

**STATUS, HABITAT USE AND FACTORS AFFECTING
BREEDING WATERBIRDS OF CHANGTHANG WILDLIFE
SANCTUARY, LADAKH (INDIA)**

Thesis Submitted to the

Saurashtra University, Rajkot (Gujarat)



For the award of the degree of

DOCTOR OF PHILOSOPHY

IN

WILDLIFE SCIENCE

By

NEERAJ MAHAR



**भारतीय वन्यजीव संस्थान
Wildlife Institute of India**

Dehradun – 248001, India

2020

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Under the guidance of

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&

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November 3, 2020

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This is to certify that the Ph.D. thesis of **Mr. Neeraj Mahar** titled “**Status, habitat use and factors affecting breeding waterbirds of Changthang Wildlife Sanctuary, Ladakh (India)**” is an original piece of work submitted to the Saurashtra University, Rajkot, (Gujarat), for the award of the degree of **Doctor of Philosophy in Wildlife Sciences**.

Mr. Neeraj Mahar has put in more than six terms of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted to any other university or institution.

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I also certify that the research work was appreciated by all and their comments were incorporated in the thesis.

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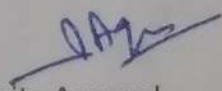


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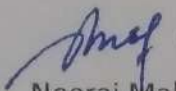
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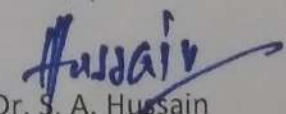
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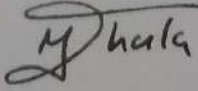
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Abbreviations

AD	Alert Distance
AIC	Akaike's Information Criterion
BHG	Bar headed Goose
BNC	Black necked Crane
BNG	Black necked Grebe
BP	Baer's Pochard
BrHG	Brown headed gull
BS	Black Stork
BTG	Black tailed Godwit
BWS	Black winged Stilt
CAF	Central Asian Flyways
CC	Common Coot
CCA	Canonical Correspondence Analysis
CDV	Canine Distemper Virus
CE	Cattle Egret
CG	Common Goosander
CI	Confidence Interval
CM	Common Moorhen
CP	Common Pochard
CR	Common Redshank
CS	Common Sandpiper
CT	Common Tern
CW	Citrine Wagtail
CWLS	Changthang Wildlife Sanctuary
DC	Demoiselle Crane
EUT	Eurasian Teal
EW	Eurasian Wigeon
FCC	False Colour Composition
FD	Ferruginous Duck
FID	Flight Initiation Distance
GCG	Great crested Grebe
GDW	Gadwall
GG	Garganey
GH	Grey Heron
GLG	Greylag Goose
GSK	Common Greenshank
HDM	Human Derived Material
ID	Initial Distance
IE	Intermediate Egret

IUCN	International Union for Conservation of Nature
J&K	Jammu and Kashmir
LAC	Line of Actual Control
LSP	Lesser sand plover
LULC	Land Use and Land Cover
MAD	Minimum Approach Distance
MEA	Millennium Ecosystem Assessment
MLD	Mallard
NMDS	Non Multidimensional Distance Scaling
NP	Northern Pintail
NL	Northern Lapwing
NS	Northern Shoveler
OLI	Operational Land Imager
PA	Protected Area
PA	Pied Avocet
PG	Pallas's Gull
RSD	Ruddy Shelduck
RUF	Ruff
SAC	Space Application Center
SECR	Spatially Explicit Capture-Recapture
TD	Tufted Duck
TM	Thematic Mapper
UD	Unidentified Duck
W	Unidentified Wader

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Neeraj Mahar

Executive Summary

The worldwide population of waterbirds has declined considerably in last thirty years and similarly a decline in the number of natural wetlands has been recorded since 1700 AD. There are evidences of range shift and distribution of waterbirds owing to change in temperature, breeding cycle, migration timing, and population sizes. In India, wetlands are prone to land-use changes, industrial and domestic pollution, habitat encroachments, excessive cattle grazing, unregulated tourism, illegal hunting of waterbirds and over-exploitation of natural resources. These factors are affecting the population structure of the waterbirds. As population estimation is considered as a linchpin tool in conservation biology and environmental quality and may affect the equilibrium of wildlife population size. Similarly, in terms of anthropogenic pressure there is a huge impact on populations and habitat quality due to easy and increased access to remote ecologically sensitive areas. Species' protection requires understanding the nature and pattern of human disturbance. Legal protection can provide a better survival rate of a species in its particular habitat.

Tourism has evolved as an alternative livelihood for the local people and has reduced their direct dependencies on natural resources and perhaps indirectly contributed towards nature conservation. However, unregulated tourism activities have led to degradation of natural systems and increased the ecological vulnerabilities of local communities. Often, tourism and other developmental activities related disturbances collide with the peak season for several biological processes and affect the ability of natural system to revive and restore itself. In case of waterbirds these disturbance affect the breeding success. Other than anthropogenic activities, domestic dogs, apparently the most abundant carnivores in the world, pose a major threat to local wildlife. Recent studies have determined waterbirds as an important part of their diet.

The existing literature clearly suggested that there was a huge information gap regarding Trans-Himalayan wetlands and their avi-faunal characteristics. Previous studies were either site-specific or species-specific, and thus, landscape level base line data was either scanty or unavailable. The Trans-Himalayan wetlands of India are increasingly under anthropogenic stress which is affecting their ecological structure and functions, especially the breeding birds. Black-necked crane (BNC) is one of the flagship species of these wetlands.

With the above background, I decided to study and understand their ecology and major threats faced by waterbirds and wetlands of Changthang Wildlife Sanctuary (CWLS). The objectives for this work were to (1) assess the population status and habitat use by waterbirds, (2) evaluate the factors affecting the breeding waterbirds, and (3) assess change in the wetland area.

To estimate the abundance of waterbirds on spatio-temporal scale, I used independent double observer method with point count technique. I generated detection probabilities and abundance estimates using program DOBSERV in combination with the SURVIV code. Minimum value of Akaike's information criteria (AIC) among models was used to select the best fit model. Overall, 275 points were surveyed in 24 wetlands over the period of two years (2016-2017) during three seasons i.e. spring, summer and autumn. I also examined the population status and breeding ecology of the endangered BNC using total count method and regular nest monitoring in 25 wetlands respectively.

During the two years of sampling, I recorded a total of 40 waterbird species (including two unidentified species of duck and wader) belonging to 8 orders and 11 families, of which 15 species breeds in CWLS (Table 2). A total of 10,208 and 13,481 individuals were recorded in spring, summer and autumn seasons of 2016 and 2017 respectively. Out of 38 species, one is "Critically Endangered", one is "Vulnerable" and two are listed as "Near Threatened" category on the IUCN Red List species. Among the breeding waterbirds, ruddy shelduck (RSD) was the most widely distributed and abundant breeding waterbird species among all, followed by bar-headed goose (BHG) and brown headed gull (BrHG). During the sampling period of both the years, highest number of waterbirds was recorded in the autumn season. Area wise, the highest number of species was recorded at Statsapuk (n=24) followed by Tso Kar (n=20), Tso Moriri (n=15), and lowest was at Mirpal Tso (n=2) followed by Tsegam Tso (n=3). No waterbird species were recorded at Tsoltak wetland in 2016-17.

Seasonal population monitoring of BNC was conducted using total count method in 25 wetlands. The mean population size of BNC in CWLS was 66.33 ± 5.04 SE (95% CI 44.6-88) and 69 ± 4.51 SE (95% CI 49.60-88.40) in 2016 and 2017 respectively with no significant difference (95% CI). Overall, breeding success of BNC declined in between 1995 and 2017 ($R^2 = 0.44$) which was attributed to predation by dogs and nesting failure due to floods.

To study habitat use and related factors was essential for better understanding of breeding biology of waterbirds. During sampling of major 13 wetlands, nine habitat parameters and activity of waterbirds was recorded along with abundance estimation. Subsequently, multivariate analysis, Canonical Correspondence Analysis (CCA) was used for elucidating factors influencing breeding waterbirds. Habitat use was species-specific, diving and dabbling ducks mostly used water habitats followed by marshes and bogs. In contrast, waders, BNC and CRS mostly used marshes and bogs and rarely recorded using water habitats. The wetland area, distance to road, pH, distance to settlement ($p < 0.001$) and elevation ($p < 0.05$) were significant explanatory variables in permutation test. CCA revealed that species like BHG was positively correlated with pH and wetland area whereas, GCG showed positive relation with distance to road. BNC, RSD, LSP and CS negatively related with distance to road. Species like CC and BrHG showed positive relation with distance to human depth and negative with pH and wetland area. Similar patterns had been recorded in previous studies across the world where responses to environmental factors by waterbirds were species-specific.

I assessed the benefits of tourism and its role in shaping the attitude of local people in CWLS. The Optimal Escape Theory predicts that animals should moderate their flight responses according to the level of risk represented by a potential predator. Flight Initiation Distance (FID) approach has been used widely and it increases when predators pose a greater threat and decreases when escape costs increase. A semi-structured questionnaire survey was carried out using snowball sampling in four villages and 10 nomadic camps. During questionnaire survey of 210 respondents, most of were satisfied with ongoing developmental activities but were not aware about the impacts of these activities on environment. Only few respondents were involved in tourism. FID observations were taken for 16 species of waterbirds in 13 wetlands of CWLS using predestine approach. Mean FID varied between 27-229.15 meters among the 16 species of waterbirds while, average minimum approach distance (MAD) varied between 40.5 and 343.72 meters. This study observed that FID can be a species-specific and site-specific trait ($p < 0.001$) and it increased with increasing biomass ($p < 0.001$) and wing span ($p < 0.001$), apparently, owing to energy-risk cost and conspicuity.

Dogs have emerged as a successful intraguild predator and major threat to wildlife and pastoralists. Understanding patterns of dog predation on livestock and wildlife can help in

developing mitigation strategies. I used polygon search method in Spatially Explicit Capture Recapture (SECR) framework and block count method for population estimation of dogs. For SECR, I identified individual dogs on the basis of body colour, sex and natural marks using photographs. I collected the dog scats opportunistically from the periphery of villages and near to the nesting sites of waterbirds during the breeding season (May–October). I segregated the dietary components for auxiliary quantification according to taxon and human-derived material. I prepared reference slides for identification of mammalian medullary hair patterns and also identified bird parts in scats as feathers, bones, chitin, claws and eggshells. Down feather in the scats were identified to order level using reference material prepared. Respondents (n=185) for interviews from grazer groups owning dogs were selected using snowball sampling.

During population estimation of dogs, large congregation was found near reservoirs of food subsidy (big infrastructures like defense camps and residential schools). The dog density varied between 10-310 individuals/100 km² in different study sites. Twenty major types of food items were found in dogs' diet including livestock, cattle, wild ungulates, rodents, lagomorphs, birds, poultry, seeds, grass, cereals, HDM. Major part of their diet constituted of livestock (83.68%) followed by wildlife (16.33%). Of which, birds (5.91%) from Anseriformes, Passeriformes, and Galliformes orders were identified in the diet of dogs. Overall, 40% respondents had negative attitude towards dogs, of which 31% confirmed dog attacks on wildlife. Pastoralists and non pastoralists' respondents had significant (p <0.001) difference in their attitudes.

Remote sensing and GIS have been widely used to evaluate land-use change, in decision making and to monitor the effectiveness of mitigation efforts. To assess change in wetlands of CWLS, satellite data of Landsat 8 and Landsat 5 images (30 m resolution) were used for supervised classification, I used polygons (training areas AOI) using a homogenous cluster of pixels from each class to create a unique signature. Training polygons were representative of all classes and different condition of each class maintaining the same pixel on the edges. Subsequently, I used Maximum Likelihood estimator for supervised classification. Supervised classification accuracy was tested using Kappa Statistics. I also determined changes in land use land cover over two time periods (1994 and 2014). The maximum change was observed in class rocky, which increased about 2.86% during two decades gap. In wetland habitat classes (marsh

and waterbody), there was a slight increase of 0.50% in marsh area and 0.02% increase in water area in the total study area. The snow also witnessed an increase of 0.40%. Conversely barren (2.34%), sand (0.71%) and vegetation (0.76%) classes showed decrease in CWLS.

The possible global/national implications of my study are (i) to declare of Tsokar-Statsapuk Wetland complex as RAMSAR site (ii) to replicate FID studies in other wetlands for delineating buffers based on scientifically robust method (iii) to prepare action plans for management of free-ranging dogs affecting wetland dependent wildlife can be replicated to other wetlands. On the basis of my results, following management implications are made for CWLS (i) to reduce the human pressure on waterbirds and their habitats, delineation of buffer zones around the wetlands should be done, (ii) strict administrative control on the vehicle traffic and off road driving is recommended, (iii) to prevent tourism benefit leakage, community based tourism should be promoted with proper mechanism such as strengthening of local institutions, (iv) to manage solid waste, garbage management system and bio toilets should be established in the CWLS, (v) to reduce the impact of dogs on threatened species, capture-neuter program should be introduced and adoption scheme has to be encouraged among community and ferlization should be discouraged by locals and defense personnel, (vi) awareness related to environment and wildlife among the local communities and other stakeholders need to be introduced through awareness, (vii) State Forest/ wildlife Department needs to be strengthened logistically to protect CWLS. Future research work should focus on migration and stopover sites of threatened waterbirds through trans-boundary management, evidence based, cost benefit analysis of socio-culture changes and studies on tourism benefit leakage are recommended. Intraguild competition and predation studies should be carried out to fill research gaps.

Chapter 1: Introduction

1.1. Importance of wetlands

Wetlands are considered as one of the most productive ecosystems on the earth (Hook 1993). Wetlands provide crucial habitats to waterbirds in the form of islands (Mitsch and Gosselink, 1993). They are also known as ‘nature’s supermarkets’ for supporting biodiversity (Mitsch *et al.* 2015). As wetlands are transition zone between terrestrial and aquatic ecosystems, and are also known as natural purifiers or ‘kidneys of the landscape’ (Hammer and Bastian 1989; Mitsch and Gosselink, 1993). They provide an array of services like suitable habitats for vegetation, invertebrates, fish and mammals including rare/threatened species, improve water quality, control floods, regulate global carbon levels and have significant cultural and recreational values (USEPA 2002; Clarkson *et al.* 2003). Wetlands also act as reservoirs of 20-30% global carbon pool (Lal 2008).

As per definitions of RAMSAR, wetlands can be defined as-

- *Article 1.1: "...wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."*

and

- *Article 2.1: "[Wetlands] may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."* *-RAMSAR Convention*

The ecosystem services of wetlands have been categorized broadly into four categories *viz.*, 1) regulating 2) cultural 3) supporting and 4) provisioning (MEA 2005). Despite covering only 3% of the world area, wetlands provide about 40% of all ecosystem services around the globe which is annually worth of up to 13,165 billion dollars in monetary value (Costanza *et al.* 1999). As regulating ecosystem services, wetlands regulate flood, manage carbon emission and reduce of disease transmission risk (Brinson and Malvárez 2002; MEA 2005). Hence, Mitsch and Gosselink (2000) recommended that 3-7% of the temperate watershed area shall be maintained as wetland to improve water quality and regulate flood. Wetlands provide spiritual and recreational values to the human beings as well; however such activities, when uncontrolled, sometimes cause threat to the wetland habitats (Bergstrom 1990; MEA 2005; Chaikumbung *et al.* 2016). As supporting service, they assist in the nutrient cycle by storing and processing (Costanza *et al.* 1999; Fennessy *et al.* 2008). Under provisioning services, by removing nitrates and other contaminants of water, wetlands improve the water quality of highly contaminated water influx (Hill 1996; Hansen *et al.* 2018). Wetlands provide refuge and food resources to several floral and faunal species which mainly include the waterbirds (Richter *et al.* 1997; Bornette *et al.* 1998; Bedford *et al.* 1999).

1.2. Why waterbirds?

Apart from being poetic muse, waterbirds play a critical role in shaping the ecosystem by serving as biological indicators for environmental changes and by providing various other ecosystem services (Kushlan 1993; Amat and Green 2010; Green and Elmberg 2014). Globally, 19% of the waterbird species are migratory of

which, 23% of waterbirds found in the Asia-Pacific region are threatened or near-threatened (Kirby *et al.* 2008). Migratory waterbirds are considered as surveillance of pandemic diseases, and are also useful in the identification of disease outbreak hotspots and their migration routes (Fig 1.1; Bourouiba *et al.* 2010; Gaidet *et al.* 2010; Prosser *et al.* 2011). Several waterbird species also act as indicators in witnessing climate change impacts on their distribution range and habitat (Galbraith *et al.* 2002; Pavón-Jordán *et al.* 2015).

Waterbirds provide various ecosystem services including cultural, provisioning, supporting and regulating services (Green and Elmberg 2014). Culturally, various waterbird species are vital for recreational activities, ecotourism and bird watching (Grado *et al.* 2011; Edgell and Williams 1992; MacMillan and Leader-Williams 2008). For provisioning purposes such as food, wax coating and feathers for clothing and ornaments, waterbirds are high in demand worldwide (Kremer *et al.* 2010; Frisch *et al.* 2007). Under supporting ecosystem services, waterbirds act as excellent bioindicators, dispersal agent, and assist in nutrient cycle, methane control (Elmberg *et al.* 1993; Burger and Eichhorst 2007). Waterbirds also provide regulating services by contributing in pest control and disease surveillance in different flyways (Fig. 1.1; Miles *et al.* 2002; Ziegler *et al.* 2010).

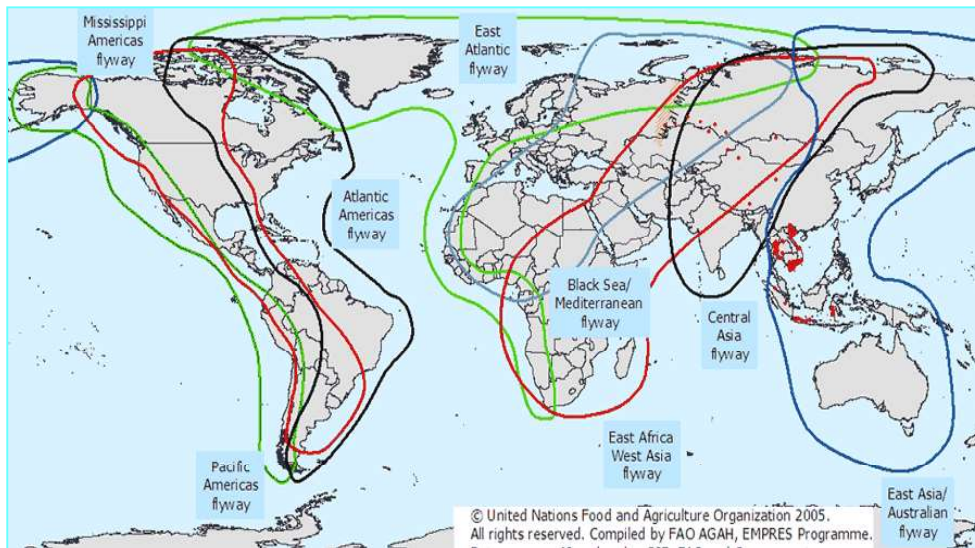


Figure 1.1. Global flyways of migratory birds with H5N1 outbreak locations in Asia (Source: FAO 2005; Gilbert, M. 2006)

1.3. Status of waterbirds and wetlands

A sharp decline in the number of natural wetlands has been recorded since 1700 AD (Davidson 2014). Similarly, worldwide population of waterbirds has declined in the last thirty years (Butchart *et al.* 2010). Unfortunately, Asia has faced high deterioration of both (Davidson 2014). In the face of climate change, wetland-dependent species might shift their potential distribution and might also affect their status (Galbraith *et al.* 2002; Pavón-Jordán *et al.* 2015). In case of migration, availability of stopover or staging sites is equally imperative to waterbirds for their long survival (Kirby *et al.* 2008). Every year the population of >100,000 individuals of different waterbird species migrates towards India using the Central Asian Flyway (Fig. 1.1; Li *et al.* 2009). India harbours around 243 species of waterbirds belonging to 34 families, of which 114 species are migratory and most (108) of them are winter visitors (Gopi and Hussain 2014).

Given that various environmental factors regulate the distribution of waterbirds in the wetlands, climate change is likely to cause distributional range shift of wintering species and perhaps further lead to decline in their population (Lehikoinen *et al.* 2013). The seasonal variations in abundance of waterbirds are driven by various factors *viz.*, the physio-chemical properties of wetlands, migration and climatic factors (Romano *et al.* 2005; Caziani and Derlindati 2000). Understanding of the demography and reproductive success of threatened species is empirical to their survival and conservation prioritization (Donovan *et al.* 1995; Zhang *et al.* 2017a).

A total of 8,536 high altitude wetlands were recorded across the five Indian Himalayan states namely J&K, Himachal, Uttarakhand, Sikkim and Arunachal (Panigrahi *et al.* 2012). Of these, 3,265 wetlands are in the eastern Himalayan states of Arunachal Pradesh and Sikkim, and 5,271 wetlands are in the western Himalayan states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir (J&K). J&K has the maximum number and area of wetlands followed by Arunachal Pradesh, whereas Sikkim has the minimum (Panigrahi *et al.* 2012). Earlier, a study identified 1,248 wetlands as small as 0.25 ha in the state with an area of 21,880 ha (Ahmedullah 1997) while Panigrahi *et al.* (2012) identified around 3,651 wetlands in the state J&K. Of which, 1,411 are >2.25 ha and 2,240 are <2.25 ha in area. Most of these natural wetlands are marshes (1,143) and rivers/streams (138). In recent time, few studies have highlighted conservation issues and status of Himalayan wetlands (Bassi *et al.* 2014; Hussain *et al.* 2018; O'Neil 2019).

1.4. Disturbance factors to waterbirds and wetlands

“Land use change and habitat loss, along with the deterioration and degradation of both breeding and nonbreeding wetland habitats, are widely recognized as being the major causes of the widespread pattern of declining waterbird populations and species (high certainty) “

-- Millennium Ecosystem Assessment (MEA) 2005

In the anthropocene, the climate change has been studied to determine their vulnerability towards stochastic changes in the recent times. Change in temperature can affect aquatic ecosystems of high altitude lakes (Sommaruga-Wograth *et al.* 1997). There are evidences of range shift and distribution of waterbirds owing to change in temperature (Lehikonin *et al.* 2013). Other changes include the changes in the breeding cycle, migration timing, and population sizes are visible in the current scenario (reviewed in Crick 2004; Tucker *et al.* 2018).

The occurrence of population does not solely depend on the factors governed by genetic, demographic and environmental processes. Disturbance and harassment may also reduce species diversity and density at multiple habitat scales (Boyle and Samson 1985). Wetland loss is considered as the prime threat to waterbirds across the globe (O’Connell 2000). Waterbirds have declined globally and about 80% of the population declined in Asian flyways in recent times owing to various negative factors (Li *et al.* 2009). In Central Asian Flyway, loss and degradation of wetland habitats have threatened many migratory waterbird species (Szabo and Mundkur 2017). In Asia, annually 5000 km sq. wetland area is being lost to land-use changes

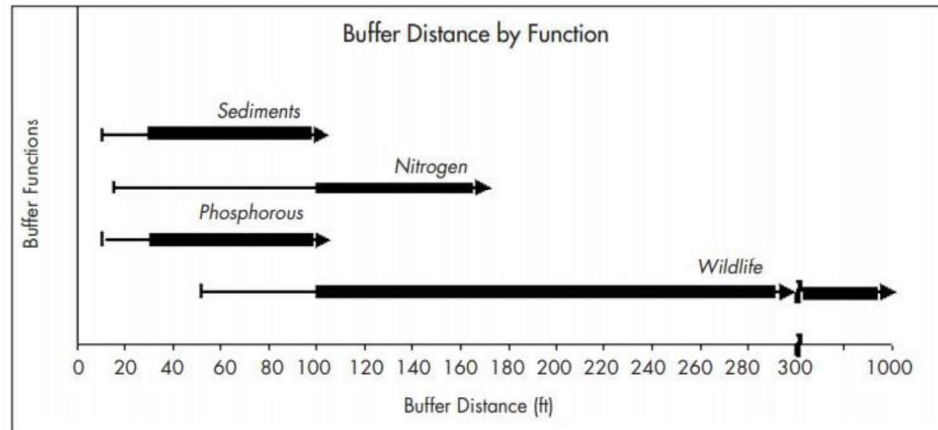
such as hydropower, agriculture expansion and other anthropogenic activities (McAllister *et al.* 2001). Consequently, many wetland dependent species including 21% of bird species, 37% of mammal species and 20% of freshwater fish species are either extinct or threatened globally (MEA 2005).

1.5. Factors governing wetlands and waterbirds

Apparently, Indian Trans Himalayan wetlands are facing the same problems as mentioned above (Chandan *et al.* 2005). In India, many wetlands are prone to land-use changes, industrial and domestic pollution, encroachments, excessive cattle grazing, tourism, illegal hunting of waterbirds and over-exploitation of their natural resources (Li *et al.* 2009; Bassi *et al.* 2014). India harbours more than 4000 high altitude lakes (SAC 2011). Trans Himalayan lakes like Tso Moriri, Tsokar, Statspuk Tso serve as a refuge for various breeding waterbirds in Ladakh (Gole 1983). Estimation of the population is considered as a linchpin tool in conservation biology (Greenwood *et al.* 1996). Environmental quality may affect the equilibrium of wildlife population size (Klok and De Roos 1998), richness and abundance of species (Zou *et al.* 2008). Furthermore, resource limitation, predation, competition, unfavourable climate and disturbance all can influence offspring quality and survival (Sutherland and Crockford 1993; Gander and Ingold 1997; Martin 2001; Kessler and Baldwin 2002). Similarly, in order to balance visitor access and species' protection requires understanding the nature and pattern of human disturbance is required. Legal protection can provide a better survival rate of a species in a particular habitat. A recent study by Kleijn *et al.* (2014) has shown a clear difference between protected 'Ramsar' sites and non-protected sites. A better understanding of the

impact of disturbance on natural habitat of waterbirds is needed to develop foolproof management strategies.

Tourism provides alternative livelihood opportunities to reduce the direct dependencies of local communities on the natural system and perhaps contributes towards nature conservation (Salafsky and Wollenberg 2000). However, if unregulated, often negatively impacts the wildlife and natural habitat (Klein *et al.* 1995). Tourism in Indian-Trans Himalaya is governed by seasonality, accessibility and harsh climatic conditions, thus tourism activities are restricted to short summers. Consequently, human-induced disturbances in the environment are concentrated in the summer, which is also the peak season for several biological processes *viz.*, mating, vegetation growth, migration and spawning (Geneletti and Dawa 2009). In the present scenario, the aforementioned factors appear to be major threats to the Trans-Himalayan region of Ladakh. Socio-politically unstable Ladakh was opened for tourism in the year 1974 with a visitation of only 527 tourists, which drastically increased around 2,58,720 tourists in the year 2017 (Tourism Department Records, Leh). Hence, prudent management of wetlands is much required using different tools and techniques (Nichols *et al.* 2008; Macfarlane and Bredin 2017). Waterbirds have been used as one of the key parameters in delineating buffer zones around the wetlands and other landuse policies (Fig. 1.2).



Effective buffer distance for water quality and wildlife protection functions. The thin arrow represents the range of potentially effective buffer distances for each function as suggested in the science literature. The thick bar represents the buffer distances that may most effectively accomplish each function (30 - > 100 feet for sediment and phosphorous removal; 100 - > 160 feet for nitrogen removal; and 100 - > 300 feet for wildlife protection. Depending on the species and the habitat characteristics, effective buffer distances for wildlife protection may be either small or large.

Figure 1.2. Effective buffer distance using different wetland parameters (Source: Nichols et al. 2008)

With increasing agriculture and pastoralist practices, human domesticated carnivore species like dogs (*Canis familiaris*) and domestic cats (*Felis catus*) for guarding their resources (Driscoll *et al.* 2009). To date, domestic dogs are apparently the most abundant carnivores in the world and major threat to local wildlife (Daniels and Bekoff 1989). In many instances colonizing dogs have acted as invasive alien species, disrupting and modifying indigenous ecosystems (Clout 1995). Recent studies have determined birds as the important part of their diet (Butler *et al.* 2004; Campos *et al.* 2007; Vanak and Gompper 2009; Silva-Rodríguez *et al.* 2010). Peoples' perception plays a vital role for survival of wildlife in a particular region (Bhatia *et al.* 2016; Kumar *et al.* 2017). Interviews with local communities have provided better insights pertaining to reasons for owning dogs and dog-wildlife interaction (Sepulveda *et al.* 2014). However, such information is lacking in the Indian Trans-Himalayan landscape where dogs have perceived as a severe threat to waterbirds and other wild species.

1.6. Rationale and objectives

The existing literature suggests that there was a huge gap in the information of Trans-Himalayan wetlands and their avi-faunal diversity. Previous studies were either site-specific or species-specific, and thus, landscape level base line data was either scanty or unavailable. To fill those gaps it was necessary to determine the status of waterbirds in Changthang Wildlife Sanctuary (CWLS) in all known wetlands and subsequently to assess the factors affecting them. In recent past, concerns related to the tourism has increased and also increasing population of the free-ranging dogs in this landscape have posed threat to native wildlife thus it was also imperative to study these aspects. With the above background, I decided to study waterbirds and wetlands in CWLS following objectives:

1. To assess the population status and habitat use by waterbirds

Sub-objectives

- (i) Determine the abundance of breeding waterbirds
- (ii) Assess the habitat use by waterbirds

2. To evaluate the factors affecting the breeding waterbirds

Sub-objectives

- (i) Assess tourism impact on waterbirds
- (ii) Assess the impact of free ranging dogs on waterbirds

3. To assess change in the wetland area

Sub-objectives

- (i) Land-use land cover classification of CWLS
- (ii) Land-use land cover change detection

Key questions

1. What is the abundance and habitat use of breeding waterbirds in different wetlands of the sanctuary?
2. What are the factors affecting the breeding waterbirds?
3. What is the change in land use land cover over time?

1.7. Organization of Thesis

My thesis is divided into eight chapters, introduction as first chapter and study area description as the second chapter. The rest six chapters describe the main findings and synthesis of my thesis. Chapter 1 deals with the general introduction of the thesis, describing the importance of waterbirds and wetland ecosystem, reviews the related disturbance and how these factors influence waterbirds' habitat use. Chapter 2 provides detailed information about my study area including physical and biological elements of the landscape. Chapter 3 deals with the status of waterbirds in Changthang Wildlife Sanctuary (CWLS) determining abundance using double observer method and the total count of waterbirds in 24 different wetlands of CWLS. Chapter 4 provides the habitat use by waterbirds in different wetlands of CWLS. Various parameters namely waterbird abundance, richness, habitat parameters have been collected. Chapter 5 deals with the impact of anthropogenic disturbances on waterbirds and I studied the behavioural observations of the different waterbirds species. Herein, I have also recorded the escape behaviour of bird and measured their Flight Initiation Distance (FID) in thirteen wetlands of CWLS between 2015 and 2017. Chapter 6 deals with the impact of free-ranging dogs on waterbirds. I used a combination of methods to decipher impact of dogs using spatially explicit capture-

recapture (SECR) method for population estimation of dogs, diet analysis and questionnaire-based surveys of locals between 2015 and 2017. Chapter 7 gives insights about the land use land cover (LULC) mapping of CWLS. Herein, I have used change detection method to calculate land-use change between 1994 and 2014. Eventually, Chapters 8 synthesizes my key findings and provides some management recommendations.

Chapter 2: Study area- Changthang Wildlife Sanctuary

2.1. Introduction

The Greater and Trans-Himalayan region of India covers an area of ca. 4,00,000 sq. km., of which ca. 1,84,823 sq. km. area falls within the Trans Himalayan region covering the states of Jammu & Kashmir (J&K), Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. This region comprises about 5.62 % of the total geographical area of India (Rodgers and Panwar 1988). The Indian Trans-Himalaya is extension of Tibetan plateau towards Himalaya and its major part falls under Ladakh. This region is bestowed with natural beauty and hence, attracts millions of domestic and international tourists every year. Despite having harsh climatic conditions and limited resources, local inhabitants have survived all odds and flourished a rich and diverse culture since ages. Owing to its strategic location between China and Pakistan, Ladakh also holds international significance and has witnessed wars and skirmishes with neighboring countries.

Erstwhile Ladakh division was divided into two administrative districts- Leh and Kargil, are now part of newly formed Union Territory of Ladakh. Leh is a *Buddhist* dominated area (77.29%), whereas Kargil is dominated by the *Muslim* community (Census of India 2001). Historically, Ladakh was ruled by *Buddhist* rulers for centuries but the region also witnessed *Muslim* conquest since the medieval era which influenced the socio-political situation of this region. A small sect of Ladakhi *Sikhs* also resides in Leh district who started following *Sikhism* after the

arrival of *Guru Nanak Dev* in Ladakh and Aksai Chin. The human density in the region is very low with 4.9 individuals per sq. km (Chandramauli 2013) and the inhabitants are mostly dependent on pastoralism and agriculture (Goodall 2007).

In Ladakh, historical evidences in the form of petroglyphs show significant association of indigenous people with nature especially wildlife (Vernier and Bruneau 2017). Owing to its location at the junction of two bio-geographical regions, Palearctic and Oriental, Ladakh resembles floral and faunal diversity of both regions (Namgail 2009). There are around 665 lakes and other small waterbodies in Ladakh region (Naseem and Keng 2012). This region harbours an array of floral species - around 500 species of wild and cultivated plants (Dvorsky *et al.* 2018). Another study by Klimes and Dickore (2006) recorded more than 1050 species from Ladakh region. In terms of faunal diversity, it holds 300 species of birds including migratory and resident (Namgail and Yom-Tov 2009), and around 31 species of mammals (Pfister 2004). Among the lower taxa, about 32 species of freshwater fishes have been recorded from the Ladakh region (Sivakumar 2002), 4 species of amphibians and 11 species of reptiles have also been recorded (Anon 2001). About 101 species of butterflies were recorded from Ladakh between 1995 and 2004 (Tshikolovets 2005). There are three protected areas in Ladakh region namely Hemis National Park, Nubra-Shyok Wildlife Sanctuary and CWLS.

2.2. Location and zonation of CWLS

The CWLS is situated between 32° 19' to 34° 35' North latitudes and 77° 45' to 79° 18' East longitudes in the Leh district of Ladakh Union Territory. It is one of the

largest protected areas of India and the average altitude of the sanctuary is about 4000 msl. The sanctuary falls under the 1B: Trans Himalaya (Tibetan Plateau) Biogeographic zone of India (Rodgers *et al.* 2000). The Indus and Shyok are two major rivers which flow through this sanctuary.

2.3. Conservation Status

In 1987, the erstwhile state Govt. of Jammu and Kashmir notified CWLS (vide SRO 155, dated 19-03-1987) with an area of around 4000 sq. km. Apart from being proclaimed as a wildlife sanctuary, one of its wetlands, Tso Moriri, was designated as a RAMSAR wetland, in 2002 (www.ramsar.org). Considering the rich avifaunal diversity of CWLS, wetlands such as Chushul, Tsokar, Pangong and Tso Moriri have been declared as Important Bird Areas (IBAs) (Islam and Rahmani 2004). Due to its unique biodiversity and conservation values the entire Changthang region was proposed as a “Biosphere Reserve” (Hussain *et al.* 2008). The management unit of this sanctuary is Range; there is only one range in the CWLS, known as Changthang. Unlike other protected areas (PAs), CWLS hasn’t been divided into smaller units like beats or compartments. The range headquarter of the sanctuary is situated at Nyoma block. The entire sanctuary falls under Nyoma and Durbuk blocks of Leh.

2.4. Administrative details

The northeastern boundary of CWLS is demarcated along the actual line of control (LAC) through Demchok, Chushul, Pangong Tso and Changchenmo areas. Down south, the CWLS boundary is also delineated along LAC covering the area of Chumur. On the western side, it lies along the ridge line of Tsokar and Manali

highway which forms the boundary of the sanctuary (Department of Wildlife Protection, Leh).

2.5. Environmental Attributes

2.5.1. Climate

The altitudinal variation of CWLS is between 3362-6667 meters (m) above sea level (a.s.l.) (Fig. 2.1). It is characterized by the arctic wind-swept deserts and barren hills with an average annual rainfall of less than 10 cm (Gujja *et al.* 2003). The strong and unpredictable winds of the region make the area very harsh (Chandan *et al.* 2005). During the summer season, the temperature of CWLS reaches upto +30°C and falls below -40°C during winters (Mishra and Humbert-Droz 1998).

2.5.2. Geology and edaphic characteristics

The CWLS is located between the Karakoram fault and Indus Suture zone (Phartiyal *et al.* 2005). The tectonic activities along the faults like Indus Suture, Karakoram Fault and Shyok Suture in Indus river and its tributaries have resulted in the formation of major lakes in the region (Phartiyal *et al.* 2005). The lakes of CWLS have constantly fluctuating owing to compression in the collision regime and possible climatic factors (Philip and Mazari 2000). The common soil type is sandy or sandy clay with sulphur and borax deposits and is nutrient deficit in nature (Murti 2001; Rawat and Adhikari 2005; Namgail 2009).

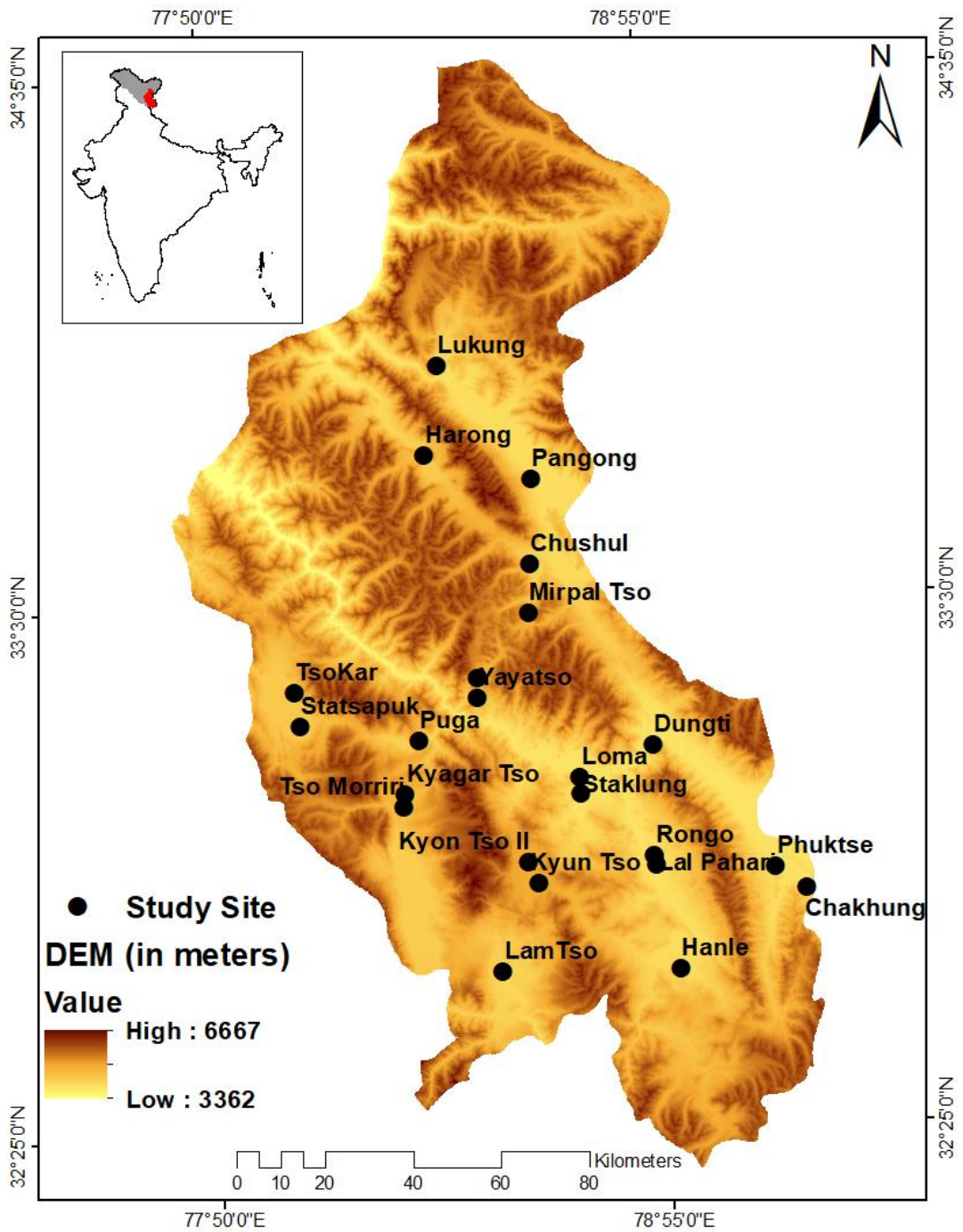


Figure 2.1. Elevational gradient of Changthang Wildlife Sanctuary

2.5.3. Land Use Land Cover and wetland characteristics

Being Trans-Himalayan region, major part of the sanctuary is either barren or permafrost with mosaic of few green patches including wetlands (Fig. 2.2). CWLS

harbours around 24 key wetlands both lacustrines and palustrines types of wetlands are found including ten major lakes. Fresh, brackish and saline water property lakes and marshes are present (Gopal *et al.* 2002; Hussain *et al.* 2008). Pangong and Tso Moriri are the largest, while Puga and Lal Pahari are the smallest wetlands. The key wetlands are in western (Tsokar, Statsapuk), southern (Lam Tso, Tso Moriri) and eastern Changthang (Pangong Tso). These wetlands also serve as breeding and staging areas for long-distance migrant ducks and other species (Ali and Ripley 1978). I sampled 24 wetlands for waterbird abundance estimation, of which 13 wetlands were also studied intensively for other objectives.

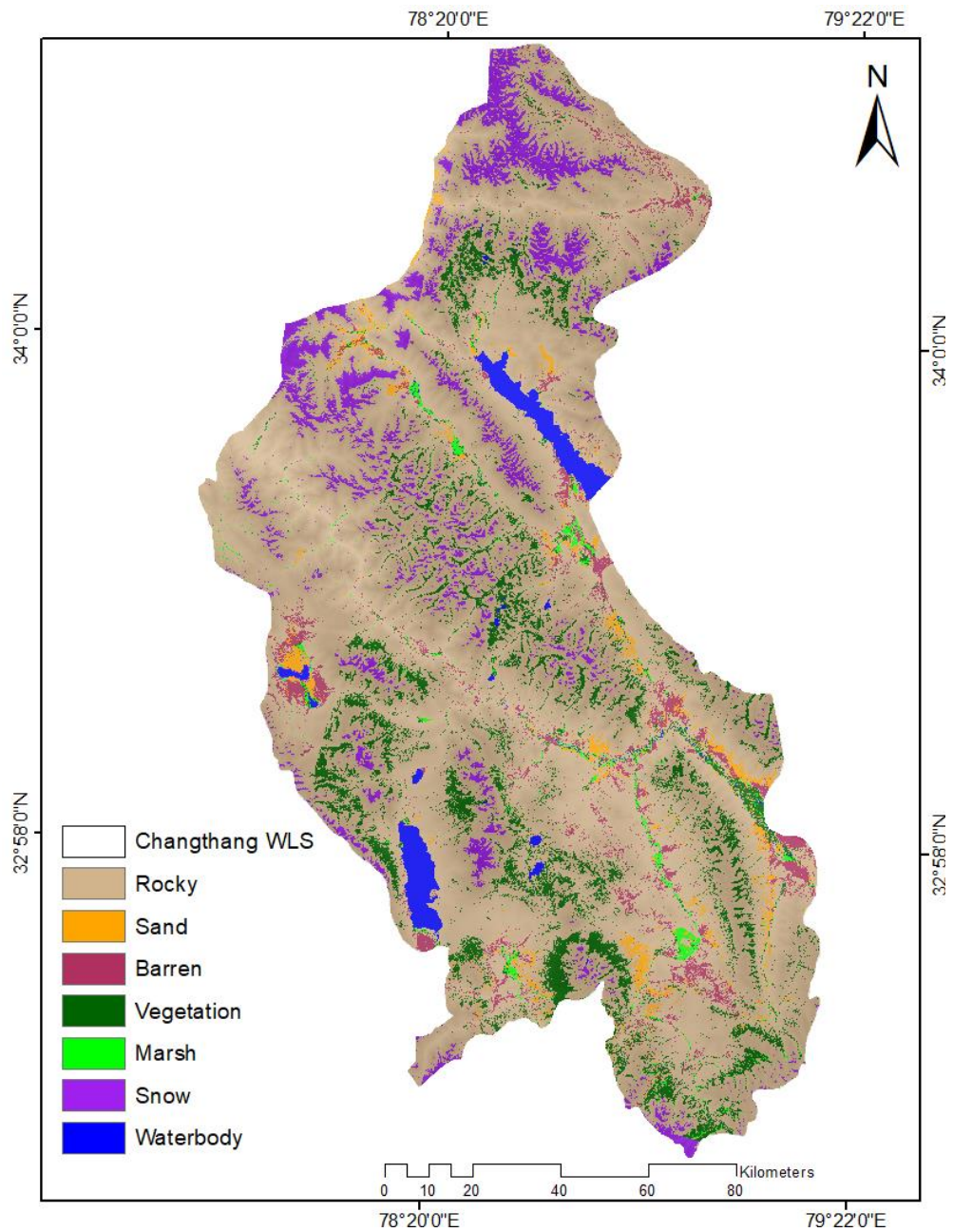


Figure 2.2. Land Use Land Cover map of CWLS

2.5.4. Flora

Around 232 species of 101 genera and 38 families have been recorded from the Tsokar Basin of CWLS (Rawat and Adhikari 2005). About 272 species of vascular

plants belonging 43 species and 127 genera was indentified in CWLS (Dvorsky *et al.* 2011). Subsequently, another study by Dvorsky *et al.* (2015) identified 306 autochthonous species of plants in CWLS. The wetlands of Tsokar basin harbour about 25–30% of the total vascular flora known from the region despite their limited extent (Rawat and Adhikari, 2005). The marsh meadows are dominated by sedges, like *Carex* (>30 species), *Kobresia* (>7 species), blysmus, rushes (>12 species of *Juncus*), *Eleocharis* and several species of grasses like *Calamagrostis falciformis*, *Poa* spp. and *Puccinellia himalaica*. Pools of shallow water support a number of aquatic species such as *Potamogeton pectinatus*, *Myriophyllum verticillatum*, *Hippuris vulgaris*, *Ranunculus natans* and *R. trichophyllus*. Typical herbaceous elements in marsh meadows include species of *Ranunculus*, *Pedicularis*, *Gentiana*, *Gentianella* and *Primula*. Some of the species are typical of saline marshes (halophytes), like *Atriplex tatarica*, *Puccinellia himalaica*, *Suaeda olufsenii*, *Triglochin maritimum* and *Glaux maritima*.

2.5.5. Fauna

The wetlands of Changthang are the only known nesting sites of the Black-necked cranes (*Grus nigricollis*) in India (Gole 1983). Other species of waterbirds, which also use these wetlands as their breeding grounds are bar-headed geese, brown headed gull (*Larus brunicephalus*), great crested grebe (*Podiceps cristatus*), ruddy shelduck (*Tadorna ferruginea*), lesser sand plover (*Charadrius mongolus*) etc. (Hussain *et al.* 2008). The mammals found in the Changthang area include blue sheep (*Pseudois nayaur*), Ladakh urial (*Ovis orientalis vignii*), Tibetan argali (*Ovis ammon hodgsonii*), Tibetan wild ass (*Equus hemionus kiang*), Himalayan marmot

(*Marmota himalayana*), red fox (*Vulpes vulpes*), Tibetan gazelle (*Procarpa picticaudata*), snow leopard (*Panthera uncia*), wild dog (*Cuon alpinus laniger*), Tibetan wolf (*Canis lupus chanko*), lynx (*Lynx isabellina*) and Pallas's cat (*Otocolobus manul*) (Fox and Chundawat 1988; Mahar *et al.* 2017).

2.6. Socioeconomic Attributes

2.6.1. People of CWLS

The Changthang region comprising of two main blocks Nyoma and Durbuk with around 28 villages is inhabited by different pastoralist *Budhhist* sects (Jina 2002; Bhasin 2012). Pastoralist communities of Changthang are mainly followers of *Drukpa*, *Drikung* and *Sherpo* Buddhist sects. Culturally, there are three distinct groups in Changthang - *Rongpa* (inhabitants of Kuyul, Damchok, Chumathang, Nyoma), *Lungpa* (Chumur and Kerey) and *Drokpa* (Rupshu and Kharnak). These people spend most of their life span in easily movable tents (locally known as *Rebos*) (Bhasin 2012). Annually, transhumance communities migrate horizontally; moving through several locations in the Changthang region during different seasons based on the availability of scanty resources for their livestock (Namgail *et al.* 2007). They are also involved in seasonal cultivation in some hamlets; however land cultivation is barely in 1% of the total Changthang region (Rawat and Adhikari 2002).

2.6.2. Livestock holding

Pastoralist nomads of Changthang rear mixed animals like domestic yak, dzo (cow-yak hybrid), Zanskar pony, sheep, *pashmina* goat, donkey and cow. In the last few decades, *pashmina* has emerged as a lucrative business for local pastoralists in the

region (Ahmed 2004; Namgail *et al.* 2007). The yaks and ponies are mainly used for transportation of goods in remote locations (Bhasin 2012). The total livestock population in Changthang is around 4,08,290 heads including 18,877 yaks, 34,174 dzo, 1,12,185 sheep, 2,30,077 goats and 12,077 heads of cattle (Leh Husbandry Department 2016). The socio-economic changes in the region have led to outmigration of pastoralists to explore the outer world and look for alternative livelihood options (Goodall 2007).

2.6.3. Dependence on CWLS

Being a pastoralists' landscape, the sanctuary receives a large number of livestock for seasonal grazing mainly in proximity to the wetlands. Scarce availability of vegetation compels pastoralists to shift their camps in different locations (Namgail *et al.* 2007). Out of the 232 identified plant species, only 50-60 species are preferred by livestock in the Changthang region (Rawat and Adhikari 2006). Apart from that, people are dependent on various resources like medicinal plants, fuel wood and tourism related livelihood. Ladakhis practice ancient medicinal healing and these healers or practitioners are known as *Amchi*, *Akhon* and *Saman* (Angmo *et al.* 2012). The healers use different medicinal plants and occasionally animal parts for curing diseases. Pastoralists of this landscape use *Caragana* spp. and *Myricaria* spp. bushes as fuel wood, however modicum availability of these species' restrict them to use other alternatives like cattle dung, goat and sheep pellets as fuel. CWLS holds one of the best tourist locations in the Indian Trans-Himalaya and with the increasing demand of tourism, local people are also getting involved directly or indirectly on the tourism industry. With the unparalleled boom in tourism since 1970's, this landscape

is going under immense anthropogenic pressure due to unregulated tourism. In the year 2017, 2,58,720 tourists visited Ladakh including domestic and foreign tourists (Tourism Department, Leh) which has increased drastically since the 1970s.

2.6.4. Conservation issues

Negative interface between wildlife and human is inevitable in CWLS. Previous studies in CWLS revealed that about 60-70% of the livestock predation cases were caused by wolf, followed by snow leopard (Namgail *et al.* 2007; Habib *et al.* 2013). The increasing population of ungulates like *kiang* has emerged as grazing competition for livestock in the resource deficit regions (Bhatnagar *et al.* 2006a), whereas species such as argali and Tibetan gazelle face forage competition with livestock in CWLS (Bhatnagar *et al.* 2006b; Namgail *et al.* 2008; Singh *et al.* 2013). In the recent past, free ranging dogs have emerged as a threat to wildlife and livestock (Bhatnagar *et al.* 2006b; Naroji and Sangha 2011). Tourism is also one of the key conservation issues in CWLS. Trekking, off road driving, garbage dumps, camping around wetlands and water channels, are key factors detrimental to local environment (Geneletti and Dawa 2009). Previous studies have also highlighted the impact of military on prime wildlife areas in the region (Fox *et al.* 1994; Humbert-Droz 2017).

Plate 2.1. Breeding waterbirds of Changthang Wildlife Sanctuary



a) Great Crested Grebe



b) Bar headed Goose



d) Common Goosander



e) Black necked Crane



f) Common Tern



g) Ruddy Shelduck

Plate 2.2. Key mammal species of Changthang Wildlife Sanctuary



a) Pallas's Cat



b) Himalayan Wolf (Melanistic)



c) Tibetan Argali



d) Blue Sheep



e) Tibetan Wild Ass



f) Stolicka's Mountain Vole

Plate 2.3. Major disturbance factors in CWLS



a) Unregulated tourism activities



b) Unplanned construction near wetlands



c) Unmanaged garbage dumps



d) Off road driving in wetlands



e) Free-ranging dogs disturbing wildlife



f) Fencing in wetlands

Plate 2.4. Wetland types in CWLS



a) Lacustrine Wetland



b) Palustrine Wetland



c) Riverine Wetland

Chapter 3: Abundance of waterbirds in Changthang Wildlife Sanctuary

3.1. Introduction

Globally, 19% of the bird species are migratory out of which, 23% of waterbirds found in Asia-Pacific region, are threatened and near-threatened (Kirby *et al.* 2008). Waterbirds provide various ecosystem services (Green and Elmberg 2014). Birds' population estimates are of fundamental importance in applied ecology and frequently used to indicate the design and effectiveness of protected area networks and to determine important sites for conservation (Perez-Arteaga *et al.* 2005). Habitat-specific population estimates can be used to direct the conservation attention by identifying habitat patches which sustain large populations (Gregory and Baillie 1998; Chamberlain and Gregory 1999), and are vital in assessing the ecological determinants of rarity, which may increase extinction risk (IUCN 2018).

Occasionally, species occurs outside its known habitat because of greater fundamental niche than its realized niche (Pulliam 1988). For the survival of the progeny, source habitat is much imperative rather than a sink habitat (James *et al.* 1984). The seasonal variations in abundance of waterbirds are driven by various factors *viz.*, physio-chemical property of habitat, migration and climatic (Romano *et al.* 2005; Caziani and Derlindati 2000). In case of migration, availability of stopover or staging site during migration is equally imperative to waterbirds for their longer survival (Kirby *et al.* 2008). Hence, studying abundance and distribution across seasons contribute effectively in the management of waterbirds (Mendez *et al.* 2018).

In addition to abundance, species richness is also empirical to ecologists deciphering conservation importance of a given habitat or landscape (Gotelli and Colwell 2011).

India harbours more than 4000 high altitude lakes (SAC 2011), such as Tso Moriri, Tsokar, Statsapuk Tso etc. which serve as refuge for various breeding waterbirds in Ladakh (Gole 1983). The erstwhile state of J&K harboured maximum number of the wetlands in India (SAC 2011; Panigrahi *et al.* 2012). Ladakh holds around 300 species of birds out of which 100 are migrants (Namgail and Yom-Tov 2009). Indian Trans-Himalayan wetlands are prone to land use changes, various anthropogenic pressures, industrial & domestic pollution, excessive cattle grazing and unregulated tourism (Chandan *et al.* 2005; Li *et al.* 2009; Bassi *et al.* 2014; Hussain *et al.* 2018). Consequently, resource limitation, predation, competition, unfavourable climate and disturbance can influence offspring quality and survival (Sutherland and Crockford 1993; Gander and Ingold 1997).

Over the past decades, few studies have been conducted in Ladakh. Hussain *et al.* (2008) identified 16 species of waterbirds from the CWLS, of which seven species are breeding species in various wetlands. The 11 species observed by Namgail *et al.* (2009) during another study represents 13% of the avian species recorded in the Ladakh region.

One of the significant species of this region is black-necked crane (BNC) *Grus nigricollis*, is an endangered species listed as “vulnerable” in the IUCN Red List (BirdLife International 2017). It breeds only in high plateau wetlands of the China and India. Globally, its population is around 6600-6800 individuals and in continuous decline owing to various factors (Birdlife International 2017). India has a

small population (< 150) of BNC in Ladakh, Sikkim and Tawang regions (Chandan *et al.* 2014). Due to their dwindling status, BNC is legally protected as a Schedule-I species under Indian Wildlife (Protection) Act-1972 (Anon 1991). Realizing the importance of BNC, it was declared as “the state bird of J&K”. It is also culturally considered as a sacred species and a harbinger of prosperity among *Buddhist* communities of Tibet, Bhutan and India, hence local communities avoid hunting of BNC in their respective places.

In recent time, the increasing impact of human and climate change are key conservation threats to BNC and its habitats (Song *et al.* 2014; Han *et al.* 2018). Several factors influence incubation in BNC including habitat, the location of nesting site, and disturbance factors including the presence of human, livestock and dogs (Li and Ma 1989). Incidences of chick and egg predation have been widely reported from India and China (Chandan *et al.* 2005; Naoroji and Sangha 2011; Zhang *et al.* 2017a). However, few studies have been carried out on the breeding ecology and success of BNC in India and China (Chacko 1995; Pfister 1998; Chandan *et al.* 2005, Zhang *et al.* 2017a, b). Several site specific attempts have been conducted to determine waterbird status in Ladakh including BNC (Mishra and Humbert-Droz 1998; Hussain and Pandav 2008; Namgail *et al.* 2009; Ahmed *et al.* 2019).

Over the decades, Ladakh has witnessed an increase in population and occupied new habitats of BNC (Chandan *et al.* 2005). Although human footprint has also enhanced exponentially in terms of tourism-related activities, developmental activities and resulted in landuse changes in and around BNC habitats (Humbert-Droz 2017). To date, several methods have been used in determining the status of

birds *viz.*, Conventional total counts methods (Bibbey *et al.* 1992), double observer method (Nichols *et al.* 2000), conventional distance sampling (Buckland *et al.* 1993) or Multi Covariate Distance Sampling (Marques *et al.* 2007), mark capture recapture (Baker 2004) and other techniques (Sutherland 2006). Understanding of demography and reproductive success of threatened species is imperative for its survival and conservation prioritization (Donovan *et al.* 1995; Zhang *et al.* 2017a). The present chapter provides detail examination of the abundance of waterbirds including wading, dabbling and diving species across different seasons in CWLS during 2016 and 2017.

3.2. Methodology

3.2.1. Point count sampling

Double observer method is time and cost effective than distance sampling, capture-recapture and removal methods (Taylor and Pollard 2008). A modified fixed distance point count using double observer method was carried out to fix detectability at different points within the time frame of 10-15 mins per point (Nichols *et al.* 2000). Sampling was conducted in a closed time during the morning-afternoon hours (6:00 and 13:00 hr).

To estimate the abundance of waterbirds on spatio-temporal scale, I used independent double observer method with point count technique (Nichols *et al.* 2000; Moore *et al.* 2004; Pangano and Arnold 2009; Vrtiska and Powell 2011). Overall, 275 fixed points were sampled in 24 wetlands over the period of two years (2016-2017) during three seasons namely spring, summer and autumn (Fig. 3.1). A total

1647 counts were conducted during two years sampling. The wetlands were differentiated into three categories based on their sizes, 1. Large (>15 sq. km) 2. Medium (6-15 sq. km) and 3. Small (< 5 sq. km). The minimum distance of 400 meters was maintained between two points at small wetlands. However, due to logistic constraints and detectability, medium and large lakes were sampled maintaining the minimum distance of 1200 and 2000 meters respectively. I fixed these distances on the basis of my previous reconnaissance surveys in this area. Sampling details of seasonal waterbirds count are given in Table 3.1.

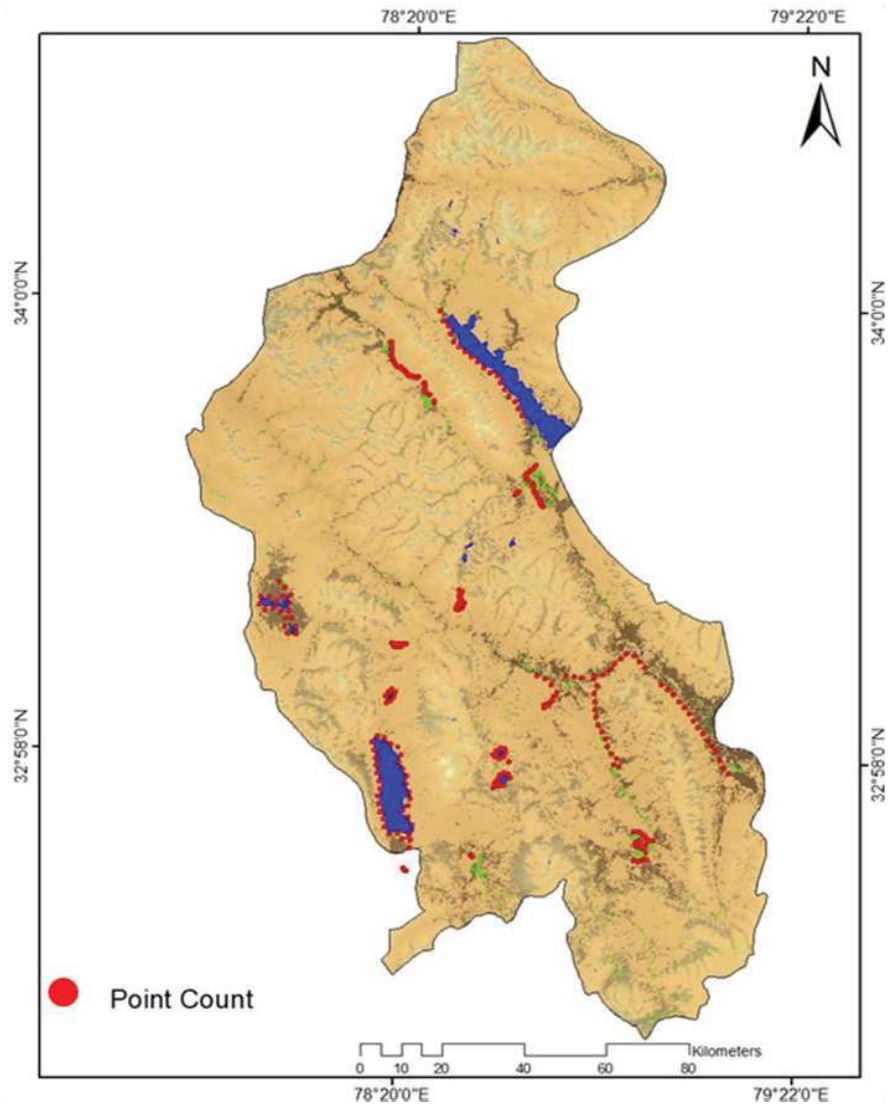


Figure 3.1. Waterbird point count sampling locations in different wetlands of CWLS

The high fatigue level due to harsh terrain and environment in this landscape were key issues for detectability. To overcome such biases, I slightly modified this method and used zoom camera to captured photographs of birds (Boyd 2000) from each vantage point. Subsequently, photographs were shared with two different observers and both counted birds in independent observer framework. Similar

approach was obtained by Vrtiska and Powell (2011) using aerial photographs to estimate waterbird population. A total of 4723 bird photographs were captured in two years.

Table 3.1. Seasonal waterbird sampling during 2016-17

Year	Spring	Summer	Autumn
2016	11 th – 25 th May	12 th – 25 th July	9 th – 21 st October
2017	13 th – 31 st May	19 th – 30 th July	7 th – 16 th October

3.2.2. Total Count Method

I used total count method for estimating BNC population in CWLS. Prior to actual counting, I thoroughly reviewed literature available on BNC in Ladakh (Osmaston 1925; Hussain 1976; Hussain 1985; Hussain and Pandav 2008; Gole 1983; Chandan *et al.* 2014) and carried out reconnaissance surveys of known sites. Subsequently, I carried out seasonal total count of BNC in 24 wetlands of CWLS during 2016-17. I divided my sighting records in three classes 1) Adult 2) Sub-adult 3) Juvenile, adults were segregated in two categories: breeding and non-breeding. Although I couldn't differentiate sexes due to monomorphism in BNC. Each wetland was visited during three seasons namely spring, summer and autumn; however locations of breeding pairs were visited each month to monitor breeding success. At each site, entire periphery of wetland was walked or covered by vehicle (as per field conditions) to estimate BNC population.

3.2.3. Data analysis

a) *Diversity and richness*

To assess the diversity and species richness across the wetlands, I used Shannon-Weiner diversity index (Hutchison 1970; Clarke and Warwick 2001), Margalef's richness index (Margalef 1958), Pielou's evenness index (Pielou 1966) and McNaughton's Community dominance index (CDI) (Krebs 1972; McNaughton 1968). The mathematical expressions used for calculation are given follow:

$$\text{Shannon-Weiner Index } H' = -[\sum P_i \ln P_i]$$

where, P_i = is the proportion of each species in the sample; $\ln P_i$ = natural log of proportion.

$$\text{Margalef's Richness index} = (S - 1) / \ln N$$

where, S = total number of species and N = total number of individuals in the sample.

$$\text{Pielou's evenness index } e = H' / \ln S$$

where H' = Shannon-Wiener diversity index and S = total number of species in the sample.

$$CDI = (y_1 + y_2) / y$$

where, y_1 = abundance of the most abundant species, y_2 = abundance of second most abundant species, y = total abundance for all the species.

There is always a chance of missing few species during the sampling. Therefore, prediction models based on species accumulation curves were used to

confirm if the number of species will increase with the survey effort or with the increase in wetland number.

We used Kindt's exact accumulator (Ugland *et al.* 2003) using the following formula:

$$\hat{s}_n = \sum_{i=1}^s (1 - p_i)$$

where, $p_i = \binom{N - f_i}{n} / \binom{N}{n}$ probabilities that species i does not occur in a sample of size n , where f_i is the frequency of species i and $\binom{N}{n}$ is the binomial coefficient, or the number of ways we can choose n (sample size) from N (population).

Assumption of the species pool prediction is the number of unseen species which is related to the number of rarely sighted/cryptic species. I used four most commonly practiced prediction models- Chao, first order Jackknife, second order Jackknife and bootstrap method (Smith and van Belle 1984; Chao 1987; Chiu *et al.* 2014). Final model was selected by observing their performance in rarefaction graph and ecological information of the study area. I performed hierarchical cluster analysis on the Bray-Curtis distances with complete linkage method to know the assemblage structure and co-occurrence of the species (Everitt 1974).

I also applied Bray-Curtis dissimilarity to compare among the wetlands. Bray-Curtis distance is used to quantify the compositional similarity between two samples based on the counts at each site (Bray and Curtis 1957). Bray-Curtis distance ranges from 0 to 1, where 1 means no similarity and 0 means exactly same community. Mathematical formula used for the calculation is as follow:

$$BC_{ij} = 2C_{ij} / (S_i + S_j)$$

where, C_{ij} is the sum of the lesser values for only common species between both the sites. S_i and S_j are the total number of specimens counted at both the sites.

Principal coordinates analysis (Gower 1966) with Bray-Curtis distances was applied to develop minimum spanning tree relation of the surveyed wetlands. Minimum spanning tree is closely related to single linkage clustering (Oksanen 2014). All the analyses were performed in program R, version 3.3.0 (R Core Team 2018) using the package “vegan” (Oksanen 2015).

b) *Waterbird abundance*

The data was arranged in three columns for each species following standard format, N1 = number of bird species counted only by first observer, N2 = number of bird species counted only by second observer and N3 = common counts by both the observers. The species with <10 observations were pooled together to calculate detection probability (Nichols *et al.* 2000). I generated detection probabilities and abundance estimates using program DOBSERV (Hines 2000) in combination with the SURVIV code (White 1983). Minimum value of Akaike’s information criteria (AIC) among models was used to select the best fit model (Burnham and Anderson 1998). Following were the inbuilt models in the DOBSERVE program (Nichols *et al.* 2000):

1. P(.,.) - detection probability (p) is the same for all species and both observers.
2. P(S,.) - detection probability (p) is different for each species, but equal among observers.

3. P(.,I) - detection probability (p) is equal among species but different between observers.
4. P(G,.) - detection probability (p) is equal within groups of species and equal among observers.
5. P(G,I) - detection probability (p) is equal within groups of species, but different between observers.
6. P(S,I) - detection probability (p) is different for each species and different between observers.

I could not analyse site-specific species data because of low numbers of some species hence data was pooled for such species to perform analysis.

c) *Breeding success and recruitment rate of Black-necked crane*

The breeding success of BNC was computed using formula (eq. 1) used by (Chandan *et al.* 2005) and recruitment rate (eq. 2) was calculated following Bradter *et al.* (2005).

Equation 1. Breeding Success (%)

$$\text{Breeding Success} = \frac{\text{Total no. of Fleged juvenile}}{\text{Total egg laid}} \times 100$$

Equation 2. Recruitment rate (%)

$$\text{Recruitment rate} = \frac{\text{Fleged juvenile}}{\text{Fleged juvenile} + 2 \times \text{Total number of Territorial pair}} \times 100$$

3.3. Results

3.3.1. Waterbird species

During two years of sampling, I recorded a total of 40 waterbird species (including two unidentified species of duck and wader) belonging to 8 orders and 11 families, of which 15 species breeds in CWLS (Table 3.2). A total of 10,208 and 13,481 individuals were recorded in spring, summer and autumn seasons of 2016 and 2017 respectively. The mean abundance of waterbirds was 3402.60 ± 1053.03 SE (95% CI 1623-5182.21) and 4493.61 ± 1689.42 SE (95% CI 1638.49-7348.73) in 2016 and 2017 respectively with no significant difference (95% CI) between both years (Fig. 3.2). Anatidae (45%) was the most dominated family followed by scolopacidae (13%), ardeidae (8%), laridae (8%), podicipedidae (5%), rallidae (5%), recurvirostridae (5%), motacillidae (3%), ciconiidae (3%), charadriidae (3%) and gruidae (3%).

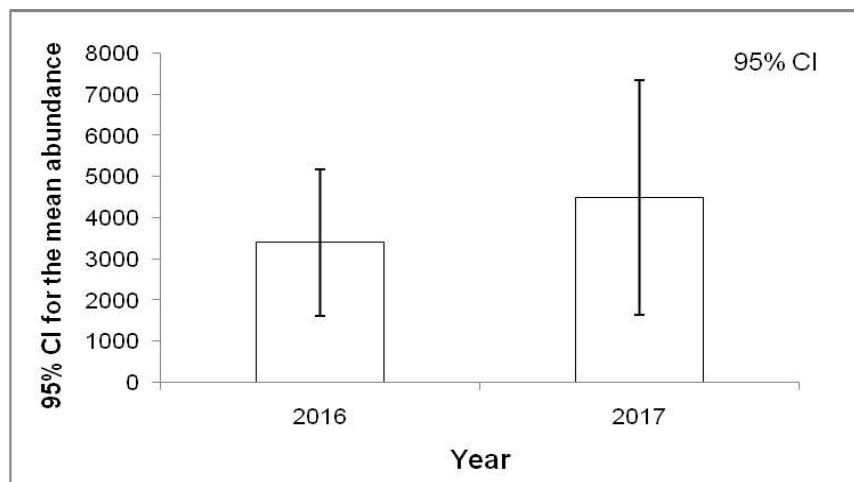


Figure 3.2. 95% Confidence Interval for the mean abundance of waterbirds during 2016 and 2017

Different species accumulation curve predicted different range of species number in CWLS (Fig. 3.3). The maximum number of species was estimated by chao estimator (59.36 ± 16.75), followed by second order jackknife predicted 58.03, first order jackknife predicted 50.56 ± 4.22 , and bootstrap method predicted 44.56 ± 2.28 species in CWLS. Due to presence of passage migrants and cryptic species, there was not species asymptote

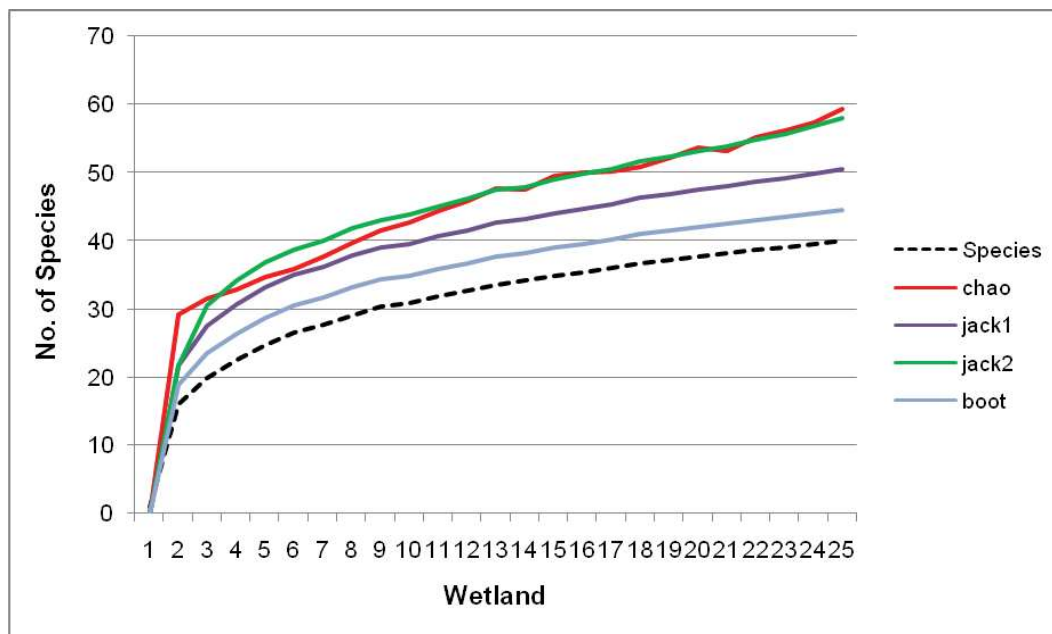


Figure 3.3. Species Accumulation Curve and prediction of species using different estimators in CWLS

However, I omitted passage migrants from species accumulation curve and reanalyzed the data. As illustrated in Fig. 3.4, the asymptote was achieved ($n=24$) after sampling of ten wetlands. Considering consistency and stability in curve, bootstrap estimator was best predictor for species richness in case of summer visitor species ($n=24$) which includes breeding and non-breeding species.

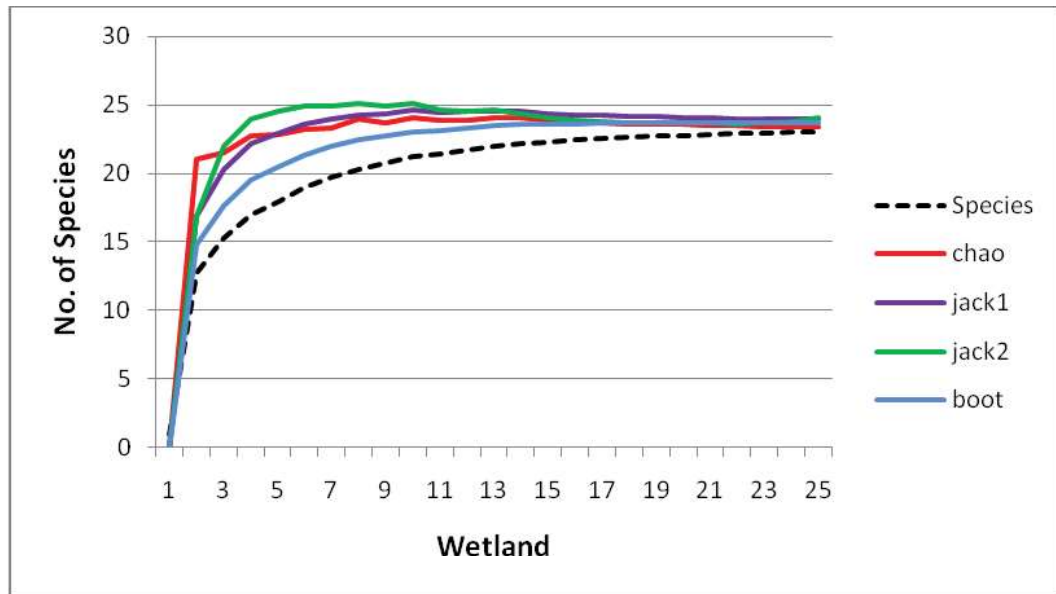


Figure 3.4. Species Accumulation Curve and prediction of summer visitor species using different estimators in CWLS

Out of 38 species, one is “Critically Endangered”, is “Vulnerable” and two are listed as “Near Threatened” on the IUCN Red List species (Table 3.2). In breeding waterbirds, ruddy shelduck (RSD) was the most widely distributed and abundant breeding waterbird species among all, followed by bar-headed goose (BHG) and brown headed gull (BrHG). During the sampling period of two years, higher number of waterbirds was recorded in autumn season (Table 3.8 and 3.12).

Table 3.2. Waterbird species listed during sampling of 2016 and 2017 in CWLS

SN	Common name	Scientific Name	IUCN status	Family
1	Bar headed Goose (BHG)	<i>Anser indicus</i>	LC	Anatidae
2	Ruddy Shelduck (RSD)	<i>Tadorna ferruginea</i>	LC	Anatidae
3	Gadwall (GDW)	<i>Anas strepera</i>	LC	Anatidae
4	Eurasian Wigeon (EW)	<i>Anas penelope</i>	LC	Anatidae
5	Mallard (MLD)	<i>Anas platyrhynchos</i>	LC	Anatidae
6	Northern Shoveler (NSH)	<i>Anas clypeata</i>	LC	Anatidae
7	Northern Pintail (NP)	<i>Anas acuta</i>	LC	Anatidae
8	Garganey (GG)	<i>Anas querquedula</i>	LC	Anatidae
9	Northern Lapwing (NP)	<i>Vanellus vanellus</i>	LC	Charadriidae
10	Common Pochard (CP)	<i>Aythya ferina</i>	LC	Anatidae
11	Ferruginous Duck (FD)	<i>Aythya nyroca</i>	NT	Anatidae
12	Tufted Duck (TD)	<i>Aythya fuligula</i>	LC	Anatidae
13	Greylag Goose (GLG)	<i>Anser anser</i>	LC	Anatidae
14	Common Merganser (CM)	<i>Mergus merganser</i>	LC	Anatidae
15	Great crested Grebe (GCG)	<i>Podiceps cristatus</i>	LC	Podicipedidae
16	Black necked Grebe (BNG)	<i>Podiceps nigricollis</i>	LC	Podicipedidae
17	Grey Heron (GH)	<i>Ardea cinerea</i>	LC	Ardeidae
18	Black Stork (BS)	<i>Ciconia nigra</i>	LC	Ciconiidae
19	Eurasian Coot (EC)	<i>Fulica atra</i>	LC	Rallidae
20	Black necked Crane (BNC)	<i>Grus nigricollis</i>	VU	Gruidae
21	Demoiselle Crane (DC)	<i>Grus vergo</i>	LC	Gruidae
22	Black tailed Godwit (BTG)	<i>Limosa limosa</i>	NT	Scolopacidae
23	Lesser sand plover (LSP)	<i>Charadrius mongolus</i>	LC	Charadriidae
24	Black winged Stilt (BWS)	<i>Himantopus himantopus</i>	LC	Recurvirostridae
25	Pied Avocet (PA)	<i>Recurvirostra avosetta</i>	LC	Recurvirostridae
26	Ruff (RUF)	<i>Philomachus pugnax</i>	LC	Scolopacidae
27	Cattle Egret (CE)	<i>Bubulcus ibis</i>	LC	Ardeidae
28	Intermediate Egret (IE)	<i>Ardea intermedia</i>	LC	Ardeidae
29	Common Redshank (CR)	<i>Tringa totanus</i>	LC	Scolopacidae
30	Common Greenshank (GSK)	<i>Tringa nebularia</i>	LC	Scolopacidae
31	Common Sandpiper (CS)	<i>Actitis hypoleucos</i>	LC	Scolopacidae
32	Eurasian Teal (EUT)	<i>Anas crecca</i>	LC	Anatidae
33	Baer's Pochard (BP)	<i>Aythya baeri</i>	CE	Anatidae
34	Pallas's Gull (PG)	<i>Ichthyaeetus ichthyaeetus</i>	LC	Laridae

35	Brown headed gull (BrHG)	<i>Chroicocephalus brunnicephalus</i>	LC	Laridae
36	Common Moorhen (CM)	<i>Gallinula chloropus</i>	LC	Rallidae
37	Common Tern (CT)	<i>Sterna hirundo</i>	LC	Laridae
38	Citrine Wagtail (CW)	<i>Motacilla citreola</i>	LC	Motacillidae
39	Unidentified Duck (UD)	---	---	---
40	Unidentified Wader (W)	---	---	---

*LC: Least Concern, NT: Near Threatened, VU: Vulnerable, CE: Critically Endangered (all endangered species in bold letters)

3.3.2. Richness and diversity of waterbirds

Overall highest number of species was recorded at Statsapuk (n=24) followed by Tsokar (n=20), Tso Moriri (n=15), and lowest was at Chakhung (n=2) and Mirpal Tso (n=2) followed by Tsegam Tso (n=3). No waterbird species was recorded at Tsoltak wetland in 2016-17. Table 3.3 depicted that, Statsapuk (1.98) was the most diverse wetland followed by Yaya Tso (1.93), whereas Mirpal Tso (0.56) was the least diverse. If considered year wise, in 2016 Statsapuk Tso (Shannon-Weiner index= 1.90) was the most diverse wetland followed by Phuktse (1.72) and least diverse was Mirpal Tso (0.56). In 2017, Lam Tso (1.93) was the most diverse wetland followed by Stastaspuk (1.82) and least was Tsegam Tso (0.69). However, no species were recorded from Mirpal Tso and Chakhung in 2017. Overall Margalef's Richness Index was highest at KyunTso II (3.33) and lowest was at Lukung (0.79). In 2016, highest score was at Phuktse (2.88) followed by Tso Moriri (2.59) and lowest was at Mirpal (0.53). In 2017, highest Margalef's Index was at Kyun Tso II (5.87) followed by Statsapuk (2.75) and lowest at Lukung (0.71). Overall Pielou Richness Index was highest at Lukung (0.92) and lowest at Puga (0.32). In 2016, Pielou Richness Index value was highest at Kyun Tso II (0.87) followed by Tsegam

Tso (0.86) and Lukung (0.86) and lowest was at Puga (0.28). While in 2017, the highest Pielou Richness Index was at Tsegam Tso (0.99) followed by Rongo (0.98) and lowest was at Puga (0.41) and Chumik Taslte (0.41). Overall dominance was highest at Tsegam Tso (0.95) and lowest at Statsapuk (0.50) and Kyagar Tso (0.50). In 2016, CDI was highest at Mirpal Tso (1) followed by Puga (0.93) and lowest was at Statsapuk (0.55). While in 2017, highest CDI was at Tsegam Tso (1) and Chakhung (1) followed by Chumik Tsalte (0.92) and lowest was at Lam Tso (0.46).

3.3.3. Similarity in wetlands based on waterbird composition

Based on waterbird species composition, Table 3.4 depicts the bray-curtis dissimilarity index. Puga and Parma (0.22) were most similar wetlands, followed by Phuktse and Indus (0.27), Chushul and Chumik Tsalte (0.29), Hanle and Staklung (0.30), Kyun Tso I and Tso Moriri (0.39), Dungti and Phuktse (0.40), Staklung and Yayatso (0.42), and Tsegam Tso and Chakhung (0.49) respectively. Despite being closely connected wetlands like Tsokar and Statsapuk (0.64), both had very less similarity in species composition, followed by Lukung and Pangong (0.91) and Kyun Tso I and II (0.98).

Table 3.3. Diversity, richness, evenness and dominance of waterbirds in different wetlands of CWLS

SN	Site	2016				2017				Combined			
		Diversity	Richness	Evenness	Dominance	Diversity	Richness	Evenness	Dominance	Diversity	Richness	Evenness	Dominance
1	Yayatso	1.56	2.12	0.65	0.68	1.68	2.23	0.70	0.62	1.93	2.82	0.73	0.51
2	Puga	0.54	1.15	0.28	0.93	0.90	1.54	0.41	0.89	0.74	1.72	0.32	0.91
3	KyagarTso	1.57	1.76	0.75	0.65	1.63	1.79	0.84	0.59	1.85	2.69	0.77	0.50
4	TsoMoriri	1.43	2.59	0.50	0.74	1.26	1.92	0.49	0.76	1.47	2.90	0.50	0.69
5	ChumikTsalle	0.78	0.80	0.49	0.89	1.02	2.03	0.41	0.92	0.99	2.11	0.40	0.89
6	LamTso	1.27	1.71	0.55	0.82	1.93	1.98	0.84	0.46	1.71	2.02	0.72	0.68
7	KyunTso.I	0.63	1.27	0.31	0.92	1.26	1.90	0.51	0.80	1.10	2.48	0.41	0.83
8	KyunTsoII	1.21	1.87	0.87	0.73	1.33	5.92	0.96	0.60	1.46	3.33	0.91	0.65
9	Hanle	1.44	1.21	0.80	0.58	1.38	1.61	0.71	0.65	1.72	2.73	0.69	0.53
10	LaiPahari	1.29	1.59	0.72	0.70	1.35	2.15	0.65	0.73	1.73	3.13	0.72	0.61
11	Rongo	1.34	2.39	0.83	0.75	1.08	0.96	0.98	0.75	1.44	2.11	0.89	0.57
12	Staklung	1.48	1.28	0.83	0.59	1.22	0.94	0.76	0.72	1.37	1.22	0.76	0.67
13	Indus	1.18	1.50	0.66	0.76	1.36	1.13	0.85	0.70	1.37	1.45	0.77	0.73
14	Dungti	1.62	1.79	0.78	0.58	1.73	2.35	0.69	0.62	1.88	2.98	0.71	0.57
15	Phuktse	1.72	2.88	0.75	0.65	1.57	2.03	0.71	0.70	1.67	3.32	0.65	0.68
16	Chushul	1.03	1.97	0.45	0.86	1.15	2.17	0.46	0.83	1.16	2.68	0.44	0.80
17	Pangong	1.49	1.54	0.68	0.65	1.49	1.55	0.65	0.65	1.53	1.98	0.61	0.65
18	Lukung	0.95	0.93	0.86	0.88	1.01	0.71	0.92	0.82	1.02	0.79	0.92	0.84
19	Parma	1.12	1.34	0.54	0.79	1.44	1.59	0.63	0.72	1.39	2.01	0.56	0.75
20	Tsegam	0.94	1.66	0.86	0.90	0.69	0.91	0.99	NA	0.86	1.74	0.78	0.95
21	Mirpal	0.56	0.53	0.81	NA	0.00	0.00	0.00	NA	0.56	0.83	0.81	NA
22	Statsapuk	1.90	2.31	0.68	0.55	1.82	2.75	0.60	0.60	1.98	3.31	0.62	0.50
23	Tso.Kar	1.65	1.94	0.64	0.64	1.69	2.71	0.58	0.66	1.80	3.05	0.60	0.60
24	Tsoltak	0.00	0.00	0.00	NA	0.00	0.00	0.00	NA	NA	NA	NA	NA

Table 3.4. Bray-Curtis Dissimilarity Index of wetlands in CWLS

	Yavatso	Puga	Kyagar Tso	Tso Moriri	Chumik	Lam Tso	Kyun TsoI	Kyun TsoII	Hanle	Lal Pahari	Rongo	Staklung	Indus	Dungti	Phuktse	Chakchung	Chushul	Pangong	Lukung	Parma	Tsegam	Mirpal	Statsapak	Tso Kar	TsoItak
Puga	0.73																								
KyagarTso	0.57	0.77																							
TsoMoriri	0.71	0.79	0.85																						
Chumik Tsalte	0.58	0.80	0.80	0.59																					
LamTso	0.58	0.71	0.75	0.79	0.58																				
KyunTsoI	0.71	0.82	0.84	0.39	0.42	0.83																			
KyunTsoII	0.96	0.97	0.90	0.99	0.99	0.97	0.98																		
Hanle	0.48	0.72	0.56	0.86	0.68	0.64	0.81	0.97																	
Lal.Pahari	0.69	0.87	0.63	0.93	0.82	0.74	0.91	0.95	0.46																
Rongo	0.93	0.95	0.88	0.98	0.96	0.94	0.97	0.80	0.88	0.75															
Staklung	0.42	0.70	0.53	0.86	0.57	0.48	0.80	0.96	0.30	0.54	0.86														
Indus	0.60	0.76	0.56	0.90	0.80	0.70	0.83	0.92	0.45	0.54	0.66	0.42													
Dungti	0.59	0.57	0.54	0.79	0.77	0.47	0.76	0.95	0.48	0.61	0.84	0.47	0.43												
Phuktse	0.55	0.72	0.40	0.88	0.74	0.71	0.81	0.91	0.37	0.53	0.74	0.36	0.27	0.40											
Chakchung	0.97	0.98	1.00	0.99	0.99	0.98	1.00	1.00	0.91	0.80	0.57	0.93	0.87	0.93	0.87										
Chushul	0.54	0.76	0.74	0.64	0.29	0.76	0.48	1.00	0.50	0.73	0.94	0.62	0.70	0.68	0.63	0.96									
Pangong	0.82	0.84	0.76	0.77	0.89	0.89	0.88	0.99	0.85	0.92	0.97	0.84	0.84	0.76	0.79	1.00	0.87								
Lukung	0.86	0.89	0.62	0.96	0.94	0.91	0.95	0.83	0.86	0.74	0.72	0.77	0.63	0.72	0.60	1.00	0.91	0.91							
Parma	0.69	0.22	0.81	0.69	0.71	0.72	0.72	0.98	0.76	0.89	0.95	0.75	0.77	0.58	0.74	0.98	0.63	0.71	0.90						
Tsegam	0.95	0.97	0.93	0.99	0.97	0.96	0.99	1.00	0.90	0.78	0.39	0.90	0.83	0.93	0.85	0.49	0.95	0.99	0.81	0.98					
Mirpal	0.95	0.97	0.89	0.99	0.96	0.97	0.98	1.00	0.92	0.82	0.67	0.92	0.86	0.94	0.88	1.00	0.96	0.98	0.69	0.98	0.54				
Statsapak	0.84	0.78	0.93	0.66	0.86	0.86	0.83	0.99	0.93	0.96	0.99	0.92	0.95	0.88	0.94	1.00	0.84	0.82	0.98	0.72	0.99	0.99			
Tso.Kar	0.72	0.47	0.86	0.67	0.79	0.78	0.73	0.99	0.85	0.93	0.98	0.86	0.90	0.77	0.88	0.99	0.75	0.84	0.96	0.45	0.99	0.99	0.64		
TsoItak	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

3.3.4. Waterbird species composition

The closeness of wetlands depicted similarity in species composition and spanning tree showed Tsoltak out from the cluster of wetlands as there were no species recorded during sampling (Fig. 3.5). In Dimension 1 (A), Tsokar and Tso Moriri, Parma and Kyun Tso I were closely associated and wetlands with resemblance in species composition were Statsapuk, Pangong, Puga and Chumik Tsalte. Dimension 1 (B) was a cluster of five wetlands. Mitapal Tso was connected with Rongo, Tsegam, Chakhung and Kyun Tso II. Tsoltak was an exception in this cluster with no association with any of above wetlands. Dimension 2 (C) was comprised of close association of Staklung and Hanle, YayaTso and Lam Tso with Chushul and Dungti. Dimension 2 (D) was clustered with wetlands like Phuktse, Indus, Lal Pahari and Kyagar Tso, with Lukung at some distance. Chushul and Chumik Tsalte were situated at mid point depicting similarity with other wetlands. Utmost located wetlands like Tsegam Tso, Statsapuk and Staklung had unque assemblage than other wetlands.

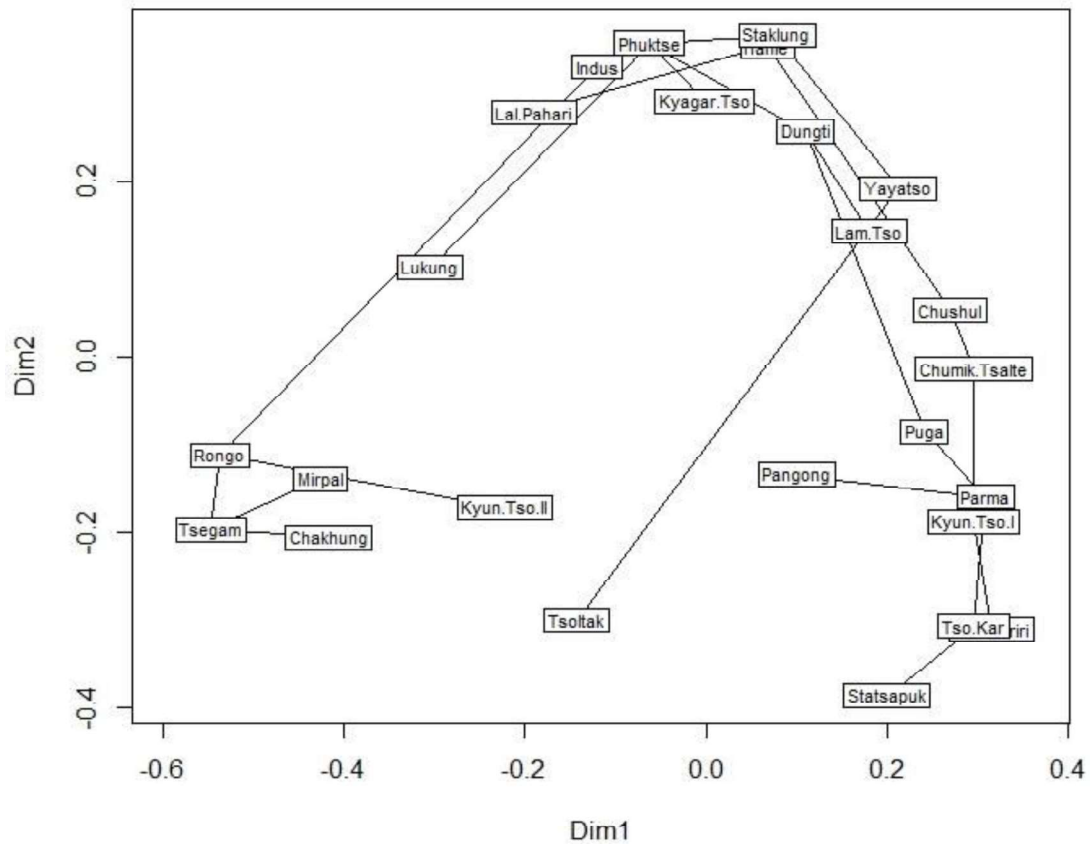


Figure 3.5. Wetland Grouping based on waterbird assemblage using maximum spanning tree

3.3.5. Status of waterbirds across the seasons of 2016-17

Significant seasonal variation in the mean abundance of RSD was found among three seasons (spring, summer and autumn) during 2016 (KW, $\chi^2 = 57.17$, $df=2$, $p < 0.001$) and 2017 (KW, $\chi^2 = 24.73$, $df=2$, $p < 0.001$), and also recorded in BHG during 2016 (KW, $\chi^2 = 32.09$, $df=2$, $p < 0.001$) and 2017 (KW, $\chi^2 = 32.09$, $df=2$, $p < 0.001$). However, no significant difference was found in mean abundance of BrHG (KW, $\chi^2 = 5.32$, $df=2$, $p > 0.05$) in 2016 and 2017 (KW, $\chi^2 = 5.50$, $df=2$, $p > 0.05$).

a) Abundance of waterbirds in spring season

In CWLS, the best fit model in 2016 was P(S,I) (AIC=61.84) and in 2017 was P(G,I) (AIC=110.66) (Table 3.5). RSD abundance varied between $n=346\pm 0.15$ (SE) (relative abundance 24%) and $n=481\pm 0.61$ (19%) during spring season of 2016 and 2017 respectively. BHG numbers also varied between $n=627\pm 0.98$ (43%) and $n=934\pm 0.86$ (36%) during springs of 2016 and 2017 respectively. Numbers of BrHG varied between $n=343\pm 0.87$ (23%) and $n=552\pm 0.66$ (21%) during springs of 2016 and 2017. Abundance of RSD and BrHG was almost equal during both the years. Few individuals of common redshank (CRS), northern pintail (NPN), gadwall (GDW) and mallard (MLD) were recorded during spring season (Table 3.8; Appendix 3.1).

Table 3.5. AIC values of top three models in spring season

2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF
P(S,I)	-16.92	0	61.84	62.13	61.84	1	P(G,I)	-51.33	28	110.66	110.7	110.7	.0497
P(G,I)	-52.27	10	112.55	112.6	112.5	.0000	P(.,I)	-54.67	30	113.33	113.3	113.3	.0197
P(.,I)	-55.40	12	114.81	114.8	114.8	.0000	P(S,.)	-53.95	17	137.89	138.1	137.9	.0001

b) Abundance of waterbirds in summer season

In 2016, lowest AIC value was recorded for model P(G,I) (AIC=171.38) and in 2017 AIC was for model P(S,.) (AIC=149.47) (Table 3.6). The abundance of RSD varied between $n=799\pm 1.17$ (22%) and $n=637\pm 0.28$ (21%) during summers of 2016 and 2017 respectively. The highest number of BHG was recorded during summers of 2016 and

2017 across three seasons, 1489 ± 1.62 (41%) and 1270 ± 0.79 (42%) respectively. BrHG abundance also peaked during summers across three seasons (2016= 657 ± 1.06 (18%), 2017= 577 ± 1.59 (19%)). Whereas, Eurasian coot (CC), NPN, GDW and MLD were relatively low or absent during summers of 2016 and 2017 (Table 3.8; Appendix 3.1).

Table 3.6. AIC values of top three models in summer season

2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF
P(G,I)	-81.69	10	171.38	171.4	171.4	.0000	P(S,.)	-65.74	9	149.47	149.5	149.5	.0000
P(.,I)	-91.06	12	186.13	186.1	186.1	.0000	P(.,I)	-74.17	16	152.33	152.3	152.3	.0000
P(S,.)	-98.57	7	211.15	211.2	211.1	.0000	P(G,I)	-72.65	14	153.30	153.3	153.3	.0000

c) Abundance of waterbirds in autumn season

In 2016, lowest AIC value was for model P(.,I) (AIC=213.7) and in 2017 AIC was lowest for model P(S,I) (AIC=151.30) (Table 3.7). During this season most of the waterbirds' abundance was high, RSD abundance was highest in autumn across all seasons and varied between $n=1594 \pm 2.1$ (31%) and $n=1644 \pm 1.33$ (21%) in 2016 and 2017 respectively. However, abundance of BHG was slightly low during autumns of 2016 and 2017 with $n=737 \pm 1.42$ (14%) and $n=1123 \pm 1.02$ (14%) respectively. BrHG abundance was also lowest across all three seasons with $n=262 \pm 0.84$ (5%) and $n=242 \pm 0.27$ (3%) in 2016 and 2017 respectively. In contrast, CC, NP, GDW, MLD abundance was highest during both autumns. Unidentified ducks/juveniles abundance was also high during autumns of 2016 and 2107 (Table 3.8; Appendix 3.1).

Table 3.7. AIC values of different models in autumn season

		2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF		
P(.,I)	-104.9	20	213.71	213.7	213.7	.0000	P(S,I)	-49.65	0	151.30	151.5	151.3	1		
P(G,I)	-103.5	18	214.96	215	215	.0000	P(S.,)	-89.50	13	205	205	205	.0000		
P(S.,)	-100.4	11	222.74	222.8	222.7	.0000	P(G.,)	-109	24	221.94	221.9	221.9	.0000		

Table 3.8. Abundance of key waterbirds in Changthang Wildlife Sanctuary

SN	Species	Year	Season	Selected Model	Detection Probability±SE	N	SE(N)	95% (LCI)	95% (UCI)
1	Ruddy Shelduck	2016	Spring	P(S,I)	.9999±.0001	346.02	0.15	346	347.07
			Summer	P(G,I)	.9983±.0002	799.35	1.17	798.31	803.88
			Autumn	P(.,I)	.9973±.0002	1594.27	2.1	1591.71	1600.65
			Mean			913.21			
			Spring	P(G,I)	.9992±.0001	481.37	0.61	481.04	484.51
2	Bar headed Goose	2016	Summer	P(S.,)	.9999±.0001	637.08	0.28	637	638.91
			Autumn	P(S.,)	.9990±.0002	1644.65	1.33	1643.41	1649.6
			Mean			921.03			
			Spring	P(S,I)	.9986±.0005	626.85	0.98	626.14	631.17
			Summer	P(G,I)	.9983±.0002	1489.51	1.62	1487.79	1494.98
			Autumn	P(.,I)	.9973±.0002	736.97	1.42	735.56	741.99
			Mean			951.11			

6	Eurasian Coot	2016	Mean				231.48							
			Spring	P(S,I)	-		2	-	-	-	-	-	-	
			Summer	P(G,I)	.9983±.0002		29.05	0.22	29	30.52				
			Autumn	P(.,I)	.9973±.0002		461.23	1.12	460.27	465.63				
			Mean			164.09								
			Spring	P(G,I)	.9992±.0001		61.05	0.22	61	62.48				
			Summer	P(S.,)	.9992±.0017		8.01	0.08	8	8.54				
			Autumn	P(S.,)	.9969±.0006		1043.19	1.89	1041.09	1049.36				
			Mean			370.75								
7	Common Redshank	2016	Spring	P(S,I)	-		-	-	-	-	-	-		
			Summer	P(G,I)	.9983±.0002		282	-	-	-	-	-		
			Autumn	P(.,I)	.9973±.0002		2.01	0.07	2	2.48				
			Mean			95								
			Spring	P(G,I)	.9992		10.01	0.09	10	10.58				
			Summer	P(S.,)	.9993±.0005		144.1	0.33	144	146.17				
			Autumn	P(S.,)	.9996±.0002		144.06	0.25	144	145.66				
			Mean			99.39								
			Spring	P(S,I)	-		19	-	-	-	-	-	-	
			Summer	-		-	-	-	-	-	-	-	-	
8	Northern Pintail	2016	Autumn	P(.,I)	.9973±.0002		711.91	1.39	710.53	716.87				
			Mean			243.64								
			Spring	P(G,I)	.9992±.0001		63.05	0.22	63	64.51				
			Summer	P(S.,)	.9992±.0017		2	0.04	2	2.23				
			Autumn	P(S.,)	.9989±.0005		342.38	0.64	342.04	345.67				
			Mean			135.81								
			Spring	-		-	-	-	-	-	-	-	-	
			Summer	-		-	-	-	-	-	-	-	-	
9	Gadwall	2016	Spring	-		-	-	-	-	-	-	-		
			Summer	-		-	-	-	-	-	-	-		
			Mean											

			Autumn	P(.,I)	.9973±.0002	150.4	0.64	150.04	153.61
			Mean			150.4			
			Spring	P(G,I)	-	1	-	-	-
		2017	Summer	-	-	-	-	-	-
			Autumn	P(S.,)	.9985±.0005	471.7	0.87	471.11	475.67
			Mean			157.57			
			Spring	P(S,I)	-	6	-	-	-
		2016	Summer	-	-	-	-	-	-
			Autumn	P(.,I)	.9973±.0002	29.08	0.28	29	30.87
			Mean			11.69			
			Spring	P(G,I)	1	8	-	-	-
		2017	Summer	-	-	-	-	-	-
			Autumn	P(S.,)	.9990±.0009	83.08	0.29	83	84.96
			Mean			30.36			
			Spring	P(S,I)	1	3	-	-	-
		2016	Summer	P(G,I)	.9983±.0002	32.05	0.23	32	33.59
			Autumn	P(.,I)	.9973±.0002	394.05	1.03	393.21	398.26
			Mean			143.03			
			Spring	P(G,I)	.9992±.0001	13.01	0.1	13	13.67
		2017	Summer	P(S.,)	.9993±.0005	14.01	0.1	14	14.68
			Autumn	P(S.,)	.9990±.0002	1941.91	1.43	1940.52	1947.06
			Mean			656.31			

3.3.6. Wetland wise seasonal abundance of waterbirds

a) *Abundance of waterbirds in spring season*

The best fit model for 2016 was P(.,I) with AIC=96.53 and in 2017, P(S,I) model had lowest AIC=74.02 (Table 3.9). In Table 6, large wetlands such as Pangong Tso, mean abundance of waterbirds varied between $n=261\pm0.54$ and $n=366\pm0.53$ in 2016 and 2017 respectively. In Tso Moriri, abundance varied between $n=367\pm0.65$ and $n=728\pm0.076$ during 2016 and 2017 respectively. In Chushul wetland complex, mean abundance varied between $n=100\pm0.34$ and $n=164\pm0.32$ during 2016 and 2017 respectively. Least abundance was recorded in Parma-Harong wetland complex (Table 3.12). In medium sized wetlands, Statsapuk was most abundant with $n=197\pm0.47$ individuals in 2016 and $n=665\pm0.72$ in 2017 and Kyun Tso-II was least abundant with < 2 individuals during both spring seasons. While nearby wetland, Kyun Tso-I had $n=52\pm0.24$ and $n=16$ individuals of waterbirds during 2016 and 2017 respectively. In small wetlands, Lam Tso had 78 ± 0.3 and 42 ± 0.18 mean population during 2016 and 2017 respectively. Abundance of all wetlands is given in Appendix 3.2.

Table 3.9. AIC values of top three models in spring season

2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF
P(.,I)	-46.27	14	96.533	96.54	96.53	.0000	P(S,I)	-23.01	0	74.021	74.19	74.02	1
P(G,I)	-44.67	12	97.344	97.37	97.34	.0000	P(G,I)	-37.27	10	82.548	82.56	82.55	.0015
P(S,.)	-73.90	8	163.80	163.9	163.8	.0000	P(.,I)	-40.92	12	85.847	85.85	85.85	.0003

b) Abundance of waterbirds in summer season

In 2016, P(S,I) had lowest AIC=114.10 value and in 2017, P(.,I) , model was best fit with AIC=116.75 (Table 3.10). In large wetlands, most abundant wetland was Tsokar with $n=719\pm 1.05$ and $n=545\pm 0.54$ individuals of waterbirds during 2016 and 2017 respectively. The mean abundance of waterbirds varied between $n=149\pm 0.47$ and $n=265\pm 0.53$ in Pangong during summers of 2016 and 2017 respectively. Parma-Harong complex was least abundant wetland among large wetlands. In medium wetlands, Kyun Tso-I had $n=606\pm 0.96$ in 2016 and 455 ± 0.49 in 2017 respectively. The least abundant wetlands were Kyun Tso-II and Mirpal Tso (Table 3.12). In small wetlands, Statspuk was most abundant ($n=810\pm 1.11$ in 2016 and $n=563\pm 0.33$ in 2017) and Tsegam Tso was the least (Table 3.12). Abundance of all wetlands is given in Appendix 3.2.

Table 3.10. AIC values of top three models in summer season

2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF
P(S,I)	-35.05	0	114.10	114.4	114.1	1	P(.,I)	-56.37	16	116.75	116.8	116.7	.0000
P(G,I)	-88.37	18	184.75	184.8	184.7	.0000	P(G,I)	-54.92	14	117.84	117.9	117.8	.0000
P(.,I)	-94.48	20	192.95	193	193	.0000	P(S,.)	-68.42	9	154.84	154.9	154.8	.0000

c) Abundance of waterbirds in autumn season

During both the years, P(S,I) model was suitable with AIC= 136.80 in 2016 and AIC=169.69 in 2017, respectively (Table 3.11). The abundance of waterbirds was highest during both sampling autumns. In Large wetland category, Tsokar was the most

abundant wetland with mean abundance $n=709\pm 2.07$ and $n=894\pm 1.18$ in 2016 and 2017 respectively. Least abundant was Mirpal Tso. In the medium size wetlands, Kyun Tso-I had 80 ± 0.44 and 504 ± 0.51 individuals during 2016 and 2017 respectively. The least abundant wetland was Kyun Tso II (Table 6). In small wetlands, Statsapuk was the most abundant with $n=1166\pm 1.91$ and $n=3044\pm 1.92$ individuals during 2016 and 2017 respectively and least abundant was Tsegam Tso (Table 3.12). Abundance of all wetlands is given in Appendix 3.2.

Table 3.11. AIC values of top three models in autumn season

2016							2017						
Model	LL	NDF	AIC	AICc	QAIC	GOF	Model	LL	NDF	AIC	AICc	QAIC	GOF
P(S,I)	-46.40	0	136.80	137	136.8	1	P(S,I)	-54.84	0	169.69	169.9	169.7	1
P(S,.)	-96.24	11	214.48	214.5	214.5	.0000	P(S,.)	-115.4	15	260.74	260.8	260.7	.0000
P(G,I)	-106.1	18	220.22	220.2	220.2	.0000	P(G,.)	-153.5	28	311.09	311.1	311.1	.0000

Table 3.12. Abundance of waterbirds in key wetlands of CWLS

SN	Wetland	Year	Season	Model	Detection Probability	N	SE(N)	95% (LCI)	95% (UCI)	
1	YayaTso	2016	Spring	P(.,I)	.9989±.0003	19.02	0.15	19	20	
			Summer	P(.,I)	.9985±.0002	20.03	0.17	20	21.2	
			Autumn	P(S.,)	.9995±.0003	302.15	0.39	302.01	304.51	
				Mean		113.73				
		2017	Spring	P(G,I)	1	10	-	-	-	-
			Summer	P(.,I)	.9995±.0001	40.02	0.15	40	41.01	
			Autumn	P(S,I)	.9995±.0004	215.11	0.34	215.01	217.24	
		Mean		88.38						
2	Puga	2016	Spring	P(.,I)	.9989±.0003	95.11	0.33	95.01	97.14	
			Summer	P(.,I)	.9985±.0002	49.07	0.27	49	50.82	
			Autumn	P(S.,)	.9974±.0008	431.14	1.13	430.23	435.74	
				Mean		191.77				
		2017	Spring	P(G,I)	.9992±.0001	115.09	0.3	115	116.98	
			Summer	P(.,I)	.9995±.0001	213.11	0.34	213.01	215.2	
			Autumn	P(S,I)	.9999	216.01	0.11	216	216.74	
		Mean		181.40						
3	TsoKar	2016	Spring	P(.,I)	.9989±.0003	65.07	0.27	65	66.81	
			Summer	P(.,I)	.9985±.0002	719.08	1.05	718.22	723.33	
			Autumn	P(S.,)	.9948±.0011	709.69	2.07	707.32	716.3	
				Mean		497.95				
		2017	Spring	P(G,I)	.9992±.0001	120.09	0.31	120	122.02	
			Summer	P(.,I)	.9995±.0001	545.29	0.54	545.03	548.2	
			Autumn	P(S,I)	.9986±.0004	894.26	1.18	893.27	898.96	
		Mean		519.88						

4	Statsapuk	Spring	P(.,I)	.9989±.0003	197.22	0.47	197.02	199.88
		Summer	P(.,I)	.9985±.0002	810.21	1.11	809.26	814.61
		Autumn	P(S.,)	.9972±.0005	1166.27	1.91	1164.13	1172.47
		Mean		724.57				
		Spring	P(G,I)	.9992±.0001	664.51	0.72	664.07	667.98
		Summer	P(.,I)	.9995±.0001	563.3	0.55	563.03	566.24
		Autumn	P(S,I)	.9955±.0022	3044.45	1.92	3042.25	3050.57
		Mean		1424.09				
5	KyagarTso	Spring	P(.,I)	.9989±.0003	5.01	0.07	5	5.49
		Summer	P(.,I)	.9985±.0002	94.14	0.38	94.01	96.4
		Autumn	P(S.,)	.9976±.0006	62.15	0.39	62.01	64.45
		Mean		53.77				
		Spring	P(G,I)	.9992±.0001	21.02	0.13	21	21.87
		Summer	P(.,I)	-	-	-	-	-
		Autumn	P(S,I)	.9999	64	0.06	64	64.37
		Mean		28.34				
6	TsoMoriri	Spring	P(.,I)	.9989±.0003	367.41	0.65	367.05	370.68
		Summer	P(.,I)	.9985±.0002	628.94	0.98	628.18	633.04
		Autumn	P(S.,)	.9990±.0004	532.55	0.76	532.07	536.21
		Mean		509.63				
		Spring	P(G,I)	.9992±.0001	727.56	0.76	727.08	731.13
		Summer	P(.,I)	.9995±.0001	533.28	0.53	533.03	536.17
		Autumn	P(S,I)	.9996±.0004	275.12	0.36	275.01	277.39
		Mean		511.99				
7	Lam Tso	Spring	P(.,I)	.9989±.0003	78.09	0.3	78	79.97
		Summer	P(.,I)	.9985±.0002	67.1	0.32	67	69.09
		Autumn	P(S.,)	.9951±.0012	484.37	1.66	482.69	490.16
		Mean		197.22				

3.3.7. Abundance and breeding success of Black-necked crane

Out of 25 wetlands (Chakhung was added later), BNC presence was recorded in 18 wetlands including 12 breeding sites. Among all wetlands, Hanle and Chushul had maximum number of BNC individuals including breeding pairs. The population of BNC varied between 61-76 individuals during 2016 and 2017 exercise (Fig. 3.6). In 2016, a total of 67 adults, 10 sub-adults and 20 juveniles were recorded in CWLS. During spring the total number of BNC was about $n=62$, in summer $n=71$ and in autumn $n=61$. In 2017, spring population was about $n=65$, in summer $n=76$ and in autumn $n=62$. The mean population of BNC was 66.33 ± 5.04 SE (95% CI 44.6-88) and 69 ± 4.51 SE (95% CI 49.60-88.40) in 2016 and 2017 respectively with no significant difference (95% CI). In 2016, the mean flock size of BNC was 1.74 ± 0.09 SE (range 1-4) and 1.78 ± 0.13 SE (range 1- 6) in 2017.

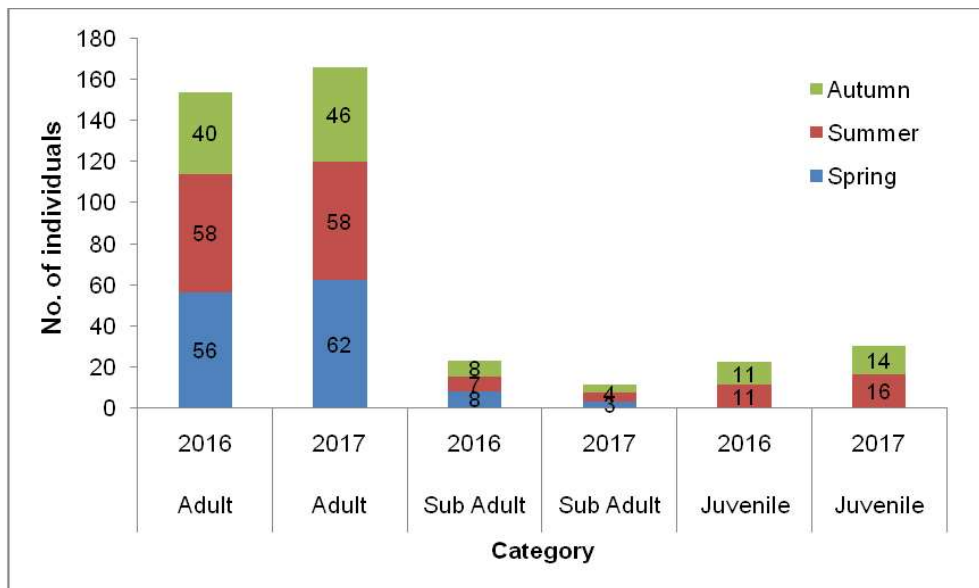


Figure 3.6. Seasonal population (total count) of Black-necked crane in CWLS

In the two breeding sites of BNC namely Tso Moriri (Kiangdom) and Tsegam Tso (highest elevational breeding site), thawing (melting of glacier snow and rise in water level in wetland) was a key reason for breeding failure which I observed during both the years of monitoring. Breeding in many sites were affected by the presence of free ranging dogs (Table 3.13). Dogs were observed predated on chicks and eggs of BNC in Lal Pahari, Hanle and Yaya Tso areas and even chasing adults and sub adults in Hanle and Rongo. I also recorded a few new locations of BNC in CWLS, one breeding pair was recorded each at Tsegam Tso, Chakhung and Chumik Tsalte wetlands, and two adult individuals were sighted at Kyun Tso-I.

Table 3.13. Breeding Success of Black-necked Crane in CWLS

S. No.	Details	2016	2017
1.	Total Pairs	29	31
	Breeding Pairs	19	21
	Total eggs laid	38	42
2.	Egg/chick lost	27	28
	Predation by dogs	9	11
	Thawing	2	4
	Unknown reasons	16	13
3.	Fledged	11	14
	Breeding Success (%)	29	33
	Recruitment (%)	16	18

Across two years, breeding success varies between 29 to 33% in 2016 and 2017 respectively, and recruitment rate in population was about 16% in 2016 and 18% in 2017 (Table 3.13). The previous information on breeding success of BNC and present study showed a decline trend ($R^2 = 0.44$) between 1995 and 2017 (Fig. 3.7; Appendix 3.3).

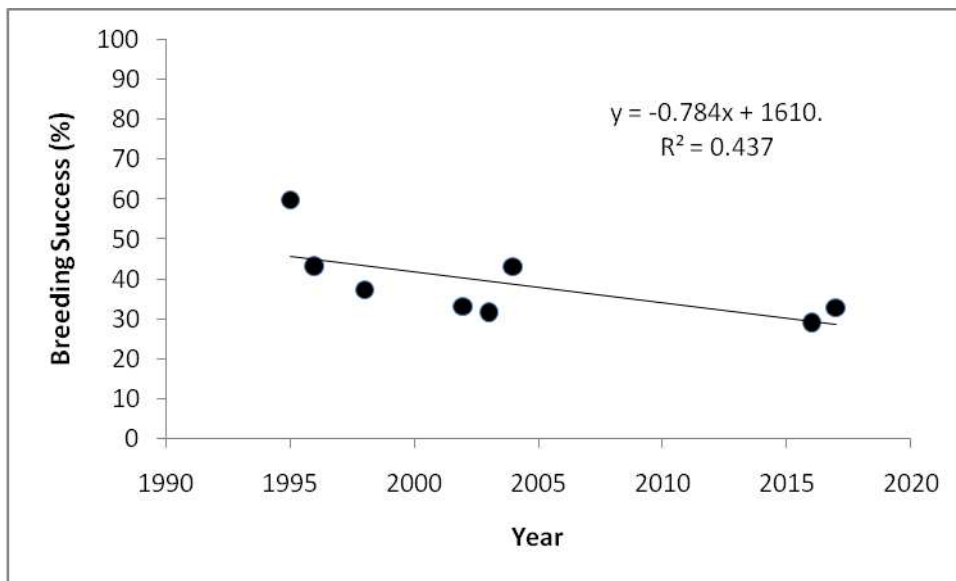


Figure 3.7. Breeding success trend (1995-2017) of Black-necked crane in CWLS (1995-2005 trend review in Chandan et al. 2005 in Appendix 3.3)

3.4. Discussion

The highest number of species (n=44) in CWLS was recorded by Hussain and Pandav (2008). While in present study, 40 species were recorded slike previous study (Jamwal *et al.* 2020). Studies by Mishra and Humbert-Droz 1998; Prins and Wieren 2004; Hussain *et al.* 2008; Namgail *et al.* 2009; recorded less than 20-30 species in Ladakh as most of these studies were restricted to few wetlands of CWLS, whereas I sampled all known 24 wetlands of CWLS.

Statsapuk was the most diverse and abundant wetland among all as recorded like previous studies (Hussain *et al.* 2008; Namgail *et al.* 2009; Jamwal *et al.* 2020). Despite being closely connected (<5 km), wetlands like Tsokar and Statsapuk, Pangong and Lukung, Kyun Tso I and II showed high dissimilarity in species composition apparently, owing to the wetland property as reviewed by Ma *et al.* (2010). Despite having smaller size, abundance of waterbird was high in wetlands like Statsapuk, Lam Tso and Chumik Tsalte. Alike previous study by Lehtikoinen *et al.* (2017), size of water body was not found to be a factor for high abundance of waterbirds. Larger water bodies namely Pangong Tso and Tso Moriri were less abundant than Statsapuk Tso. The availability of food resources like vegetation, fish and invertebrates in shallow water and shores could be the reason of high waterbird abundance (Namgail *et al.* 2009). Similarly, resource availability and environmental heterogeneity attributed to species richness and diversity (Keddy 2000).

In Ladakh, previous studies have used total count method using two observers to estimate waterbird abundance (Mishra and Humbert-Droz 1998; Prins and Wieren 2004; Namgail *et al.* 2009). Whereas, Hussain *et al.* (2008) used encounter rates to depict waterbird abundance in the different wetlands. In photo counts, there are fewer chances of observer fatigue and missing observations (Boyd 2000). The low standard error in the abundance estimation indicates high detection probability by both observers (>0.95) (Nichols *et al.* 2000). Due to vast open habitat and with less dense vegetation cover (absence of tall grasses and trees), detectability was high (0.99). Further, photo counts enhanced the accuracy in counts for larger flocks (>20). Presence of few of the globally

threatened species depicts the significance of CWLS's wetlands, occurrence of species like BTG and BP in Phuktse and Tso Moriri wetlands respectively, holds high global conservation value. Detection of cryptic species always remains an issue in population count (Mancke and Gavin, 2000; Odell and Knight 2001). Detection of small wader species was one of the major limitations in the present study, especially species with disruptive coloration.

Comparatively, high number of waterbirds during autumn season was due to passage migrants. During autumn season, waterbirds migrate towards their wintering sites in south Asia and other known sites, and these migrants use wetlands of CWLS as their stopover sites during their long migration (Ali and Ripley 1978). WII (2014) confirmed winter migration of BHG from CWLS to Gharana wetland, Jammu through collar band recovery. Our radio-telemetry study revealed that BHG moved in between wetlands of India and Pakistan during winters however we couldn't track their summer migration towards Ladakh (Mahar *et al.* 2015). Hence, CWLS has strategic location in Central Asian Flyway which provides refuge to different passage migrant species. Furthermore, CWLS is harbouring considerable amount of breeding population of different species. For instance, India supported 17.8-30.5% of global wintering population of BHG in between 2003 and 2007 (Li *et al.* 2009). While CWLS harbours the only existing breeding population of BHG in India that is about 2% of the total global population. Long term monitoring of waterbird arrival in different seasons might be useful for management practice. Another breeding species RSD is one of the most abundant waterbirds in CWLS. Apart from that, only Sikkim and Chandra tal in

Himachal Pradesh has breeding records in Indian Trans-Himalayas till date (Ganguly-Lachungpa 1998; Thakur and Mehta 2016).

Additionally, population of BNC in CWLS is only regular breeding population in India and outside China at present. Previously, few breeding pairs had reported from high altitudes of Sikkim (Ganguly-Lachungpa 1998; Ghose *et al.* 2012). The seasonal change in population dynamics of BNC was recorded perhaps, owing to close connectivity with the wetlands of Tibet which resulted frequent movement within wetlands of CWLS and Tibet as suggested by previous telemetry study (WII 2014). The largest breeding population of BNC exists in China mainly in Tibet, Qinghai, Gansu, Sichuan and in parts Xinjiang Provinces (Li 2014). Despite decline in its global population, new breeding sites have been continuously reported by scholars (Chandan *et al.* 2014; Han *et al.* 2018), however, this can be artefact of limited surveys and accessibility issues in high mountains. The global decline in the population of BNC is due to various anthropogenic pressures (Birdlife International 2017). Predation by carnivores including red and Tibetan foxes, and herding dogs largely affects the breeding success of BNC in China (Farrington and Zhang 2013; Zang *et al.* 2017a). Additionally, presence of livestock, human and dogs are key disturbance factors to the incubating pairs (Li and Ma 1989). In my study, predation and flood were the key issues of breeding failure. In comparison to previous studies, breeding success was almost similar to China (Zhang *et al.* 2017a), but present study shows decline in breeding success in Ladakh since 1995 (Fig. 3.7).

Chapter 4: Habitat use by waterbirds

4.1. Introduction

Given that various environmental factors regulate distribution of waterbirds around the globe, climate change may likely cause distributional range shift of waterbird species and perhaps further lead to decline in their population (Lehikoinen *et al.* 2013; Ramirez *et al.* 2018). On a local scale, multiple site-specific factors alter the behaviour and habitat of species, and further negative factors compel smaller population towards extinction (Shaffer 1981). Hence, studying site-specific and endangered species is empirical for prompt conservation actions (Wright *et al.* 2013). Habitat use has several implications in the management of waterbirds by indicating factors affecting their distribution and abundance (Larson *et al.* 2004; Brandolin and Blendinger 2016). Habitat use can be defined as “*the way an organism use the physical and biological resources in a habitat. Further it can be elaborated as habitat can be used for breeding, foraging, denning and escaping*” (Krausman 1999). The multiple habitat use of several migratory shorebird species is driven by their spatio-temporal requirements (Jackson *et al.* 2019).

Usually, the ecological requirement of waterbird species varies with salinity, water depth, pH, type of wetland etc. (Ma *et al.* 2010). Often, decline in abundance of waterbirds is attributed to the physiochemical properties of wetlands (Aarif *et al.* 2014). Vegetation and landscape features also shape abundance and distribution of waterbirds (Halse *et al.* 1995; King *et al.* 2010, Rosselli and Stiles 2012). Waterbird abundance also gets affected by availability of fish and invertebrates in their habitats (Zou *et al.* 2008;

Baschuk *et al.* 2012). Many studies have shown wetland size as another empirical factor which influences abundance of waterbirds (Paracuellos and Telleria 2004; Paracuellos 2006; Murray *et al.* 2013; Sebastián-González and Green 2014). High species richness/abundance of waterbirds in any given wetland indicates high resource quality and availability of mosaic of habitats (González-Gajardo *et al.* 2009).

Generally, several species show sensitivity towards anthropogenic factors such as livestock grazing, hunting, tourism, pollutants, predation, invasion, trampling of eggs and nests (Quan *et al.* 2002; Gan *et al.* 2007; Cardoni *et al.* 2008; Villamagna *et al.* 2012; Tavares *et al.* 2015; Ramachandran *et al.* 2017). Excessive presence of heavy metals and chemical contamination in water pose severe threats to dependent species including waterbirds (Eriksson 1984; Murray and Hamilton 2010). For instance, in China, more than 60% threatened waterbird species have negatively influenced by pollution (Wang *et al.* 2018). Also, human activities like mining have caused decrease in waterbird abundance in wetlands in around the globe (Aarif *et al.* 2015).

Colonial breeding waterbirds have also been considered as flagship or umbrella species of aquatic ecosystem (Brandis and Bino 2016). They are the key factors for receiving attention and subsequent implementation for conservation measures (Yang and Zhang 2014; RAMSAR 2018). Breeding waterbirds are found to be more susceptible to environmental changes (Ronka *et al.* 2005). Human activities are found to be negatively affecting nesting waterbirds in some wetlands (Carney and Sydeman 1999; Brandis *et al.* 2018). Consequently, breeding waterbirds have reported as to abandoning their nests and

nesting sites (Li *et al.* 2017). Additionally, livestock grazing also increase chances of breeding failure in waterbirds (Kirsch 1969; Harrison *et al.* 2017). On the landscape level, landuse changes have also altered habitats of waterbirds (Liu *et al.* 2010).

In Indian context, several studies have been conducted on habitat use of waterbirds using different approaches (Nagrajan and Thiyagesan 1996; Namgail *et al.* 2011; Aarif *et al.* 2014; Sundar *et al.* 2018). However, there is a gap of information regarding habitat use of waterbirds in high altitude wetlands of India. Trans-Himalayan wetlands of Ladakh are prime breeding habitats of 19 species of waterbirds (Hussain and Pandav 2008). The waterbirds use a variety of habitats, which includes lacustrine, paulstrine marshes, varying alkaline water lakes and riverine wetlands. In case of Ladakh, livestock grazing is intense and concentrated around the wetlands, and most of the time availability of high nutrient value in fodder species restricts waterbirds' movement around the wetlands. Better transport facilities and picturesque Trans-Himalayan lakes have resulted tourism increase in Ladakh (Geneletti and Dawa 2009). Onset of spring attracts millions of tourists in Trans-Himalayan lakes like Pangong, Tsokar and Tso Moriri. Considering significance of ecological and anthropogenic factors in influencing occurrence of waterbirds, the present chapter determines the habitat use by breeding waterbirds in CWLS.

4.2. Methodology

4.2.1. Field Sampling

The intensive study was conducted in the 13 major wetlands of CWLS. I recorded habitat used by each flock/individual during waterbird count exercise during peak summer season of 2016. Waterbird recorded during sampling period was assumed to be using resources at the particular wetland (Hamilton *et al.* 2002). Sampling was conducted in a closed time during the morning to afternoon hours (6:00 and 13:00 hr). I divided activity of waterbirds in five different categories, (i) loafing (ii) nesting (iii) foraging and (iv) escaping (Krausman 1999; Mancini *et al.* 2018). The broad habitat categories used by waterbirds were divided into seven, (i) water (ii) sand (iii) saltpan (iv) marsh (v) grass (vi) bog and (vii) barren (cliff/ boulders).

To identify key parameters influencing waterbirds, I collected different habitat parameters which were divided into two categories; (i) ecological (ii) anthropogenic variables. In ecological variables, data on waterbird abundance (Chapter 3), wetland properties (area, water quality) and disturbance factors were collected (Table 4.1). Within studied wetlands, I collected aforementioned variable at each sampling point. Based on field based ecological understanding and literature based knowledge (Ma *et. al* 2010), nine continuous explanatory variables were collected. The elevation and water properties (pH and salinity) were recorded at each point. Total area of wetlands was calculated using ArcGIS spatial analysis software. Total number of free ranging dogs and *kiang* (Tibetan wild ass) were recorded at each point. In anthropogenic variables,

euclidean distance to nearest human settlement and nearest road was calculated from each point. It was assumed that presence of *kiang*, dogs and humans tend to have some level of effect on breeding waterbirds thus, included them for multivariate analysis.

Table 4.1. Details of different explanatory variables collected during sampling

SN	Explanatory Variables	Range or Unit
1	Elevation of the survey point (Ele)	Meters
2	Shoreline depth (Depth)	centimeters
3	pH of water (pH)	4-10
4	Salinity	Fresh: <3000 mg/l, Brackish: 3000-10000 mg/l, Saline: >10000 mg/l
5	Distance to nearest settlement (DS)	Meters
6	Distance to road (DR)	Meters
7	Dog Presence (Dog)	Total number
8	Presence of Kiang (Kiang)	Total no. recorded
9	Total area of wetland (Area)	Sq. kilometer

4.2.2. Data analysis

I depicted habitat use proportion based on presence of waterbirds in different habitats and involved in activities. Prior to Canonical Correspondence Analysis (CCA), correlation coefficient among explanatory variables was checked using correlation matrix to exclude any highly correlated ($R > 0.60$) variable which could have a profound effect on the modeling. The abundance of waterbirds was the ‘response variable’ and nine environmental variables were used as explanatory variables to perform CCA. Prior to CCA, Monte Carlo permutation test of each explanatory variable was performed and

only significant variables ($p < 0.05$) were used for model. Permutation test was also tested for all canonical axes of reduced model with 999 permutations. Subsequently, based on the eigen value, contribution of each CCA axis was determined (Ter Braak and Verdonschot 1995). Inference of environmental variables was evaluated using plot at x, y axis. The direction and angle of arrow determined the relationship between species and environmental variable, arrow in similar direction of species with $< 90^\circ$ was considered as positively related, angle near 90° was considered as neutral and $>90^\circ$ was considered having negative relationship (Brandolin and Blendinger 2016). The multivariate statistical analyses for ordination was performed in R using statistical packages ‘vegan’ with dependence ‘permute’ and ‘lattice’.

4.3. Results

Activity of total 2938 flocks of seven breeding waterbird species were recorded in different habitat types, of which highest flocks of RSD ($n=1161$) was recorded during point counts followed by BHG ($n=642$), BrHG (402) and GCG ($n=377$). Least flocks of BNC ($n=135$) followed by CG ($n=115$) and CR ($n=106$) were observed. Maximum flocks ($n=1439$) were observed in water and minimum ($n=4$) were recorded in barren habitat (Table 4.2).

Table 4.2. Number of flocks recorded for each species in different habitat types

	BHG	BNC	RSD	BrHG	CG	GCG	CR
Habitat	No. of flocks						
Barren	-	-	3	-	1	-	-
Bog	104	48	209	36	4	2	19
Grass	36	35	33	2	1	-	-
Marsh	134	29	359	110	12	4	80
Saltpan	5	13	47	2	-	-	1
Sand	48	3	46	54	16	-	2
Water	315	7	464	198	81	371	3
Total	642	135	1161	402	115	377	106

4.3.1. Habitat use by waterbirds

Activity based habitat use indicated that BHG mostly used habitat for escaping (42.30%) followed by foraging (32%) and loafing (25.71%). BNC mostly used habitats for foraging (65.50%) followed by loafing (14.04%), escaping (13.45%) and occasionally used for nesting (7.02%). Most commonly distributed species RSD, mostly used habitats for foraging (40.12%) followed by loafing (35.18%) and escaping (24.70%). BrHG mostly used habitat for escaping (41.30%) followed by loafing (35.27%) and foraging (23.43%). Escaping (60.71%) was the key habitat use by CGS, followed by loafing (30.36%) and foraging (8.93%). GCG mostly used for escaping (69.05%) followed by loafing (17.72%) and occasionally for foraging (6.88%) and nesting (6.35%). CR used foraging as habitat use (85.58%) and occasionally for loafing (13.46%) (Fig. 4.1).

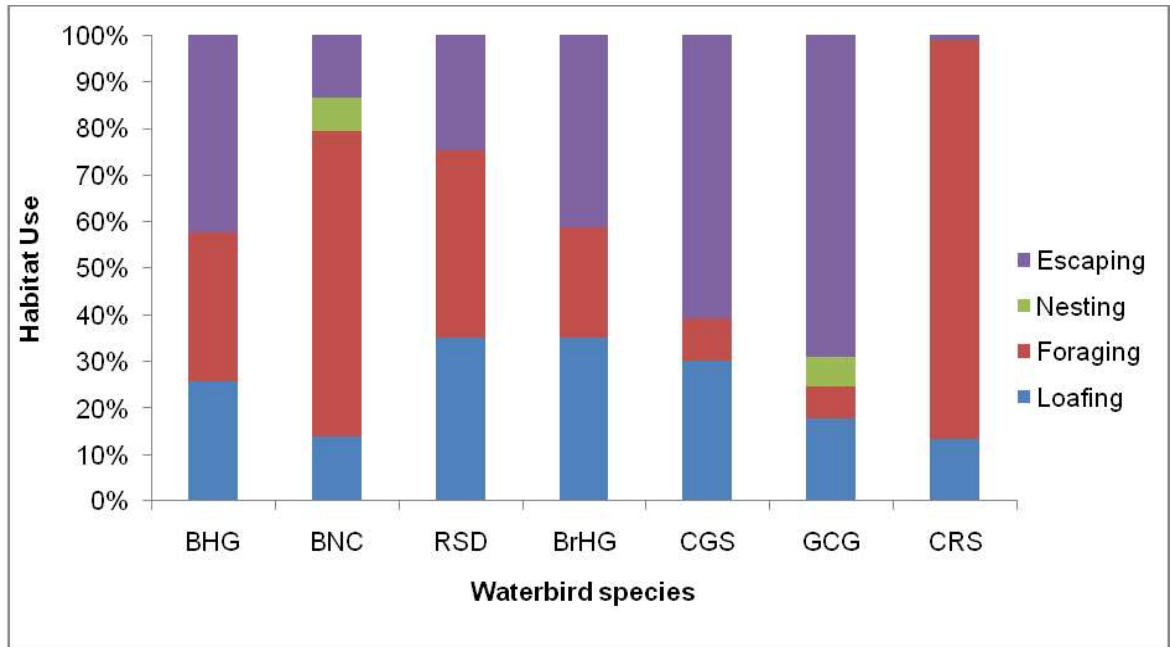


Figure 4.1. Habitat use by key breeding waterbirds

Different breeding waterbird species used an array of different habitats. BHG mostly used water (49.07%) followed by marsh (20.87%) and bog (16.20%) habitats. BNC used bog (35.56%), grass (25.93%) and marsh (21.48%) habitats most of the time, whereas saltpan (9.63%), water (5.19%) and sand (2.22%) habitats were used on few occasions. RSD mostly used water (39.97%) followed by marsh (30.92%) and bog (18%) areas. Half of the proportion of BrHG habitat use was constituted by water (49.25%) followed by marsh (27.36%) and sand (13.43%). CGS mostly used water (70.43%) habitats and occasionally used sand (13.91%) and marsh (10.43%) habitats. GCG was water (98.41%) dependent species and rarely used marsh (1.06%) and bog (0.53%) habitats. CRS mostly used marsh (75.47%) habitats followed by bogs (17.92%), while rarely used water (2.83%) and sand (1.89%) habitats (Fig. 4.2).

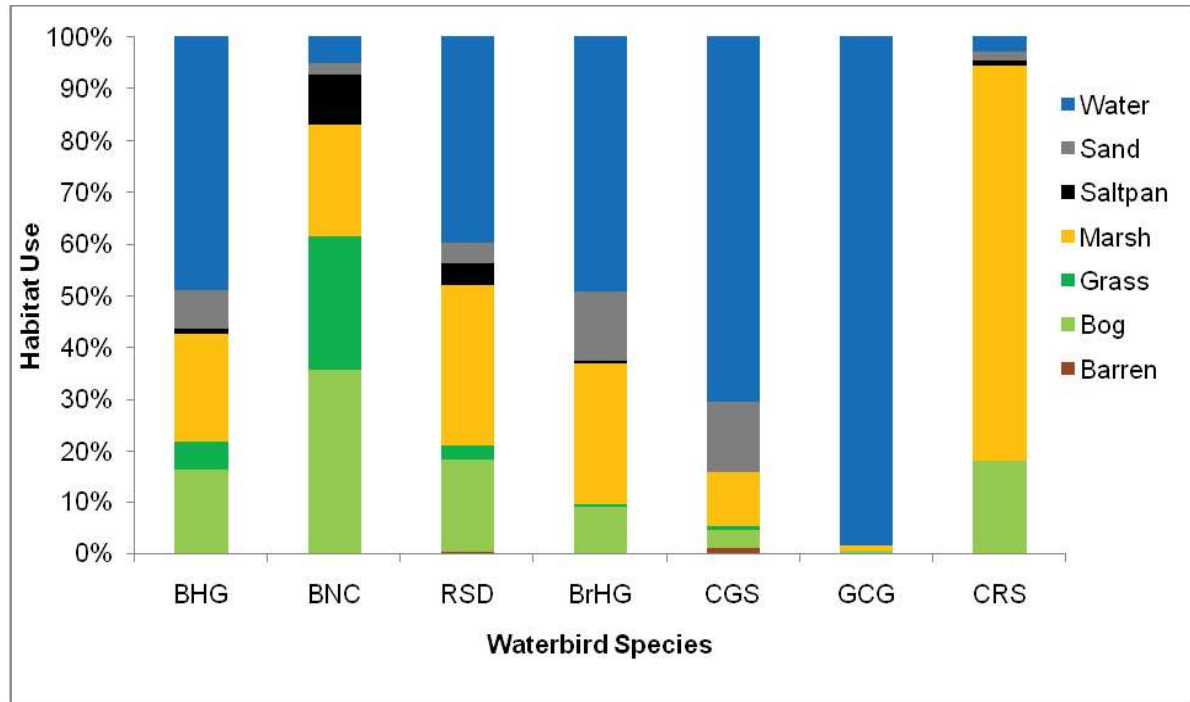


Figure 4.2. Different habitat types used by waterbirds

4.3.2. Factors influencing abundance of waterbirds

Prior to CCA, correlation among environmental variables was tested and found to be weakly correlated or independent of each other ($R < 0.60$). Therefore, I included all the environmental variables for permutation test (Table 4.3).

Table 4.3. Correlation matrix of all the explanatory variables used for Canonical Correspondence Analysis (CCA)

	Area	Elevation	Dog	Kiang	DH	DR	Depth	pH	Salinity
Area	1								
Elevation	-0.0362	1							
Dog	-0.18015	0.087826	1						
Kiang	-0.05558	-0.33895	-0.02619	1					
DH	-0.18069	0.305386	0.324647	-0.15771	1				
DR	0.066209	0.445447	-0.13368	-0.13285	0.03357	1			
Depth	-0.08657	0.052861	0.195965	-0.07416	0.401098	0.055191	1		
pH	0.180558	-0.12971	0.017476	0.166613	-0.16987	-0.02209	-0.51166	1	
Salinity	-0.08095	-0.06748	-0.0856	-0.04319	0.086555	0.067762	-0.13774	0.185147	1

Subsequently, among the nine tested response variables, permutation test revealed that only wetland area ($p < 0.001$), distance to road ($p < 0.001$), pH ($p < 0.001$), distance to human settlement ($p < 0.001$) and elevation ($p < 0.05$) were significant variables (Table 4.4).

Table 4.4. Permutation test for explanatory variables

Variable	ChiSquare	F	Pr(>F)	Significance
Area	0.675	20.5573	0.001	***
Dog	0.062	1.9043	0.124	
Kiang	0.0273	0.8334	0.363	
DR	0.240	7.3323	0.001	***
Depth	0.022	0.6792	0.559	
pH	0.174	5.3176	0.001	***
Salinity	0.048	1.47	0.164	
Elevation	0.083	2.5495	0.037	*
DH	0.228	6.9462	0.001	***

‘***’ p value= 0.001, ‘*’ p = 0.05

In CCA, first two axes explained 83% (0.8305) of variance of environmental variables on the abundance of waterbirds. A total of five axes were obtained explaining variance in abundance due to environmental variables. First component explained 50% of variability (eigen value= 0.6845) followed by 32% (eigen value = 0.4419) of the second component and 11% (eigen value = 0.1575) by third component (Table 4.5). Monte Carlo permutation test of all canonical axes was significant in reduced model ($F=7.9303$, $p < 0.001$).

Table 4.5. Eigen values and proportion of variation explained by CCA axes

	CCA1	CCA2	CCA3	CCA4	CCA5
Eigen value	0.6845	0.4419	0.1575	0.03863	0.03366
Proportion explained	0.5047	0.3258	0.1161	0.02848	0.02482
Cumulative proportion	0.5047	0.8305	0.9467	0.97518	1

There was a positive correlation of CC and BrHG with depth, salinity and distance to human settlement, whereas negative correlation with the wetland area and pH. Species like GCG and BHG did not form any cluster, GCG had positive relation with distance to road and elevation. BHG was positively correlated with wetland area and pH, while negatively with depth and distance to human settlement and salinity. LSP, RSD, BNC and CRS had a negative correlation with distance to road and elevation, whereas dog and *kiang* were insignificant variable showing a positive relationship (Fig. 4.3).

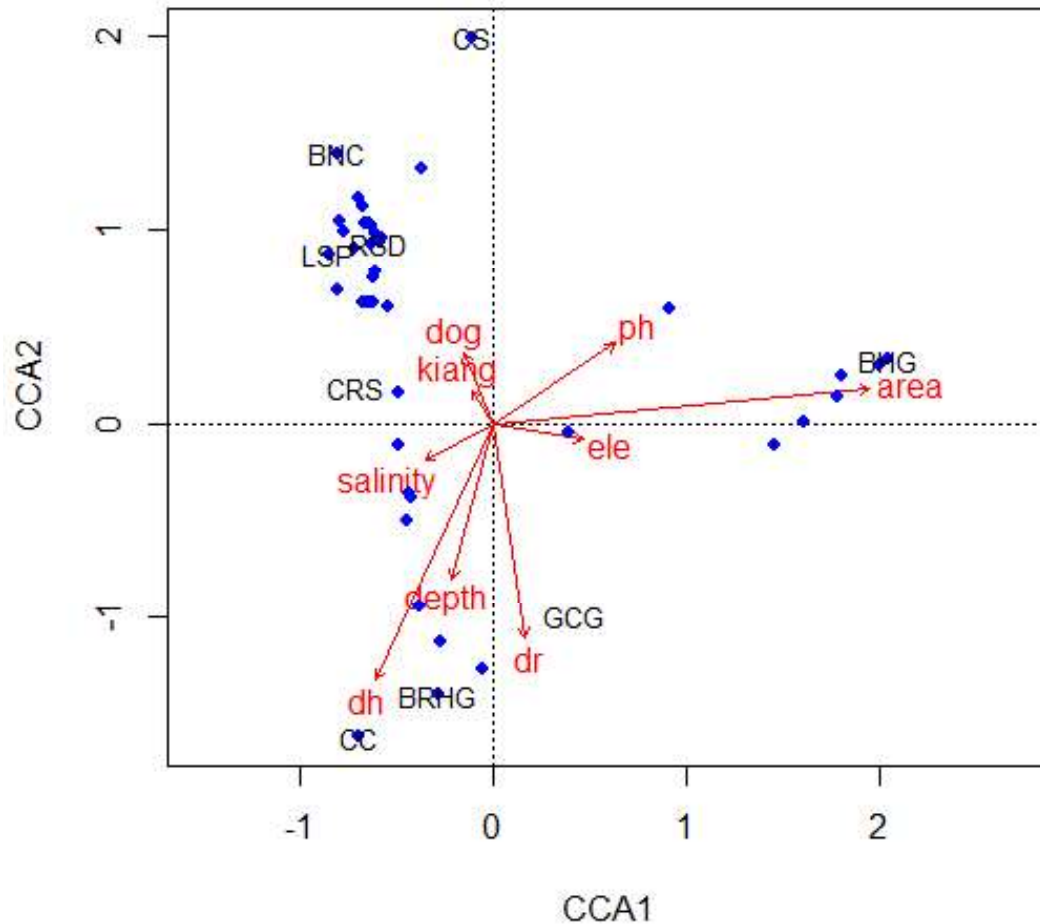


Figure 4.3. CCA plot of abundance and environmental variables (*only variables, area = wetland area; dr = distance to road; dh = distance to human settlement; ph= ph value of wetland point; ele = elevation were statistically significant, $p < 0.05$)

First component was mostly defined by wetland area and second was positively correlated with distance to human settlements and distance to road. Wetland elevation had positive relation with component 3 and component 4 was explained by negative relation with distance to road and positive with pH. Component 5 was not related to any of the given variables (Table 4.6).

Table 4.6. Constrained environmental variables relationship with CCA axes

Variable	CCA1	CCA2	CCA3	CCA4	CCA5
Area	0.98604	-0.1413	-0.05921	0.03391	0.05578
DR	0.09579	0.7015	-0.12206	-0.60198	-0.34844
pH	0.31626	-0.3161	-0.45796	0.67582	-0.36552
Elevation	0.23896	0.0862	0.83495	0.07352	-0.48262
DH	-0.2889	0.8597	0.18183	0.37036	0.08536

4.4. Discussion

Akin to previous studies, BNC preferred alpine bogs, lacustrine, riverine marshes and shallow waterbodies for nesting and foraging (Chandan *et al.* 2005; Wu *et al.* 2009; Liu *et al.* 2010, 2014). BHG extensively used lake, marsh and river habitats (Gou-Gang *et al.* 2015) and similarly, in Ladakh, BHG found exploiting fresh and brackish water lakes (Prins and Weiner 2002, Namgail *et al.* 2009a). CRS mainly used marsh habitats (mudflats and shallow water), which are reservoir of carnivore diet for foraging (Namgail *et al.* 2009b). RSD found in all types of habitats including fresh, brackish and saline, but for nesting it preferred nearby cliffs and sand bank crevices maintaining considerable distance from water (Scott and Rose 1996; Quan *et al.* 2001). GCG formed floating nests in open water and deep habitats, which mostly survives on fishes, insects and crustaceans (Del Hoyo *et al.* 1992; Snow and Perrins 1998; Fjeldså 2004). Unlike nesting in trees in other parts of the world (Snow and Perrins 1998), CGS selected cliff

ledges for nesting in CWLS; however for foraging it mostly used open fresh water wetlands (Kear 2005). Likewise, BrHG also exploited open water habitats for fish and crustaceans availability but also used sand islands for colonial nesting (del Hoyo *et al.* 1996).

Water depth play crucial role in providing habitat to fishing and diving waterbirds (Brandolin and Blendinger 2016), CC and BrHG both showed a positive relationship with depth; however GCG was more correlated with distance to road. Literature shows that salinity has profound impact on waterbirds either positive or negative (Ma *et al.* 2010). Some waterbirds are adversely affected by salinity which impacts their feathers and skin, while few waterbirds show console with saline water (Hannam *et al.* 2003; Takekawa *et al.* 2006; Gutierrez *et al.* 2012). Similarly in present study, some species had positive and negative relation with salinity. Generally, wetland area shows positive relationship with richness and abundance of waterbirds (Zou *et al.* 2008; Rossellie and Stiles 2012). In contrast, some species show negative relation with wetland area increase (Guadagnin *et al.* 2009). Not necessarily a larger area would have more species or more numbers that would also depend on other factors *viz.*, habitat heterogeneity, wetland property and anthropogenic factors. Present study shows negative relation with anthropogenic factors by BHG similar to study in Bharatpur, India (Middleton 1992). Several studies have assessed waterbirds and pH relationship and found different patterns (Ma *et al.* 2010). In present study pH had positive relationship with abundance of BHG. However, many studies have shown pH had negligible or neutral effect on waterbirds (Halse *et al.* 1993; Tavares *et al.* 2015).

Dogs have been reported feeding on BNC eggs and chicks in CWLS (Chapter 3). Rossellie and Stiles (2012) determined negative role of dogs on waterbirds in highland wetlands of Andes. In present study, false absence of dogs could be an artifact of denoting insignificant ($p > 0.05$) relation with breeding waterbirds. GCG mostly prefers water habitats and nesting takes place in floating nests away from the shorelines. Wild ungulates also pose threats to ground nesting birds (Cocquelet *et al.* 2019). A weak correlation ($p > 0.05$) was found between abundance of BNC, RSD, LSP and CS and *kiang* presence. Anthropogenic factors like distance to human settlements and roads were used to check their impact on waterbird abundance. Human disturbance was a species-specific trait; previous studies have shown same response towards anthropogenic factors (Barbaro *et al.* 2007; Trvares *et al.* 2015; Brandolin and Blendinger 2016). In Ladakh, dirt and asphalt road near wetlands give access to vehicles which often create disturbance for waterbirds by off road driving.

Chapter 5: Human disturbances and escape behavioural response of waterbirds

5.1. Introduction

Tourism in the mountain regions has rapidly developed worldwide in the last few decades (Price 1992; Moss and Godde 2000). Tourism provides alternative livelihoods to local communities and reduces their direct dependencies on natural resources and contributes towards nature conservation (Salafsky and Wollenberg 2000). However, if unregulated, tourism often negatively impacts the wildlife and natural habitat (Klein *et al.* 1995). Although, tourism also generates alternative and more stable livelihood (Jackson and Wangchuk 2004) and enables them to access modern facilities and contributes towards their resistance towards economic and policy failure (Badola *et al.* 2015). However, the tourism benefit leakage occurring at the global and local scale may deprive local communities of actual benefits (Akama and Kieti 2007; Sandbrook 2010a).

Despite providing economic growth, tourism often disturbs wildlife by flushing animals from suitable habitats and leads to behavioral changes (Klein *et al.* 1995). Owing to unregulated tourism, adverse effects have also been observed on wetlands and other protected areas (Geneletti and Dawa 2009). Human impacts on waterbirds have been studied using different methods globally (Klein *et al.* 1995; Lafferty 2001; Blumstein 2003). Disturbance and harassment may also reduce species diversity and density at the multiple habitat scales (Boyle and Samson 1985).

Similarly, there could be chances of other negative impacts on nesting, foraging and roosting behavior of waterbirds (Datta and Pal 1993, Green and Higginbottom 2001). Recreational activities disturb different taxa, a study by Yasue and Dearden (2006) on Malaysian plover (*Charadrius peronii*) concluded, human disturbance through trampling or crushing nests and chicks pose major threats to these birds. Several factors might influence the distribution and abundance of waterbirds (Paracuellos and Telleria 2004). Anthropogenic causes viz., recreational activities (Madsen 1998; Cardoni *et al.* 2008; Geffroy *et al.* 2015), illegal hunting (Madsen and Fox 1995; Ramachadran *et al.* 2017), landuse landcover change (Wright and Wrimbley 2013) etc. pose threats to waterbirds and their habitats.

The ‘optimal escape theory’ predicts that animals should moderate their flight responses according to the level of risk represented by a potential predator (Bateman and Fleming 2014). Therefore, Flight Initiation Distance (FID) increases when predators pose a greater threat and decrease when escape costs increase. It also predicts that a prey should begin to escape from an approaching predator when the predator reaches a point at which the risk of predation equals the cost of escape (Ydenbreg and Dill 1986). Even if birds are habituated to human presence, still can be vulnerable to predation (Geffroy *et al.* 2015) and physiological stress, for example change in heart beat rate or metabolic rate (Burger and Gochfeld 1991). Previous studies show escape behaviour in birds is driven by several predictors like body mass (Laursen *et al.* 2005; Blumstein 2006; Moller 2008; Glover *et al.* 2011; Samia *et al.* 2015a), brain size (Moller and Erritzoe 2014; Samia *et al.* 2015a), clutch size (Blumstein 2006; Moller and Garamszegi 2012;

Samia *et al.* 2015b), sex (Guay *et al.* 2013), group size, habitat (Guay *et al.* 2013; Samia *et al.* 2015a,b) and diet (Samia *et al.* 2015a,b).

There are about 8536 wetlands in Indian Himalaya covering approximately an area of 756,501 hectares (SAC 2011), are under threat owing to different anthropogenic pressures (Prasad *et al.* 2002). Being a developing country and one of the fastest world economies in the world, development has considered as a twin-edged sword for natural environment (Bassi *et al.* 2014). Unregulated tourism has emerged as one of the major problems in the Indian wetlands (Bassi *et al.* 2014). Ladakh Himalaya is known as one of the hot spots for tourism and also located amidst China and Pakistan holding a significant position in guarding the northern frontier of India (Geneletti and Dawa 2009).

Hence, developmental activities owing to increased influx of tourism and defense infrastructure has changed the scenario in Ladakh. Securing wetland ecosystems is exigent as most of the developmental activities take place near wetlands owing to availability of water in this cold habitat. These Trans-Himalayan wetlands are also considered as important habitats for migratory birds (Pfister 2004). In Ladakh region, local inhabitants practice pastoralism as their primary occupation, (Namgail *et al.* 2007). However, the pursuit of modern and easy life style and improved socio-economic conditions led new generations to explore other livelihood options like government jobs and tourism-based employment (Goodall 2001; Bhasin 2012). Previous studies reported religious compassion towards nature and wildlife owing to their religious belief and a

decade back anti wildlife crime campaign of eminent *Buddhist* leader His Holiness Dalai Lama (Yeh 2012; Bhatia *et al.* 2016).

Socio-politically unstable Ladakh was opened for tourism in year 1974 with visitation of only 527 tourists, which drastically increased around 2,58,720 tourists in year 2017 (Tourism Department Records, Leh) and CWLS emerged as a tourism hot spot and lakes in the area get maximum tourists visits (Gujja *et al.* 2003). The tourism in the area is not only providing alternative livelihood to local people, but also increasing their ability to access and avail the modern facilities. However, it has also impacted the local social and cultural setup as well as threatened the ecological integrity of the area.

Previous studies on animal behavior have shown that animals have to moderate their responses according to the level of risk represented by a potential predator and threat (Guay *et al.* 2016; Braimoh *et al.* 2018). Birds habituated or adapted to human presence are still vulnerable to predation (Geffroy *et al.* 2015) and physiological stress, for example change in heart beat rate or metabolic rate (Burger and Gochfeld 1991). To reduce the impact of human presence, studies have suggested delineation of zones in Ladakh (Genteletti and Dawa 2009). Buffer can be defined as an area peripheral to a national park or equivalent reserve, where restrictions are placed upon resource use or special development measures are undertaken to enhance the conservation values of the area (Sayer 1991). However, such approach cannot be ruled out in CWLS because human settlements are deep inside PAs and they are highly dependent on CWLS. Moreover, delineating zones around key wetlands can be a prudent solution to cope up

the problem in some extent rather than impacting local communities severely in terms of their dependents on natural resources.

Present chapter evaluates the role of tourism as an alternative livelihood opportunity for the local people and evaluate its impact on ecological health of natural system. I also assessed impact of human activities on escape behavior of waterbirds and recommended 'practical' zonation around the key wetlands of CWLS which are under anthropogenic pressure.

5.2. Methodology

A combination of ecological and socio-culture assessment framework was developed to evaluate tourism as alternative livelihood option and subsequently effective management of its impact on wetlands (Fig. 5.1).

5.2.1. Questionnaire survey

To assess the impact of tourism on social, economic and ecological structure of CWLS region a semi structured questionnaire was used. Overall, 210 respondents from 10 *rebos* groups and four villages were interviewed over three consecutive years (2015-2017). Respondents were selected using snowball technique. To avoid language barrier local people were hired as assistance. Prior to actual sampling, questionnaire was tested for its efficacy and other ambiguities (Dobriyal, 2015). Respondents representing different age, gender, religious sect, profession and educational background were interviewed (Appendix 5.1). Primary data was supplemented with secondary information available in

peer reviewed literature, records of government and non-government organizations such as District Statistical Handbook.

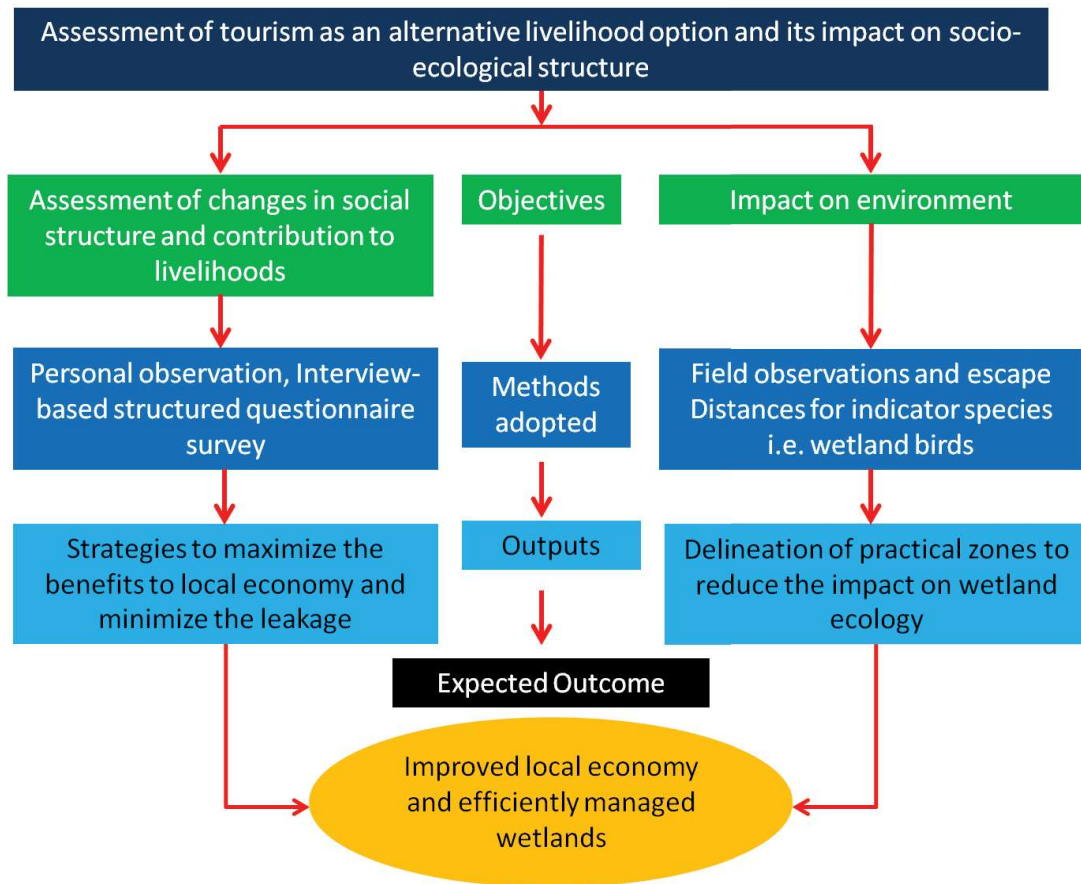


Figure 5.1. Methodological framework of ecological and socio-cultural studies

5.2.2. Field Sampling and Flight Initiation Distance (FID) estimation

In behavioural study, FID exercise was used to quantify the predation risk with the help of two observers (Blumstein *et al.* 2003; Blumstein 2003). FIDs of different waterbirds were measured for three consecutive years (2015 to 2017) from May to October each year (n=290 FID observations). Different wetlands were visited on varying days of the

week and at varying times of the day in between 0700 and 1900 hr (Ikuta and Blumstein 2003). The first observer walked towards the target bird individual with constant pace speed (0.5–1.0 m/s), till the bird flushed from its location. Range Finder was used to record ID (initial distance) and FID (Fig. 5.2), whereas the second observer monitored bird activity with the help of spotting scope (Nikon Field Scope ED50). To avoid repeated sampling of the same individual or any possible bias, sampling location or bird individual was changed (Blumstein *et al.* 2003). To maintain disturbance free breeding of waterbirds, I avoided FID records of nesting individuals or birds with chicks. The intensive study was conducted in thirteen wetlands of eastern part of sanctuary, situated between an altitude of 4100-5200 m a.s.l. (Fig. 5.3) within fresh (Statsapuk, Yaya Tso, Tsegam Tso, Hanle, Kyun I & II, Lal Pahari, Rongo and Staklung), brackish (Tso Moriri and Kyagar Tso) and saline (Tsokar and Puga) wetlands.

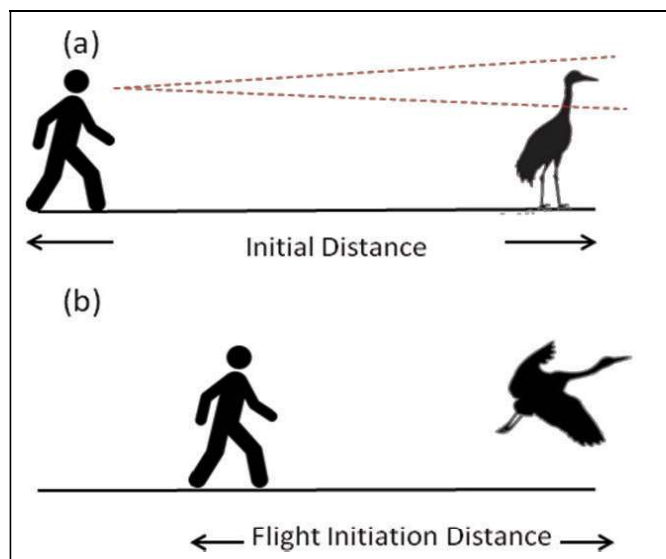


Figure 5.2. Demonstration of escape behaviour calculation (a) Initial distance (b) Flight initiation distance

5.2.3. Target Waterbird Species

For bird behaviour study, overall, 16 species of waterbirds were targeted during the exercise including waterfowl viz., BHG, great crested grebe GCG (*Podiceps cristatus*), gadwall GW (*Anas strepera*), common goosander CG (*Mergus merganser*) and RSD. Large waders viz., BNC, black stork BS (*Cinconia nigra*) and grey heron GH (*Ardea cinerea*); small waders viz., common redshank CR (*Tringa totanus*), black winged stilt BWS (*Himantopus himantopus*), lesser sand plover LSP (*Charadrius mongolus*), common sandpiper CS (*Actitis hypoleucos*), common greenshank CGS (*Tringa nebularia*); gulls viz., brown-headed gull BrHG (*Chroicocephalus brunnicephalus*) and Pallas's gull PG (*Ichthyaetus ichthyaetus*) and common tern CT (*Sterna hirundo*).

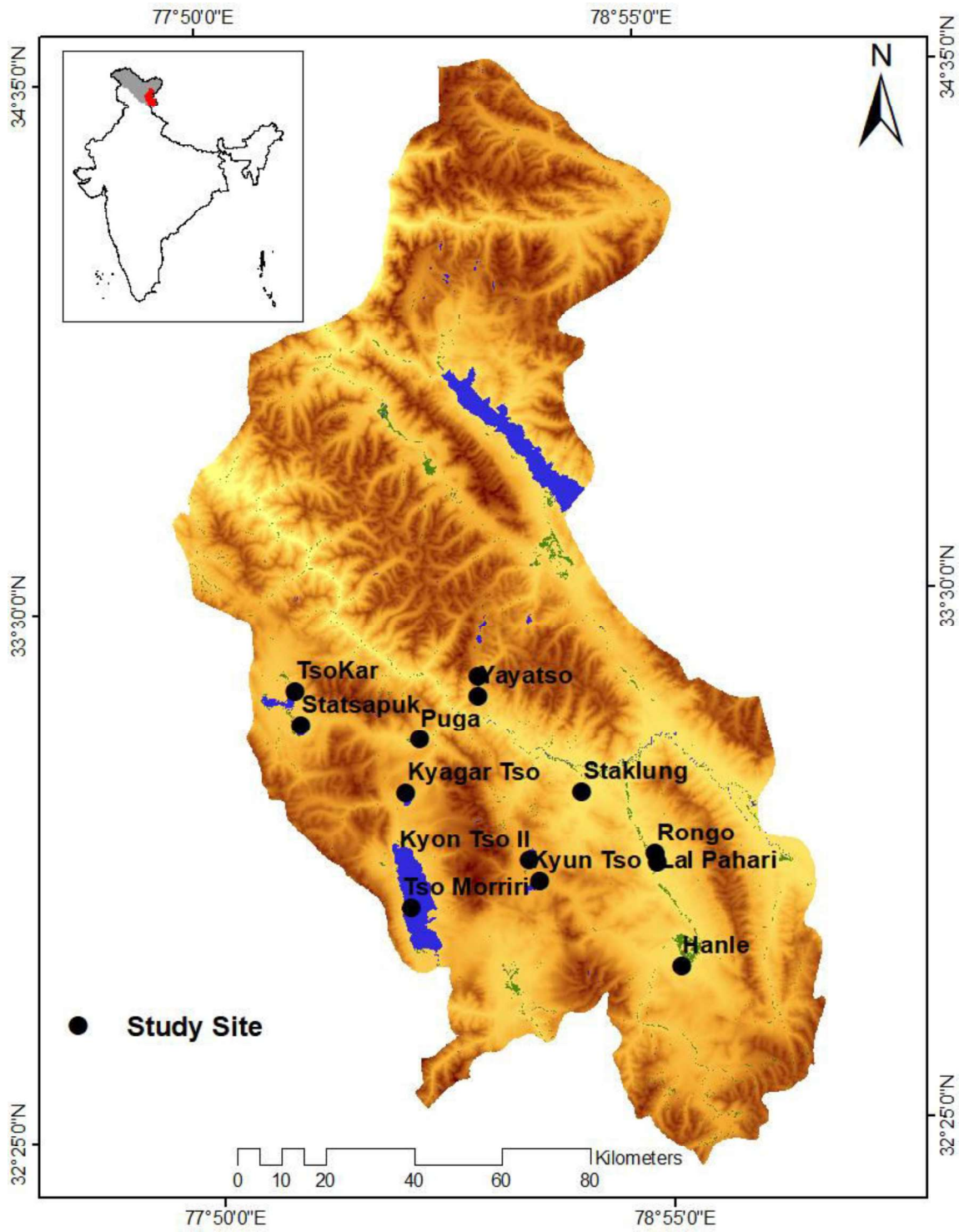


Figure 5.3. Intensive sampled sites (black points) in CWLS (blue and green features are wetlands)

5.2.4. Data Analysis

Non-parametric chi-square test was used to assess gender based difference in the opinions and compositional analysis was used to decipher peoples' attitude towards tourism and ongoing developmental activities. Species and site wise mean FIDs were calculated and minimum approach distances (MAD) was calculated considering most sensitive species as per highest FID response and standardized formula (Fox and Madsen 1997; Livezey *et al.* 2016). I performed two-way ANOVA to test if FID was species specific and site-specific trait or not (Blumstein *et al.* 2003). Linear regression was used to test relationship of FID (response variable) with body mass and wing span (explanatory variables) of different species (Moller 2008; Weston *et al.* 2012), both variables were log10 transformed to normalize data. Relationship of FID with clutch size of breeding waterbirds was also checked using linear regression. FID variations in major feeding guilds were also checked using Kruskal-Wallis non-parametric test. All analyses were performed in MS Excel and R Software (R Development Core Team 2019).

$$\text{Minimum Approach Distance (MAD)} = 1.5 * \text{mean FID}$$

5.3. Results

5.3.1. Respondents' profile

Out of 210 respondents, 52% were males and 46% were females and, average family was 5.75 (SE .16). The average age of respondents was 44 years (SE .99; range 18-74 years). Most of the respondents were illiterate (69%) and only 16% completed higher

secondary. Primary occupation of the area is pastoralism with about 63% respondents involved in it, followed by farming (20%), labour (4%), private job (3%), homemaker (3%), student (2%) and monk (1%). Livestock rearing was the most common secondary occupation among the respondents.

5.3.2. Ongoing developmental activities and their impact

I enquired about the ongoing development activities including road construction, tourism and defense infrastructure development in the CWLS and respondents' satisfaction with these activities (Fig. 5.4). Out of total 210 respondents, about 47% denied any developmental activities in their areas while 29% respondents were not aware about any such activities. Only 24% respondents were aware of the developmental activities in their area of which 64% families confirmed that they are being benefited by ongoing developmental activities. Most of the respondents who were aware of developmental activities in their areas were positive (88%), while 4% found the impact negative and 8% of respondents couldn't ascertain about the impacts of the developmental activities. No significant difference was found in the attitude of male and female respondents towards impact of developmental activities (χ^2 value= 0.653, df=2, $p > 0.05$). Positive impacts of developmental activities reported by respondents included improved livelihood opportunities, better and easy transportation and increased basic amenities while negative impacts were leakage of benefits to outsiders, unequal distribution of benefits leading to social stratification, degradation of environment quality such as increased water pollution.

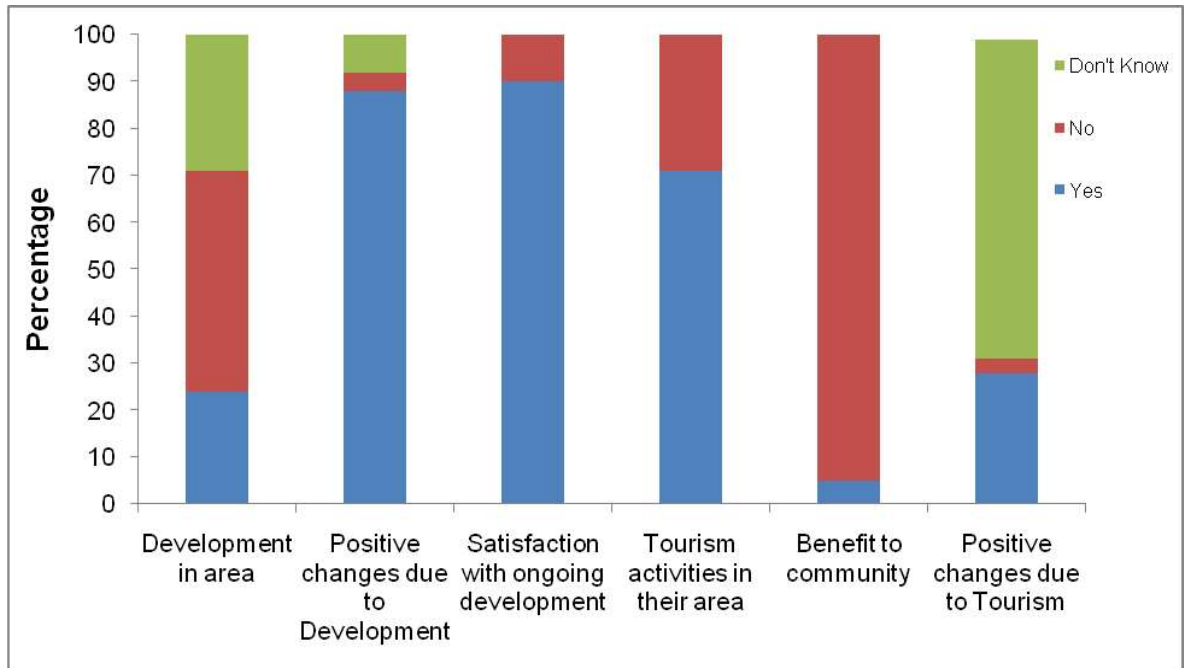


Figure 5.4. Perception of respondents towards tourism and development in CWLS

5.3.3. Tourism profile

The tourism in CWLS can be divided into four broad categories; i) Nature and rural ii) Wildlife iii) Adventure and iv) Health (Table 5.1). Secondary data and interaction with local people indicated that over the last fifteen years there was an unprecedented growth in the tourist numbers in Ladakh (Fig. 5.5). In 2002, total 8068 tourists visited Ladakh which reached about 235698 tourists in 2016. In 2010, visitation of Indian tourists was around 55685 which reached around 142829 in 2011, which was a sharp increase of 61% in the number of Indian tourists during one year interval 2010-2011.

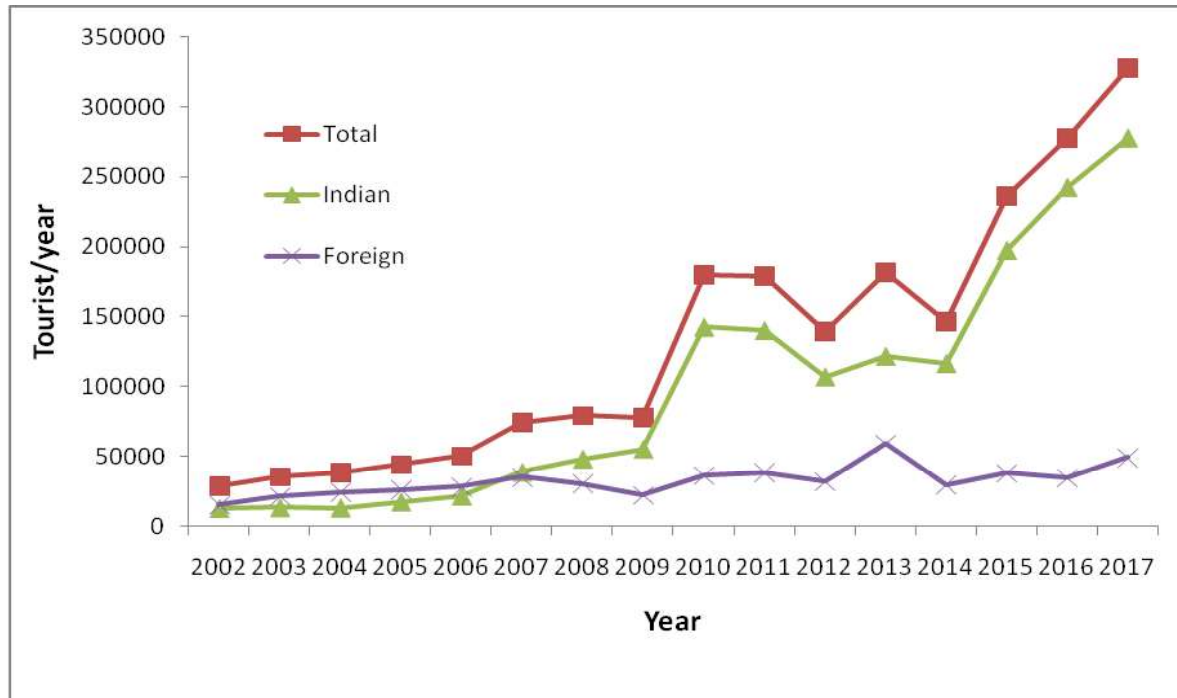


Figure 5.5. Annual tourism influx in Ladakh (2002-2017)

5.3.4. Benefits of tourism to local inhabitants

The season of tourism starts from June and ends in September where respondents worked as porter, labourer and guide. Average earning of these respondents from tourism was about US\$ 596.52±149.13 (SE) individual⁻¹ season⁻¹. Out of total 210 respondents, 28% of respondents were positive about tourism, while 3% respondents said that tourism does not provide any substantial benefit but degrades the environment. About 68% of respondents were aware about tourism activities in their areas (Fig. 5.4). However, only 7% of local inhabitants were involved in tourism related occupation. Gender did not play any significant role in shaping the attitude of the respondents towards tourism (χ^2 value= 0.179, df=2, p>0.05). I also didn't find any significance

difference on the basis of literacy (in between illiterate and literate respondents (χ^2 value= 0.895, df=2, p >0.05). Irrespective of education status, most of respondents were not aware about tourism and its benefits or impacts.

Table 5.1. Types of tourism and its impact in CWLS

SN	Types of Tourism	Impact		Sites	Type of tourist
		+(ve)	-(ve)		
1	Nature and Rural (Sightseeing)	Improved employment, cultural exchange, improved basic amenities and market for local products	Vehicular pollution, solid waste pollution, weaker community structure. Landuse change	Pangong, Tsokar, Tso Moriri, Chushul, Hanle	Domestic and International
2	Wildlife (Photography)	information on rare species and remote ecosystem, employment, market for local products and awareness	Disturbance to wildlife and its habitat	Hanle, Tsokar, Tso Moriri	Domestic and International
3	Adventure (Trekking, hiking, camping, biking)	Employment, market for local products	Disturbance to habitat and wildlife, pollution	Tsokar-Tso Moriri Trek, Krozok-Spiti Trek	Mostly International
4	Health (for healing at natural sulphur hot springs)	Economy	Pollution in hot water springs	Hot water spring Puga & Chumathang	Mostly Local Ladakhi

5.3.5. Environmental changes due to tourism

With increasing number of tourists, there is also an increase in the number of hotels and vehicles in the region. There are about 100 tents and lodging destinations in Tsokar and Tso Moriri. In Pangong Tso, there are around 1000 tents at Spangmik, Mirak and Man villages, for instance a drastic increase in number of tourist camps has been observed at Spangmik area between year 2013 and 2017 resulting changes in landuse practice (Fig. 5.6). Most of them have illegally placed near lakes and often recorded discharging their sewage waste directly into waterbodies (Department of Wildlife Protection, Leh). Off road driving is another issue near wetlands in CWLS resulting loss of habitats and disturbance to wildlife (in the breeding habitats of waterbirds in Tsokar and Tso Moriri). Several times, it has been observed that tourist vehicles approaching shorelines and nesting habitats of waterbirds, and chasing *kiang* (*pers. obser.*). About 4227 taxis have been registered in between 1994-2017 in Leh headquarter.

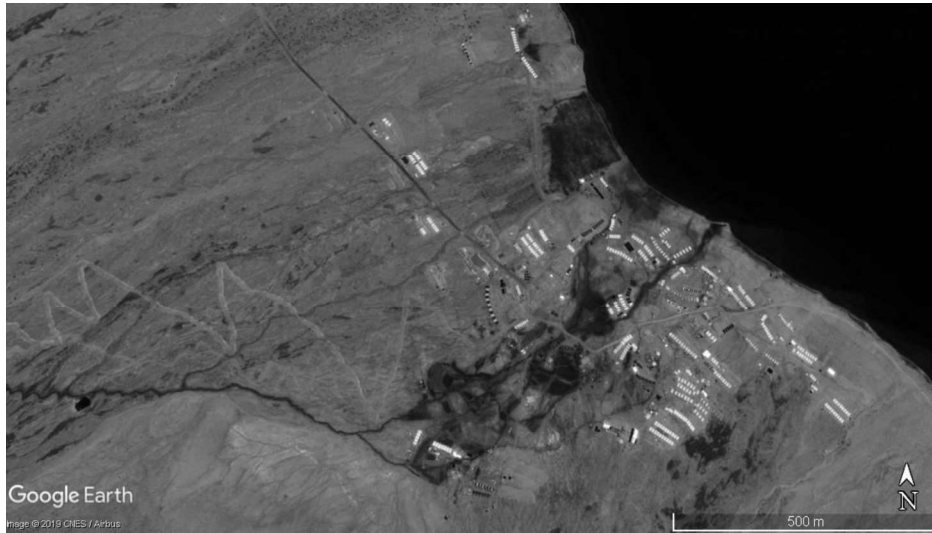
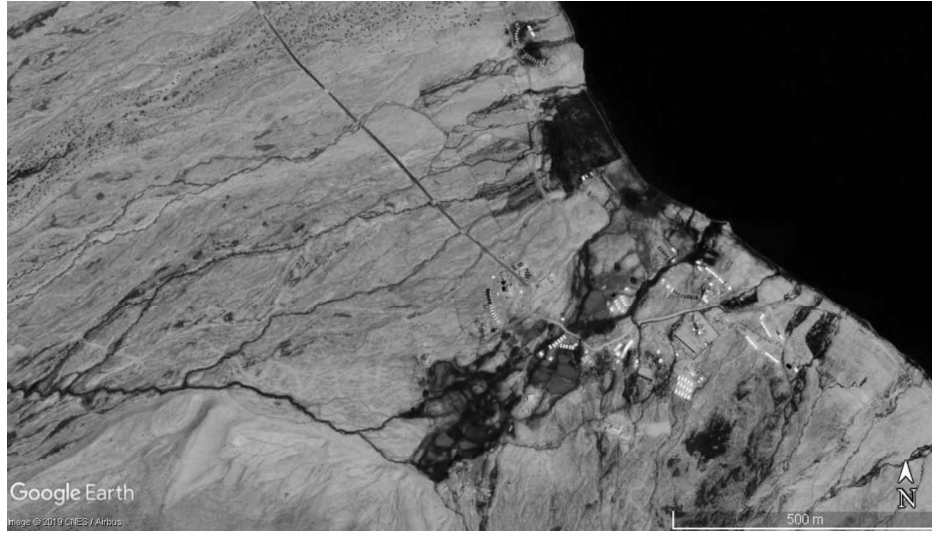


Figure 5.6. Tourist camps at Spangmik village near Pangong lake (Image year: 2013 & 2017, Source: Google Earth)

5.3.6. FID of different waterbird species

Mean FID varied between 27-216.8 meters among the 16 species of waterbirds minimum for LSP and maximum BNC respectively, while mean MAD varied between 40.5 and meters. Maximum FID observations were recorded for RSD (n=113) and minimum for CT and BS (n=1 each) respectively. FID was found to be a species and site specific trait (ANOVA, $F(28, 261) = 2.422$; $p < 0.001$). Overall FIDs and ADs of different species are given separately in Table 5.2.

Table 5.2. Details of FID and AD of 16 waterbird species in CWLS

SN	Species	No. of FID Observations	FID		AD	
			Mean	SE	Mean	SE
1	Ruddy Shelduck (<i>Tadorna ferruginea</i>)	113	156	7.94	208.31	8.57
2	Bar headed Goose (<i>Anser indicus</i>)	66	189.85	11	247.39	89.48
3	Brown headed Gull (<i>Chroicocephalus brunnicephalus</i>)	34	127.24	12.42	196.9	18.62
4	Black necked Crane (<i>Grus nigricollis</i>)	19	186.58	22.85	247.33	24.46
5	Common Redshank (<i>Tringa tetanus</i>)	11	90.82	13.80	109.29	10.97
6	Great crested Grebe (<i>Podiceps cristatus</i>)	11	125.55	16.97	157.3	16.40
7	Black winged Stilt (<i>Himantopus himantopus</i>)	07	91.86	31.40	136.17	31.10
8	Grey Heron (<i>Ardea cinerea</i>)	05	216.8	29.59	290.2	38.83
9	Gadwall (<i>Anas strepera</i>)	05	111.8	23.44	237.33	42.14
10	Lesser Sandplover (<i>Charadrius mongolus</i>)	04	27	1.87	67.75	31.17
11	Common Sandpiper (<i>Actitis hypoleucos</i>)	04	55.5	5.87	86.5	7.5
12	Common Merganser (<i>Mergus merganser</i>)	04	92	18.85	106	25
13	Common Greenshank (<i>Tringa nebularia</i>)	02	170.5	74.5	214	NA
14	Pallas's Gull (<i>Ichthyaetus ichthyaetus</i>)	02	90.5	5.5	205.5	42.5
15	Common Tern (<i>Sterna hirundo</i>)	01	199	NA	204	NA
16	Black Stork (<i>Ciconia nigra</i>)	01	216	NA	291	NA

* Breeding waterbirds in CWLS

I also calculated site specific mean FIDs of 16 species in 13 wetlands (Fig 5.7), of which maximum observations were recorded in Statsapuk (n=55) wetland, and least in Rhongo (3) and Tsegam Tso (2). Maximum FID records for individual species were collected for RSD (n=113) in 11 wetlands and maximum number of species' for FIDs were recorded in Statsapuk and Hanle wetlands. MADs of most sensitive species for different wetlands are given in Fig. 5.7 and appendix 5.2.

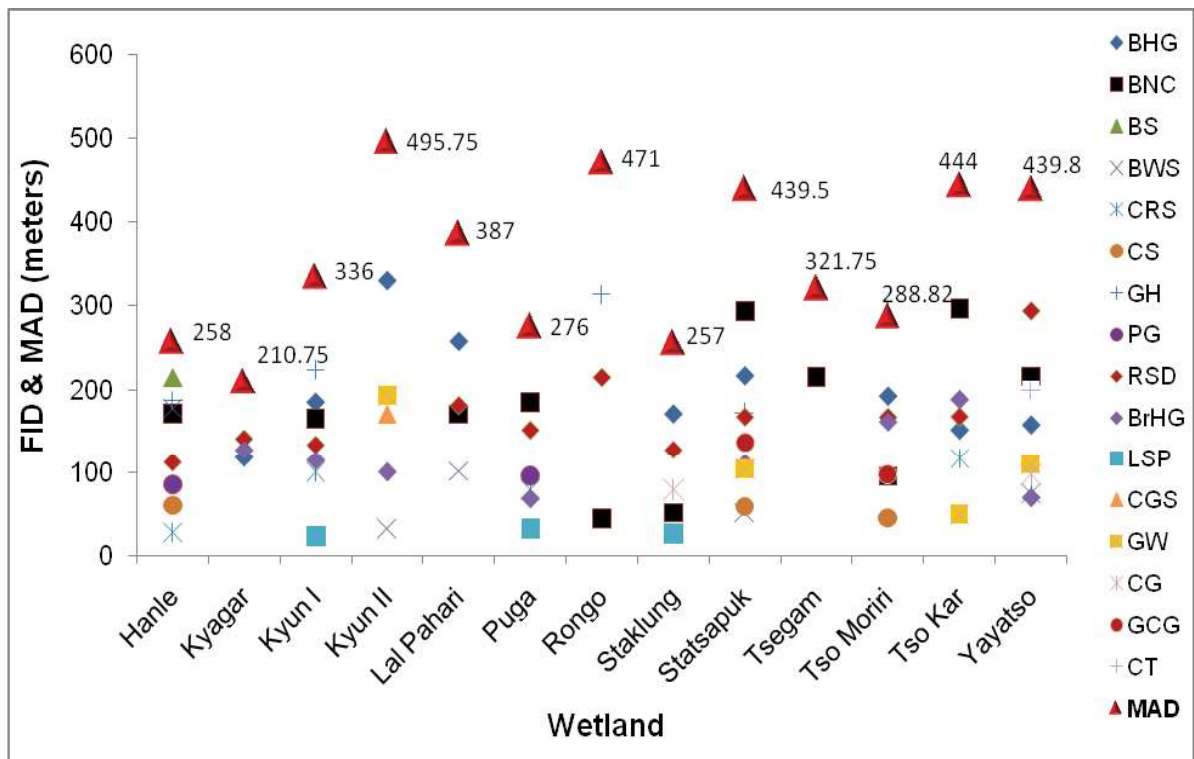


Figure 5.7. Site wise MAD and FID records 16 waterbird species in CWLS

5.3.7. Group wise FIDs of waterbirds

Target waterbird species were divided into four major groups like large wader, waterfowl, gull and small wader. The FIDs showed a positive trend with size of

waterbird group. The mean FID of six small wader species calculated was about 105.78 m, 108.87 m of two gull species, 134.04 m of five waterfowl species and 206.45 m of three large waders respectively (Table 5.3).

Table 5.3. Group wise FID details in CWLS

	Group	No. of Species	Mean FID ± SE (meters)
1.	Large Wader	3	226.19 ± 36.91
2.	Waterfowl	5	163.15 ± 6.10
3.	Gull	2	125.19 ± 11.81
4.	Small Wader	6	86.62 ± 12.11

5.3.8. Relationship of body parameters, feeding and breeding behaviour with FID

A positive relationship was observed between body mass and mean FID ($R^2 = 0.40$, $F_{1,14} = 9.275$, $p < 0.001$) (Fig. 5.8), larger birds flush earlier than smaller birds. Similarly, wing span and FID of waterbirds also showed positive relation ($R^2 = 0.46$, $F_{1,14} = 12.04$, $p < 0.001$), with increasing wing span, birds flushed earlier than birds having smaller wing span (Fig. 5.9).

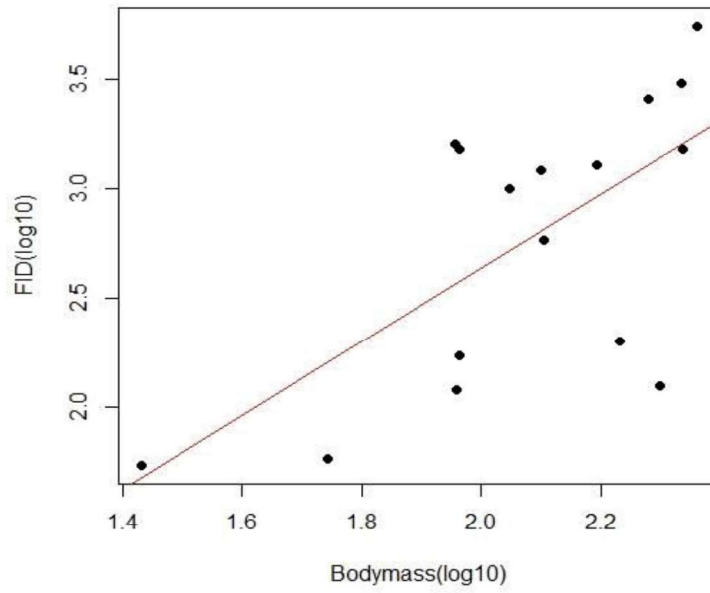


Figure 5.8. Relationship between FID (log transformed) and body mass (log transformed) of 16 waterbird species in CWLS

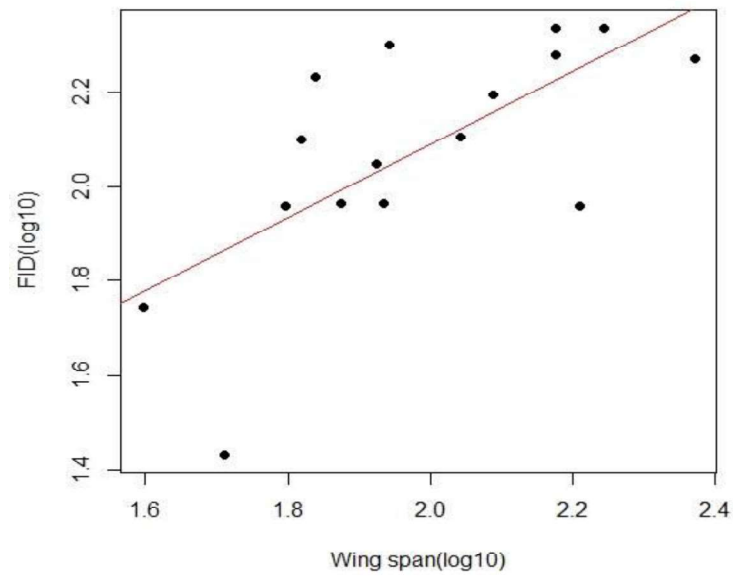


Figure 5.9. Relationship between FID (log transformed) and wing span (log transformed) of 16 waterbird species in CWLS

I also examined the relationship between mean clutch size and FID however, no relationship was found between clutch size of 11 breeding waterbirds of Ladakh and their respective mean FIDs ($R^2=0$, $F_{1,9}=0.0$, $p=0.98$) (Fig. 5.10).

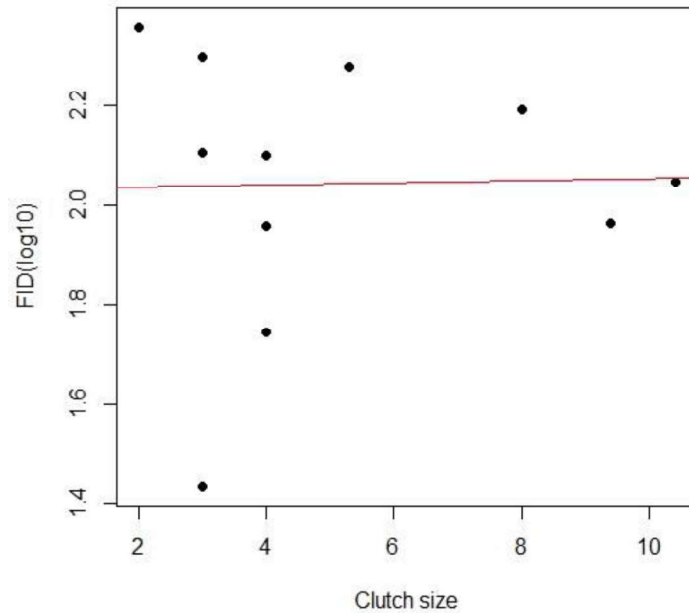


Figure 5.10. The relationship between FID (log transformed) and mean clutch size of 16 waterbird species in CWLS

The guild wise difference in the average FIDs of carnivorous, herbivorous, insectivorous and omnivorous birds were significantly different (KW test, $H = 29.057$, $df=3$, $P < 0.001$). Among four guilds, insectivorous showed more tolerance than others and flushed late (Fig. 5.11).

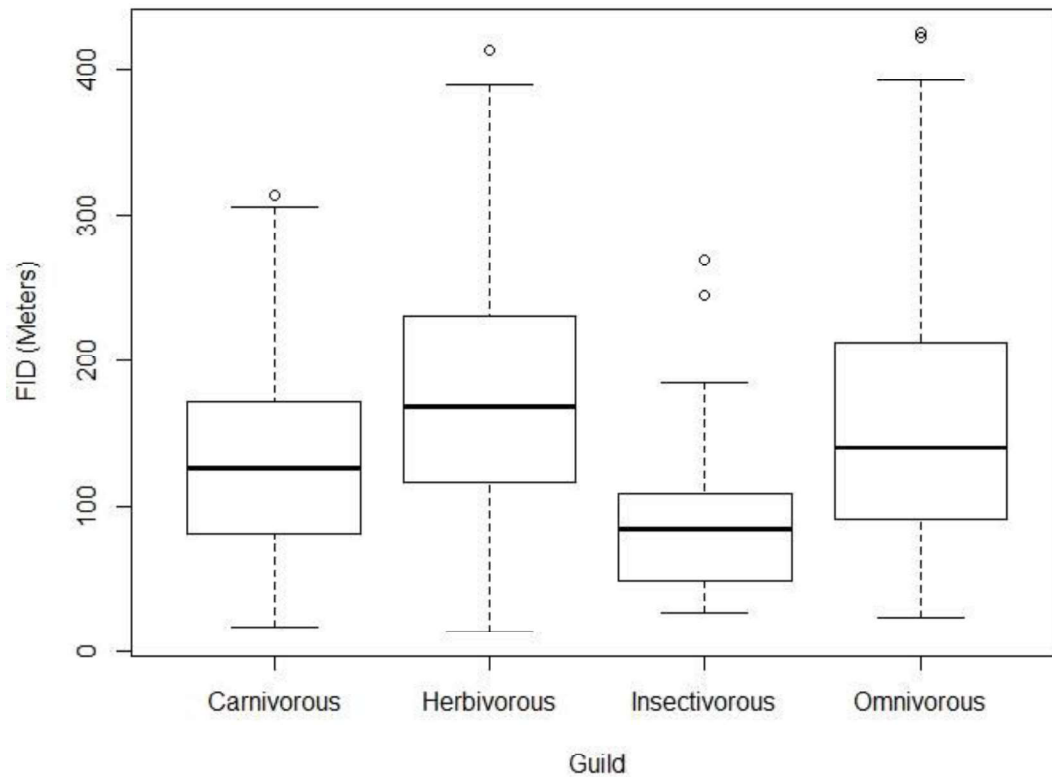


Figure 5.11. Box plot denotes Median values and quartiles, 5- and 95-percentiles of FIDs of carnivorous, herbivorous, insectivorous and omnivorous waterbirds in CWLS

5.4. Discussion

The results show that although tourism has evolved as an alternative livelihood option, most of the inhabitants are still practicing the traditional activities (Sabharwal 2016). Tourism surely brings socio-culture changes in a region (Archer *et al.* 2005), pastoralist might unaware of changes presently but might realize in near future. Young respondents were positive about tourism in Ladakh, mostly owing to possibility of new job opportunities and related developmental activities. Gender based attitude had no

difference in CWLS, perhaps owing to undivided work profile and active involvement of women in pastoralism and in running of small business. According to majority of respondents, benefits of tourism were not reaching directly to local inhabitants because most of tour operators are from main city Leh or outside of the state. In purview of tourism benefit leakage, local communities need to be strengthened by state authorities and proper mechanism of income should be channelized to actual beneficiaries (Badola *et al.* 2018). In Ladakh, however, department of wildlife protection and non-governmental organizations have provided alternative livelihood options to local people like supporting home stay programs (Anand *et al.* 2012; Jamwal *et al.* 2018). However, CWLS requires a foolproof tourism mechanism akin to Hemis National Park, where local institutions and community are able to ensure equal benefit sharing (Badola *et al.* 2018; Jamwal *et al.* 2018).

With increasing tourism pressure on CWLS and considering vulnerability of landscape towards any anthropogenic change, certain precautionary measures need be taken by authorities to secure its wetlands and other pristine habitats. Hence, present chapter quantified escape distance of waterbirds in the Indian Trans Himalayan region and also reconfirmed that FID is a species specific and site specific trait akin to previous studies (Blumstein *et al.* 2003; Koch and Paton 2014). The body mass and wingspan supported FEAR hypothesis (Flush Early and Avoid the Rush) (Blumstein 2010). Positive relation between FID and body mass apparently determined the conspicuity and vulnerability of large body size species to predation risk thus to avoid last time rush and risk, these birds flushed early than smaller size birds. Additionally, energy is also a vital

factor in escaping early because there is more energy loss when predator approaches closely (Cooper *et al.* 2002). I also tried to determine relationship between clutch size of breeding waterbirds and FID, but no relationship was observed in between these two variables. However, studies have found that species with small clutch size are tolerant to close approach owing to high energy cost in rearing small clutch thus might take more risk (Samia *et al.* 2015b). Generally, omnivorous birds were found to be more tolerant than carnivorous birds especially raptors (Samia *et al.* 2015b). However, in the present study insectivorous birds were most tolerant while comparing feeding guilds. Both carnivorous and omnivorous waterbirds showed almost same FID range (Fig. 5.10).

Previously two types of approaches have been used to study escape behaviour (i) predestine (Blumstein 2003) and (ii) vehicle and that depends on level and mode of disturbance at particular site (Lafferty 2001). Methods can be changed as per requirement like variation in the intruder group size, walking speed, hunting pressure, dog presence and vehicle disturbance (Blumstein *et al.* 2003; Geist *et al.* 2005; Glover *et al.* 2011; Ikuta and Blumstein 2003; Legagneux and Ducatez 2013). In this context, delineation of Buffer is considered as an imperative mechanism to safeguard waterbirds (Rodgers and Smith 1997). Several studies have suggested use of FID approach in creation of buffer zone (Fox and Madsen; Koch and Paton 2014). FID tends to be a species specific trait (Blumstein *et al.* 2003); therefore the most sensitive species should be considered ideal for the creation of buffer around wetland (Fox and Madsen 1997). Argumentatively, few studies have cautioned in creation of buffers solely based on escape behaviour. Hence, different parameters may be considered while delineating

buffer *viz.*, under estimation of FID (Fernandez-Juricic *et al.* 2005), visitation (Lafferty 2001), ecological and social acceptance (Glover *et al.* 2011) and calculation of buffer (Livezey *et al.* 2016). Studies have also recommended alert distance (AD) for measurement of disturbance and in creation of buffer (Fernandez-Juricic *et al.* 2005; Tarlow and Blumstein 2006), however it has been found difficult to record always the actual alert behaviour (Rodger and Smith 1997). Present study also encountered the same problem in recording AD on many occasions especially for small species.

Globally, good governance has shown an increase in different waterbird populations (Amano *et al.* 2017). Countywide exercise may contribute to a tool like “AvianBuffer”, an easy decision making portal for park managers using scientific information (Guay *et al.* 2016). Many countries have considered buffer as an essential part of wetland management using science based studies (Glover *et al.* 2011; Koch and Paton 2014; Guay *et al.* 2016), whereas such an approach lags in India. Comparatively, Indian terrestrial PAs have received a considerable amount of attention unlike wetlands (DeFreis *et al.* 2010). Even escape behaviour studies are uncommon in India; only one study has reported flush distances of 128 species of birds (resident and migrant) including ten species of waterbirds in northern parts of India and concluded that owing to community tolerance resident birds were more habituated than migrant species (Burger and Gochfeld 1991).

Present chapter has provided insights about escape behaviour information of migratory birds in various wetlands of Ladakh. A study by Genelitti and Dawa (2009)

recommended zonation of the protected areas in Ladakh. The concurrent arrival of tourists and waterbirds in Ladakh during summer season, apparently, tourism activities disturb waterbirds and their habitats (Humbert-Droz 2017). The MAD information can be used in effective PA management (Fox and Madsen 1997; Livezey *et al.* 2016). Besides FID, other factors *viz.*, visitation, vehicle, and dog presence should also be taken into consideration while delineating buffer (Lafferty 2001). Further, socio-political acceptance should be included in decision making for the effectiveness of buffers (Castelle *et al.* 1994; Glover *et al.* 2011).

Chapter 6: Impact of free-ranging dogs on waterbirds

6.1. Introduction

Today, domestic dogs are apparently the most abundant carnivores in the world and a major cause of extinction and threat to many species (Doherty *et al.* 2017). In the past few decades, free ranging dogs emerged as a primary cause of wildlife predation (Vanak and Gompper 2009; Home *et al.* 2017), competitor (Butler *et al.* 2004; Vanak and Gompper 2009), disease transmitter (MacPherson 2005; Sepulveda *et al.* 2014) and accountable for outbreeding depression (Gottelli *et al.* 1994). Several studies have determined wildlife as the important part of their diet around the globe (Schaller 1998; Butler *et al.* 2004; Campos *et al.* 2007; Vanak and Gompper 2009; Silva-Rodríguez *et al.* 2010).

Often, humans let domestic dogs turn feral and, forcing them to compete with the other wild carnivores for resources (Butler and Toit Du, 2002). Further, feralization occurs due to the fear response to human that doesn't necessitate genetic divergence from its domestic ancestors (Daniels and Bekoff 1989). Feral dogs are considered to be excellent opportunistic feeders (Vietch 2002). Dogs have emerged as a successful intraguild predator among the all canid species and prevented other carnivores to approach human habitats by competition (Vanak and Gompper 2009; 2010). Dogs mainly predate on ungulates, small mammals, birds and livestock (Scott and Causey 1973; Butler *et al.* 2004; Vanak and Gompper 2009; Home *et al.* 2017). Birds have been an important part of dogs' diet in Chile (Silva-Rodríguez *et al.* 2010). In New Zealand, a single free-

ranging dog killed around 500 kiwis (*Apteryx australis*) in the remaining population of 900 birds in a few months (Taborsky 1988).

6.1.1. Dog's impact on global and local scale

Humans, worldwide generated 1.3 billion tonnes of garbage in year 2012 and expected to reach around 2.2 billion tonnes by year 2025 (<http://www.worldbank.org>). Easily available human derived food provisioning and low prey availability might enhance competition between dogs and other carnivores (Vanak and Gompper 2009). Intentionally or unintentionally, human often provide subsidies to animals shaping their ecosystems and communities leading to competition and predation (Oro *et al.* 2013). Over the half century, dogs have shown an increase in body size owing to sufficient supply of human subsidy in Israel (Yom-Tov 2003). In many parts of the world, dogs have been recorded to feed on human faeces (Lantis, 1980; Suryavanshi *et al.* 2009; Butler *et al.* 2018).

In Indian subcontinent, feral dogs have been seen searching and feeding eggs of marine turtles in coastal areas in Sri Lanka (De Silva 1999, Ilangakone 2000, Bambaradeniya 2002) and attacking wild animals in Bundala National Park, West Province (Bambaradeniya 2002). India harbours several endemic and endangered species like Asiatic lion (*Panthera leo persica*), Great Indian bustard (*Ardeotis nigriceps*), Tibetan gazelle (*Procapra picticaudata*), Tibetan antelope (*Pantholops hogsonii*) and black-necked crane (*Grus nigricollis*) which are more prone to predation and disease transmission (Schaller 1998; Chandan *et al.* 2005; Balamurugan *et al.* 2012; Dutta 2014). Dogs cause huge loss of wildlife throughout India (Home *et al.* 2017). The major threats

for the leatherback turtles are predation of eggs by humans and feral dogs at the Galathea in Great Nicobar Island and Rutland Island. Feral dogs are a major predator to turtle eggs and nesting turtles in Andaman and Nicobar Islands. The remoteness and inaccessibility makes it difficult to monitor and protection sea turtles during nesting in islands and beaches of Nicobar (Andrews 2000). The decline in the *Gyps* spp. vulture population in the several parts of the India was attributed by loss of habitat followed by increasing population of feral dogs, anthropogenic pressure, predation, competition etc. (Chhangani and Mohnot 2004). As successful facultative scavengers, dogs have replaced vultures, a study by Prakash *et al.* (2003) confirmed drastic increase in population of dogs on carcass dump over the years in western Rajasthan. In Gujarat, studies suggest that the feral dogs compete with the wolves and also prone to infectious diseases such as rabies, canine distemper virus (CDV), parvovirus and canine hepatitis (Jhala and Giles 1991).

6.1.2. Importance of demographic survey

Despite being used as a vital tool in assessing the ecological determinants of rarity (IUCN 2014), population estimates often used in managing dogs (Hiby *et al.* 2011), fundamentally important for applied ecology (Perez-Arteaga *et al.* 2005). Several methods have been used globally but few studies have used Spatially Explicit Capture Recapture (SECR) method with a range of detection devices (Belo *et al.* 2015), some of which are traps while others detect without actually trapping. The devices include cage-traps (single-catch traps, mist-nets (a kind of multi-catch trap), acoustic detectors (both terrestrial and marine), sightings by humans, and detection by cameras (Borchers 2012). Additionally, SECR method overcomes issues of conventional capture-recapture method like edge effect and heterogeneity in detection probability (Efford 2004; Brochers and

Efford 2008; Efford 2015). This method also provides precise spatial information on the density of dogs which could contribute in management of dog population in protected areas.

6.1.3. Interaction with local inhabitants

In Ladakh, pastoralists often retaliate their heavy loss due to interface with wildlife especially with carnivores (Bhatnagar *et al.* 2006a; Namgail *et al.* 2007). Dogs that accompany the pastoralists are observed to chase and kill lambs and juveniles of wild herbivores in Ladakh (Singh 2008). Understanding patterns of dog predation on livestock and wildlife can help in developing mitigation strategies. During last few years, feral dogs have emerged as major predator of livestock followed by snow leopard and wolf in Upper Spiti (Himachal Pradesh) (Suryavanshi *et al.* 2009; Home *et al.* 2017). Feral dogs are also known to hunt the wild prey species such as blue sheep and are believed to compete with native predators such as red fox in Spiti (Ghoshal 2012) and snow leopards.

Present situation of Ladakh appeared akin to Spiti, which required a further quantification. Thus, understanding their demography, diet and perception of locals towards dogs was essential for the negative interaction mitigation in Trans Himalayan region of Ladakh. Dogs tend to have dependency on the human subsidy as easy food availability thus the major proportion of their diet suppose to come from human subsidy however they will also be dependent on wildlife by scavenge or hunt. Additionally, most of large congregations of dogs tend to found around human dominated landscapes and near infrastructures with easy food like defense camps and residential schools.

6.2. Methodology

6.2.1. Field methods and laboratory analysis

a) *Population estimation of dogs*

I carried out fieldwork during June–July 2015 to estimate the size of the dog population. I divided the study sites into two categories: (i) large human settlements close to wetland habitats and (ii) human settlements or temporary pastoralist tents with fewer than 10 households close to wetland habitats (Fig. 6.1). There were three sites in the first category and seven in the later. I used polygon search method in first category sites (Gogoi 2015) and carried out block counts to survey the sites of the second category (Home *et al.* 2017). A total extent of 104 km² was sampled in Tsokar, 127 km² in Tso Moriri and 78 km² in Hanle. Ground surveys were conducted during the breeding season of waterbirds in June and July 2015. I divided my three intensive study areas into 1 × 1 km² polygons, their extent representing the average known home range of free-ranging dogs, ~0.72 km² (Pal *et al.* 1998b; Meek 1999; Dürr and Ward 2014). I sampled each polygon on five occasions during consecutive days. I obtained the help of experienced field personnel and searched the entire study area on foot and using vehicle. I followed existing trails and motorable roads in each polygon, following the same paths each time (Gogoi 2015; Punjabi *et al.* 2012). I photographed dogs using a prosumer camera and recorded their GPS locations and the activity they were involved in. I identified individual dogs on the basis of body colour, sex and natural marks (Punjabi *et al.* 2012).

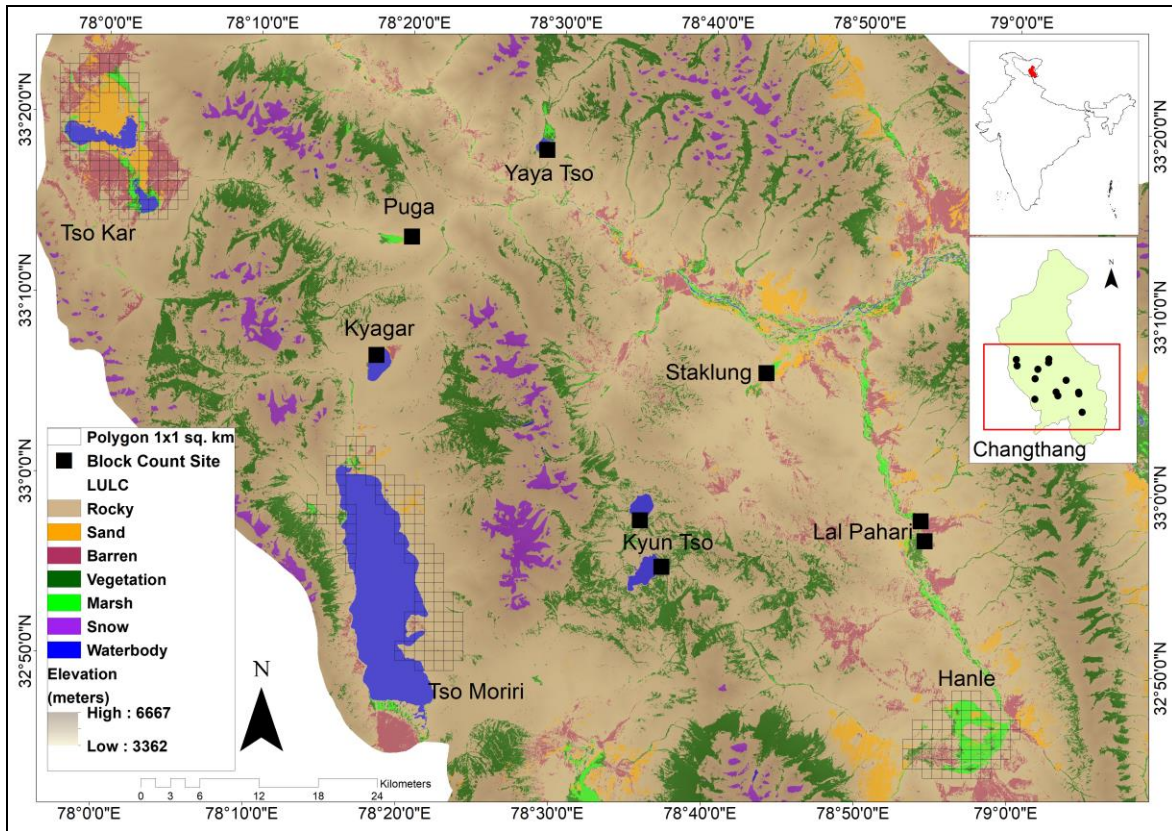


Figure 6.1. Intensive study sites in CWLS

b) Scat collection and laboratory analysis

In order to study dietary composition of dogs, I used the non-invasive technique by collecting a total of 850 scat samples between the years 2015 and 2017. I collected the scats opportunistically from the periphery of villages, from the nesting sites of waterbirds and from buffer areas (Vanak and Gompper 2009) during the breeding season (May–October) of birds and mammals. Most of the scat samples were collected during focal sampling of dog individuals or whenever we encountered fresh scats in vicinity to shepherd dogs. The scat of the dog can be easily distinguished from those of sympatric species such as the wolf (*Canis lupus*) (Habib 2007). I placed all the scats in paper bags marked them with the date, GPS location and collection site and air-dried them for 5–10

days. I weighed and washed the scats in running water and dried the washed samples in an oven at 40°C for 24–48 hours. Subsequently, I segregated the dietary components for auxiliary quantification according to taxon (mammals, birds, reptiles, invertebrates and plants) and human-derived material (HDM, such as plastic, polythene, rubber and paper) separately (Reshamwala *et al.* 2018). I prepared reference slides for identification of mammalian medullary hair patterns (Bahuguna *et al.* 2010). I also identified bird parts in scats such as feathers, bones, chitin, claws and eggshells. When I came across any down feather in the scats, I identified it to order level using reference material prepared during this study and material available in the literature (Dove and Koch 2011).

Due to economic constraints, I randomly selected 100 scats from 10 sites for identification of species using molecular tools. DNA was extracted from fecal samples using Guanidine iso-thiocyanate method (Boom *et al.* 1990). DNA extractions were performed in a room dedicated to low-copy DNA extraction. For every extraction, negative controls composed of reagent only without sample was included to monitor the contamination. Species identification from fecal samples was carried out using Cytochrome b region primers 412 bp fragment of the mtDNA Cyt b gene (Canid L1 and H15149, Paxinos *et al.* 1997; Kocher *et al.* 1989). PCR amplification conditions includes initial denaturation at 95°C for 15 minutes, followed by 35 cycles at 94°C for 30 seconds, 55°C for 30 seconds and 72°C for one minute, and a final elongation step at 72°C for ten minutes. Followed by the amplification of target DNA, the PCR products are loaded in 2% agarose gel electrophoresis along with negative and positive controls. The PCR products were sequenced where initially treated with ExoSAP (GE Healthcare, USA) and then sequenced the samples in both directions using the BigDye Terminator v3.1 Cycle

SequencingKit (Applied Biosystems Inc., USA) following the manufacturer's instructions accordingly. DNA sequences were then resolved on the ABI Prism 3130 Genetic Analyzer (AppliedBiosystems Inc., USA). The generated sequences were then blasted with avialbale references in NCBI to confirm the species.

c) Questionnaire surveys with local inhabitants

I interviewed 210 respondents in four major villages and 10 nomadic camps during three consecutive years (2015–2017) using a semi-structured questionnaire. Respondents from grazer groups owning dogs were selected using snowball sampling. However, to validate the information collected from grazers, people of different occupations were involved in interactions/interviews. Prior to the actual sampling, I conducted 25 interviews to test the efficacy of the questionnaire and to eliminate ambiguities (Dobriyal 2015). All respondents' locations were marked using GPS. Respondents belonging to different age, gender, religious sect, profession and education groups were interviewed (format of questionnaire is given in appendix 6.1).

3.2.2. Data Analysis

a) *Population estimation of dogs*

I developed individual capture histories for dogs and polygon vertices were used for developing trap files. For estimation of dog abundance, I used SECR method (Borchers 2012) in R (R Development Core Team, 2018) using ‘secr’ package (Efford 2016). Polygon search method was used that provides flexibility in counting of individuals which has been used on lions (Gogoi 2015). In maximum likelihood framework, for stationary detector, detection probability is modelled as a decreasing function of the distance between the animal’s home range centre and the detector. In polygon detector method, the probability of detection is a function of the quantitative overlap between the home range and the polygon (i.e., the instantaneous probability that an animal is within the polygon) (Efford 2011). I used detection parameter, lambda (λ), the per capita detection probability in per unit effort and sigma (σ), the spatial scale of animal movement (Lamb *et al.* 2018). I only used null model for density estimation because sex identification and differentiation between pet and free ranging dog couldn’t be ascertained. Most of the owners kept unleash their dogs during day and night hours and, also they didn’t use neck belts for pet dogs. Hence, in my case such heterogeneity was not considered in density estimation. Subsequently, density contour maps were prepared using density surface modeling in ArcGIS and R (R Development Core Team, 2018).

I masked study areas as per availability of habitats and resources *viz.*, terrain complexity, vicinity to human settlements and availability of food resources (hamlets, schools and defense infrastructure), dumping sites, distance to nearest wetland and

distance to pastoralists' camps. The mask file was prepared using 25 x 25 meter grids based on field experience with local dogs. I considered that many dogs kept leashed for around 24 hours in premises so such dogs won't move much.

b) Dietary analysis of dogs

I calculated percent occurrence of prey or food items in scats using total number of a particular prey item in total number of scats. However, given the high digestibility of large prey than small prey species and low occurrence of hair in scat, often mislead prey consumption (Karanth and Sunquist, 1995). Thus, estimation of biomass consumption plays a pivotal role in deciphering more reliable dietary spectrum of carnivores. Considering logistic constraints, I used wolf correction factor equation for dog's diet. The biomass estimation of prey items was calculated using regression equation calibrated by Jethva and Jhala (2004). With the help of correction factor *Y*, I also calculated proportion of relative biomass (*D*) and relative number of individual (*E*) consumed by dog.

Frequency of occurrence

$$= \frac{\text{Total number of a particular prey}}{\text{Total number of scats}} * 100$$

$$\text{Biomass estimation (Y)} = 0.0148(X + 0.135)$$

Y= correction factor, X= prey species

$$\text{Relative biomss of Prey species } D = \frac{A * Y}{\Sigma(A * Y)} * 100$$

$$\text{Relative number of Prey species } E = \frac{D * X}{\Sigma(D * X)} * 100$$

c) Perception of locals towards dogs

I used compositional analysis to decipher peoples' attitude towards free ranging dogs. Non-parametric test chi square test was used to check variation between variables like gender, occupation and education. The analysis was performed in R software.

3.3. Results

3.3.1. Population estimates of dog

a) Dog population in Tsokar basin

In Tsokar, a total of 104 km² area was sampled. Overall only $M_{t+1}=11$ unique individuals were identified in and around village Thukje while, dogs were absent in the rest of the landscape (Fig. 6.2). Density estimation was 10 individuals / 100 km² (6-19 95% confidence intervals). The value of sigma (δ) was 42.8 m and lambda (λ) was 0.869 (Table 6.1).

b) Dog population in Tso Moriri basin

Total 127 km² area was sampled in Tso Moriri, of which I covered areas like Korzok, Paldo, Korzok Phoo, tourist camps, defence camps and road construction camp and other small *Rebos* (Fig. 6.3). Overall, $M_{t+1}=72$ unique individuals were captured during 5 occasions. The density of dog was 61 individuals/100 km² (48-77 95% CI). The δ value was 71.35 m and λ value was 0.633 (Table 6.1).

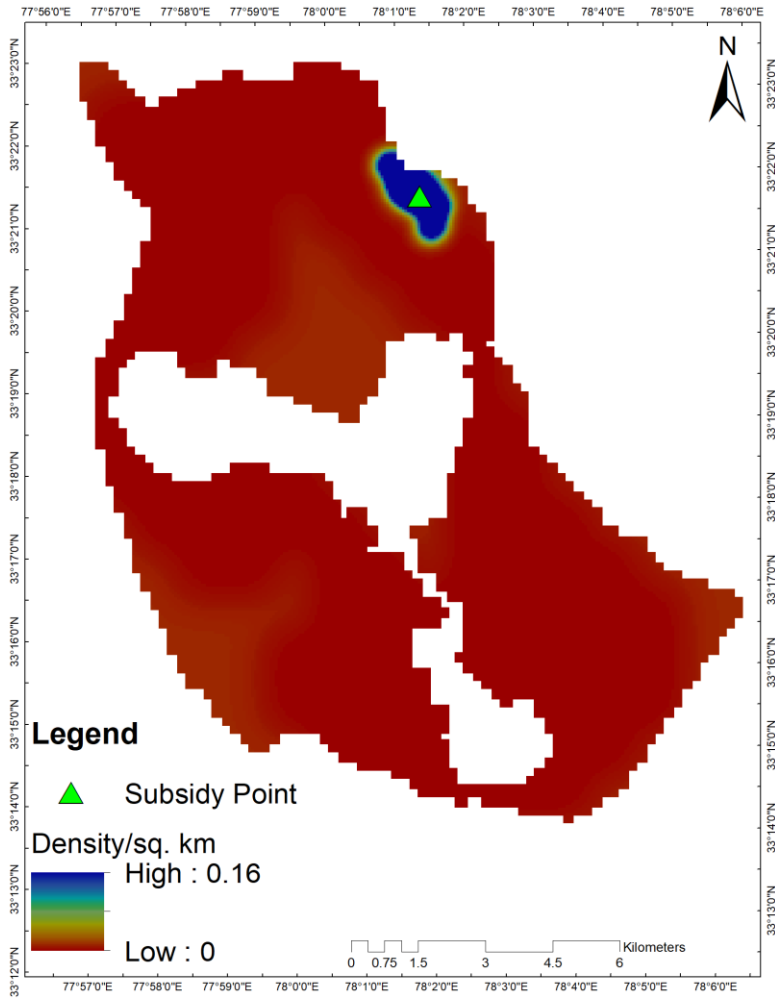


Figure 6.2. Density surface map of dog population in Tsokar basin

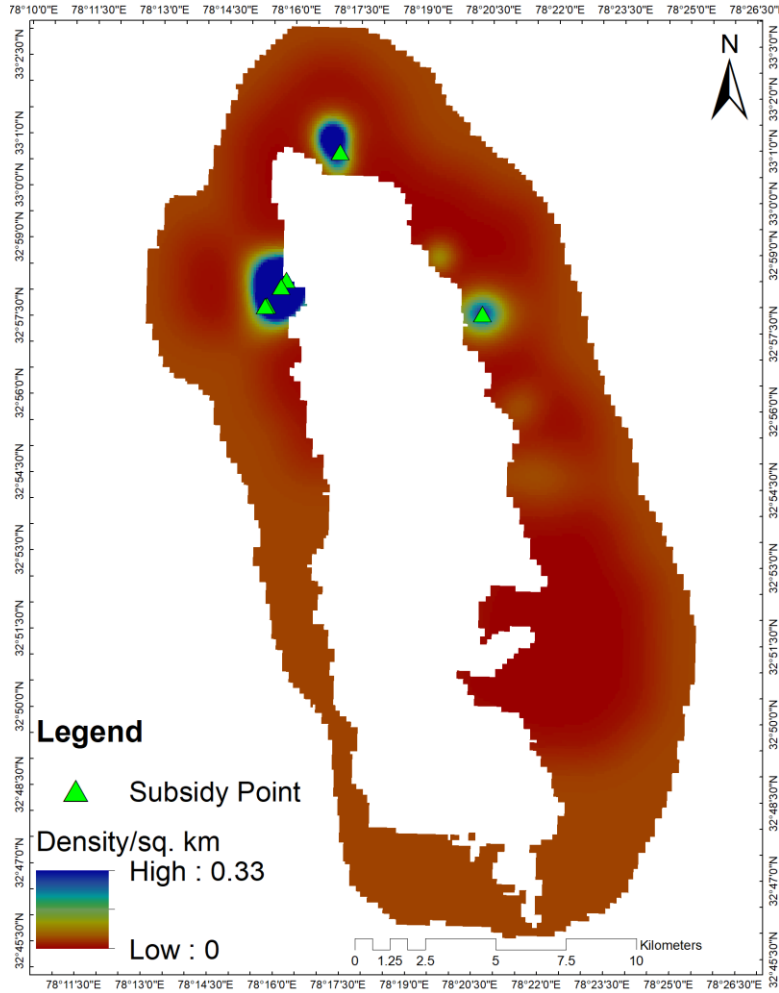


Figure 6.3. Density surface map of dog population in Tso Moriri basin

c) Dog population in Hanle

In Hanle, a total of 78 sq. km area was sampled. Among the three sites, dog density was highest here (Fig. 6.4). Total $M_{t+1}=224$ unique individuals were captured during 5 days sampling. The density was 310 individuals/ 100 km² (270-360 95% CI). The value of δ was 348.11 m and λ was 0.363 (Table 6.1).

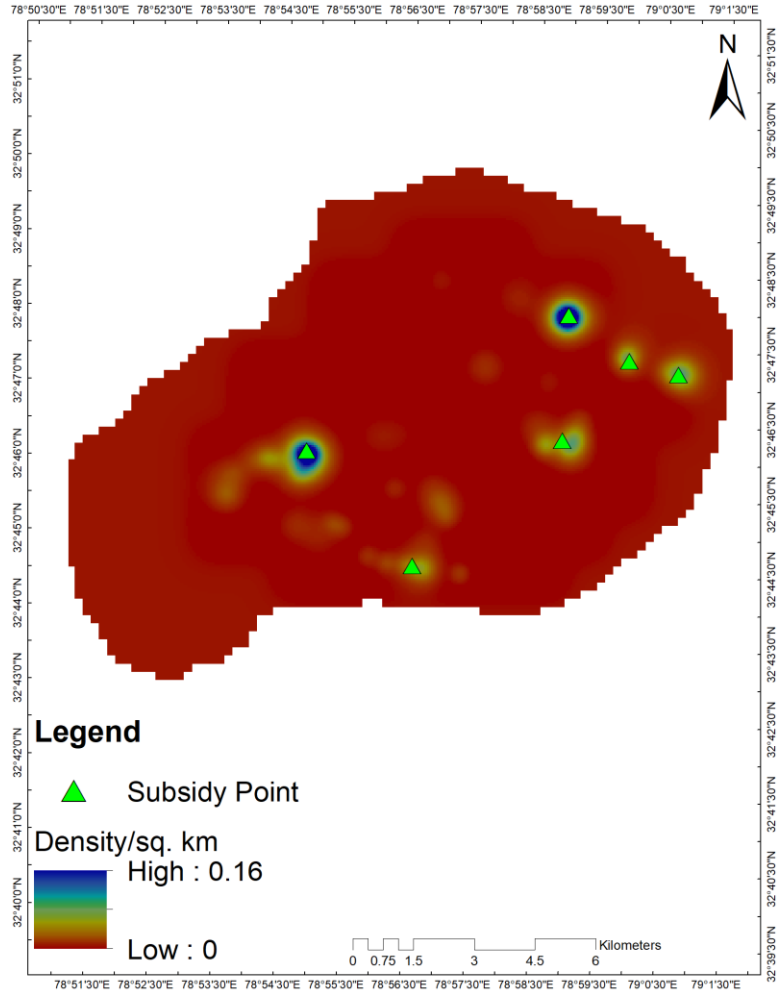


Figure 6.4. Density surface map of dog population in Hanle basin

Table 6.1. Site specific SECR density of dogs with 95% Confidence Interval (CI)

Site	Area (km ²)	Density (individuals/100km ²)	95% CI	Lambda	Sigma (m)
Tsokar	104	10	6–19	0.869	42.8
Tso Moriri	127	61	48–77	0.633	71.35
Hanle	78	310	270–360	0.363	348.11

d) Dog population in other sites using block counts

Apart from polygon search method, I also estimated dogs' population using block counts in lesser human dominated sites where < 10 households or *rebos* were present (Table 6.2). The entire area was sampled and total dog counts were recorded. Overall, seven sites were covered under this exercise. The dog abundance varied between n=2-8, and most abundant site was Kyun Tso (n=8) while least was Rongo wetland (n=2). In Kyagar Tso, no dog was recorded because pastoralists were not reached in their camps till sampling was completed. Usually these all sites temporary nomad sites and are away from human vicinity except Puga. Mostly leashed or unleashed shepherd dogs were encountered in these sites.

Table 6.2. Block count of dogs in different sites with < 10 households

SN	Study Site	Area (sq. km)	Total Count
1	Puga	6	7
2	Yaya Tso	10	4
3	Staklung	18	3
4	Rongo	8	2
5	Lal Pahari	11	6
6	Kyun Tso	54	8
7	Kyagar Tso	11	0

3.3.2. Dietary pattern of dogs

A total of 850 scat samples were collected, of which 103 were discarded and 747 scats were analyzed further for microscopic identifications. In 2015, overall 121 scats were collected followed by 402 in 2016 and 224 in 2017. I measured length and diameter of the 42 well intact scat samples, mean length of scats was measured about 17.52 SD \pm 7.25 cm (range 7.9-36.6 cm) and diameter (at thickest section) 2.83 SD \pm 0.52 cm (range 1.7-3.8 cm). Out of randomly selected 100 scat samples, we could successfully extract DNA from 80% of samples and PCR identification using carnivore specific primer identified 88% samples as dogs (Appendix 6.2).

Overall, twenty major type of food items were found across the study area including livestock, cattle, wild ungulates, rodents, lagomorphs, birds, poultry, seeds, grass, cereals and HDM. Most of the scats contained single food item (55%), whereas few scats contained five items (10%). Major part of the diet was constituted by livestock (83.68%) followed by wildlife (16.33%) [birds (5.91%), rodents (4.63%), ungulates (4.59%) and lagomorphs (1.03%)] (Fig. 6.5). Sheep, goat, cattle including yak, cow-yak hybrid and poultry was key domestic food items in dogs' diet and species like blue sheep, argali, kiang, woolly hare and rodents were wild items in the diet. In birds, I could only ascertain feathers till order level including anseriformes, passeriformes and galliformes (Appendix 6.3). Many scats contained HDM including paper, polythene, plastic, thermocol and rubber items.

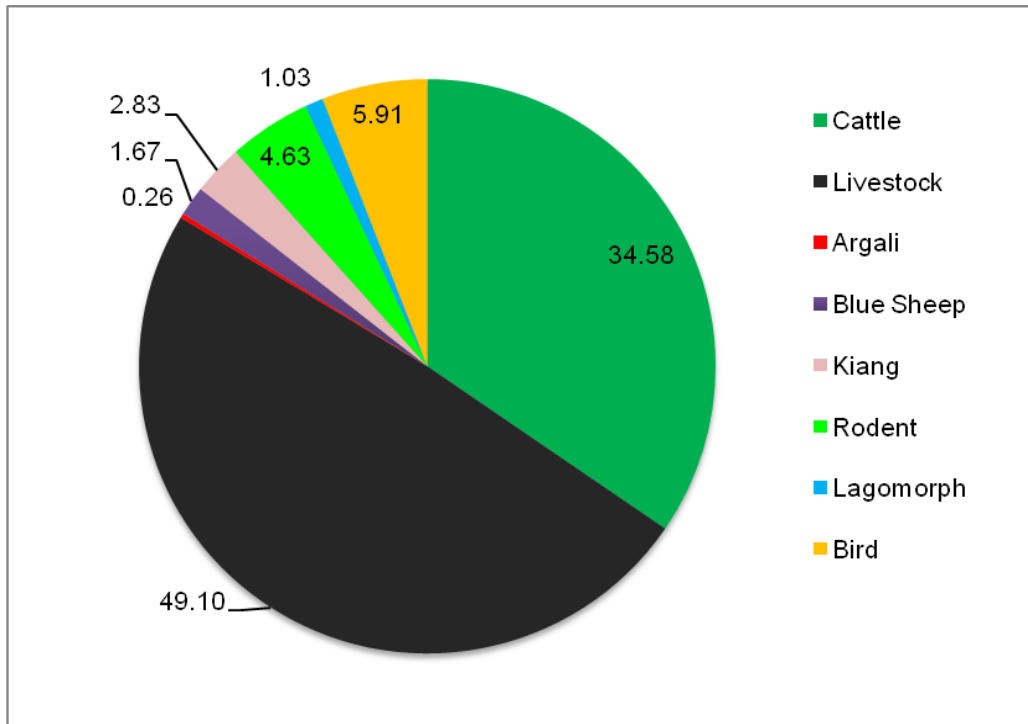


Figure 6.5. Frequency of occurrence of different prey items in Dogs' diet

The correction factor of the diet (Y), Frequency of occurrence (A), proportion of relative biomass (D) and relative number of individual (E) of prey species consumed by dogs is given in Table 6.3. Dogs mostly consumed individual of livestock and minimum of argali. For small species like rodents and birds, number of the relative individual was high however; proportion of the relative biomass was low. In large wild prey items, the highest proportion of relative biomass was comprised of blue sheep (1.49%) and argali was in the lowest proportion (0.48%). Birds constituted about 0.27% proportion of relative biomass which includes chicken poultry and wild species. However, domestic species like livestock (goat and sheep) constituted 25.88% and 58.40% by cattle (yak and dzo) constituted as a major proportion of dogs' diet (Table 6.3).

Table 6.3. Frequency of occurrence (A), average weight of prey item (Wt), correction factor (Y), proportion of relative biomass (D) and relative number of individual (E) of prey species consumed in diet of dog

SN	Prey items	A	Wt (Kg)	Y	D %	E %
Wild Prey items						
1	Blue Sheep	1.67	52	1.08	1.49	1.32
2	Argali	0.26	110	2.24	0.48	0.20
3	Rodent (Pika/vole)	4.63	0.5	0.05	0.17	15.93
4	Woolly Hare	1.03	2.5	0.09	0.07	1.34
5	Tibetan Wild Ass	2.83	280	5.64	13.23	2.18
6	Bird	5.91	1	0.06	0.27	12.42
Domestic Prey items						
1	Livestock (Goat and Sheep)	49.1	30	0.64	25.88	39.72
2	Cattle (Yak, Dzo)	34.58	100	2.04	58.40	26.89

3.3.3. Description of respondents and their perception towards dogs

A total of 210 respondents comprising of 52% males and 46% females with an average family size of 5.75 (SE 0.16) were interviewed. There was no significant gender based difference in perception towards dogs (χ^2 value=0, df =1, p >0.05). The average age of respondent was 44 (SE 0.99) years (range 18-74 years) as I targeted all age group people. Most of the respondents were illiterate (69%), while only 16% had higher secondary, 12% had primary education and 3% had education till senior secondary. There was no significant difference in the perception of respondents based on education (χ^2 value =0.27, df =2, p >0.05). Primary occupation of the respondents was pastoralism with about

63% respondents involved in it, followed by farming (20%), labour (4%), private job (3%), house wife (3%), student (2%) and monk (1%) (Table 6.4). Despite having different primary occupations, 93% respondents were involved in livestock rearing as their secondary occupation or traditional family occupation. There was significant difference in the attitude of pastoralist and non pastoralist respondents towards free-ranging dogs (χ^2 value = 44.95, df =1, p <0.001). Overall, 31,130 head of livestock were owned by respondents, of which 18811 were goats, 10929 were sheep, 978 were yaks, 317 were horses, 52 were cows and 43 were donkeys. The average monetary value of livestock was estimated around 937861.53 INR/family.

Table 6.4. Description of respondents in CWLS

	Category	Total number	Percentage (%)
1	Age (years) (i) 18-30 (ii) 31-45 (iii) 46-60 (iv) >60	44 66 75 25	21 31 36 12
2	Gender (i) Male (ii) Female	110 100	52 48
3	Religious Sect (i) Drukpa (ii) Drikung (iii) Sherpo (iv) Other	96 21 19 74	46 10 9 35
4	Education (i) Illiterate (ii) Primary (iii) Junior High School (iv) Senior Secondary	145 26 33 6	69 12 16 3
5	Occupation (i) Grazer (ii) Farmer (iii) Student (iv) Govt. Employee (v) Private (vi) Monk (vii) Home maker (viii) Labour (ix) Other	132 42 5 4 6 2 6 9 4	63 20 2 2 3 1 3 4 2
6	Family Size (i) < 2 (ii) 2-5 (iii) 6-10 (iv) >11	2 108 92 8	1 51 44 4

a) Details of shepherd dogs

Out of 210 respondents, 163 respondents owned dogs in their houses. Total n=240 shepherd dogs were recorded in respondents' houses. The sex ratio was highly skewed towards males, few respondents owned females (Fig 6.6). Perhaps owing to high fecundity and cost of care prevented respondents to own female dogs. As dogs were

mainly utilized for guarding houses, *rebos* and livestock, hence male dogs were preferred over females for getting maximum service with less care. Usually, pups were brought from some far located villages where people usually rear females for pup business.

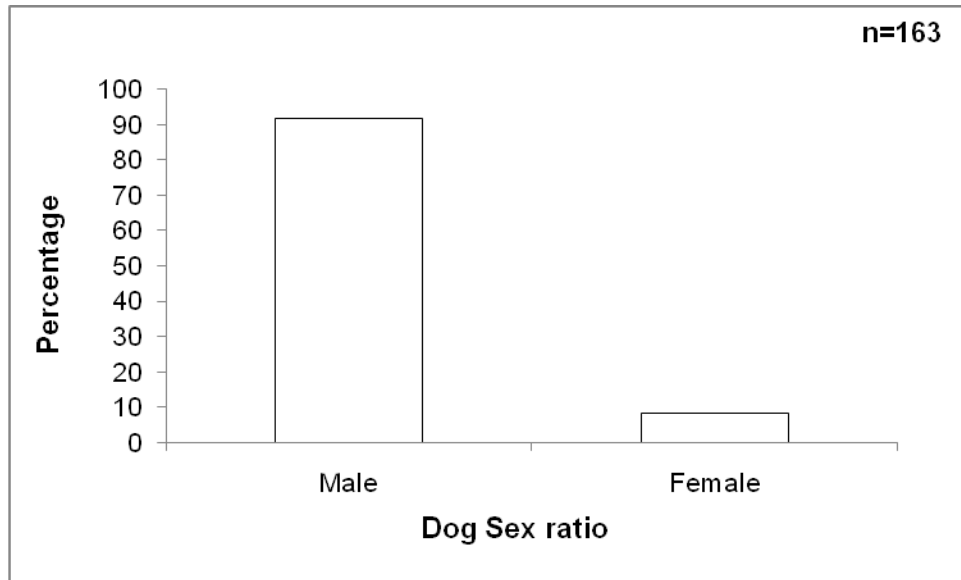


Figure 6.6. Sex ratio of shepherd dogs in respondents' houses

I also enquired about disease and vaccination program for dogs in remote villages of Changthang. About 13% respondents reported disease in their dogs while other did not report any disease. While enquiring about vaccination programs, only 10% respondents vaccinated their dogs (Fig 6.7). During informal interactions, I found that most of the respondents were not aware of possible disease outbreaks and vaccination schemes.

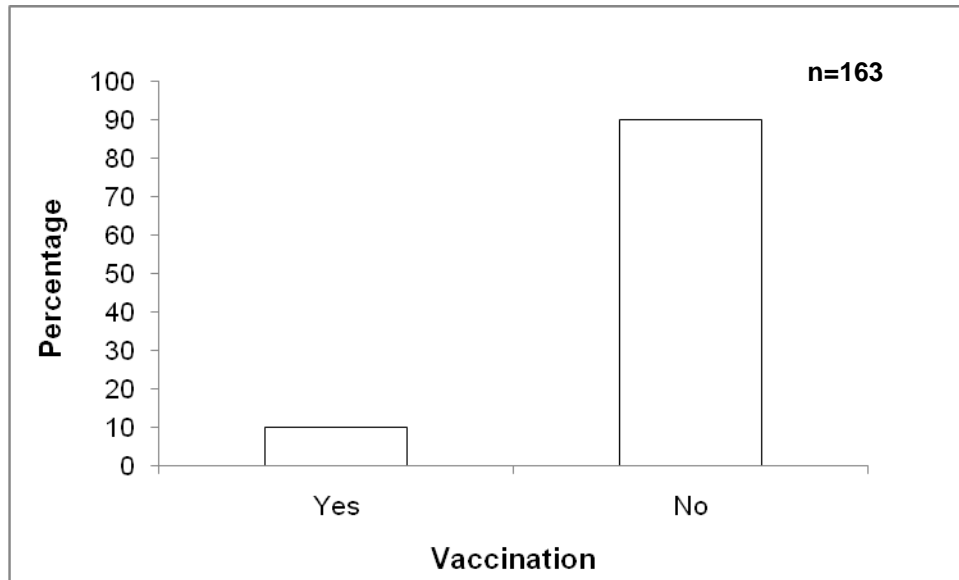


Figure 6.7. Vaccination of shepherd dogs in CWLS

Most of the dog owners kept their dogs continuously free (78%) followed by continuously leashed (10%), leashed during night (5%), leashed during day (4%) and leashed sometime irrespective of the time (2%). Respondents kept their dogs continuously free to safeguard their livestock and cattle from predators (Fig 6.8). Often, ferocious behaviour of shepherd dogs kept their sympatric carnivores away from livestock and cattle. Distance travelled by guard dogs varied in between 1-30 km along with their owners.

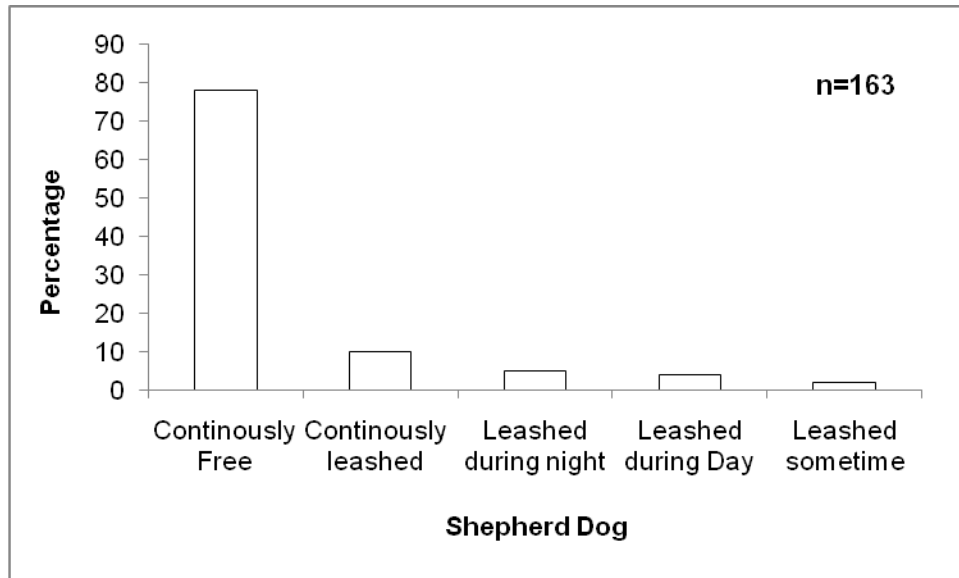


Figure 6.8. Types of Care for shepherd dogs in CWLS

I also enquired about involvement of shepherd dogs in attack on wildlife. Few respondents (6%) reported that their dogs were involved in attacks on wildlife including Himalayan marmot and woolly hare. Most of the respondents (75%) did not report any such cases and rest (19%) had no idea (Fig. 6.9). During study period, these results were also confirmed by my direct opportunistic behavioural observations of dogs chasing and predating on various wild species including birds and mammals (Appendix 6.4).

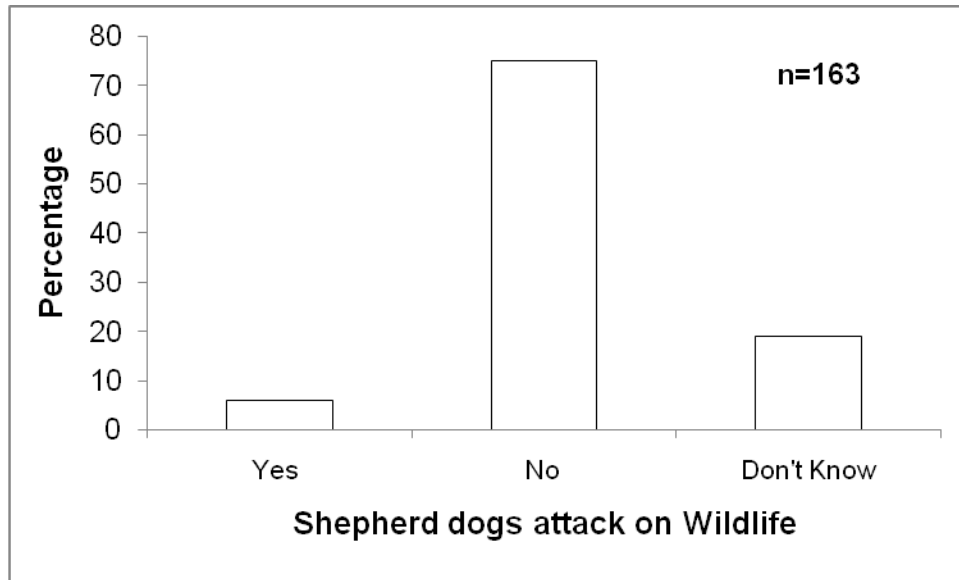


Figure 6.9. Attack on wildlife by shepherd dogs in CWLS

b) Attacks of free-ranging dogs on wildlife, livestock and human

Overall 40% of the respondents considered free-ranging dogs as problem; while 23% respondents had no problem with dogs and about 37% respondents could not figure out if dogs were a problem. A total of 185 livestock predation incidences were reported by respondents between 2015 and 2017. About 32% respondents reported free ranging dogs as threat to livestock including sheep and goat, while 67% respondents did not report free-ranging dog as threat to livestock and 1% respondents were unaware of dog's impact on livestock who were not involved in pastoralism. During year 2018, average market value of adult sheep was INR 5000, goat INR 4000, yak INR 40000, horse INR 80000, pony INR 20000 and *dzo* was INR 8000 in Leh town. In case of predation on wildlife, only 10% respondents reported free ranging dogs harassing and predating on wildlife including birds like black necked crane and bar-headed goose. Only four cases of dogs

attacking/ biting humans were reported by respondents (2%) in eastern Changthang (Fig. 6.10).

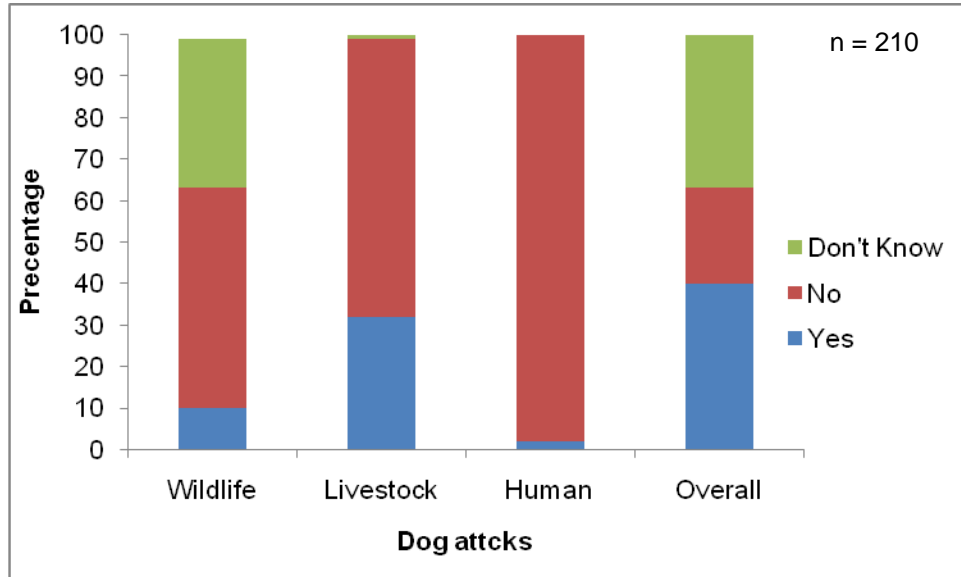
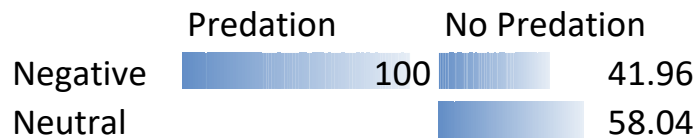


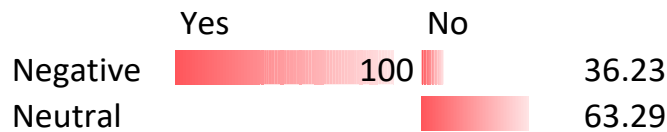
Figure 6.10. Impact of free-ranging dogs on wildlife, livestock and human

Only 9% respondents were aware of compensation scheme provided by Dept. of Wildlife Protection, most the respondents (91%) were totally unaware of compensation scheme. Those who ever applied for compensation were aggrieved about long and tedious process of getting compensation by department. They were also aggrieved about insufficient amount of compensation against their loss. While enquiring about solution of free ranging dogs problem, most of the respondents (90%) were unaware of solutions however, few (10%) were certain about ‘removal’ of dogs from their pasture lands and habitation areas. By ‘removal’ they meant to state that it could be either shifting dogs somewhere else or euthanise. Nevertheless, proportion of respondents supporting euthanasia was comparatively very less (4%).

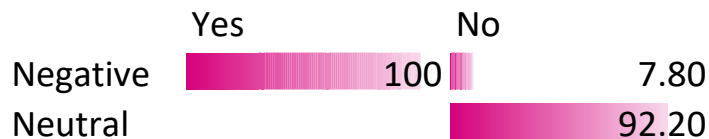
In Fig. 6.11 (a) depicts that respondents were 100% negative whenever they encountered any wildlife predation incidence by free-ranging dogs. Nevertheless, no predation encountered by 42% respondents were still negative towards dogs, while rest was neutral. In fig. 6,11 (b) 36.23% respondents were negative despite not reporting any attack/bite by dogs on humans, whereas rest were neutral. In case of livestock predation by dogs, about 8% respondents were negative towards dogs who didn't report any predation incidence.



a) Wildlife Predation by Free-ranging dogs



b) Human attack by Free-ranging dogs



c) Livestock predation by Free-ranging dogs

Figure 6.11. Peoples' perception towards free ranging dogs on wildlife, livestock and human (n=210)

3.4. Discussion

My results show a high dependence of dogs on humans. Dog density surface maps show that large congregations of dogs in and around large facilities such as defence camps, residential schools and construction company camps, perhaps functioning as reservoirs of easy food. The human subsidy has led the dogs in these areas to concentrate here. Information on the population abundance and demography will be helpful in developing strategies for the management of the dog problem. SECR is a workforce and resource-intensive method. So I used block counts in sites where small dog populations were present. Globally, several methods have been used to estimate dog populations (Belo *et al.* 2015), the most preferred of which is the capture–recapture method is; however, this method lacks reliability owing to some limitations. In India, a few studies have used the mark–resight method (Punjabi *et al.* 2012; Hiby *et al.* 2011), capture–recapture method (Home *et al.* 2017) and the Huggins heterogeneity model in a capture framework (Tiwari *et al.* 2018).

For species identification, initially I followed Farrell *et al.* (2000), however due to confusion in identification between dog and wolf scat eventually I relied on Paksions *et al.* (1997) and Kocher *et al.* (1989). This study revealed that dogs mainly consumed livestock in CWLS. Apparently, unlike wild animals, domestic livestock do not display anti-predatory behaviour. Hence these animals are easier prey for carnivores (Diamond 2002). Dogs have also been reported to sustain themselves on carrion of livestock by excluding wild competitors (Butler and du Toit 2002). Also, my finding could be an artefact of abundant availability of livestock in the form of carrion in CWLS. Hence, even if livestock is not preyed on by dogs, there are substantial chances of scavenging.

Other recent studies have also found the same trends wherein livestock constitutes the major part of the diet of dogs (Butler and du Toit 2002; Home *et al.* 2017). The availability of wild prey items in the diet indicates that the dogs were in competition with sympatric carnivores and scavengers (Vanak and Gompper 2009; Ghoshal *et al.* 2016). A dietary study conducted in Africa confirmed that dogs surviving mainly on human subsidies and carrion were in competition with vultures and other carnivores (Butler and du Toit 2002). Nonetheless, several studies have described dogs as being a prey item for other major carnivores in intraguild predation (antagonist interactions) (Gade-Jorgensen and Stagegaard 2000; Vos 2000; Butler *et al.* 2004; Athreya *et al.* 2014). A comparison of diet studies carried out in Asia shows that the consumption of livestock and cattle by dogs in Ladakh is high. Perhaps the close proximity to human provides more chances to scavenge on carrion, with a small part of the diet coming from wildlife (Appendix 6.5).

Conversely, other sympatric carnivores mainly consumed wild species. The maximum sheep and goat consumption was recorded in Mongolia and the maximum cattle consumption in India, both by the snow leopard, indicating obvious conflicts between humans and snow leopards (Appendix 6.4). To date, there is a dearth of studies on intraguild competition in sympatric carnivores in the Indian Trans-Himalaya; hence, my results are unable to describe the actual situation in the present study site. The limited occurrence of down feathers in the scats was one of the limitations of my study. Because of this limitation, I was unable to identify most of the bird feathers beyond the order level. The presence of Anseriformes and Passeriformes items, in addition to human subsidies, in the scats indicates that the dogs were also dependent on wild bird species. The impacts of dogs can be very severe, for instance, endangered birds such as the black-

necked crane are under threat due to increasing populations of dogs around wetlands (Naoroji and Sangha 2011). Since poultry rearing has never been practiced in Changthang, the poultry leftovers were generated from chickens brought from Leh market by the local people for their consumption. In contrast, in the neighbouring district of Kargil, poultry is an essential part of the diets of the locals and foxes. Kargil is a dog-free area owing to different religious views (Reshamwala *et al.* 2018). The wildlife in CWLS is dominated by the *kiang*, followed by the blue sheep (Chundawat and Qureshi 1999; Bhatnagar *et al.* 2006), and the argali and Tibetan gazelle are sparsely distributed, and their numbers are small (Namgail *et al.* 2007c; Bhatnagar *et al.* 2007). Similar patterns were recorded in the present dietary analysis of dogs in terms of occurrence of mammal species.

Being a facultative scavenger, the dog explores the possibilities of food *via* various modes equally, and my study confirmed that HDM, carrion, plants, etc. were items in the dogs' diet. Availability of garbage along with livestock affects predation by dogs (Home *et al.* 2017). Akin to foxes, dogs also consumed a range of HDM items including plastic, polythene and rubber items in the Ladakh region (Reshamwala *et al.* 2018). Unmanaged garbage in parts of CWLS acts as open food reservoirs for dogs. Dogs congregated around defence camps most of the time and received subsidies from such infrastructure. Even scraps such as undigested sanitary napkins, currency notes and cloth pieces were found to have been eaten by dogs. Dogs dependent on leftovers and dumps hunt prey species more often than do satiated pet dogs, which receive more nutrition (Silva-Rodriguez and Sieving 2012).

My results from questionnaire survey show that mostly local pastoralists were impacted by free-ranging dogs in terms of livestock loss and attacks on humans. The same pattern has been reported in the Spiti region of Himachal Pradesh, where livestock predation by dogs was a key reason for negative interactions (Home *et al.* 2017). Interview-based surveys in Europe and the Americas yielded similar results in places where dogs preyed on livestock (Ciucci and Boitani 1998; Schüttler *et al.* 2018; Montecino-Latorre and San Martín 2018). Nevertheless, free-ranging dogs still have social acceptance among the local communities in Ladakh; however, this attitude might change in the near future with increasing negative interactions. Since Ladakh is a Buddhist-dominated area, religious beliefs prevent locals from retaliating against carnivores here (Bhatia *et al.* 2017). It also emerged from my questionnaire survey that a few individuals (4%) support the culling of problematic dogs.

Questionnaire studies have revealed the negative impacts of dogs on wildlife in India and other parts of the world (Home *et al.* 2017; Schüttler *et al.* 2018; Villatoro *et al.* 2019). Dogs play a key role in disease transfer, which can affect humans, wildlife and livestock (Daszak *et al.* 2000). Free-ranging dogs account for 99% of the cases of rabies transmission worldwide (WHO 2004), and they can transmit more than 60 other zoonotic diseases (Beck 2000; Reece 2005). A few of respondents were aware of disease transmission by dogs and of vaccination of dogs. Dogs often spread the canine distemper virus (CDV) to wildlife (Cleaveland *et al.* 2000), and they particularly pose a severe threat to endangered species (Laurenson *et al.* 1998; Seimon *et al.* 2013). In Asia, the highest incidence of rabies found in India, Bangladesh and Pakistan (WHO 2001), and about 36% of all human rabies deaths occurred in India (Dutta 1999). The rabies virus is

more common in male dogs, and thus male dogs account for 59–70% of all bites (Wright 1991). Suraweera *et al.* (2012) found that about 97.1% of the rabies deaths in India were due to dog bites. Jhala and Giles (1991) reported that wolves in the arid Indian landscape were prone to infectious diseases such as rabies, canine parvovirus, distemper, canine hepatitis and faced competition from feral dogs. During informal interviews with respondents, I found that compensation for livestock loss to carnivores was a key issue. Usually, the wildlife department of Leh District provides compensation for livestock lost to carnivores such as the wolf and snow leopard. However, compensation for livestock lost to free-ranging dogs was not a matter of concern for the wildlife department because these problematic dogs are not wild species, and they are a nuisance for wildlife that the department has yet to manage. It could be argued that the compensation scheme itself has pros and cons. Hence, many studies have suggested alternative ways to cope with negative human–wildlife interactions (Mishra 1997; Naughton-Treves *et al.* 2003; Dickman *et al.* 2011). Livestock depredation was a key factor in the negative attitude of local people towards free-ranging dogs. Economic loss due to livestock death further influences the economics of the respondents', therefore, their attitude.

Chapter 7: Land-Use and Land-Cover change in wetlands

7.1. Introduction

Worldwide, increasing human-induced disturbances have enhanced the rate of land-use change and affected native habitat and biodiversity (Collinge 1996; Newbold *et al.* 2015). Land-Use and Land-Cover (LULC) changes are no more considered as local environmental issues. Habitat degradation, fragmentation and loss are three different forms of habitat destruction (Hunter and Gibbs 2007). The world has witnessed a loss of 33% of the wetlands till 2009, mostly in the Asian continent (Hu *et al.* 2017). About 87% of natural inland wetlands have lost from 17th century to 20th century (Davidson 2014). In contrast, artificial wetlands have increased over the years (Swift 1964; Davidson 2014), only China has witnessed an increase of 122% in artificial wetlands (Niu *et al.* 2012). In the events of climate change and anthropocene, future predictions are even worse as 22% of the world's wetlands could be lost, of which 70% coastal wetlands could vanish till 2080s (Nicholls *et al.* 1999). Alteration of wetlands into agriculture lands was the key cause of wetlands loss in the 19th century (O'connell 2000). In Europe, 65% of the important bird areas (IBAs) have witnessed the change of wetlands into agriculture lands (Heaths and Evans 2000). Such changes in wetlands might cause a change in species' ecological functions (Erwin 2009).

India has 58.29 million hectares (mi. ha.) of the area under wetland category, of which 32.39 mi. ha. falls under manmade wetlands and 19 mi. ha. as under natural wetlands (Ramsar Bureau 2008). Many wetlands are prone to land-use changes (agriculture alteration and deforestation), climate change, hydrologic alteration, industrial and domestic pollution, habitat encroachments, excessive cattle grazing, tourism, illegal hunting of waterbirds and over-exploitation of their natural resources (Foote *et al.* 1996; Li *et al.* 2009; Bassi *et al.* 2014). Wetland ecosystems such as rivers, lakes, marshes and coastal estuaries provide many benefits for human well-being. People living in close proximity to wetlands depend partially or entirely on wetland ecosystem services (Mitsch *et al.* 2015). These include water supply, water purification, flood regulation, coastal protection and cultural and recreational services (USEPA 2002; Clarkson *et al.* 2013).

In an inventory of Indian Himalayan wetlands, a total of 8292 wetlands were identified, out of which, 2240 wetlands were present in the state of Jammu and Kashmir (J&K), covering around 3915.01 km² of area (Panigrahy *et al.* 2012). In Ladakh, a total of 968 lakes (above 3000 m) have been identified by SAC (2012), of which, 925 exist in Leh district covering around 1033.74 km² area. Furthermore, 12 major lakes (>5 km²) occupy 92% of the total water of lakes in Leh district (Panigrahy *et al.* 2012). The Trans-Himalayan wetlands are an oasis of productivity and have significant conservation value, particularly as breeding grounds for the globally threatened black-necked crane and other key waterbird species breeding in the region (Humbert-Droz 2000, Hussain and Singh 2001, Hussain and Pandav 2008).

The wetlands in J&K provide livelihood and play a significant role in the socioeconomic status of local communities. Catchment areas of many lakes are extensively used for paddy cultivation and fishery. In Ladakh, large wetlands consisting serene landscape of the Changthang region is a popular tourist destination. The lake basins are grazing grounds for both domestic livestock and wild ungulates such as *kiang* (Hussain *et al.* 2008). Realizing the ecological and aesthetic value of the wetlands, the Department of Wildlife Protection, J&K, has identified 15 wetlands across the three regions of the state to be protected as Wetland Reserves in accordance with the J&K Wildlife (Protection) Act, 1978. The Government of India has notified Wular, Hokersar and Tso Moriri as wetlands of national importance. Tso Moriri, one of the Trans Himalayan wetlands was designated as RAMSAR wetland declared in 2002 (www.ramsar.org). Considering rich avi-faunal diversity of Changthang, wetlands such as Chushul, Tsokar, Pangong and Tso Moriri have been declared as Important Bird Areas (IBAs) (Islam and Rahmani 2004).

Wetland mapping is an imperative tool for understanding wetland functions and monitoring wetland response to natural and anthropogenic factors. Remote sensing and GIS has been widely used to evaluate land-use change, in decisions and monitor the effectiveness of mitigation efforts (Muller *et al.*, 1993; Rebelo *et al.*, 2009). Change detection studies help out in assessing change in landscape on the temporal scale (Gibson and Power 2000). Wetlands are often affected by increased surface flows in urban or suburban areas with high densities of impervious surfaces (i.e., buildings and paved surfaces) (Ehrenfeld 2000; Mitsch and Gosselink 2000; Wang *et al.* 2001). Also,

landscape-scale mapping of these patchy habitats help to understand the population dynamics of faunal species (Semilitsch and Bodie 1998).

Recently, an atlas of high altitude lakes of India has digitized important Ramsar wetlands using NDVI, NDWI and NPI indices with LISS images (Panigrahy *et al.* 2012). Mostly wetland based research in India has been conducted on the limnological aspects and ecological/environmental economics of wetland management. Wetland loss is considered being the prime threat to waterbirds across the globe (O'Connell 2000). But, the hydrological and land-use changes in the catchment and socioeconomic processes leading to limnological changes have not been explored substantially (Bassi *et al.* 2014). Moreover, wetland centric tourism in CWLS during the last few years has put an extra pressure on this landscape (Genelitte and Dawa 2009; Humbert-Droz 2017). Hence, studying status of wetlands was imperical in CWLS.

7.2. Methodology

7.2.1. Data acquirement and image processing

The wetlands in CWLS were classified by using satellite data of Landsat 8 and Landsat 5 image data (30 m resolution) sufficed the essential scale of my objective to assess change in LULC (Table 7.1). I downloaded respective images from online open-access source <https://earthexplorer.usgs.gov/>, a United State Geological Survey Database (Woodcock *et al.* 2008). The land use land cover for the present scenario was done using supervised classification aimed to classify CWLS, Landsat 8 Operational Land Imager

(OLI) with image resolution of 30 meters. The past scenario was classified using Landsat 5 Thematic Mapper (TM) with image resolution of 30 meters (Appendix 7.1).

The LULC was categorised in seven broad classes (i) Waterbody (ii) Barren (iii) Rocky (iv) Sand (v) vegetation (vi) Marsh (vii) Snow. I included grass and scrubland under ‘vegetation’ land cover class and wet meadows, bogs, shallow pools and wet riverine beds were included under ‘marsh’ class. The barren cover was differentiated based on a relatively flat surface with stones and pebbles and the area with sandy soil and salt was characterized separately as sand class. Rest of the features like mountains, hills and hillocks with hard stone shapes and structures were considered under rocky class.

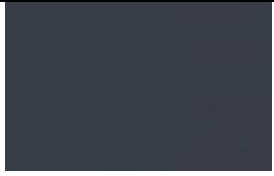



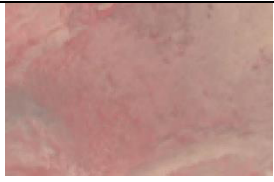


Table 7.1. Description of images used for classification

SN	Image detail	Acquisition Date	Sensor
1	LC08_L1TP_146036_20140820_2017420_01_T1	20 Aug 2014	Landsat 8 Operational land imager (OLI)
2	LC08_L1TP_146037_20140820_2017420_01_T1	20 Aug 2014	
3	LC08_L1TP_147037_20140928_20170419_01_T1	28 Sep 2014	
4	LC08_L1TP_147036_20130621_20170503_01_T1	21 Jun 2013	
1	LT5_146037_1994_273ISP00	30 Sep 1994	Landsat 5 Thematic Mapper (TM)
2	LT5_147036_1994_296ISP00	30 Sep 1994	
3	LT5_147037_1994_264ISP01	21 Sep 1994	
4	LT05_L1TP_146036_19940813_20170113_01_T1	13 Aug 1994	
5	LT05_L1TP_146038_19940930_20170112_01_T1	30 Sep 1994	
6	LT05_L1TP_146038_19940914_20170112_01_T1	14 Sep 1994	

7.2.2. Supervised Classification

Ground truthing was conducted from May 2013 to August 2014 during the fieldwork of CWLS. Ground validation points were collected using Garmin Etrex GPS 10 with ± 3 meter accuracy of the device and collected points were used for LULC confirmation of various classes during the supervised classification of 2014 image. An image of 2013 was taken as a surrogate due to the unavailability of 2014 image for the same area. I used polygons (training areas AOI) using a homogenous cluster of pixels from each class to create a unique signature. Training polygons of different classes were taken into consideration for classification. Training polygons were representative of all classes and different condition of each class maintaining the same pixel on the edges. Subsequently, I used Maximum Likelihood estimator for supervised classification. Supervised classification accuracy was tested using Kappa Statistics (Khat coefficient) (Lillesand and Kiefer 1994). The classification for analysis was carried out using ERDAS Imagine 2015.

Table 7.2. Characteristics of LULC classes

SN	LULC class	Colour	Texture/ Shape	Image reference
1	Waterbody	Dark blue or blue	Smooth/ Irregular	
2	Barren (plain, moderately flat)	Grey	Smooth/ Irregular	
3	Rocky	Grey, Blackish brown	Rough/ Irregular	
4	Sand	Light Pink	Smooth/ Irregular	
5	Vegetation (grass/scrub)	Red, Reddish Brown	Patchy or Rough/ (Ir)regular	
6	Marsh (bog/ wet meadow)	Red	Smooth or Patchy/ Irregular	
7	Snow	White	Smooth/ Irregular	

7.2.3. Change detection (1994 and 2014)

For analyzing changes in and around the catchment of these wetlands, I determined changes in land use land cover over two time periods (1994 and 2014). To determine changes in LULC, I used the post-classification change detection technique using pixels. The change detection analysis was performed in ArcGIS 10. Software. Subsequently, change in the area (percentage) of each class was calculated using the formula given below-

$$\text{Percentage change (P)} = \frac{Cb - Ca}{Ca} \times 100$$

where, Ca denotes changes in initial year and Cb denotes changes in recent year.

7.3. Results

7.3.1. Image interpretation: False Colour Composition (FCC)

In 1994 image, Band combination 4 (Near Infrared, (NIR)), 3 (Red) & 2 (Green) was used to denote FCC image and subsequently used in the image classification. In 2014 image, Band combination, 5 (Near Infrared, (NIR)), 4 (Red) & 3 (Green) FCC was used for supervised classification (Fig. 7.1).

7.3.2. LULC pattern of CWLS during 1994

The LULC was classified through supervised classification using Landsat-5 TM image of year 1994 (Fig.7.2). The area was found to be dominated by rocky land followed by vegetation. The total marsh area was found 0.39% of total area (73.13 km²), 2% of water

(376.39 km²), 73.42% of rocky (13811.22 km²), 5.65% of barren (1062 km²), 9.48% of vegetation (1783.74 km²), 2.85% of sand (535.97 km²) and 6.22% of snow (1169.24 km²) (Fig. 7.3). I obtained about 86.17% accuracy of the supervised classification of image with 0.8332 Kappa statistics value.

7.3.3. LULC pattern of CWLS during 2014

For year 2014, Landsat-8 OLI sensor image was used for image classification (Fig. 7.2) and 0.89% of the total study area was identified as marsh (167.01 km²), 2.02% as water (380.45 km²), 76.30% as rocky (14348.62 km²), 3.30% as barren (621.23 km²), 8.73% as vegetation (1641.67 km²), 2.14% as sand (402.57 km²) and 6.62% was snow (1244.92 km²) (Fig. 7.3; 7.4). Overall, 85.39% accuracy assessment for LULC classification was obtained with value of 0.667 Kappa statistics.

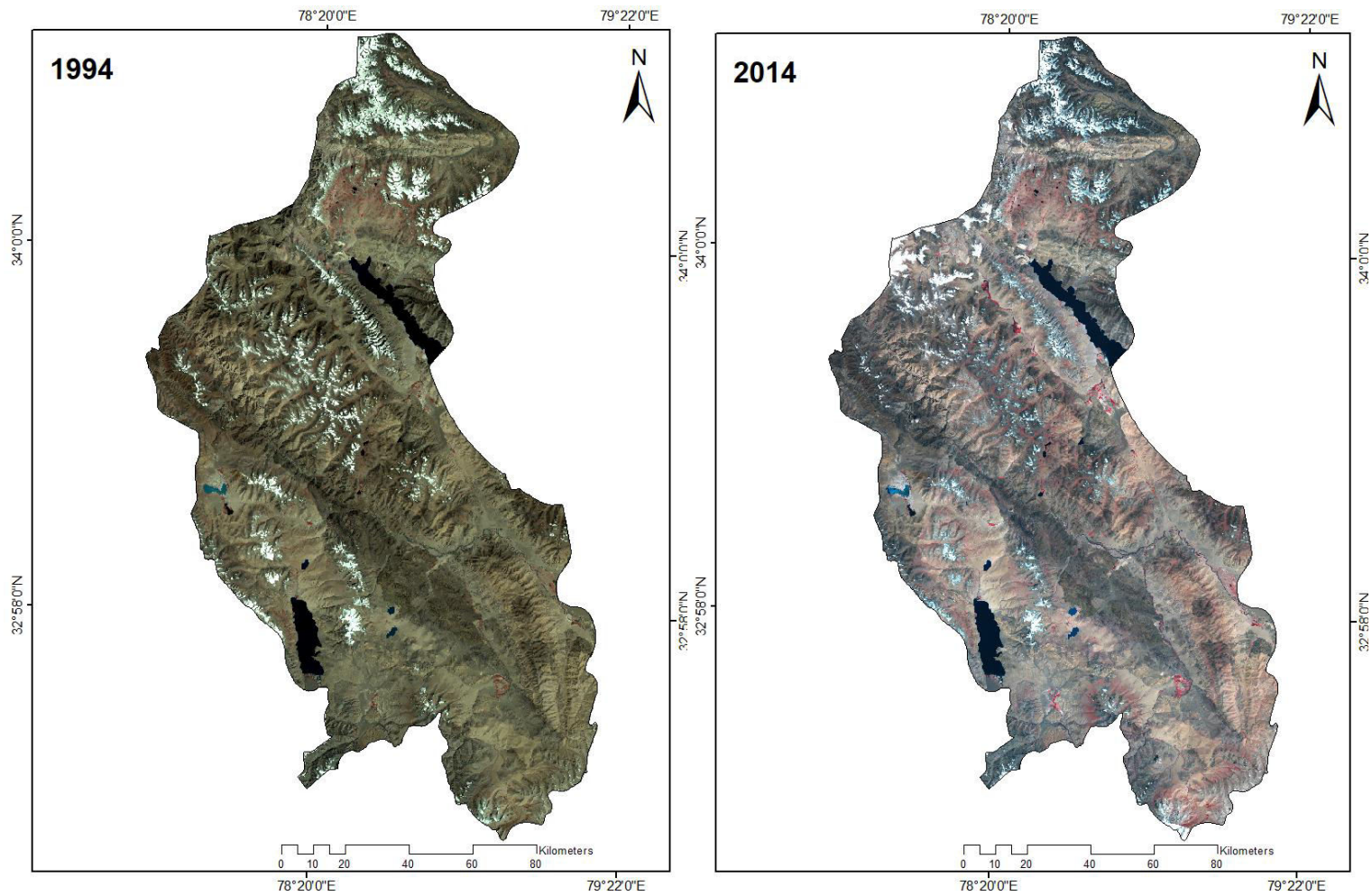


Figure 7.1. False Colour Composition (FCC) Images of 1994 and 2014 of CWLS

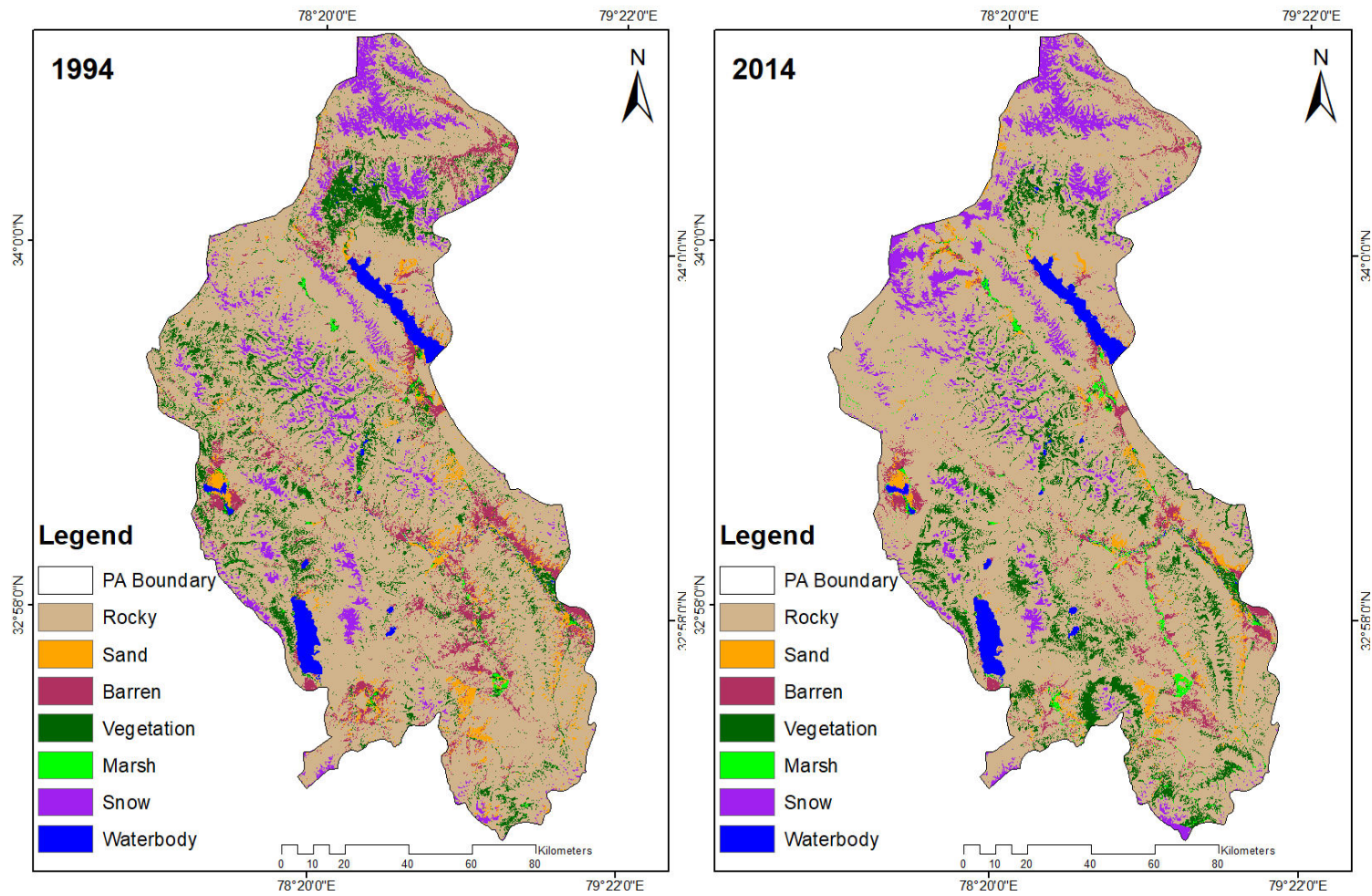


Figure 7.2. Land Use Land Cover maps of 1994 and 2014 of CWLS

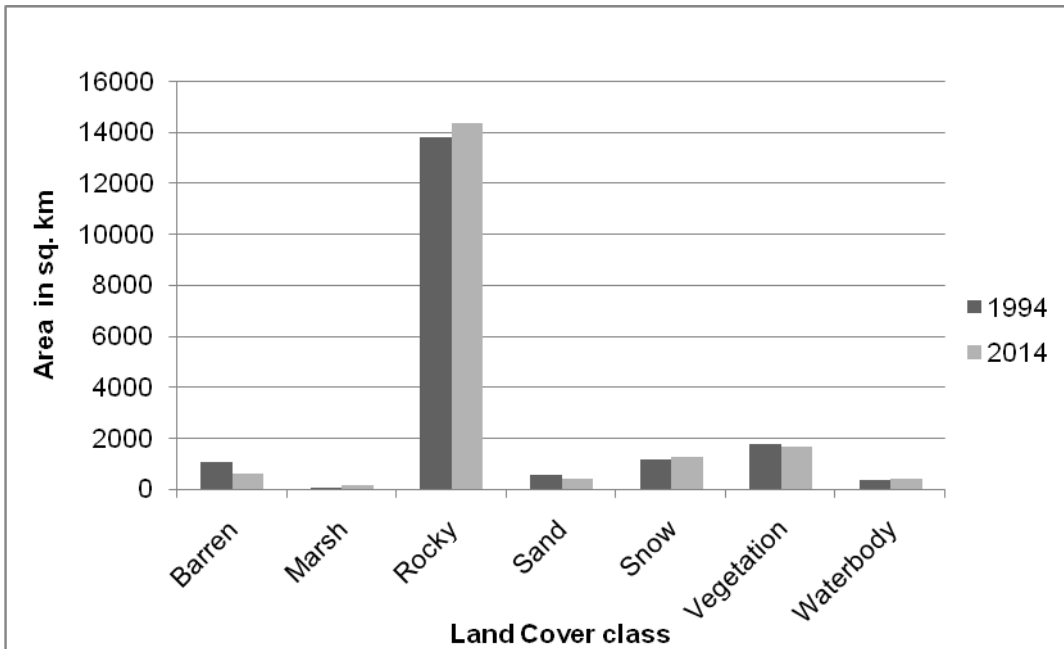


Figure 7.3. Area under each land cover class during 1994 and 2014

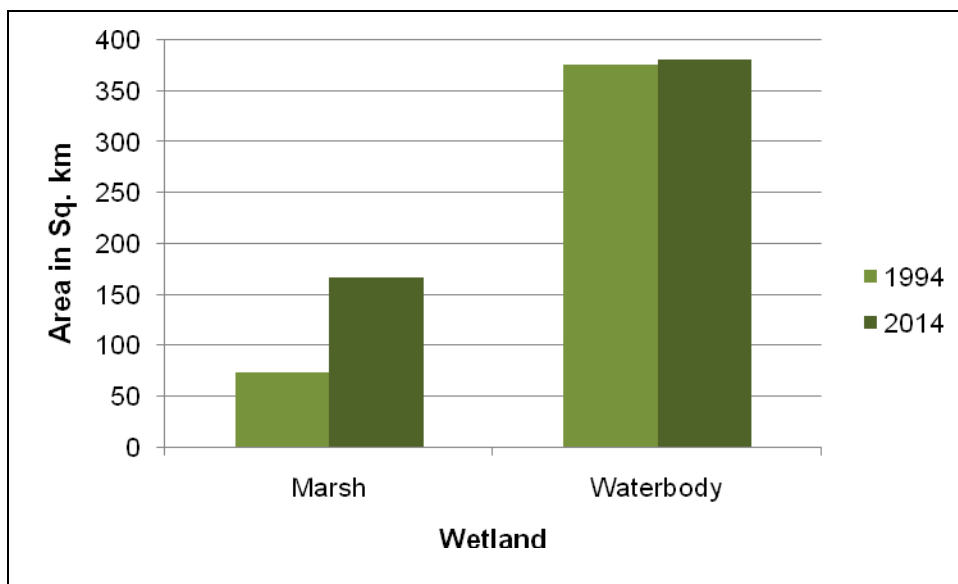


Figure 7.4. Area of marsh and water during 1994 and 2014

7.3.4. Change detection (1994-2014)

The maximum change was observed in class rocky, which increased about 2.86% during the gap of two decades. In wetland habitat classes (marsh and waterbody),

there was a slight increase of 0.50% in marsh area. Snow also witnessed an increase of 0.40% and 0.02% increase in water area in the total study area. Conversely barren (2.34%), sand (0.71%) and vegetation (0.76%) classes showed decrease in CWLS (Fig. 7.5).

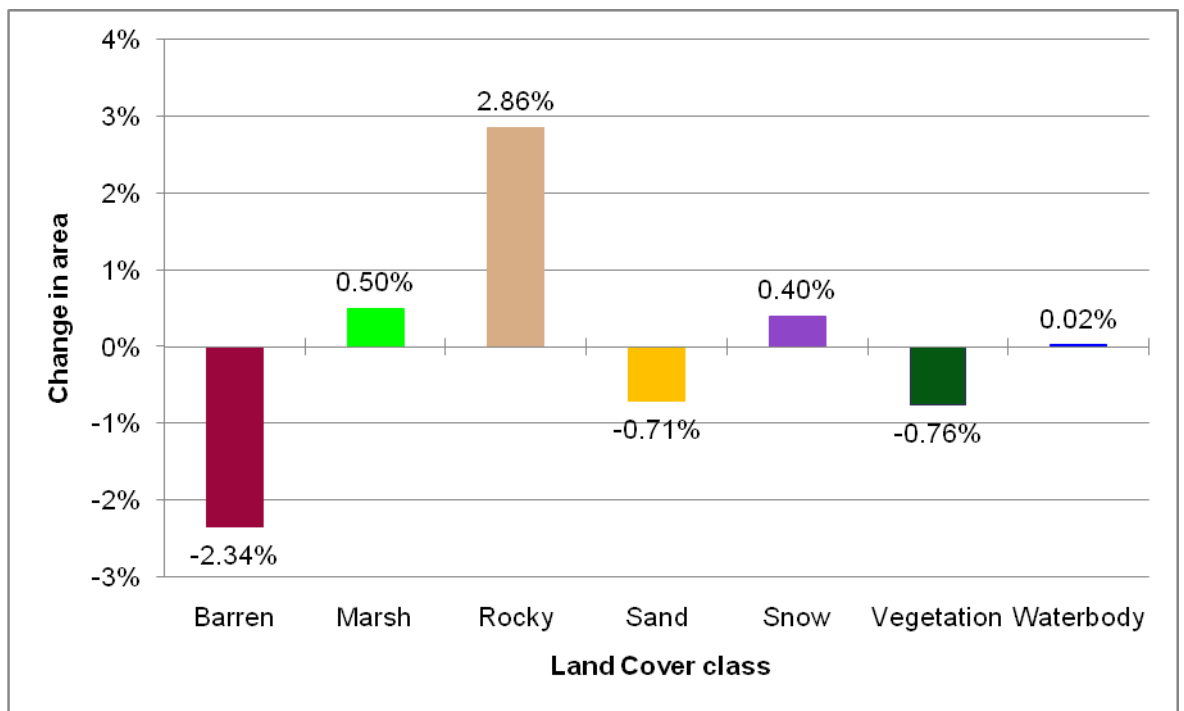


Figure 7.5. Land Use Land Cover change of two decades (1994-2014)

Table 7.3 and Fig. 7.6 provide the detail of the changes of each class into other classes with respect to area and percentage. The class specific changes were also calculated in the present study where 87.24% of 13818 km² rocky area was unchanged from 1994 to 2014 followed by 6.45% (891.07 km²) into vegetation, 2.41% (332.40 km²) into snow, 2.11% (291.77 km²) into barren, 1.38% (190.02 km²) into sand, 0.28% (38.66 km²) into marsh, 0.10% (13.40 km²) into waterbody and 0.04% (5.35 km²) into uncertain class respectively. Out of 535.97 km² of sand, less than half 28.88% (154.79 km²) was unchanged, the maximum of 62.63% (335.66

km²) sand class changed into rocky followed by 3.18% into barren (17.03 km²), 1.83% into vegetation (9.81 km²), 1.63% into marsh (8.74 km²), 1.36% into snow (72.8 km²), 0.44% into water (2.34 km²) and 0.06% into uncertain (0.31 km²) class respectively. Out of 1057.47 km² of barren area, only 27.73% (293.27 km²) remained the same, whereas maximum 65.98% barren changed into rocky (697.76 km²) followed by 4.66% into sand (49.29 km²), 1.11% into vegetation (11.75 km²), 0.25% into snow (2.60 km²), 0.14% into water (1.47 km²), 0.09% into marsh (0.93 km²) and 0.04% into uncertain (0.40 km²) class respectively.

Table 7.3. Transition matrix of area (km²) each class into other classes from 1994 to 2014 in Changthang Wildlife Sanctuary, Ladakh

LULC		1994							
		Rocky	Sand	Barren	Vegetation	Marsh	Snow	Waterbody	Uncertain
2014	Rocky	12055.39	335.66	697.76	961.83	10.82	274.28	11.30	1.58
	Sand	190.02	154.79	49.29	6.94	0.56	0.08	0.87	0.04
	Barren	291.77	17.03	293.27	18.82	0.09	0.04	0.03	0.18
	Vegetation	891.07	9.81	11.75	713.57	14.35	0.58	0.43	0.11
	Marsh	38.66	8.74	0.93	69.37	47.01	0.04	2.26	0.00
	Snow	332.40	7.28	2.60	9.16	0.22	892.65	0.41	0.20
	Waterbody	13.40	2.34	1.47	0.80	0.83	0.61	360.99	0.00
	Uncertain	5.35	0.31	0.40	0.40	0.01	0.97	0.08	17065.51
	Total	13818.06	535.96	1057.47	1780.89	73.89	1169.25	376.37	17087.42

In wetland related classes (marsh and waterbody), a total of 73.90 km² area of marsh, 63.61% (47 km²) marsh remained the same from 1994 to 2014, 19.42%

(14.35 km²) marsh changed into vegetation followed by 14.65% (10.82 km²) into rocky, 1.13% (0.83 km²) into water, 0.76% (0.56 km²) into sand, 0.30% (0.22 km²) into snow, 0.13% (0.09 km²) into barren and 0.01% (0.01 km²) into uncertain. Out of 376.37 km² area of water, 95.91% remained the same and maximum change was recorded into rocky 3% (11.30 km²), followed by marsh 0.60% (2.26 km²), vegetation 0.11% (0.43 km²), snow 0.11% (0.41 km²), uncertain 0.02% (0.08 km²) and barren 0.01% (0.03 km²) respectively.

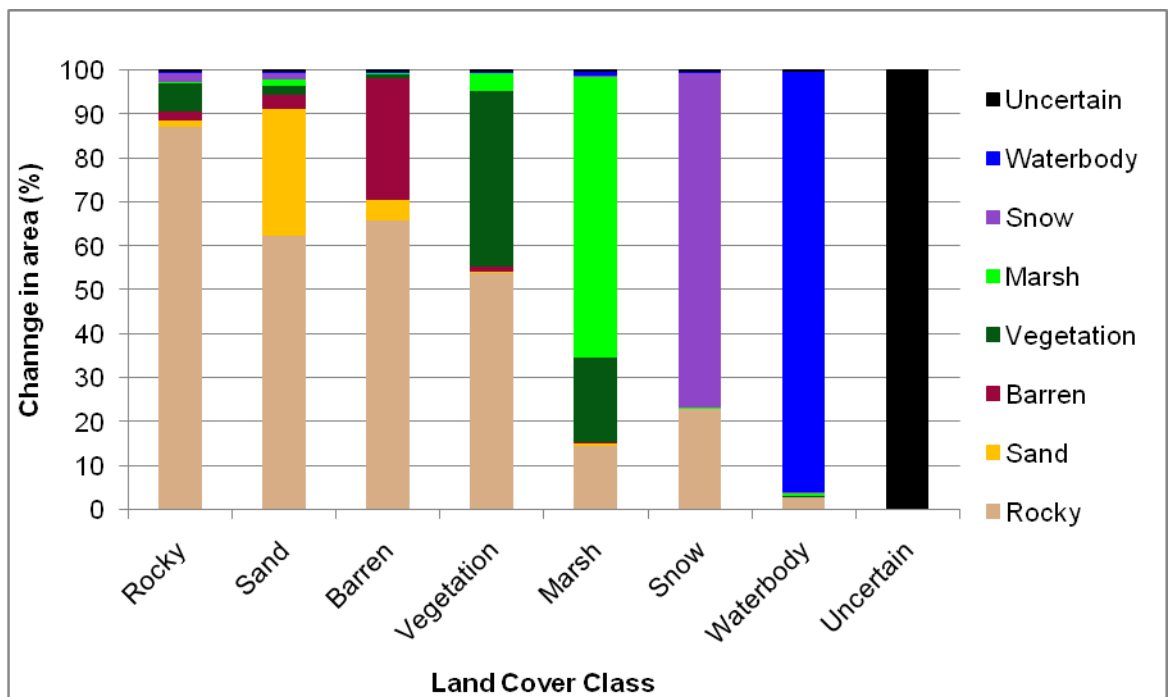


Figure 7.6. Change in the area (%) of each class into other classes from 1994 to 2014

Out of total 1780.90 km² area in the vegetation class, 40.07% remained unchanged; however, half of the vegetation 54.01% (961.83 km²) converted into rocky class followed by 3.90% (69.37 km²) into marsh, 1.06% (18.82 km²) into barren, 0.51% (9.16 km²) into snow, 0.39% (6.94 km²) into sand, 0.05% (0.80 km²)

into water and 0.02% (0.40 km²) into uncertain respectively. Out of 1169.24 km² area of snow, most of the snow 76.34% (892.65 km²) remained unchanged, followed by 23.46% (274.28 km²) into rocky, 0.08% (0.97 km²) into uncertain class, 0.05% (0.58 km²) into vegetation, 0.05% (0.61 km²) into waterbody and 0.01% (0.08 km²) into sand, whereas no conversion into barren class was recorded. The uncertain class completely remained unchanged during the two decades analysis.

The visible changes in the extent of wetlands have been recorded in small and large wetlands like Staklung and Hanle respectively (Fig. 7.7& 7.8). For instance in large wetland like Hanle, the land cover has interchanged into the vegetation and marsh.

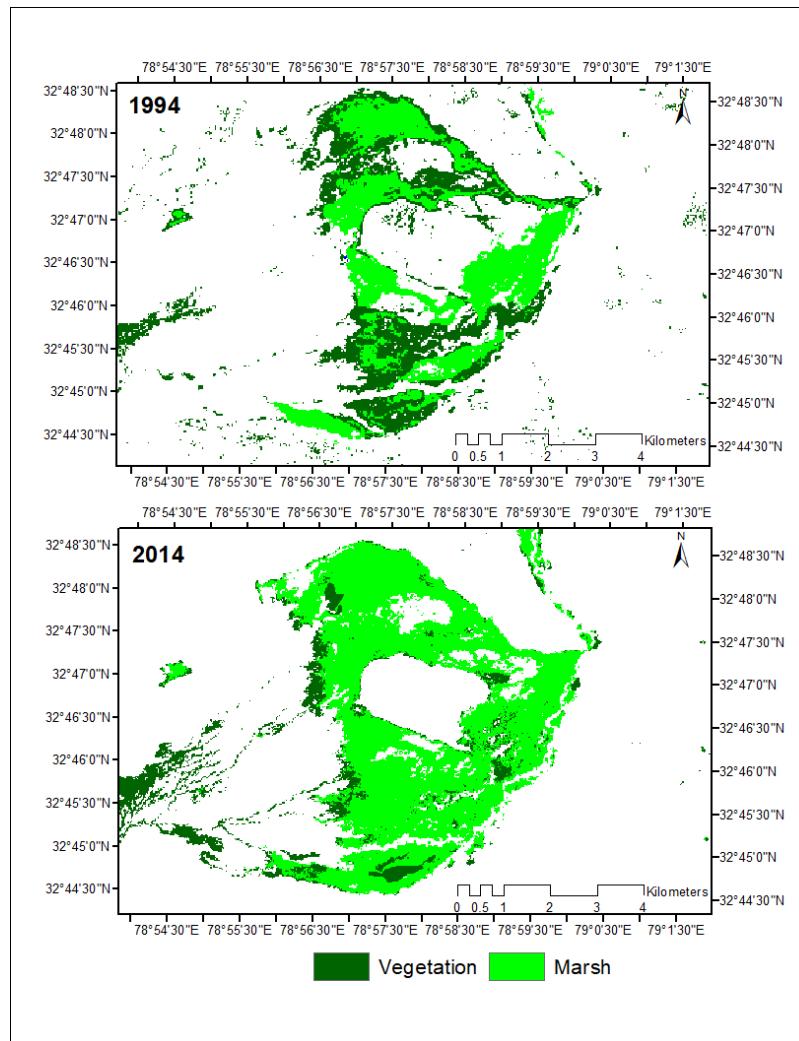


Figure 7.7. Change in the vegetation and marsh area in Hanle wetland complex during 1994-2014

In small wetland like Staklung, extent of wetland has increased over two decades. Here marsh has extended on northern side and occupied previous grass covered patch on south-west portion. During summers various waterbirds utilize this wetland including the black-necked crane.

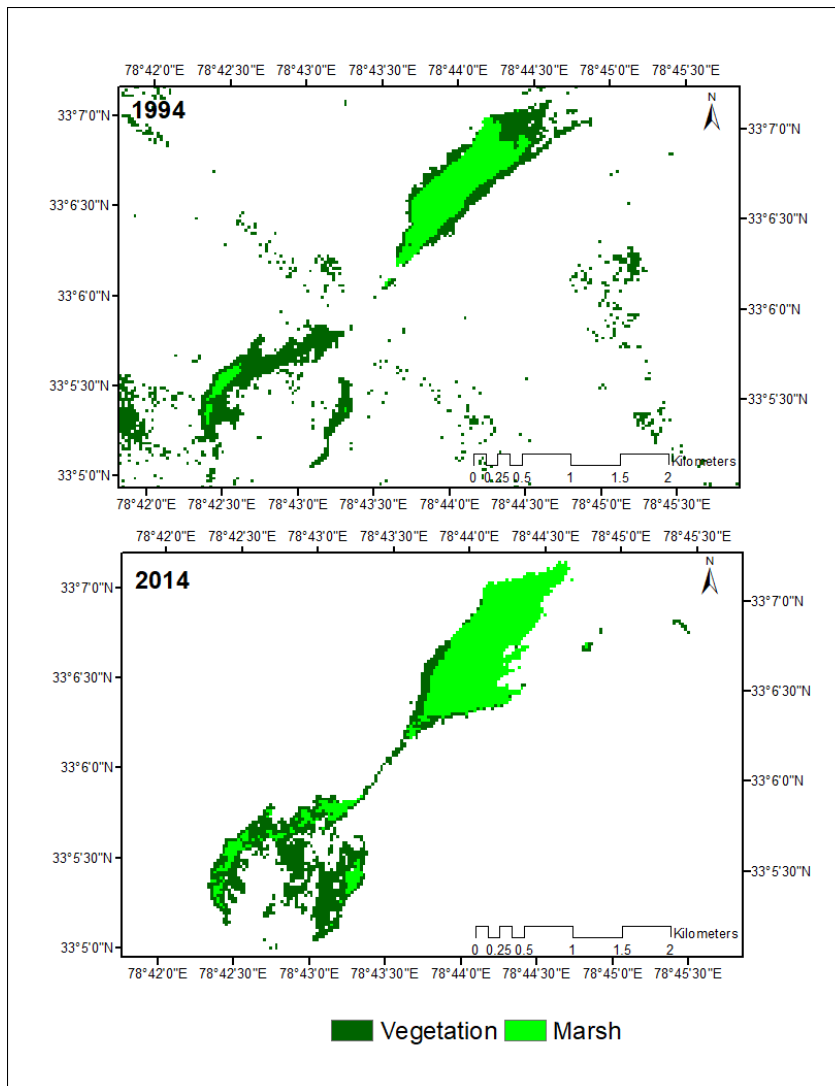


Figure 7.8. Change in the vegetation and marsh area in Staklung wetland during 1994-2014

7.4. Discussion

Overall, results showed an increase in wetlands' area of CWLS mostly due to increase in water and marsh in some wetlands. Previous studies also confirmed change in the water level of the lakes in this landscape, of which Pangong, Kyagar Tso and Tsokar showed an increase in water level (Srivastava *et al.* 2013). In Kyun Tso I & II, water level of lakes have also increased over the years. The small and

large both types of wetlands have witnessed a change in land cover over the two decades. For example, few marsh patches have been altered into the fenced grasslands and willow plantations for supplementing demand of local communities in Hanle. However, most of the vegetation class has changed into marshland. The vegetation has increased in Tso Moriri, and Chushul which could be due to increase in plantation and cultivation area. The wetlands in high altitudes are mostly fed by glacier run-off rather than rainfall (Bookhagen 2016). Many glaciers of Himalayan and Trans-Himalayan region have witnessed depletion and drastic change in snow line (Bolch *et al.* 2012; Schmidt and Nüsser 2017). However, over the two decades, snow cover almost remained the same as the earlier and there was minute (<0.50%) increase in snow cover in CWLS which could be due to seasonal variation or annual fluctuations. Evidences showed that there was an increase in the flash floods and rainfall in Ladakh during last few decades (Ziegler *et al.* 2016; www.worldweatheronline.com) which could be a reason of increase in water availability in wetland habitats. Studies have shown that climate change may not necessarily decline extent of wetlands; thermokarst and thawing can form new wetlands and interchange vegetation classes of wetlands in Tundra habitats (Gorham 1991; Gossman and Taylor 1996). Recent study has shown a significant increase in subnival vegetation between areas of 5000-5500 m a.s.l. in Hindu Kush Himalaya, (Anderson *et al.* 2020).

Apart from Changthang, a detailed LULC mapping of a small part of Nubra valley was done with the LISS III data (Joshi *et al.* 2005). In Changthang, LULC change study has only restricted to Tso Moriri, revealed that there was an increase in

the area of vegetation, grassland and agriculture but decrease in waterbody size over 15 years gap (Gupta and Shukla 2016). However, vegetation phenology in Tsokar, Tso Moriri and Pangong haven't showed much variation over the years (Bagchi *et al.* 2017). Being a Trans Himalayan arid zone, most of the area (82%) falls under rocky, barren and sand category. Only 10% of the green area exists which was comprised of marshland, grassland and scrubland, while the remaining area was covered by snow and water (8%). Usually, during summers, the marshy areas of CWLS hold maximum prominence value for graminoids followed by forbes (Rawat and Adhikari 2006). In Ladakh, marshlands are comprised of species like *Hippuris vulgaris*, *Myriophyllum verticillatum*, *Potamogeton pectinatus*, *Ranunculus* spp., *Kobresia*, *Carex*, *Blysmus*, *Poa* spp., *Puccinellia* spp. etc. (Rawat 2008).

Over two decades, landscape has not changed much, the small infrastructure development has taken place in specific sites which could not be depicted on this scale. Temporary tourist camps pitched at predefined locations during each summer season which has also increased many folds (Chapter 5). However, the seasonal tourism has increased many folds and tourism sector has affected lacustrine wetlands (Humbert-Droz 2017). Mainly defense camps have also been constructed near wetlands due to availability of water and strategic locations near LAC with China.

Unavailability of clear images of 1980s and 70s for the concurrent time/season was one of the limitations for this study. Usually, rapid seasonal variation in vegetation results in visible change in greenery. Another limitation of supervised classification was to classify settlement and agriculture land. The reflectance of the settlement could not be segregated from other class due to pixel

mixing like barren/rocky/ sand as settlements were mostly made up of mud (especially roof tops). Also, size of the settlements was very small which could not be visible in pixel value. Agriculture class was also confusing with respect to vegetation and was not easy to classify separately as a new class due to pixel mixing.

Chapter 8: Conclusions and Management Implications

8.1. Synthesis

Present study provided a systematic account of the status of waterbirds in CWLS. Despite being a small wetland, Statsapuk was found to be the most diverse wetland in CWLS. RSD and BHG were two most abundant species in CWLS, whereas globally threatened BNC had <100 individuals with about 22 breeding pairs. Despite increase in BNC population, behavioural observations of BNC nesting revealed that breeding success has decreased in last two decades. In 1990s breeding success was around 60% which has decreased below 30% in recent past owing various anthropogenic pressures (Chapter 3).

Waterbirds used major seven type of habitats namely water, sand, saltpan, marsh, grass, bog and barren (Chapter 4). The habitat use by breeding waterbirds was influenced by various factors. Species were highly correlated with wetland area, distance to human settlement, distance to road, water depth and pH. The correlation was species-specific some species were either positively or negatively correlated with variables. Key species like BNC was negatively correlated with distance to road. BHG showed positive relation with wetland and area and pH, while negatively correlated with anthropogenic factors. To date, pH and salinity of wetlands are normal and favourable for aquatic flora and fauna except natural exceptions like hot spring and borax deposition in wetlands.

The increase in tourism and other anthropogenic activities in recent past have posed new challenges for CWLS environment and people. As study revealed that most of the locals still practice pastoralism as their primary occupation therefore little tourism benefits reach to these people. As per locals various type of tourism are practiced in CWLS namely, adventure, wildlife, medical and recreational and such activities act like double edged sword if not regulated. For regulation, ecologically meaningful behaviour studies were conducted using FID and MAD measurements (Chapter 5). Study provided insights related to escape behaviour of breeding waterbirds where a positive relation was found between their FID and bodymass and wingspan. Species like BNC, GH had higher FIDs than small waders and waterfowls.

This study also assessed negative impacts of dogs on wild and domestic animals (Chapter 6) and it was found that birds had significant role (>5%) in shaping diet of free ranging dogs in CWLS. Dogs mostly preferred livestock followed by wild species. The population of dog was recorded maximum in Hanle (n=310/ 100 km² (CI=270–360)) and least was in Rongo (n=2) wetland. While interviewing locals, it was found that pet dogs were not vaccinated due to lack of awareness among them. During interviews, people also revealed that their pet guarding dogs were also involved in hunting or harassment of wild species like marmots, hares and also carnivores. The attitude of respondents was mainly influenced towards free-ranging dogs was due to their occupation.

The LULC study found that there was an interchange in the areas of waterbody, marsh, rocky and vegetation classes (Chapter 7). The changes might occur due to various factors starting from regional climatic changes to local anthropogenic factors.

Accuracy of supervised classification was fair in case of both images (1994 & 2014). Nevertheless, classification of images had its own limitations and misidentification of classes. The unavailability of suitable images of certain season/month was one of the limitations. Another issue related to image classification was pixel mixing which created difficulties in classification.

8.2. Global and regional significance of study

The present study holds some global significance especially, declaring Tso Kar basin as RAMSAR site would be welcome step, and will provide global recognition and conservation status to it. Increasing anthropogenic pressures pose various threats to wetlands. Following a country level tool for maintaining records of FID and other disturbance factors will contribute in management of wetlands. A tool like ‘AvianBuffer’ has been developed for Australian wetlands which is helping their managers in delineating buffers around the wetlands (Guay *et al.* 2016). Problem of dogs has increased many folds in India within last few decades. In countries such as the United States, animal protection organizations have recently initiated capture, neuter and return (CNR) programmes for dogs and cats. However, studies around the world have confirmed that at most 15% of dog’s population may be inaccessible to vaccination (Cleaveland *et al.* 2006). Present study also revealed dogs’ impact on wetland dependent species hence dogs should be declared as ‘invasive’ in the wildlife habitats since they are not the natural predators.

8.3. Recommendations

8.3.1. RAMSAR designation and delineation of buffer zones

In Tso Kar basin, Stasapuk and Tso Kar lakes are formed by fresh and saline water, provides mosaic of different habitats *viz.*, marshes, grasslands, bogs, saltpans, lakes, streams and small ponds. Due to low human disturbance during summers, both lakes provide ideal breeding habitats for various colonial waterbirds including BHG, BNC, GCG, CC, BrHG etc. Tso Kar basin is also a key habitat of Tibetan argali. Both lakes form highest waterbird richness and provide refuge to thousands of the waterbirds. Hence, the wetlands should be considered for RAMSAR designation.

The concurrent arrival of tourists and waterbirds in Ladakh during summer season, thus tourism activities disturb waterbirds and their habitats (Humbert-Droz 2017). The MAD information generated from present study can be used as buffer distance in effective wetland management like previous studies (Fox and Madsen 1997; Livezey *et al.* 2016). Besides FID, other factors *viz.*, visitation, vehicle, nesting sites and dog presence should also be taken into consideration while delineating buffer (Lafferty 2001). Further, socio-political acceptance should be included in decision making for the effectiveness of buffers (Castelle *et al.* 1994; Glover *et al.* 2011). Additionally, fencing reduces wetland habitats by altering marshland into grassland or agriculture. Removal of fencing from key wildlife habitats is required because often these obstacles prevent fledglings of waterbirds movement while approaching wetlands and increases vulnerability towards their predation. For example, species like RSD and CGS prefers nesting in crevices of nearby cliffs.

8.3.2. Promotion of community based tourism

Argumentatively, tourism still remains controversial topic thus, to maintain reliance and sense of accountability towards environmental cause, participation of local people is much needed. For foolproof mechanism, locals must be beneficiary of tourism economy along with other stakeholders (Badola *et al.* 2017). Nonetheless, other array of tourism related livelihood options also need to be provided to locals. Tourism benefit leakage is suspected on local level which needs a further quantification. Concurrently, there is a need of awareness campaigns among the local communities about ecotourism and such efforts always envisage positive changes among the peoples' attitude (Barthwal and Mathur 2012). My Study highlights need of 'Community based Ecotourism' in this fragile ecosystem with more environmental conscious and equal sharing of benefits. These steps will reduce dependency on pastoralism which could eventually reduce livestock related challenges to wildlife. Fencing of wetlands for using as grassland patches for winter fodder storage is one of the major concerns which has to be scrutinized. Wetland habitats need to be managed wisely for the use of wildlife and humans. Result of this study can also be used in developing conservation strategies based on participatory approach in consideration with impact of various human activities on wildlife behavior.

8.3.3. Management of garbage and other pollutants

Presently, garbage management, ban on off road driving, sewage management and control on visitors' number is a herculean task for authorities. The region has to be 'polythene free' as there is no alternative to this problem. Over the years, Ladakh has

shifted from traditional bio-toilets to water based flush toilets due to increasing demand from tourists, which might enhance problem of sewage effluents in near future. In some instances, authorities have taken actions against direct outlet of sewage into lakes. Hence, there is a need to promote bio toilets among tourists instead of water based toilets. During peak tourist season, vehicle volume increases drastically that also has to regulated by administration to avoid situation like Rohtang pass (Himachal Pradesh) in future. Additionally, district administration has provision of environmental fees for tourists and this amount been utilized for conservation efforts which can be collectively used with consultation to local communities.

8.3.4. Control on dogs' population

Dogs in CWLS need to be managed through CNR or removal, mainly from the wildlife hotspots such as breeding sites. This study revealed negative impacts of dogs on wild and domestic animals, and thus controlling the dog population in CWLS is required. Options such as poisoning pose threats to humans, including children, other animals and the environment. For example, strychnine causes respiratory problems in humans (Reece 2005). In addition to control measures, the economic impacts, the risk of disease and the costs related to dog bites need to be quantified through socio-economic studies (Pain *et al.* 2003). Predator-proof fencing (corral) can be used which has worked effectively in keeping feral dogs away and protecting livestock in Australia (Van't Woudt 1990). Concurrently, pastoralists need to leash their dogs to avoid harassment and predation of wildlife. In Ladakh, the sex ratio of the dogs is skewed towards males as the cost of care prevented pastoralists from owning female

dogs. Usually, pups are brought from some villages located far away where people usually rear females for the pup business. To avoid any disease transmission, vaccination of dogs should also be promoted by Wildlife and Animal Husbandry departments. Human subsidies play a vital role in shaping the dogs' demography, and thus subsidies like garbage and dumping sites need to be managed. This may reduce the dependence of the dogs on humans and hence will naturally control the dog population, and negative interactions with animals will also abate (Newsome *et al.* 2015). Adoption of dogs can be encouraged in Ladakh by authorities. An integrated approach would be required to manage the dog populations in habitats supporting wildlife (Vanak and Home 2018). And if aforementioned measures fail, then free-ranging/feral dogs should be declared as 'invasive' in the wildlife habitats since they are not the natural predators like fox, wolf or snow leopard.

8.3.5. Awareness and sensitization

Frequent sensitization workshops of stakeholder namely defense personnel, forest department and other line agencies are also needed to strengthen and improve management. For instance, the local pastoralists and defense personnel should also be sensitized about dogs' impact on wildlife, particularly on BNC nesting sites. For sensitization of locals, monasteries could play an effective role because religious leaders have substantial influence on society of Ladakh. Moreover, cooperation from active non-government organizations could play pivotal role in such activities.

8.3.6. Strengthening of wildlife staff

Due to vast area of sanctuary and limited number of wildlife staff, is one of the major limitations for the effective management of CWLS. With increasing pressure on CWLS, it's very urgent to recruit more staff and they should be better equipped and well trained. Training programs could be arranged with the collaboration of Wildlife Department, govt. institutions and non-governmental organizations. The Wildlife Department should also improve and expand their infrastructure inside CWLS. More entry point check posts are required and also need to have better intelligence network with defense forces for effective anti-poaching drive. Due to remote location, CWLS has very less facilities for rescue and rehabilitation of injured or rescued animals hence it is also recommended that there should be a rescue centre inside CWLS which could at least be able to handle normal cases or able to provide first aid. However, as an option local Veterinary staff of animal husbandry might be introduced to handle wild animal cases and their skill enhancement could be done by Wildlife Department itself.

8.3.7. Future research

Continuous monitoring of the waterbirds in all identified wetlands should be formulized and should be considered as mandatory annual exercise. Further, stopover sites play critical roles in sustaining migratory populations (Hutto 1998); thus, conservation of stopover sites is also vital for long term survival of BNC (Qian *et al.* 2009). Enigma of migration and important site needs to be unfolded through telemetry studies. It is imperative to identify such stopover sites and include them under legal protection through trans-boundary management between India and

China. More detailed and robust scientific studies are required on the ecology of BNC in India. Landscape level study of LULC changes is also recommended to see changes over last 50 years. Through this study, evidence based, cost benefit analysis of socio-culture changes and studies on tourism benefit leakage are recommended in Changthang region and other parts of Ladakh. It is also recommended that a study should be conducted on the intraguild competition and predation in the Trans-Himalayan region to fill research gaps.

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Appendices

Appendix 2.1: Mammal species recorded in Changthang Wildlife Sanctuary during study period (2015-2017)

SN	Species	Scientific name	IUCN status
1	Himalayan Wolf	<i>Canis lupus chanco</i>	LC
2	Himalayan Red Fox	<i>Vulpes vulpes</i>	LC
3	Tibetan Red Fox	<i>Vulpes ferraigata</i>	LC
4	Pallas's Cat	<i>Octolobous manul</i>	NT
5	Tibetan Argali	<i>Ommon ovis hognie</i>	NT
6	Blue Sheep	<i>Pseudois nayaur</i>	LC
7	Tibetan Kiang	<i>Eqqus kiang</i>	LC
8	Tibetan Gazelle	<i>Procapra picticaudata</i>	NT
9	Silver Mountain Vole	<i>Alticola argentatus</i>	LC
10	Stoliczka's Mountain Vole	<i>Alticola stoliczkanus</i>	LC
11	Himalayan Marmot	<i>Marmota himalyensis</i>	LC
12	Plateau Pika	<i>Ochotona curzoniae</i>	LC
13	Royle's Pika	<i>Ochotona roylei</i>	LC
14	Woolly Hare	<i>Lepus oiostolus</i>	LC

Appendix 2.2: Bird species recorded in Changthang Wildlife Sanctuary during study period (2015-2017)

SN	Species	Scientific name	Order	IUCN status
1	Himalayan Snowcock	<i>Tetraogallus himalayensis</i>	Galliformes	LC
2	Chukar Partridge	<i>Alectoris chukar</i>	Galliformes	LC
3	Tibeatn Partridge	<i>Perdix hodgesoniae</i>	Galliformes	LC
4	Common Kestral	<i>Falco tinnunculus</i>	Falconiformes	LC
5	Eurasian Hobby	<i>Falco subbuteo</i>	Falconiformes	LC
6	Saker Falcon	<i>Falco cherrug</i>	Falconiformes	EN
7	Black-eared Kite	<i>Milvus migrans lineatus</i>	Accipitriformes	LC
8	Bearded Vulture	<i>Gypateus barbatus</i>	Accipitriformes	NT
9	Himalayan Vulture	<i>Gyps himalayensis</i>	Accipitriformes	NT
10	Upland Buzzard	<i>Buteo hemilasius</i>	Accipitriformes	LC
11	Golden Eagle	<i>Aquila chrysaetos</i>	Accipitriformes	LC
12	Tibetan Sandgrouse	<i>Syrrhaptis tibetanus</i>	Pterocliiformes	LC
13	Snow Pigeon	<i>Columba leuconota</i>	Columbiformes	LC
14	Little Owl	<i>Athene noctua</i>	Strigiformes	LC
15	Eurasian Eagle Owl	<i>Bubo bubo</i>	Strigiformes	LC
16	Common Hoopoe	<i>Upupa epops</i>	Bucerotiformes	LC
17	Grey-backed Shrike	<i>Lanius tephronotus</i>	Passeriformes	LC
18	Eurasian Magpie	<i>Pica pica</i>	Passeriformes	LC
19	Northern Raven	<i>Corvus corax</i>	Passeriformes	LC
20	Red-billed Chough	<i>Pyrrhocorax pyrrhocorax</i>	Passeriformes	LC
21	Alpine Chough	<i>Pyrrhocorax graculus</i>	Passeriformes	LC
22	Eurasian Crag Martin	<i>Ptyonoprogne fuligula</i>	Passeriformes	LC
23	Wire-tailed Swallow	<i>Hirundo smithii</i>	Passeriformes	LC
24	Barn Swallow	<i>Hirundo rustica</i>	Passeriformes	LC
25	Tibetan Lark	<i>Melanocorypha maxima</i>	Passeriformes	LC

26	Hume's Short-toed Lark	<i>Calandrella acutirostris</i>	Passeriformes	LC
27	Horned Lark	<i>Eremophila alpestris</i>	Passeriformes	LC
28	Tickell's Leaf Warbler	<i>Phyllosopus affinis</i>	Passeriformes	LC
29	White-throated Dipper	<i>Cinclus cinclus</i>	Passeriformes	LC
30	Bluethroat	<i>Luscinia svecica</i>	Passeriformes	LC
31	Black Redstart	<i>Phoenicurus ochruros</i>	Passeriformes	LC
32	Guldenstadt's Redstart	<i>Phoenicurus erythrogastrus</i>	Passeriformes	LC
33	Desert Wheatear	<i>Oenanthe deserti</i>	Passeriformes	LC
34	House Sparrow	<i>Passer domesticus</i>	Passeriformes	LC
35	Tibetan Snowfinch	<i>Montifringilla adamsi</i>	Passeriformes	LC
36	Blanford's Snowfinch	<i>Pyrgiada blanfordi</i>	Passeriformes	LC
37	Robin Accentor	<i>Prunella rubeculoides</i>	Passeriformes	LC
38	Brown Accentor	<i>Prunella fulvescens</i>	Passeriformes	LC
39	Twite	<i>Carduelis flavirostris</i>	Passeriformes	LC
40	Great Rosefinch	<i>Carpodacus rubicilla</i>	Passeriformes	LC
41	Red-fronted Serin	<i>Serinus pusillus</i>	Passeriformes	LC

Appendix 3.1: Aundance of species in 2016 and 2017

Aundacne of species in Spring, 2016								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
RSD	346	0.9999	0.0001	346.02	0.15	346	347.07	23.6%
BHG	626	0.9986	0.0005	626.85	0.98	626.14	631.17	42.8%
GCG	24	1		24				1.6%
BrHG	342	0.9981	0.001	342.65	0.87	342.09	346.76	23.4%
CW	1	1		1				0.1%
CC	2	1		2				0.1%
BNG	2	1		2				0.1%
CS	8	1		8				0.5%
W	1	1		1				0.1%
PG	1	1		1				0.1%
NP	19	1		19				1.3%
MLD	6	1		6				0.4%
UD	3	1		3				0.2%
CM	1	1		1				0.1%
CR	3	1		3				0.2%
CT	17	1		17				1.2%
CRS	1	1		1				0.1%
LSP	2	1		2				0.1%
CG	56	0.9979	0.0019	56.12	0.36	56.01	58.35	3.8%
GH	2	1		2				0.1%
Aundacne of species in Summer, 2016								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance

BHG	1487	0.9983	0.0002	1489.51	1.62	1487.79	1494.98	40.7%
RSD	798	0.9983	0.0002	799.35	1.17	798.31	803.88	21.9%
CGS	3	1		3				0.1%
BrHG	656	0.9983	0.0002	657.11	1.06	656.23	661.4	18.0%
LSP	23	1		23				0.6%
CW	3	0.9983	0.0002	3.01	0.07	3	3.46	0.1%
CRS	282	1		282				7.7%
CS	30	1		30				0.8%
W	32	1		32				0.9%
GCG	135	0.9983	0.0002	135.23	0.48	135.02	137.91	3.7%
BNG	3	0.9983	0.0002	3.01	0.07	3	3.46	0.1%
CR	11	0.9983	0.0002	11.02	0.14	11	11.94	0.3%
CC	29	0.9983	0.0002	29.05	0.22	29	30.52	0.8%
UD	32	0.9983	0.0002	32.05	0.23	32	33.59	0.9%
CM	3	1		3				0.1%
GG	1	0.9983	0.0002	1	0.04	1	1.24	0.0%
BP	5	0.9983	0.0002	5.01	0.09	5	5.61	0.1%
PV	4	0.9983	0.0002	4.01	0.08	4	4.54	0.1%
BWS	5	0.9983	0.0002	5.01	0.09	5	5.61	0.1%
CE	1	0.9983	0.0002	1	0.04	1	1.24	0.0%
BTG	2	1		2				0.1%
CTL	1	0.9983	0.0002	1	0.04	1	1.24	0.0%
CG	103	0.9983	0.0002	103.17	0.42	103.01	105.62	2.8%
PG	1	0.9983	0.0002	1	0.04	1	1.24	0.0%
CT	2	1		2				0.1%
Aundance of species in Autumn, 2016								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
RSD	1590	0.9973	0.0002	1594.27	2.1	1591.71	1600.65	31.3%
BHG	735	0.9973	0.0002	736.97	1.42	735.56	741.99	14.5%
CT	230	0.9973	0.0002	230.62	0.79	230.09	234.25	4.5%
CSP	2	0.9973	0.0002	2.01	0.07	2	2.48	0.0%
GH	7	0.9973	0.0002	7.02	0.14	7	7.94	0.1%
TD	23	0.9973	0.0002	23.06	0.25	23	24.69	0.5%
BrHG	262	0.9973	0.0002	262.7	0.84	262.11	266.47	5.2%
GDW	150	0.9973	0.0002	150.4	0.64	150.04	153.61	3.0%
W	24	0.9973	0.0002	24.06	0.25	24	25.72	0.5%
UD	393	0.9973	0.0002	394.05	1.03	393.21	398.26	7.7%
CC	460	0.9973	0.0002	461.23	1.12	460.27	465.63	9.1%
NS	59	0.9973	0.0002	59.16	0.4	59.01	61.52	1.2%
RUF	56	0.9973	0.0002	56.15	0.39	56.01	58.47	1.1%
MLD	29	0.9973	0.0002	29.08	0.28	29	30.87	0.6%

CR	2	0.9973	0.0002	2.01	0.07	2	2.48	0.0%
NP	710	0.9973	0.0002	711.91	1.39	710.53	716.87	14.0%
GCG	212	0.9973	0.0002	212.57	0.76	212.08	216.11	4.2%
EW	25	0.9973	0.0002	25.07	0.26	25	26.75	0.5%
BWS	1	0.9973	0.0002	1	0.05	1	1.32	0.0%
PG	54	0.9973	0.0002	54.14	0.38	54.01	56.43	1.1%
CP	1	0.9973	0.0002	1	0.05	1	1.32	0.0%
CG	47	0.9973	0.0002	47.13	0.36	47.01	49.3	0.9%
Aundance of species in Spring, 2017								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
RSD	481	0.9992	0.0001	481.37	0.61	481.04	484.51	18.8%
W	10	0.9992	0	10.01	0.09	10	10.58	0.4%
GDW	1	1		1				0.0%
BrHG	552	0.9992	0.0001	552.42	0.66	552.05	555.7	21.5%
GCG	137	0.9992	0.0001	137.11	0.33	137.01	139.13	5.3%
TD	5	1		5				0.2%
CC	61	0.9992	0.0001	61.05	0.22	61	62.48	2.4%
BHG	933	0.9992	0.0001	933.72	0.86	933.11	937.54	36.4%
NP	63	0.9992	0.0001	63.05	0.22	63	64.51	2.5%
NS	20	0.9992	0.0001	20.02	0.12	20	20.85	0.8%
EW	54	0.9992	0.0001	54.04	0.2	54	55.4	2.1%
UD	13	0.9992	0.0001	13.01	0.1	13	13.67	0.5%
CP	3	1		3				0.1%
MLD	8	1		8				0.3%
FC	2	1		2				0.1%
LSP	12	0.9992	0.0001	12.01	0.1	12	12.64	0.5%
CG	136	0.9992	0.0001	136.1	0.32	136.01	138.12	5.3%
CRS	10	0.9992	0	10.01	0.09	10	10.58	0.4%
CW	6	1		6				0.2%
BP	5	1		5				0.2%
NL	1	1		1				0.0%
GH	1	1		1				0.0%
CT	1	1		1				0.0%
PF	48	0.9992	0.0001	48.04	0.19	48	49.32	1.9%
IE	1	1		1				0.0%
Aundance of species in Summer, 2017								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
RSD	637	0.9999	0.0001	637.08	0.28	637	638.91	20.9%
CRS	144	0.9993	0.0005	144.1	0.33	144	146.17	4.7%
BrHG	575	0.9962	0.0009	577.21	1.59	575.62	582.82	18.9%

LSP	11	1		11				0.4%
BNG	30	0.9972	0.0033	30.08	0.31	30	32.06	1.0%
FP	2	0.9992	0.0017	2	0.04	2	2.23	0.1%
BHG	1270	0.9995	0.0001	1270.6	0.79	1270.08	1274.3	41.6%
GCG	207	0.9999	0.0002	207.03	0.18	207	208.23	6.8%
UD	14	0.9993	0.0005	14.01	0.1	14	14.68	0.5%
CC	8	0.9992	0.0017	8.01	0.08	8	8.54	0.3%
CG	131	0.9995	0.0005	131.07	0.28	131	132.85	4.3%
CS	14	0.9993	0.0005	14.01	0.1	14	14.68	0.5%
NP	2	0.9992	0.0017	2	0.04	2	2.23	0.1%
W	3	0.9992	0.0017	3	0.05	3	3.3	0.1%
CGS	1	0.9992	0.0017	1	0.03	1	1.15	0.0%
BWS	2	0.9992	0.0017	2	0.04	2	2.23	0.1%
Aundance of species in Autumn, 2017								
Species	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
RSD	1643	0.999	0.0002	1644.65	1.33	1643.41	1649.6	20.9%
CG	79	0.9996	0.0002	79.03	0.18	79	80.25	1.0%
BrHG	242	0.9997	0.0002	242.07	0.27	242	243.8	3.1%
BHG	1122	0.9991	0.0002	1122.97	1.02	1122.18	1127.24	14.3%
MLD	83	0.999	0.0009	83.08	0.29	83	84.96	1.1%
GDW	471	0.9985	0.0005	471.7	0.87	471.11	475.67	6.0%
UD	1940	0.999	0.0002	1941.91	1.43	1940.52	1947.06	24.7%
GH	13	0.9996	0.0002	13.01	0.07	13	13.47	0.2%
GCG	350	0.9991	0.0004	350.3	0.57	350.03	353.36	4.5%
CC	1040	0.9969	0.0006	1043.19	1.89	1041.09	1049.36	13.3%
EW	67	0.997	0.0023	67.2	0.48	67.01	69.98	0.9%
NP	342	0.9989	0.0005	342.38	0.64	342.04	345.67	4.4%
W	2	1		2				0.0%
PG	59	0.9996	0.0002	59.02	0.16	59	60.08	0.8%
NS	48	0.9995	0.0007	48.02	0.15	48	49.04	0.6%
FP	2	1		2				0.0%
CT	7	1		7				0.1%
CRS	144	0.9996	0.0002	144.06	0.25	144	145.66	1.8%
TD	183	0.9996	0.0002	183.08	0.28	183	184.86	2.3%
GLG	6	1		6				0.1%
CM	1	1		1				0.0%
PV	3	1		3				0.0%
BNG	4	1		4				0.1%

Appendix 3.2: Wetland specific abundance of waterbirds in 2016 and 2017

Wetland specific abundance of waterbirds in Spring, 2016								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Yayatso	19	0.9989	0.0003	19.02	0.15	19	20	1.3%
Puga	95	0.9989	0.0003	95.11	0.33	95.01	97.14	6.5%
Tsokar	65	0.9989	0.0003	65.07	0.27	65	66.81	4.4%
Statsapuk	197	0.9989	0.0003	197.22	0.47	197.02	199.88	13.5%
Kyagartso	5	0.9989	0.0003	5.01	0.07	5	5.49	0.3%
Tsomoriri	367	0.9989	0.0003	367.41	0.65	367.05	370.68	25.1%
Lamtso	78	0.9989	0.0003	78.09	0.3	78	79.97	5.3%
Kyun TsoI	52	0.9989	0.0003	52.06	0.24	52	53.64	3.6%
Hanle	18	0.9989	0.0003	18.02	0.14	18	18.98	1.2%
Lal Pahari	17	0.9989	0.0003	17.02	0.14	17	17.95	1.2%
Rongo	2	0.9989	0.0003	2	0.05	2	2.28	0.1%
Staklung	71	0.9989	0.0003	71.08	0.28	71	72.89	4.9%
Phuktse	36	0.9989	0.0003	36.04	0.2	36	37.38	2.5%
Dungti	8	0.9989	0.0003	8.01	0.09	8	8.63	0.5%
Indus	1	0.9989	0.0003	1	0.03	1	1.18	0.1%
Chushul	100	0.9989	0.0003	100.11	0.34	100.01	102.19	6.8%
Pangong	261	0.9989	0.0003	261.29	0.54	261.03	264.22	17.8%
Lukung	19	0.9989	0.0003	19.02	0.15	19	20	1.3%
Harong	52	0.9989	0.0003	52.06	0.24	52	53.64	3.6%
Wetland specific abundance of waterbirds in Summer, 2016								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Yayatso	20	0.9985	0.0002	20.03	0.17	20	21.2	0.5%
Mirpaltso	13	0.9985	0.0002	13.02	0.14	13	13.96	0.4%
Tsegamtso	5	0.9985	0.0002	5.01	0.09	5	5.57	0.1%
Puga	49	0.9985	0.0002	49.07	0.27	49	50.82	1.3%
Tsokar	718	0.9985	0.0002	719.08	1.05	718.22	723.33	19.7%
Statsapuk	809	0.9985	0.0002	810.21	1.11	809.26	814.61	22.2%
Kyagartso	94	0.9985	0.0002	94.14	0.38	94.01	96.4	2.6%
Tsomoriri	628	0.9985	0.0002	628.94	0.98	628.18	633.04	17.2%
Chumiktalte	169	0.9985	0.0002	169.25	0.5	169.02	172.03	4.6%
Lamtso	67	0.9985	0.0002	67.1	0.32	67	69.09	1.8%
Kyun TsoI	605	0.9985	0.0002	605.91	0.96	605.17	609.96	16.6%
Kyun TsoII	15	0.9985	0.0002	15.02	0.15	15	16.04	0.4%
Hanle	23	0.9985	0.0002	23.03	0.19	23	24.28	0.6%
Lal Pahari	7	0.9985	0.0002	7.01	0.1	7	7.69	0.2%
Rongo	1	0.9985	0.0002	1	0.04	1	1.22	0.0%
Indus	64	0.9985	0.0002	64.1	0.31	64	66.05	1.8%

Phuktse	7	0.9985	0.0002	7.01	0.1	7	7.69	0.2%
Dungti	19	0.9985	0.0002	19.03	0.17	19	20.17	0.5%
Chushul	134	0.9985	0.0002	134.2	0.45	134.01	136.77	3.7%
Pangongtso	149	0.9985	0.0002	149.22	0.47	149.02	151.89	4.1%
Lukung	2	0.9985	0.0002	2	0.05	2	2.34	0.1%
Harong	54	0.9985	0.0002	54.08	0.28	54	55.9	1.5%
Wetland specific abundance of waterbirds in Autumn, 2016								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Tsokar	706	0.9948	0.0011	709.69	2.07	707.32	716.3	14.0%
Statsapuk	1163	0.9972	0.0005	1166.27	1.91	1164.13	1172.47	22.9%
Puga	430	0.9974	0.0008	431.14	1.13	430.23	435.74	8.5%
Mirpaltso	7	1		7				0.1%
Yayatso	302	0.9995	0.0003	302.15	0.39	302.01	304.51	5.9%
Kyagartso	62	0.9976	0.0006	62.15	0.39	62.01	64.45	1.2%
Tsomoriri	532	0.999	0.0004	532.55	0.76	532.07	536.21	10.5%
Chumiktsalte	195	0.9976	0.0006	195.46	0.69	195.05	198.86	3.8%
Lamtso	482	0.9951	0.0012	484.37	1.66	482.69	490.16	9.5%
Kyun Tsol	80	0.9976	0.0006	80.19	0.44	80.01	82.72	1.6%
Kyun Tsoll	3	1		3				0.1%
Hanle	114	0.9963	0.002	114.42	0.69	114.04	117.95	2.2%
Lal Pahari	43	0.9976	0.0006	43.1	0.32	43	45.11	0.8%
Rongo	7	1		7				0.1%
Staklung	88	0.9976	0.0006	88.21	0.46	88.02	90.83	1.7%
Indus	14	1		14				0.3%
Phuktse	22	0.9976	0.0006	22.05	0.23	22	23.56	0.4%
Dungti	114	0.9976	0.0006	114.27	0.52	114.02	117.13	2.2%
Chushul	44	0.9976	0.0006	44.1	0.32	44.01	46.13	0.9%
Pangongtso	189	0.9978	0.0011	189.42	0.68	189.05	192.89	3.7%
Lukung	5	1		5				0.1%
Harong	470	0.9961	0.001	471.82	1.44	470.47	477.14	9.3%
Wetland specific abundance of waterbird in Spring, 2017								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Tsokar	120	0.9992	0.0001	120.09	0.31	120	122.02	4.7%
Statsapuk	664	0.9992	0.0001	664.51	0.72	664.07	667.98	25.9%
Puga	115	0.9992	0.0001	115.09	0.3	115	116.98	4.5%
Yayatso	10	1		10				0.4%
Tsegamtso	2	1		2				0.1%
Kyagartso	21	0.9992	0.0001	21.02	0.13	21	21.87	0.8%
Tsomoriri	727	0.9992	0.0001	727.56	0.76	727.08	731.13	28.4%
Chumiktsalte	69	0.9992	0.0001	69.05	0.23	69	70.58	2.7%

Lamtso	42	0.9992	0.0001	42.03	0.18	42	43.24	1.6%
Kyun TsoII	1	1		1				0.0%
Kyun TsoI	16	1		16				0.6%
Hanle	11	1		11				0.4%
Lal Pahari	11	1		11				0.4%
Rongo	8	1		8				0.3%
Staklung	45	0.9992	0.0001	45.03	0.19	45	46.29	1.8%
Indus	21	0.9992	0.0001	21.02	0.13	21	21.87	0.8%
Phuktse	23	0.9992	0.0001	23.02	0.13	23	23.92	0.9%
Dungti	41	0.9992	0.0001	41.03	0.18	41	42.23	1.6%
Chushul	164	0.9992	0.0001	164.13	0.36	164.01	166.3	6.4%
Pangongtso	366	0.9992	0.0001	366.28	0.53	366.03	369.17	14.3%
Lukung	29	0.9992	0.0001	29.02	0.15	29	30.03	1.1%
Harong	58	0.9992	0.0001	58.04	0.21	58	59.45	2.3%
Wetland specific aundance of waterbird in Summer, 2017								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Tsokar	545	0.9995	0.0001	545.29	0.54	545.03	548.2	17.9%
Statsapuk	563	0.9995	0.0001	563.3	0.55	563.03	566.24	18.5%
Tsegamtso	3	0.9995	0.0001	3	0.04	3	3.23	0.1%
Yayatso	40	0.9995	0.0001	40.02	0.15	40	41.01	1.3%
Puga	213	0.9995	0.0001	213.11	0.34	213.01	215.2	7.0%
Tsomoriri	533	0.9995	0.0001	533.28	0.53	533.03	536.17	17.5%
Chumiktsalte	100	0.9995	0.0001	100.05	0.23	100	101.57	3.3%
Lamtso	50	0.9995	0.0001	50.03	0.16	50	51.13	1.6%
Kyun TsoI	455	0.9995	0.0001	455.24	0.49	455.02	457.98	14.9%
Kyun TsoII	2	0.9995	0.0001	2	0.03	2	2.18	0.1%
Hanle	10	0.9995	0.0001	10.01	0.07	10	10.47	0.3%
Lal Pahari	19	0.9995	0.0001	19.01	0.1	19	19.68	0.6%
Staklung	22	0.9995	0.0001	22.01	0.11	22	22.73	0.7%
Dungti	17	0.9995	0.0001	17.01	0.09	17	17.64	0.6%
Chushul	129	0.9995	0.0001	129.07	0.26	129	130.77	4.2%
Pangongtso	265	0.9995	0.0001	265.14	0.38	265.01	267.4	8.7%
Lukung	12	0.9995	0.0001	12.01	0.08	12	12.52	0.4%
Harong	73	0.9995	0.0001	73.04	0.2	73	74.36	2.4%
Wetland specific aundance of waterbird in Autumn, 2017								
Wetland	Abundance	P	SE(P)	N	SE(N)	Lower CI (95%)	Upper CI (95%)	Relative Abundance
Harong	728	0.9993	0.0002	728.54	0.76	728.07	732.17	9.3%
Lukung	9	1		9				0.1%
Pangong	364	0.9994	0.0003	364.23	0.5	364.02	367.04	4.6%
Chushul	157	0.9961	0.0018	157.61	0.83	157.08	161.56	2.0%

Indus	75	0.9999	0	75	0.06	75	75.4	1.0%
Chakhung	123	0.9999	0	123.01	0.08	123	123.54	1.6%
Dungti	253	0.9999	0.0001	253.02	0.16	253	254.09	3.2%
Rongo	10	1		10				0.1%
Lal Pahari	36	0.9999	0	36	0.04	36	36.26	0.5%
Staklung	135	0.9955	0.0022	135.61	0.84	135.08	139.59	1.7%
Hanle	71	1		71				0.9%
Kyun Tsoll	2	1		2				0.0%
Kyun Tsol	504	0.9995	0.0003	504.25	0.51	504.02	507.12	6.4%
Lamtso	184	0.9985	0.0008	184.28	0.55	184.02	187.31	2.3%
Tsomoriri	275	0.9996	0.0004	275.12	0.36	275.01	277.39	3.5%
Chumiktsalte	496	0.9995	0.0002	496.27	0.53	496.02	499.17	6.3%
Kyagartso	64	0.9999	0	64	0.06	64	64.37	0.8%
Puga	216	0.9999	0	216.01	0.11	216	216.74	2.7%
Yayatso	215	0.9995	0.0004	215.11	0.34	215.01	217.24	2.7%
Tsokar	893	0.9986	0.0004	894.26	1.18	893.27	898.96	11.4%
Statsapuk	3041	0.9989	0.0002	3044.45	1.92	3042.25	3050.57	38.7%

Appendix 3.3: Breeding success studies in Ladakh

	Study	Study Year	Breeding success (%)
1	Chacko 1995	1995	60
2	Chacko 1996	1996	43
3	Chacko 1997	1997	37.5
4	Chandan et al 2005	2002	33.3
5	Chandan et al 2005	2003	31.5
6	Chandan et al 2005	2004	43.3
7	Present study	2016	29
8	Present study	2017	33

* Reference Chandan et al. 2005 (1-6)

Appendix 5.1: Questionnaire survey performa

Interviewer name:

Date:..... Village/ Camp

(Revo):..... GPS

Location:.....

Block:..... District:.....

Distance from the nearby wetland.....km

1. Respondent Gender: M/F/Other.....
2. Age:.....
3. Religion:.....
4. Caste:.....
5. Education:.....
.....
6. Occupation:.....
.....
7. If related to tourism then what exactly 1) tour operator 2) guide 3) Home stay
4) Shop 6) Drive 5) other
8. Are You satisfied with ongoing tourism development- Yes/No
Why?
9. What changes You feel should have been done for tourism development in
Changthang region-
10. Are You satisfied with ongoing development activities in area such as road,
infrastructure etc?

Appendix 5.2: Minimum Approach Distance (meters) of 16 waterbird species in 13 wetlands of CWLS

Wetland	Waterbird species																
	BHG	BNC	BS	BWS	CRS	CS	GH	PG	RSD	BrHG	LSP	CGS	GW	CG	GCG	CT	MAD
Hanle	172	170.40	214	178	27	60	187	85	111.70	-	-	-	-	-	-	-	258
Kyagar	118.33	-	-	-	-	-	-	-	140.50	127	-	-	-	-	-	-	210.75
Kyun I	185.33	164	-	-	99.50	-	224	-	133	114	23	-	-	-	-	-	336
Kyun II	330.50	-	-	32	-	-	-	-	-	100	-	170.50	193	-	-	-	495.75
Lal Pahari	258	169.50	-	101	-	-	-	-	180.50	-	-	-	-	-	-	-	387
Puga	-	184	-	-	78.50	-	-	96	151	67.75	32	-	-	-	-	-	276
Rongo	-	43	-	-	-	-	314	-	214	-	-	-	-	-	-	-	471
Staklung	171.33	50	-	-	-	-	-	-	127.14	-	26.50	-	-	78	-	-	257
Statsapuk	216.90	293	-	51.33	-	58.50	172	-	166.81	110.20	-	-	103.50	-	136.13	-	439.50
Tsegam	-	214.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	321.75
Tso Moriri	192.55	94	-	-	-	45	-	-	166.44	161.10	-	-	-	-	97.33	-	288.83
Tso Kar	151.83	296	-	-	116.75	-	-	-	167.12	188	-	-	49	-	-	-	444
Yayatso	158	215	-	-	74.50	-	-	-	293.20	69	-	-	110	96.67	-	199	439.80

Appendix 6.1

Questionnaire Performa of dog questionnaire

Interviewer name:

Date:..... Village/ Camp (Rebo):..... Block:.....

GPS Location:..... District:.....

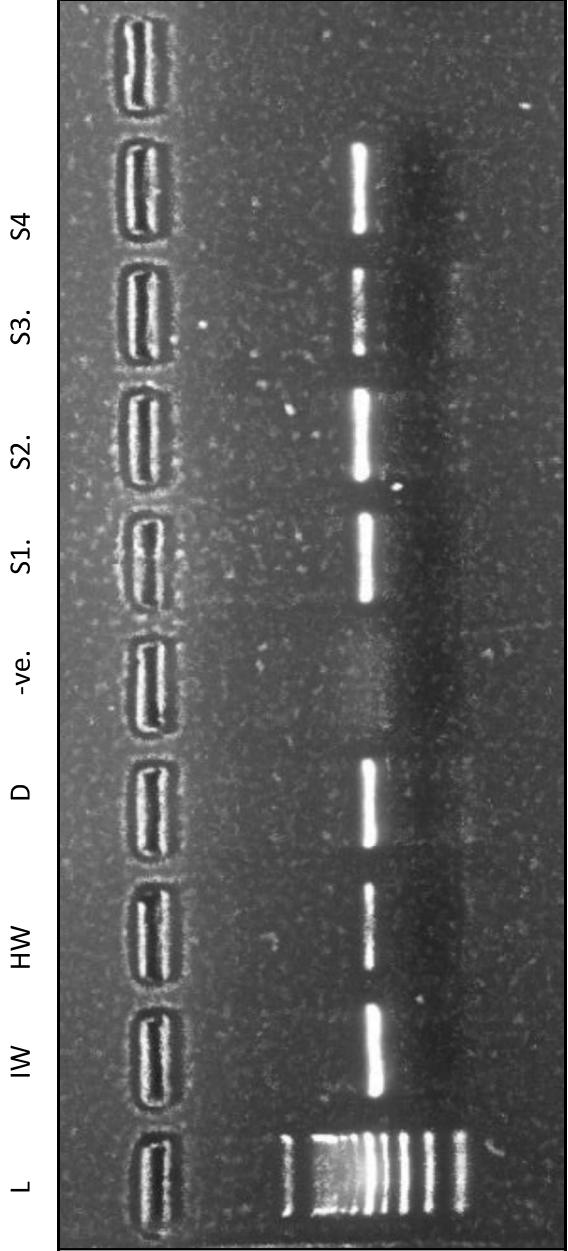
Nearest Wetland:.....

11. Respondent name:
2. Respondent Gender: M/F.....
3. Age:.....
4. Religion:.....
5. Caste/Sect.....
6. Education:.....
7. Occupation:
8. Members in family:
9. Land holding:
10. Livestock – 1) Yak: 2) Sheep: 3) Goat: 4) Mule: 5) Horse: 6) Other:
11. Which nearby wetland used by you or livestock-
12. Do you own dogs, if Yes How many?
13. Breed of dogs (local language/english):
14. How Old are they, M?.... F?....
15. From where you get these dogs?
16. Why you own dog? (✓) a) for livestock protection b) house guard c) companion/friend d) other
17. Do they accompany you during your visit to nearby areas (road, market, wetlands, and grazing sites)..... How far (km)..... How many Days/month
18. Continuously free/ leashed/ unleashed only during day or night?.....
19. Are your pets vaccinated or treated against parasites? When was the last time they were treated?.....
20. Any disease noticed (in dog/ in livestock due to dog):
21. During the last year, how many of the females gave birth....., no. of puppies born..... and how many died.....
22. What did you do with puppies?
23. What are the main predators in this area? (✓) a) Wolf b) Snow Leopard c) Fox d) Feral Dog e) other (specify)
24. Have you seen any of above predator during the last 2 year (when, where):

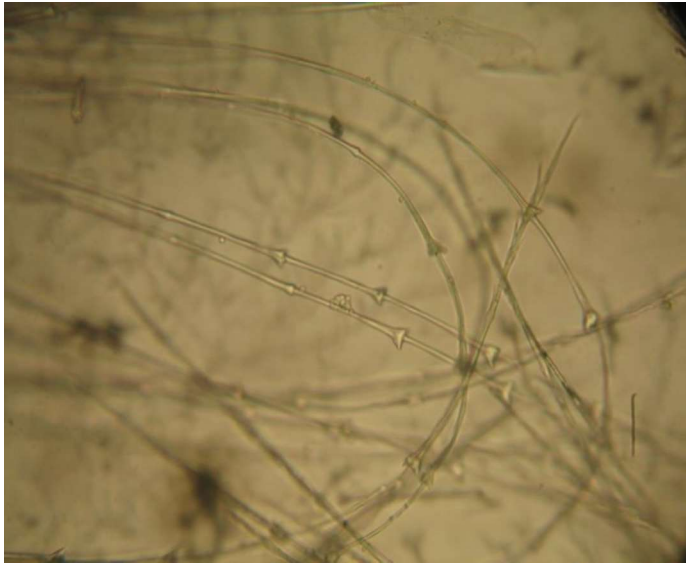
25. What other majors you opt for protection of livestock from predators? (✓) a) enclosure b) traps/pits c) Crackers d) shotguns e) own vigilance f) poison g) dog e) other
26. Are you aware of Wildlife Dept.'s compensation scheme Y/N, if yes have you ever applied or benefitted?
27. Have you seen feral dogs in the area during the last 2 year?
28. Do feral dogs create problems in the area or around you?
- i. Do these dogs attack human? (Any incident),
M/F?.....Age.....Place.....Date/Month/Year.....
 - ii. Livestock: Place.....
Date/Month/Year.....
 - iii. According to you?, what could be the solution of feral dogs?
29. Do you know if these dogs hunt or harass any of the following animals? Do you know if these dogs hunt or harass wild species? ****Black-necked Crane, Bar-headed Goose, Ruddy Shelduck, Great Crested Grebe, Himalayan Marmot, Woolly Hare, Blue Sheep, Kiang, Urial, Argali, Pika* etc.
- i. Where?..... how far from this place (km approx.).....
 - ii. When?.....
 - iii. What happened to the animal?
.....
 - iv. Was your dog with you? Y/N.....
30. Predation in last two years by your dog, if any? When was the last time that one of your dogs hunted one of the following species: *Black-necked Crane, Bar-headed Goose, Ruddy Shelduck, Himalayan Marmot, Woolly Hare, Blue Sheep, Kiang, Urial, Argali, Pika* etc.
31. Have you seen any of the following species during the last 2 years if yes when and where (approx date and place)? (*Species same as above*)
32. According to you, what are the threats to wildlife? Dog (negative or neutral)?

Remarks:

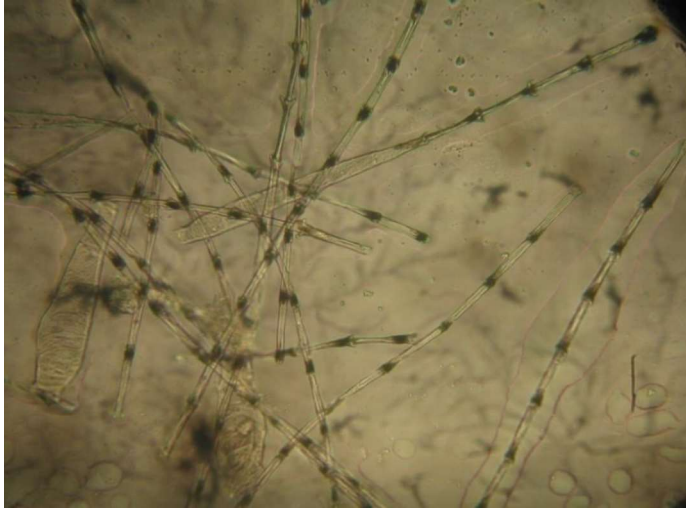
Appendix 6.2: Gel picture showing amplification of Mitochondrial Cytochrome b in IW (Indian wolf), HW (Himalayan wolf), D (Pariah Dog), S1-S4 (Samples)



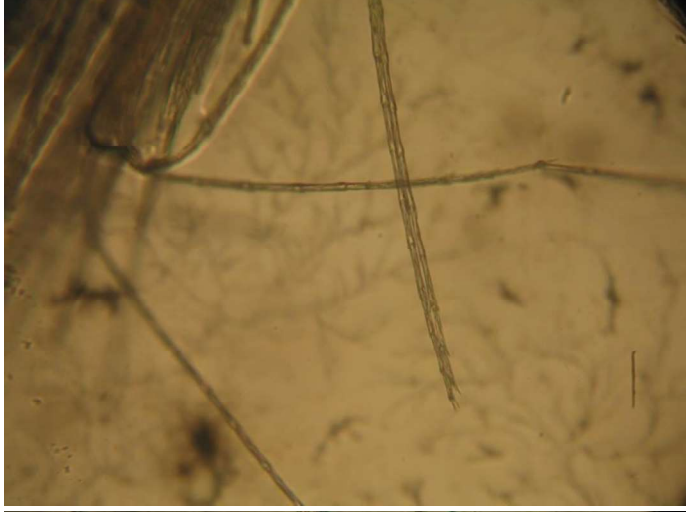
Appendix 6.3: Microscopic structure of down feather of different bird groups (a, b, c)



(a) Anseriforme

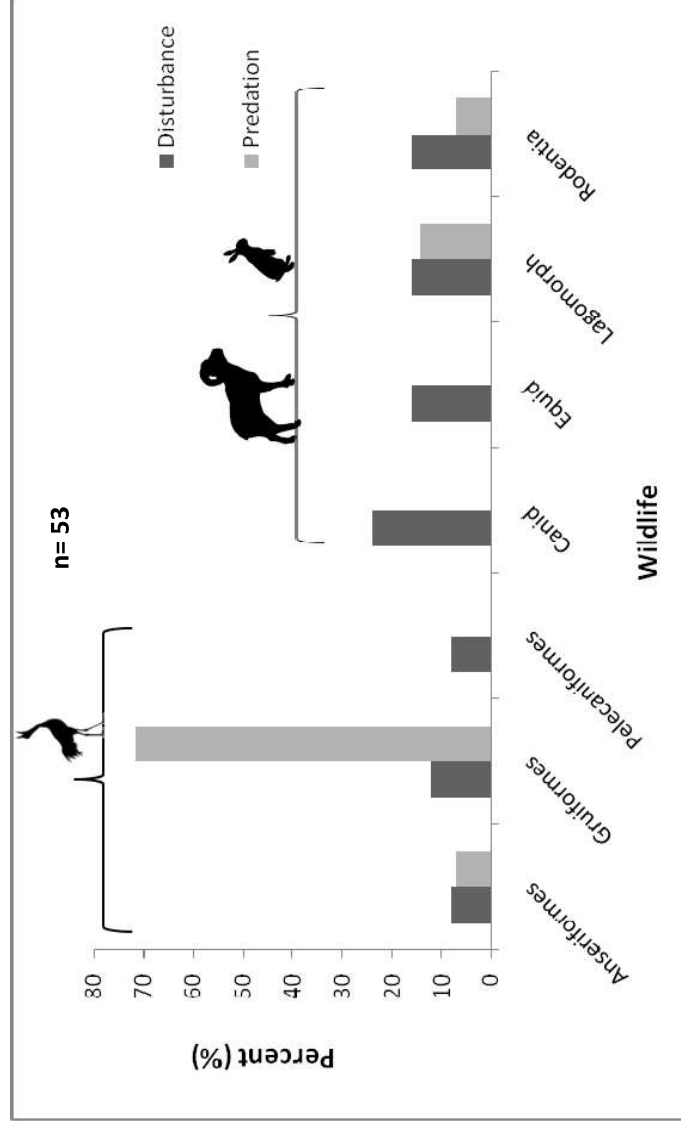


(b) Passeriformes



(c) Galliformes

Appendix 6.4: Opportunistic direct observations of negative interactions between dog and wildlife in Changthang Wildlife Sanctuary, Ladakh



Appendix 6.5: Dietary comparison (frequency of occurrence) of dogs and other large carnivores in Central and South Asia

	Prey items	Domestic dog	Snow leopard														
			Himalayan wolf	Tibetan wolf	Annapurna-Manaslu landscape, Nepal (n = 182) (Chetri et al. 2017)	South Gobi, Mongolia (n = 81) (Shehzad et al. 2012)	Balistan, Pakistan (n = 49) (Anwar et al. 2011)	Kibber, India (n = 44) (Bagchi and Mishra 2006)	Pin Valley, India (n = 51) (Bagchi and Mishra 2006)	Uvs& South Gobi, Mongolia (n = 168) (Lhagvasuren and Munkhtsog 2002)	Ladakh, India (n = 173) (Chundawat and Rawat 1994)	Manang, Nepal (n = 213) (Oli et al. 1993)					
		Present study															
	Wild ungulates																
1	Blue sheep	1.67	4.42	—	56.85	—	—	—	20.5	—	—	—	—	23.4	—	—	51.6
2	Argali	0.26	8.95	—	0.78	8.6	—	—	—	—	—	—	—	—	—	—	—
3	Ladakh urial	—	—	—	—	—	—	—	—	—	—	—	—	0.4	—	—	—
4	Tibetan wild ass	2.83	10.84	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	Tibetan gazelle	—	11.05	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	Siberian ibex	—	—	—	—	70.4	9.7	9.1	56.9	38.7	—	—	—	—	—	—	—
7	Markhor	—	—	—	—	—	3.2	—	—	—	—	—	—	—	—	—	—
8	Goitered gazelle	—	—	—	—	—	—	—	—	3.6	—	—	—	—	—	—	—
9	Red deer	—	—	—	—	—	—	—	—	2.4	—	—	—	—	—	—	—
10	Roe deer	—	—	—	—	—	—	—	—	0.6	—	—	—	—	—	—	—

Meso and small mammals/birds													
1	Red fox	—	—	—	—	—	—	—	—	—	—	4.3	0.9
2	Marten/badger	—	—	4	—	—	—	—	—	—	—	—	3.8
3	Weasel	—	—	—	—	—	—	—	—	—	—	—	4.7
4	Rodents (pika/vole/marmot)	4.63	35.83	16	9.97	—	—	—	—	—	7.7	9.8	44.1
5	Woolly hare	1.03	4.81	24	3.52	—	—	—	6.8	3.9	1.2	3.1	—
6	Birds	5.91	0.32	5	1.09	1.2	2.2	15.9	—	—	2.4	3.1	1.4
Domestic mammals													
1	Goat and sheep	49.1	9.76	5	8.92	19.8	17.9	13.5	5.9	20.9	12.5	2.4	1
2	Cattle (yak/dzo/horse/mule)	34.58	14.04	18	18.34	—	8.6	24.9	17.7	10.2	2.4	—	16.9

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Appendix 7.1: Band details of Landsat 8 and 5

Sensor	Band	Wavelength (micrometers)	Resolution (meters)
Landsat 8 (OLI)	Band1 - Ultra Blue	0.43 – 0.45	30
	Band 2 - Blue	0.45 – 0.51	30
	Band 3 - Green	0.53 – 0.59	30
	Band 4 - Red	0.64 – 0.67	30
	Band 5- Near Infrared (NIR)	0.85 – 0.88	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.57 – 1.65	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.21 – 2.29	30
	Band 8 - Panchromatic	0.50 – 0.68	15
	Band 9 - Cirrus	1.36 – 1.38	30
Landsat 5 (TM)	Band 1 - Blue	0.45 – 0.52	30
	Band 2 - Green	0.52 – 0.60	30
	Band 3 - Red	0.63 – 0.69	30
	Band 4 - Near Infrared (NIR)	0.76 – 0.90	30
	Band 5 - Shortwave Infrared (SWIR) 1	1.55 – 1.75	30
	Band 6 - Thermal	10.40 – 12.50	60
	Band 7- Shortwave Infrared (SWIR) 2	2.08 – 2.35	30

LIST OF PUBLICATIONS AND CONFERENCES

Peer reviewed articles

1. **Mahar, N.**, Habib, B., Hussain, S. A., Shawl, T., and Takpa, J. (2021). Imperiled Prancing Crane: Population Status and Breeding Performance of Black-Necked Crane *Grus nigricollis* in Trans-Himalayan Ladakh Region. *Proceedings of the Zoological Society* doi.org/10.1007/s12595-021-00392-4.
2. **Mahar, N.**, Habib, B., Gopi, G. V., Shawl, T., Suhail, I., Takpa, J. and Hussain, S. A. (2015) Tracking movement pattern of Bar-headed Goose (*Anser indicus*) capture from Gharana Conservation Reserve, India. *Journal of Bombay Natural History Society*, 112(1): 12-20. DOI: 10.17087/jbnhs/2015/v112i1/92194.
3. **Mahar, N.**, Shrotriya, S., Habib, B., Singh, S., Takpa, J. & Hussain, S. A. (2017) Recent records of Pallas's cat in Changthang Wildlife Sanctuary, Ladakh, India. *Cat News*, 65: 36-37. ISSN no. 1027-2992.




Book chapter

1. Hussain, S. A., **Mahar, N.**, Tuboi, C. and Badola, R. (2018) Wetlands of the Indian Himalayas: Status and Conservation Initiatives. (eds) Bhatta, L.D., Wu, N., Udas, E., Agrawal, N.K., Ranabhat, S., Basnet, D. *Wetlands in the Himalaya: Securing services for livelihoods*. Kathmandu: ICIMOD. ISBN 978 92 9115 577 4. Pp. 33-46.

Conference presentations

1. **Mahar, N.**, Habib, B. and Hussain, S. A. (2016) Buffer zone concept beyond terrestrial protected areas: a study of the Trans-Himalayan wetlands of Changthang Wildlife Sanctuary, India. 10th INTECOL International Wetlands Conference, Changsu (China).
2. **Mahar, N.**, Hussain, S. A., Habib, B., Dobriyal, P. and Badola, R. (2019) Friend or foe: tourism in Indian Trans-Himalayan Region. 29th International Conference for Conservation Biology, Kuala Lumpur (Malaysia).
3. **Mahar, N.**, Hussain, S. A., Habib, B., Gopi, G. V., Takpa, J. and Suhail, I. (2016) Application of Flight Initiation Distance of waterbirds for delineating buffer zone around wetlands. 30th Annual Research Seminar, Wildlife Institute of India, Dehardun (India).

Imperiled Prancing Crane: Population Status and Breeding Performance of Black-Necked Crane *Grus nigricollis* in Trans-Himalayan Ladakh Region

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Abstract The trans-Himalayan wetlands of India and China are home to many breeding birds of conservation significance. The ecological structure and functions of these habitats are increasingly affected by anthropogenic pressures. Black-necked crane (BNC) is one of the flagship species of trans-Himalayan wetlands facing anthropic disturbances. We examined the population status, breeding ecology and factors affecting BNC in Changthang Wildlife Sanctuary, Ladakh during 2016–2017. Seasonal population monitoring of BNC was conducted using total count method in 25 wetlands. The mean population size of BNC was 66.33 ± 5.04 SE and 69 ± 4.51 SE in 2016 and 2017 respectively with no significant difference (95% CI). For nesting, breeding pairs of BNC preferred palustrine wetlands, and avoided riverine habitats. Overall, nest survival, hatching success, breeding success and recruitment rate of BNC was attributed to predation by dogs, nesting failure due to thawing and unknown reasons. Water property, water depth, presence of ungulates and free-ranging dogs were found as important characteristics around nest-sites. Control of dog population at the breeding sites, and nearby human habitations using capture-neuter relocations and, awareness among locals and defense personnel can

potentially contribute towards the conservation of this charismatic species. Habitats of BNC should also be conserved against increasing vulnerability from myriad anthropogenic pressures to ensure their long-term survival in the Indian trans-Himalaya.

Keywords Breeding failure · Disturbance · Free-ranging dogs · Predation · Wetland

Introduction

Globally, various species and ecosystems are facing threats due to anthropogenic factors (Sanderson et al. 2002). Previous studies have pointed out that land use changes for construction of dams, agricultural expansion, rapid industrial development, domestic and industrial pollution, and expansion of human settlements play major role in degradation of ecological integrity of natural ecosystem (Li et al. 2009; Gopal 2013; Bassi et al. 2014). Wetlands are one of the ecosystems that are being degraded at a high rate and warrant immediate conservation attention as more than 50% of the wetlands have been vanished in last century (Ma et al. 2010). To address the issue, strategic assessments of type, scale and intensity of pressures on wetlands need to be conducted, which can contribute to effective and policy-smart actions and decisions that focus on their conservation and restoration (Bassi et al. 2014; Reis et al. 2017).

Almost all climatic and biogeographic zones in south Asian region have wetlands with unique characteristics which provide refuge to critical waterbird species during their annual migration in India and Tibet (Gopal and Krishnamurthy 1993; Prins and Namgail 2017). In recent past, about 80% waterbird populations have shown decline

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in the Asian flyways (Li et al. 2009), for which high altitude wetlands act as stopover and breeding sites (Namgail et al. 2017). Multiple site-specific factors have altered the behaviour and habitat of species, and environmental factors compelled smaller waterbird population towards extinction (Shaffer 1981; Wang et al. 2018). Understanding the demography and breeding behaviour of threatened species is thus, imperative to their survival and conservation (Donovan et al. 1995; Wu et al. 2009; Zhang et al. 2017a). Cranes (family Gruidae), often serve as biological indicators for ecological health of wetland ecosystems (Walkinshaw 1989), are facing various threats due to climate change complexities and human induced disturbances (Harris and Mirande 2013).

The black-necked crane (BNC) *Grus nigricollis* has been listed as “Near Threatened” on the IUCN Red List and breeds only in high plateau wetlands of China and India (BirdLife International 2020). Globally, their population is around 6600–6800 individuals and they are in continuous decline (BirdLife International 2020). India has a small population of BNC (< 150) in Ladakh, Sikkim and Arunachal Pradesh (Chandan et al. 2014), of which trans-Himalayan wetlands in Ladakh are the only key breeding habitats of BNC outside China (Gole 1981). Owing to its dwindling status, BNC is legally protected as a Schedule-I species under the Indian Wild Life (Protection) Act, 1972. It is considered sacred and a harbinger of prosperity among the Buddhist communities of Tibet, Bhutan and India indicating its cultural value. In view of ecological and cultural importance of BNC in the Union Territory of Ladakh, it has been declared as the ‘state bird’.

BNC is a territorial and monogamous species with long lasting bonding pair (Johnsgard 1983) and it prefers biparental incubation (Zhang et al. 2017b). Usually, cranes including BNC lay two eggs but are also known to be indeterminate layers if the first breeding attempt fails (Sauey and Brown 1977). In recent times, the increasing impact of humans and climate change are key conservation threats to BNC and its wetland habitats (Song et al. 2014; Han et al. 2018). Further, several factors influence breeding success of BNC such as habitat type, the location of nesting site, and disturbance factors including the presence of human, free-ranging dogs (*Canis lupus familiaris*) and livestock (Zhang et al. 2017a). Previous studies have explored the breeding ecology of BNC in India and China indicating threats to their offspring (Wu et al. 2009; Zhang et al. 2017a, b; Chandan et al. 2006).

The trans-Himalayan region of Ladakh has not only witnessed an increase in population of BNC over last two decades, but also recorded an exponential growth in human footprint (Chandan et al. 2014). Increasing demand of tourism and defense related developmental activities have induced land-use changes in and around BNC habitats

(Hussain 2003; Humbert-Droz 2017; Hussain et al. 2018). Similarly, unprecedented growth in population of free-ranging dogs has also increased predation risk on chicks and eggs of BNC (Chandan et al. 2006; Naoroji and Sangha 2011). Considering such factors as threats to the long-term survival of BNC in India, a systematic study was conducted to understand the ecology of BNC in Ladakh. We assessed population status, breeding ecology and evaluated factors affecting breeding performance of BNC in Changthang Wildlife Sanctuary (CWS), Ladakh.

Material and Methods

Study Area

CWS is an Indian trans-Himalayan protected area in Ladakh, extended over 4000 km² area with 25 major palustrine, lacustrine and riverine wetlands (34° 79′–33° 79′ E and 78°–79° N) (Fig. 1A). This rocky arid region receives < 100 mm rainfall annually (Gujja et al. 2003), resulting in low plant productivity (Rawat and Adhikari 2005). The temperature fluctuates between – 40 to + 30 °C in winters and summers, respectively (Mishra and Humbert-Droz 1998). The present study was focused on 25 freshwater, brackish and saline wetlands of CWS situated between altitudes of 4100–5200 m a. s. l. (Hussain et al. 2008). Considering the global importance of these wetlands, Tso Moriri and Tso Kar wetlands of CWS have been constituted as RAMSAR sites (RAMSAR 2020). Besides BNC, these wetlands are also major breeding habitats of bar-headed goose (*Anser indicus*) and ruddy shelduck (*Todorna ferruginea*) in India (Pfister 2004). CWS also has scanty population of the local transhumance community called *Changpa*, which resides in extreme climatic conditions and survive mainly on *pashmina* wool trade (Bhasin 2012). Due to sharing of international boundary with China, CWS also has significant presence of defense forces, related infrastructure and wide networking of asphalt and dirt roads. During summer season, millions of domestic and international tourists arrive in CWS to sight picturesque lakes and mountains which pose additional pressure on this fragile ecosystem (Humbert-Droz 2017).

Data Collection

Prior to field work, we thoroughly reviewed existing literature on BNC distribution in Ladakh (Osmaston 1925; Hussain 1985; Hussain and Pandav 2008; Hussain et al. 2008; Chandan et al. 2014) and carried out reconnaissance surveys of previously documented sites. Subsequently, we carried out seasonal counts of BNC in 25 wetlands of CWS during 2016–2017 using total count method for population

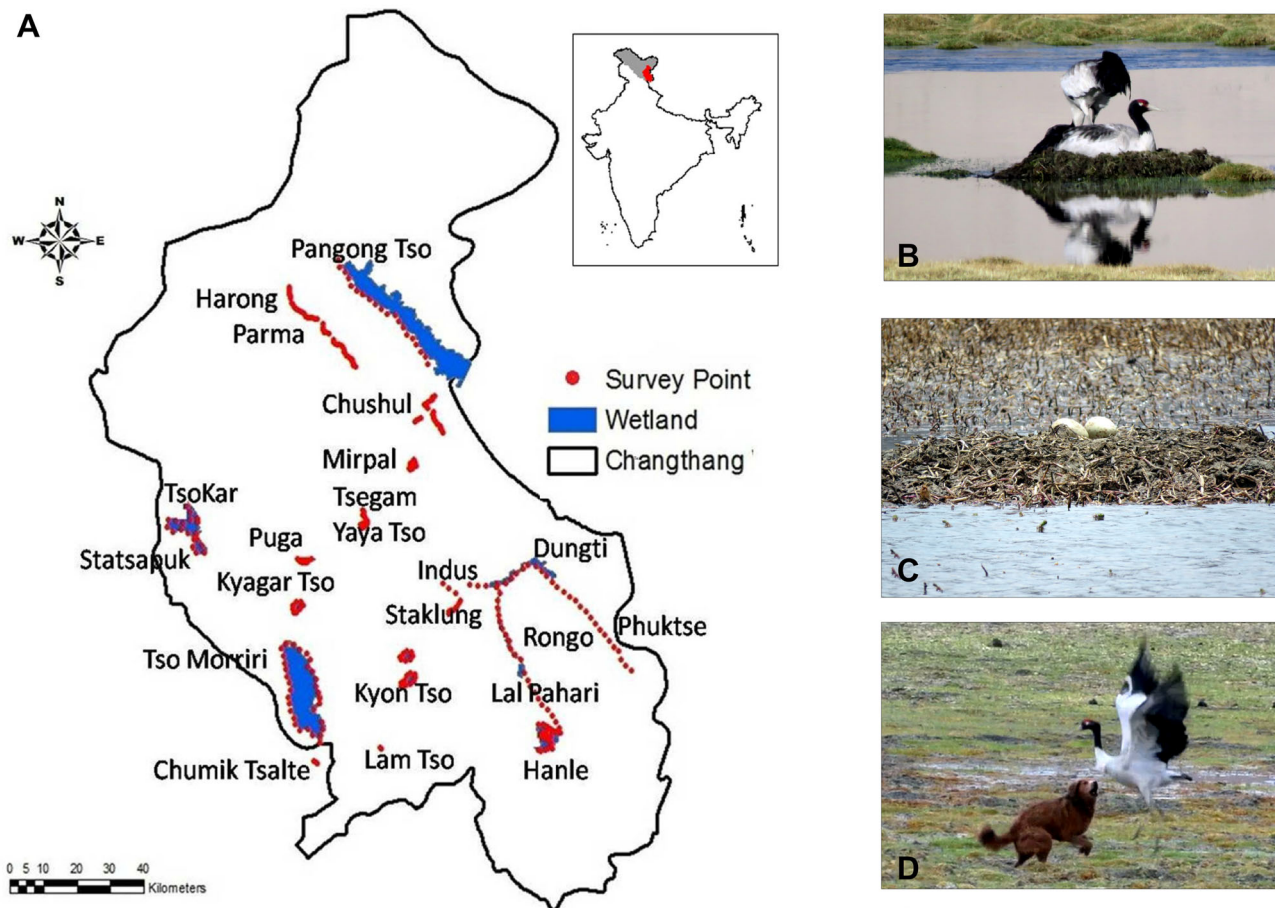


Fig. 1 **A** Detailed map of surveyed wetlands in Changthang Wildlife Sanctuary, Ladakh, India. **B** A breeding pair of Black-necked crane nesting in Changthang. **C** A nest type of Black-necked crane

estimation (Fig. 1A). Overall, 275 fixed points were surveyed in 25 wetlands throughout two years during three seasons, i.e. spring, summer and autumn using multiple observers (preferably two or three). A minimum distance of 400 m was maintained between two nearest survey points. We fixed these distances based on our reconnaissance surveys. At each site, the entire periphery of wetland was either walked or covered by vehicle (as per the field conditions). We recorded the flock size and divided the sighting records in three classes: (1) adult, (2) sub-adult and (3) juvenile. Adults were segregated into two categories based on evidence of breeding (presence of juvenile and nest) and non-breeding. Individuals recorded in close vicinity (< 100 m) were considered as a flock. However, we could not differentiate between individuals based on the sex due to monomorphism in BNC.

To monitor the breeding success, each nest-site was visited in all three seasons within an interval of 15 days (May to October). We collected data on clutch size, nesting stage, initiation date and fate (success/failure) (Fig. 1B, C). Nesting was monitored using spotting scope (Nikon Field

constructed with aquatic plants. **D** Free-ranging dog: a threat to Black-necked crane (Photo: Neeraj Mahar)

Scope ED50), and each location was marked on GPS etrex10. In addition, we collected information on presence (direct sighting) of dogs, tourists and ungulates. Any direct observation within the vicinity (< 300 m) of nest was considered as a potential threat (Fig. 1D). We confirmed dog predation by monitoring (morning and evening hours) and opportunistic sightings. We also took assistance of local pastoralists camping beside the nesting sites to monitor activity of BNC, potential predators and nest status. To avoid disturbance in incubation or nesting by our team, we maintained a minimum distance of 300 m (based on our calculated minimum approach distance) during monitoring of nests or chicks. We closely approached nest-sites (< 1 m) only once during collection of basic water parameters.

In 2016, we collected nine habitat parameters from 16 nest-sites under two categories (1) ecological and (2) physiochemical. The habitat parameters like continuous available habitat around nest-site for foraging, elevation of nest-site (m), water depth (cm), presence of ungulates near nesting sites (total numbers), pH and total dissolved solids

(TDS) (ppm) were collected. The water parameters were collected using digital pH and TDS meter near nesting site within one meter periphery of nest location. In anthropogenic variables, distance to nearest settlements (village/tourist/nomadic camp) and distance to road (asphalt or dirt) from nest-site was recorded by range finder or GIS domain. Total number of owned and unowned free-ranging dogs within 200 m proximity to nests was also recorded.

Data Analysis

We represented seasonal abundance of BNC using stack bars, and 95% confidence interval (CI) was used to test significance in annual variation. The proportions of marsh, lake and river available in the landscape were calculated and used in the Ivlev's Selectivity Index (Ivlev 1961; Wu et al. 2009). The value of selectivity index varies between -1 and $+1$ indicating utilization of the microhabitat to its availability. The nest survival of BNC was computed using Maximum Likelihood Estimator, Mayfield estimator (Mayfield 1975; Johnson 1979). Daily survival rate probability (d_{sr}), nest survival chance (\hat{S}), variance and 95% CI were also calculated (Johnson 1979). The annual recruitment rate was calculated using the method by Bradter et al. (2005). Hatching success was estimated as proportion of eggs which reached the stage of young (Zhang et al. 2017a) and breeding success was calculated as number of fledglings survived from total number of eggs laid (Mukherjee et al. 2002). Non parametric Chi square (χ^2) test was used for testing variation in nest distribution and site selection. Proportion and causes of breeding failure on different nesting stage (egg and chick) were also specified. Nest habitat parameters such as the euclidean distances from nearest settlement and road, and continuous habitat area available around the nest-site were calculated using ArcGIS Software (Version 10.2, ESRI, Redlands, CA, USA). Principal component analysis (PCA) was used to understand the habitat characteristic around nest sites recorded in field surveys (Wu et al. 2009). All analyses were performed in Microsoft Excel 2010 and R 3.6.2. Core Team (R Core Team 2019).

Results

Population Status

With total survey effort of 45.84 h/season, BNC presence was recorded in 19 out of 25 wetlands, of which 18 were identified as breeding sites. The mean population of BNC remained stable during two consecutive years of sampling (2016–2017). In 2016, mean population was 66.33 ± 5.04 SE (95% CI 44.6–88), while it was 69 ± 4.51 SE (95% CI

49.60–88.40) in 2017 with no significant difference (95% CI). The adult population was recorded slightly higher during spring ($n = 62$) and autumn ($n = 46$) season of 2017 than 2016, while remained same during both the summers ($n = 58$) (Fig. 2). In contrast, sub-adult population was recorded higher during all three seasons in 2016 (spring = 8, summer = 7, autumn = 8) than in 2017 (spring = 3, summer = 4, autumn = 4) (Fig. 2). Mean flock size of BNC was similar for both years, it was 1.74 ± 0.09 SE (range 1–4 individuals) in 2016 while 1.78 ± 0.13 SE (range 1–6 individuals) in 2017. A total of 29 and 31 pairs were recorded in 2016 and 2017, respectively, of which 19 breeding pairs were recorded in 2016 and 21 breeding pairs recorded in 2017 (Table 1). A total of 38 eggs were reported in 2016 and 42 were recorded in 2017. These eggs were mostly laid in the month of May (73%) followed by June (25%), while only two eggs were reported in the month of July (3%). Subsequently, 14 and 18 hatchlings were recorded during summer season of 2016 and 2017, respectively. Eventually, 11 chicks survived in 2016 and 14 in 2017 till autumn season.

Nest Habitat Selection

About 77% nests were found in marsh habitats followed by lakes (20%) and rivers (3%). In wetland habitats, lakes occupied around 64% of the area followed by marshes (30%) and rivers (5%). The nest distribution was significantly different in pooled analysis of two years in three different microhabitats ($\chi^2 = 17.85$, $df = 2$, $P < 0.001$). However, no annual variation in nest distribution was found in the different microhabitats ($\chi^2 = 0.934$, $df = 2$, $P > 0.05$) (Table 2). Ivlev's selectivity index revealed that the marsh habitats were selected in proportion across two years, while lake and river habitats were avoided for nesting. The lacustrine habitat was used in proportion to availability in 2016 but avoided in 2017, while river habitat was negatively selected across two years.

Breeding Performance

In 2016, 37% hatching success was recorded in 19 nests with 14 hatchings. A total of 21 nests were monitored with 18 hatchings in 2017 with 43% hatching success. The breeding success varied between 29 to 33% in 2016 and 2017, respectively. The annual recruitment rate was 16% in 2016, and 18% in 2017 (Table 1). We recorded 695.5–944.5 exposure days and daily survival probability (d_{sr}) of a nest was calculated as 0.982 in 2016 and 0.987 in 2017. In 2016, there was 21% chance of nesting success (\hat{S}), while 17% in 2017.

Up to 59% of breeding failure of BNC was attributed to unknown reasons like potential predators (raven, raptors

Fig. 2 Seasonal population (total count) of Black-necked Crane in Changthang Wildlife Sanctuary, Ladakh, India during 2016–2017

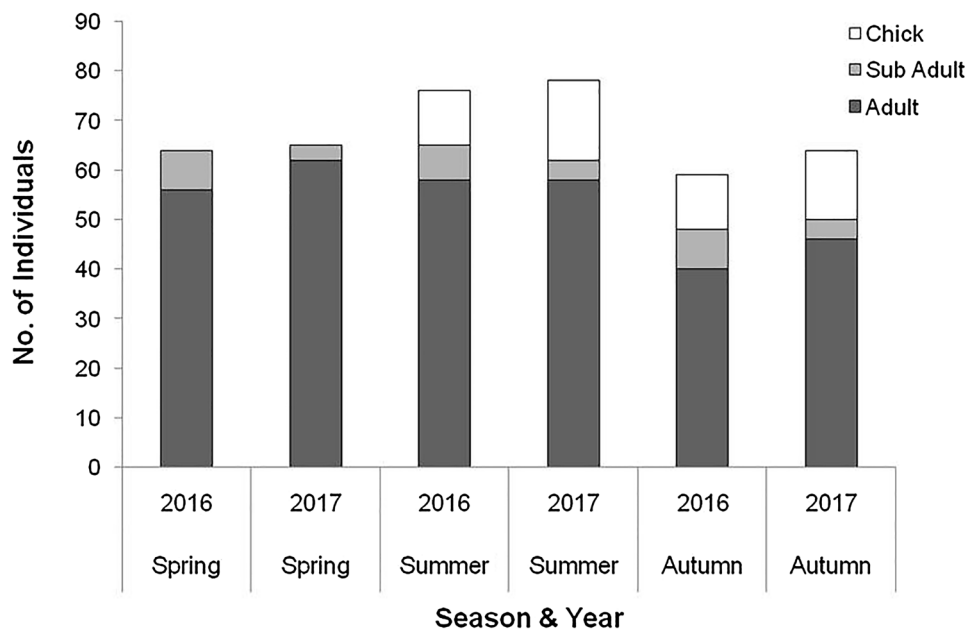


Table 1 Reproductive parameters of Black-necked Crane [Hatching success, breeding success, Recruitment rate, Daily Nest Survival probability (*d_{sr}*), % nest survival] in Changthang Wildlife Sanctuary, Ladakh, India

Year	2016	2017	Mean ± SE
No. of nests	19	21	20 ± 1
No. of eggs laid	38	42	40 ± 2
No. of hatching	14	18	16 ± 2
No. of chick survived	11	14	12.5 ± 1.5
Hatching success (%)	37	43	40 ± 3
Breeding success (%)	29	33	31 ± 2
Recruitment rate (%)	16	18	17 ± 1
Exposure days	695.5	944.5	820 ± 124.5
<i>d_{sr}</i>	0.982	0.987	0.985 ± 0.003
<i>S</i> % (95% CI)	21 (8–51)	17 (5–45)	19 ± 2

and fox) which were beyond the scope of documentation in our study. Predation of eggs and chicks by free-ranging

dogs was the second major reason, and contributed 33–39% in breeding failure during 2016–2017, respectively (Table 3). Dogs were also observed chasing adults and sub-adults in Hanle and Rongo wetlands (Fig. 1D). During monitoring across two years, thawing (melting of glacier snow and rise in water level in the wetland) in Tso Moriri and Tsegam Tso wetlands contributed 7–14% in breeding failure during 2016–2017, respectively. In 2016, mortality of total 3 chicks and 24 eggs was observed, while in 2017, total of 4 chicks and 24 eggs was confirmed (Table 3).

BNC used mean water depth (cm) of 14.05 ± 1.47 (SE) for nesting in CWS. Water pH value was 9.19 ± 0.26 near nest-sites and TDS (ppm) quality was 435.19 ± 88.73 indicating use of fresh and brackish water habitats (Table 4). In PCA, about 86% of the variance was accounted by the first 5 Principal Components (PC). About 33% variance in 9 variables explained by PC 1 axis followed by PC2 (22.9%) and PC3 (13.5%). Water quality (TDS) was mostly associated with PC1 with low ungulate presence, water depth was correlated in PC 2, and factors

Table 2 Nest habitat selection (Ivlev’s Selectivity Index) by Black-necked Crane in Changthang Wildlife Sanctuary, Ladakh, India (2016–2017)

Year	2016			2017			Combined		
	Marsh	River	Lake	Marsh	River	Lake	Marsh	River	Lake
Availability	0.305	0.055	0.640	0.305	0.055	0.640	0.305	0.055	0.640
Nest observed	15	0	4	16	1	4	31	1	8
Nest expected	5.8	1	12.2	6.4	1.2	13.4	12.2	2.2	25.6
<i>P</i> < 0.001									
Selectivity index	+ 0.44	– 1	– 0.5	+ 0.43	– 0.07	– 0.54	+ 0.43	– 0.37	– 0.52

Table 3 Causes of breeding failure in Black-necked Crane Changthang Wildlife Sanctuary, Ladakh, India (2016–2017)

Cause of failure	Mortality stage	Frequency		% Per nest stage		% Per failure	
		2016	2017	2016	2017	2016	2017
1. Unknown	Egg	14	11	51.9	39.3	59.3	46.4
	Chick	2	2	7.4	7.1		
2. Predation by dogs	Egg	8	9	29.6	32.1	33.3	39.3
	Chick	1	2	3.7	7.1		
3. Thawing	Egg	2	4	7.4	14.3	7.4	14.3
	Chick	–	–	–	–		
Total		27	28	100	100	100	100

Table 4 Principal component analysis (PCA) of variables describing the habitat of recorded nest sites of Black-necked Crane in Changthang Wildlife Sanctuary, Ladakh, India

	PC1	PC2	PC3	PC4	PC5
% Of variance	32.9	22.9	13.5	10	6.86
% Of cumulative proportion	32.9	55.8	69.3	79.2	86.1
Standard deviation	1.72	1.44	1.10	0.95	0.79
<i>Variable (mean ± SE)</i>					
Area (17.57 ± 7.96 sq. km)	0.320	0.175	– 0.293	0.683	– 0.231
Elevation (4405 ± 47 m. asl)	– 0.394	0.310	– 0.391	0.064	0.074
No. of dogs (0.69 ± 0.22)	– 0.151	– 0.442	– 0.370	– 0.240	– 0.663
No. of ungulates (3.69 ± 1.75)	0.480	0.154	– 0.072	– 0.026	– 0.089
Distance to settlement (2809 ± 835 m)	0.069	0.566	0.066	– 0.147	– 0.596
Distance to road (1418 ± 855 m)	0.104	0.278	– 0.690	– 0.347	0.0351
Water depth (14.05 ± 1.47 cm)	– 0.271	0.495	0.336	– 0.032	– 0.024
pH (9.19 ± 0.26)	0.398	0.070	0.154	– 0.565	– 0.026
TDS (435.19 ± 88.73 ppm)	0.492	– 0.074	0.032	0.093	0.111

like elevation of nesting site and presence of dogs were correlated to PC 3 axis (Table 4).

Discussion

Since early 1900s, BNC population has increased many folds in Ladakh, from three individuals and one breeding pair in 1919 (Ludlow 1920) to 44–88 individuals and 21 breeding pairs at present. A long-term study by Chandan et al. (2014) recorded relatively higher number of BNC in Ladakh (100–120 individuals) but less breeding pairs than present study. However, aforementioned study only provided total annual counts while present study included seasonal abundance variations. In our study, BNC population remained stable across two years with maximum individuals during summer, usually when juveniles fledged. Less numbers were recorded during spring and autumn attributed to seasonal to-and-fro migration of BNC between India and Tibet. Global declining trend in the population of BNC enhance the importance of the Ladakh population, as it is the only breeding population outside of Tibet (China). Despite a decline in the global population of BNC, new breeding sites have been reported by recent

studies in India and China (Chandan et al. 2014; Han et al. 2015), but earlier that could be an artefact of limited surveys and accessibility issues in high mountainous region.

The present study also confirmed that BNC has occupied some new wetland habitats in CWS over the years. BNC usually migrate during winters from CWS to lower valleys of Tibet, but in a rare occasion, a pair of BNC remained at Lam Tso wetland (CWS) for the entire winter (Chandan et al. 2006). In our findings, distribution of BNC in Ladakh was restricted to wetlands of the Changthang region, occupying about 70% sampled wetlands as breeding or foraging sites between 4100–5200 m and selected elevation < 4800 m for nesting. BNC preferred palustrine and lacustrine habitats for nesting and riverine habitat for nest-site was used once, while grasslands were only used as foraging habitat. In contrast, BNC in China mostly utilized lacustrine habitats for nesting (Wu et al. 2009; Zhang et al. 2017a). Nest-sites were mostly influenced by water parameters; BNC mostly used freshwater marsh habitats in CWS. Apart from that, low ungulate presence and availability of large wetland area also played a crucial role. Large connected wetland habitats perhaps provide ample food resources and hideouts; hence were preferred for nest-

sites. Similarly, wetland size played pivotal role in nest-site selection by BNC in Tibetan wetlands (Zhang et al. 2017a).

Alike present study, Dwyer et al. (1992) recorded similar water depth (average ~ 14 cm) near nesting sites in central and southwest Tibetan autonomous region. In CWS, water depth in marsh areas was comparatively lower (< 20 cm) during the onset of spring (May) with frozen snow but increased during summer (June and July), perhaps water level rise could have washed away nests at few sites during summer season. Occasional flooding due to glacial melted water during summers washed away active nests at Tso Moriri and Tsegam Tso wetlands which perhaps attributed to wrong preference of nesting site and BNC might shift it in near future. Water depth also influenced nest-site selection of BNC in Tibetan wetlands (Wu et al. 2009; Zhang et al. 2017a), and populations require similar water depth (< 30 cm) preferences in wintering habitats (Johnson et al. 2021). In CWS, Tsegam Tso wetland (highest nesting site in CWS) was such an example of low water level (< 5 cm) during the month of May when temperature was still low. While in some nest-sites in lakes, water depth was much deeper ≥ 25 cm which functioned as a natural barrier for predators. Other factors like distance to water and nearest nest had profound influence on nest-sites in wetlands of China (Wu et al. 2009; Zhang et al. 2017a; Wei et al. 2021).

Despite population increase in CWS, breeding success has declined in the last three decades from 60% in 1994 (Chacko 1995) to 33% in 2017. The present study's average breeding success (31%) of two years was comparable to a study in China (33%) by Zhang et al. (2017a). However, the nest survival in present study was lower than survival in China (Farrington and Xiulei 2013; Zhang et al. 2017a). Comparatively, chick recruitment rate of BNC in Ladakh was also found lower than China (Farrington and Xiulei 2013; Zhang et al. 2017a). However, our results have shown higher recruitment rate than Chandan et al. (2019) in CWS.

In comparison to present study, high hatching success was recorded in previous studies (Zhang et al. 2017a; Chandan et al. 2019). Presence of dogs affected nest-site selection along with elevation (4100–4800 m) in CWS. Predation considered as major cause of breeding failure in BNC, chicks and eggs are being predated by free-ranging dog and other wild carnivores (Chandan et al. 2006; Wu et al. 2009; Farrington and Xiulei 2013; Zhang et al. 2017a). Even the wintering populations in Bhutan are vulnerable to predation by common leopard (*Panthera pardus*) (Choki et al. 2011). The present study confirmed 30–40% predation of chicks and eggs by dogs. The dog population in Ladakh has drastically increased in the last few decades due to feralization by defense forces, locals

and tourism generated availability of abundant food subsidy (Gagne 2019).

In addition, increasing demand for defense infrastructure near Indo-Tibetan border has expanded the intensity of developmental works in the region especially near wetlands due to the availability of water and other resources (Humbert-Droz 2017). Recently, Ladakh has become tourism hotspot and gained popularity among domestic tourist, the wetlands in CWS are being affected by unaware tourists' activities, off-road driving in wetlands, unauthorized camping and subsequent degradation of habitat. These factors can pose challenges for the conservation planning of BNC in the region.

Role of climate change and its possible impacts on survival of the species are still not very clear, however, few studies have predicted that climate change may not necessarily decline extent of wetlands; thermokarst and thawing can form new wetlands and subnival zones in Tundra habitats (Gorham 1991; Anderson et al. 2020).

Conclusions

In CWS, any land use alterations need to be restricted especially in and around marsh and lake habitats, thus demarcation of buffer zones around such critical habitats are essential for undisturbed nesting and breeding of BNC. Free-ranging dog populations also need to be controlled through effective population management strategies such as capture neuter relocation programmes. Further, to reduce their negative impacts on threatened species, dogs should be treated as 'Invasive Species' inside protected areas and other critical wildlife habitats such as breeding/nesting sites. The local pastoralists and defense personnel should be sensitized about impacts of dogs on wildlife, particularly on BNC nesting sites. Strict tourism management policies need to be developed to regulate nest-site affecting tourist movements in the area. We recommend nest specific (parameters) studies for better understanding of nest-site selection, which was a limitation in present study. Intensive camera trap-based nest monitoring is also recommended to elucidate unknown reasons of breeding failure and ensure survival of a near-threatened species like BNC.

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Author Contribution NM, BH, SAH, TS and JT conceived the idea of this study and NM carried out field work, analysed data and wrote the manuscripts with inputs from BH, SAH, TS and JT.

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Data Availability Due to sensitivity (near international boundary) of study sites, data would be available on reasonable explanation and permission from the Director, Wildlife Institute of India.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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TRACKING THE MOVEMENT PATTERN OF BAR-HEADED GOOSE *ANSER INDICUS* CAPTURED FROM THE GHARANA CONSERVATION RESERVE, INDIA

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Bar-headed Goose *Anser indicus* is a long distance migrant to the Indian subcontinent, with the major population breeding in China. There is a small breeding population in Ladakh, Mongolia, and Kyrgyzstan. To gain an understanding of their movement pattern and home range, we monitored two PTT tagged Bar-headed Geese (BG111847 & BG111848) captured from the Gharana Conservation Reserve, Jammu & Kashmir, India, during March to August 2012. The origin of the tagged birds, whether from Ladakh or extralimital, could not be ascertained as both the PTTs functioned only for 5–6 months; also, the birds did not move to their breeding grounds till the signals were received in August. During the tracking period, the PTT fitted geese used the Tawi river floodplains of India and Pakistan, in Jammu and Sialkot districts respectively. BG111847 used a 431 km long stretch of the Tawi floodplains, while BG111848 used only a 54 km stretch. The home range of BG111847 was 52.60 sq. km [85% MCP (Minimum Convex Polygon)] and the core area was 7 sq. km (50% MCP), while the home range for BG111848 was 29.68 sq. km (85% MCP) and the core area was 2 sq. km (50% MCP). Post winter, the two geese used around 17 small wetlands in the Tawi river floodplains, moving between India and Pakistan intermittently, indicating the need for cross-border efforts for the long-term conservation of the species in this region. Our results are preliminary and further studies are needed to understand the migration pattern and habitat use of the Bar-headed Goose wintering in the Gharana Conservation Reserve and adjoining areas.

Keywords: Bar-headed Goose, satellite telemetry, migration, home range, wetland, Platform Transmitter Terminal, Important Bird Area

INTRODUCTION

The Bar-headed Goose *Anser indicus* occurs in Afghanistan, Pakistan, Tajikistan, Russia, Bhutan, China, India, Mongolia, Nepal, Bangladesh, Vietnam, Thailand, Uzbekistan, and Kyrgyzstan (IUCN 2014). The major breeding population inhabits China, with smaller populations in Mongolia and Kyrgyzstan (Koppen *et al.* 2010; Takekawa *et al.* 2009). In India, breeding Bar-headed Goose has been reported from Ladakh (Ali and Ripley 1987) where about 500 pairs breed around several lakes and marshes (Hussain and Pandav 2008; Hussain *et al.* 2008; Prins and Wieren 2004). Migrating Bar-headed Geese have been reported from many protected and non-protected wetlands of Assam, Himachal Pradesh, Jammu & Kashmir, Uttar Pradesh, Rajasthan, Andhra Pradesh, Odisha, Karnataka, Tamil Nadu, Kerala, and Maharashtra (Ali and Ripley 1987; Neelakantan *et al.* 1993; Rahmani 1992; Rahmani and Arora 1992; Rahmani and Islam 2008; Rahmani *et al.* 2010).

The Bar-headed Goose is listed as a Schedule I species under the Indian Wildlife (Protection) Act, 1972 and J&K Wildlife (Protection) Act, 1978. Globally, it is a “Least Concern” species (BirdLife International 2002; Collar *et al.* 1994), though it is believed that its population is declining rapidly due to habitat loss, illicit egg collection, and hunting (Koppen *et al.* 2010). Its global population is estimated to be <60,000 (Miyabayashi and Mundkur 1999), with estimates of around 20,000–30,000 wintering in India (Li *et al.* 2009). Over 30,000 birds are reported during winter in China and the Tibet Autonomous Region (Bishop and Drolma 2007; Bishop *et al.* 1997).

Scientists and naturalists have always been fascinated by the Bar-headed Goose due to its ability to fly over the Himalaya during migration to the Indian subcontinent and back (Hawkes *et al.* 2010, 2013; Javed *et al.* 2000; Kalra *et al.* 2011; Lee *et al.* 2008; Swan 1970; Scott and Milsom 2007). Kasambe *et al.* (2008) recovered neck-collared Bar-headed Geese in Maharashtra and Karnataka which were tagged in

Mongolia. Similarly, a neck-collared Goose from Mongolia was reported in Tamil Nadu during winter (Van der Ven *et al.* 2010). The species was found to migrate *c.* 780 km over the Himalaya from India to China (Javed *et al.* 2000). Kalra *et al.* (2011) also recorded their migration between India and China. Platform Transmitter Terminal (PTT) deployed geese in China, Mongolia, and Kyrgyzstan have been reported from Keoladeo National Park (Rajasthan) and Pong Dam (Himachal Pradesh) in India. Bar-headed Geese have been identified as carriers of the highly pathogenic H5N1 virus (Bourouiba *et al.* 2010; Chen *et al.* 2005; Prosser *et al.* 2011; Zhou *et al.* 2006), which necessitates monitoring of their movement pattern at international and regional levels. Hence, we undertook this study to examine the movement pattern and habitat use of the Bar-headed Goose frequenting the Gharana Conservation Reserve using satellite telemetry.

Capture site

The Gharana Conservation Reserve is an 'Important Bird Area' (Islam and Rahmani 2004), situated near Gharana village in Ranbirsinghpura *tehsil* in the Tawi floodplains (32° 32' 26" N; 74° 41' 24" E) of Jammu & Kashmir State. It is *c.* 500 m from the India-Pakistan international border and is a small wetland with an area of *c.* 100 ha surrounded by agricultural lands. The wetland is covered with Water Hyacinth *Eichhornia crassipes* and *Typha* sp. (Islam and Rahmani 2004). The Tawi river, agricultural lands, and several small wetlands adjacent to Gharana offer habitats for waterbirds in the floodplains. A study reported 21 species of waterbirds from this wetland (Sharma and Saini 2012) with around 20,000 birds reported during winter, which includes more than 2,000 Bar-headed Geese (Islam and Rahmani 2004). The adjacent floodplains of Indus, Degh, Panynad, and Ravi rivers in Pakistan also have wintering population of Bar-headed Geese numbering around 5,000 (Koppen *et al.* 2010; Van der Ven *et al.* 2010). The nearest breeding ground for the Bar-headed Goose from Gharana is Ladakh, *c.* 300 km to its north. The breeding sites in Ladakh mainly comprise lacustrine (e.g., Tso Kar, Tso Moriri) and palustrine (e.g., Dungti, Chushul) wetlands (Chandan *et al.* 2005; Islam and Rahmani 2004; Prins and Weiren 2004). In China, their breeding sites are steppes, saline meadows, swamp meadows, alpine meadows, and cropland habitats, while preferred stopover sites are lakes, marshes, and shallow wetlands (Zhang *et al.* 2011).

METHODS

Capture and deployment of PTTs

On March 19, 2012, seven adult Bar-headed Geese were captured from the Gharana Conservation Reserve using noose

snare by trained professional bird trappers of the Bombay Natural History Society. After biometric measurements, two individuals were randomly selected for the deployment of pre-designed PTTs. The PTT model TAV-2630, with around nine months of battery life, was attached onto the backs of the birds with a backpack harness. The weight of PTT was 29 gm, which is around 1% of the total body weight of the geese and is within the recommended 3% weight limit (Wilson and McMahon 2006). Unique identification numbers were given to the birds, *viz.* BG111847 and BG111848, for receiving data from ARGOS (ARGOS 2007). PTTs were set to receive five fixes per 24 hour cycle. Generally, ARGOS provides fix (location) classes of different accuracies; the high accuracy fix classes are 3, 2, 1 and 0. Low accuracy classes A, B, and Z are also transmitted from the PTT. The high accuracy fix classes provide a range of error as follows: 3 = <150 m, 2 = 150–350 m, 1 = 350–1,000 m and 0 = >1,000 m. As classes A, B, and Z indicate poor satellite connection (ARGOS 2007), only classes 3 to 0 were used for analysis (Ueta 2000).

Data analysis

We used adehabitatHR for home-range and movement pattern analysis in R core 3.0.2 version software (R Development Core Team 2014). Conventional Minimum Convex Polygon (MCP) method was used for home range analysis and core area was calculated with 50% MCP. ARGOS fixes received from both individuals were overlaid on Land Use Land Cover (LULC) maps using ArcGIS Version 9.3 (ESRI 2008). Habitat types were broadly divided into five categories, namely water (river and waterbodies), vegetation (largely grass-dominated areas), settlement (village and town), agriculture, and open areas (uncultivated and riverbed). We used Google Earth images Version 6.1 (Google, Mountain View, California, USA) to identify wetlands utilized by the geese and the potential wetlands in the region suitable for geese and other waterbirds.

RESULTS

Performance of PTTs

We received 647 fixes between March and August 2012, with maximum fixes during April, and minimum during August 2012 (Fig. 1). We analyzed 205 high class fixes [from both geese, Location Class (LC) 3 (33%), followed by LC 2 (32%), LC 1 (26%) and LC 0 (9%)], of which 176 fixes were of BG111847 and 29 were of BG111848. The PTT on BG111847 functioned till August 2012 while that on BG111848 provided irregular fixes till July 2012 (Table 1). Both the PTTs functioned for 5–6 months below the expected life of 9 months.

Table 1: Home range (50% & 85% MCP) and movement pattern of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve

Bird ID	Start Date	Total Fixes	Fixes used for analysis	End Date	50% MCP (sq. km)	85% MCP (sq. km)	Movement (km/day)
BG111847	March 19, 2012	550	176	August 25, 2012	7	52.60	2.69
BG111848	March 19, 2012	97	29	July 7, 2012	2	29.68	0.46

Spatial Distribution

We computed 85% MCP after excluding the outliers. As depicted in Fig. 2, 90% MCP for BG111847 was justifiable, unlike BG111848. As prominent increase in home range of BG111848 till 90% was ineffective, we determined home range using an acceptable average of 85% MCP, and core range was computed with 50% MCP. Average home range of the two birds was calculated as 41 sq. km (85% MCP), and core area as 4 sq. km (50% MCP).

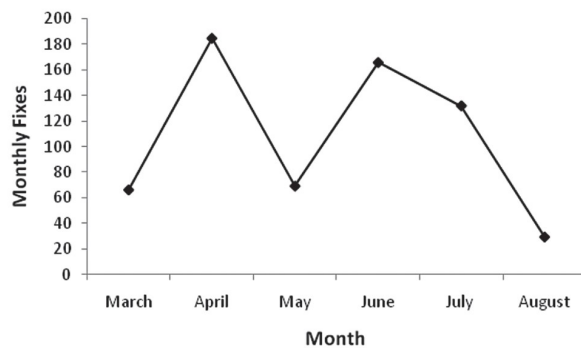


Fig. 1: Monthly fixes received from ARGOS for two PTT-fitted geese captured in Gharana Conservation Reserve

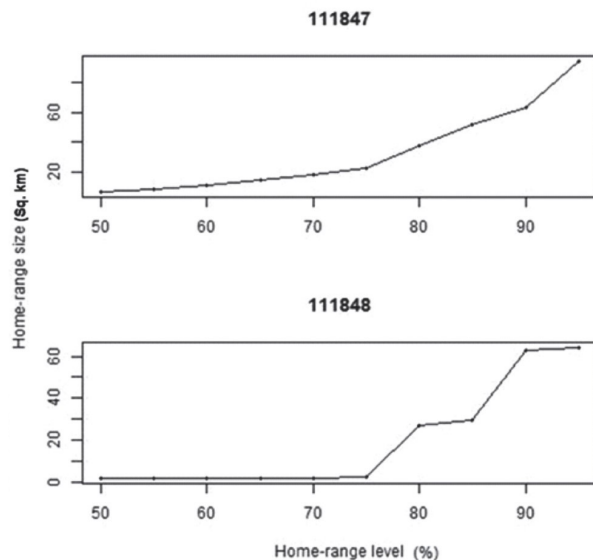


Fig. 2: Saturation in home ranges of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve

Individually, the home range of BG111847 was 52.60 sq. km with a core area of 7 sq. km that mainly consisted of wetlands/waterbodies. The core area for BG111847 was in Chaprar, Pakistan, and near Ranbirsinghpura, India. The home range of BG111848 was 29.68 sq. km between March to July (Fig. 3), with a core area of 2 sq. km in and around Tawi river within Indian territory, c. 12 km away from Gharana (Fig. 4). Both the individuals did not return to Gharana after tagging; they moved towards the north and used the Tawi floodplains extensively. There was an overlap of 10 sq. km area between the home ranges of these two birds, but no interaction was recorded since very few fixes were received from the overlapping area (Fig. 3).

Movement Pattern

Instead of migrating towards Ladakh/Central Asia/China, the geese that were tagged in March 2012 remained in Tawi floodplains till July–August 2012. The birds moved extensively within areas of the Tawi floodplains in Jammu (India) and Sialkot (Pakistan). For BG111847, the total movement was computed as c. 431 km and the average movement was 2.69 km/day (Table 1), while the maximum distance between two consecutive fixes was 25 km. The PTT-fitted goose occasionally visited nearby areas of River Chenab in Pakistan (Fig. 5). Eventually, BG111847 settled in Chaprar (Pakistan) till we received the last fix in August 2012. BG111848 moved c. 54 km, and the average distance travelled was 0.46 km/day with a maximum of 13 km between two consecutive fixes on March 21, 2012; the last fix for this bird was received in July 2012.

Habitat Use

Most of the fixes were received from open areas (a combination of open barren lands, empty crop lands and riverbeds), followed by vegetation (mostly grass-dominated areas), agriculture and wetlands (Fig. 6). Fixes were not received from any human settlements, indicating that the geese avoided such areas. The least number of fixes were received in water/wetland habitats, most of the fix clusters in other habitat types were within 1–2 km of the Euclidean flight distance from the wetlands. The total area used by the two

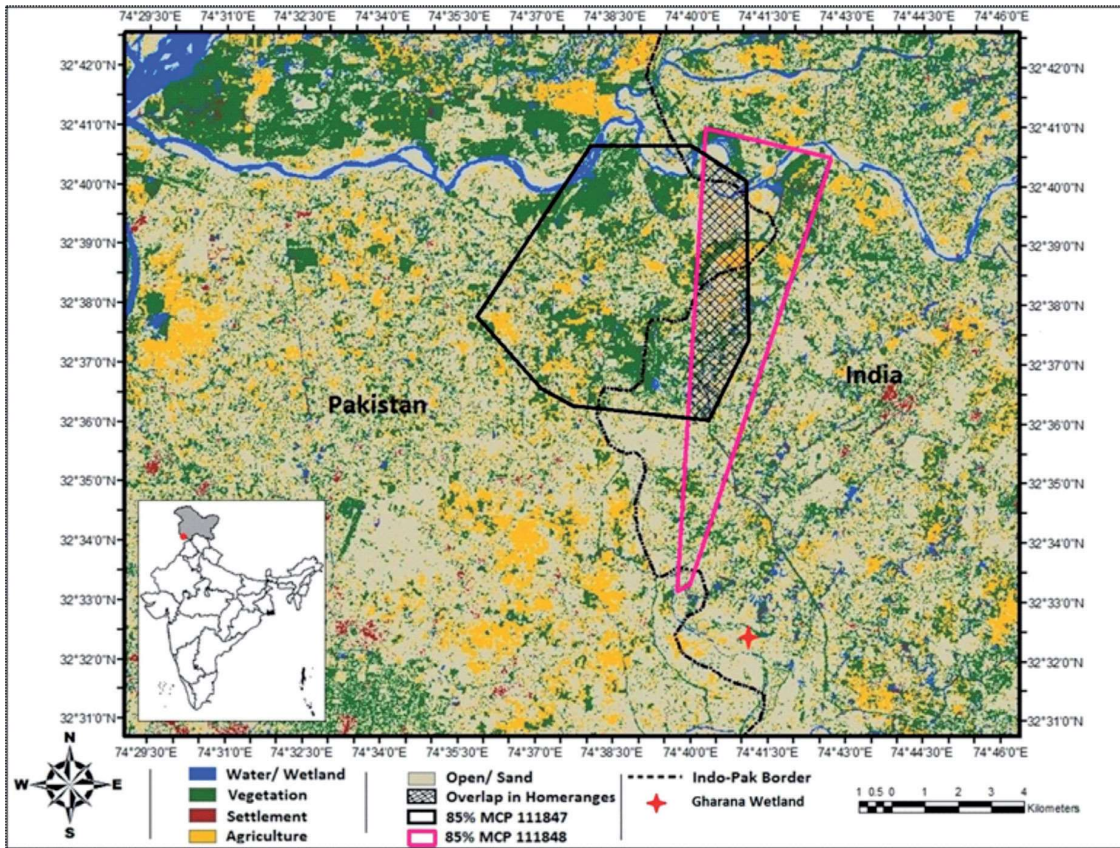


Fig. 3: Home ranges (85% MCP) of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve

Table 2: Wetlands in Tawi floodplain of India and Pakistan

Wetland ID (see Fig. 7)	Area (sq. km)	Perimeter (km)	Type	Country
1	0.005	0.15	Canal	
2	0.004	0.292	Pond	I
3	0.006	0.418	Pond	P
4	0.001	0.146	Pond	P
5	0.431	4.5	Pond, Canal	I & P
6	0.001	0.19	Pond	P
7	0.014	0.057	Pond	P
8	0.002	0.21	Pond	P
9	0.002	0.246	Pond	P
10	0.019	0.781	Pond	P
11	0.014	0.712	Pond	P
12	0.023	0.7	Pond	P
13	0.0008	0.126	Pond	P
14	0.125	5.6	Stream	P
15	0.014	0.797	Canal	I
16	0.004	0.666	Pond	P
17	0.0006	0.13	Pond	P

Source: - Google Earth Image; I - India and P – Pakistan

birds was *c.* 72 sq. km, of which open area constituted 31.78 sq. km, followed by areas with grass-dominated vegetation (25.58 sq. km), agriculture (10.41 sq. km), and river/wetland (3.21 sq. km). The home range, however, encompassed 0.47 sq. km human settlements.

Important wetlands in the Tawi floodplain

The birds used around 17 small wetlands in the Tawi floodplain (Fig. 7; Table 2), varying in size from *c.* 0.0006 to 0.431 sq. km with a total available area of *c.* 0.66 sq. km, of which *c.* 0.44 sq. km was in India and *c.* 0.22 sq. km in Pakistan. Most of these wetlands served as optional habitats for the geese. Occasionally, stagnant water canals were used. In Chaprar (Pakistan), *c.* 0.20 sq. km cluster of wetlands were utilized by BG111847 in July and August. Among these clusters, smaller wetlands of size 0.0008 sq. km also served as staging sites (Table 2). Apparently, these are potential habitats for waterbirds in the Tawi and Chenab river floodplains in India and Pakistan (Fig. 7).

DISCUSSION

Neck-banded Bar-headed Geese have been reported

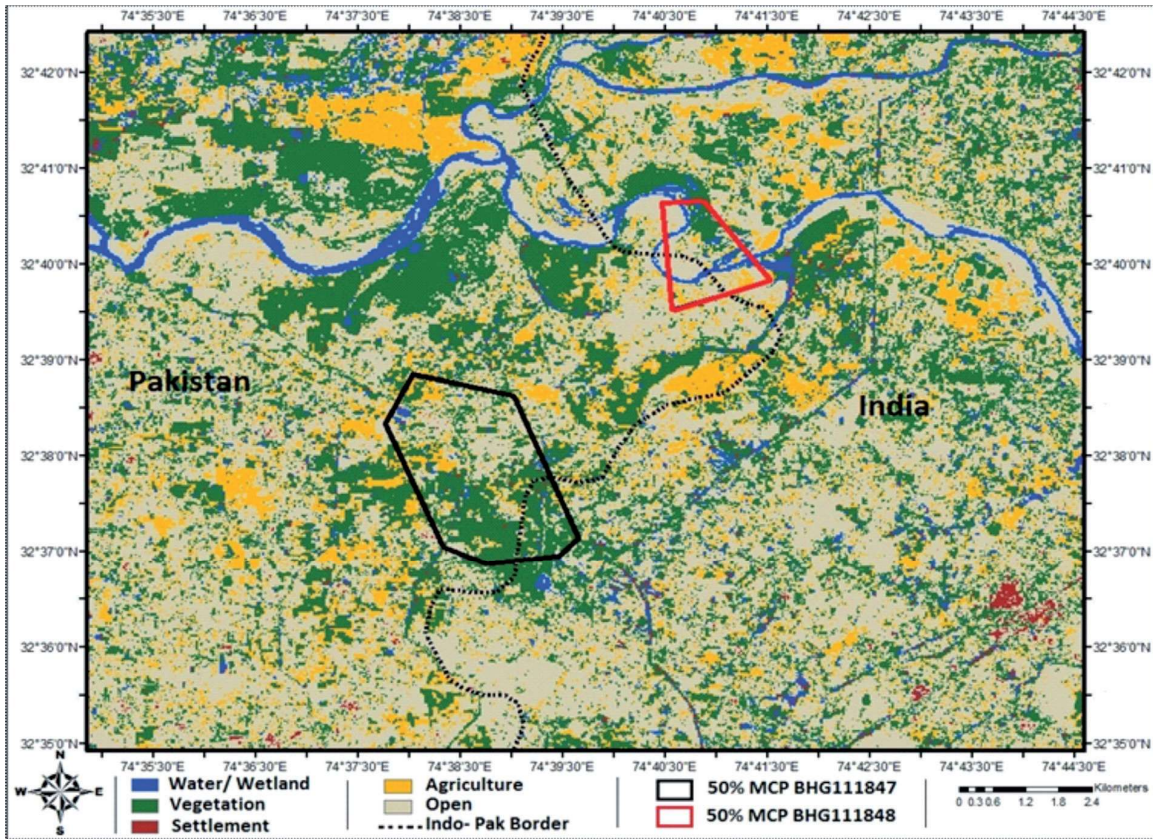


Fig. 4: Core areas (50% MCP) of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve

to visit the Gharana Conservation Reserve (Agency India Press, December 23, 2011; DNA December 27, 2011), which are believed to have been tagged in Mongolia, the Qinghai province of China, or possibly Himachal Pradesh (A.R. Rahmani, pers. comm.). Earlier satellite tracking studies reported the maximum migration distance of the Bar-headed Goose to be 3,000 km, from Mongolia to India (Hawkes *et al.* 2013; Takekawa *et al.* 2009). PTT-fitted Bar-headed Geese from Keoladeo National Park (Rajasthan) and Sur Sarovar (Uttar Pradesh) moved to their breeding grounds in the Tibetan Autonomous Region and Xizang Province (China) by March–April (Javed *et al.* 2000; Kalra *et al.* 2011). However, our study showed a comparatively short movement (maximum 431 km) and the birds were recorded in the Tawi floodplains of India and Pakistan till August (Table 3). This indicates that either the PTT-fitted birds are from a resident population of nearby areas, such as Ladakh, or they did not return to their breeding sites because of some other reason, which needs further investigation.

The extent of area utilized by the two PTT-fitted birds in our study varied perhaps due to the availability of suitable habitats or inter/intra-specific competition among species (Schoener 1968; Nudds and Ankney 1982). However, from

the small sample size, we could not make any definitive conclusion in the difference observed in the extent of area used by these two birds. Gharana is a very small wetland, so, agricultural land around it and other smaller wetlands serve as an obligate habitat for wintering waterbirds such as Bar-headed Geese. The PTT-fitted birds did not return to Gharana, but used nearby wetlands and agriculture fields and

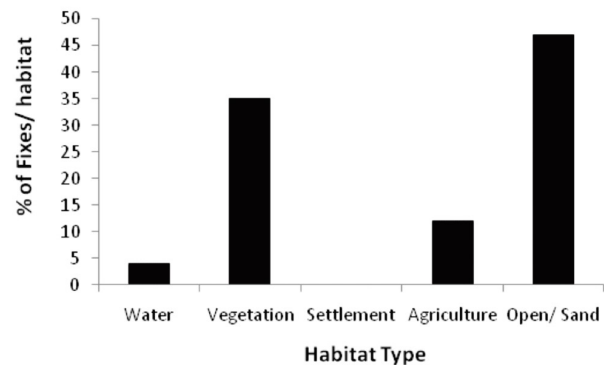


Fig. 6: Percentage of ARGOS fixes of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve in different habitats

Note: Vegetation here denotes grass-dominated areas

TRACKING THE MOVEMENT PATTERN OF BAR-HEADED GOOSE CAPTURED FROM GHARANA CONSERVATION RESERVE

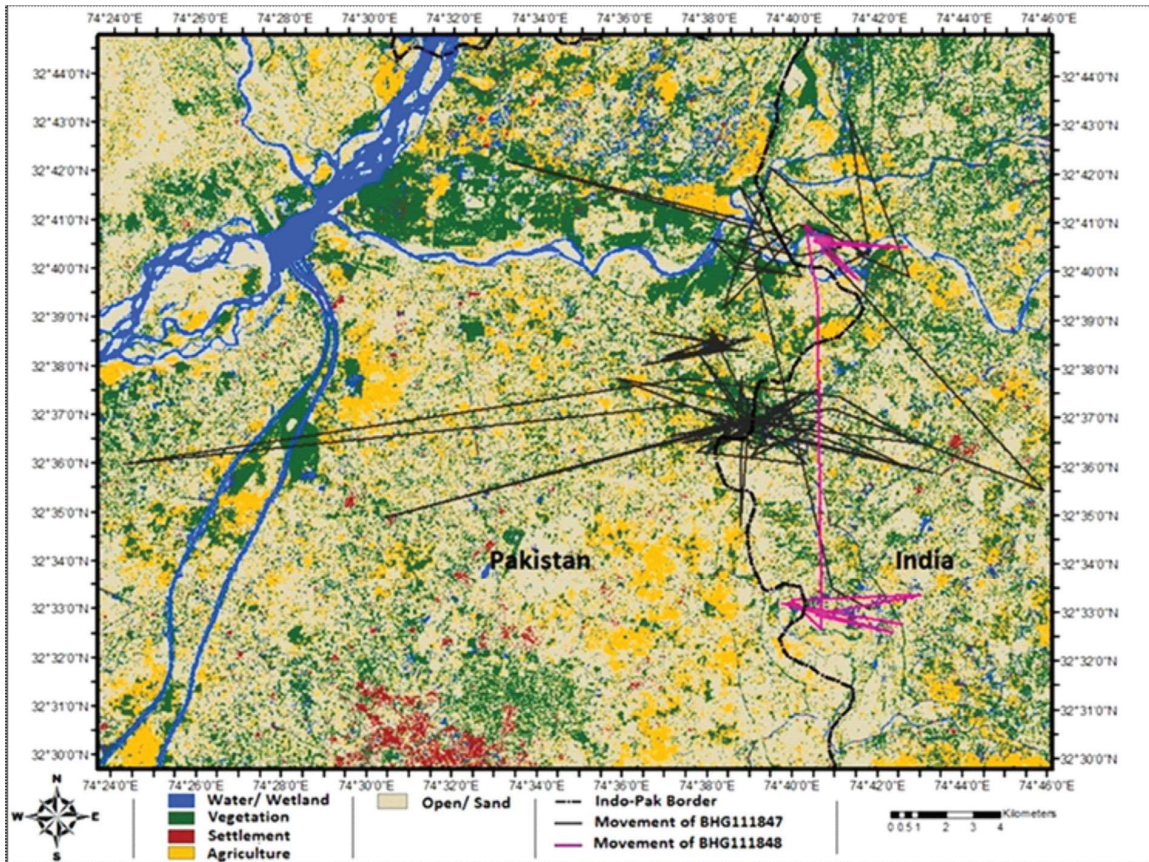


Fig. 5: Movement pattern of two PTT-fitted Bar-headed Geese captured in Gharana Conservation Reserve

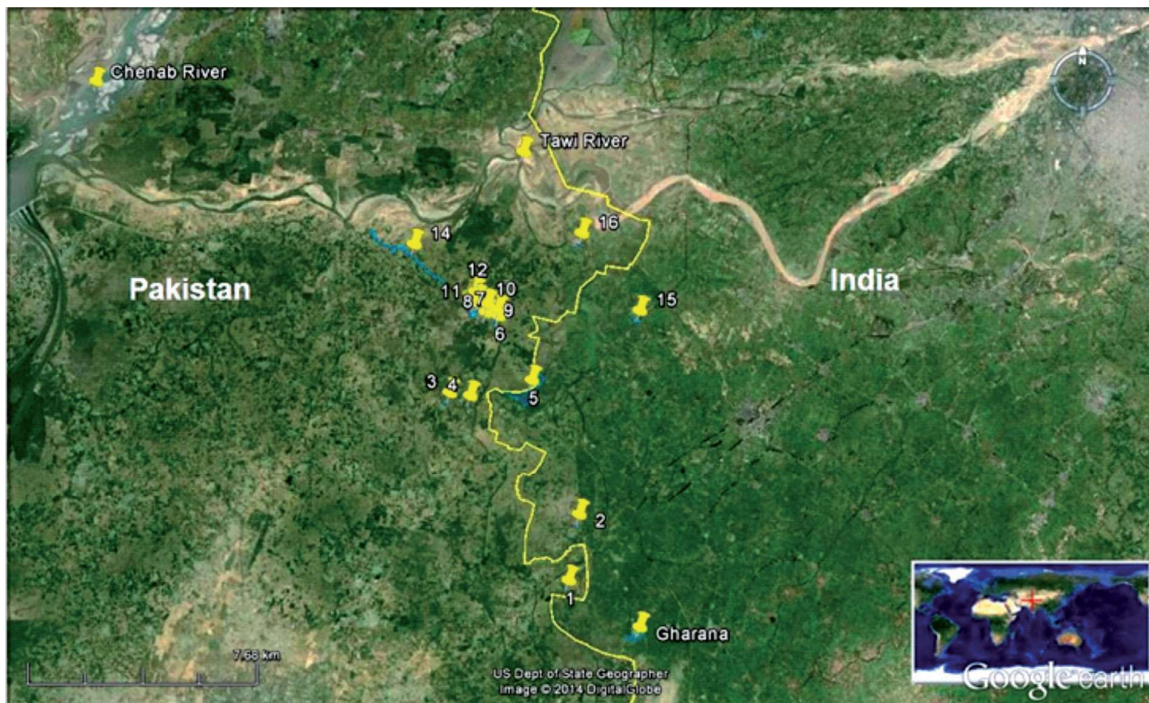


Fig. 7: Important wetlands outside Gharana Conservation Reserve, India

Source: Google Earth accessed 12 September 2014

TRACKING THE MOVEMENT PATTERN OF BAR-HEADED GOOSE CAPTURED FROM GHARANA CONSERVATION RESERVE

Table 3: Migration and movement pattern of satellite-tracked Bar-headed Geese

Reference	Type of Transmitter	Total distance covered (km)	Individuals tagged	Countries recorded	Type of migration	Stopover sites	Total days of movement	Total Fixes
Javed <i>et al.</i> 2000	PTT	~780	2	India, China	Spring	3	137	192
Takekawa <i>et al.</i> 2009	PTT	500–3,000	60	China, India, Mongolia, Nepal	Winter, Fall, Spring, Breeding, Moulting	NA	1-213	93,009
Koppen <i>et al.</i> 2010	PTT	790–1,550	4	Uzbekistán, Kyrgyzstan, Tajikistán, India, Pakistán	Autumn and Spring	4	1–53	5000
Guo-Gang <i>et al.</i> 2011	PTT	1,270–1,470	10	China	Autumn	4	50–90	NA
Cui <i>et al.</i> 2011	PTT	17.89–404.41	21	China	Moulting, Autumn and Breeding	NA	185–298	16,342
Prosser <i>et al.</i> 2011	PTT	260–2,330	15	China, India	Breeding and Spring	7	1–154	NA
Kalra <i>et al.</i> 2011	PTT	807–1,305	4	China, India	Winter	2	193–263	4663
Zhang <i>et al.</i> 2011	PTT	1,300–1,500	11	China	Autumn	5	73–83	NA
Hawkes <i>et al.</i> 2013	PTT	3,000	91	India, China	Autumn and Spring	NA	135–1,216	NA
This Study	PTT	54–431	2	India, Pakistan	Winter	NA	115–160	647

*NA= Not Available

grasslands in India and Pakistan, indicating that this landscape as a whole is important for migratory birds.

In the last few decades, hunting and anthropogenic pressures have adversely affected the population of the Bar-headed Goose in Kyrgyzstan (Koppen *et al.* 2010). Even if these birds do not migrate to other countries, there still exists a potential threat of avian influenza via interaction with migratory populations of other species. Hotspots of interaction must be located and prioritized for national and trans-boundary conservation efforts, since there might be possibilities of uncertain conservation status in other countries. For instance, in India, population loss of Siberian Crane was attributed to population decline during migration (Meine and Archibald 1996). Thus, the conservation of migratory Bar-headed Goose populations would be uncertain without trans-boundary collaborations. Additionally, studies with a landscape approach are needed for the identification and conservation of multiple stopover sites, since waterbirds migrate long distances within different geographic regions and countries seasonally.

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Recent records of the Pallas's cat in Changthang Wildlife Sanctuary, Ladakh, India

Despite a wide distribution in Asia, Pallas's cat or manul *Otocolobus manul* is a rarely recorded small carnivore in India. Here, we report three observations of this majestic furry carnivore in Changthang Wildlife Sanctuary CWLS. In India, there is little information available on the ecology and status of this threatened species.

The Pallas's cat or manul, a small furry felid, is found throughout northern and central Asia with a broad but fragmented distribution (Ognev 1935, Allen 1938, Heptner & Sludskii 1972, Nowell & Jackson 1996, Aghili et al. 2008). Its largest population is thought to live in Mongolia (Jutzeler et al. 2003, Murdoch et al. 2006). However, little information exists on populations elsewhere and it is considered rare particularly in the southern portion of its range (Nowell & Jackson 1996, Jutzeler et al. 2003, Aghili et al. 2008). In South Asia, the Pallas's cat is reported from Afghanistan, Pakistan, India, Nepal and Bhutan, which forms the southern limits of its distribution (Belousova 1993, Nowell & Jackson 1996, Habibi 2003, Chanchani 2008, Thinley 2013, Hameed et al. 2014, Shrestha et al. 2014). In India, it is restricted to the Trans-Himalayan region of Ladakh and Sikkim, where its occurrence could be nominal (Prater 1972, Pfister 2004, Chanchani 2008, Menon 2014). The Pallas's cat prefers empty burrows of marmots and foxes as a den and proximity to pika *Ochotona* spp. habitats (Pfister 2004, Menon 2014). The Pallas's cat is listed as a Near Threatened species on the IUCN Red List (Ross et al. 2016) and is included into Appendix II of CITES, due to its population decline and habitat degradation. It is also legally protected as a Schedule I species under the Indian Wildlife Protection Act, 1972.

The CWLS spreads over ca. 4,000 km² and lies between 34°79' to 33°79' E and 78° to 79° N in eastern Ladakh (Fig. 1). Temperature falls to -40 °C during winters in this landscape of broad open valleys and the rugged terrain in CWLS (Hartmann 1983). In spite of the existence of 13 major lakes and flood plains of the Indus River and its tributaries, the area is relatively dry, barren and characterised as a cold desert (Kichloo 1997). The Tibetan ass or kiang *Equus kiang*,

wolf *Canis lupus*, red fox *Vulpes vulpes*, snow leopard *Panthera uncia* and black-necked crane *Grus nigricollis* are among the key faunal species of the sanctuary. The Pallas's cat is locally known as "Ribilik" or "Trak Sham" in Ladakh. Considering its rare appearance in Ladakh, recent and updated reports of its presence hold utmost importance for conservation and management. We sighted a pair of Pallas's cat on the bank of Hanle River (tributary of Indus) near Lal Pahari area (32°57'36.86" N / 78°54'06.30" E) at an elevation of 4,202 m on 31 August 2013 at 9:45 h. The pair was seen at about 300 m distance and disappeared into the rocks when approached. The second sighting was made on 14 May 2015 at 7:07 h when a single individual was sighted at a distance of about 100 m near Staklung (33°09'24.08" N / 78°42'01.72" E) at an elevation of 4,160 m. In the third incidence, we sighted a group of four cats on 4 September 2015 at 09:00 h about 500 m away from Hanle (32°47'22.39" N / 78°59'15.83" E; Fig. 2). All observations took place in the morning hours and close to the water bodies, ideal places to find prey, such as the pikas and marmot *Marmota himalayensis*. Our sighting locations were separated by about 45 km aerial distance, implying that this area could be valuable for the species. The previous record of the Pallas's cat in Ladakh by Mallon (1991) was also from Hanle area, eastern Changthang region.

The area is seasonally inhabited by a local pastoralist community called the Changpas, who carry along large herds of livestock. Major threat to the Pallas's cat is habitat loss and degradation due to development activities, which continue to grow. Precise information on such species is earnestly desirable to minimise the threats. Our report updates and adds information on the presence of the Pallas's cat in Ladakh, India, its southern range limit.

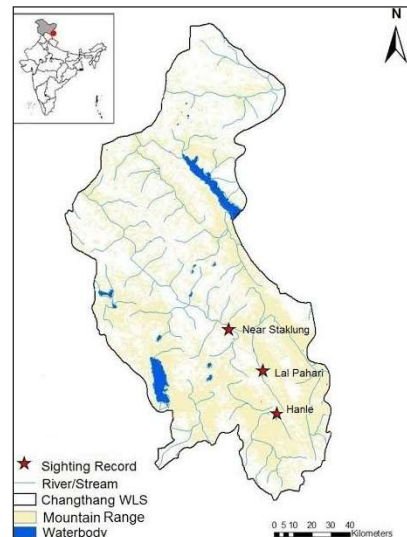


Fig. 1. Sighting locations in Changthang Wildlife Sanctuary.

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Fig. 2. Pallas's cat records in Changthang Wildlife Sanctuary (Photo 1 & 2 N. Mahar; Photo 3 S. Singh).

Special Publication

Wetlands in the Himalaya: Securing Services for Livelihoods

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FOR MOUNTAINS AND PEOPLE



Special Publication

Wetlands in the Himalaya: Securing Services for Livelihoods

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Wetlands of the Indian Himalayas: Status and Conservation Initiatives

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Abstract

Globally, wetlands are vital elements of the ecosystems and economies and occur extensively in all climatic zones. Himalayan wetlands harbour rich biodiversity and numerous ecosystem services. High-altitude wetlands in the Himalayas include lakes, swamps and seasonal marshes. They are the source of major rivers like the Indus, Brahmaputra and tributaries of the Ganga. India has a great diversity of wetlands owing to its location at the junction of three biogeographic realms. The Indian Himalayas harbour some of the most spectacular and biologically rich wetlands in the world. Some of these wetlands are extensively explored, but most of them are still unknown. At present, these wetlands are under immense pressure due to increasing anthropogenic pressure and underlying natural causes. An assessment on location, characteristics, functions, values, threats and status of wetlands is necessary to develop fundamental knowledge and sustainable wetland conservation programme. Current review discusses the conservation status of wetlands in the Indian Himalayas, particularly the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh, with the objective to consolidate the status of the Indian Himalayan wetlands for conservation prioritization.

Keywords: Himalayas, wetlands, conservation, threats, biodiversity

Introduction

The Indian Himalayas harbour some of the most spectacular and biodiversity rich wetlands in the world. While some of these wetlands have been extensively explored, most of them remain little known. Wetlands in the Himalayas are the product of climate, precipitation, geology, geomorphology, drainage and soil condition of the region (Wadia 1960). All the drainage in the region passes through newly emerged deep gorges that have very little area of inundation and, consequently, have little riverine marshes, except in large valleys and plateaus. Apart from lakes, the Himalayan wetland system comprises networks of rivers with associated floodplain marshes and swamps, glaciers and hot springs, seasonal waterlogged areas and manmade reservoirs (Upadhyaya et al. 2009). High precipitation in the eastern Himalayas has produced more extensive seasonal waterlogged areas, marshes and swamps than in the western Himalayas.

Distribution of Wetlands in the Indian Himalayas

Through a literature review and examination of toposheets from the Department of Survey of India, we compiled approximately 8,536 wetlands in the Indian Himalayan region, covering 55 administrative districts (NWA 2011). Of these, 3,265 wetlands are in the eastern Himalayan states of Arunachal Pradesh and Sikkim, and 5,271 wetlands are in the western Himalayan states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir. Jammu and Kashmir has the maximum number of wetlands followed by Arunachal Pradesh, and Sikkim has the minimum (NWA 2011) (Table 4.1). The total area of wetlands covering the five states of India, including small (<2.25 ha) and large (>2.25 ha) wetlands was 756,501 ha (Table 4.2). Of these, the wetlands of Jammu and Kashmir covered the maximum area (391,501 ha) followed by Arunachal Pradesh (155,208 ha), and Sikkim (7,477 ha) has the minimum area (NWA 2011) (Table 4.2).

Wetland ecosystems such as rivers, lakes, marshes and coastal estuaries provide many benefits for human well-being. People living in proximity to wetlands depend partially or entirely on wetland ecosystem services. These include water supply, water purification, flood regulation, coastal protection and cultural and recreational services (Table 4.3).

Arunachal Pradesh

There are 1,593 wetlands in Arunachal Pradesh with area >2.25 ha, covering a total area of around 154,609 ha (Tables 4.1 and 4.2). There are around 1,119 wetlands with area <2.25 ha. Due to lack of data, it is difficult to estimate the exact number of wetlands in the

Table 4.1: **Number of wetlands in the Indian Himalayas based on remote sensing data**

Types	Jammu & Kashmir	Himachal Pradesh	Uttarakhand	Sikkim	Arunachal Pradesh	Total	Percentage
NATURAL WETLANDS							
Lakes/ponds	36	8	12	1	3	60	0.7
Marshes	1,143	42	29	259	1,231	2,704	31.68
Waterlogged	0	10	1	0	107	118	1.38
Riverine	88	0	0	0	88	176	2.06
River/stream	138	67	81	12	128	426	4.99
MAN MADE WETLANDS							
Reservoir	4	13	10	0	4	31	0.36
Tanks/ponds	2	27	21	0	32	82	0.96
Waterlogged	0	3	9	0		12	0.14
Sub Total	1,411	170	163	272	1,593	3,609	42.28
WETLANDS (<2.25 ha)	2,240	471	816	281	1,119	4,927	57.72
Total	3,651	641	979	553	2,712	8,536	100

Source: NWA 2011

Table 4.2: **Extent of wetlands (ha) in the Indian Himalayas based on remote sensing data**

Types	Jammu & Kashmir	Himachal Pradesh	Uttarakhand	Sikkim	Arunachal Pradesh	Total	%
Lakes/ponds	13,762	52	2,081	15	18	15,928	2.11
Marshes	109,170	387	142	3,050	11,422	124,171	16.43
Waterlogged	0	47	9	0	8,146	8,202	1.09
Seasonally flooded	9,594	0	0	0	0	9,594	1.27
River/stream	231,597	55,558	80,133	4,131	134,244	505,663	66.91
Reservoirs	25,132	41,817	20,319	0	164	87,432	11.57
Tanks/ponds	6	134	108	0	95	343	0.05
Waterlogged	0	30	211	0		241	0.03
Sub Total	389,261	98,025	103,003	7,196	154,089	751,574	99.46
Wetlands (<2.25 ha)	2,240	471	816	281	1119	4927	0.65
Total (ha)	391,501	98,496	103,819	7,477	155,208	756,501	100

Source: NWA 2011

Table 4.3: **Ecosystem service value of the wetlands of Indian Himalayas**

Trans Himalayas – Tibetan Plateau, North Sikkim, Northwestern Arunachal Pradesh	<ul style="list-style-type: none"> • Source of water • Major pasture for domestic & wild ungulates • Cultural & aesthetic value
Northwestern Himalayas – Jammu and Kashmir	<ul style="list-style-type: none"> • Source of water • Recharge groundwater • Cultural & aesthetic value
Western Himalayas – Jammu and Kashmir, Himachal Pradesh, Uttarakhand	<ul style="list-style-type: none"> • Source of water • Recharge groundwater • Flood control and maintain regional stream • Cultural & aesthetic value
Central Himalayas – Sikkim	<ul style="list-style-type: none"> • Source of water • Recharge groundwater • Maintain regional stream • Cultural & aesthetic value
Eastern Himalayas – Arunachal Pradesh	<ul style="list-style-type: none"> • Source of water • Recharge groundwater • Maintain regional stream flow • Cultural & aesthetic value

state. However, by excluding the wetlands in the Tirap district, which is mostly plains, the estimated wetlands of the state includes the wetlands in Lohit, East, West and Upper Siang, and Changlang districts. Of the total wetlands >2.25 ha, majority (1,231) are marshes, followed by river/stream (128), waterlogged (107) and riverine (88) (Table 4.1).

Arunachal Pradesh is a biodiversity rich state owing to its unique climatic conditions and its location at the junction of the Afro-tropic, Indo-Chinese and Indo-Malayan realms. As far as aquatic species are concerned, fish fauna is zoo-geographically rich and connects the Indo-China, Indo-Malayan and Indian sub-region. Around 200 species of amphibians have

been reported from the state. Small flocks of endangered black-necked crane (*Grus nigricollis*) have also been reported during winter from Sangti Valley in West Kameng district, Zimithang Valley in Tawang district (Singh 2000), Apatani Valley in Lower Subansiri district (Betts 1954) and Gandhigram Valley in Changlang district (Neog and Bhatt 1990). The state is also home to all the three Indian species of otter viz., Eurasian otter (*Lutra lutra*), smooth-coated otter (*L. perspicillata*) and oriental small-clawed otter (*Aonyx cinerea*). The Brahmaputra River and its tributaries harbour endangered gharial (*Gavialis gangeticus*) and river dolphin (*Platanista gangetica*) (Chaudhury and Hussain 1992).

Sikkim

There are approximately 272 wetlands >2.25 ha in Sikkim, with an area of around 7,196 ha (Table 4.2). There are approximately 281 wetlands <2.25 ha in area (Table 4.1). Of the total 553 wetlands identified at present, majority are marshes (259), followed by river/stream (12) and lakes and ponds (1) (Table 4.1). North Sikkim has the highest number of wetlands followed by East Sikkim and West Sikkim.

In Sikkim, most of the wetlands are situated at higher altitudes and rugged terrain and are hence unexplored. Of the identified wetlands, 147 wetlands have rich wildlife, 54 have religious value, 16 have domestic use value and 7 have recreational value. Of the 123 wetlands in North Sikkim district, 41 have religious value and 96 have wildlife value (Roy and Thapa 1998). The Lhonak valley in North Sikkim is perhaps one of the richest Trans-Himalayan biodiversity areas in Sikkim (Lachungpa 1998). There is a good breeding population of the ruddy shelduck (*Tadorana ferruginea*) and the common redshank (*Tringa tetanus*). The number and frequency of arrival of the small population of less than 10 black-necked cranes that regularly visited Lhonak Valley dropped down to less than 5 due to defense-related activities in 1980 (Lachungpa 1998). The lower altitude wetlands are home to all the 3 species of otters, viz. Eurasian (also occurs at higher altitudes), smooth-coated and oriental small-clawed otter.

The Trans-Himalayan part of Sikkim is home to herbivore species like Tibetan gazelle (*Procapra picticaudata*), southern kiang (*Equus kiang polydon*), blue sheep (*Pseudois nayar*), nayan (*Ovis ammon hodgsoni*), Royle's pika (*Ochotona roylei*) and woolly hare (*Lepus oiostolus*). It also harbours carnivores like red fox (*Vulpes vulpes montana*), wolf (*Canis lupus chanco*) and snow leopard (*Uncia uncia*) (Shah 1994). The streams and marshes harbour the endemic Himalayan Salamander (*Tylototriton verrucosus*), found in the eastern Himalayas at an altitude of 1,500–2,500 m (Roy 1999). Apart from having conservation significance, most of the lakes are culturally significant as well.

Himachal Pradesh

Of the 641 wetlands in the state, 170 are >2.25 ha with an area of 98,025 ha and 471 are <2.25 ha (Table 4.1 and Table 4.2). Kullu district has the highest number of wetlands (28) and most of these lakes freeze during winter. Chamba and Kangra districts have large areas

under wetlands because of Pong and Govind Sagar reservoirs. Of the 170 wetlands >2.25 ha, most exist in the form of river/stream (67) followed by marshes (42) and manmade tanks and ponds (27) (Table 4.1).

The Pong reservoir (a Ramsar site) and Govind Sagar have been identified as major waterbird refuges. Pong Dam harbours a major wintering population of the bar-headed goose (*Anser indicus*) in India (Li et al. 2009). Situated at the southern edge of the Tibetan plateau, wetlands in Lahul and Spiti have Tibetan elements. Little is known about the conservation value of the wetlands in this district except Chandra Tal. Most of the wetlands in Himachal Pradesh are small in size with little conservation value with respect to waterbirds but have high aesthetic value.

Jammu and Kashmir

At present 3,651 wetlands have been identified in the state, of which 1,411 are >2.25 ha with an area of 389,261 ha and 2,240 are <2.25 ha (Tables 4.1 and Table 4.2). Majority of the natural wetlands are marshes (1,143) followed by river/stream (138) (Table 4.1). Previously the Directorate of Environment and Remote Sensing, Government of Jammu and Kashmir, identified 1,248 wetlands as small as 0.25 ha in the state with an area of 21,880 ha (Ahmedullah 1997).

The wetlands of the state are important staging grounds for migratory waterbirds; at least 24 species of Anatids are prominent. Around 85 species of waterbirds have been recorded from the state (Ahmedullah 1997). The Trans-Himalayan wetlands are an oasis of productivity in an otherwise arid steppe environment and have significant conservation value, particularly as breeding grounds for the bar-headed goose and the globally threatened black-necked crane. Other key waterbird species breeding in the area include ruddy shelduck, common redshank, brown-headed gull (*Larus brunnicephalus*), lesser sand plover (*Charadrius mongolus*) and great crested grebe (*Podiceps cristatus*) (Anon 1997). At least 34 species of birds are using the wetlands of Ladakh (Humbert-Droz 2000, Hussain and Singh 2001, Hussain and Pandav 2008). The key mammals of the area are snow leopard, Tibetan wolf, bharal and kiang (Chundawat and Qureshi 1999).

The wetlands in Jammu and Kashmir provide livelihood and play a significant role in the socioeconomic status of local communities. Catchment areas of many lakes are extensively used for paddy cultivation and fishery. Trout angling in the riverine wetlands is a major tourist attraction. Large wetlands like Dal and Wular are part of the local culture and the unusual and serene landscape of the Changthang region is a popular tourist destination. The lake basins are grazing grounds for both domestic livestock and wild ungulates such as kiang (Hussain and Singh 2001).

Realizing the great ecological and aesthetic value of the wetlands, the Department of Wildlife Protection, Jammu and Kashmir, has identified 15 wetlands across the three regions of the

state to be protected as Wetland Reserves in accordance with the Jammu & Kashmir Wildlife (Protection) Act, 1978. The Government of India has notified Wular, Hokersar and Tso Moriri as wetlands of national importance.

Uttarakhand

The state of Uttarakhand, created in November 2000 from the northern Himalayan region of the erstwhile Uttar Pradesh state, is bordered by Uttar Pradesh in the south, Himachal Pradesh in the west, Tibet Autonomous Region of China in the north, and Nepal in the east. A total of 979 wetlands have been identified (NWA 2011), of which 163 are >2.25 ha and 816 are <2.25 ha. Majority of natural wetlands are river/stream (81) followed by marshes (29) (Table 4.1). The total area of wetlands >2.25 ha is 1,03,003 ha and that of <2.25 ha is 816 ha (Table 4.2). Of the 13 districts, Chamoli district has the maximum number of lakes; most of them are glacial in origin and remain frozen from November to March. Nainital district has nine lakes and most of these lakes are situated in the Lesser Himalayan zones at altitudes below 2,000 m (Garg et al. 1998).

The wetlands, owing to their smaller size, have little significance for waterbirds. However, there are reports of sporadic use by waterbirds such as gadwall (*Anas strepera*) and northern pintail (*Anas acuta*) from Deoria Tal (low altitude lake) (Sathyakumar 1994). Three species of Indian otter have been reported from the lower altitudes of the Garhwal Himalayas, which are rapidly becoming rare in the state (Hussain 1998). The lakes of the Kumaun Himalayas form one of the most remarkable and beautiful features of the Lower Himalayas (Atkinson 1882) and are major tourist destinations.

According to *Skanda Purana*, all 66 lakes in the Garhwal Himalayas are spiritually and culturally significant. Some of these lakes have significant hydrologic value i.e., maintenance of regional stream flow. The wetlands and the streams have significant domestic as well as medicinal value as local people believe that water from some of these lakes can cure several diseases.

Biodiversity and Its Changes of the Wetlands in Ladakh

Ladakh represents the Trans-Himalayan region of the Indian Himalayas. The Changthang region is the extension of the Tibetan Plateau towards the southwest into Ladakh. The area is characterized by a barren and rugged landscape interspersed with several lakes and marshes in the upper Indus River valley. The area receives <100 mm of annual rainfall with little snow, and is therefore recognized as a cold desert. Most of the lakes and streams of Ladakh are of glacial origin and remain frozen during winter (November-April). Around 13 major lakes and several marshes are found along the Indus River and its tributaries.

In Ladakh, tourist access is restricted to summer months, which is also the peak period of breeding season and other biological activities for several avifaunal species. The wetlands of Ladakh are fragile and various anthropogenic activities resulting from unprecedented human

population growth, faulty rangeland management, livestock grazing and increased tourism threaten the wetlands and breeding waterbirds (Geneletti and Dawa 2009).

Water quality

Hussain et al. (2008) examined the physio-chemical properties of water and found significant variation in seven lakes of Ladakh. Among inorganic non-metal constituents, except dissolved oxygen (DO), ammonia as a form of nitrogen ($\text{NH}_4\text{-N}$) and sulfite ($\text{SO}_3\text{-S}$) differed significantly ($p < 0.05$). Both the quantified metallic constituents (calcium and magnesium) were found to differ significantly among the lakes. Based on the Total Dissolved Solids (TDS) concentration (Tilzer and Serruya 1990) the system of lakes in the Changthang region can be grouped into three types – first, the fresh water lakes with $\text{TDS} < 2,000 \text{ mgL}^{-1}$, such as Statsapuk Tso, Kyon Tso-I and II, and Tso Moriri; second, the brackish water lakes with $\text{TDS} > 2,000\text{-}20,000 \text{ mgL}^{-1}$, such as Thatsangkaru, and Pangong Tso; and third, the saline lakes with $\text{TDS} > 20,000\text{-}40,000 \text{ mgL}^{-1}$, such as Tso Kar.

Biodiversity value of the lakes and their catchments

Hussain et al. (2008) recorded 16 species of water birds from the Changthang region, of which 7 species were breeding at Statsapuk Tso, 6 species at Tso Moriri and Tso Kar, 5 species at Pangong Tso, 4 species at Kyon Tso II, and 2 species at Thatsangkaru (Figure 4.1). The great-crested grebe and black-necked crane were recorded from Statsapuk Tso and Tso Moriri, and common merganser (*Mergus merganser*) was found at Pangong Tso and the Indus River. Another study by Hussain and Pandav (2008) recorded 44 species of waterbirds, of which 19 species were breeding in various wetlands of Ladakh.

The encounter rate of six common breeding waterbirds was calculated for various wetlands of Changthang (Hussain et al. 2008). Bar-headed geese were found to be nesting at all the lakes except Kyon Tso I. The mean encounter rate of bar-headed goose varied from 3.5 to 17 per km. It was lowest for Thatsangkaru and highest for Kyon Tso II. Previously, Tso Moriri and Tso Kar had been identified as important breeding grounds for both the bar-headed goose and the ruddy shelduck, perhaps because of their large size and gentle shelving shorelines. During the survey, presence of six species of carnivores, seven species of ungulates and three species of other mammals was recorded based on direct and indirect evidence. The most common species were snow leopard, Tibetan wolf, bharal, Tibetan argali (*Ovis ammon hodgsonii*) and kiang. The other animals of conservation significance were Tibetan antelope (*Pantholopos hodgsoni*) and wild yak (*Bos grunniens*), which were reported from the Changchenmo valley (Chundawat and Qureshi 1999).

Movement pattern of flagship waterbird species

Modern satellite tracking techniques can be used to study precise migration paths and stopover sites. Bar-headed goose is a long-distance migrant to the Indian subcontinent with major breeding population in China and small breeding population in Ladakh (India).

Figure 4.1: Different breeding waterbird species in high-altitude wetlands



a) Black-necked crane, b) Bar-headed goose, c) Common tern, d) Ruddy shelduck

However, India harbours major wintering population in the states of Jammu and Kashmir, Uttar Pradesh, Assam and Rajasthan (Ali and Ripley 1987). But there is a lack of information on the migration pattern of bar-headed goose in India unlike in other central Asian countries (Mahar et al. 2014). To have a better understanding of their movement pattern and home range, Mahar et al. (in press) monitored two Platform Transmitter Terminal (PTT) tagged bar-headed geese in March-August 2012 from the Gharana Conservation Reserve, India. The origin of the tagged birds, whether from Ladakh or extralimital, could not be ascertained as both the PTTs functioned only for 5–6 months. The geese, also, did not move to their possible breeding sites in Ladakh (India) and other central Asian countries during the tacking period. The PTT fitted geese used the Tawi River floodplains of India and Pakistan in Jammu and Sialkot districts respectively. Post winter, the two geese used several small wetlands in the Tawi River floodplains, moving between India and Pakistan intermittently, indicating the need for transboundary efforts for long-term conservation of the species in this region (Mahar et al. in press).

During a further study carried out to generate information on the migration pattern of waterbirds in Ladakh, four geese were captured at Chushul area of the Changthang Wildlife Sanctuary using nooses in 2013 (WII 2014). Two of them were fitted with PTT and conventional neck bands and rings and two were collared with only conventional neck bands and tagged with tarsus rings. Two black-necked cranes were also fitted with PTT and tarsus bands. The cranes moved towards the Chinese territory and showed lateral migration, while PTT fitted bar-headed geese moved towards the Himachal Pradesh border till early winter (December) and the two geese fitted with only neckband and rings were reported from Gharana Wetland, Jammu. This study was able to track the migration of bar-headed geese from breeding site (Ladakh) to wintering site (Gharana wetland) via Himachal Pradesh (probably Pong Dam) (WII 2014). However, results are preliminary and more telemetry based studies are needed to track migration route.

Human use and resultant disturbance

The Changthang region has around 41 villages with a population of 9,500 people. They have approximately 140,000 domestic livestock, 90% of which are sheep and goat and the remaining 10% are domestic yak, ponies and dzo (hybrid between yak and cattle). People and livestock depend on the lakes and marshlands of the region for grazing pastures and associated livelihood options (Hussain et al. 2008). The study also found that the overall disturbance score was highest for Tso Moriri followed by Tso Kar, Statsapuk Tso and Pangong Tso. Both Kyon Tso I and II were least disturbed. The human use parameters that pose threats to the lakes and their catchments are: presence of villages in their vicinity, army camps, grazing by livestock and unregulated tourism. The resultant impacts are: extraction of biomass from the catchments, diversion of stream waters for agricultural purposes, problems of solid waste disposal and increasing pollutant load in the lakes (Figure 4.2).

Discussion

The great geomorphological, climatic and altitudinal variations in the Himalayas has ensured rich diversity of wetlands such as large and small lakes, seasonally flooded marshes, hot springs and some of the most important river systems in the Indian subcontinent. Most of these wetlands have significant conservation values attached to them. Climate change studies have shown the vulnerability of wetlands to their stochastic changes in recent times. The change in temperature can affect aquatic ecosystems of high-altitude lakes (Sammaruga-Woghrath et al. 1997). There is evidence of shift in range and distribution of waterbirds owing to change in temperature (Lehikonin et al. 2013). Many changes such as changes in the breeding cycle, migration timing and population size are visible in the current scenario (Crick 2004).

In recent years, efforts, though minimal, are being made to prepare inventories of these wetlands for conservation prioritization. Of the 8,536 wetlands in the entire Himalayan region, only 6 wetlands, 3 each in Jammu and Kashmir (Wular, Tso Moriri, Tsigul Tso) and Himachal Pradesh (Renuka, Chandra Tal and Pong Dam), have been formally identified as wetlands of national importance and conservation inputs have been extended. Conservation

Figure 4.2: Different anthropogenic activities in the wetlands of the Himalayas



a) Livestock grazing, b) Free ranging dog in Changthang, c) Resource extraction, d) Tourist camps near Tso Moriri Wetland

efforts for the Himalayan wetlands have largely been concentrated in the two western Himalayan states of Jammu and Kashmir and Himachal Pradesh. The eastern Himalayas, which contains around 38.2% (3,265) of the total Himalayan wetlands, are grossly neglected though they have equal conservation value as the wetlands of the western Himalayas. These wetlands are important wildlife habitats and have significant socio-cultural values. Around 83.1% of the wetlands in Arunachal Pradesh and 16.9% in Sikkim warrant immediate conservation measures. Conservation programmes for the wetlands in the Himalayas should take into consideration transboundary issues that affect conservation in the border region of India, Nepal, China and Bhutan. Regional cooperation is essential for effective management of artificially divided ecological units. The Ramsar Strategic Plan actively supports the identification of transboundary wetlands of international importance including those with shared catchment/river basins.

A study by Hussain et al. (2008), which obtained limnological estimates different from those obtained by Hutchinson (1937), confirmed that the character of the lakes has changed. These changes may be attributed to human water use in the basins. At the onset of summer, large

numbers of *Rebos* (tents) are pitched along the streams and people use stream water for domestic purposes. These *Rebos* contribute to the large amount of nitrogenous compounds in the lakes, resulting in unusually high concentrations of Ammonium-N and Nitrate-N, particularly in Tso Moriri.

Conservation and development issues in Changthang are primarily due to high population growth in Ladakh; the population increased by approximately 30% between 1971 and 2001 (Hussain and Badola 2003). It has led to resource crunch leading to conflict between the indigenous communities and the refugees, and between domestic livestock and wildlife, especially near wetlands. Large herds of goats and sheep disturb nesting birds and trample their eggs while shepherd dogs predate eggs, chicks and fledglings (Chandan et al. 2005). Furthermore, tourist influx to Ladakh, which was predicted to reach 94,762 per annum by the year 2016 (Kichloo 1997), already crossed this limit in the year 2011 (William-Oerberg 2014). The increasing pressure on camping grounds will lead to further degradation of catchments and the pastures.

Recognizing the conservation significance of the area, the entire Indian Changthang was declared a protected area (Chundawat and Qureshi 1999). However, due to lack of alternatives, local people are forced to depend on the scarce natural resources and the designated protected area status has been ineffective. From our synthesis we conclude that instead of developing conservation measures for individual lakes, an integrated landscape approach is required to conserve the complex system of lakes and marshes in Changthang. Declaring the area as a Biosphere Reserve would be a welcome step. Studies to assess the carrying capacity of the proposed Biosphere Reserve in terms of livestock density, biomass productivity, negative human-wildlife interaction and number of tourists, needs to be conducted and incorporated in the decisions pertaining to its management. Local level institutions need to be established to resolve the conflict over resource use between the communities in the region. Studies on the movement pattern of waterbirds would be helpful for transboundary collaboration as species like bar-headed goose and black-necked crane migrate between India and China, and other countries as well (WII 2014; Mahar et al. in press). Eventually, developmental activities ensconced within conservation ethos is the only way to secure the long-term conservation of this fragile ecosystem.

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Research Coordinator