetlands. Their study was focused on moult migration, nesting and pre-autumn migration. Additionally, the extrapolated home range sizes (95% kernel) varied between the pre-nesting period ( $109.5 \pm 288.5 \text{ km}^2$ ), nesting period ( $242.5 \pm 316.6 \text{ km}^2$ ) and moulting period ( $8.5 \pm 9 \text{ km}^2$ ).

Spatial dynamic modeling was used to understand the migration and disease dynamics to prevent transmission of diseases to humans, migratory birds and poultry (Bourouiba *et al.* 2010). This study reported that stopover sites could cause outbursts of the disease and that even juveniles were vulnerable to the H5N1 virus. Another concurrent study suspected that BHG was the carrier of HPVI. Satellite telemetry confirmed the potential of waterbirds as carriers of disease up to 2,900 km with asymptomatic infections (Gaidet *et al.* 2010). The role of migratory birds in disease transmission reconfirmed that the birds somehow interacted with H5N1 sources such as poultry farms, captive BHG and outbreak points (Prosser *et al.* 2011). Additionally, the telemetry data revealed that BHG migrate a distance up to 2,330 km from China to India to reach the wintering grounds.

Furthermore, satellite tracking study correlated autumn migration route and environmental factors like temperature and vegetation (Zhang *et al.* 2011). Most of the stopover sites were close to lakes, marshlands, and shallow water bodies. The habitats were mostly swamp steppes, alpine meadows, shrub lands and croplands. The temperature recorded for stop over sites remained above 0°C. The previous record of flying above Mt. Everest (Swan 1970) has been broken by a maximum flying height of 7,290 m as reported by a recent study although 95% of the locations were received from less than 5,489 m (Hawkes *et al.* 2012). Overall, a lot of information has been obtained using advanced telemetry tools. Thus this technique works wonders for the BHG and migration studies on other waterbirds.

## Satellite Telemetry: Indian Context

The issues and problems related to telemetry studies in India have been explicitly reviewed in the recent literatures (Javed *et al.* 2003, Habib *et al.* 2010; 2014). In many studies, BHG have been reported to be regular winter visitors in India though only a few studies have been conducted. Only three studies have been published on the migratory behaviour of BHG from India. Unfortunately the only breeding population, of Ladakh, has not been studied intensively (Javed *et al.* 2000; Takekawa *et al.* 2009; Kalra *et al.* 2011). In this context, Javed *et al.* (2000) conducted a pioneering telemetry study on BHG in India and discovered a 780 km migration over the Himalaya from India to China. Furthermore, Kalra *et al.* (2011) deployed transmitters on four BHG individuals in Sur Sarovar and received a total of 4,663 locations from these individuals. The total distance covered by BHG between India and China varied from 807 to 1,350 km, and site fidelity was noted. One individual returned to the same site at Sur Sarovar where it was tagged earlier. It was also found that BHG fly over the Himalaya at heights of up to 6,257 m to reach their breeding grounds in China. We need more satellite telemetry-based studies for various migratory species that cross many geographical barriers and continents to reach India (see box).

A collaborative study between Wildlife Institute of India and Dept. of Wildlife Protection, Govt. of Jammu and Kashmir is currently underway to understand the distribution, movement pattern and habitat use of breeding waterbirds with respect to the Bar-headed Geese and Black-necked Cranes in Gharana Wetland Conservation Reserve, Jammu and Changthang Wildlife Desert Sanctuary, Ladakh. This study aims to understand the migratory patterns and stop over sites of these breeding waterbirds. Eventually, this information will be used as a tool for better conservation and management of these birds with trans-boundary collaboration with other range countries. We are using Platform Transmitter Terminals (PTTs) for tracking birds and we are using noose traps and Teflon harness for capture and deployment of PTTs. We are receiving data through ARGOS satellite center which receive data from PTT. To date, we have fitted total of 4 PTTs on Bar-headed Geese in Gharana and Changthang. The study is progressing and we are expecting some new findings with respect to movement pattern of these birds.

## Capture, Tracking and Analysis

Most of the studies have used noose traps to capture BHG, which seems to be a reliable technique. Mostly microwave PTTs have been used in telemetry studies carried out on BHG. Compared with other traditional VHF transmitters, PTTs are more precise for far-ranging species and are effective for longer durations. Moreover, new technologies such as GPS, GSM and isotope methods are more precise than the use of simple PTTs. The performance of ARGOS and GPS has been precisely compared, and it has been confirmed that GPS is the best option for telemetry studies (Tanferna *et al.* 2012). ARGOS analyses the position of a satellite and the received frequency to determine the longitude and latitude of the PTT. The technology is based on the Doppler Effect-as a satellite approaches a PTT, the received frequency is shifted higher. As a satellite moves away from a PTT, the received frequency is shifted downward. This information, combined with measurements of the time between transmissions, allows the systems to determine the location of the PTTs. Using the Doppler effect, a PTT provides locations with different error ranges such as 3, 2 and 1 (high class locations) and 0, A, B and Z (low class locations). Filters can be used to avoid these errors to some extent (Douglas *et al.* 2012). Generally, ArcView and ArcGIS software have been used for GIS analysis (Takekawa *et al.* 2009; Kalra *et al.* 2011), while the ATLAS software has been used in spatial interpretation (Koppen *et al.* 2010). However, Bourouiba *et al.* 2010 used spatial modeling to define bird migration. Different methods have been utilized by biologists. Recently, the more precise Brownian Bridge Movement Model (BBMM) has been used for determining the movement patterns of migratory birds (Horne *et al.* 2007, Prosser *et al.* 2011, Namgail *et al.* 2011). Home range data obtained using telemetry have been analysed using various methods. The most commonly used methods for calculating home ranges are the minimum convex polygon (MCP) and kernel density estimator (KDE) methods (Mohr 1947; Worton 1989). However, both these methods have been criticized globally (Laver & Kelly 2008; Nilsen *et al.* 2008).

## Discussion

To date, the use of telemetry at a global level has been concerned with and has solved numerous mysteries related to migration routes, movement patterns, habitat use, foraging behaviour, disease transmission, etc. (Kou *et al.* 2005, in Kalra *et al.* 2011). From India, migratory birds usually fly towards their breeding grounds till April (Javed *et al.* 2000; Kalra *et al.* 2011). The published literature provides valuable information regarding the migration patterns of the BHG in Asia (Figure 2). However, disease transmission mechanisms have not yet been identified by any of the studies. Besides, the

greatest movement of the BHG recorded is 3,000 km (Takekawa *et al.* 2009; Hawkes *et al.* 2013), whilst in China the least movement was as little as 17.89 km (Cui *et al.* 2011). Recent advances in tracking techniques include GPS-based PTTs, which are far more precise and reliable than ARGOS-based PTTs (Tanferna *et al.* 2012). Although valuable information on migration has been obtained, the available literature confirms that the studies have been affected by technical failures of the transmitters (Hawkes *et al.* 2013). Thus sufficiently large sample sizes are recommended for telemetry studies. However, funding could be a limiting factor for developing countries such as India.

**Figure 2 :** Various Bar-headed Goose migration-based studies conducted in Asia  
(Source: Javed *et al.* 2000; Koppen *et al.* 2010; Kallra *et al.* 2011; USGS <http://www.werc.usgs.gov/>)



## Conclusions

Landscape-level efforts will need to conserve multiple stopover sites since waterbirds migrate through different landscapes and stopover sites annually. Conserving a single site is not sufficient for conserving a migratory species (Haig *et al.* 1998). In the case of the BHG, more telemetry studies are required to learn more about different migration routes, wintering sites, stopover sites, breeding areas and avian influenza in range countries. These scientific studies could be used as tools for improving the conservation and management of the species.

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