Data and Conservation of Himalayan Galliformes

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Garima Gupta

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Abstract

The Greater Himalaya is home to many sacred landscapes and source of the eight largest rivers of Asia and has three of the world's 35 global biodiversity hotspots. The region has been identified as having a high number of threatened species which makes the Himalaya an area of high conservation concern. One key taxonomic group that is found throughout the Greater Himalaya and is thought to be of a particular concern is the bird Order Galliformes (gamebirds) which includes species of pheasant, partridges and quail. There are 24 species of Galliformes that are either endemic or near-endemic to the Greater Himalaya and are well recognized for their ecological, socio-cultural and economic values. Despite their ecological and conservation prominence, the group remains poorly known, making conservation decision making difficult. Therefore, I explore the availability and use of data in understanding and planning for the conservation of Himalayan Galliformes.

I describe the database from which point locality data has been used in the research. I examine the detailed information held in the database and compare it with published syntheses of both altitude and geographic ranges used for conservation purposes. I show that altitude information from localities in the database allows much more focussed depiction of altitudinal ranges of species.

I then determine the threats faced by the Himalayan Galliformes by undertaking a systematic literature review to identify the threats reported in the literature and the evidence supporting them. I show that hunting and habitat loss are the threats for the Galliformes but there is not enough evidence to prove that. I then show how the ecological life traits can be used to assess if there are any correlates between threat types and species life- history. I found that most of the Least Concern species inhabits open habitats at higher altitudes.

Geographic ranges are a fundamental part of ecology and species conservation. Knowing where a species occurs is important as it allows conservationists to make an accurate assessment of threats for individual species. I show that our knowledge on Himalayan Galliformes species is good and that it has improved more rapidly than expected by chance by examining the pattern of accumulation of information on a species' range over time and comparing this with a suitable simulated model. Finally, I show the dependency of the Himalayan Galliformes species on conservation actions by testing the IUCN Green List protocol to quantify the species recovery because of the conservation actions and legislation. I report all the challenges in assessing the Green List status of the species.

I conclude by discussing the generality of my findings and how they can be applied to other taxa and localities and finally making a series of recommendation for future conservation and research work in the Greater Himalaya.

Dedication

I dedicate this thesis to my grandfather, Shri Jagdish Prashad Gupta. RIP.

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Chapter 1. General Introduction

1.1. Global biodiversity in threat: a human induced crisis

The term biodiversity, which is the contraction of "biological" and "diversity", refers to the variety of life found in different ecosystems. The Convention on Biological Diversity defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (CBD, 2010b) . Currently, global biodiversity is in a state of crisis and it is diminishing rapidly around the world (Cafaro, 2015). Anthropogenic activities have caused individual populations of many species to decline and many more have lost parts of their habitats in the past (Butchart *et al.*, 2010). Scientists believe that human actions have triggered a wave of mass extinction (Dirzo *et al.*, 2014) by putting many species at risk at ever increasing rates (Tilman *et al.*, 2017).

1.2. Mass extinction: past, present, and future

Mass extinction is described as an event when there is a loss of 75% of the earth's biodiversity over a geological short span of time (Ceballos and Ehrlich, 2018). Extinction of species is a natural evolutionary process (Brand, 2015; Thomas, 2017): 99% of the four billion species that have been estimated to have lived on this planet over the last 3.5 billion years have gone extinct (Novacek, 2001). Earth, as a result of evolution and catastrophic natural phenomenon, has witnessed five mass extinctions in the past (Ripple *et al.*, 2017) (see Table 1.1). The most recent and infamous of the five mass extinction events marked the extinction of dinosaurs at the end of the Cretaceous period that happened approximately 65 million years ago (Alvarez *et al.*, 1980; MacLeod *et al.*, 1997; Archibald *et al.*, 2010; Brusatte *et al.*, 2015). Although, the loss of life in the past is attributed to physical and natural phenomena, such as volcanic eruptions and climate change, the recent annihilation of species is human induced (The Lancet Planetary Health, 2017) .

Table 1.1 General characteristics of the "Big Five" extinction events as identified by Raup and Sepkoski (1982) from the fossil record.

Source: Braje and Erlandson (2013). Also see Barnosky *et al.,* (2011)**.**

Mass extinction	**Age mya**	**Extinctions**			**Characteristics**
		% Families	**% Genera**	**% Species**	
Ordovician-Silurian	450–440	27	57	86	Two extinction pulses, about 1 million years apart. Likely resulted from glacial, interglacial cycles, marine transgressions and regressions, uplift and weathering of Appalachians causing atmospheric and ocean chemistry changes, and CO_2 sequestration.
Late Devonian	375–360	19	35	75	Likely marked by several extinctions over 3 million years, the cause is unclear but may include global cooling, spread of anoxic waters, oceanic volcanism, or an extra-terrestrial impact.
Permian-Triassic	252	57	56	96	The most severe extinction event that occurred over 1–3 pulses. The earliest pulse was likely the result of gradual environmental change, but later pulses may have been triggered by an impact, volcanism, the Siberian Traps, or sea floor methane release.
Triassic-Jurassic	200	23	47	80	Occurred quickly, in less than 10ky, and allowed dinosaurs to flourish. May have been triggered by gradual climate change, sea-level changes, ocean acidification, an impact, or volcanism.
Cretaceous-Paleogene	65.5	17	40	76	Marked by the extinction of the non-avian dinosaurs and the beginning of the age of mammals. Most scientists point to an asteroid impact as the cause and the extinctions may have occurred over several thousand years.

The current massive habitat degradation and extinction of the planet's biodiversity is unprecedented and is occurring at an exceptionally high rate (Novacek and Cleland, 2001; Matuštík and Kočí, 2019). This has triggered a sixth mass extinction in roughly 540 million years which can lead to the extinction of many life forms that exist on this planet by the end of this century (Ripple *et al.*, 2017).

1.3. Sixth mass extinction: The dawn of the Anthropocene Era

There is an increasing concern among scientists that earth has either entered or is entering a sixth mass extinction event (Wake and Vredenburg, 2008; Barnosky *et al.*, 2011; Ceballos and Ehrlich, 2018) dominated by humans and termed it "Anthropocene" (Waters *et al.*, 2016). The Anthropocene, an era that has arisen since the Industrial Revolution (Crutzen, 2002; Rockström *et al.*, 2009; Steffen *et al.*, 2018), is defined by a shift from Earth's unusually stable period known as Holocene (Dansgaard *et al.*, 1993; Petit *et al.*, 1999; Rioual *et al.*, 2001; Rockström *et al.*, 2009).

Palaeontologists are still not clear about the causes behind the historical mass extinction events, but the primary cause of the sixth extinction event is clear and is attributed to anthropogenic activities (Cafaro, 2015) with the predominant reason being the growth in human population; increased income (Vitousek *et al.*, 1997; Steffen *et al.*, 2006; Traffic, 2008; Cardinale *et al.*, 2012); and consumerism behaviour (Myers, 1989). Anthropogenic activity is considered to be the biggest threat to ecosystems & their components. It is estimated that one out of every three species present on earth could go extinct within next two centuries because of human actions (The Secretariat of the Convention on Biological Diversity, 2010). The present extinction crisis is considered as a unique event in the history of Earth with the current rate of extinction estimated as one thousand times the background rate (Pimm *et al.*, 2014; Proença *et al.*, 2017). The background rate being 0.1 – 1 extinctions per million species per year for marine life and 0.2- 0.5 extinctions per million species per year for mammals (Mace *et al.*, 2005; Ceballos *et al.*, 2015). The present rate of extinction is profoundly higher than the last five mass extinction events suffered by earth throughout the last 3.5 billion years of geological times when life existed on earth (Lawton *et al.*, 1995; Wake and Vredenburg, 2008) (see Table 1).

Human population growth has increased by 130 percent in last five decades (Tilman *et al.*, 2017), and has been projected to increase further and is likely to reach 9.6 billion by 2020. (UN, 2013). This has put tremendous pressure on earth's natural resources and humans through their activities have altered the natural equilibrium. For example, humans have over- exploited natural resources and hunted species to levels, which caused the species to go extinct. The increasing demand for land for agriculture and other developmental activities have resulted in massive deforestation, causing loss of the habitat for many species. About two- third of the species which inhabit tropical humid forests (Raven, 1980) are under threat due to the loss of their habitat, which is caused due to change in land use and it is projected that by 2100, 18% of species in tropical forests will be extinct due to deforestation to date (Pimm and Raven, 2000). Deforestation has also caused an increase in carbon dioxide emissions in the environment, contributing to the accelerating rate of climate change.

Climate change caused by anthropogenic activities is one of the major threats to the biodiversity (Rockström *et al.*, 2009). There is increasing demand for fossil fuels with an increase in human population.

The sixth extinction event may lead to a 50% loss of the remaining biodiversity on earth as predicted by some biologists, which might further disrupt the equilibrium in the nature (Braje and Erlandson, 2013). Of the 96,951 species assessed for the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, more than 27% (26,500) of all assessed species are threatened with extinction, which includes 40% amphibians, 25% of mammals, 34% of conifers, 14% of birds, 31% of sharks & rays, and 33% of corals (IUCN, 2019b). Since 1500 AD which is considered as the modern extinction, 338 species among vertebrate taxa assessed by the IUCN have gone "extinct" with an additional 279 species either "extinct in wild" or listed as "possibly extinct" (Ceballos *et al.*, 2015).

It is imperative to prevent further biodiversity loss and enhance the benefits associated with them. It is with this mission that the Convention on Biological Diversity (CBD) adopted the Strategic Plan for Biodiversity 2011- 2020 in 2010 (Marques *et al.*, 2014).

1.4. Convention of Biological Diversity and Aichi Targets: Response to the sixth mass extinction

Biodiversity underpins the functioning of the ecosystem and provides a range of ecosystem services, which are benefits upon which we depend for humankind. These services include the provision of clean air and water and carbon sinks provisioning. Another indirect benefit includes providing food security contributing to the livelihoods of local people, and helps achieve one of the Millennium Development Goals, which is to reduce poverty (Assessment Millennium Ecosystem, 2005). Despite being an integral and fundamental part of ecosystems, biodiversity is being continuously lost at a global scale, altering the earth's ecosystems and the services that they provide (Cardinale *et al.*, 2012; Hooper *et al.*, 2012). In response to the incessant degradation of the ecosystems and the services it provides to humans, various international agreements e.g. Convention of Biological Diversity (CBD) have been adopted to halt the extinction of species and the ecosystem services (Tittensor *et al.*, 2014). The Convention of Biological Diversity was adopted with a vision that "by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people" (Secretariat of the Convention on Biological Diversity, 2010).

The Convention on Biological Diversity (CBD), a multilateral treaty for the conservation of biodiversity, adopted the Strategic Plan for Biodiversity 2011- 2020 in Nagoya, Japan in 2010 (CBD, 2010b). According to the Secretariat of the Convention on Biological Diversity, 2011, the mission of the Strategic Plan is to 'take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication'. There are 20 Aichi Biodiversity Targets (commonly known as Aichi Targets) in this Strategic Plan, which are organised under five Strategic Goals (see Table 1.2) (Marques *et al.*, 2014) and provide logical guidance on how to meet the targets that are aimed at improving the status of biodiversity and protecting ecosystems (Fenu *et al.*, 2015).

Of the 20 Aichi Targets, my research presented herein focuses on Aichi Target 12, Strategic Goal C, "to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity" (CBD, 2010a). This target specifically relates to known threatened species and has two components, one to prevent extinction and second to improve the conservation status of those species that are threatened (CBD, 2010a) (see Table 1.3).

Table 1.2 Strategic goals underlying the Aichi Targets 2011- 2020. Source: CBD (2010a)**.**

Strategic Goals	Aim
Strategic Goal A	Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
Strategic Goal B	Reduce the direct pressures on biodiversity and promote sustainable use
Strategic Goal C	To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
Strategic Goal D	Enhance the benefits to all from biodiversity and ecosystem services
Strategic Goal E	Enhance implementation through participatory planning, knowledge management and capacity building

Table 1.3 Two components of Aichi Target 12. Source: CBD (2010a)**.**

Component	Description
Preventing Extinction	'Preventing further extinction entails that those species which are currently threatened do not move into the extinct category. Of the more 19,000 species known to be threatened globally, more than 3,900 are classified as critically endangered. Critically endangered species are considered to be facing an extremely high risk of extinction in the wild'
Improving the conservation status of threatened species	'An improvement in conservation status would entail a species increasing in population to a point where it moves into a lower threat status. Using the IUCN criteria, a species would no longer be considered as threatened once it moved into the near threatened category'

1.5. Progress towards Aichi Target 12

The importance of biodiversity conservation is reflected in Aichi Target 12 (Target 12 henceforth) which is centred on prevention of threatened species from extinction. Currently according to the Secretariat of the Convention on Biological Diversity, there has been no progress against the prevention of the extinction of the threatened species with further extinction likely to happen in the future. With the IUCN Red List Index declining, there is no sign of overall reduction in risk of extinction across species (see 'Dashboard- Progress Towards Target' in Secretariat of the Convention on Biological Diversity, 2014) (Leadley *et al.*, 2014). This declining trend needs not to be just halted but in order to achieve the Agenda 2030 Sustainable Development Goals (SDGs) it has to be reversed (Mace *et al.*, 2018).

Tentative progress may have been made in achieving Target 12 which is not yet evident, as conservation actions are slow and needs continuous monitoring. Such actions has proved to be effective in species conservation by reducing the risk of extinction of vertebrate species (Butchart *et al.*, 2006; Hoffmann *et al.*, 2010) however there has been little assessment on the overall impact of ongoing conservation efforts in preventing biodiversity loss (Ferraro and Pattanayak, 2006; Brooks *et al.*, 2009; Hoffmann *et al.*, 2010). This makes it challenging to assess the achievements of the conservation action and detecting species recovery over a short span of time (Butchart *et al.*, 2010).

Also, if we are to achieve Target 12 we need to work towards the other 19 Targets as, all 20 Targets are interactive and are interdependent i.e. actions taken to achieve one target may have an influence on other targets (Marques *et al.*, 2014). To achieve Aichi Target 12 structured under Strategic Goal C, which is 'to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity', it is imperative to take actions towards achieving Strategic Goal B which considers to 'reduce the direct pressures on biodiversity and promote sustainable use'. Also, addressing those targets that are related to the main causes of loss of biodiversity, such as overexploitation (Target 6&7), loss of habitat (Target 5), climate change (Targets 10&15), pollution (Target 8), will all help in contributing towards achieving Target 12 (Marques *et al.*, 2014).

Target 11, ensuring 17% of the land under protected area coverage by 2020, plays a critical role in achieving Target 12 (Marques *et al.*, 2014). Currently, 15% of the earth's land and 10% of terrestrial water is covered under protected area but according to the *2016 Protected Planet* report "crucial biodiversity areas are being left out, key species and habitats are underrepresented and inadequate management is limiting the effectiveness of protected areas" (UNEP-WCMC, 2016). The establishment of new protected areas may not have a profound impact in halting the extinction of the species unless the designated area encompass viable species population that are already encompassed under current protected area network (Joppa *et al.*, 2013; Venter *et al.*, 2014). Therefore, the impetus is to understand where a species occurs in space & time and what are the probable threats to that target species in its habitat that might cause its extinction. It is also important to monitor the effectiveness of the existing protected areas on a regular basis by quantifying species recovery owing to the current conservation action in place (Akçakaya *et al.*, 2018).

1.6. Why is it important to have locality data in conservation science – setting species conservation goals?

Due to the limited funds, there is an urgent need to prioritize conservation activities and resources in an effective and efficient manner (Wilson *et al.*, 2006; Tulloch *et al.*, 2015). In order to make informed decisions on which areas to conserve and which species to prioritise, conservationists need historical as well as contemporary distribution data to track changes in biodiversity (Boakes *et al.*, 2010). In the face of continuing losses of global biodiversity, there has been interest in data sources, which can be used in assessing where species occur and how has their status changed (Boakes *et al.*, 2010).

Information from locality data can be used to fill many gaps in conservation science. For example, it can help to identify the long- term decline of a species (Schaefer, 2003), inform on species' extinction status (Collen *et al.*, 2010), and be used to investigate the effectiveness of conservation measures (i.e. the efficacy of PAs to prevent the loss of habitat) (Clark *et al.*, 2013).

Geographic range (the area where a species is found) is a fundamental part of a species' ecology (Gaston, 2003) and is an important criterion in assessing the IUCN Red List status of a species (IUCN, 2012). Knowing where a species occurs in space & time, and the extent to which the geographic range is accurately described, is important as it allows conservationists to make an accurate assessment of threats. Thus, it is important to understand and study the spatial patterns of change in range, but the lack of data availability makes it biased and restricted (Boakes *et al.*, 2010).

Conservation actions have a profound role in protecting species from extinction and it is because of the conservation actions only that the statuses of many species have improved over time. Point locality data can be used to assess the change in the status and change in the trend of data collection, which can help conservationists to understand if conservation actions have any significant role in the improvement or change in the species' status. Boakes *et al.* (2010) reported that 'the proportions of literature records relating to the threatened species showed a decline from the 1870s to the 1940s followed by a sharp increase from 1960 to the present day, presumably reflecting current conservation interest and a changing focus of scientific field studies".

Among the uncertainties regarding predicting the rate of species extinction in the future, it is important to know the effect conservation actions have in halting or reducing extinction (Waldron *et al.*, 2013). Some species might have gone extinct regardless of conservation actions or the rate of species extinction might have been higher than it is. For example, if there were no conservation efforts, the rate at which species have moved towards extinction over the last few decades would have been 20% higher (Hoffmann *et al.*, 2010). Conservation successes therefore need to be quantified to illustrate that conservation actions are necessary and facilitate in reducing the rate of loss of species. Measuring conservation success is difficult and we need protocols to assess in my research. In my last chapter, I attempt to assess the proposed IUCN Green List protocol to quantify species recovery due to the conservation actions.

I explore a point locality database which is opportunistically collected but is a nearly-exhaustive historical database, containing information on 131 species of Galliformes in the Palearctic and Indo-Malay biogeographic realms (Boakes *et al.*, 2010). I use this database to understand and plan for the conservation of a highly threatened group of birds in the Order

Galliformes, found in the entirety of the Greater Himalayan region, an area of high conservation concern.

1.7. The Greater Himalaya: importance and threats

The Greater Himalaya, known as the 'Third Pole of the World' (Wang *et al.*, 2014), covers an area of about seven million square kilometres of northern Pakistan, Nepal, Bhutan, north-western and north-eastern states of India and represents the major part of Hindu-Kush Himalayan mountain system (Mittermeier *et al.*, 2004). The region contains the most extensive and rough high altitude areas on Earth and include the inner and south Asian mountains (Xu *et al.*, 2009).

The Himalaya has the most extensive areas of glaciers and permafrost globally and is the source of nine large rivers and hence, it is called 'water tower of Asia' (Xu *et al.*, 2009; Xu and Grumbine, 2014). The Greater Himalaya are rich in biodiversity and have much higher values in terms of biodiversity than the global average (Körner and Paulsen, 2004) with the eastern Himalaya having a higher plant diversity and richness than the west (Xu and Wilkes, 2004; Mutke and Barthlott, 2005; Salick *et al.*, 2006). Furthermore, the geology of the region makes the area even richer in biodiversity, with the level of species richness much higher than that of surrounding lowland areas (Xu *et al.*, 2009). Out of 825 ecoregions recognised globally, 13 are present in the Himalayan region (Olson *et al.*, 2000; Wikramanayake *et al.*, 2002a) representing globally distinctive ecologies (see Figure 1.1).

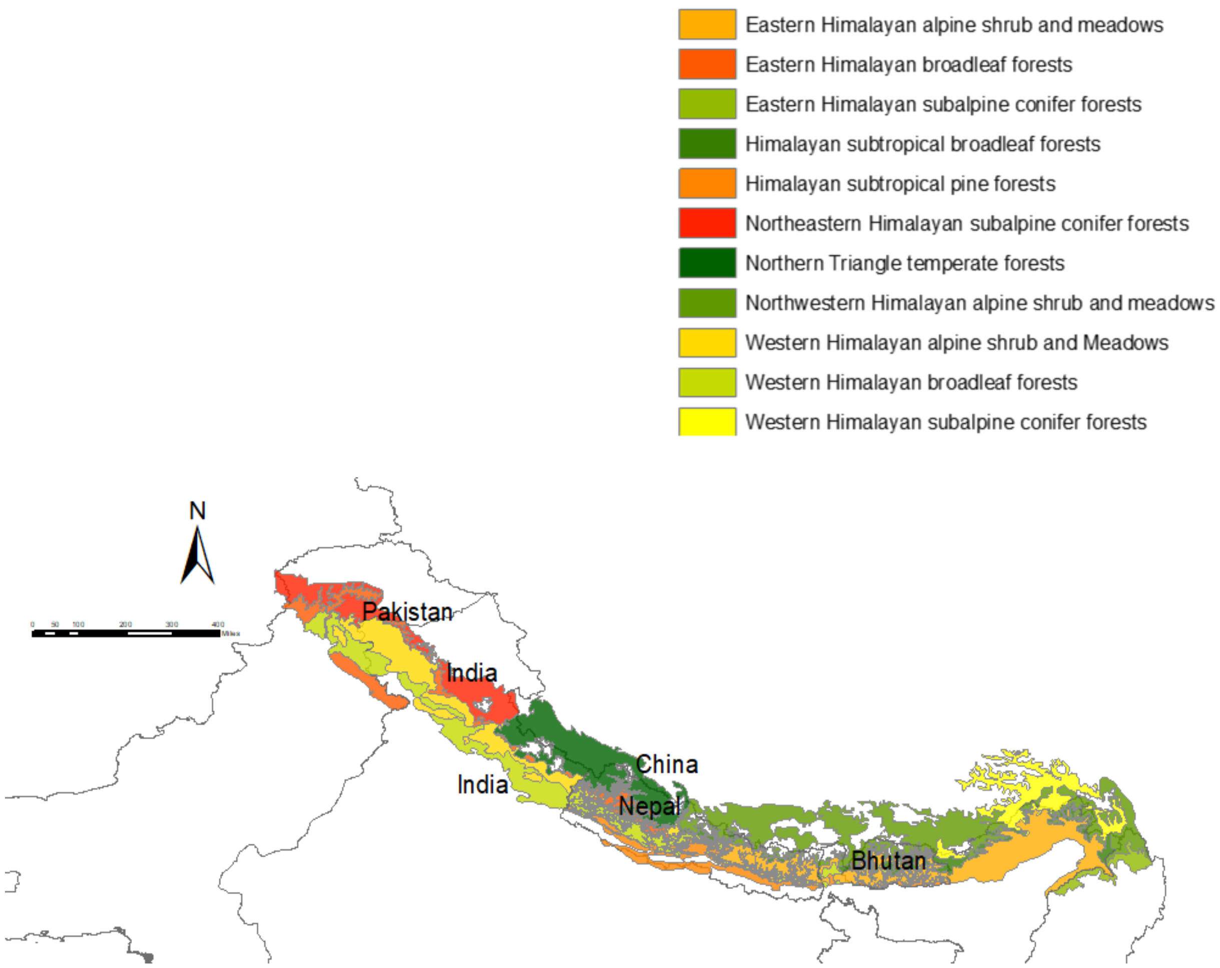

Figure 1.1: Map showing *WWF ecoregions* (Mittermeier *et al.*, 2004) used in this thesis to delimit the Greater Himalayan study region overlain over national boundaries of Himalayan countries. (Dunn (2015))

Containing a high number of endemic species, the Greater Himalaya is the point of intersection of three of the world's 35 biodiversity hotspots (Mittermeier *et al.*, 2004). This makes the region important from the conservation point of view, as to qualify for a hotspot a region should have 1500 endemic species of vascular plants but must have lost 70% of its primary vegetation (Myers *et al.*, 2000a). This signifies that the Greater Himalaya is one of the biodiversity rich areas containing many endemic species of flora and fauna, but the species are currently under threat.

Seventeen percent of the Greater Himalayan region is covered by glaciers, ice, and snow , however this area is receding rapidly (Dyurgerov and Meier, 2005; Bernstein *et al.*, 2008). The Intergovernmental Panel on Climate Change (IPCC) has predicted an average mean warming to be around 3 °C by the 2050s (Kumar *et al.*, 2006; Solomon *et al.*, 2007), and that it might that the climate of the earth would warm by 5°C by the end of this century (Pachauri *et al.*,

2014) which could be seriously damaging to the Greater Himalayan ecosystem & peoples (Anderson and Bows, 2008; Hansen *et al.*, 2008; Solomon *et al.*, 2009).

1.8. Galliformes: Himalayan species and threats to them

Galliformes, also known as 'gallinaceous birds' or 'game birds', is a diverse group of birds found throughout the Greater Himalaya and includes species such as partridges, pheasants and quails (Sathyakumar and Sivakumar, 2007). Galliformes are used as a barometer to measure the success of wildlife conservation (McGowan *et al.*, 2009) and are considered as flagship species to study changes in ecosystems (Sathyakumar and Sivakumar, 2007). These birds are beneficial for human beings as they have been domesticated and hunted for food and for their strikingly beautiful plumage and feathers (Fuller and Garson, 2000b).

There are 308 species of Galliformes in total, of which 24 are found throughout the Greater Himalaya, 16 of which are endemic to the area. These birds are native species of the Greater Himalayan region and have a cultural and historical importance in the life of humans in the Himalayan region; "pheasant" and "chicken" characters have appeared in oracle inscriptions in the Shang Dynasty of China since ~1700 BC (Peters *et al.*, 2016). These species also bring material benefits to humans for example, domestication of red junglefowl (*Gallus gallus*) has proved to be a significant event for human food security (BirdLife International 2018). These species receive national importance for they have been listed as national birds for three of the Himalayan countries. Common peafowl (*Pavo cristatus*) is the national bird for India; Himalayan monal (*Lophophorus impejanus*) is the national bird of Nepal and is also a state bird of Uttarakhand (a northern state in India), and chukar partridge (*Alectoris chukar*) is the national bird of Pakistan.

The Himalayan Galliformes vary greatly in the habitats that they reside in, their geographical distributions, and their extinction risk. Some species of pheasants such as Himalayan monal (*Lophophorus impejanus*), koklass pheasant (*Pucrasia macrolopha*), cheer pheasant (*Catreus wallichii*) and western tragopan (*Tragopan melanocephallus*) have strong habitat preferences and are sensitive towards even the small changes in their habitats (Jolli and Pandit, 2011b).

In spite of being ecologically and culturally significant, these species are under intense pressure mainly from hunting and habitat loss (Keane *et al.*, 2005). Twenty- five percent of the 308 Galliformes species are listed as threatened with extinction whilst only 13.2% of the 10,424 threatened species of birds are threatened on the IUCN Red List, (IUCN, 2011; Grainger *et al.*, 2018). They are widely hunted throughout their habitats and are thought to be an important source of dietary protein locally. The Himalayan region, being an important source of rivers, has been extensively exploited to harness hydropower (Jolli and Pandit, 2011b), which has resulted in deforestation and loss of habitat for many of these species. Shifting agriculture (also known as *jhum* cultivation) in northeast states of India have also been a major cause for change in land use and deforestation. Grazing pressure is one of the threats on the abundance of several species in the region (Bhattacharya *et al.*, 2009).

1.9. Aims of thesis

The aim of my research is to facilitate the conservation of the Galliformes species in the Greater Himalayan region. By using an opportunistically collected exhaustive database, GALLIFORM: WPA Eurasian Database v 1.0 (Boakes *et al.*, 2010), I explore the availability and use of data in understanding and planning for the conservation of Himalayan Galliformes.

The aims of my research are to:

1. describe a database that is thought to be a near- exhaustive collation of point locality data;
2. understand what we know about threats to Himalayan Galliformes;
3. assess how complete our knowledge of species' range size is; and
4. test the Green List protocol on a suite of species.

1.10. Thesis outline

To achieve the aforementioned aims of my thesis, I start with my first aim by exploring and understanding the point locality database, GALLIFORM: WPA Eurasian Database v 1.0 (Boakes *et al.*, 2010), a database that has underpinned a range of research and is used in my thesis. I explain the details of the information held in this database that can help to bridge many gaps in the conservation of Galliformes. The database has information on the source of data; the year of record; name of the species the record relates to; IUCN Red List status of the species; and country from where the record was collected. The data held in the database is then compared with published synthesis of both altitude and geographic ranges and I show that altitude information from localities in the database allows much more focussed depiction of altitudinal ranges of the species.

To address the second aim, I undertook a systematic literature review to determine the extent of our knowledge of the threats faced by the Galliformes in the Greater Himalaya. This includes studies that are not readily accessible on standard search engines. I justify all the inclusion criteria used in this systematic literature review. Through this review, I demonstrate how little quantitative data is available on the threats to Galliformes in the Greater Himalaya. Using the ecological traits of the species synthesised from the published literature, I then assess the correlates between threat types and species preferences for their habitat to understand threats in the absence of direct evidence.

Using the results from Aim 1, I then examine the geographic range size of my suite of species to achieve Aim 3. I use point locality data from the database to understand how good our knowledge is on species' geographic range sizes and if the knowledge has improved more rapidly than expected by chance. I explain why it is important to assess the quality of information in constructing geographic ranges if we are to prioritise species and area correctly for conservation action. The analysis is a novel way to assess the quality of the locality datasets and can be applied to other locality datasets to examine the robustness of geographic range size estimates.

Finally, to quantify species recovery due to the conservation actions and legislation, I test the proposed IUCN Green List protocol on my suite of species. Using the results of Aim 3, I described the indigenous ranges (one of the components in the protocol) of the Himalayan Galliformes species. Determining the most appropriate spatial unit is a key focus in testing the protocol, as it is the most important step in assessing the Green List status of a species.

I conclude by discussing my results and the generality of my findings. I make a few recommendations on future conservation work in the Greater Himalaya.

Chapter 2. Understanding species occurrence data that underpins conservation decisions

2.1. Abstract

Historical and current species distribution data are needed to understand global patterns of species occurrence and to track changes in the rate at which it's changing. I explore an opportunistically collected historical database Galliform: Eurasian Database V.10. that comprises point localities for 131 species of Order Galliformes that occur in the Palaearctic and Indo-Malay biogeographic realms. In this chapter, I describe the database by extracting the point localities for 24 Galliformes species, which are endemic or near-endemic to the Greater Himalaya. The database has a total of 35,900 point locality records for 24 Himalayan Galliformes species, of which 15,237 are within the Greater Himalaya. Records for these species comes from museum specimens, references, and trip records from China, India, Bhutan, Pakistan, and Nepal. I describe the number of localities collected over time, compared the observed elevation value extracted from point locality data with the elevation value extracted from the literature, and compared the minimum convex polygons (MCP) created using the localities of each species with the BirdLife International's species range maps. This database underpins several peer-reviewed studies in investigating the biases in the data, changes in the geographic range and in mapping the potential distribution of the Critically Endangered Himalayan quail (*Ophrysia superciliosa*). It provides valuable information for further studies in conservation science and decision making.

2.2. Introduction

Understanding global patterns of species distributions, and the rate at which they are changing, requires knowledge of where species occur (Boakes *et al.*, 2018). For many species in numerous parts of the world, it can be challenging to obtain detailed knowledge of where a species is found and, therefore, to describe adequately what its global distribution is. Traditionally, species distribution maps appeared in field guides and species or family monographs and aimed to describe where a species occurs in broad terms, rather than where it occurs precisely. These broad-brush descriptions appear to have been produced by accumulating information on where an individual species has been recorded and then using some, often unspecified, assumptions (e.g. on habitat use and the distribution of habitats) to depict species geographic ranges. Monographs of pheasants that have appeared over the last 100 or so years (Beebe, 1936; Delacour, 1977; Johnsgard, 1986) have been very typical of the way that geographic ranges have been depicted. These maps were intended as broadly illustrative and so were, perhaps, not suited to the analysis that they were subjected to when research into various aspects of geographic ranges developed with the establishment of macroecology (Blackburn and Gaston, 2002), which recognises geographic range size as a key ecological attribute of a species (Gaston and Fuller, 2009). Many diverse descriptions and analyses of geographic range size have been carried out, especially for the most well-known taxonomic group, birds (e.g. Grenyer *et al.* (2006); Orme *et al.* (2006)).

At around the same time, concern about the conservation status of species has intensified, increasing the desire to understand both which species had the highest probability of extinction and where conservation should be directed. Both of these, and other species conservation purposes required more detailed, and defensible, information on where species occur than had been available. Geographic range size, and changes in it, is one of the most important characteristics that determine species extinction risks (Purvis *et al.*, 2000; Ceballos and Ehrlich, 2002) and the IUCN Red List includes change in geographic range as one of five criteria (IUCN, 2001) that may be used to assess the extinction probability of an individual species (Mace *et al.*, 2008). Nonetheless, the IUCN Red List does not require detailed information on species locations, recognising perhaps how difficult such information can be to obtain. Analysis of this list, including changes in geographic ranges of individual species, has led to the suggestion that the rate at which species are being lost is so high that the Earth is entering a sixth 'mass extinction' event (Barnosky *et al.*, 2011; Ceballos *et al.*, 2015).

Given the importance of distribution information for both understanding the ecology of geographic range size and for informing conservation decisions on species, it is, perhaps, surprising that the basis upon which range maps have been developed, has not been scrutinised in more detail. This is, perhaps, partly inevitable where there are many locality records for a species gathered over many decades and so there are significant challenges to simply gathering together data on where a species has been recorded reliably. Nonetheless, given the importance of understanding where species occur, both for conservation purposes and for understanding patterns in geographic ranges, a more detailed assessment of the locality data that, at least notionally, underpins geographic ranges, would be very helpful.

A database of locality records throughout Europe and Asia exists for the avian Order Galliformes (see Boakes *et al.* (2010) for a description of how this database was compiled). This database provides a near-exhaustive collection of 171,948 records across the entire geographic range of 131 species in this order from the date of their first record, although this is not the final size of the database. There were more locality records added between publication of Boakes *et al.*, 2010 and finalisation of the database, which led the number of records to grow from 171,948 to 208,759. This database of known localities is the raw data upon which descriptions and syntheses of geographic range should be based. I seek, therefore, to describe the data held in this database for 24 species of the Himalayan Galliformes to understand how much data there is for an order of birds, given that birds are perhaps the best-known taxonomic class of species. I then compare the information documented for these locality records with published syntheses of both altitudinal and geographic ranges that have been used for conservation purposes. In particular, I examine 1) the number of records of each species, both within the Greater Himalaya and throughout the rest of each species' range; 2) the type of record (museum specimen, published reference or trip report) and how the number and type of new records has changed over time; 3) to explore how published syntheses, reflect these raw data, I compare the altitudinal information associated with individual records with published altitudinal records, and individual localities and with currently used geographic range information for conservation purposes.

2.3. Methods

2.3.1. Data extraction

Extracting Himalayan records from GALLIFORM: Eurasian Database V.10

All records of Galliformes that occur in the Himalaya were extracted from GALLIFORM: Eurasian Database V.10 (Boakes *et al.*, 2010). The dataset contained a total of 208,759 point locality records gathered between 1625 and 2007.This dataset contains point locality data on 131 species of the avian Order Galliformes, of which 24 are found in the study region, the Greater Himalaya. As my focus is on information that will inform the conservation of Galliformes species in the Greater Himalayan region, species' point locality records were extracted from Himalayan countries (India, China, Nepal, Pakistan, and Bhutan) only. The dataset comprises point locality data accurate to 0.62 – 30 miles (1 – 48.3 km) and was compiled using a wide- range of sources including museum specimens, ringing records, biological atlas data and trip reports (see Boakes *et al*., 2010 for a detailed description of the collection of records). The resolution of locality records varies across all locations for all species and have been categorised as Accurate, Close or Vague.

Describing the locality information for Himalayan Galliformes

The first step was to determine how many records there were for each Himalayan species. Although some of the 24 Himalayan Galliformes species are endemic to Himalaya, some have a much wider global distribution, so all records of these species were extracted to compare it with records within the study site i.e. the Greater Himalaya. Records where localities were listed simply as ‘Asia’ were also included in this database since the locations of the records were known to be within the Himalaya. The total number of point locality records for all 24 species are 35,900, of which 15,237 are within the Greater Himalaya.

Point shape files were created for each species in the Greater Himalayan region using the point locality data extracted from the locality database over the years using ArcGIS version 10.3.1.

Extracting elevation values for Himalayan Galliformes

Information on elevation values for each Himalayan Galliformes species was extracted from the most recent authoritative monographs on pheasants and partridges (McGowan, 1994) and Himalayan Galliformes (Sathyakumar and Sivakumar, 2007). These monographs have compiled information on elevation ranges from a wide range of published sources and are, therefore, seen as fairly exhaustive compilations of data on species, such as altitude and habitat. Furthermore, they are still widely cited as the most reliable sources of such information for these species and this makes them ideal references for comparison with the raw data associated with point locality records. Some species undertake altitudinal migration, and some species do not. Therefore, some have a wide altitude range, and other species have a single, year-round altitude range. We treated higher altitudinal limit as the summer elevation and lower altitudinal limit as the winter elevation of a species. For some species only one altitudinal value was available, and, in such cases, the single elevation value was treated as the maximum and minimum altitude of the species.

2.3.2. Size and content of the database

In describing the records that exist for each species in the database, which is thought to be near-exhaustive collection of locality records for these species, it is important to understand the distributions of records in both the space and time for each. As noted above, some of the 24 species occur outside the Greater Himalaya, sometimes extensively so, and it is, therefore, important, to understand the distribution of records of each species within the study region and outside. The following attributes of the dataset were examined for each species:

- Number of records for each species within and outside the Greater Himalaya;
- Number of records for each species for types of records sources;

- Number of records for Himalayan Galliformes species from each Himalayan country; and
- Number of records for each Himalayan Galliformes species through time;

Number of records for each species within and outside the Greater Himalaya

To compare the total number of point locality records found within and outside of the Greater Himalaya, bar graphs were plotted to show: a) the total number of records for each Himalayan Galliformes species worldwide; and b) the number of records within the Greater Himalaya and outside the Greater Himalaya.

Number of point localities for Himalayan Galliformes species from different Himalayan countries

A bar graph was plotted to show the numbers of records for each Himalayan Galliformes species in each Himalayan country, namely India, China, Bhutan, and Pakistan. Locality records listed simply as Asia are also included because the locality is from the Greater Himalaya, but the precise location is not known.

Number of point localities for each Himalayan Galliformes species through time

Histograms were plotted to show the different number of records for: a) all Himalayan Galliformes species through time; and b) species by species changes through time.

Number of point localities for each species for types of records sources

Bar graphs were plotted to show: a) the number of each type of record (museum collections, trip reports and references) in the five Himalayan countries; and b) the different types of record sources (museum collections, trip reports and references) for all Himalayan Galliformes species.

2.3.3. Comparison of the observed elevation value extracted from point locality data with the elevation value extracted from the literature

The point shape files were overlaid with a digital elevation raster and their corresponding elevation raster values were then extracted. For this, ArcGIS version 10.3.1 was used. The mean, median, maximum and minimum elevation for each Himalayan Galliformes species was calculated using the raster values extracted (see Table 2.6). This comprised the 'observed' elevation information. The 'literature' values comprised the minimum and maximum elevation value given in the two monographs (McGowan et al., 1994 and Sathyakumar and Sivakumar,

2007) as noted above. The observed elevation range for each Himalayan Galliformes species extracted from the point locality data were used to plot a box and whisker plot. All calculations were undertaken, and graphs plotted, in R (R Development Core Team, 2016).

2.3.4. Comparing BirdLife International range map with the range map created using point locality data

A shape file of presence locations for each Himalayan Galliformes species was created using point locality data and clipped to the study region, the Greater Himalaya. Using this shape file of each species, a minimum convex polygon (MCP) was drawn to construct an Extent of Occurrence (EOO: see IUCN, 2012) for each Himalayan Galliformes species and this was then clipped to the study region. MCP is the smallest polygon in which no internal angle exceeds 180 degrees, and which contains all the site of occurrence (IUCN, 2012).

BirdLife International produce the geographic range maps for the world's birds that are then used in the assessments of bird species against the criteria in the IUCN's Red List of Threatened Species. These maps are therefore, used as the authoritative geographic range maps for species conservation. The BirdLife International range maps are based on Area of Habitat (AOH) (Brooks *et al.*, 2019) rather than MCP or Extent of Occurrence (BirdLife International, 2017) and it is intended that they are based upon up-to-date information in the compilation of each geographic range map. The BirdLife International range map for each Himalayan Galliformes species was clipped to the study region.

For each species, the number of point records inside and outside the clipped BirdLife International range map and the clipped MCP was calculated. To compare the area of the two range maps i.e. the BirdLife International range map and the MCP, the percentage of area of the clipped the BirdLife International range maps inside MCP was calculated. There are a number of different metrics that can be used to compare the ranges, in particular the number of localities and the area. The database used in this study contains point locality data and so the number of localities can be readily quantified and compared. Similarly, area was assessed because conservationists use the range map of a species to show its distribution and to inform conservation decisions. Using the area will help in comparing the EOO maps created by using point locality data from historical database with the extent of suitable habitat (ESH) generated by BirdLife International, which might be based on information other than raw locality data. Ideally the area of both range maps (i.e. EOO from point locality data and ESH from BirdLife International) should be similar and ESH should overlap with EOO. If ESH and EOO does not overlap, then adjustments might need to be made to BirdLife International's range maps, because the understanding of where species' ranges are positioned, and the subsequent assessments of extinction risk may not reflect reality. All analysis were undertaken in ArcGIS version 10.3.1.

2.4. Results

2.4.1. Distribution of records

Number of records for each species within and outside the Greater Himalaya

Twenty-four species of Galliformes occur in the Greater Himalaya. Some species are found only within the Himalaya whereas others extend beyond this region. There were 35,900 records for these 24 species, of which 15,237 were within the Greater Himalaya. The number of records of each species within and outside the Himalaya is shown in Figure 2.1.

The species with highest number of locality records (N = 15,083) is common quail (*Coturnix coturnix*) (Figure 2.1). There were fewer than 3,000 records that, at least in theory, underpin the global distribution for all other species (appendix Table A.1, with the fewest being 55 for Himalayan Quail (*Ophrysia superciliosa*) (Figure 2.1). The mean number of total records for all Himalayan Galliformes species is 1,496.

Twenty-one of the 24 species have more than 50% of records collected from inside the Greater Himalaya (Table 2.1). Nine species are near endemic to the Greater Himalaya with more than 90% of the records within the Greater Himalaya and there are two, Buff- throated hill partridge and Himalayan Quail, which are endemic species with all the records collected from within the Himalaya (Table 2.1). The mean number of records for all Himalayan Galliformes species within the Greater Himalaya is 634.87 635 with a standard error of 638.63.

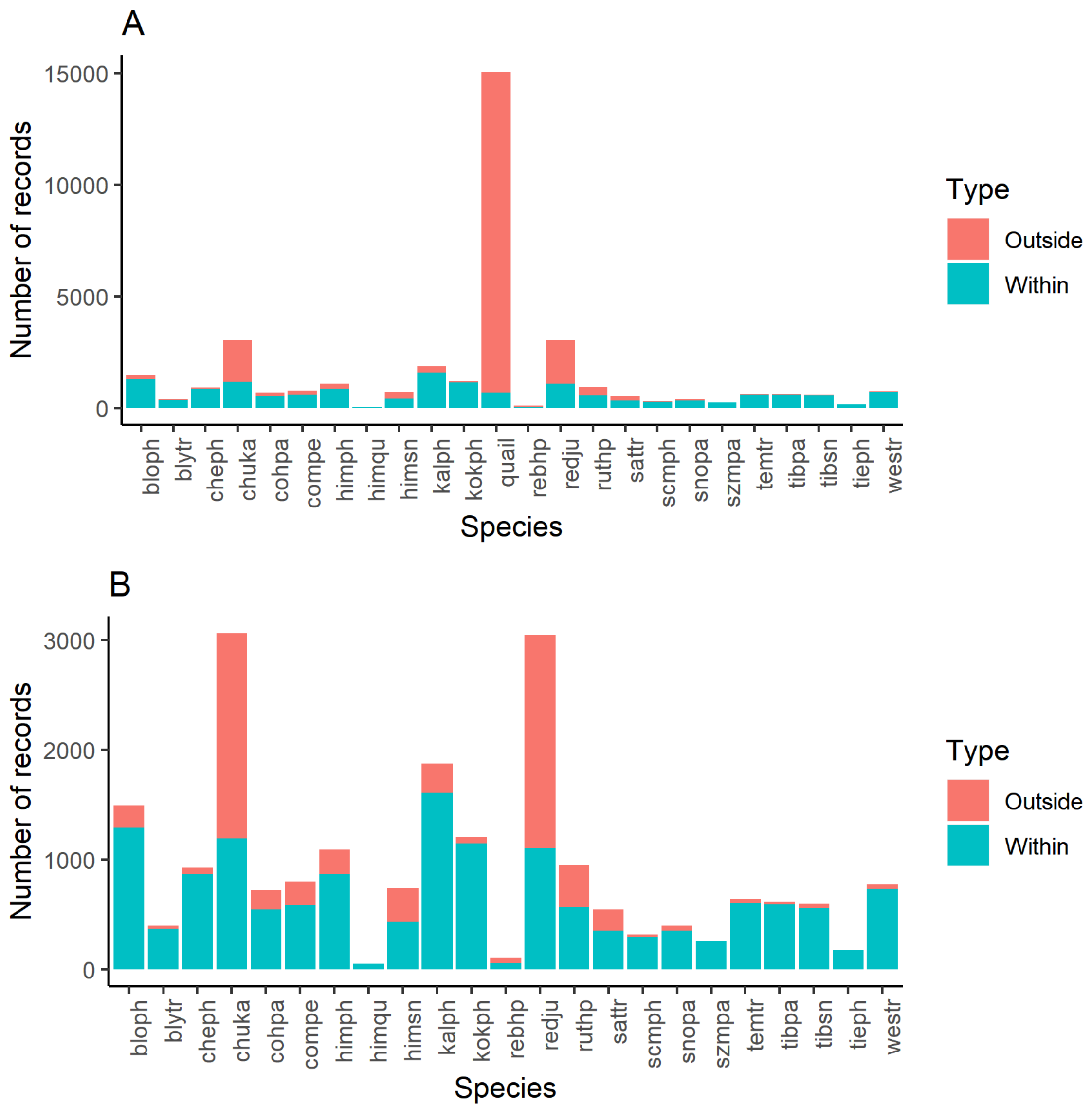

Figure 2.1: Number of records of Himalayan Galliform species indicating the number found inside and outside the Greater Himalaya.

A) shows the number of records for all Himalayan Gallifomes (N= 24) species outside (orange) the Greater Himalaya vs. inside (cyan) the Greater Himalaya. B) shows the number of records for all Himalayan Galliformes species excluding common quail (N=23) outside (orange) the Greater Himalaya vs. inside (cyan) the Greater Himalaya.. Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = chestnut-breasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr = satyr tragopan, scmph = Sclater's monal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan.

Table 2.1: Percentage (%) of point localities within the Greater Himalaya.

% records inside Himalaya	Species
>50%	chukar, red junglefowl, common quail
50-59%	rufous-throated partridge
60-69%	Himalayan snowcock, kalij
70-79%	Blyth's tragopan, hill partridge, Indian peafowl, Sclater's monal
80-89%	Chestnut-breasted hill partridge, satyr tragopan, Temminck's tragopan
90-99%	blood pheasant, cheer pheasant, Himalayan monal, koklass pheasant, snow partridge, Tibetan partridge, Tibetan snowcock, Tibetan-eared pheasant, western tragopan
100%	buff-throated partridge, Himalayan quail

Number of point localities for Himalayan Galliformes species from different Himalayan countries

The country with the largest number of records is India (6,843: Figure 2.2), followed by China (5,032). Together these comprise 78% of all records. Those listed as Asia were museum specimens that were labelled simply as Asia with no more specific locality information.

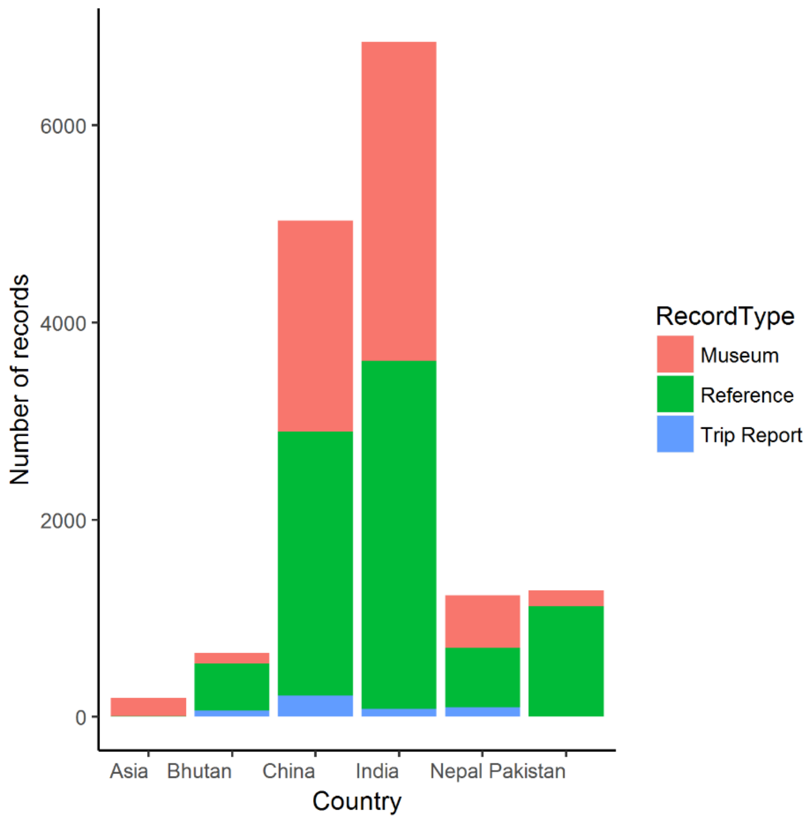

Figure 2.2: Number of different types of records in each Himalayan countries.

Number of point localities for each species for types of records sources

Locality records of Himalayan Galliformes are derived from three types of records: museum specimens, trip reports and literature references, made up as follows: 8,407 (55%) references, 6,371 museum specimens (42%) and 459 trip reports (3%) (see Figure A.1 in thesis Appendix). References contributed a mean of 60% of locality records, and museum specimens 37%, with trip reports contributing 3% (see Table 2.2).

Considering species individually, more than 50% of locality records derive from references for 17 of the 24 species (Table 2.2), with museum records comprising the major source of locality records for the remaining seven. Trip reports comprised less than 10% of records in all cases and 5% or less for 20 species (Table 2.2).

Table 2.2: Number of records from different sources for each Himalayan Galliformes species.

Species	Number of records			Total	Percentage of records		
	Museum	References	Trip Reports		Museum	References	Trip Reports
Blood pheasant	873	445	63	1381	63	32	5
Blyth's tragopan	47	254	4	305	15	83	1
Cheer pheasant	156	750	2	908	17	83	0
Chukar	652	556	4	1212	54	46	0
Hill partridge	323	186	29	538	60	35	5
Common peafowl	143	428	26	597	24	72	4
Himalayan monal	349	606	30	985	35	62	3
Himalayan quail	2	53	0	55	4	96	0
Himalayan snowcock	211	243	3	457	46	53	1
Kalij	697	508	53	1258	55	40	4
Koklass pheasant	412	738	23	1173	35	63	2
Common quail	315	399	7	721	44	55	1
Chsetnut breasted hill partridge	12	70	8	90	13	78	9
Red junglefowl	399	579	24	1002	40	58	2
Rufous-throated partridge	322	187	15	524	61	36	3
Satyr tragopan	187	279	15	481	39	58	3
Sclater's monal	42	204	1	247	17	83	0
Snow partridge	203	165	18	386	53	43	5
Buff-throated partridge	105	143	11	259	41	55	4
Temminck's tragopan	167	350	38	555	30	63	7
Tibetan partridge	345	213	41	599	58	36	7
Tibetan snowcock	237	307	30	574	41	53	5
Tibetan-eared pheasant	33	128	14	175	19	73	8
Western tragopan	139	618	0	757	18	82	0
Maximum					63	96	9
Minimum					4	32	0
Mean					37	60	3

The overall pattern of most records deriving from references also applies to each country, but the relative proportions vary. Bhutan and Pakistan have relatively small proportions of museum records (17% and 13% respectively), whereas the other three countries have 43-47% (Table 2.3).

Table 2.3: Number of different types of locality records in each Himalayan country.

	Number of records				Percentage (%) of records		
Country	Museum	Reference	Trip Reports	Total	Museum	Reference	Trip Reports
Asia	189	6	0	195	97	3	0
Bhutan	111	474	66	651	17	73	10
China	2141	2675	216	5032	43	53	4
India	3234	3528	81	6843	47	52	1
Nepal	532	604	96	1232	43	49	8
Pakistan	164	1120	0	1284	13	87	0
Total	6371	8407	459	15237	260	317	23

Number of point localities collected over time

The earliest record in the dataset was of a cheer pheasant (*Catreus wallichii*) museum specimen collected in 1620. There are 71 records collected before 1850.

The identification and documentation of locality records increased sharply during the second half of the 19th Century, with the 1860s and 1870s marking a step change in the overall number of records collected (Table 2.4). The number of records gathered in each decade continued to rise until the 1930s after which they declined, to a 100 year low in the 1960s before increasing again. The decades with the overall highest number of locality records are the last two for which there is a complete decadal record (i.e. 1980s and 1990s). The highest number collected in a single year was 387 in 2003 which consisted of 361 reference records and 26 records from trip reports

The type of locality record has changed over time. For a long time records from museum specimens comprised the majority of locality distributions. They increased, overall, until the 1920s and 1930s after which they declined by 21% from 1349 records in 1929 to 1062 in 1930 (Table 2.4). By comparison, locality records from references remained fairly modest, apart from a peak in the 1920s, until the 1980s. They then comprised the overwhelming majority of records of Himalayan Galliformes in 1990s. Locality records from trip reports have increased notably since 2000, although their distribution appears uneven between Himalayan countries (Table 2.3).

Table 2.4: Number of different types of records through time.

Year of record	Record type			Total
	Reference	Museum	Trip Record	
>1819	1	2	0	3
1820-1829	1	2	0	3
1830-1839	2	9	0	11
1840-1849	0	54	0	54
1850-1859	10	36	0	46
1860-1869	39	162	0	201
1870-1879	37	583	1	621
1880-1889	16	211	0	227
1890-1899	22	303	0	325
1900-1909	38	533	0	571
1910-1919	215	383	0	598
1920-1929	543	806	0	1349
1930-1939	272	790	0	1062
1940-1949	183	424	0	607
1950-1959	186	412	0	598
1960-1969	117	70	0	187
1970-1979	616	56	0	672
1980-1989	1097	49	3	1149
1990-1999	1118	25	27	1170
2000-2007	771	2	429	1202

For all 24 species in 23 decades, there should have been 552 combinations of species per decade (24 x 23 species/decade) but not all species have been recorded in each decade. A total of 379 combinations were obtained for species/decade. Only one point locality was recorded for cheer pheasant (*Catreus wallichii*) in 1625. From 1640 until 1800 there were no further records collected for any of the 24 species until after 1800 when records were collected in each decade until 2007. Prior to 1840, no species had more than 50 records per decade (see Table 2.5). Fourteen species had less than 50 records and only one species had more than 200 records from 1840 to 1850. Of the 379 combinations of species/decade, 268 combinations had fewer than 50 records from 1620 to 2007 however, 88 combinations of species/decade had more than 100 records in each decade from 1840 to 2000. The number of records per species per decade increased after 1870 (see Table 2.5). Between 1870 and 2007, 21 species had between 50 and 100 records per decade and 17 species had records between 100 and 150 per decade (see Table 2.5). Across the whole database, there were records for all 24 Himalayan species only in the decades 1920-1930 and 1990-2000.

Table 2.5: Number of species having different number of records in each decade.

Decade	1-50 records	51-100 records	101-150 records	151-200 records	201+ records	No of species
1620	1	0	0	0	0	1
1640	1	0	0	0	0	1
1800	1	0	0	0	0	1
1810	2	0	0	0	0	2
1820	5	0	0	0	0	5
1830	8	0	0	0	0	8
1840	14	0	0	0	0	14
1850	14	0	0	0	1	15
1860	15	0	0	0	2	17
1870	15	1	1	0	5	22
1880	19	1	0	0	1	21
1890	18	1	1	0	1	21
1900	15	0	4	1	2	22
1910	16	0	3	1	3	23
1920	10	3	0	4	7	24
1930	10	1	1	4	7	23
1940	18	2	0	2	1	23
1950	16	2	2	1	0	21
1960	19	2	0	1	0	22
1970	15	0	0	1	7	23
1980	13	5	0	2	3	23
1990	13	2	3	1	5	24
2000	10	1	2	1	9	23

Some species (e.g. blood pheasant (*Ithaginis cruentus*), chukar (*Alectoris chukar*), Himalayan snowcock (*Tetraogallus himalayensis*), and kalij (*Lophura leucomelanos*)) show a bimodal distribution over time with a peak of records in the 19th century, whereas other species (e.g. cheer pheasant (*Catreus wallichii*), Himalayan monal (*Lophophorus impejanus*), and western tragopan (*Tragopan melanocephalus*)) have records from late 20th or early 21st century (see Figure 2.3).

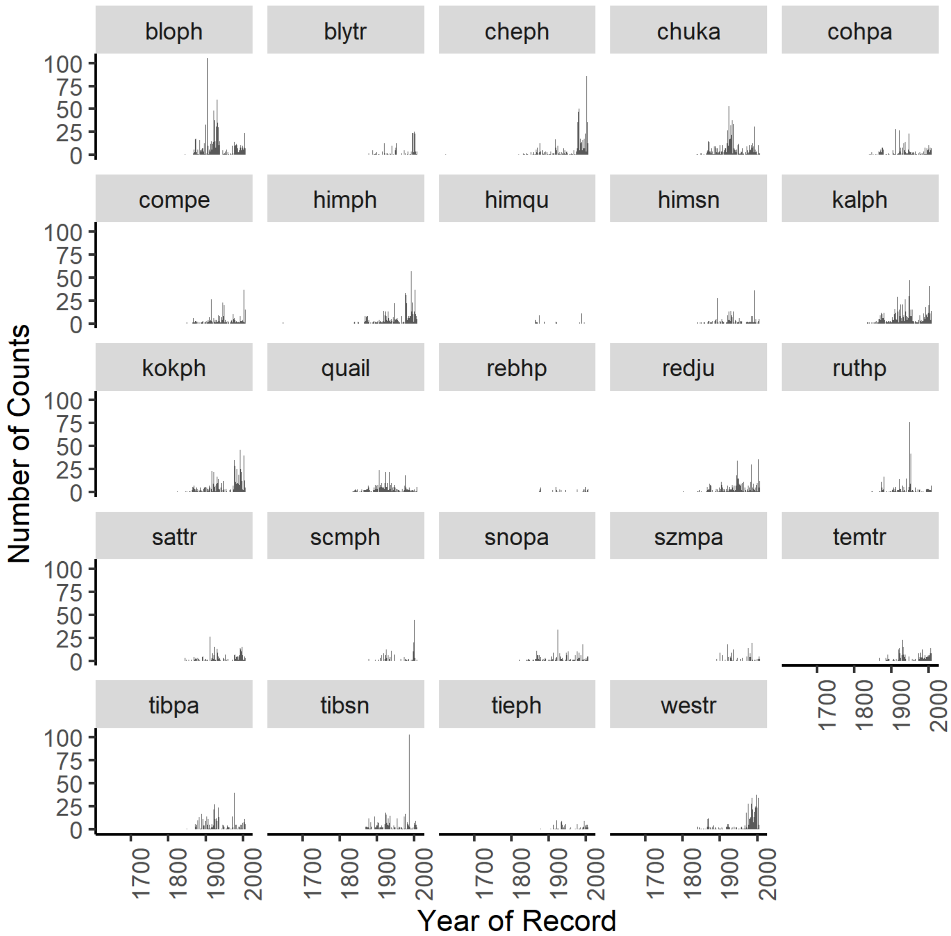

Figure 2.3: Number of records for each Himalayan Galliformes species within Himalaya throughout time.

Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = chestnut-breasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr = satyr tragopan, scmph = Sclater's monal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan. N = 24 species

2.4.2. Comparison of data with synthesised information

Comparison of the observed elevation value extracted from point locality data with the elevation value extracted from the literature

The data associated with individual locality records in the database describes the altitudinal range of each species in detail (Figure 2.4). Most species have been recorded at a very wide range of altitudes, but a pattern emerges of species that are largely found at low elevations (e.g. common peafowl (*Pavo cristatus*), red junglefowl (*Gallus gallus*) and rufous-throated partridge (*Arborophila rufogularis*)), at mid-level elevations (e.g. chukar (*Alectoris chukar*), koklass pheasant (*Pucrasia macrolopha*), and Himalayan monal (*Lophophorus impejanus*)), and those at high altitude (e.g. Tibetan partridge (*Perdix hodgsoniae*) and Tibetan snowcock (*Tetraogallus tibetanus*)). The median altitude for all 24 species range from 1519m for common peafowl to 4470m for Tibetan snowcock (*Tetraogallus tibetanus*). Some species such as snow partridge (*Lerwa lerwa*) had a large interquartile range (see Figure 2.4) indicating a large elevation niche whereas some species such as Blyth's tragopan (*Tragopan blythii*) had a small interquartile range (see Figure 2.4) which indicated a more restricted elevation niche. A few species have been recorded outside their range for e.g., Blyth's tragopan (*Tragopan blythii*), kalij (*Lophura leucomelanos*), Tibetan snowcock (*Tetraogallus tibetanus*) etc. (see Figure 2.4).

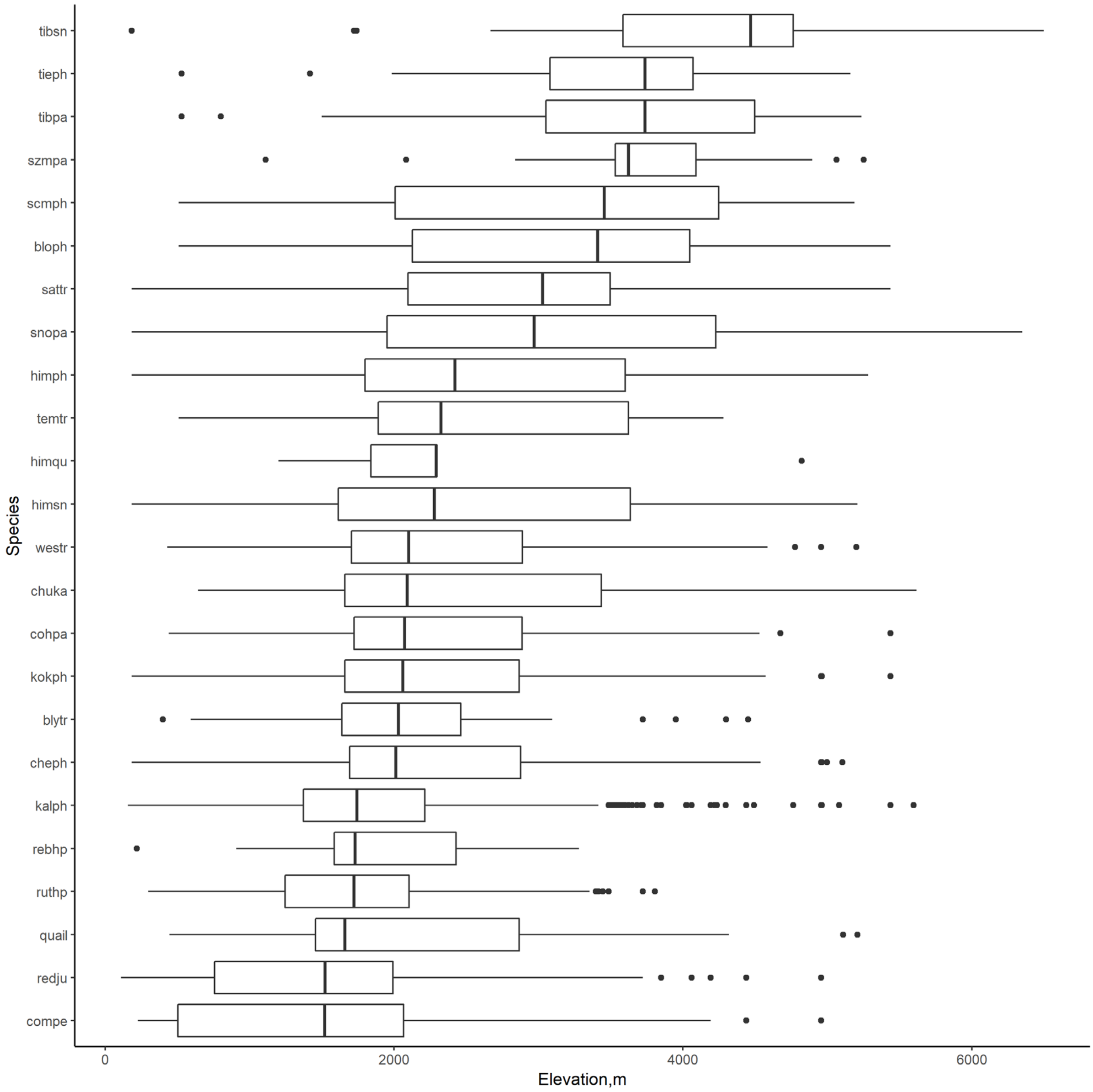

Figure 2.4: The observed elevation values for each Himalayan Galliformes species.

Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = chestnut-breasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr = satyr tragopan, scmph = Sclater's monal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn = Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan. N = 24 species.

Comparison of these values with altitudinal ranges published in authoritative volumes (McGowan, 1994; Sathyakumar and Sivakumar, 2007) that synthesise ecological information on these species reveal differences. Figure 2.5 shows the elevation values extracted from the point locality data based on the 'accurate' geo-referencing accuracy (); the red line represents the elevation values obtained from the literature. There was just one elevation value available in these syntheses for common quail (*Coturnix coturnix*) and red junglefowl (*Gallus gallus*).

Considering the locality records that were judged to be 'accurate' and 'close', there was reasonably good agreement between the raw locality data and the published data that had been synthesised for seven species: blood pheasant (*Ithaginis cruentus*), Blyth's tragopan (*Tragopan blythii*), cheer pheasant (*Catreus wallichii*), common hill-partridge , Himalayan quail (*Ophrysia superciliosa*), rufous-throated partridge (*Arborophila rufogularis*) and buff-throated partridge (*Tetraophasis szechenyii*). The concentration of observed records represented by the boxes fell, or nearly fell, within the upper and lower altitude limits from published syntheses in eight: Himalayan monal (*Lophophorus impejanus*), satyr tragopan (*Tragopan satyra*), Sclater's monal (*Lophophorus sclateri*), Tibetan snowcock (*Tetraogallus tibetanus*), Tibetan-eared pheasant (*Crossoptilon harmani*), and arguably koklass pheasant (*Pucrasia macrolopha*), Tibetan partridge (*Perdix hodgsoniae*) and western tragopan (*Tragopan melanocephalus*). For common peafowl (*Pavo cristatus*), kalij (*Lophura leucomelanos*), and Temminck's tragopan (*Tragopan temminckii*) the published data fell between the upper altitude and the median altitudinal range described by raw data. This left four species: chukar (*Alectoris chukar*), Himalayan snowcock (*Tetraogallus himalayensis*), chestnut-breasted hill partridge (*Arborophila mandellii*), snow partridge (*Lerwa lerwa*) where there was particularly poor agreement between altitude range described by locality records and that synthesised in published accounts. See Figure 2.5 for box and plot figure summarising the result.

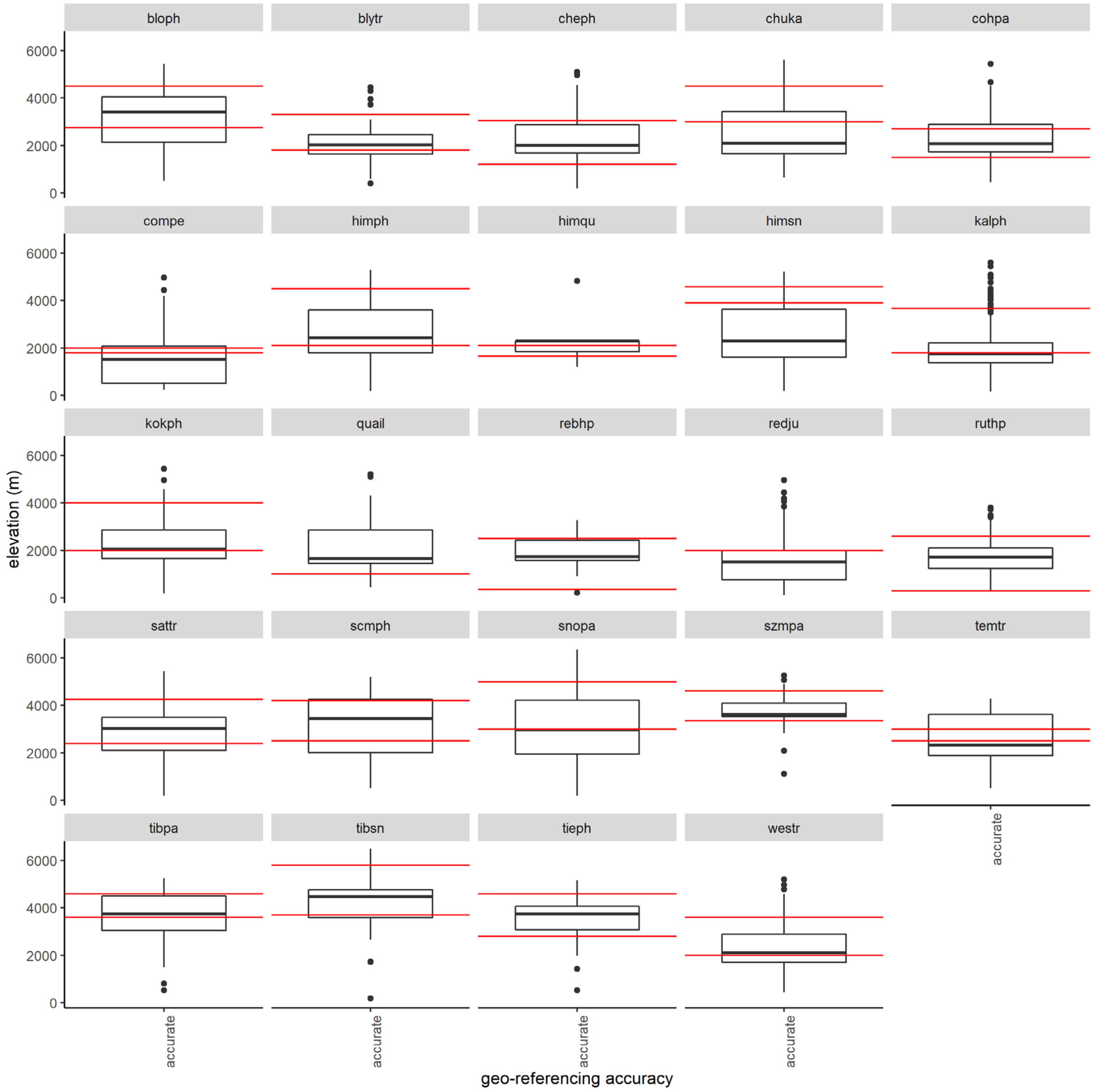

Figure 2.5: The comparison between the observed elevation values from point locality data (box and whisker plot) and the elevation values extracted from the literature (red lines).

Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = chestnut-breasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr = satyr tragopan, scmph = Sclater's monal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan. N = 24 species

Table 2.6: Mean, median, maximum and minimum observed elevation for each Himalayan Galliformes species.

	From database				From literature	
Species	**Mean elevation(m)**	**Median elevation(m)**	**Minimum elevation(m)**	**Maximum elevation(m)**	**Min elevation(m)**	**Max elevation(m)**
Blood pheasant	3169	3409	509	5437	2750	4500
Blyth's tragopan	2112	2030	398	4452	1800	3300
Cheer pheasant	2268	2011	182	5104	1200	3050
Chukar	2495	2091	643	5618	3000	4500
Hill partridge	2286	2073	440	5437	1500	2700
Common peafowl	1631	1519	226	4958	1800	1800
Himalayan monal	269	2422	182	5281	2100	4500
Himalayan quail	2178	2292	1198	4821	1650	2100
Himalayan snowcock	2583	2280	182	5209	3900	4570
Kalij	1928	1742	157	5598	2000	2000
Koklass pheasant	2280	2061	182	5437	2000	4000
Common quail	2130	1658	444	5209	1000	1000
Chestnut-breasted partridge	2019	1731	219	3279	350	2500
Red junglefowl	1485	1520	109	4958	2000	2000
Rufous-throated partridge	1759	1723	298	3805	300	2600
Satyr tragopan	2917	3029	182	5437	2400	4250
Sclater's monal	3118	3455	509	5189	2500	4200

Snow partridge	2985	2971	182	6349	3000	5000
Buff-throated partridge	3783	3622	1109	5252	3350	4600
Temminck's tragopan	2522	2324	509	4280	2500	2500
Tibetan partridge	3634	3738	529	5236	3600	4600
Tibetan snowcock	3975	4470	182	6499	3700	5800
Tibetan-eared pheasant	3643	3738	529	5159	2800	4600
Western tragopan	2326	2101	429	5202	2000	3600

Comparing BirdLife International range map with the range map created using point locality data

The geographic range sizes of all species within the Greater Himalaya, given as minimum convex polygons drawn around the locality data reveal range sizes from 39881 Km^2 for Himalayan quail (*Ophrysia superciliosa*) to 654139 km^2 for chukar (*Alectoris chukar*) (Table 2.7). Comparison of the MCPs generated by the locality data with the geographic range maps used in current conservation assessments (the BirdLife International range maps), reveals marked differences in geographic range estimates between the two.

The highest percentage of BirdLife International species range maps covered inside the minimum convex polygon (within the study area) was for rufous-throated partridge (*Arborophila rufogularis*: 81%) (See Table 2.7) and the lowest percentage was for koklass pheasant (*Pucrasia macrolopha*: 22%) (See Table 2.7). This suggest that for some species point locality data and the range map from BirdLife International are in high accordance while for some species there is a great disparity. A summary is given in Table 2.7. The BirdLife International range map area covered inside our range map was very small (see Figure 7 in Appendix) and it covered 20% to 80% of the MCP area (see Table 2.8). 20% to 40% of MCP area of eleven species is covered inside BirdLife International range maps, eight species have 41% to 60% area covered inside BirdLife International range maps and five species have 61%

to 80% area covered (see Table 2.8). No species have more than 80% of MCP area covered in BirdLife International range map.

For some species, a large number of point locality data (within study site) are found inside the BirdLife International species range map but only a smaller proportion of BirdLife International species range map was covered inside our range map (see Table 2.8 and Figure A.3 in Appendix). 15 species have 60% to 100% of point locality records within the BirdLife International range maps. For species like cheer pheasant (*Catreus wallichii*), chukar (*Alectoris chukar*), common hill partridge (*Arborophila turqeola*), rufous-throated partridge and snow partridge (*Lerwa lerwa*), the BirdLife International range map was almost as good as our range maps and covered almost all points from point locality data (see Figure A.2 in Appendix).

Table 2.7: Total number of point localities inside MCP and BL maps and % area of BL range maps covered inside the MCP range maps in the Greater Himalaya.

Species	Total no. of points in MCP	No. of points in BL map	No. of points outside BL map	BL area (Km^2)	MCP area (Km^2)	% area covered (Km^2) (MCP area – BL area)
Blood pheasant	304	229	75	139118	340362	41
Blyth's tragopan	62	52	10	56285	151316	37
Buff-throated partridge	46	45	1	93560	186173	50
Cheer pheasant	730	715	15	197098	594100	33
Chestnut-breasted hill partridge	61	39	22	65942	112578	58
Chukar	289	285	4	336110	654139	51
Common peafowl	93	46	47	109461	488878	22
Common quail	81	41	40	223202	652110	34
Hill partridge	258	255	3	400015	569975	70
Himalayan monal	723	583	140	367649	623716	59
Himalayan quail	16	0	16	1557	39881	39
Himalayan snowcock	140	102	38	221601	322102	69
Kalij	606	585	21	412971	609368	68
Koklass pheasant	537	405	132	141330	651561	22
Red junglefowl	247	150	97	241994	582146	41
Rufous-throated partridge	209	207	2	318939	391825	81
Satyr tragopan	324	298	26	98489	407429	24
Sclater's monal	73	66	7	104793	142454	73
Snow partridge	190	100	90	310070	614445	50
Temminck's tragopan	51	17	34	76887	143334	53
Tibetan-eared pheasant	63	55	8	32320	137054	23
Tibetan partridge	88	38	50	152923	441377	34
Tibetan snowcock	101	73	28	158612	411852	38
Western tragopan	625	201	424	16485	277128	59

Table 2.8: Percentage of point localities of each species and percentage of areas of BirdLife International range maps of each species covered inside the minimum convex polygon of each species.

Percentage (%)	Percentage of point data	Percentage of area
0-20	Himalayan quail	
21-40	western tragopan, Temminck's tragopan	blood pheasant, Blyth's tragopan, cheer pheasant, common peafowl, Himalayan quail, koklass pheasant, common quail, satyr tragopan, Tibetan partridge, Tibetan snowcock, Tibetan-eared pheasant
41-60	common peafowl, common quail, snow partridge, Tibetan partridge, red junglefowl	chukar, Himalayan monal, chestnut- breasted hill partridge, snow partridge, buff-throated partridge, Temminck's tragopan, western tragopan, red junglefowl
61-80	blood pheasant, Himalayan monal, Himalayan snowcock, koklass pheasant, chestnut-breasted hill partridge, satyr tragopan, Tibetan snowcock	hill partridge, Himalayan snowcock, Kalij, rufous-throated partridge, Sclater's monal
81-100	Blyth's tragopan, cheer pheasant, chukar, common hill partridge, kalij, rufous-throated partridge, buff-throated partridge, Tibetan-eared pheasant	

2.5 Discussion

Locality records over the years are an important conservation tool used in making informed decisions in conservation science. Applications of locality data range from revealing changes in species' population abundances and geographic ranges to assessments of extinction risk of species by the IUCN Red List of Threatened Species (McClenachan *et al.*, 2012). The GALLIFORM: Eurasian Database V.10 contains 35,900 records for 24 Himalayan Galliformes species of which 15,237 records are from within the Greater Himalaya and have been used in my thesis. These records encompass museum collections, references, and trip reports.

References contributed the maximum number of records (55%) followed by museum records (42%). The highest number of records from Himalayan countries is from India with a total of 6843 records constituting 3234 records from museum specimens, 3528 records from references, and 81 records from trip reports. The number of records documented increased after second half of the 19th century and marked a change in number of records increasing it from 46 records in 1850s to 201 records in 1860s. The majority of record searches were conducted between 1980s and 2007. The maximum number of records collected in a single year was in 2003 when a total of 387 records were documented.

Many geographic ranges are accumulations of localities over several decades and the number of recent records over a timescale that is meaningful in conservation terms (e.g. a decade) for some species is very small. This work highlights how challenging it is to provide regular assessments of known localities for a species across its global distribution. I found that the number of locality records documented were not consistent and varied substantially between species and through time. Not all species were documented in each decade which decreased the number of combinations of records per species per decade from 552 to 379 and I found that it was only during 1920s and 1990s when all 24 species were recorded. This is because Himalayan quail (*Ophrysia superciliosa*), which is a Critically Endangered species has not been seen in its habitat for years. Until mid-19th century, there were less than 50 records collected per species per decade and even after that there were only 88 species per decade combinations reported to have more than 100 records within a decade. This inconsistency in number of records collected through time makes it challenging to do the global assessment of a species for example, for the IUCN Red List assessment, species should be assessed in every 10 years but in the absence of records the assessment would be based more on assumptions. If there are no sampling biases and there is consistency in the number of records collected, then the comparisons of the assessment would be stronger and also the assessment would be based on fewer assumptions.

I found that most species have a wide altitudinal range. When information from point locality data was compared with information synthesised from published literature, I found that for some species, published information agreed well with point locality data e.g. blood pheasant (*Pucrasia macrolopha*). However, for other species, e.g. chukar (*Alectoris chukar*), there was poor agreement between altitudinal ranges. I also showed the possibility of finding species outside the range of altitudinal ranges as shown in Figure 4, which suggests that altitude information from localities in the database will allow much more focussed depiction of altitudinal ranges of species. This is important for conservationists as it will inform them using the most comprehensively described habitat of a species available when making conservation decisions.

On comparing MCP, which measures the extent of occurrence and is drawn using the point locality data with the BirdLife International range maps, measuring the extent of suitable habitat (ESH), I found that there is a difference in the number of locality data and the area of MCP and BL range maps. Since BirdLife International range maps uses the most up to date information and are used in conservation decision making, it was expected that the greatest concentration of records would be within the BirdLife International range maps if it reflects range well. It was also assumed that the area of the BirdLife International range maps would be similar to MCP. This disparity might be due to BirdLife International ESH being based on incorrect set of assumptions; the species in question having lost a part of its habitat; or because there are biases in recorder efforts.

Locality data has been used extensively in terrestrial and marine ecology to reveal substantial changes in the population size of a species and to provide a baseline against which present populations can be benchmarked (Pauly, 1995; McClenachan *et al.*, 2012). It has also been used to demarcate local extinction of a species, for e.g., the giant clam *Hippopus hippopus* was not known to have occurred in Fiji until the discovery of archaeological evidence suggested that this species once inhabited the Fijian reefs around 750 B.C., but was extirpated because of exploitation by humans (Seeto *et al.*, 2012).

Geographic range of a species is a key attribute in understanding its ecology (Gaston and Fuller, 2009) and is an important characteristic in determining its extinction risk (Purvis *et al.*, 2000; Ceballos and Ehrlich, 2002; Di Marco and Santini, 2015). The lack of availability of species occurrence records makes it difficult to assess the complete geographic range of a species and the inconsistency between numbers of records over different timescales makes it difficult to predict if our knowledge of the geographic range size of a species has improved. I explore this further in Chapter-3 of my thesis where using the point locality records from this database, I assess the completeness of our knowledge of species' range size and whether our knowledge has improved with time.

Considering the purposes to which geographic range information is utilised, this will allow a better understanding of the optimal altitude (within the interquartile range) and the altitude limits of species. This is important in understanding where conservation action might be most appropriate, and in understanding changes in the most important part of the species' altitudinal range. This could help in, for example, ensuring that Protected Areas are appropriately placed and in increasing the Protected Areas network in order to achieve the Convention of Biological Diversity's Aichi Target 11 (Diversity, 2011). Using the locality database GALLIFORM, Dunn *et al.* (2016) assessed if the Himalayan Galliformes are well protected under the current Protected Area network and found that the current Protected Area do not cover habitat of these species.

Despite having great potential in filling gaps in conservation science, the use of locality data presents some challenges. This includes reliability of source, robustness of the data, and if the reported data is subject to any biases (Thurstan *et al.*, 2015). Data collection is a tedious process and it is likely that the data collected can have some temporal and spatial biases (Boakes *et al.*, 2010).

Chapter 3. Assessment of knowledge of threats to Himalayan Galliformes

3.1. Abstract

Global biodiversity is at the risk of extinction and we are losing species faster than any other time. It is important to understand the threats that drive a species towards extinction and to address those factors. In this chapter, I assess our knowledge of the threats faced by 24 Himalayan Galliformes species by undertaking a systematic literature review to identify the threats reported in the published literature and the evidence supporting that the threat is having an impact on the species population. Only 40 papers were deemed suitable to be included in the study. I found that biological resource use and agriculture & aquaculture are the predominant threats to the Galliformes in the Greater Himalaya but the evidence available in the studies is quite poor as only two papers documented the impact on species. I also assessed if there is any correlate between the species habitat preference and their IUCN classification, I found that Least Concern species are found in higher altitude. This study shows that major gaps exists in our understanding of threats to the species and it is imperative to fill those gaps if we want to prevent the species from going extinct.

3.2. Introduction

3.2.1. Threats to species

Current rates of biodiversity loss are a threat to human existence (Rockström *et al.*, 2009; Steffen *et al.*, 2015) and if species considered at very high risk of extinction disappear, we will see extinction rates seen only five times in 540 million years (Barnosky *et al.*, 2011) (also see Chapter 1). The scale and nature of change to biodiversity is becoming clear, along with predictions of future losses. Globally around 75% of natural vegetation since the last ice age has been cleared by human activity (Ellis *et al.*, 2010). Deforestation to date in tropical forests projected to cause extinction of 18% of species by 2100 (Pimm and Raven, 2000; Ellis *et al.*, 2010; Pimm *et al.*, 2014). The clearing of forest patches has led to the fragmentation of habitats of many species, which further contributed towards the global biodiversity crisis, and there is increasing evidence that over the past 10 millennia, biodiversity has been profoundly transformed by human activities (Hoffmann *et al.*, 2010; Dulvy *et al.*, 2014).

There is sharply increasing political realisation of societal impact of deteriorating biodiversity (Griggs *et al.*, 2013; Guerry *et al.*, 2015) and this is encapsulated in a variety of multilateral environmental agreements (MEAs), most notably the Convention on Biological Diversity and the UN Sustainable Development Goals, national policies and strategies. The predominant factors behind species extinction and continual growth in both human population and increase in per capita consumption (Pimm *et al.*, 2014; Guerry *et al.*, 2015). These give rise to a variety of pressures that have direct consequences for species and the scale of these pressures is increasingly understood. For example, food webs are disrupted by eliminating top predators and other large animals (Ceballos and Ehrlich, 2002) and depleting predatory fish in the oceans (Myers and Worm, 2003)

Direct pressures on species stem from these two factors, and general patterns in their prevalence can be drawn from the IUCN Red List of Threatened Species (see Figure 3.1, which is taken from Maxwell *et al.*, (2016)). The most significant anthropogenic pressure is agricultural activity, with 62% (5407) of those species that are assessed as threatened or near- threatened are affected by crop farming, livestock farming, timber plantation, and/or aquaculture (Maxwell *et al.*, 2016). Overexploitation affects 72% (6,241) of species listed as threatened or near-threatened on the IUCN Red List of Threatened Species. Overharvesting of species for consumption by humans has been long considered to be a significant threat to many species (Fa *et al.*, 2003; Milner-Gulland and Bennett, 2003; Vié *et al.*, 2009; Wittemyer *et al.*, 2014) and changing hunting technology and an absence of alternative sources of protein (Bennett and Robinson, 2000) are thought to have resulted in increase in the exploitation of 'bush meat' and 'wild meat' in tropical forests (Milner-Gulland and Bennett, 2003). Some species may also be overexploited for non-subsistence purposes, such as commerce or recreation and there are many high profiles examples: Tiger (*Panthera tigris*), which is Endangered, is hunted illegally because of the high demand for its skin and bones. Often species are threatened by more than one threat, with the combined effects of overexploitation and agricultural activity having the greatest impacts on the biodiversity (Mace *et al.*, 2000; Peres, 2001). Together they are responsible for affecting 75% of all the species that have gone extinct since AD 1500 (Maxwell *et al.*, 2016).

Overexploitation of species leads to changes in population abundance at a site and potentially local extinction, and which may lead to national, regional or even global extinction. This can have a significant impact beyond the reduction and loss of the species itself. For example, removing species from habitats and ecosystems may lead to disruption of food web by eliminating top predators and other large animals (Ceballos and Ehrlich, 2002) or massively depletion predatory fish from oceans (Myers and Worm, 2003).

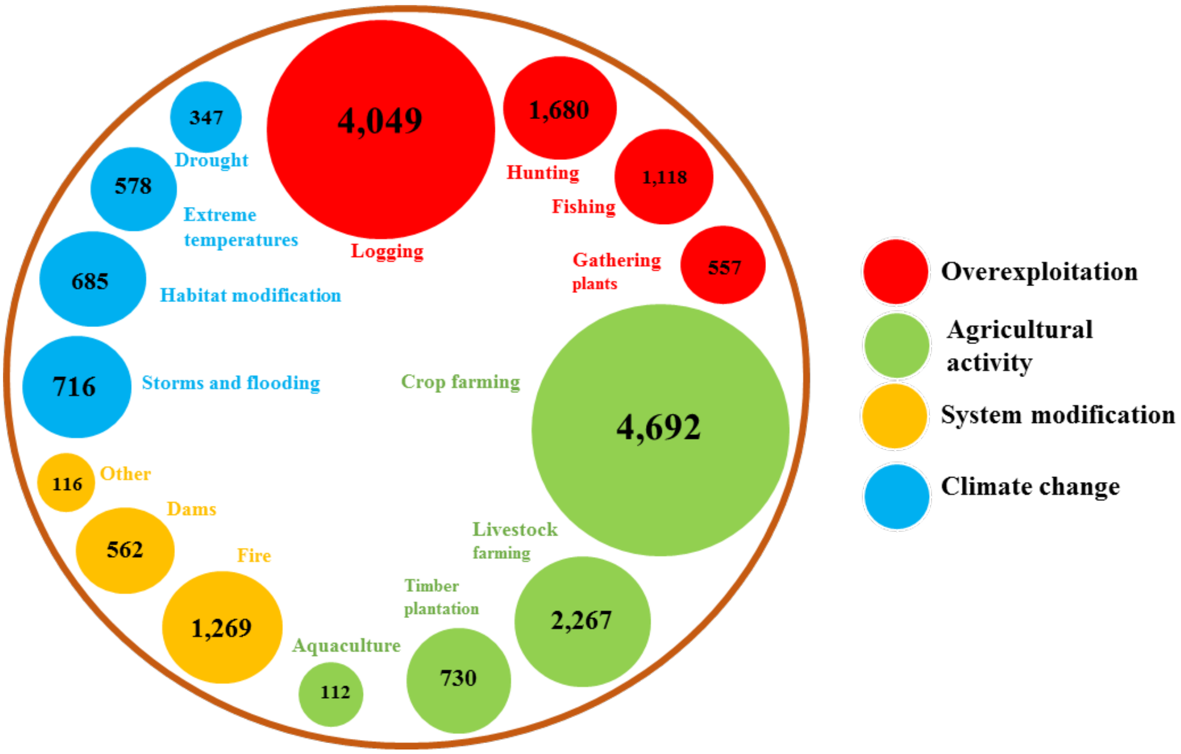

Figure 3.1: Types of threats and number of species affected by them.

Source: Maxwell et al., (2016). Also see: IUCN (2019a).

In the Figure 3.1 threats are classified under four major threat classes: overexploitation (red), agricultural activity (green), systematic modification (orange), and climate change (blue). Figures inside the circles represent the number of species affected by the individual threat. Overexploitation and agricultural activity are the most predominant threats faced by 8,688 threatened and non- threatened species assessed by IUCN Red List. System modification which includes fire, dams, and other affects 1,865 species and climate change is responsible for affecting 1,688 species. Most of the species are affected by more than threat and hence the number do not add to the overall number of the species. For example, 8,688 species are threatened by overexploitation but the number in red circles add up to more than 8,688. It is predicted that human induced climate change, such as increases in storms, flooding, extreme temperatures, and melting glaciers, will become an increasingly dominant threat to the biodiversity (Foden *et al.*, 2013). As consumption of natural resources by humans increases worldwide, the exploitation of fuel and fodder continues to rise. Energy consumption has also increased, which has led to more greenhouse gas emissions (Field *et al.*, 2012). Consequently, Earth's temperature has increased by around 0.74 °C in the last 100 years (Field *et al.*, 2012) and if there is no abatement in greenhouse gas emission, global temperatures may increase further by 0.3-4.8 °C in 21st Century (Stocker *et al.*, 2013). Given the precise climatic conditions required by many species, this raises the possibility that anthropogenic climate change could act as a major cause of extinctions (Pacifici *et al.*, 2015), having both direct impacts on species and mutually with other factors (Mantyka-pringle *et al.*, 2012; Stocker *et al.*, 2013). Nineteen percent (1688) of the species that are listed as threatened or near threatened on the IUCN Red List are affected by the climate change (Maxwell *et al.*, 2016) (see Figure 3.1).

3.2.2. Mitigating threats to species

All of this suggests that we have a strong general understanding of the overall pattern of the drivers and pressures that are affecting the conservation status of species. As our understanding of the consequences of species extinctions for both ecosystems and humankind increases, conservation efforts are increasing (e.g. the Convention on Biological Diversity as mentioned above, and the national policies that arise from it). Amongst the range of conservation measures that are proposed and that may make a difference to biodiversity, there is a clear need for planning for species conservation and this has received a significant amount of research attention over the last 10-15 years (Mair *et al.*, 2018). In order to halt the global loss of biodiversity, conservationists need conservation planning which can help them to allocate limited available resources for the conservation of threatened species (Clark *et al.*, 2002) and for the establishment of large-scale protected areas (Margules *et al.*, 2002). As the emphasis moves increasingly towards action for species, we need to be confident that the action we take will be truly effective in tackling the threats to species so that we see a positive change in the population status of those species that are the subject of the action.

In order to achieve Aichi Biodiversity Target 12, which is 'By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained' (CBD, 2010), we need to go beyond an understanding of the extinction risk of species (e.g. global or national Red Lists), a general understanding of pressures and their scale, and broad reviews (e.g. global or national) of the consequences of pressures for species to a detailed understanding of how to mitigate threats so that species do recover. In other words, we need to deepen our assessments of pressures and the conservation status of species so that know which threats have a documented impact on species' populations and that, when they are reduced they are likely to result in population increase.

This is important because pressures on biodiversity change as pressures may increase or decrease over time (and this may be over the short- or long-term) and new pressures emerge. As pressures change, the specific threats that they produce and the impacts that they have on species, and other elements of biodiversity, may vary as a result. So, when deciding on conservation measures in a given place at a given time, whether policy or legislation, management, or some other intervention, we do need to know that the action being taken should, or will, have a beneficial impact on species. In this Chapter, I explore what we know about threats to a group of 24 bird species, the Galliformes of the Himalaya.

3.2.3. The Galliformes of the Himalaya

Galliformes are important ecologically, economically, and culturally in the Himalaya and are one of the most threatened bird orders (McGowan and Fuller, 2006; Sathyakumar and Sivakumar, 2007) and yet, no study specifically examines all threats facing an entire taxonomic group within the Himalaya. Most studies to date have focussed on only a few species, and we need to be clear about the impact of a reported threat on the population of a species. In order to make optimal use of limited conservation resources, we need to know with as much certainty as possible what the threats are, where they occur, and whether there are any patterns in the type and distribution of threats for Himalayan Galliformes. This should then form the basis of targeted responses.

3.2.4. Human pressures and threats to the Himalayan Galliformes species

The threats outlined in the previous section all apply to Himalayan Galliformes and here I focus on some of the threats that have been mentioned in particular in the last two decades. Habitat loss and hunting are the main drivers that are believed to have imperilled the survival of many Asian bird species, including Galliformes (McGowan and Fuller, 2006) and this has been reflected in action plans developed by Specialist Groups of the IUCN Species Survival Commission for nearly 20 years (McGowan *et al.*, 1995; McGowan and Garson, 1995; Fuller *et al.*, 2000; Fuller and Garson, 2000a). There are many reasons behind deforestation, which is the main habitat that has been lost. Forests are destroyed primarily by logging, slash and burn shifting cultivation, expansion of agriculture, hydro-electric dams resulting in the submergence of large areas of habitat (Grumbine and Pandit, 2013), unplanned clearance for human settlement, encroachment by developmental activities, road and railway construction, large scale and unplanned bamboo harvesting for paper production and oil and coal mining (Choudhury *et al.*, 2007). Loss of winter habitats at lower elevations (Ramesh, 2007) and extraction of forest resources, logging and forest fires are also the drivers behind habitat loss (Lalthanzara *et al.*, 2014).

For many tribal countries all over the world, hunting of wild animals for sustenance has been a way of life. Hunting has become a severe global problem because of growing human populations (Bennett and Robinson, 2000), increased accessibility to remote forests and adoption of modern tools. Hunting of Galliformes species is mainly undertaken to supplement sources of animal protein and for the sale of meat and other body parts (Kaul *et al.*, 2004). Galliformes are characterized by large body size, ground dwelling habits and striking plumage.

All these characteristics make them even more vulnerable to hunting e.g. male Himalayan monal (*Lophophorus impejanus*) is hunted mostly because of its crest feathers, which are used in hat decoration, whereas koklass pheasant (*Pucrasia macrolopha*) and western tragopan (*Tragopan melanocephalus*) feathers were used in decorating clothes at least until 1980s (Gaston *et al.*, 1983).

Other potential threats include egg collection, disturbance during the breeding season (Ramesh, 2007), cattle and sheep grazing (Khaling, 1998), pesticides (Sathyakumar and Kaul, 2007) and climate change. Tourism activity (Lalthanzara *et al.*, 2014), lack of awareness (Lalthanzara *et al.*, 2014), collection of medicinal plants and '*guchhi*' (*Morchella escluenta*: an edible mushroom) (Jolli and Pandit, 2011a) and loss of broods due to forest fires (Bisht *et al.*, 2007) have also been claimed to affect Galliformes species' populations.

There is a need to understand what is really known with as much certainty as possible rather than assumed, about the impacts of threats on species that are poorly known. Where there is no firm information on how threats are affecting species and what is needed to address the threats, we need to structure our predictions logically and transparently (e.g. Grainger *et al.* (2018)). Developing our understanding of what may be threatening Galliformes in the absence of firm evidence that documents that a threat is resulting a population decline requires careful thought. One possibility is to review the habitats that species that have been assessed for their risk of extinction (i.e. their IUCN Red List status) and determine whether there are patterns that might inform conclusions about threats and suggest where conservation interventions would be most beneficial. This would help make conservation responses logical and transparent in as much as it would be clear that conclusions about the impact of threats are being inferred from other information.

In this Chapter, I seek to understand our knowledge of the threats facing Himalayan Galliformes. I do this by; 1) providing the status of species from the IUCN Red List of Threatened Species2) undertaking a systematic literature review to identify the threats reported in the literature and the evidence supporting them; and 3) assessing if there are any correlates between species' habitat preferences and the IUCN Red List category. Thus, my aims are two-fold: first to collate and assess the existing information on threats from a variety of sources; and second, to link threat types to species' habitat preferences.

3.3. Methods

3.3.1. IUCN Red List conservation status

The conservation status of 24 Himalayan Galliformes was collated from the IUCN Red List of Threatened Species (IUCN Red List 2016).

3.3.2. Assessing published knowledge of threats to Himalayan Galliformes

Search engine and search terms

Searches were undertaken on Web of Science and Google Scholar for research articles that included potential threats to Galliformes in the Himalaya. Search terms were selected to increase the possibility of obtaining relevant articles on all potential threats. The main aim of the literature search was to glean information on possible on factors thought to be causing declines in Himalayan Galliformes species in the Himalayan region, and what evidence existed for these factors actually causing declines in species' populations. The term 'Galliformes'tends to be used in keywords of papers, if not in the paper themselves, to describe the taxonomic group to which each species belongs: I am confident that the majority of, if not all, relevant papers have been found.

Web of Science was searched for terms 'TS = (Galliformes* and Himalaya*)', 'TS = (Galliformes* and conservation*)' and 'TS = (Galliformes* and threat*)'. For grey literature, Google Scholar was also searched for 'threats to Galliformes in Himalaya' as Web of Knowledge does not include those papers.

Articles from 'Proceedings of the 3rd International Galliformes Symposium, 2004' (Fuller and Browne, 2005), which was a CD-ROM and so the articles not easily indexed, were also screened.

Papers from Environmental Sciences/Ecology fields were searched for inclusion in the study since there was an overlap of research articles in other fields. These fields have been identified in the Web of Science database, but Google Scholar does not provide these fields to narrow down the search results. Searches were made across all years and the language search criterion was set to include papers in English.

Criteria for inclusion in study

All papers were screened on the basis of titles and abstracts. Articles that reported threats to Galliformes in the Himalayan region were deemed appropriate and were included in the study. Articles that dealt with other species, were outside the region, or covered other topics such as genetics were discarded, see Figure 3.3 for process.

3.3.3. Definitions used in classification of quality of documentation of threats

Papers were assigned to one of four categories according to the evidence that the paper provides for each threat actually affecting the population of the species being studied. The four categories were:

a) Unsubstantiated Assertion: A study has been categorised as ‘unsubstantiated assertion’ when a threat has been reported as a probable factor in driving a species towards its decline, but the threat has not been documented in the study site. In other words, if a threat has been reported to cause decline of at least one species but this was not substantiated with evidence that the threat exists in the study area.

b) Threat Documented: A study is allocated to this category when a threat has been documented but there is not enough evidence to show that the threat is causing a decline in species’ numbers. For example, if it is shown that hunting occurs in an area but it is known shown that the species’ population is changing.

c) Impact Inferred: A paper has been categorised as ‘impact inferred’ if it shows that a threat does exist and then suggests that the threat has an impact on a Galliformes species, but it does not provide evidence to show what that impact is in the paper. For example, a paper may provide evidence that a particular species is hunted for its meat or other body parts, but how this affecting the population of a Galliformes is not shown, but rather it is inferred.

d) Impact Documented: A study has been classified as ‘impact documented’ when there is direct evidence to show that the population has declined due to a reported threat.

3.3.4. Classification and reporting of threats

Threats identified in the research papers included in the study were classified based on Level 1 categories of the International Union for Conservation of Nature-Conservation Measures Partnerships Unified Classification of Direct Threats (IUCN CMP, 2019) (see Table 3.1). The level 1 categories in the IUCN threat classification are: biological resource use, agriculture & aquaculture, natural system modifications, residential, transportation and service corridors, human intrusion and disturbance, pollution and others. The papers found during the literature survey were nearly all published before the Classification of Direct Threats was finalised and so they did not report threats using the terminology of the level 1 categories of IUCN threat classification. The way that the papers reported each threat to a species made it straightforward to classify the threats in one of the Level 1 categories. For example, Aiyadurai (2011) reported hunting as a threat to the Galliformes in the Himalaya and according to the IUCN-CMP (2019) is a sub-level classification under Biological Resource Use.

Table 3.1: IUCN- CMP unified level 1 classification of direct threats (IUCN CMP 2019)

Level 1 classification of threats	Examples
Residential & Commercial Development	Threats from human settlements or other non- agricultural land uses with a substantial footprint
Agriculture & Aquaculture	Threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture and aquaculture (includes the impacts of any fencing around farmed areas)
Energy Production & Mining	Threats from production of non-biological resources
Transportation & Service Corridors	Threats from long narrow transport corridors and the vehicles that use them include associated wildlife mortality
Biological Resource Use	Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species
Human Intrusions & Disturbance	Threats from human activities that alter, destroy and disturb habitats and species associated with non-consumptive uses of biological resources.
Natural System Modifications	Threats from actions that convert or degrade habitat in service of “managing” natural or semi-natural systems, often to improve human welfare
Invasive & Other Problematic Species, Genes & Diseases	Threats from non-native and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance
Pollution	Threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources
Geological Events	Threats from catastrophic geological events
Climate Change & Severe Weather	Threats from long-term climatic changes which may be linked to global warming and other severe climatic/weather events that are outside of the natural range of variation, or potentially can wipe out a vulnerable species or habitat
Other Options	The threats classification scheme is intended to be comprehensive, but as there are often new and emerging threats, this option allows for these new threats to be recorded

3.3.5. Species habitat preferences and the risk of extinction

I created a matrix of species by their habitat preferences based on literature published (McGowan, 1994). Although this account of the Phasianidae is now 25 years old, it did review knowledge comprehensively. In the following decade further field studies were carried out but few provided information that would update information that I have extracted to use here. A Principle Component Analysis (PCA) was conducted to assess the relationship between the species' preference for their habitat and their IUCN Red List category. The analysis was undertaken using the VEGAN Package (Oksanen, 2015) in R. Two plots were created from this, with one showing the relationship between habitats, such that habitats close to each other had similar species of Galliformes, and the second showing a plot of species where species close to each other were found in similar habitats. To aid the interpretation of the species plot, I assigned different colours to each species depending upon their IUCN threat category.

3.4. Results

3.4.1. IUCN Red List conservation status

Of the 24 Himalayan Galliformes species, 16 species are listed as Least Concern (LC), two species are listed as Near Threatened (NT), five species are Vulnerable (V) and one species is Critically Endangered (CR) (See Figure 3.2).

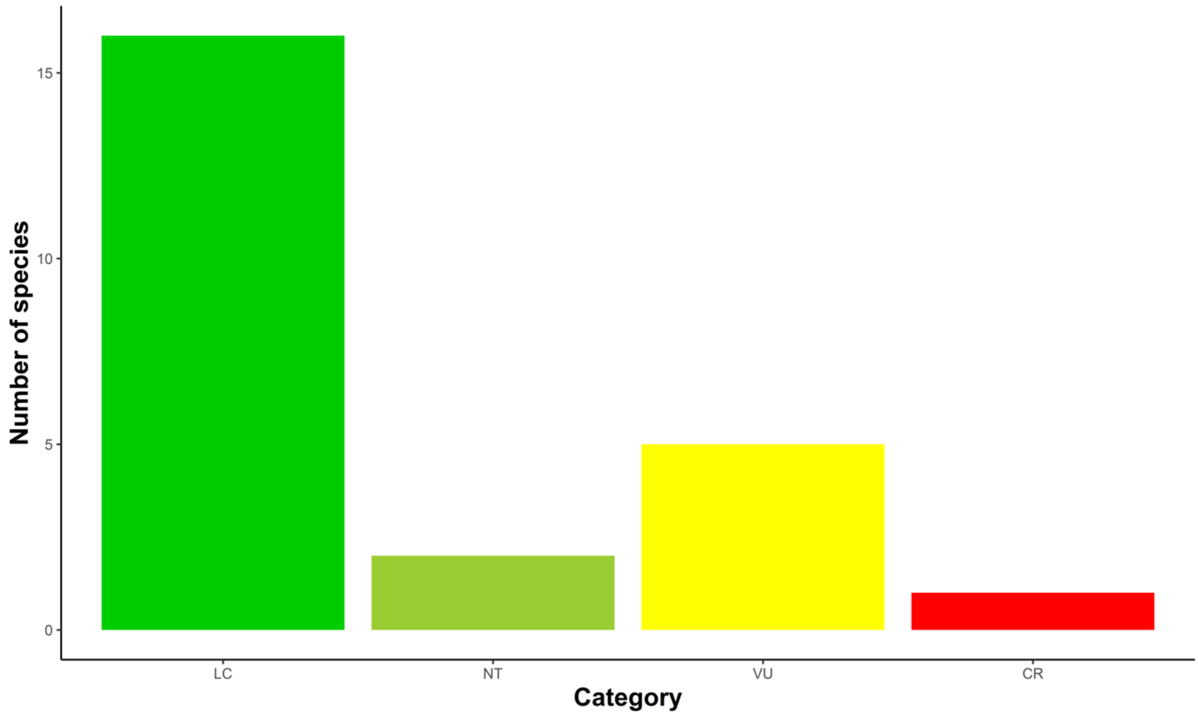

Figure 3.2: Number of Himalayan Galliformes species by their global extinction status.

LC = Least Concern, NT = Near Threatened, VU= Vulnerable, CR = Critically Endangered.

3.3.2 Total number of records and articles included in study

The total number of papers identified by searching the Web of Science for "TS = (Galliformes* and Himalaya*)" was 125. Similarly, the total number of hits returned by searching for "TS = (Galliformes* and conservation*)" and "TS = (Galliformes* and threats*) were 2033 and 275 respectively. Google Scholar returned 365 records when the term "threats to Galliformes in Himalaya" was used. Our search of relevant publications yielded 31 studies. There were many duplicate papers when databases were searched using different terms, which resulted in fewer articles included in the study. Another nine papers were included from "Proceedings of the 3rd International Galliformes Symposium 2004" (Fuller and Browne, 2005). (See Figure 3.3 for detail).

The searches returned a total of 2797 unique references of which only 31 (2.1%) met the inclusion criteria and were consequently included in the study. Approximately 98% (2740) references were excluded as they did not fit the inclusion category and were, for example based on genetic and molecular studies, which has no relevance to the current study. There were also duplicate papers when different terms were searched on Web of Science and Google Scholar, which resulted in fewer papers included in the present study.

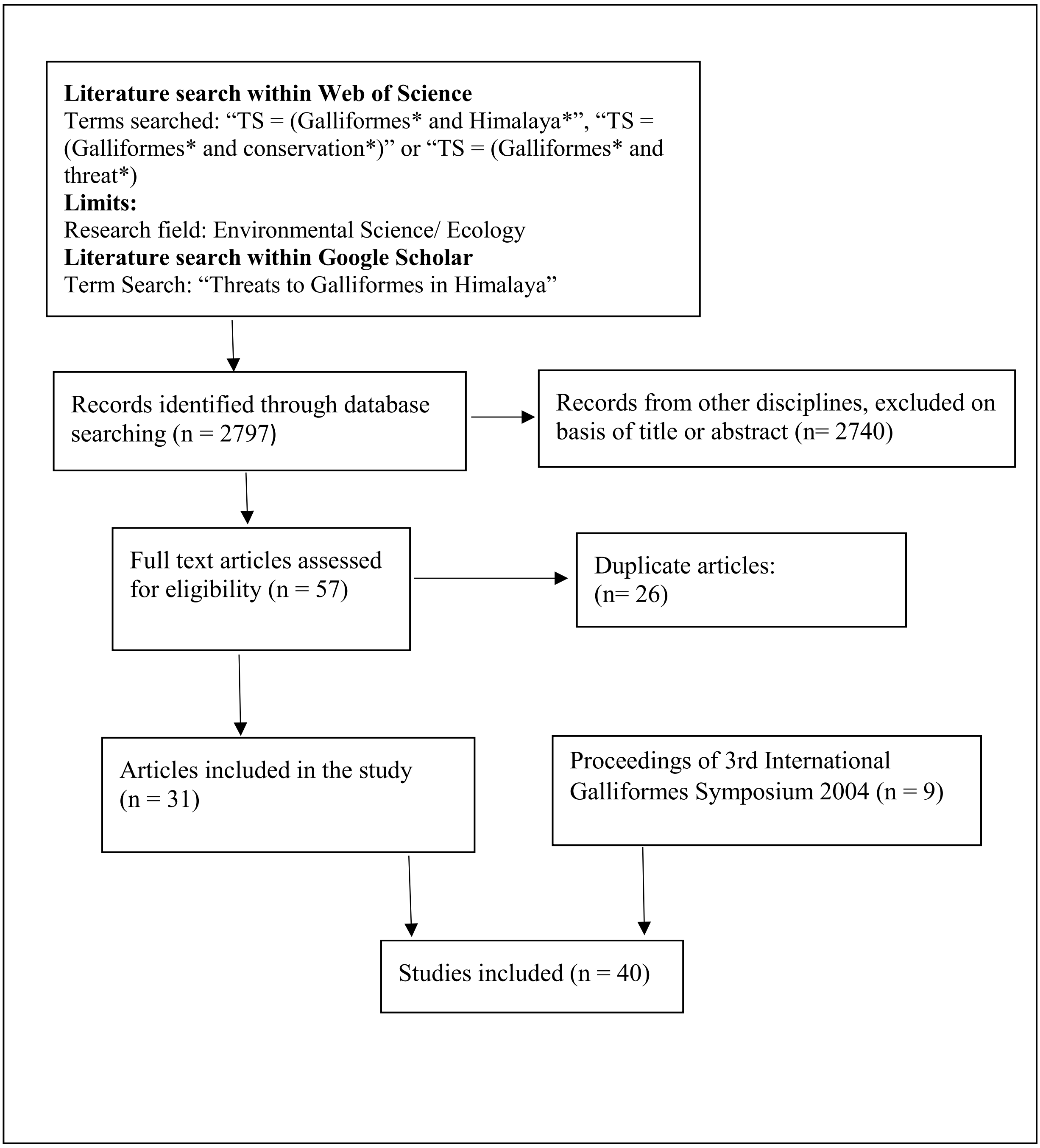

Figure 3.3: PRISMA flow diagram of literature search, based on Liberati et al. (2009); see also Bolam *et al.* (2018).

3.3.3 Species for which threats have been reported

Some studies are based on more than one species and approximately 53% of papers, were not based on a particular species. These papers reported threats either for all Galliformes species in Himalayan region or were based on Himalayan pheasants in general. Out of 24 Himalayan species, only eight species; Blyth's Tragopan (*Tragopan blythii*), cheer pheasant (*Catreus wallichii*), chukar partridge (*Alectoris chukar*), Himalayan monal (*Lophophorus impejanus*), kalij (*Lophura leucomelanos*), koklass pheasant (*Pucrasia macrolopha*), satyr Tragopan (*Tragopan satyra*), western tragopan (*Tragopan* *melanocephalus*) were documented in studies with just one paper each on Himalayan monal, koklass pheasant, and kalij (see Figure 3.4).

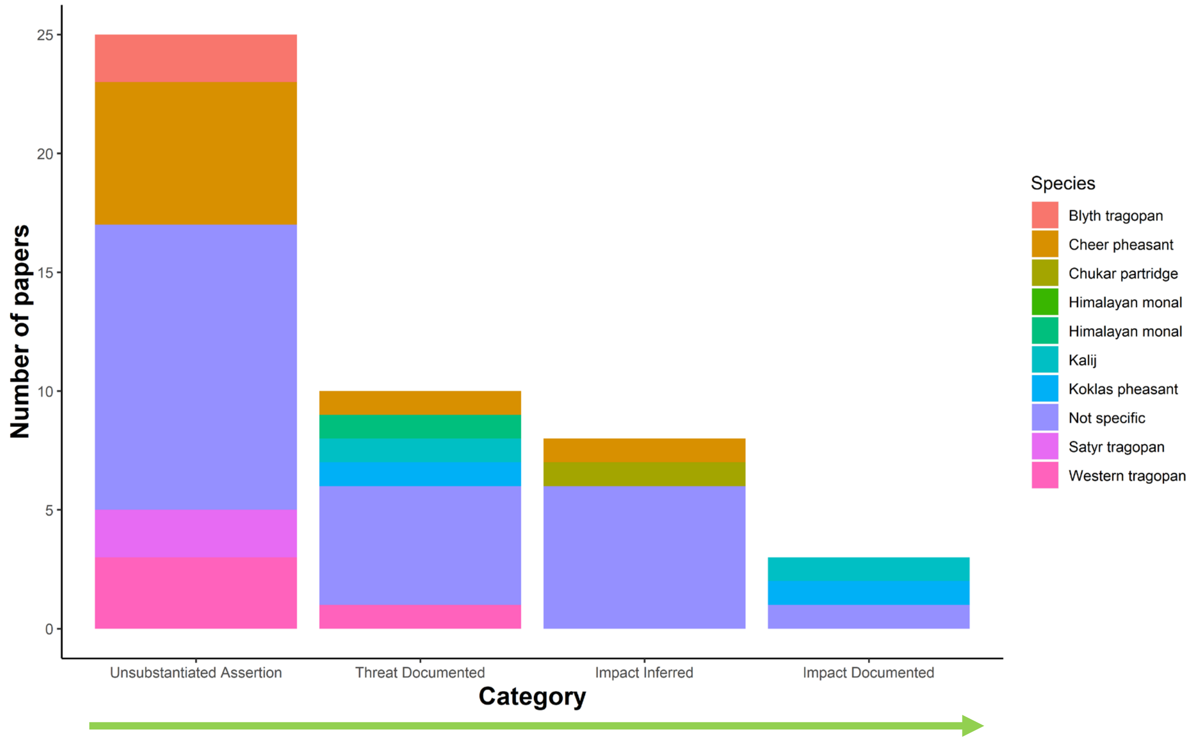

Figure 3.4: Number of studies on each species and the quality of documentation of threats.

Out of 24 Himalayan Galliformes species, papers included in this study are based on eight species others are based on Himalayan Galliformes in general. Western Tragopan (*Tragopan melanocephalus*) and cheer pheasant (*Catreus wallichii*) have been studied most of all the eight species that have been documented. Green arrow below plot shows the gradient from poorest quality documentation to highest quality documentation.

3.3.4 Quality of threat reporting

Papers were assessed for the quality of threat reported and 39 out of 40 papers classified threats as one of the four classifications used in the study. One paper reported hunting as a threat to Himalayan monal (*Lophophorus impejanus*) based on evidence (impact documented) and made an unsubstantiated assertion for a threat affecting western tragopan (*Tragopan melanocephalus*). This increased the total number of threats reported from 40 to 41. Of the 40 studies identified, just 4.87% (two papers) actually reported threats to Galliformes as having an impact on a population (see Figure 3.5). Wang *et al.* (2008) and Hilaluddin *et al.* (2012) reported habitat degradation as having an impact, and reported hunting as a problem to the kalij and koklass pheasant in the western Indian Himalaya. More than half (approximately 61%) i.e. 25 papers included in the study were based on unsubstantiated assertions.

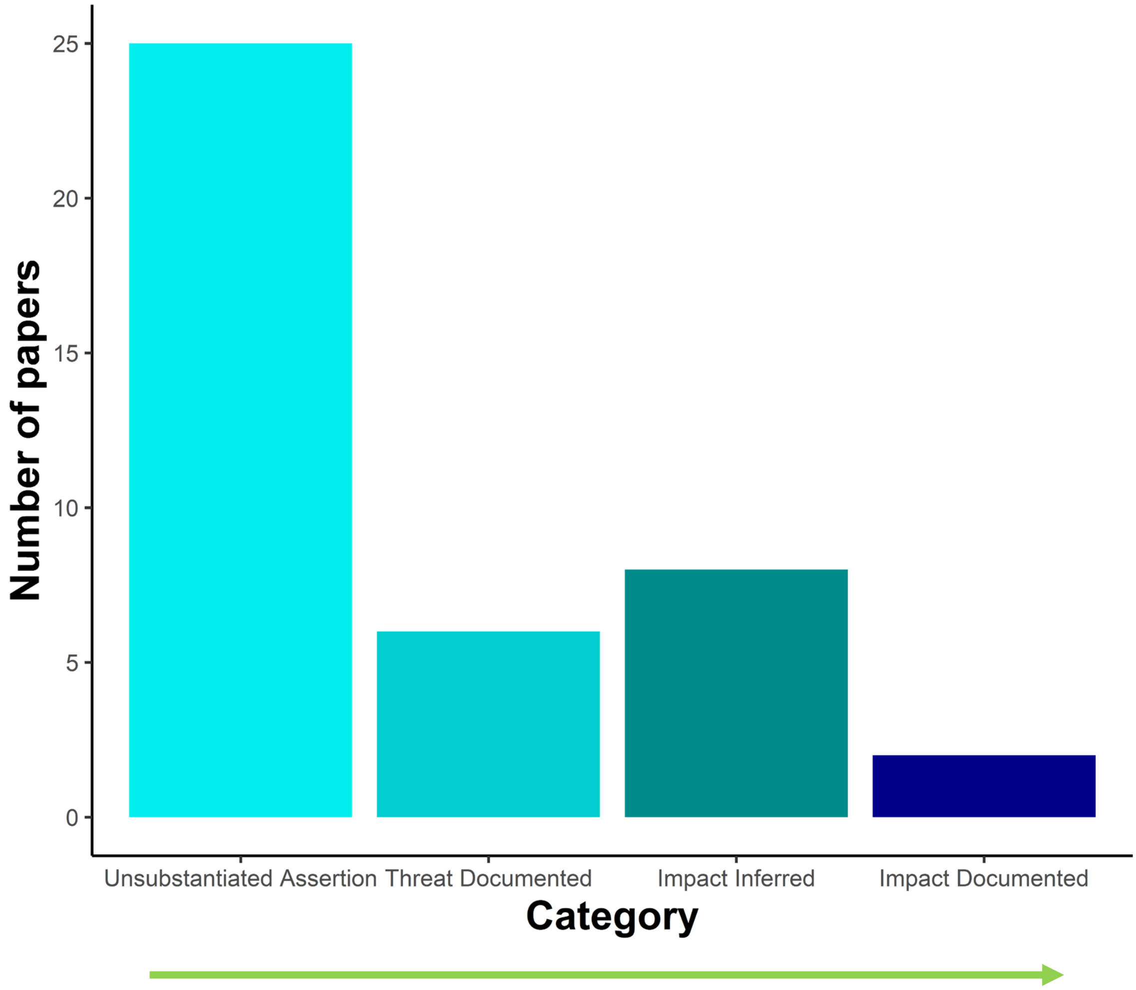

Figure 3.5: Quality of threat reported in papers based on the four different category.

Green arrow below plot shows the gradient from poorest quality documentation to highest quality documentation.

3.3.5 Reported threats

Twenty-three papers reported more than one threat to the Galliformes in the Greater Himalaya, the total number of research papers included in the study increased from 40 to 81. For example, Wang *et al.* (2008) reported Biological Resource Use, Residential & Commercial Development, and Transportation & Service Corridors as threats to the pheasants in the Trans-Himalaya, China and hence the number of "Impact Documented" papers increased from two to five (see Figure 3.6).

Biological Resource Use (see Table 3.1) which included hunting, logging and collecting terrestrial plants and animals was claiming to be the greatest threat to Galliformes in the Himalaya. 35 papers reported Biological Resource Use as a potential threat to Himalayan Galliformes. Out of 35 papers, only 5.7% (two papers) had Biological Resource Use as an impact documented, while the majority of them were based on unsubstantiated assertions.

Agriculture and Aquaculture was reported in 19 papers, out of which only one was based on the threat being reported and rest all were unsubstantial assertion. One paper out of total of 40 reported use of herbicides in agricultural activities as a probable threat to some Galliformes species, part of IUCN-CMP (2019) pollution category.

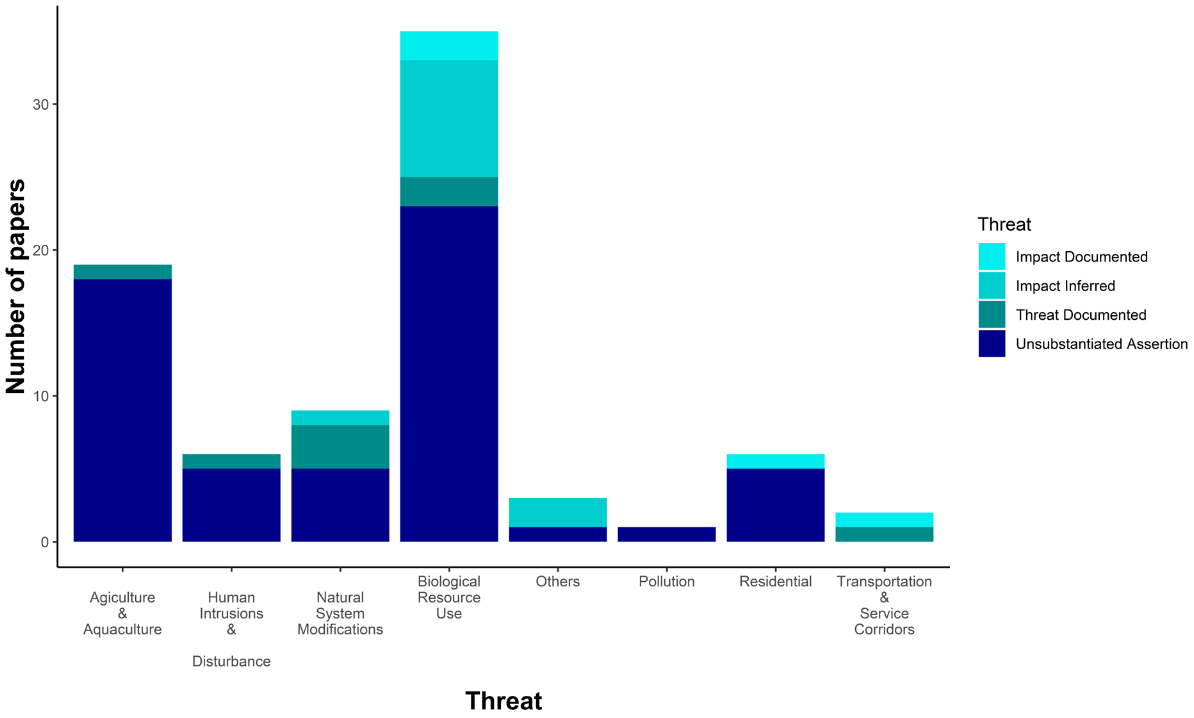

Figure 3.6: Different types of threats reported in research papers included in the study and the quality of documentation of threats.

3.3.6 Habitat and risk of extinction?

PC1 (x-axis) explains 29.87% of the variation (Eigen value= 0.5801) and shows a trend from closed habitat as low PC1 scores through to open habitat with high PC1 scores. PC2 (y-axis) explains 22.2 % of the variation (Eigen value= 0.4236) and shows a trend from low altitudes with low PC2 scores through to high altitudes with high PC2 scores (see Figure 3.7 & 3.8). Red junglefowl (*Gallus gallus*) has wide distributions and was also found in mangroves habitats, but this was not relevant to the Himalayan study region and occurred at the centre of the PCA plot (0, 0).

Where species are close to each other on the PCA plot, it indicates that they have similar preferences for habitat for e.g. common hill-partridge (*Crossoptilon harmani*), Indian peafowl (*Pavo cristatus*), and Himalayan quail (*Ophrysia superciliosa*) have almost the same habitat preference and they inhabit open habitats at lower altitude (see Figure 3.8). My analysis shows that on PC1, most of the Least Concern species (green in colour) prefer open habitats at higher altitudes e.g. buff-throated partridge, Himalayan snowcock, snow partridge, Tibetan snowcock etc. whereas threatened species such as cheer pheasant, chestnut breasted hill partridge, Blyth’s tragopan, Himalayan quail etc. have similar requirement for closed habitats at lower altitude.

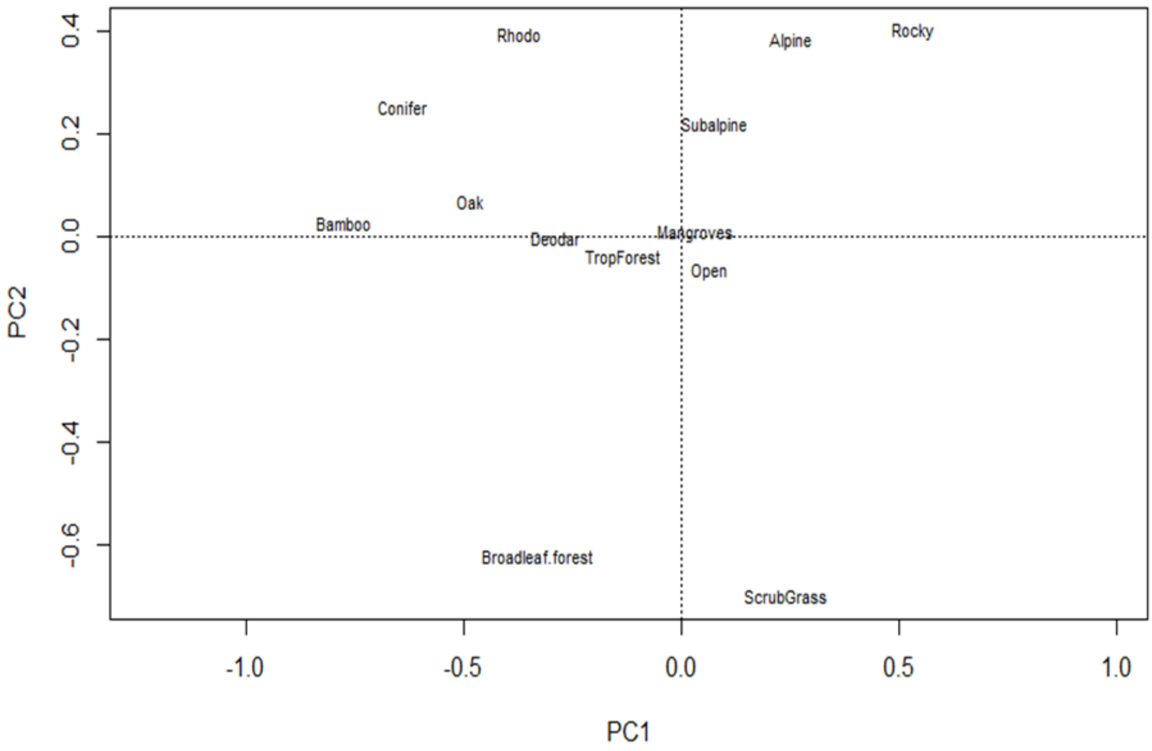

Figure 3.7: Habitat scores for different habitats preferred by Himalayan Galliformes species.

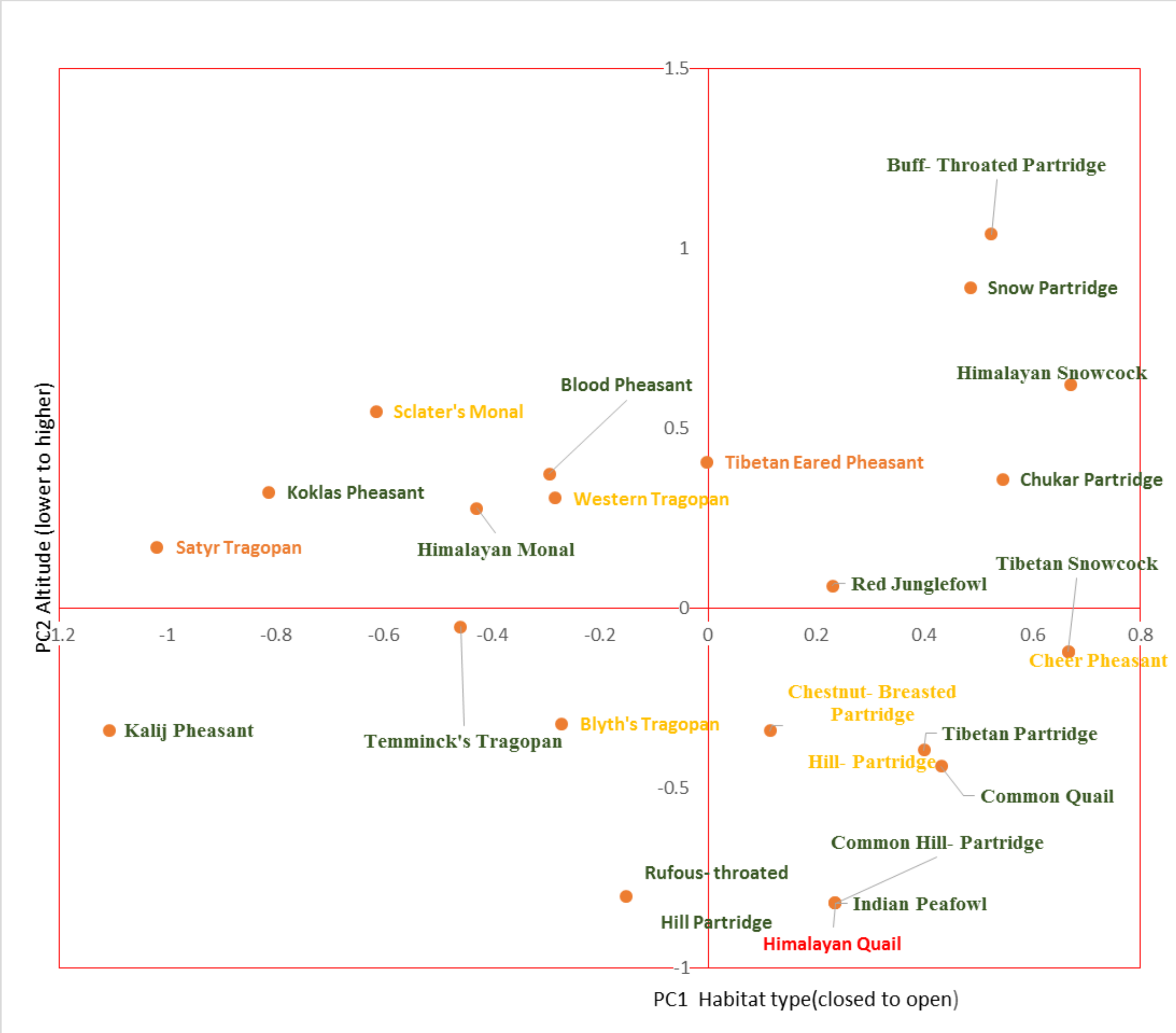

Figure 3.8: Principal Component Analysis (PCA) of habitat preferences of Himalayan Galliformes.

3.5. Discussion

Conservation decisions are difficult to make because our knowledge of the natural world is imperfect and the impact of our actions upon it are uncertain (Bolam *et al.*, 2018). Also, it is not easy to predict the impact of human actions on each species, and at the same time, it is challenging to assess where and how to act in order to have the most significant conservation benefit in the long term (e.g. Grainger *et al.* (2018)). In this study, 'only' 40 papers were found that reported a threat to the Galliformes in the Greater Himalayan region. Of the 40 papers more than half of the papers referred to Galliformes as a group rather than identifying threats for individual species. Whilst 35 papers stated hunting as a threat to Himalayan Galliformes species, there were clear knowledge gaps, as only two papers had firm, documented evidence that threat was having an impact on a population. In contrast 21 papers had no evidence that the threat was reported and no firm evidence offered that it was operating in the area studied. Most of the Least Concern species inhabit open habitats at higher altitude, whereas threatened species prefer closed habitats at lower altitude.

In spite of being a highly threatened group of birds with 25% of the 308 Galliformes species threatened with extinction (McGowan, 2002; IUCN, 2016; Grainger *et al.*, 2018), the group remains understudied. With only 40 papers documenting impacts of threats on a Galliformes species, it reflects how incomplete our knowledge is on the threats that are actually causing population declines. It might be that either we need more research in the Himalayan area to study human pressures on the species, or we need a shift in the way studies report and examine threats.

Hunting & poaching, which is classified under Biological Resource Use (see IUCN CMP threat classification scheme IUCN CMP, 2019), was found to be the predominant reported threat with 35 papers reported hunting as a threat to Galliformes in the Greater Himalaya. Even though hunting and poaching is prohibited in many countries, still many species are hunted for their body parts and meat. Many tropical areas suffer from hunting that can have profound impacts on biodiversity, which can then affect food webs and ecosystems (Milner-Gulland and Bennett, 2003; Bennett *et al.*, 2007; Wright *et al.*, 2007). Although, wildlife in Asia has been undergoing rapid declines in their geographic range and population, there are relatively few studies that have documented the actual impact of hunting as a problem for a species (O'Brien *et al.*, 2003; Steinmetz *et al.*, 2006; Corlett, 2007). Thus, there is often not enough evidence to understand the significance of hunting in the decline of individual species. I found that of the 35 papers that reported hunting as a threat to the Galliformes in the Greater Himalaya, only two papers (5.7%) had threat as impact documented whilst others were based on unsubstantiated assertions i.e. there was no evidence to prove that hunting is a threat to the Galliformes.

Galliformes, being an important source of protein are hunted to varying degrees throughout their geographical range. Hunting and poaching of animals is illegal in many countries and this might be one of the reasons behind lack of evidence on hunting in the Himalayan area. People might not be open about the prevalence of hunting of the animals in the region, as they might be afraid of being caught and penalised for their actions.

Species preferences for their habitats can also make them susceptible to the human pressures, as it was found that species that are most threatened with extinction, were found at lower altitudes and non-threatened species generally inhabit higher altitudinal regions. For example, cheer pheasant, which is a Vulnerable (V) species, has habitats in close proximity to human settlements (Garson *et al.*, 1992) , which makes it vulnerable to the disturbance from human activities and easy to hunt, whereas Himalayan monal, a Least Concern (LC) species prefers habitats at higher altitudes, which is not easily accessible by humans.

Climate change is expected to have far- reaching impacts on the species' extinction rates. Foden *et al*., 2013 indicated that by 2050, 6-9% (670- 851) of bird species will be highly vulnerable to climate change. Since, several Himalayan Galliformes species appear to be altitudinal migrants, inhabiting higher elevations in the summer as the temperatures increase and lower elevations in the winter as temperatures decrease, climate change can have a profound effect on altitudinal migration of the species. Also, multivariate analysis show that non- threatened species prefer high altitudes which means that if the temperature goes up, the non- threatened species' habitat might be affected leading them to extinction. There might be some positive effects of climate change on threatened species, which prefers to stay at lower altitudes and in close proximity with humans. With increase in temperature, these species might move at higher altitude and will not stay close to the human settlements, which can make them less susceptible to hunting. This might have its own repercussions though. With lower altitude species moving to higher altitude, it might force people to follow them, which can put other non- threatened species at risk.

There is a need therefore to understand the threats to biodiversity, regions where risks occur, the rate and the intensity at which the threat is changing, and the most appropriate actions to address them in order to assess the reducing rates of loss of biodiversity and to achieve environmental goals (Geldmann *et al*., 2015). We can achieve this by focussing our studies on studying threats in areas with high biodiversity and high human pressures or there might be enough studies on threats, but we might need to change the way the studies are designed and reported.

In conclusion, this study has shown that major gaps exist in our knowledge on threats to species that can lead to extinction of species and it is imperative to fill these gaps if we are to achieve the Convention on Biological Diversity's Aichi Target 12 of halting species extinction and improving the status of the declining threatened species.

Chapter 4. How well do we know Himalayan Galliformes species' range sizes? (Published as "A simple method for assessing the completeness of a geographic range size estimate" in *Global Ecology and Conservation*)

4.1. Abstract

Understanding geographic ranges is a fundamental part of ecology and species conservation. It is used as a criterion by the IUCN Red List of Threatened Species in categorizing species extinction risk. The decline in geographic range of a species can also help us in understanding the response of a species to anthropogenic disturbances. Knowing where a species occurs is also prerequisite to know if we are to prioritize areas to conserve areas of particular interests to biodiversity in order to achieve Aichi Target 11. It is important, therefore, to know if our understanding of species' geographic ranges is adequate for these purposes. We explore the construction of geographic range sizes for a suite of species using a large and near-exhaustive dataset of localities. Specifically, we describe the geographic range size of those species and assess whether our knowledge of their ranges is complete or not. We use data extracted from an extensive database of point locality records for 24 Himalayan Galliformes species, which are highly threatened bird species from the avian Order Galliformes. Explicitly, we examine the pattern of accumulation of information on a species' range over time and compare this with a null model. We found that our knowledge of the geographic ranges of this group of species is good and the knowledge has improved more rapidly than expected by chance.

4.2. Introduction

The geographic distribution of a species is fundamental to understanding its ecology and conservation needs, and there has been much research analysing the spatial occurrence of biodiversity (Gaston, 2000; Myers *et al.*, 2000b; Hawkins *et al.*, 2003; Koleff *et al.*, 2003; Orme *et al.*, 2005; Naidoo *et al.*, 2008). Geographic range size plays a prominent role in categorizing species according to their short-term likelihood of extinction, including listing on the IUCN Red List of Threatened Species (Gaston and Fuller, 2009), as well as how their distributions may change in response to anthropogenic perturbations such as habitat loss (Channell and Lomolino, 2000; Ceballos and Ehrlich, 2002) and climate change (Parmesan and Yohe, 2003; Thomas *et al.*, 2004). Small absolute range size, or rapid declines in range size can indicate a high risk of imminent species extinction, because species with small ranges are more vulnerable to stochastic threats than species with widespread distributions, and declining geographic range can lead to population reductions (Bland *et al.*, 2016).

It therefore follows that knowledge of species distributions influences conservation efforts at all scales (Margules and Pressey, 2000; Whittaker *et al.*, 2005). Knowing where a species occurs is important as it allows conservationists to make an accurate assessment of threats for individual species. It also allows us to understand global patterns of biodiversity in relation to threats (Joppa *et al.*, 2016), which enables conservationists to identify how best to ameliorate threats and to target conservation actions. The distributions of species are also commonly used to determine coverage of protected areas, and to inform the placement of new protected areas (Venter *et al.*, 2014; Watson *et al.*, 2014; Butchart *et al.*, 2015).

There are different ways of describing geographic ranges (Gaston and Fuller, 2009), but all methods rely on accurate and unbiased information about species distribution. Our knowledge of species distributions is ultimately generated from field records of individual taxa often collected for reasons far removed from those for which they might be used for in macro-ecological or applied conservation analyses. Such data collection is labour intensive, requires a high level of expertise, and is expensive. Consequently, only a very small proportion of the planet has so far been covered by systematic spatial surveys (Price *et al.*, 1995; Hagemeijer and Blair, 1997), and the comprehensiveness of distributional data varies spatially and temporally with factors such as observer effort, taxon detectability and ease of identification (Bibby *et al.*, 2000; Boakes *et al.*, 2010).

There is a potential for much of the information used in large scale spatial analyses to be biased, particularly for tropical species, where species richness is very high, and taxonomy poorly known. For example, no tree species has been accurately mapped in the Amazon basin, and there are significant known taxonomic biases in estimates of species' range sizes (Pitman *et al.*, 1999; Ruokolainen *et al.*, 2002). If such biases are widespread across taxa and regions, spurious patterns may arise in large scale analyses such as those described above. Despite the improving knowledge and availability of data sets on a wide range of species, our understanding of species' geographic distribution remains inadequate (Whittaker *et al.*, 2005; Rondinini *et al.*, 2006; Jetz *et al.*, 2012) .

Here, we develop a framework for testing the efficiency of our sampling of species' ranges that could in principle be applied to any spatial dataset prior to conducting large scale analyses. The underlying principle of the modelling framework is that we gain more information about the distribution of individual species the more effort we spend surveying, but that other thing being equal, the information gained will eventually asymptote as we move towards a position of perfect knowledge. In this case the more records we have of an individual species, the more likely we are to get a more complete picture of the distribution. In the absence of systematic sampling we assume that knowledge about the distribution will accrue with time as records are made opportunistically. In effect we expect that the overall total area of the distribution will be asymptotically related to the number of records. If this is indeed the case, then it is a straightforward matter to assess the extent to the estimated area it reaches an asymptote with the number of records or if data collection is opportunistic with year.

Distribution data for Galliformes were analysed here, but we emphasise that the method is generally applicable. Specifically, we explore the geographic range sizes of 24 Himalayan Galliformes using a large and near-exhaustively collected dataset of localities up until 2007 to assess the completeness of our geographic range size estimate. The analysis was restricted to the species found in the Greater Himalayas as the region is rich in biodiversity (Singh, 2006) and it is also a target for expansion of protected areas (Venter *et al.*, 2014). Largely restricted to forested habitats, most Himalayan Galliformes are severely affected by hunting and habitat loss, and many are declining (Fuller and Garson, 2000a).

Ultimately, we will never know the "true" range size of any species. Instead, we suggest examining the pattern of accumulation of information on a species' range over time and comparing this with a modelled estimate. Here we test: a) the completeness of our knowledge of species' range size; b) whether our knowledge of the geographic ranges of this group of birds has improved more rapidly than expected by chance; and c) whether this improvement has accelerated toward the present.

4.3. Methods

4.3.1. Bird records

The point locality data were extracted from the GALLIFORM: Eurasian Database V.10 (Boakes *et al.*, 2010). This database contains records on 131 Galliformes species, and 24 of these are found in the Greater Himalayas. The Greater Himalayas which covers approximately seven million square kilometres of north-west and north-east Indian states, north of Pakistan, Nepal and Bhutan represents the major parts of the Greater Hindu-Kush Himalayan mountain system (Wikramanayake *et al.*, 2002b). The study site is delimited based on WWF Ecoregions (Wikramanayake *et al.*, 2002b) (see Figure 4.1). For each Himalayan Galliformes species, all records from the date of their first occurrence up to 2007, when the last records were entered into the database, were used to create shape files. Records without a year or geographical co-ordinates were omitted.

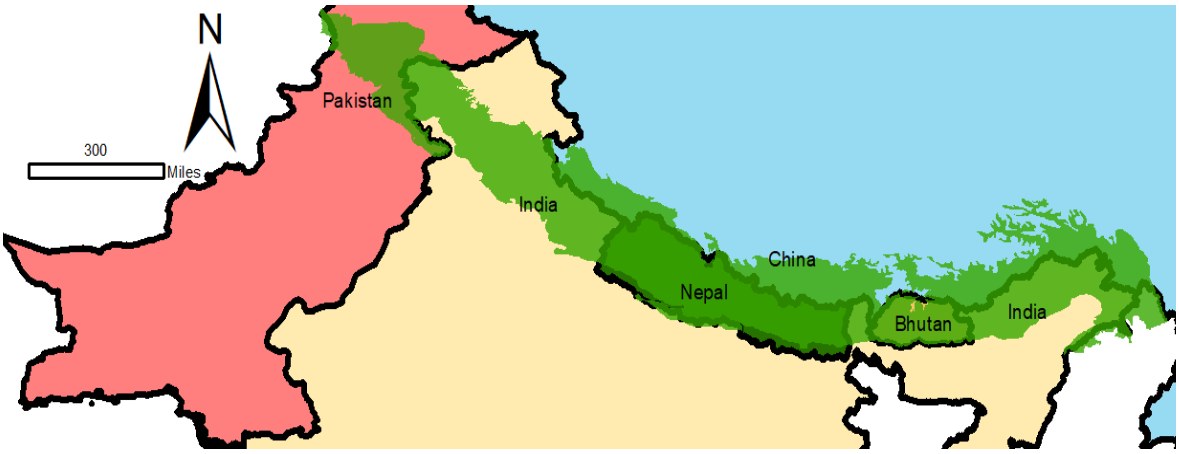

Figure 4.1: Map displaying the global location of the study site, the Greater Himalayas.

The region (represented in green) is delimited by WWF Ecoregions and covers approximately 700,000 Km^2 (Wikramanayake *et al.*, 2002b).

4.3.2. Area accumulation curve: Modelling historical sampling of geographic ranges

Point locality records were arranged in chronological order (henceforth 'historical records'). For each species, we constructed the minimum convex polygon (henceforth 'MCP') shape file from the earliest locality records of the species and calculated the resulting area and number of records used. Next, records from the following year were added to the previous dataset and a new MCP and area were estimated. This process was iterated until the final locality record from the most recent year was added. This resulted in multiple MCP shape files for each species based on cumulative year (e.g. if the earliest year was 1950, the first MCP was constructed based on all 1950 records. Therefore, the MCP for 1951 was based on all records from 1950 plus those from 1951, and so on for all subsequent MCPs).

For each species, the MCP area was plotted as a function of year and as a function of count for number of records. The resulting accumulation curves were then compared to the simulated curve derived by randomising the addition sequence as described below.

4.3.3. Generating the random simulation model

The simulated accumulation curves were generated by performing 1000 iterations for each species in which the point locality records used in MCP construction were added in a random and not chronological order (henceforth 'simulated records').

For each iteration, we created a new column called 'year random', which was based on the actual year column, but the order of the year was shuffled. Therefore, the number of record counts for each unique year was same, but the locality information associated with the years was different. Again, we split the shape file of each Himalayan Galliformes species into multiple shape files but this time, it was based on the cumulative random year. The MCP area was calculated and the number of records were also counted for each MCP. We then added the MCP area and the record count from each iteration and formed two different columns. The data were then summarised to get the mean MCP area +/-1SE for each year and for each record count across the 1000 iterations. The mean MCP area was plotted as a function of year for year records and as a function of count for count records, both with the standard error bars. The simulated curves thus represented the predicted range size estimate after the addition of each record if all parts of the geographic range were sampled with equal probability. This is a Monte-Carlo approach.

4.3.4. Analysis of asymptote

To assess the completeness of our estimate of species range size, we tested whether the historical and simulated accumulation curves had reached an asymptote. An asymptote indicated that the addition of more records did not change the MCP area estimate, indicating that new knowledge has not increased our estimate of the species' geographic range size. Failure to reach an asymptote indicated that our knowledge of that species' range was incomplete. To assess whether an asymptote had been reached, we undertook the following procedure: 1) identify total number of records and the total area of the geographic range; 2) identify the year or number of records that corresponded to 80% of the total number of records; 3) calculate the difference between total MCP area and the MCP area that corresponded to 80% of the total number of records; and then 4) area accumulation curve were considered asymptotic when the final 20% of the records added less than 10% to the range size area estimate. There is no standard threshold by which an asymptote is identified in this context: the 20% and 10% figures used here are arbitrary, but reasonable approximations.

4.3.5. Statistics

How complete is our knowledge of species' ranges?

We used McNemar's test to see if the number of species with an asymptote was similar for the random accumulation curve vs. historical accumulation curve. Data were paired for each species and coded 1 where the area accumulation curve reached an asymptote and 0 where the curve did not reach asymptote.

Has our knowledge of species' geographic ranges improved more rapidly than expected by chance?

To test whether our knowledge of species' geographic ranges has improved more rapidly than expected by chance, we used logistic regression models to compare historical and simulated area accumulation curves separately for each individual species. We hypothesised that the historical and simulated curves for each species would be temporally auto correlated in that the value in any one year would be dependent to some extent on the values in previous year. We created a binomial variable (1/0) indicating that the simulated area in one year was greater (1) or less than (0) than observed. We assessed the trend in accordance (1/0) with time using Generalised Estimating Equations (GEE) with an auto regression correlation structure. This adjusts for any bias introduced because of serial correlate.

In this way, MCP area was implicitly assumed to reflect range knowledge, with larger MCP areas indicating better range knowledge. Thus, for both the logistic regression and GEE models, the predictor variable was year and the response variable was whether historical range area exceeded or was less than simulated range area. The only difference was that each single-species logistic regression model used a single row of data for each year, whereas the multi-species GEE used multiple rows of data for each year for each species. A significant positive logistic regression model would indicate that our knowledge has improved more rapidly than expected by chance.

Has our knowledge of range size accelerated towards present?

We used generalised least squares (GLS) to test whether our improvement in knowledge has accelerated towards the present. To do this, we calculated the difference in area actually observed in each year and that predicted from the simulated range we then investigated if there was any trend in this difference with year. The 1970s marks the time when there was a change in the forest policies and new legislation was enacted in the Himalayan region to protect the forests after the demonstrations by "hill tribes" against ongoing deforestation in the Greater Himalayas (Shah, 2008). The dependent variable was whether historical range area exceeded or was less than simulated range area (coded as 1/0 as before) and the independent variable was whether the time period was before/after 1970. If the improvement in knowledge has accelerated towards the present, we predicted the probability of obtaining a 1 to be greater post-1970 than pre-1970.

4.4. Results

The random simulation models showed that sampling all areas of a geographic range with equal probability should lead to an asymptotic area accumulation curve (see example given in Figure 4.2), with the probability of each new record falling within the known MCP range increasing as each record is added. The actual historical patterns of geographic range size estimate generally produced sigmoidal area accumulation curves i.e. knowledge initially increased slowly, with a rapid phase of improvement before finally reaching an asymptote. Using the number of records added or year of record as the independent variable produced graphs of similar pattern.

Knowledge of geographical ranges was judged to be complete where accumulation curves based on both historical and simulated records reached an asymptote. Where an asymptote was reached for curves based on historical records only, it suggested that survey effort (and therefore our range knowledge) is better than random. 16 out of 24 species reached an asymptote for historical records whereas 20 out of 24 species reached asymptote for simulated records. Accumulation curves for hill partridge (*Arborophila torqueola*) and koklass pheasant (*Pucrasia macrolopha*) did not reach an asymptote for either historical or for simulated records.

Sixteen out of 24 (66.6%) species' historical range accumulation curves reached asymptote whereas 20 out of 24 (83.3%) species' random range accumulation curves reached asymptote (see Table 4.1).

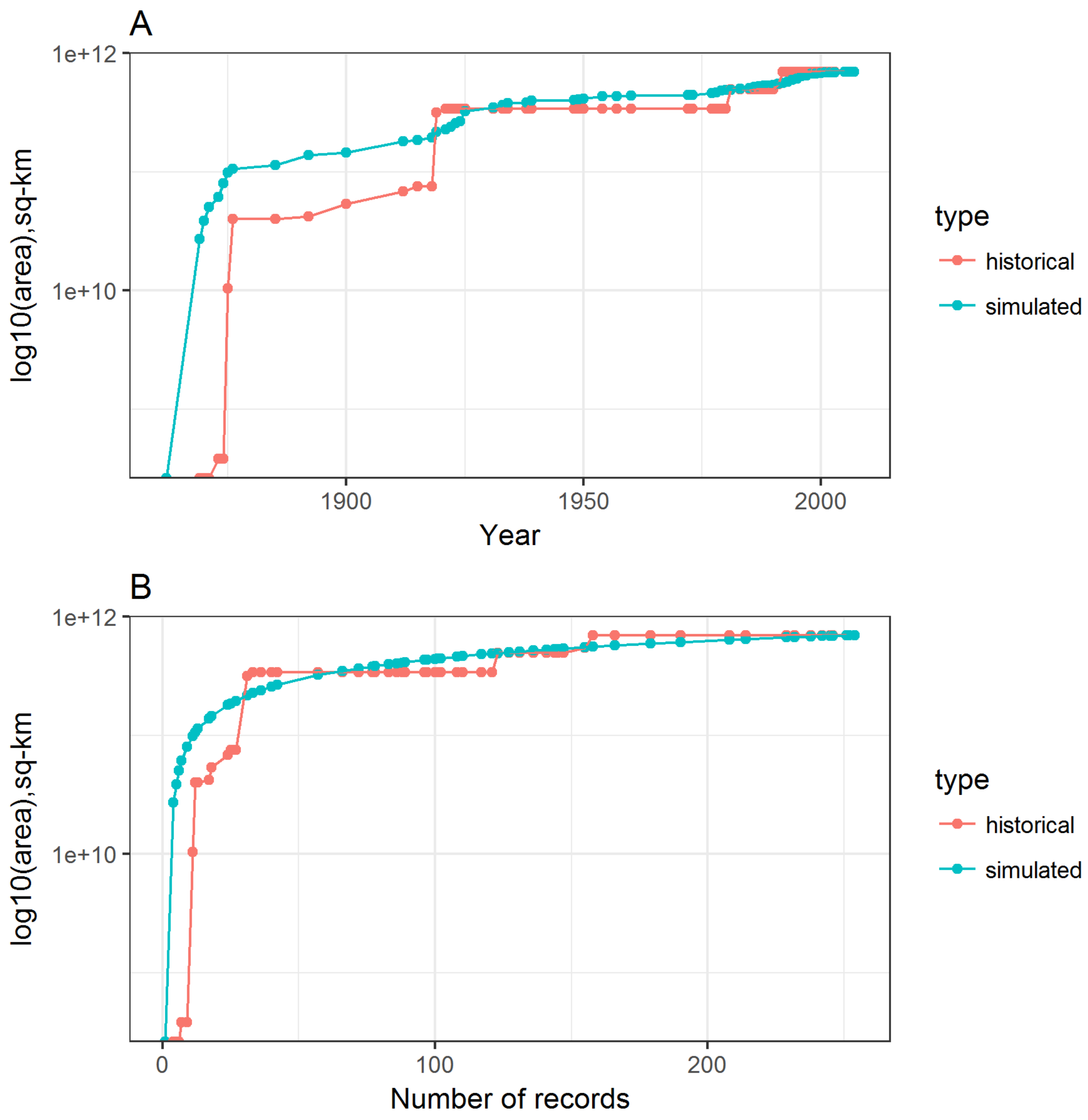

Figure 4.2: Range accumulation curves for satyr tragopan (*Tragopan satyra*).

A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for number of records. When the area of the range based of historical records exceeds that of the range based on simulated records, it indicates that our knowledge of that species' range is better than random. Plots based on N=1000 iterations and show mean range areas +/- 1SE. Note: Standard errors estimated at each point are so small that they cannot be represented on plot.

Table 4.1: Assessment of knowledge status for Himalayan Galliformes species' geographical ranges using accumulation curves. Improved rapidly means that our knowledge of species' range size has improved more rapidly than expected by chance i.e. the MCP area for historical records accumulation curve was generally larger than for the corresponding curve based on simulated records for any given year. Improved recently represents if our knowledge of range size has accelerated towards the present (post 1970) i.e. the difference between MCP areas for the historical records accumulation and the corresponding simulated records accumulation curve was larger post-1970 than pre-1970.

		Asymptote reached			
Species	**Number of records**	**Historical records**	**Simulated records**	**Improved rapidly**	**Improved recently**
Ithaginis cruentus	834	Yes	Yes	No	No
Tragopan blythii	288	Yes	No	Yes	No
Catreus wallichii	698	Yes	Yes	Yes	No
Alectoris chukar	2092	Yes	Yes	No	No
Arborophila torqueola	437	No	No	Yes	No
Pavo cristatus	476	Yes	Yes	Yes	Yes
Lophophorus impejanus	635	Yes	Yes	Yes	No
Ophrysia superciliosa	40	No	Yes	No	No
Tetraogallus himalayensis	459	No	Yes	No	No
Lophura leucomelanos	1140	Yes	Yes	Yes	No
Pucrasia macrolopha	839	No	No	Yes	Yes
Coturnix coturnix	13188	Yes	Yes	Yes	Yes
Arborophila mandellii	54	Yes	Yes	No	No
Gallus gallus	2031	No	Yes	No	No
Arborophila rufogularis	677	Yes	Yes	Yes	Yes

Tragopan satyra	256	Yes	Yes	Yes	Yes
Lophophorus sclateri	217	Yes	No	No	No
Lerwa lerwa	237	Yes	Yes	Yes	No
Tetraophasis szechenyii	161	No	Yes	Yes	No
Tragopan temminckii	408	No	Yes	Yes	No
Perdix hodgsoniae	392	No	Yes	No	No
Tetraogallus tibetanus	387	Yes	Yes	Yes	Yes
Crossoptilon harmani	123	Yes	Yes	No	No
Tragopan melanocephalus	520	Yes	Yes	Yes	Yes

4.4.1. How complete is our knowledge of species' ranges?

Table 1 shows that for 16 out of 24 Himalayan species, the curve for historical records has reached an asymptote suggesting that the sampling efforts for those species is good and hence, our knowledge on those species' range size is complete. For eight species the curve did not reach an asymptote for the historical records, although the simulated curve reached asymptote for six of the species, suggesting that sampling effort is not adequate to robustly determine geographic range size.

Common hill partridge (*Arborophila torqueola*) and koklass pheasant (*Pucrasia macrolopha*) did not reach asymptote for either historical or simulated records suggesting that either that sampling is not sufficiently broadly distributed in space and time, or that more survey effort is needed. The curve for Blyth's tragopan (*Tragopan blythii*) and Sclater's monal (*Lophophurus sclateri*) reached an asymptote for historical records but not for the simulated records, suggesting that survey effort for these two species has been better than random.

McNemar's test showed that there was no difference in the number of species with historical accumulation curves that reached an asymptote and those with simulated accumulation curves that reached an asymptote (McNemar's χ^2 = 1.13, df = 1, p-value= 0.29). This suggests that sampling and thus, our knowledge of all Himalayan Galliformes species' range reflect reality and that we know the range of our species rather well.

4.4.2. Has our knowledge of species' geographic ranges improved more rapidly than expected by chance?

Our estimates of geographic range size have improved more rapidly than predicted by chance for 16 of the 24 (66.6%) Himalayan Galliformes species while the opposite was true in the remaining eight cases (Table 4.1). When all species were pooled together, the GEE suggested that for the majority of species, range knowledge has improved more rapidly than at random through time (β= 0.00529, SE = 0.002, $p < 0.028$).

4.4.3. Has our knowledge of range size accelerated towards present?

The difference between actual area and the random area increased over time, and after 1970 the difference became positive (see Figure 4.3), which indicates that after the inception of conservation actions the actual (historical) area was greater than that predicted (simulated) using the simulated model (see Figure 4.3). However, the estimates of area were not independent of each other, in that records in any one year would also contribute to the observed area and the simulated areas in subsequent years, indicating that the data were serially correlated. This means that the estimates of significance are likely to have been biased.

Therefore, to avoid this problem an autocorrelation component was included in the GLS, which meant that the contribution of time to increased area was not significant (which is actually implausible).

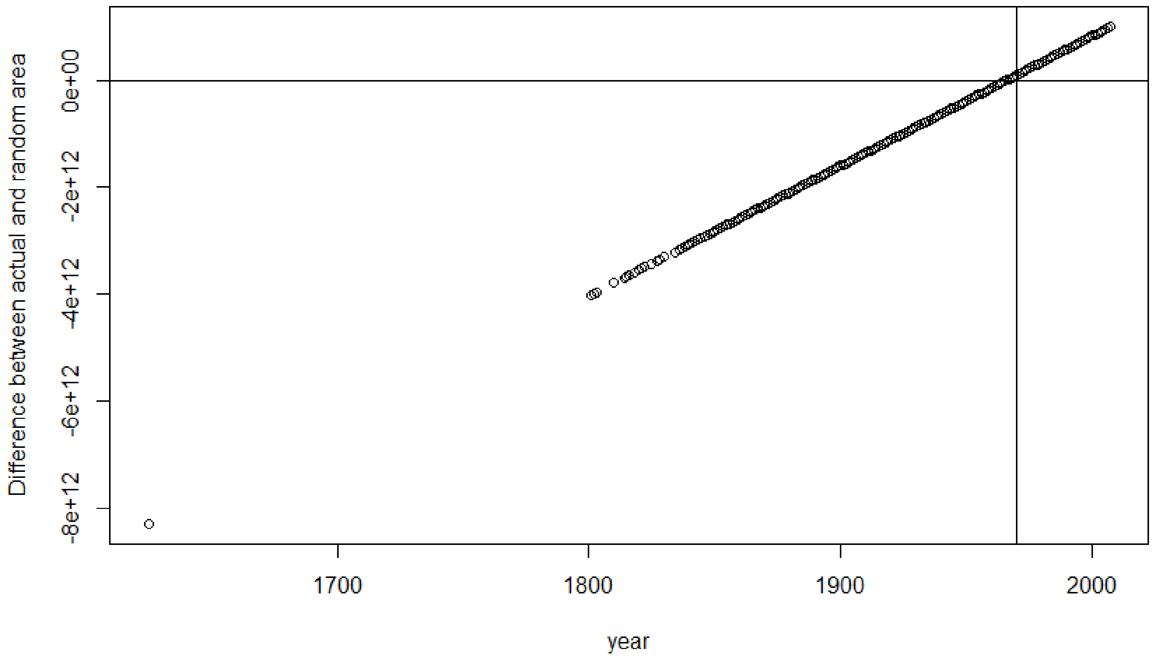

Figure 4.3: Graphical representation of model output showing that the difference between actual (historical) area and the random (simulated) area became positive after 1970.

4.5. Discussion

Assessment of the quality of information used to construct geographic ranges is crucial if we are to prioritise conservation actions correctly. We found that sampling and thus our knowledge of range sizes of Himalayan Galliformes is generally rather complete, has improved rapidly over time, and has accelerated since 1970 owing to increased survey effort. An intensive research and survey programme was developed after 1970(McGowan *et al.*, 1999; Fuller and Garson, 2000a) and similar efforts have occurred for many other highly threatened groups. We now have evidence that this effort laid solid knowledge foundations of species distribution in this group.

Despite this, knowledge of the geographic range of two of the 24 species (koklass pheasant and common hill partridge) remains incomplete, suggesting that the sampling efforts are still insufficient to describe the complete geographic range of these species. If such knowledge gaps are representative of birds globally, then many hundreds of species still have incomplete estimates of geographic range size.

Despite having reasonably large numbers of records, the range accumulation curve for koklass pheasant (*Pucrasia macrolopha*) did not reach an asymptote for either historical or simulated records. This might be due to the fact that koklass pheasant has an extremely large suspected range (BirdLife International, 2019) and we need more survey effort to accurately quantify this species' range size. However, it could also be that early survey efforts were focussed in only a few areas of the suspected total range before 1970, as a positive linear regression model for koklass pheasant suggests that knowledge of range size of koklass pheasant has accelerated towards the present.

We found that of the six threatened Himalayan Galliformes species, range size knowledge of five species, namely cheer pheasant (*Catreus wallichii*), Blyth's tragopan (*Tragopan blytii*), Himalayan quail (*Ophrysia superciliosa*), chestnut-breasted partridge (*Arborophila mandellii*) and Sclater's monal (*Lophophorus sclateri*) has not accelerated towards the present. This could be because the small, fragmented population of cheer pheasant has a patchy distribution (BirdLife International, 2019) that was previously understudied, or that species such as Blyth's tragopan and Sclater's monal occur at least partly in areas that were difficult to access historically. For the Critically Endangered Himalayan quail, the species has not been reliably recorded since 1876 (BirdLife International, 2019) suggesting that thorough surveys are required, as there is a possibility that the species may be rediscovered (Dunn *et al.*, 2015).

To our knowledge, this is the first attempt to evaluate sampling effort across species' ranges. Once this method has been used to identify whether ranges have been described adequately, other techniques may be used to extend our understanding and help focus conservation research efforts further. For example, Grainger *et al.* (2018) developed a Bayesian belief network for a highly threatened bird species, Edward's pheasant (*Lophura edwardsi*) to assess the probability of its persistence and where surveys or other conservation action should be targeted in light of suspected uncertainty in its distribution.

The biggest constraint in identifying the complete geographic range of a species is the paucity of documented species occurrence records. Often survey effort is heavily biased in space and time (Tingley and Beissinger, 2009a) and surveyors tend to focus on areas rich in biodiversity for documenting localities (Boakes *et al.*, 2010). Also, habitats where species of interest have been recorded in the past may be more likely to be surveyed in future. Consequently, habitats may be under-surveyed where other similar habitats have few records, possibly because of unrelated environmental conditions. This makes it difficult to identify the true range of a species, as areas with other biodiversity values are often understudied.

Our results show that examining data chronologically may enable the identification of taxa for which further geographic data are required and provide a way of prioritising taxa and areas for further survey work. The methods we outline here can also help identify biases in survey efforts since it is crucial to resolve the current spatial biases in biodiversity monitoring to correctly estimate extinction risk (Boakes *et al.*, 2016). Alternatively, if range size estimates are shown to be adequate for a species, greater confidence can be placed in the recommendations concerned with setting up of protected areas.

The main limitation of our approach is that the accumulation curves are unable to distinguish between where a species' range has expanded or contracted and where survey effort has been better targeted. Range expansion in this case, however, seems unlikely to any meaningful extent because these species are largely, if not entirely sedentary (except for the common quail *Coturnix coturnix*), and have quite specific habitat requirements. There may be a similar issue surrounding species detectability with the diverse methods that have been used over time (collecting specimens, targeted surveys, birder trip reports), although again it seems unlikely to be a significant factor. Whilst it is not possible, therefore, to distinguish between a range expansion and an increasing ability to detect and record the species with time, the long-standing keen interest in collecting these species, hunting them, and now recording them seems likely to have ensured that detectability has remained fairly constant despite the use of different detection methods. Further simulation modelling is required to uncover the effect of different range change trajectories and changes in detectability on accumulation curves. For example, if a species' range has declined, it is unlikely this will be reflected in the historical accumulation curve.

In conclusion, this study has provided an important new insight for use in assessing the conservation status of species and demonstrated the limits to the general utility of spatial data. It has shown clearly that our knowledge or geographic range size is built up non-randomly and has provided a novel means to examine the quality of a locality dataset and assess the robustness of geographic range size estimates. The importance of using geographic information appropriately in global conservation priority setting cannot be overstated.

Chapter 5. Determining spatial units and functionality for the IUCN Green List assessments: testing the proposed Green List protocol

5.1. Abstract

Prevention of a species from extinction is a basic pillar of conservation biology. Conservation action has had success in the field of biodiversity conservation, however these actions take time in achieving its objective and it is imperative to evaluate the outcomes of these actions. In spite of the fact that IUCN Red List has been remarkably effective in catalysing conservation efforts, a robust method is needed to assess species recovery owing to positive conservation actions and to celebrate the conservation victory. The IUCN Green List of Species has been proposed with an aim to complement the IUCN Red List by providing a tool for assessing the recovery of a species population and for measuring conservation success. I have assessed the implementation of the IUCN Green List methodology with different spatial units for Galliformes in the Himalaya to understand what challenges and limitations exists for each of the different spatial units. Countries are assessed to be the most feasible spatial unit for Himalayan Galliformes. Determining ecological "functionality" of the species was found challenging. Information on other variables such as indigenous (natural) range (spatial baseline) and "Past" definition (temporal baseline used for counterfactual state) were based on experts' opinion. Once implemented, the IUCN Green List will help the conservationists and decision makers to focus on those species that are greatly reliant on conservation actions and have high potential to gain from these conservation actions.

5.2. Introduction

Preventing species from going extinct is a basic pillar of conservation science and practice (Redford *et al.*, 2011; Akçakaya *et al.*, 2018). Conservation action has had success (Sodhi *et al.*, 2011; Balmford, 2012). It has, for example, prevented the extinction of multiple species (Butchart *et al.*, 2006; Brooke *et al.*, 2008); facilitated decrease in the risk of extinction of other species (Hoffmann *et al.*, 2010); and helped improve population trajectories (Donald *et al.*, 2007; Deinet *et al.*, 2013; Chapron *et al.*, 2014).

Conservation actions do not, however, lead to instant improvements in the status of populations or species. They take time to achieve their objectives and, therefore, it is crucial to both monitor progress and to evaluate the outcomes of actions taken for species. However, to date, few assessments have been carried out to understand the overall impact of ongoing actions in reducing biodiversity loss (Ferraro and Pattanayak, 2006; Brooks *et al.*, 2009). It is also a considerable challenge to predict with certainty what would have happened in the absence of conservation intervention because conservationists, instead of focussing on quantifying their actions and impacts, are generally engrossed with reacting to emergencies (Rodrigues, 2006; Hoffmann *et al.*, 2015). This means that whilst overall trajectories of the biodiversity are deteriorating, the situation may be much worse if there had been no conservation action. For example, Tittensor *et al.* (2014) report that whilst conservation efforts have increased, the status of global biodiversity has continued to deteriorate because anthropogenic pressures have increased at a much greater rate than the responses.

For species conservation, the global 'standard' for assessing conservation status is the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN Red List, hereafter). This has been in existence for more than 50 years and the current system, with its categories and criteria was adopted in 1994 and is regarded as the world's most comprehensive inventory of the global conservation status of animal and plant species (IUCN, 2019a). The aim of this process is to assesses extinction risk of species (Ogden, 2019), and this list is used both as a start point for conservation prioritisation in many cases and as an indicator of the overall extinction risk facing species (e.g. Brummitt *et al.* (2015) and Butchart *et al.* (2007)).

Despite these challenges, there is increasing recognition that biodiversity conservation should not just focus on preventing a species from going extinct but also on its recovery once the risk of extinction has reduced and stabilised. This has potential to identify not only when a species has been recovered, but also to provide a more structured framework for considering the success of species conservation by assessing critically what would have happened in the absence of any conservation intervention. As conservation is often considered to be providing gloomy stories about decline and deterioration, the opportunity to celebrate successes would have a considerable communication benefit as well.

The long-term aspiration for the species should be to maintain the attributes of each species that allow it to both survive and perform its ecological function (Redford *et al.*, 2011). This suggests that there may well be various objectives for species conservation, including preventing extinction, the maintenance of viable populations, and facilitating the recovery of a declining species (Akçakaya *et al.*, 2018). There are various conservation actions that focus on preventing species extinction and reducing the rates of species' decline (Akçakaya *et al.*, 2018), such as Protected Areas, and regulating international trade (e.g. through the Convention on International trade in Endangered Species). The IUCN Red List, designed to assess each species risk of extinction is, therefore, only the first, albeit necessary, step towards achieving more ambitious conservation goals at more regional and local scales (Soulé *et al.*, 2003; Sanderson, 2006; Redford *et al.*, 2011).

In spite of the fact that IUCN Red List has been remarkably effective in catalysing conservation efforts (Brooks *et al.*, 2015), an optimistic vision of species conservation is still required in order to pave the way for methods to conserve at risk species and facilitate their recovery . Specifically, a robust method that would provide a structure for broader and concerted global efforts to assess species recovery arising from positive conservation actions and to celebrate conservation success. With this vision, IUCN passed a resolution (WCC 2012 Res 041 https://portals.iucn.org/library/node/44008) in 2012 stating that conservation actions that focussed only on preventing and reversing declines in species are essential but not sufficient (Ogden, 2019) and that a new framework should be proposed to quantify measures of species recovery and conservation success. The IUCN Green List of Species has been developed in response to this resolution, with the aim of complementing the IUCN Red List by providing a tool for assessing the recovery of population of a species and for measuring conservation success (IUCN, 2019a). The components of the proposed IUCN Green List of Species (IUCN Green List hereafter) framework were outlined for the first time by Akçakaya *et al.* (2018).

The IUCN Green List is intended to inform not only about the current recovery status of a species but also about how the status of the species has changed over time due to conservation actions and how these actions might affect a species' status in the future. The draft approach and protocol consider different aspects of a species conservation status than the IUCN Red List. The Red List draws on known changes in status that are the results of genuine observed change in conservation status, rather than arising from, for example, new information or taxonomic changes. Such changes due to change in knowledge are still a considerable influence on the Red List for many taxa in many parts of the world. The Green List, in contrast, is based on different counterfactual scenarios, which allow for structured consideration of the probable status of species in the absence of any conservation action, past, present or future. It is intended to provide insights into the legacy of past efforts, the need for present action, and the potential for future recovery (see Figure 5.1). Developing counterfactual assessments is new in species conservation and provides considerable challenges, but if they are well structured and conducted they can provide information and powerful insights into what conservation actions work and are needed (see Hoffmann *et al.* (2015)). The IUCN Green List, once implemented, is intended to provide information on the dependence of a species on continued conservation actions and the potential long-term aspirations for that species.

The proposed protocol now needs testing on a range of species to determine whether it is suitable for widespread application. This will then inform a decision on its suitability as a global standard for species conservation in a similar vein to, and complementing, the IUCN Red List of Species.

5.2.1. Proposed Green List approach and protocol

The Green List of species has been designed to achieve four main objectives: 1) to identify achievements pertaining to conservation actions and to demonstrate the positive impact of those actions on a species even if there is no improvement in the Red List status of that species; 2) to identify and highlight the species that are dependent on conservation actions; 3) to demonstrate the expected impact of conservation action; and 4) to encourage conservation actions in future. These objectives are reflected in four conservation metrics (see Table 5.1) that are calculated as the difference between the Green List status of a species at different times and in different scenarios (see Figure 5.1 and Table 5.1).

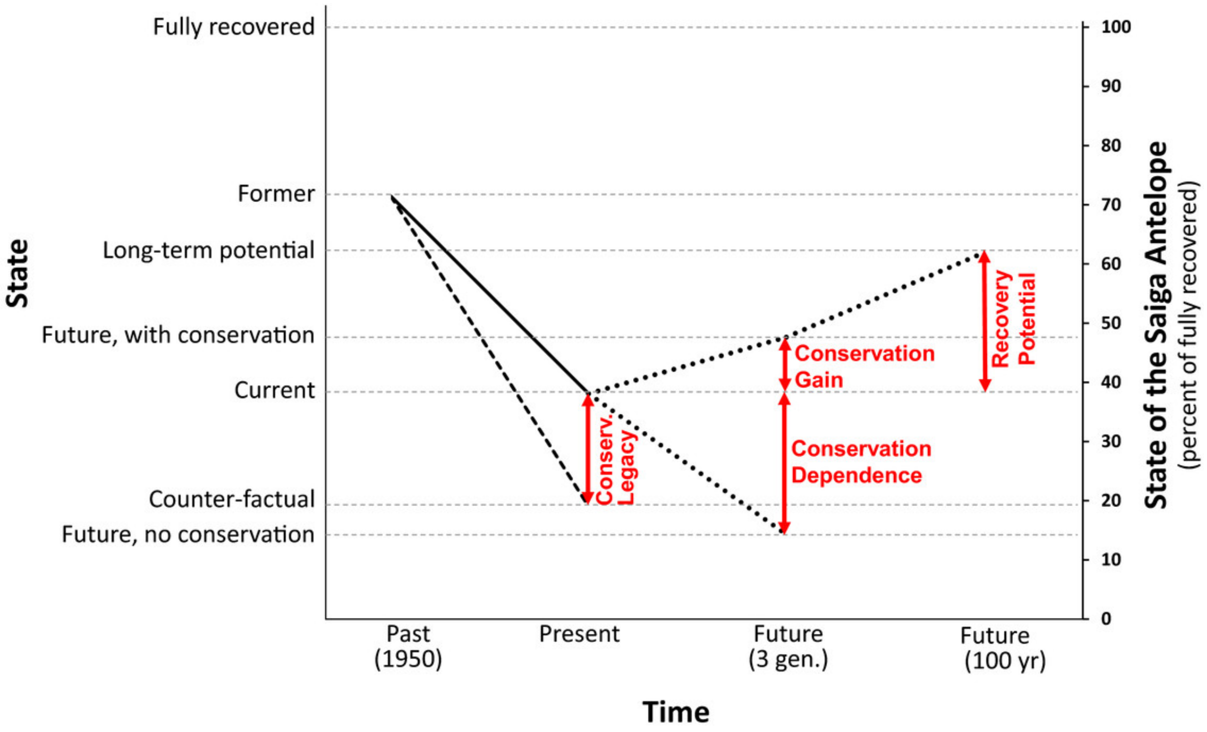

Figure 5.1: Conservation metrics (vertical arrows) expressed as differences in the species' recovery state (left axis) (solid line, observed change in state of the species; dashed line, past change expected in the absence of past conservation efforts [counterfactual]; dotted lines, future scenarios of change expected with and without current and future conservation efforts). The states are calculated for the case-study species Saiga antelope in the paper (right axis) as a percentage of fully recovered state. Source: Akçakaya et al. (2018).

Table 5.1: Different counterfactual scenarios with their definition and significance.

Counterfactual Scenario	Definition	Significance
Conservation Legacy (L)	Difference between the current state and the current state in the absence of past conservation actions (L = current - counterfactual)	Measures the impacts of conservation actions in the past that has helped in achieving the present status of species
Conservation Dependence (D)	Difference between current status and future without conservation (D = current - future without conservation)	Measures the impact on the status of a species in the absence of ongoing and future conservation actions
Conservation Gain (G)	Difference between the current and the future state with conservation (G = current - future with conservation)	It measures the expected improvement in the species' status because of ongoing and future conservation actions
Recovery potential (P)	It is the difference between the current state and long-term aspirations (P = long-term - current)	It quantifies the long-term conservation goals, measuring the possible improvement in the status of the species because of current and future conservation actions

The intention, therefore, is that the IUCN Green List will provide a new set of metrics in conservation biology, which aim to evaluate three common dimensions of recovery of a species as identified by conservationists (e.g. Redford *et al.* (2011) and Sanderson (2006)). A species may be considered fully recovered when: a) the population is viable i.e. it has all the attributes necessary for long-term persistence and is therefore at a low risk of extinction; b) when the population is fully functional i.e. the species exhibits the full range of its ecological interactions and fulfils its ecological role in the ecosystem; and c) when the species occurs in a representative set of ecosystems and communities across its geographic range (Akçakaya *et al.*, 2018). Based on these factors, the Green List methodology defines the species' "fully recovered state" and then generates a score that shows how far a species is from that state (Figure 1).

The methodology that has been proposed requires testing in a range of contexts to explore its generality. These contexts include different regions, a diverse range of species, and where there are differing levels of knowledge about species, and conservation action and potential. In particular, the IUCN Green List methodology requires assessors to make a range of decisions, including some on impact of conservation actions many of which are specific to species' biology. Knowledge of these may vary across a species' range and between species. There are three key parameters that need to be assessed:

1) *Range:* how to define the temporal (for counterfactual) as well as spatial baseline (indigenous range) of a species;
2) *Spatial units:* how to consider representative parts of species geographic range; and
3) *Status:* how to consider functionality of a species.

Specifically, the process ideally assesses the status of the species in each of the several sub-units or spatial units throughout its range (IUCN, 2018a). Spatial units can be defined in different ways and single definition will not be applicable to every species.

In this chapter, I will attempt to apply the Green List methodology to a suite of threatened bird species in a region of conservation concern. My study system is suitable for testing the proposed IUCN Green List methodology because it incorporates a range of species with differing Red List statues, different geographic range sizes and different conservation attention. Further, I identify the challenges and limitations associated with different choices of spatial units. Specifically, I test the applicability of the variables on 12 Himalayan Galliformes species used in the assessment of the IUCN Green List which are:

1) determining the "Past" definition (temporal baseline used for counterfactual state);
2) determining indigenous (natural) range description (spatial baseline);
3) delineating spatial units;
4) defining ecosystem functionality; and
5) generating Green List conservation metrics.

5.3. Methods

5.3.1. Species and information sources

Twenty-four species are found in the Greater Himalaya, of which, six are classified on the IUCN Red List as threatened and the remaining 18 are considered to be non-threatened, with two classified as Near Threatened and 16 as Least Concern. All six threatened species: Blyth's tragopan (*Tragopan blythii)*, cheer pheasant (*Catreus wallichii)*, Himalayan quail (*Ophrysia superciliosa)*, chestnut-breasted hill partridge (*Arborophila mandellii)*, Sclater's monal (*Lophophorus sclateri)*, and western tragopan (*Tragopan melanochephalus*) were selected for the study. Six of the 18 non-threatened species were selected to explore how the metric may be applied to non-threatened species providing 12 species in total to test the proposed IUCN Green List protocol.

The six non-threatened species were selected to give a spread of ecological and knowledge contexts and were: blood pheasant (*Ithaginis cruentus)*, Himalayan monal (*Lophophorus impejanus)*, koklass pheasant (*Pucrasia macrolopha*), satyr tragopan (*Tragopan satyra*), Tibetan-eared pheasant (*Crossoptilon harmani*), and Tibetan snowcock (*Tetraogallus tibetanus*). All selected non-threatened species are classified as Least Concern except for satyr Tragopan (*Tragopan satyra*) which is a Near Threatened species. All non-threatened species selected are found in temperate regions and prefer forests and shrub land as habitat (BirdLife International datasheets, 2016). The other reason for selecting these six species relates to their distribution. Almost all of the six non-threatened species have the same ecological distribution and are either endemic or near-endemic to the Greater Himalayan countries, which was judged to help in determining the spatial unit consistently across all the species.

Information on each species' ecological distribution, its natural and indigenous range, conservation status, conservation actions and legislation were obtained from different sources mentioned below.

a) The indigenous range of each species was constructed using GALLIFORM: WPA Eurasian Database v 1.0 (Boakes *et al.*, 2010). It is a historical database that contains records for 127 species that occur within WWF's Palaearctic and Indo-Malay biogeographic realms.
b) the relevant BirdLife International (2018) species factsheet, which also serves as the formal documentation for the IUCN Red List assessment of that species;
c) the family and species accounts given by McGowan 1994 in *Handbook of the Birds of the World, Volume 2 (McGowan, 1994)*;
d) *The Pheasants of the World (Johnsgard, 1986)*; and
e) the very detailed species accounts of the threatened species given in *Threatened Birds of Asia: the BirdLife International Red Data Book (BirdLife International, 2001)*.
f) Ecosystem functionality (see 2.4) was based on experts' opinion. Experts were selected from IUCN Species Survival Commission (SSC), Galliformes Specialist Group in the region. Eleven experts were selected based on their experience or knowledge on Himalayan Galliformes species. These people were contacted via email and were requested to provide some information on the status of Himalayan species. This information was then used to determine the status of species in each time-state combination, as shown in Figure 5.4, as described in section 5.3.4.

5.3.2. Determining geographical range

For the IUCN Green List assessment, two components of range are used: "past" baseline (temporal) for counterfactual study; and indigenous (natural) range (spatial baseline). Range is defined as the total area of the species' indigenous range and potential future range. According to the IUCN Guidelines for Reintroductions and Other Conservation Translocations, indigenous range is defined as "the known or inferred distribution generated from historical (written or verbal) records, or physical evidence of the species' occurrence. Where direct evidence is inadequate to confirm previous occupancy, the existence of suitable habitat within ecologically appropriate proximity to observed range may be taken as adequate evidence of previous occupation" (IUCN, 2013). Data for delimiting the indigenous range came from the point locality database (see above 5.3.1 and Chapter 3). For assessments to be comparable across all species, it was important to set a benchmark date for the "past" range (temporal baseline) as well as indigenous range (spatial baseline) for geographic range.

5.3.3. Determining the most appropriate spatial units

A key requirement of the Green List assessment procedure is that conservation status, conservation actions and legislation are linked explicitly to each spatial unit under consideration. Consequently, the choice of spatial unit is extremely important for this link to be meaningful and realistic. According to Akçakaya *et al*., (2018), 'the number of spatial units will determine how ambitious the "fully recovered" state is because smaller units and a larger number of units will mean that a larger number of viable and functional populations are needed to achieve the fully recovered state'. This step divides the geographical range of a species (indigenous and potential range) into spatial subdivisions that will be used in the IUCN Green List assessments. There are several ways of defining spatial subunits. Table 5.2 shows the different categories of spatial subunit that have been proposed for use in the assessment (IUCN, 2018a).

Table 5.2: Different spatial units and their definitions. Source: (IUCN, 2018a).

Spatial Subunit	Definition
Subpopulations, and other species-specific biological subdivisions	Subpopulations (as defined in the Red List Guidelines), as well as subspecies, stocks, genetic units, flyways, evolutionary significant units, and discrete population segments.
Ecological features	Divisions based on ecoregions, habitat types, or ecosystems. They are defined based on ecological criteria and thus captures the different "ecological settings" a species exists in.
Geological features	Watersheds, mountain ranges, islands, lakes, and other geological features.
Locations	Areas of similar threatening processes. In some cases, countries, states, provinces, and other political/administrative units
Grid cells	Appropriate for widespread and uniformly distributed species, or for species whose spatial structure is not known

5.3.4. Ecological functionality and status in each spatial subunit

Loss of biological diversity has been assessed through the extinction of species (Valiente-Banuet *et al.*, 2015). However, extinction of a species' ecological function, an important component, which either precedes or coincides with biodiversity loss, is less studied (Tylianakis *et al.*, 2008; Aizen *et al.*, 2012; Valiente-Banuet *et al.*, 2015). Ecosystem functionality of a species is defined as "the degree to which it performs its role as an integral part of the ecosystem in which it is embedded" (Akçakaya *et al.*, 2018). Sometimes a species population may persist to levels that are demographically sustainable but its abundance is too low to fulfil its function ecologically; such populations have been described as "ecologically extinct" (Estes *et al.*, 1989; Sanderson, 2006). Hence conserving "ecologically effective density" of a species - the minimum number of individuals of a species required for maintaining its ecological function - is an important conservation goal (Soulé *et al.*, 2003; Sanderson, 2006; Brodie *et al.*, 2018).

Thus, the framework of the IUCN Green List of Species incorporates ecological functionality as one of the three criteria in assessing the recovery of a species (Akçakaya *et al.*, 2018). Ecological functionality of a species is assessed within each spatial unit (e.g. at the population level). See Table 5.3 for types and examples of functions of species.

Table 5.3: Types and examples of ecological functions of species. Source: IUCN (2018a).

Type of function of species	Example
Species interactions (including trophic functions)	Pollination, seed dispersal, predation (including seed predation), host- paradise relationships, facilitation, providing resources (e.g., as prey)
Structural (landscape) functions	Creation of habitat for other species, ecosystem engineering, substrate stabilization, peat formation, bushfire fuel accumulation, facilitation of landscape connectivity, maintenance of heterogeneity
Ecosystem-level functions	Primary production, decomposition, nutrient cycling or redistribution, modification of fire and hydrological regimes
Within- species processes	Migration, colony formation and other aggregations of individuals, adaptation (evolutionary potential)

The proposed Green List protocol requires that the functionality of each species in each spatial subunit is assessed to give an indication of the status of the species in each spatial unit. Four categories are described in Green List guidelines that are intended to reflect the spectrum from absent to functional (see Table 5.4).

Table 5.4: Different species statuses (with their weight score) and their definition. Source: (IUCN, 2018b).

Status	Definition
Absent (weight=0)	Species does not exist in the wild within the spatial unit.
Present (weight=1)	Species occurs in the spatial unit but does not have a viable population.
Viable (weight=2)	Regional Red List of the species in the spatial unit would result in a category of LC, or NT and is not declining within the spatial unit.
Functional (weight=3)	Spatial unit is functional, if the majority of the population within the spatial units are functional in addition to being viable.

5.3.5. Working through the Green List protocol

A standard procedure for working through the Green List protocol was adopted, in discussion with the Green List Officer (Dr Molly Grace, University of Oxford) who is responsible for promoting the testing of the Green List protocol. Dr Grace provided a template, in a Microsoft Excel workbook, that contained embedded calculations that derived the key Green List conservation metrics (see Introduction and Figure 5.1). The template was filled in for each focal species to assess its Green List status. The resulting metrics for each species were then reviewed and 'sense-checked' by Dr Philip McGowan to see if the metrics presented a defensible picture of what is known about the conservation of these species.

Figure 5.2 shows the flow of information to calculate the conservation metrics, and which indicates the central importance of both the choice of spatial unit and assessing status/functionality in each unit. Identifying the suitable spatial unit is the first and most important step in Green Listing of a species (see Table 5.1) because determining the status of the species in each spatial unit throughout its range will help in assessing whether or not a species has fully recovered across its range. The next step is to assess the state of the species in each spatial unit based on 1 of 4 ordinal categories (see Table 5.4): Each of the four categories has a weight (0-3) which is used in scoring (see Table 5.4).

For each spatial unit, the best estimate of the species' status is made as one of those four categories. Then, to take into account uncertainty, the most pessimistic state of the species is assessed as 'minimum' and the most optimistic status of the species is recorded as 'maximum'. These assessments are made for the following six time-period combinations:

- the former state (as measured just before the start of any conservation actions taken to date, default 1950);
- current state with conservation action (i.e. the present situation);
- current state without conservation (i.e. the counterfactual, considering what if there had been no conservation action in the past);
- future (three generations) with conservation action;
- future (three generations) without conservation action (i.e. if there is no action); and
- long-term potential (100 years).

The overall best, minimum, and maximum Green List score (as a percentage of full recovery) is then obtained for each state (see Figure 5.2 & 5.3) (for detailed information on how the Green List score is calculated, refer to Akçakaya *et al*., 2018). Using the score obtained, conservation metrics (conservation gain, conservation legacy, conservation dependence, and recovery potential) are then calculated as the difference between pairs of states:

- Conservation legacy = current - counterfactual;
- Conservation dependence = current - future without conservation;
- Conservation gain = future with conservation - current; and
- Recovery potential = long-term - current.

All these are underlying values assigned and calculations that give the conservation metrics. The basis of these calculations is not examined in this thesis because here I aim to test the protocol and examine how easy it is to derive the basic input values. It is, however, straightforward to obtain the conservation metrics once the information on status of species in each spatial unit for each time-period is entered in the template. This emphasises the critical importance of entering appropriate information on spatial unit and status in each unit for each time-period combination.

According to the Akçakaya *et al.* (2018) "a Green List score is obtained with the following formula

$$G = (\textstyle\sum_s W_s / W_F \times N) \times 100$$

where s is each spatial unit, W_s the weight of the state in the spatial unit (0 to 3), W_F is the weight of the functional category, and N is the number of spatial units. The denominator is the maximum possible score attained when all spatial units are assessed as functional."

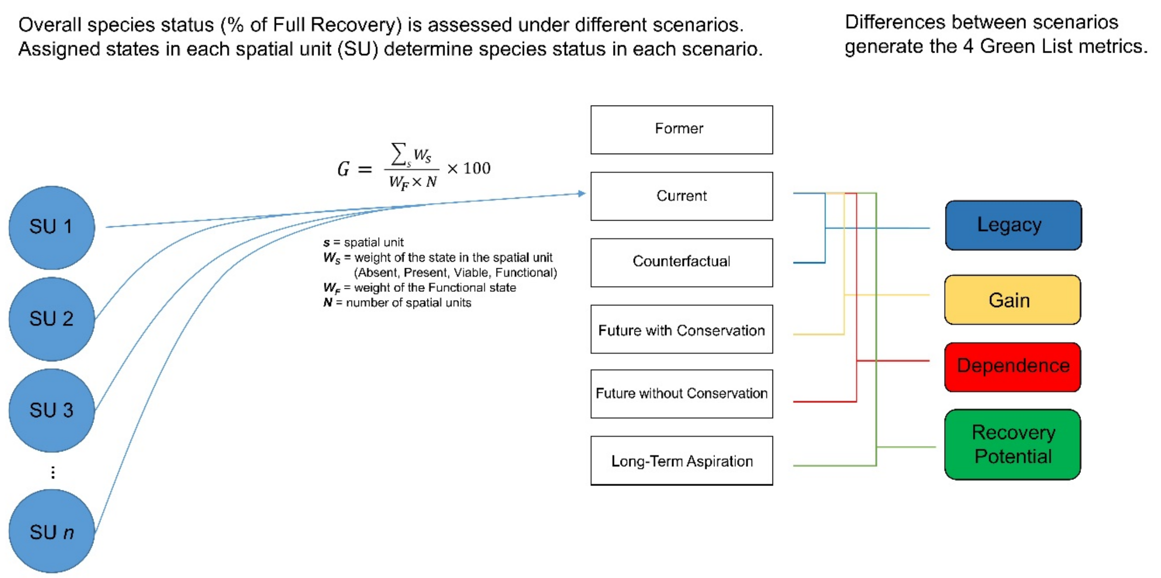

Figure 5.2: Flow of information through green listing.

SU1, SU2, SU3, and SUn represents spatial unit 1, spatial unit 2, spatial unit 3 up to nth spatial unit.. This figure emphasises that delimiting appropriate spatial units and understanding the species' functionality is critical as this influences the assessment status in each spatial unit in each time period-scenario combination.

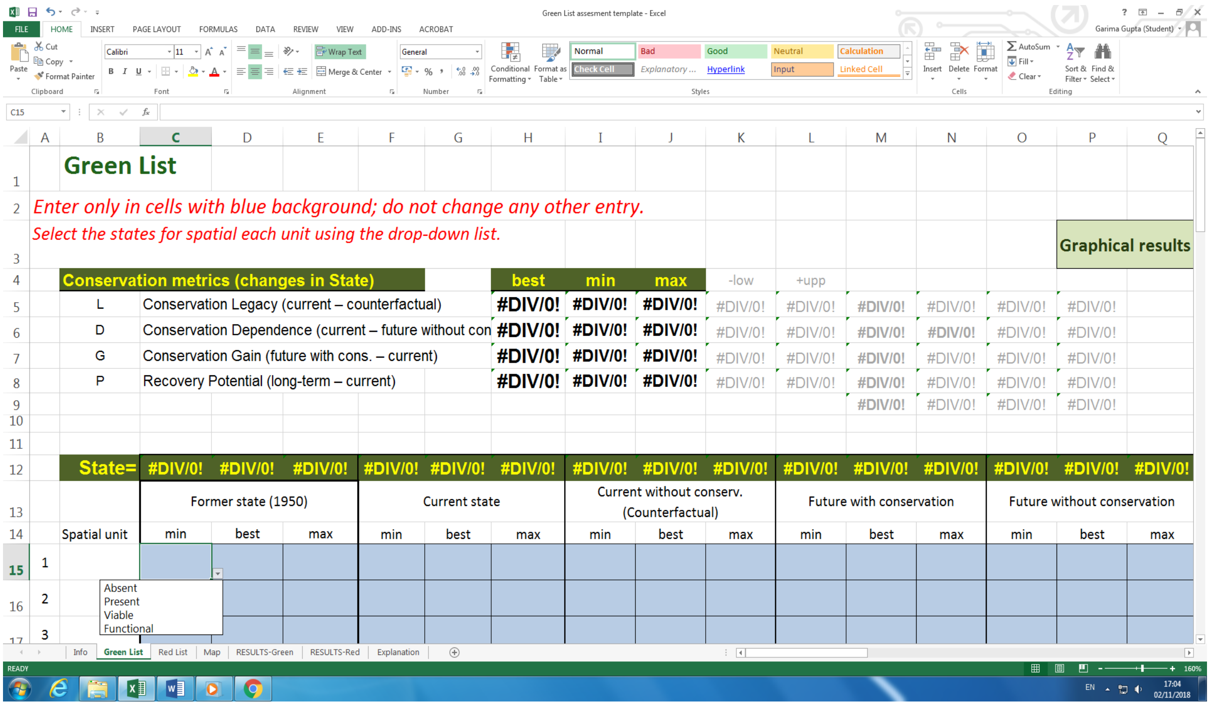

Figure 5.3: Screen shot of the blank template used to assess the Green List status.

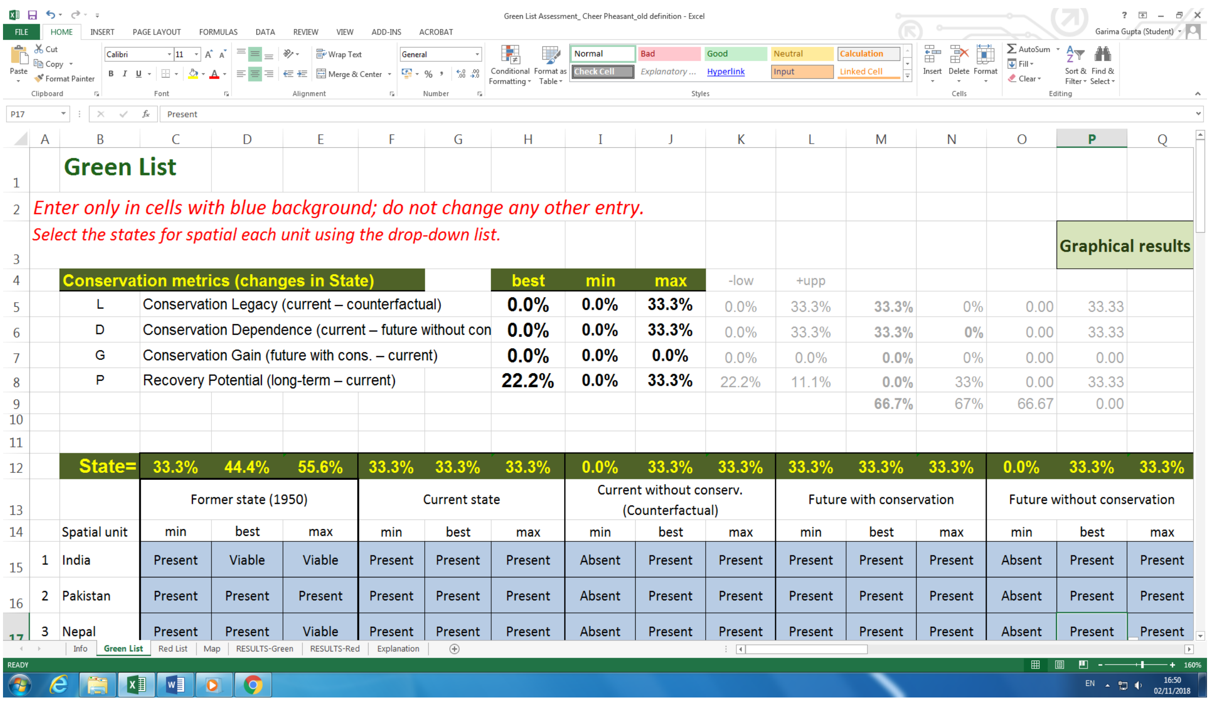

Figure 5.4: Screen shot of the template used to assess the IUCN Green List status completed for the cheer pheasant (*Catreus wallichii*) as an example.

5.4. Results

Information on the status of Himalayan Galliformes species from selected experts was too limited to complete the templates provided by Dr Grace for the assessment of the Green List. The assessment of each species status in each time-state was determined collaboratively by with Dr Philip McGowan who has experience spanning over 20 years on Galliformes especially in South-east Asia, India, China and Nepal, and me. The assessment was made using the information based on the sources described in section 2.1, his past experience on Galliformes and my knowledge of subject and the region. While I am confident that the information used in this assessment is as comprehensive as data availability allows and represents the most accurate synthesis to date, I acknowledge that there is a possibility of missing data and would benefit from further testing.

5.4.1. Defining "Past" to provide a temporal baseline for the counterfactual assessment

Determining how a species has benefitted from conservation requires a clear statement of the time-period over which the conservation action is considered to have been underway. This is challenging for Himalayan Galliformes as they have not been subject to attention and conservation measures in the same way as tigers or elephants have been in South Asia. As far as I am aware, there have been no species-specific conservation actions for the Galliformes across any of the Greater Himalayan countries (India, Pakistan, Nepal, Bhutan and China) and most of the species, I have assessed are either endemic or near-endemic to the Greater Himalayan countries. There have been scattered measures, such as the creation of particular protected areas, but little that indicates a clear beginning of Galliformes conservation activity targeted at this group of species across the region.

The start date for conservation actions in the Himalayas is, therefore, taken here as 1972 after the enactment of The Wildlife Protection Act of India, 1972 that provided legal protection to Galliformes. India comprises a significant part of the range of the collective Greater Himalayan range of these species and no other Himalayan countries had any conservation actions or legislation in place prior to this Act. Therefore, 1972 was used as the baseline year against which the “Past” definition is used in the counterfactual scenario to calculate conservation legacy. This is also about the time that protected areas were first gazetted on any scale, although the reasons why many of these protected areas were established was not well documented and so remains unclear.

5.4.2. Determining the natural geographic range to provide a spatial baseline

The geographic range size of Himalayan Galliformes is discussed in Chapter 1 and Chapter 3 of my thesis and information from these chapters has been taken as the baseline in determining the geographic range. These demonstrate the challenge in being precise about the size of a geographic range because of differing definitions of range size and change in knowledge over time. For Green List purposes, the Extent of Occurrence (EOO: see IUCN, 2012b) is taken as the definition of indigenous geographic range. For Himalayan Galliformes, there is no reason to believe that the EOO has changed over time because the species are sedentary, except for the quail, which is thought to be either migratory or nomadic. Those species that migrate altitudinally (e.g. Himalayan monal) are not thought to have adjusted their ranges since the time they were first recorded, and there is no evidence of movements to new areas for any species. Although Chapter 3 indicates that the area from which species are known to have occurred over time has increased, to differing degrees for each species, this is likely to be a result of the expansion of human activity in the Greater Himalayan region resulting in more areas being visited by naturalists. It is thus almost certainly an artefact of expanding search effort rather than colonisation of new area by Galliformes species.

1850 is used as a benchmark date for the indigenous range for each species, as this is considered a period when human activities started expanding in the Himalayan region after the British moved into the Greater Himalaya. The significant increase and continual felling of trees during the British reign resulted in the loss of much forest, especially in the lower altitudes and more accessible areas (Tucker, 1982) . The flamboyant colours of these birds, their attractive flavour, and evasive behaviour have made these species a very popular for sportsmanship since the early days of British reign in India.

5.4.3. Delineating spatial units

Below I discuss the spatial units that seem feasible to be considered for my focal species for the Green List procedure. Note: where I have indicated that information was unavailable, this means that data were not available from the BirdLife International species factsheets, other literature or Galliformes experts that responded to my request for information.

Sub-populations

Sub-populations are defined as “geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less)” (IUCN, 2017). Of the 12 focal species, six threatened species are thought to have sub-populations while the sub-populations for other six non-threatened species have not been documented (BirdLife International, 2016). Currently there is no information available on these sub-populations, such as exactly where they are found and how large they are (IUCN, 2019a).

The locality database GALLIFORM provides point locality data that may form the basis for delineating sub-populations. Within each species, point localities that are clustered together could be treated as a sub-population (see Figure 5.5 as an example). At present, however, there is no information available on the demography or genetic exchange for the Himalayan species that would allow the clustering together of these point localities so that biologically meaningful sub-populations could be identified. There is insufficient information on movement and dispersal of the species and on land cover in order to divide the range into spatial units corresponding to the sub-population.

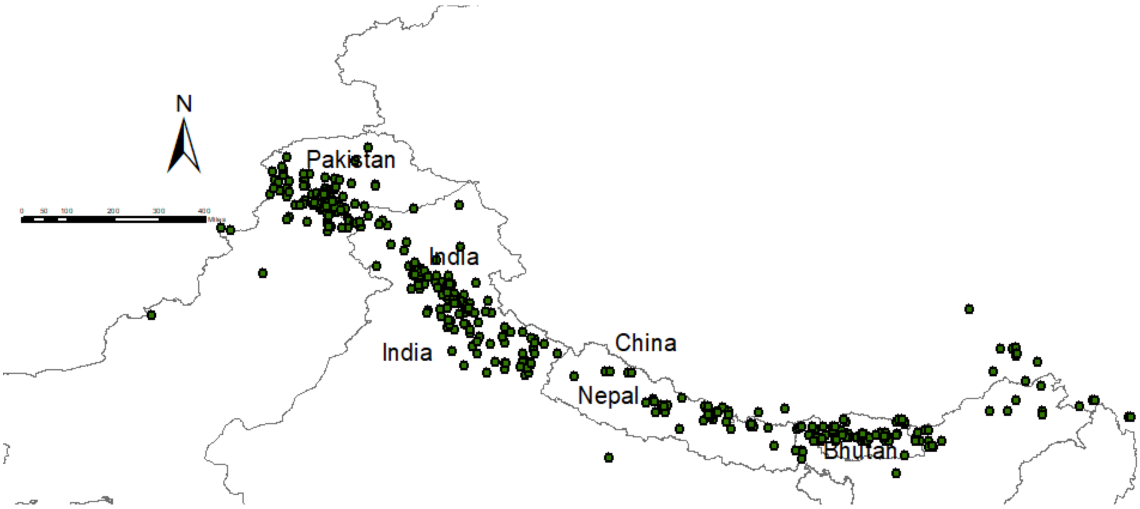

Figure 5.5: Map showing the distribution of Himalayan monal (*Lophophorus impejanus*) locality records in Himalayan countries.

Green dots in the map represent the point locality data for Himalayan monal that were extracted from GALLIFORM: WPA Eurasian Database v 1.0.

Considering both published information and the point locality information together, it was judged not possible, at this stage, to assess the status of each species in sub-populations as the extent and distribution of sub-populations in each species could not be accurately defined and this would prevent the past, present and future conservation state being assessed or predicted with any degree of confidence.

Ecological features

Ecological features are defined on the basis of ecological criteria and capture the different "ecological settings" in which a species exists, such as ecoregions. Olson *et al.* (2001) defined ecoregions as "relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change". Almost all the 12 focal species are either endemic or near-endemic to the Greater Himalayan region. WWF ecoregions may be suitable to consider as spatial units and there are 11 in the Himalayan region (Wikramanayake *et al.*, 2002b) (see Figure 5.6). Two factors made it challenging to use ecoregions in practice. First, the resolution of locality records varies across all locations for the target species and have been categorised as Accurate, Close or Vague, and may be up to 50km (see Chapter 2 and Boakes *et al.* (2010)) from the actual locality that the species was recorded in (Figure 5.7). This makes it difficult to assign localities to ecoregions confidently given the configuration of each region and especially the width of significant tracts of each ecoregion and their intricate contours. Second, the extent to which national boundaries bisect ecoregions makes it challenging to determine confidently the extent of at least some of the ecoregions, and the species' populations within them, in each country (see cheer pheasant example presented in Figure 5.7). Assessing each species' counterfactual status (in the absence of past and future conservation) in each ecoregion based on the counterfactual studies was judged difficult because conservation actions and legislation differs from one political boundary to another, and thus would require the different proportions of each ecoregion in each country to be considered. Consequently, dividing the range into different spatial units corresponding to ecoregions was not considered feasible.

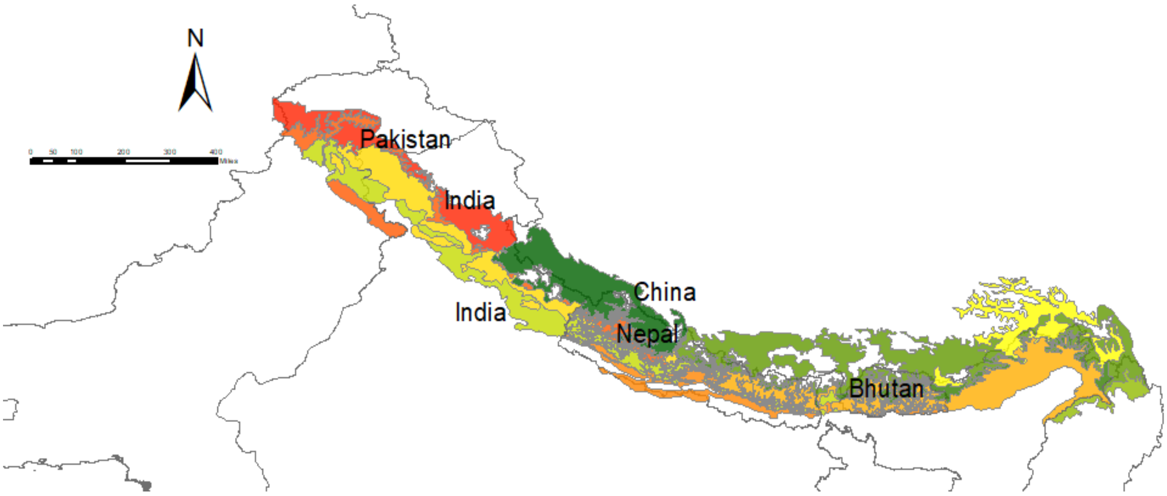

Figure 5.6: Map showing WWF ecoregions ***(Mittermeier*** **et al.*, 2004) used in this thesis to delimit the Greater Himalayan study region (see Dunn (2015)) overlain over national boundaries of Himalayan countries.***

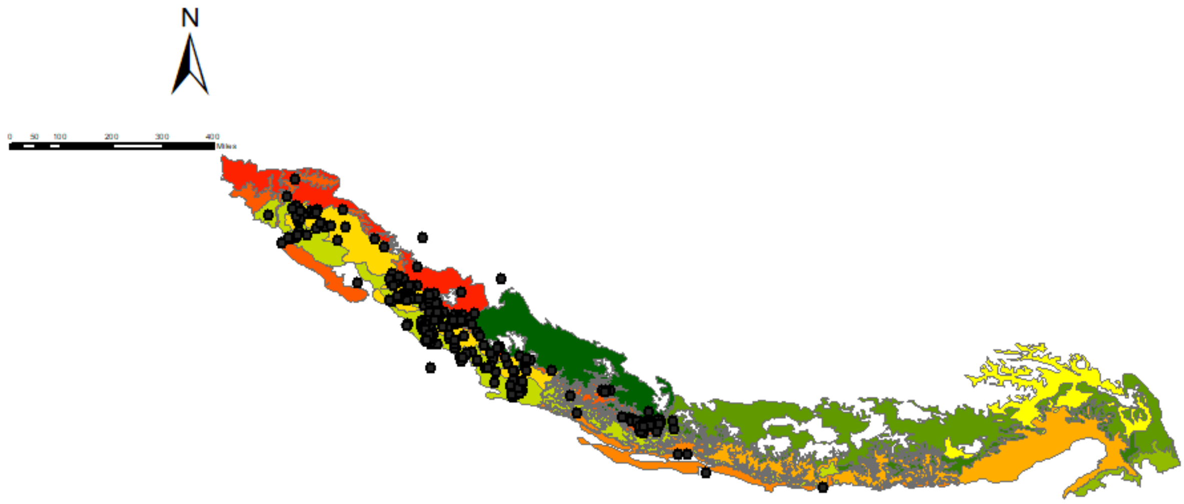

Figure 5.7: Map showing the distribution of cheer pheasant (*Catreus wallichii*) in the WWF Himalayan ecoregions.

Black dots in the map represents the point locality data for cheer pheasant which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

Locations

According to the IUCN Red List guidelines, "the term 'location' defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat." (IUCN, 2012b).

The Green List guidelines imply a much broader spatial extent for a location, as it is defined as an area facing 'similar threatening processes' and explicitly indicates that countries may be considered as locations. The spatial resolution (co-ordinates and written description) of Galliformes records in the database allows for records to be confidently assigned to countries (see Himalayan monal example in Figure 5.5 and Appendix from Figure A.7 to FigureA.32) indicating the distribution of the species within each country can be meaningfully described.

Considering the assessment of counterfactual states, changes in pressures arising from actions, legislation or policy (either negative or positive) are far more likely to be consistent across countries. This is relevant here, because there are currently no species-specific conservation actions or legislation for Galliformes in any of the Himalayan countries and so it is national conservation-relevant management and policy that is likely to affect the conservation status of species for the better or worse. Information on conservation actions and legislation that are in place in each country can be obtained, as well as information on the degree to which these are enforced and other management activities (e.g. protected areas) are designed and implemented. Therefore, country was selected as the most practical spatial unit.

5.4.4. Ecological functionality

We have very little detailed knowledge of the ecological functionality of Galliformes. These species might be a significant disperser of seeds as they are known to feed on buried seeds, berries and tubers. Seed dispersal helps in the maintenance of the plant species diversity and composition, which is classified under trophic function. Species like Himalayan monal and koklass pheasant have sharp bills, which they use to dig the ground for buried roots and tubers.

Assigning spatial unit status under the different Green List scenarios

To apply the Green List method to assess the overall recovery score of the species, the status of the species must be assessed separately in each spatial unit, assigning one of the different status levels: Absent, Present, Viable, and Functional. Uncertainty in status is recording by giving a minimum, best, and maximum status for each spatial unit. This assignment of status is done under different scenarios: former, current, current without conservation (counterfactual), future with conservation, future without conservation, and long-term aspiration. Since there is no regional Red List available for any of the Himalayan countries except for Nepal, expert opinion and the Green List guidelines were used to assess the current status of species in each spatial unit. According to the IUCN Green List, a spatial unit is considered viable if a regional Red List assessment of the species in the spatial unit would result in a category of Least Concern (LC), or Near Threatened if the population in the spatial unit is not undergoing continue decline". It was judged difficult to assign a category to each species during different time periods. It was easy to assess if a species is Absent from its spatial unit or Present in its spatial unit but was challenging to determine if it is Viable or Functional in its spatial unit. What is an ecologically effective density of a species, which can perform its ecological function is not known. There might be enough individuals of a species to be classified as Viable but not enough to be Functional.

Without conservation action, it is expected that most of the species' populations will decline further in every spatial unit except in Bhutan. In Bhutan, conservation of the ecosystem is one of the basic pillars of their Gross National Happiness (GNH) and as mandated in their constitution, Bhutan preserves (at all times) 60% of their forest cover (https://www.worldwildlife.org/projects/bhutan-committed-to-conservation). As a result, even if a species is threatened globally according to the IUCN Red List of Threatened Species, the status of the species is considered to be better in Bhutan. It is assumed that even in the absence of any conservation actions in Bhutan, there will be no major impact on the status of species studied here because of the commitment to conserve ecosystems and the awareness amongst people in Bhutan.

5.4.5. Conservation metrics for Himalayan Galliformes

All 12 species had declined throughout their indigenous range since 1850 and all of them are dependent on conservation actions. The current state of all 12 species has declined from its former state irrespective of their IUCN Red List category (see Table 5.5). The best estimate of current state of all the Least Concern (LC) species (blood pheasant, Himalayan monal, koklass pheasant, Tibetan snowcock, and snow partridge) in their corresponding spatial subunits is in the range of 55% to 66% of their fully recovered state (see Table 5.5). In case of the threatened species (Blyth's Tragopan, cheer pheasant, Sclater's monal, western Tragopan, and chestnut-breasted hill partridge), the best current state is in the range 33% to 66% of its fully recovered state. It is low for Critically Endangered (CR) Himalayan quail, with minimum state being 0% of its fully recovered state and maximum being 33% of its fully recovered state.

In the absence of conservation, most of the species would still be extant, presumably because of their large ranges. The Himalayan quail is however an exception. The best estimate in counterfactual state for all species ranges from 33% to 55% (see Table 5.5) of their fully recovered states.

Conservation legacy, which is the difference between current state and counterfactual current state and measures the impact of conservation actions in the past, ranged from 0% to 33% for all species (see Table 5.6). Conservation legacy varies between species signifying that some species have only moderate positive effects with conservation e.g. satyr tragopan 8% (8% - 25% with uncertainty) while other species have made substantial recovery e.g. Himalayan monal (26% and 0% - 60% with uncertainty) (see Table 5.6). All threatened species have either -11% or 0% conservation legacy as minimum and 0% conservation legacy as best estimate whereas for LC species the minimum state varied between -33.3% to 0%. The general pattern shows that most of the species were moderately to largely dependent on conservation, apart from Sclater's monal and western tragopan. Sclater's monal and western tragopan have 0% conservation legacy.

Most of the species would not retain their current state if conservation actions were to cease in the future. Species like western tragopan, cheer pheasant, Sclater's monal, and Himalayan quail might go extinct in the future in the absence of conservation as the minimum state for these species is 0% of the fully recovered state (see Table 5.5). Even the LC species would decline in number in their currently inhabited range if there will be no more conservation action in the future.

Conservation dependence, which signifies the effect of ongoing and future conservation actions on the species and is the difference between current state and future without conservation state, for LC species ranges (best estimate) from 5.6% to 33.3% (see Table 5.6). For threatened species except for Blyth's tragopan, the best estimate for conservation dependence is 0%. For Blyth's tragopan it is 16.7% (0% - 25% with uncertainty).

Expert opinion indicates that the population of most species could increase to their former states or significantly improve compared to their current states because of ongoing and future conservation actions. Blood pheasant, Himalayan monal, and snow partridge state in future with conservation is expected to improve from the current state, potentially to the levels of their former states (see Table 5.5). The state of the threatened species, for e.g. cheer pheasant and western tragopan is expected to improve as compared to the current state with current and future conservation but it might not be same as their former state (see Table 5.5).

Conservation gain, the difference between current and future with conservation and measures the expected improvement in the species' status because of ongoing and future conservation actions, ranges from 0% to 33% (see Table 5.6). All threatened and non-threatened species have a potential to improve their state in response to conservation.

With long-term conservation, it is possible to have at least Viable population for most of the species while improving the state of other species. For some species, it might be possible to have Functional populations in the long-term for e.g. blood pheasant, Himalayan monal, western tragopan, and koklass pheasant (see Table 5.5). The recovery potential, which is the difference between long-term and current, for all species is more than 50% (maximum state) (see Table 5.6). Himalayan quail, a Critically Endangered species, despite being absent in its spatial unit, might change its status to Present in the long-term.

Table 5.5: Total percentage (%) of fully recovered scores of all Himalayan species during different time period/ scenario.

It is expressed as a percentage of the maximum score. LC = Least Concern, V = Vulnerable, CR = Critically Endangered, NT = Near Threatened

Species	IUCN Category	Former (1972)	Current state with conservation	Current state without conservation (counterfactual state)	Future with conservation	Future without conservation	Long-term potential
			(minimum, medium, maximum recovery score)				
Blood pheasant	LC	66,100,100	33,66,66	33,33,66	66,100,100	33,33,33	100,100,100
Blyth's tragopan	V	41,66,91	33,33,33	8,33,33	33,50,66	8,16,33	33,66,75
Cheer pheasant	V	33,55,88	33,33,33	0,33,22	33,55,66	0,33,33	55,66,88
Himalayan monal	LC	100,100,100	60,66,93	33,40,60	66,100,100	33,33,33	100,100,100
Tibetan snowcock	LC	61,88,88	44,55,72	44,55,61	61,88,88	27,50,55	61,88,94
Chestnut breasted hill partridge	V	55,77,77	33,44,44	11,44,44	44,66,77	11,11,44	44,77,77
Sclater's monal	V	66,77,77	33,33,33	33,33,33	33,66,66	0,33,33	33,66,66
Himalayan quail	CR	0,33,33	0,0,33	0,0,33	0,0,33	0,0,33	33,33,33
Western tragopan	V	33,66,100	33,33,33	33,33,33	33,66,66	0,33,33	33,66,100
Koklass pheasant	LC	66,93,100	53,66,93	26,33,66	40,80,93	6,33,40	53,93,100
Snow partridge	LC	61,88,88	44,55,72	44,55,61	61,88,88	27,50,55	61,88,94
Satyr tragopan	NT	58,91,91	41,41,41	16,33,33	33,58,66	8,25,33	41,66,91

Table 5.6: Conservation metrics for Himalayan Galliformes species with their IUCN Red List category.

Conservation legacy = current – counterfactual; conservation dependence = current – future without conservation; conservation gain = current – future with conservation; and recovery potential = long-term – current. LC = Least Concern, V = Vulnerable, CR = Critically Endangered, NT = Near Threatened.

Species	IUCN Category	Conservation legacy (%)	Conservation dependence (%)	Conservation gain (%)	Recovery potential (%)
		(minimum, best, maximum recovery score)			
Blood pheasant	LC	66,100,100	33,66,66	33,33,66	66,100,100
Blyth's tragopan	V	41,66,91	33,33,33	8,33,33	33,50,66
Cheer pheasant	V	33,55,88	33,33,33	0,33,22	33,55,66
Himalayan monal	LC	100,100,100	60,66,93	33,40,60	66,100,100
Tibetan snowcock	LC	61,88,88	44,55,72	44,55,61	61,88,88
Chestnut breasted hill partridge	V	55,77,77	33,44,44	11,44,44	44,66,77
Sclater's monal	V	66,77,77	33,33,33	33,33,33	33,66,66
Himalayan quail	CR	0,33,33	0,0,33	0,0,33	0,0,33
Western tragopan	V	33,66,100	33,33,33	33,33,33	33,66,66
Koklass pheasant	LC	66,93,100	53,66,93	26,33,66	40,80,93
Snow partridge	LC	61,88,88	44,55,72	44,55,61	61,88,88
Satyr tragopan	NT	58,91,91	41,41,41	16,33,33	33,58,66

5.5. Discussion

The IUCN Green List of species is potentially an important development in recognizing the value of conservation actions and quantifying species recovery. Nevertheless, identifying and establishing a standard for the assessment of species that would allow the IUCN Green List of species to become a useful conservation tool, alongside the IUCN Red List of Threatened. In order to assess how far a species is from the fully recovered state, the Green List protocol requires information that allows: a) a time in the past to be defined when the species was not subject to significant human pressures (a temporal baseline used for counterfactual state); b) determination of indigenous (natural) range description (spatial baseline); c) delineation of spatial units; and d) ecosystem functionality of the species that can be used to interpret a fully recovered state when it is fulfilling all of its natural roles in the ecosystem. This Chapter explored the application of this Green List protocol to 12 Himalayan Galliformes species. Information was drawn from literature syntheses, a substantial locality database (Boakes *et al.*, 2010), and expert opinion. Data gathered from these sources was used to test the feasibility of each aspect of the proposed protocol. As well as an assessment of the applicability of the protocol to these species, I produced initial Green List metrics for these 12 species. The utility of the approach requires consideration of the theory underlying value of the individual protocol components as well as more practical consideration of the approach that can be applied to Galliformes.

5.5.1. Temporal and spatial baseline

Geographic range size plays a prominent role in assessing species' likelihood of extinction, including through listing on the IUCN Red List of Threatened Species (Gaston and Fuller, 2009) and for many species, their geographic ranges are shifting or are expected to shift in response to the climate change (Perry *et al.*, 2005; Chen *et al.*, 2011). When quantifying the recovery of the species geographically, the total range of the species is considered, and a specific historical date is set to estimate the indigenous range.

For Galliformes, 1850 was set as a reasonable benchmark for the temporal baseline, as deforestation and other human activities expanded in the Greater Himalayan region after the expansion of the British Empire in the Himalayan region. 1972 was set as the benchmark year for the counterfactual baseline, because this corresponded to the start date of conservation actions in the Himalayan countries with the enactment of the Wildlife Protection Act in India.

5.5.2. Spatial units

The range of Himalayan Galliformes is divided into different spatial units corresponding to countries, which according to the IUCN Green List guidelines is classed under locations. These countries were India, China, Nepal, Pakistan, and Bhutan. Other spatial units assessed were sub-populations and ecological features, but they were considered inappropriate for Himalayan Galliformes.

According to the IUCN Red List, six of the 12 species studied here have sub-populations but there is not enough information available to be able to define the extent of these of these sub-populations and where they occur. Although we have point locality information, these data are not appropriate for delineating sub-populations because we do not know enough about the ecology of the species. Species dispersal and migration patterns need to be studied in order to classify each Himalayan Galliformes species' localities into sub-populations and then use the sub-populations created to divide the geographical range into appropriate spatial units. We would also benefit from spatial images of vegetation cover and land cover to understand the connectivity between the various localities so that we could combine them into sub-populations. However, such data was lacking to sufficiently demarcate sub-populations here.

Ecological features, which includes ecoregions, was the other spatial unit assessed for Galliformes that was not deemed feasible. There are 11 ecoregions in the Greater Himalaya spread across five countries and each country has different conservation actions. This makes it difficult to assess the counterfactual status of the species in each ecoregion based on conservation, which differs from one political boundary to another. Furthermore, the resolution of the point locality data from the database and the complexity of the ecoregion boundaries makes it difficult to assign the locality confidently to a specific ecoregion.

5.5.3. Ecological functionality and status in spatial units

According to the IUCN Green List guidelines, the other parameter used to assess whether or not the species has fully recovered, is whether the species is functional in all spatial units. Determining whether a species is fully functional presents practical challenges in many ways, and in particular how feasible it is to distinguish reliably between viable and functional remains to be seen. Among vertebrates, birds exhibit the most diverse range of ecological functions and yet ecologically they are relatively less well known in many ecosystems (Sekercioglu, 2006). An ecologically functional population of a species should have a natural population structure that allows it to perform its ecological interactions, roles and functions in all spatial units (Akçakaya *et al.*, 2018). Therefore, according to the IUCN Green List guidelines, in order to assess if the population has reached "ecologically effective density" to maintain its ecological function, it is important to identify the functionality of the species in its habitat. Since not enough information was available on the function of the species studied here, it was assumed that they help in maintenance of diversity of plant species and its composition through seed dispersal, given that seeds and berries are the primary source of food for the Galliformes. But whether or not this assumption is correct and whether there are other ecological functions that are important, requires further studies.

It was difficult to obtain information on the population size of Least Concern species because not much information has been synthesised on them in the BirdLife International datasheets and the IUCN Red List of Threatened Species: Least Concern species are low priority for such information gathering. In addition, the non-availability of a national Red List in all the Himalayan countries except Nepal made this classification further challenging.

Based on the size of the population, a species can have one of the four states, Absent, Present, Viable, or Functional. It was fairly straightforward to judge if a species is Absent or Present in its spatial unit but assessing if the species status has changed from Viable to Functional was challenging, if not impossible. This is because the population of a species might increase in its habitat and there might be enough individuals of a species to consider its status changing from Present to Viable, but when does a species reach an ecologically effective density to be classified as Functional in its spatial unit? This was judged to be very difficult. We need information on what size of species' population can be considered ecologically effective in performing its ecological functions in its habitat. Based on the status of species in all its spatial units, the Green List template generates a conservation metrics.

5.5.3.1. Green List Conservation Metrics for Himalayan Galliformes

This metrics produced during this test of the Green List protocol suggest that all twelve species have declined in the spatial units in which they are found, but that all species have also benefitted from conservation action. The status of blood pheasant, Himalayan monal, koklass pheasant, and satyr tragopan would have declined in absence of ongoing conservation actions. According to the Green List conservation metrics derived in this study, the best estimate of species in both current state and current state without conservation suggest that for eight species would be no worse off in the absence of conservation. The result suggests that in the long-term conservation will have a benefit on the status of all 12 species (see Table 5.5 and Table 5.6). The conservation metrics also suggest that the ongoing and future conservation actions will potentially aid the recovery of most of the species to their Viable states. I found that in future all twelve species are likely to be dependent on conservation actions and in the absence of it, their status would deteriorate. Further long-term conservation can have a positive impact in improving the status of Critically Endangered species from absent to present in their spatial units as shown here in the Himalayan quail.

5.5.4. Challenges using the IUCN Green List

Despite being a potentially important tool in facilitating positive assessments for species conservation and a practical answer to many questions in the conservation biology, widespread implementation of the IUCN Green List of species in a diverse range of contexts is still challenging.

Limited availability of data at an adequate resolution and a lack of understanding of a species' biology and ecology presents a barrier in achieving the specified goals of the IUCN Green List of species goals, which is to assess the recovery status of a species due to conservation actions. Galliformes receive relatively little conservation attention with compared with charismatic mammals e.g. the tiger (*Panthera tigris*) or even the saiga antelope (*Saiga tatarica*), the example application of the Green List protocol given by Akçakaya *et al*., 2018). This is despite the fact that Galliformes are often considered charismatic amongst bird species and are relatively well known. Most of the information used in assessing the IUCN Green List of species for Galliformes is based on expert opinion and we have no basis for quantifying the validity of the assessments made. It would clearly be preferable to base the assessment on more transparently objective information. Given the difficulties of implementing the IUCN Green list for Galliformes in the Greater Himalayas, it follows that it will be particularly challenging to implement the protocol for other, less studied species in South-East Asia to an acceptable standard. Given that South-East Asia is more speciose but less well studied ecologically composed with other areas, this work highlights the difficulties of applying the Green List more generally.

The proposed IUCN Green List of species' conservation metrics places substantial emphasis on the ecological functionality of a species because it considers that a species is only fully restored within each spatial unit when it has an ecologically functional population. Ecological functionality of many species is not clear, which makes it challenging to apply this aspect of the proposed Green List protocol. Unlike the tiger, which is a top predator or elephant, which is an ecosystem engineer, the full ecological functionality of many species is not clear.

Despite the fact that birds are probably the most studied taxonomic class, we do not know the ecological functionality of most species to be confident that we can assess that a species has been restored to fulfilling its full suite of roles in the ecosystem. Seed dispersal was assumed to be the ecological functionality of Himalayan Galliformes based on their feeding habits but the extent to which this is true, or a complete picture is far from clear. It is to be argued that if Galliformes main source of diet is seeds and berries and they dig soil for buried roots, can that possibly have a negative influence on vegetation as Galliformes might be damaging seeds by eating them? In this scenario it is not clear what impact it would have on the assessment if a species was misclassified as functional rather than viable or vice versa.

Human Footprint index, which is a measure of cumulative impacts caused by humans on land has increased by 9% between 1993 and 2009, predominantly due to the conversion of habitats for agricultural activities (Johnson *et al.*, 2017). There is, therefore, a very high probability, if not certainty, that many species will not be considered Functional status in all spatial units its entire native range. For example, Grizzly bear (*Ursus arctos horribilis*) will never occupy its complete native geographic range in Canada because a wide area of its natural range has been converted due to agricultural activity (Ogden, 2019). This will result in the future potential falling below the original (past) conservation status (i.e. its risk of extinction) despite the best conservation efforts on its behalf. Nonetheless, the counterfactual assessments of species status in the absence of any conservation action will indicate how much difference targeted interventions may make.

5.5.5. The IUCN Green List as applied to Himalayan Galliformes

There are no species – specific conservation actions and legislation for Himalayan Galliformes, but they receive protection under existing but more general legislation and conservation actions. The Himalayan Galliformes species are under threat because of hunting and habitat loss (Keane *et al.*, 2005) with their populations declining throughout their ranges (IUCN, 2019a). These species rely on legislation and general conservation measures such as protected areas, to ensure the protection of their habitat and the prohibition of hunting. In contrast, large and charismatic mammals often receive a disproportionate amount of conservation attention, with targeted actions that are monitored with greater regularity. The proposed Green List protocol is a conceptual idea, which, if operationalised meaningfully, could help in identifying the conservation dependence of a species, the legacy of conservation efforts in the past and how a species could expect conservation gains from ongoing or new conservation actions in the future (Akçakaya *et al.*, 2018). It could, therefore, supplement the IUCN Red List of Threatened Species in assessing the current status of species and at the same time could inform about the conservation dependence of species which could help improve the overall status of species.

There have been a considerable amount of resources and effort spent in biodiversity conservation, but quantification of success and benefits of those conservation actions have been very limited (Butchart *et al.*, 2006; Hoffmann *et al.*, 2010). The IUCN Green List of species' framework is intended to be a practical approach to filling such knowledge gaps in conservation science, offering the prospect of quantifying species recovery and the benefits of conservation actions, and also in recognizing conservation success (Akcakaya *et al.*, 2018). There are, however, some practical challenges to work through first if the protocol is to have wide applicability across diverse species conservation contexts.

Chapter 6. General Discussion

6.1. Background

There is growing recognition that the ongoing extinction crisis has accelerated and that conservation funds available to address this problem are limited. This has had a profound effect on governmental and non-governmental organizations' methods of planning and conservation strategies (Groves *et al.*, 2002). For example, many areas that are considered to be ecoregions and/or biological "hotspots", rich in endemic species and containing some of the most significant biological diversity remaining in the world today, have been identified and prioritised for conservation (Olson and Dinerstein, 1998; Myers *et al.*, 2000b). Often, these hotspots are found in areas where biodiversity is poorly quantified and located within low-income countries that cannot afford to implement the effective data collection needed to make decisions and initiate conservation. Globally, data on species distribution is a critically important source of information if we are to implement the 20 Aichi Targets adopted by the Convention on Biological Diversity by 2020 (Girardello *et al.*, 2018). Currently, we are unable to achieve these global targets unless we know what is there and whether/how it is changing. As there is now only a narrow time window left in order to achieve the set Aichi Targets by 2020, species occurrence and information on threats are crucial to make informed decisions to achieve these ambitious but necessary conservation goals. Understanding the potential and constraints of such data will also provide important context for setting post-2020 targets for species conservation.

In this thesis, I have examined the importance of understanding and use of locality data and threats by focussing on species in one key taxonomic group: the avian order Galliformes that are found throughout the Greater Himalaya. The Galliformes, also known as 'gallinaceous birds' or 'game birds' are a large group of charismatic birds, which are widely distributed all over the world comprising 70 genera and 300 species. Twenty-four of these species are found in Himalaya with 16 species endemic to the region, which makes them important from conservation point of view. The difficult terrain of the Himalaya and some of the inaccessible areas in the mountains makes it difficult to study these birds. Galliformes are under pressure from two key threats likely to be important for biodiversity generally: overexploitation and habitat loss (Maxwell *et al.*, 2016). Galliformes are therefore an ideal group with which to work, especially given that we have access to all known historical records from an existing database, and so they provide a good model group to test hypotheses about the use of recording data in conservation.

In the following sections, I will discuss the main findings from my four data chapters and in the subsequent sections, I will discuss how my research can help in supporting biodiversity conservation in general. I will then recommend future research directions for achieving the global conservation targets.

6.2. Main findings of thesis

6.2.1. Aim 1: describe a database that is thought to be a near-exhaustive collation of point locality data

Locality data has been extensively used in conservation science, but it has thus far been less important to assess the quality of information contained within the database. In Chapter 2, I explore the GALLIFORM: WPA Eurasian Database v 1.0 (Boakes *et al.*, 2010). It is an opportunistically collected and thought to be nearly-exhaustive database that has point locality information on 131 species, which occur within WWF's Palaearctic and Indo-Malay biogeographic realms. Using information on 24 species of Galliformes found in the Greater Himalaya, I describe the information contained within this database. Each point locality record indicates the source of data (museum, reference, and trip reports), identity of the species, location, and date of record collected. I found that information from a locality database is much more comprehensive than information synthesised from literature and geographic range maps from BirdLife International and there was a higher probability of finding a species outside the altitudinal range published in literature. I also found that there was a variation in the number of records collected for each species over time.

6.2.2. Aim 2: understand what we know about threats to Himalayan Galliformes

Aichi Target 12 of the Convention on Biological Diversity focusses on halting species extinction and improving the status of declining threatened species. To achieve Aichi Target 12, it is imperative to assess and understand threats that are jeopardising the species survival. In Chapter 3, I assess how much we know about the threats to Galliformes. I undertook a systematic literature review to look for papers on threats to Galliformes in the Greater Himalaya. After searching Web of Science and Google Scholar using different terms, only 40 papers were deemed suitable to be included in the study. Biological Resource Use and Agriculture & Aquaculture were found to be the main threats for Galliformes in Himalaya but there was not enough evidence to support the hypothesis that these threats are causing a decline in the species population. In this study, species habitat preferences have also been found to play a significant role in their risk of extinction. I found that species that prefer open habitats at higher altitudes were listed as Least Concern according to the IUCN Red List of Threatened

Species, whereas all threatened species were found at lower altitudes. This indicates that species' close proximity with humans makes them more susceptible to hunting and destruction of habitats by human activities.

6.2.3. Aim 3: assess how complete our knowledge of species' range size:

Geographic range is an important characteristic of species biology and is one of the key components used by the IUCN Red List of Threatened Species in categorising species by extinction risk. In Chapter 4, using the point locality data, I mapped the geographic range of each of the 24 Himalayan Galliformes species to assess our knowledge of species' range size. I found that the knowledge of range size of most of the species is complete, which means that we have enough records for 24 Himalayan Galliformes species to define their geographic range. My study shows that our knowledge has accelerated since 1970, suggesting that the sampling efforts increased, and more records were collected after 1970. This study has provided a novel technique in assessing the quality of the data.

6.2.4. Aim 4: test the Green List protocol on a suite of species

Conservation plays an important role in preventing extinction of a species, but not enough assessments have been made to date to understand the impact of ongoing conservation efforts. To address this, a protocol was proposed by a group of researchers, which aimed to quantify the recovery of a species through conservation actions. In Chapter 5, I tested the proposed IUCN Green List on 12 Himalayan Galliformes species by testing the applicability of variables (ranges; spatial units; and functionality) used in the IUCN Green List. For "past" (temporal) baseline for the counterfactual assessment, 1972 was used as a baseline year as the Wildlife Protection Act of India was enacted this year and 1850 marks the start date of expansion of human activities in the Greater Himalaya, which was treated as baseline year for natural geographic range (spatial baseline). The Himalayan Galliformes species range is divided into spatial units corresponding to countries, which is classed under locations in the Green List protocol. Dispersal of seeds was considered as the most obvious ecological functionality of these species, which then helps in the maintenance of the plant species diversity.

I found that only four species have benefitted from past and current conservation actions, but my study suggests that in the future, the status of all 12 species of Himalayan Galliformes would deteriorate further in the absence of conservation actions. Though the IUCN Green List of species is the first step towards quantifying species recovery due to conservation actions at present there are a few limitations in the proposed protocol in assessing the Green List status of a species.

6.3. How my thesis contributes to the conservation of Himalayan Galliformes species

My research assessed the importance of raw information on species occurrence and threats in conservation science and how we can use the available information to target conservation actions to reduce the risk of species extinction. I focus on Himalayan Galliformes in my thesis but the findings of my research have a general applicability that provides new insights in assessing the conservation status of biodiversity as a whole and the need of achieving conservation targets. In this section I will discuss how the results from my chapters link together to address the burgeoning conservation issues.

6.3.1. What is known about species occurrence data and threats to species

For several decades now, declines in biodiversity have been a global concern (Pimm *et al.*, 1995; Jenkins, 2003; Rodrigues *et al.*, 2006) and there is a recognised need to assess the conservation status and needs of species if we are to prevent further extinctions. 98,512 species have been assessed so far by the IUCN Red List of Threatened Species, an important conservation tool that is an indicator of the health of the world's biodiversity (IUCN, 2019a). This number represents a small fraction of the total number of extant species, which is estimated to be around 5-10 million (May, 2000; Mora *et al.*, 2011). According to the IUCN Red List criteria, assessment of conservation status of a species' requires robust data on ecology of a species, its geographic range, trend in its population, threats, habitat, and ecology, for the evaluation to be rigorous and unquestionable (Régnier *et al.*, 2015).

Birds and large mammals are generally considered to be well-studied and that we have reasonably good information on their distribution, biology, and threats; however, massive gaps exists in our understanding of even these well-studied groups (Stork, 1997; Costello, 2015). But how much can we say we know about the understudied species that are threatened with risk of extinction? To reduce the rates at which biodiversity is declining and to achieve environmental goals it is important to know the drivers that are threatening biodiversity, where risks occur, the intensity with which a threat is changing, and then to find the appropriate actions to avert them (Geldmann *et al.*, 2014).

There is a massive decline in the population sizes and geographical ranges of terrestrial mammals but the causes and consequences of this decline are not very well understood (Ripple *et al.*, 2016). As shown in Chapter 3, too often the link between threats and population declines is unsubstantiated assertions and overly general. Overexploitation (Maxwell *et al.*, 2016) and habitat loss and fragmentation (Newbold *et al.*, 2015) are generally considered to be the main pressures threatening biodiversity but there is not enough evidence available from the papers reviewed in Chapter 3 to prove that these threats are causing a decline in the population of a particular species. Also, if a particular threat is a major cause behind declines in the population of one species, we cannot assume that the threat will have the same impact on other species, as each species may respond differently to different threats (Barnosky *et al.*, 2011). Until we address the main causes of biodiversity loss and have robust evidence to support the hypothesis that a particular threat is affecting the population of a species, it will be difficult to reduce the impact of direct pressures on biodiversity and hence achieve global conservation targets. Further, this will prevent us from achieving global Target 5 (habitat loss), Aichi Targets 6 & 7 (overexploitation), and Aichi Target 10 & 15 (climate change) and together, they will prevent us from achieving Target 12 (prevent extinction of species) due to the fact that all 20 Aichi Targets set by CBD are interactive and interdependent in nature (Marques *et al.*, 2014).

Knowing where a species is found is a prerequisite to knowing which areas we are to conserve if we are to cover 17% of land under Protected Areas in order to achieve Aichi Target 11. Therefore, the geographic range of a species plays a significant role in conservation science. The geographic range of a species can be described in different ways (Gaston and Fuller, 2009) but the method has to be accurate and the information used should be unbiased. Locality data is often used in describing the geographic range but due to sampling efforts there are temporal and spatial biases (Chapman, 2005; Engemann *et al.*, 2015). This sampling bias can often influence the results of analyses aimed at studying species abundance and distribution (Sánchez-Fernández *et al.*, 2011; Yang *et al.*, 2013; Ficetola *et al.*, 2014b). Sometimes incomplete sampling due to inaccessibility of the area for data collection (Girardello *et al.*, 2018) leaves a species undetected, which can have an influence on the outcome of studies (Ficetola *et al.*, 2014a). In Chapter 4 of my thesis, I show that due to the sampling biases and variations in the number of records collected over each decade and with some species having more records than other through time, it is difficult to assess if our knowledge of species' geographic range is complete and that it has built up with time. We need to assess ways to address these issues to find ways for better utilization of the available information and the methodology I used in Chapter 4 could be one such approach in evaluating the sampling biases.

6.3.2. Aichi Targets and the IUCN Green List of species

With the year 2020 fast approaching and therefore Aichi Targets nearing the end, it is apt now to assess the attainment of these targets (Visconti *et al.*, 2019) and to learn from our conservation successes (Balmford, 2017). The IUCN Green List protocol has been proposed with an aim to quantify species' recoveries owing to conservation actions and to explore the dependence of species on conservation efforts to ensure long-term survival. Consequently, it is the most opportune time to test the Green List protocol on a wide range of taxa in assessing the recovery of many species owing to conservation interventions and to measure how many species we have prevented from extinction, which can also help us in assessing the progress towards Aichi Target 12. However, as shown in Chapter 5, the current protocol has several challenges, which should be addressed prior to implementation.

Uncertainty and data deficiency can be a major challenge in assessing the Green List status of many taxonomic groups. Historical datasets on biodiversity are important, even necessary sources in detecting and quantifying long-term impacts on biodiversity as a consequence of human activity and informing conservation of species that are threatened with extinction (Willis *et al.*, 2007; Tingley and Beissinger, 2009b; Turvey *et al.*, 2015; Mihoub *et al.*, 2017). Taxonomic biases in conservation biology have been identified as a major issue in this regard (Clark and May, 2002) with some taxonomic groups better studied than others making ubiquitous implementation of Green List protocol a Herculean challenge. Despite the fact that Galliformes are generally considered as a good model group, being a relatively well-studied taxon, it was still notably difficult to implement the proposed Green List protocol. It remains to be discovered how feasible it would be to assess the Green List status of many taxonomic groups of tropical forests of which our understanding is so limited (see (Platnick, 1991; Collen *et al.*, 2008; Schipper *et al.*, 2008; Marshall *et al.*, 2016)).

According to the proposed Green List protocol, a recovered species means that the species' population is viable and will have ecologically functional densities across its range in all its spatial units (Akçakaya *et al.*, 2018). This means that the status of a species in all its spatial units at different time-scenarios is dependent on understanding ecological functionality of a species. The proposed IUCN Green List protocol would be best applied to well-studied species where we have enough species-specific information and the functionality is well-known. For example, Vultures are known to be the only vertebrate scavenger species that feed on dead animal carcasses, maintaining the flow of energy in food webs and minimizing the spread of diseases (Sekercioglu, 2006) and therefore are an ideal candidate for applying the Green List protocol. But, for many species the functionality is uncertain. For example, the ecological functionality of Galliformes species was not clear in this study and it was assumed that since Galliformes feed on seeds and berries, they probably function in dispersal of seeds. Yet, how would the status of the species and hence the conservation metrics be affected if the functionality was something else? Even if the functionality of a species is known, the point at which a population is considered functional is not clear. It is easy to judge if a species is Absent or Present in its spatial unit but what we don't know is when a species population changes from

Present to Viable and then from Viable to Functional. Even if the functionality of a species is known, it is rarely quantifiable. Furthermore, it is unclear as to why this category is given the weight that it is, as a population may be viable without being functional.

Ecological functionality needs to be considered within the ecosystem as a whole. The assumption that Galliformes disperses seed and help in maintenance of plant diversity may not have a significant effect on its ecosystem as the habitat might have a climax vegetation and does not rely on the seed dispersal. Also, the efficiency of seed dispersal declines with the size of seeds (Levey, 1987; Sekercioglu, 2006), there might be a possibility that these species feed on small seeds or they might be digesting the whole seed, which decreases the chances of seed germination. Whether there are high rates of functional redundancy also needs to be considered in this context.

6.4. Recommendations for future work

My research has provided insights into the significance of locality data in conservation science and why it is crucial to understand threats to biodiversity. It has also shown how important it is to measure the effectiveness of current conservation actions by quantifying species recovery. There is clearly more work to be done to fill gaps in our knowledge of a species and in providing information to support global conservation targets.

I have shown how locality data are important for research undertaken in conservation planning. To fill the gaps and uncertainties in the current database, we need to prioritise efforts and appropriate methods such as citizen science and scientific approaches to improve the quality of existing database. The citizen science projects are highly recognised for their role in monitoring biodiversity and taxonomical studies (Fattorini, 2013). More analytical approaches are required to analyse the data and changes to certain types of modelling techniques to overcome the limitations in data (Girardello *et al.*, 2018). Also, if we are to achieve global conservation targets, which involve all taxonomic groups, we need to address the taxonomical biases by having locality data on all taxa other than birds and mammals.

Often, we make assumptions or use proxies on threats due to the lack of data and information; for example, distance to roads is often treated as a proxy for hunting, which can bias our results. To ensure conservationists make the right decisions to protect a species by targeting the relevant driver threatening a species survival and in formulation of policies for biodiversity conservation, there is a necessity to understand the threats having an impact on species population. Too often our understanding of threats and their threats and their impact is weak, being overly general and based upon unsubstantiated assertions. Once robust evidence is available on threats and the intensity with which that threat is affecting species, we can then make informed decisions to halt the extinction of species and in achieving Aichi Target 12. We also need information to map threats spatially, especially hunting, so that we can use that information in identifying the area with greatest probability of extinction using Bayesian Belief Networks (BBN) (Grainger *et al.*, 2018). This will have a significant impact in prioritising suitable areas for Protected Area and hence in achieving Aichi Target 11.

Specifically, for individual Himalayan Galliformes species, more locality records are required for koklass pheasant (*Pucrasia macrolopha*) and common hill partridge (*Arborophila torqueola*) because our knowledge of their geographic ranges is not complete.

Finally, from the Green List perspective, a species is considered recovered when the population of a species is viable in all its range. By definition, a Least Concern species is considered viable even if its population is declining continuously in its range. This means that we may be erroneously ascribing Least Concern species with a falsely optimistic conservation status. Given this, it is important to assess the temporal trend in the change in species populations and this can be done using time-series analysis (Houlahan *et al.*, 2000). Furthermore, it is important to assess the difference in the conservation metrics by giving higher weight to Viable category and not including Functional category in the assessment. Most importantly, the Green List protocol needs to be tested in taxonomic groups beyond birds and mammals, which are well-studied, to assess how this approach can be applied to less-known species.

6.5. Conclusion

Ever since life has existed on earth, extinction has been a natural phenomenon but the incessant growth in human population and their activities have played a significant role in increasing the rate of species extinctions above pre-human levels. To address this current extinction crisis at global level, conservation targets are set. In order to achieve those targets, there is a need to understand a species' ecology, its life-traits, the geographical range it occupies and identifying threats. Locality data collected over time can be the biggest source of information in providing new insights into conservation status and hence in achieving the conservation goals. From finding geographical range of a species to identifying Important Biodiversity Areas and Key Biodiversity Areas, locality data have immense use in conservation science. However, severe biases (temporal, spatial, and taxonomic), gaps, and uncertainties can hamper the use of this data in conservation biology and prevent us from making the best progress towards the set of international conservation targets. There is a need to prioritise efforts if we are to fill those gaps to enhance the use of locality data in decision making and in halting species extinction.

I have shown that it is important to understand these data biases, which can then reduce the biases in our analyses and hence in making the right conservation decisions. Biological Resource Use and Agriculture & Aquaculture have been identified as main threats to the Galliformes in the Greater Himalaya, but most of the times it is based on unsubstantiated assertions and we do not have enough evidence to prove that these threats are causing decline in the population of Galliformes species. I have also recommended a novel approach in identifying the sampling biases and have suggested how spatial data could be used in conservation science.

Conservation interventions have a profound impact in halting extinctions of many threatened species for example, analysis shows that the IUCN Red List status of birds and mammals would have worsened by 18% in the absence of conservation actions (Johnson *et al.*, 2017). It is important to quantify the impacts these conservation actions have on recovery of species. We can learn from these success stories about the effectiveness of these interventions in allowing a species or an ecosystem to recover. The proposed Green List protocol is the first step in this direction but there are some limitations that need to be addressed before its implementation.

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Appendix

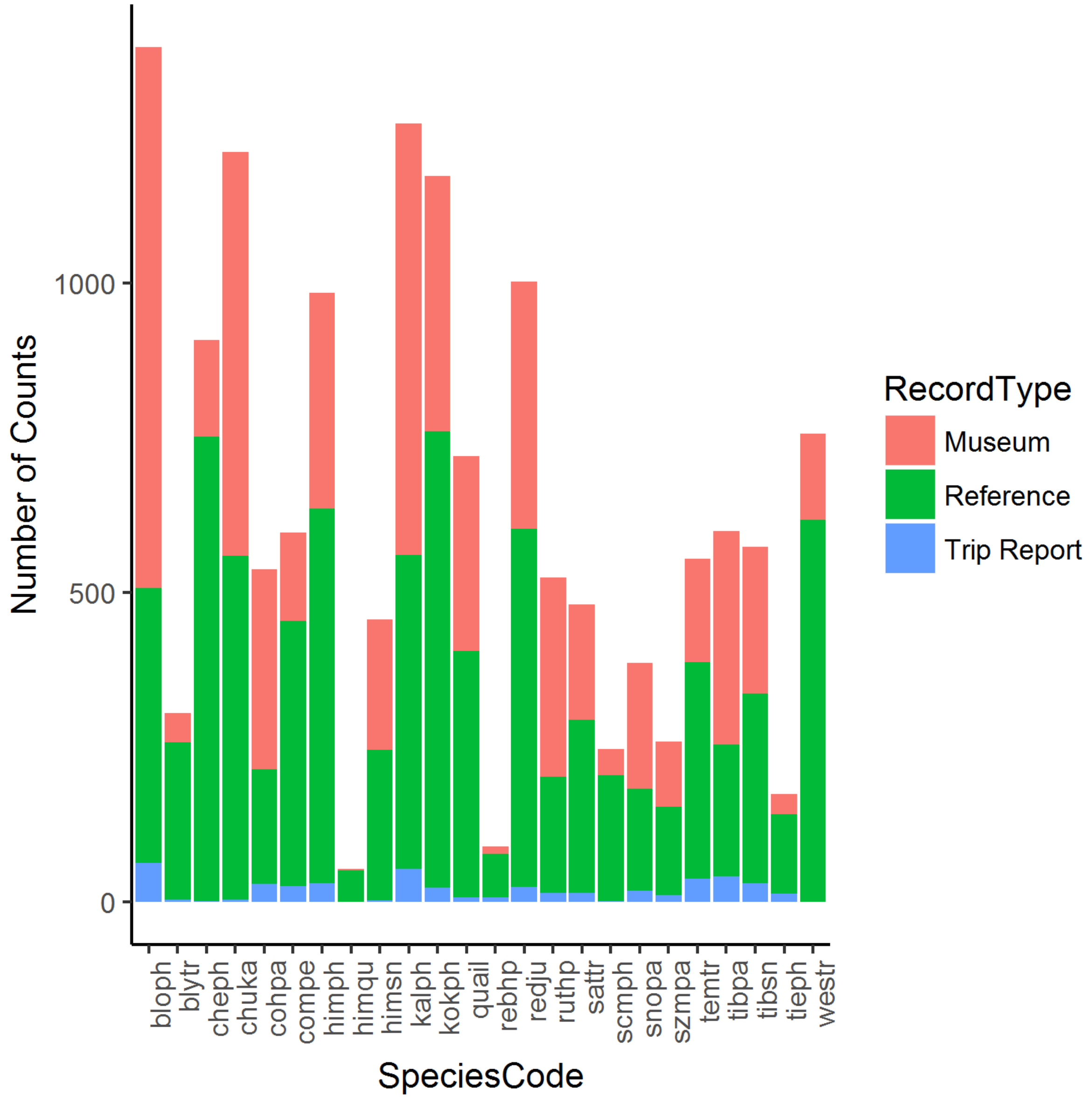

Figure A.1: Different sources of point locality data for each species. Maximum number of records are collected from reference followed by museum with minimum number of records from trip reports. Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = redbreasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr= satyr tragopan, scmph = sclater'smonal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan. Figure 3. Different sources of point locality data for each species. Maximum number of records are collected from reference followed by museum with minimum number of records from trip reports.

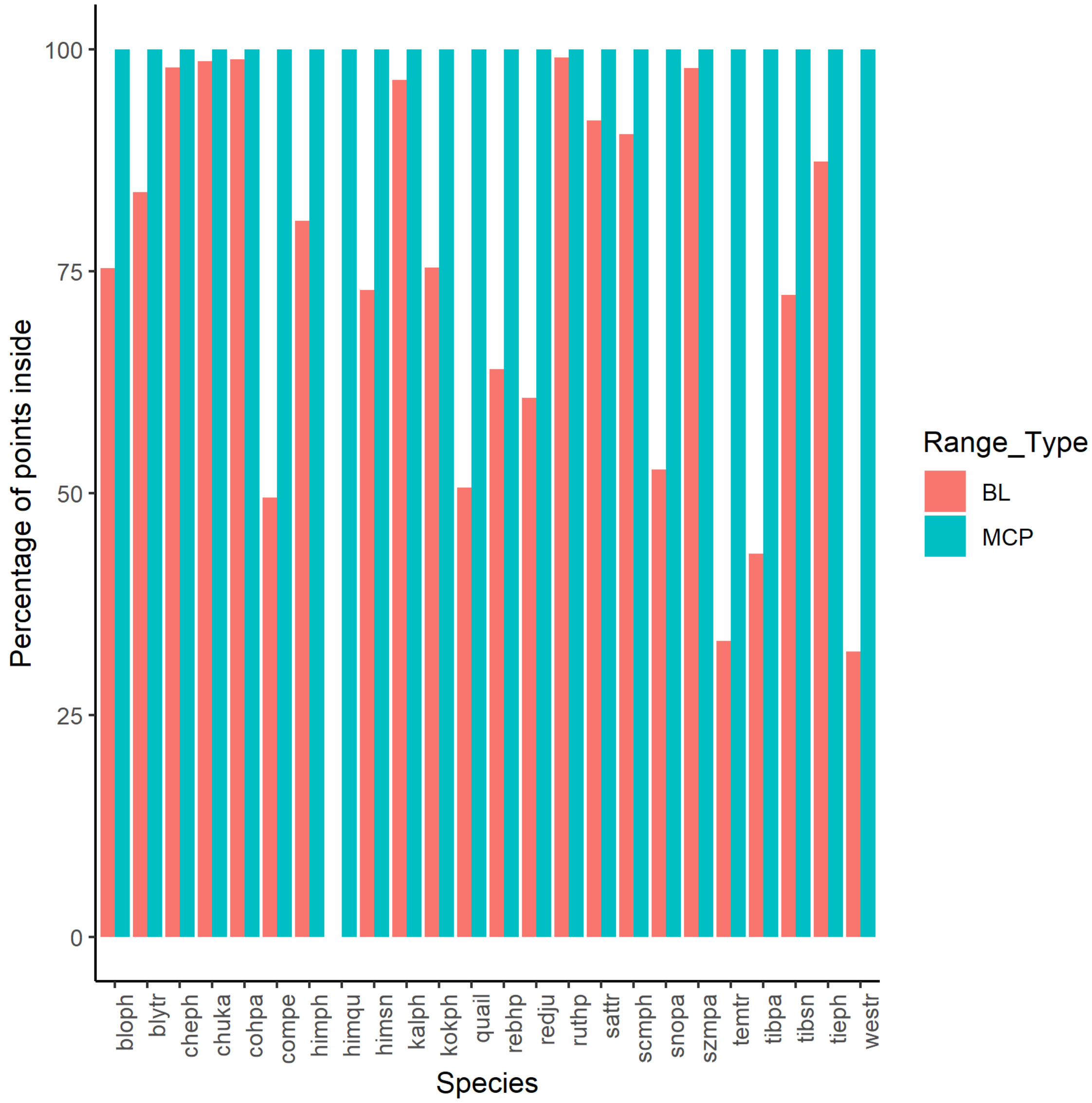

Figure A.2: Percentage of point locality data covered inside the MCP maps and the BirdLife International range maps. Orange bars represents points inside the BirdLife International range maps and green bars represents point inside the MCP. MCP's are constructed using the point locality data and cover all the points but the BirdLife International range maps do not cover all the points. Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij, kokph = koklass pheasant, quail = common quail, rebhp = chestnut breasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr= satyr tragopan, scmph = sclater'smonal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan.

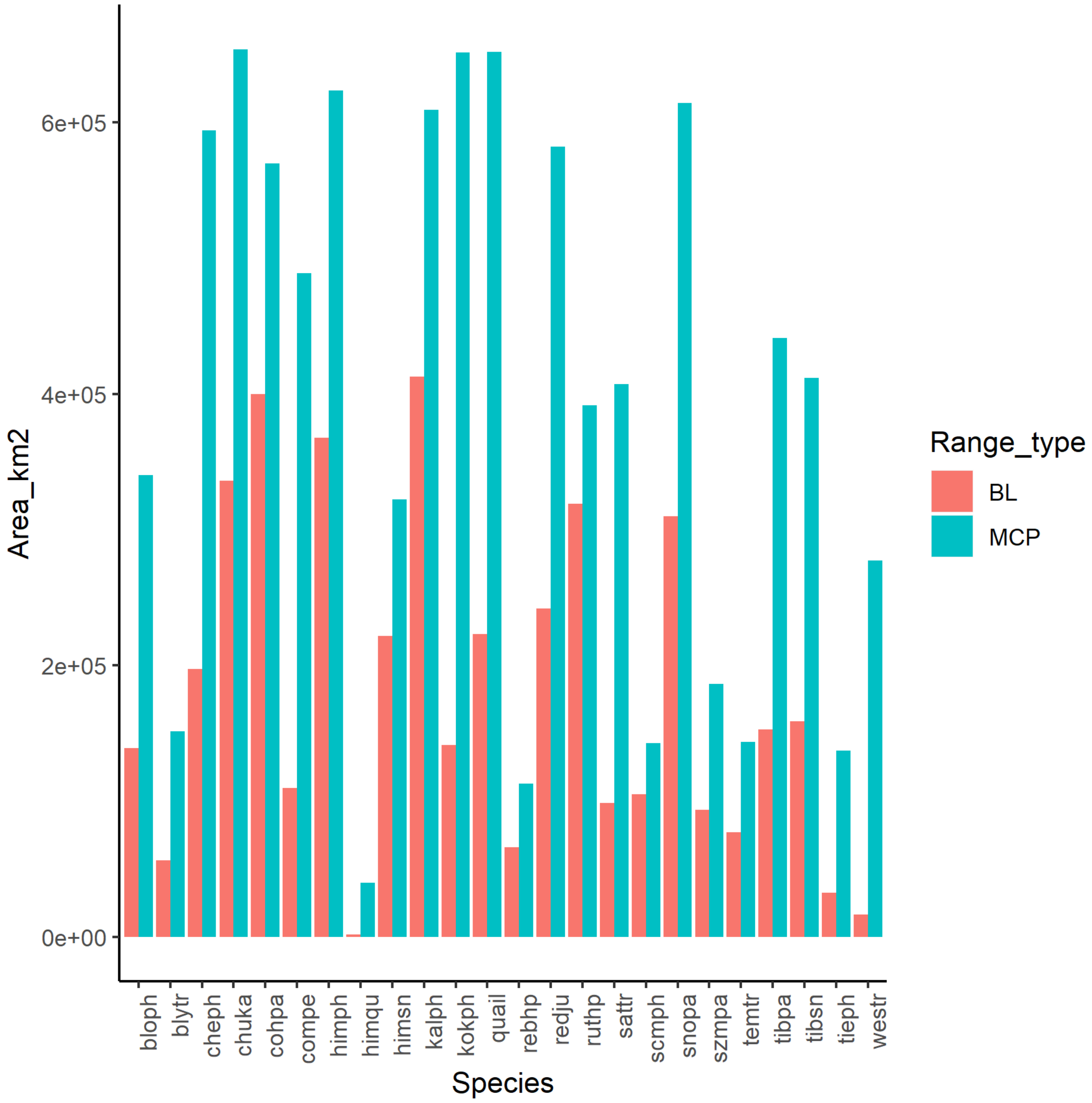

Figure A.3: Area of the MCP and the BirdLife International range maps. Orange bars represents area of the BirdLife International range maps and green bars represents the MCP area. There is a big difference in the area of the two maps for all species. Key: bloph = blood pheasant, blytr = Blyth's tragopan, cheph = cheer pheasant, chuka = chukar, cohpa = hill partridge, compe = common peafowl, himph = Himalayan monal, himqu = Himalayan Quail, himsn = Himalayan snowcock, kalph = kalij pheasant, kokph = koklass pheasant, quail = common quail, rebhp = redbreasted hill partridge, redju = red junglefowl, ruthp = rufous-throated partridge, sattr= satyr tragopan, scmph = sclater'smonal, snopa = snow partridge, szmpa = buff-throated partridge, temtr = Temminck's tragopan, tibpa = Tibetan partridge, tibsn =Tibetan snowcock, tieph = Tibetan-eared pheasant, westr = western tragopan.

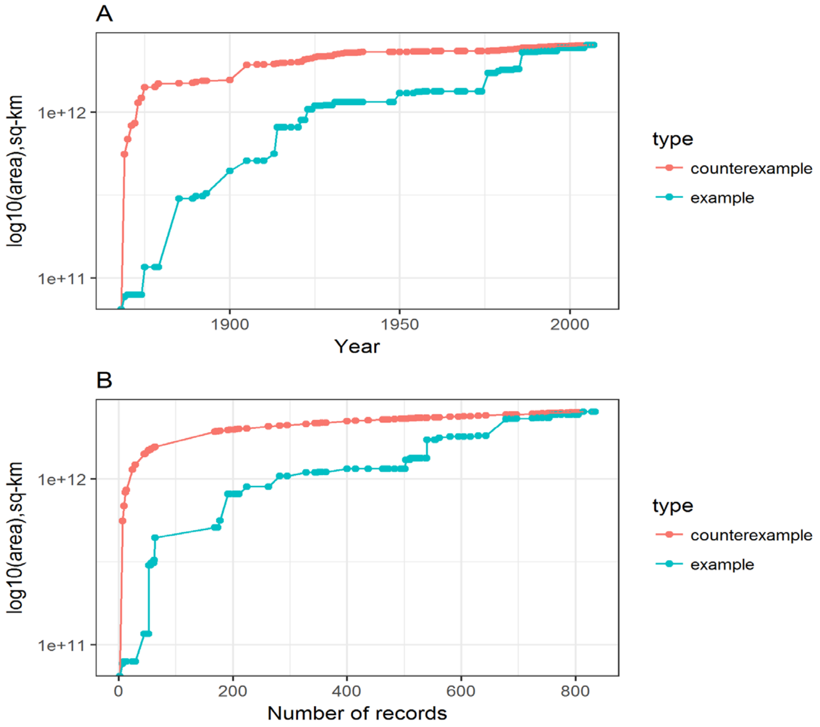

Figure A.4: **Range accumulation curves for blood pheasant (*Ithaginis cruentus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

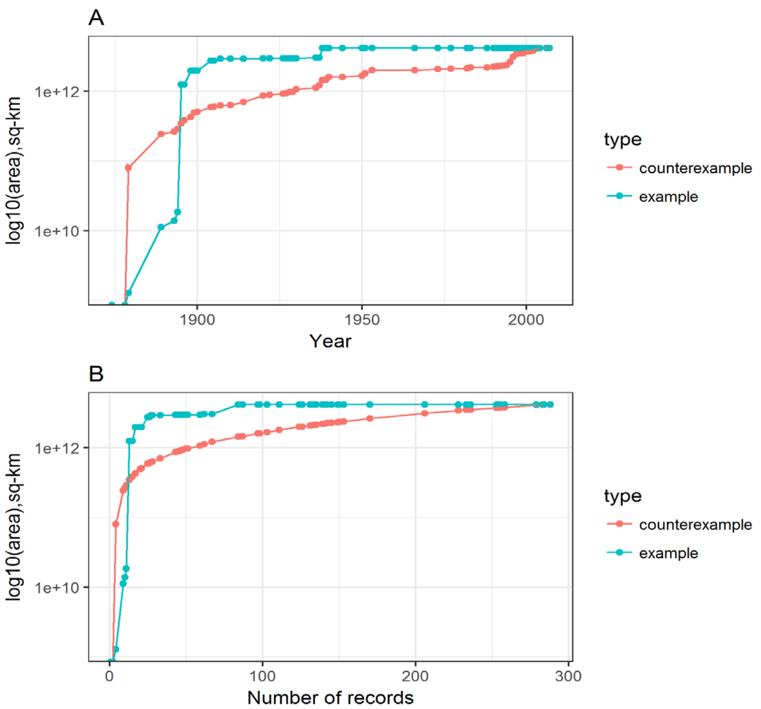

Figure A.5: **Range accumulation curves for Blyth's tragopan (*Tragopan blythii*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

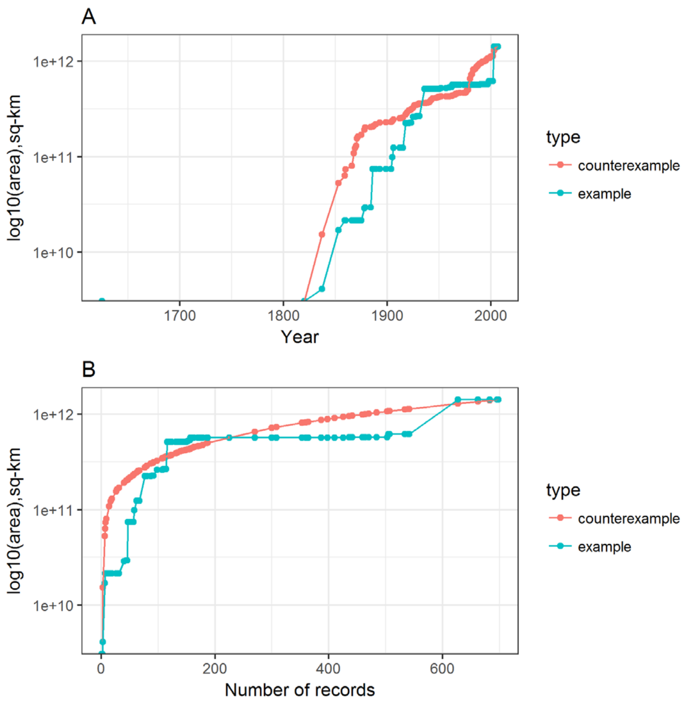

Figure A.6: **Range accumulation curves for cheer pheasant (*Catreus wallichii*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

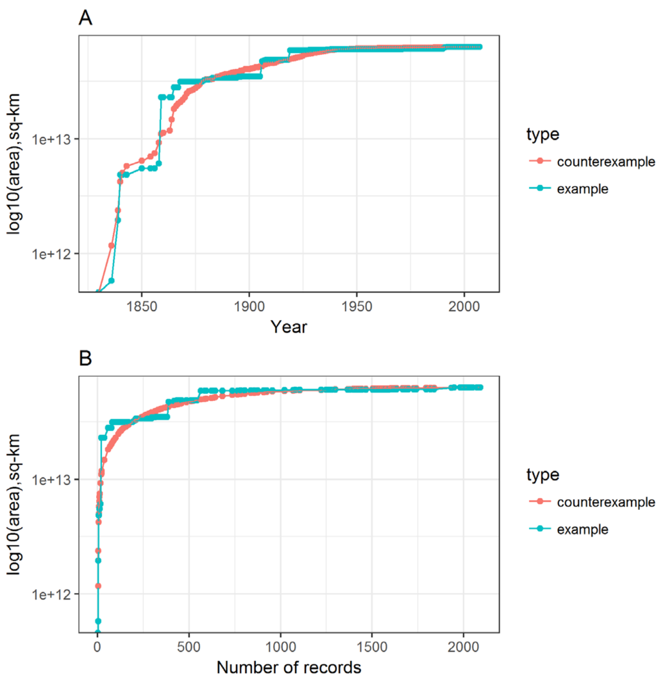

Figure A.7: **Range accumulation curves for chukar (*Alectoris chukar*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

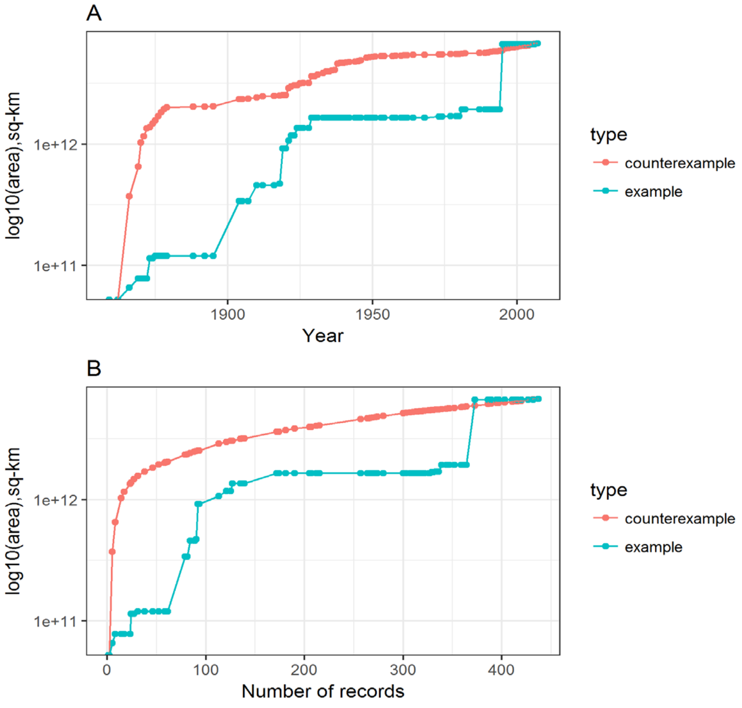

Figure A.8: **Range accumulation curves for common-hill partridge (*Arborophila torqueola*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

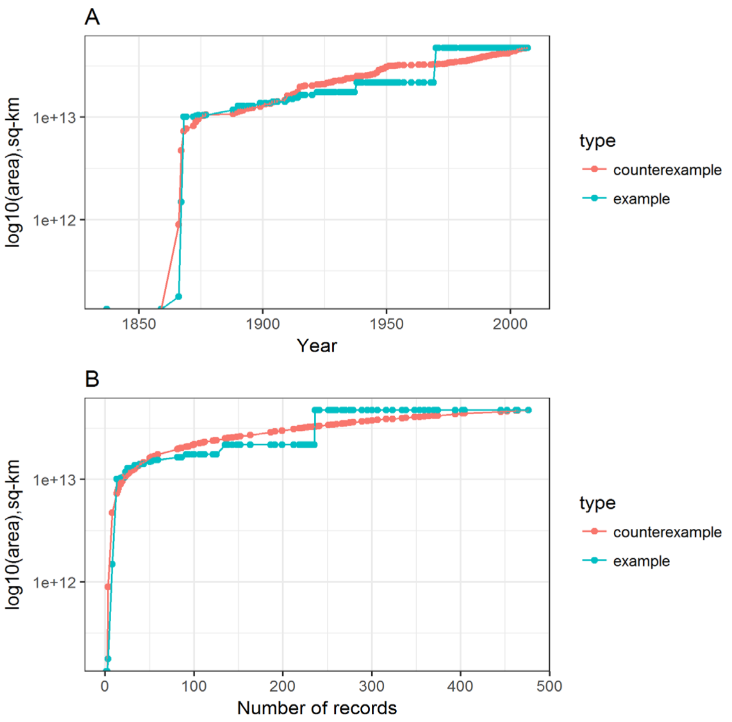

Figure A.9: **Range accumulation curves for common peafowl (*Pavo cristatus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

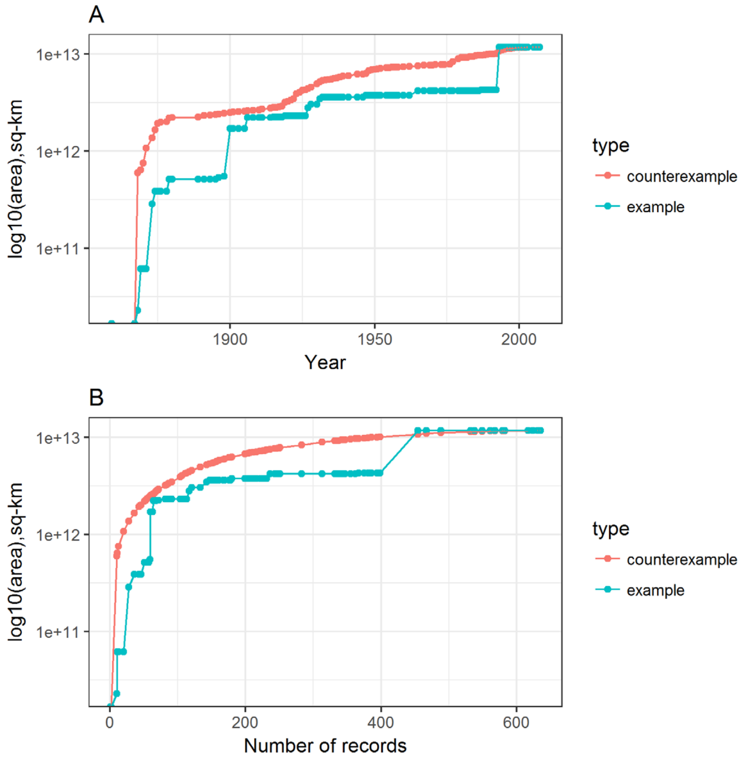

Figure A.10: **Range accumulation curves for Himalayan monal (*Lophophorus impejanus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

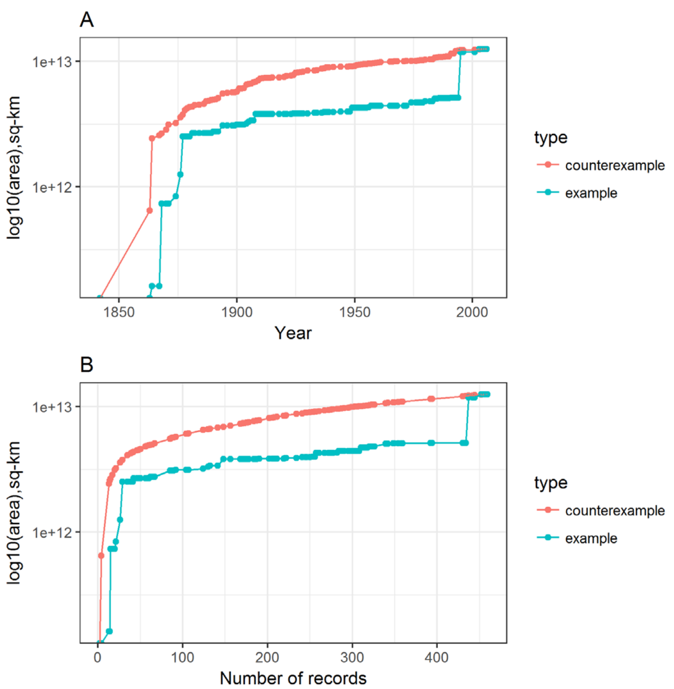

Figure A.11: **Range accumulation curves for Himalayan snowcock (*Tetraogallus himalayansis*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

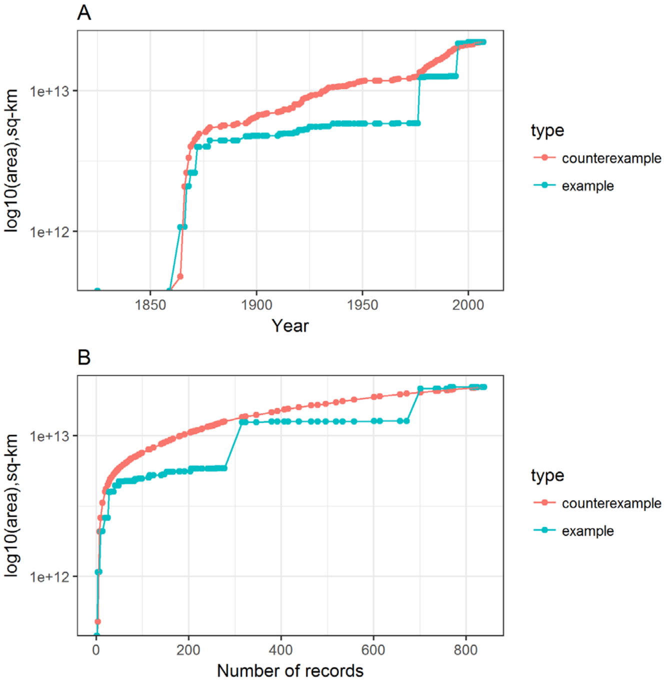

Figure A.12: **Range accumulation curves for koklass pheasant (*Pucrasia macrolopha*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

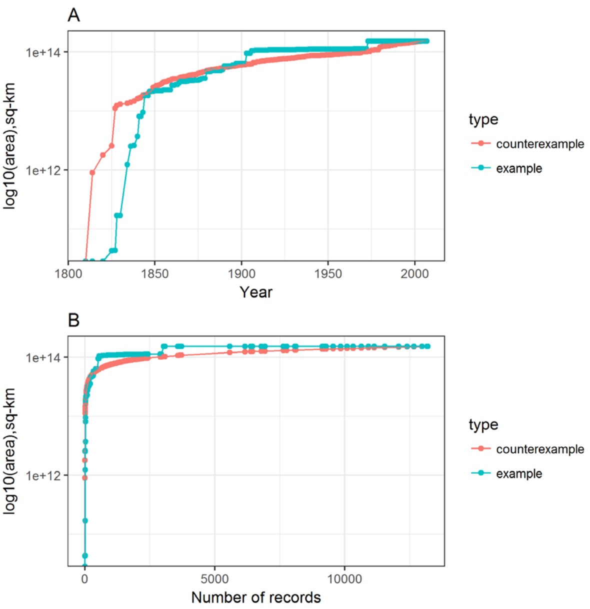

Figure A.13: **Range accumulation curves for common quail (*Coturnix coturnix*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

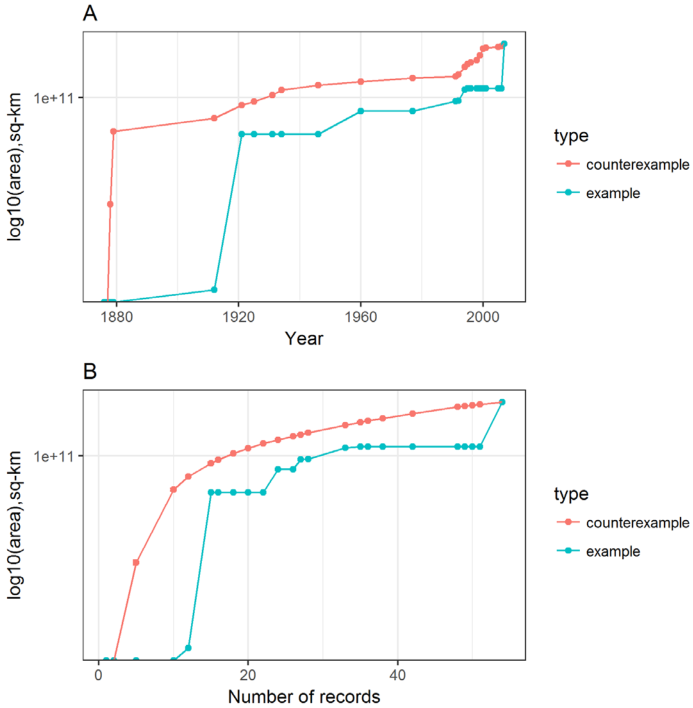

Figure A.14: **Range accumulation curves for chestnut-breasted hill partridge (*Arborophila mandellii*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

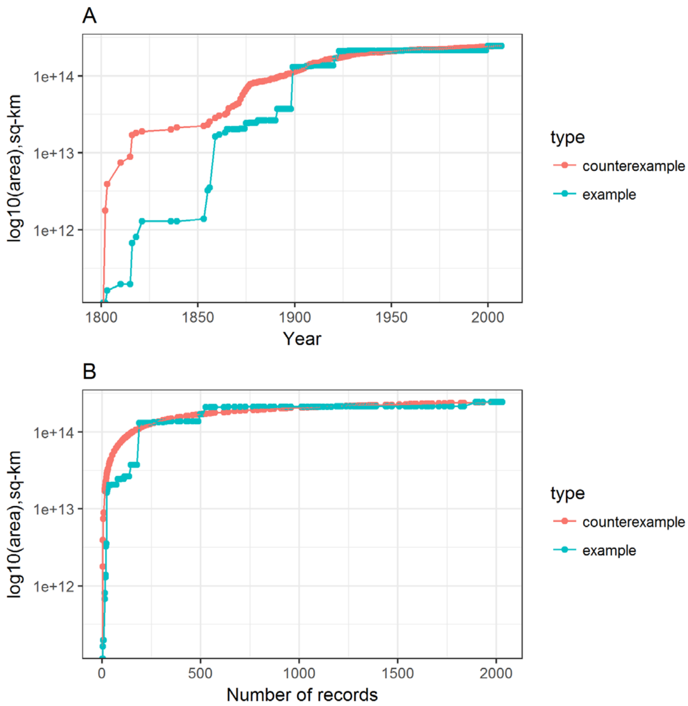

Figure A.15: **Range accumulation curves for red junglefowl (*Gallus gallus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

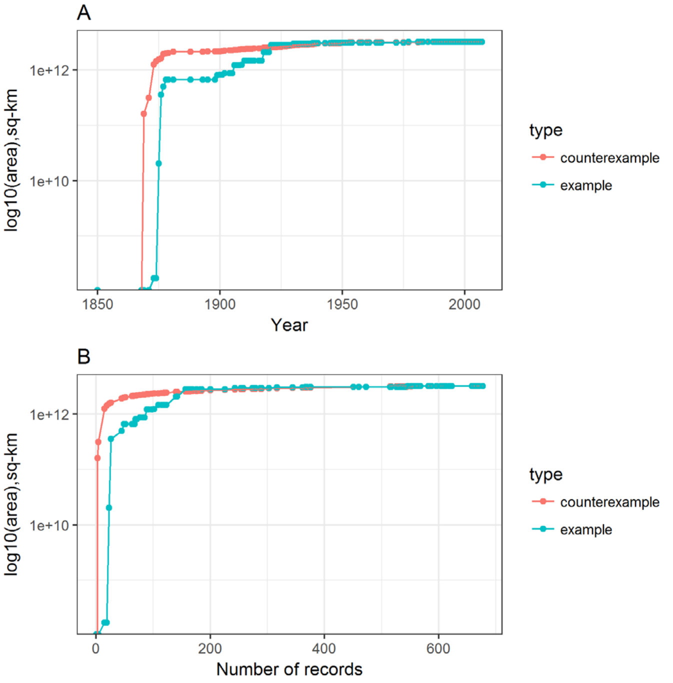

Figure A.16: **Range accumulation curves for rufous-throated partridge (*Arborophila rufogularis*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

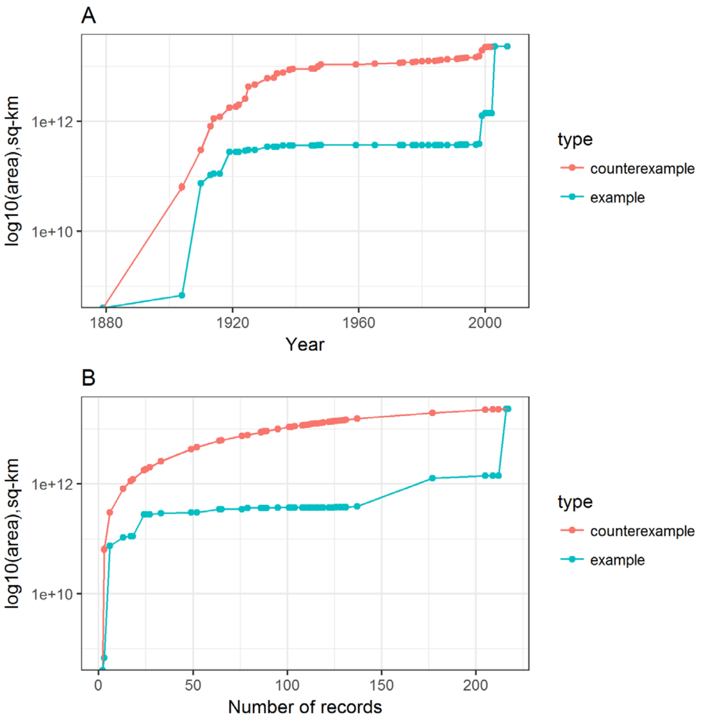

Figure A.17: **Range accumulation curves for Sclater's monal (*Lophophorus sclateri*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

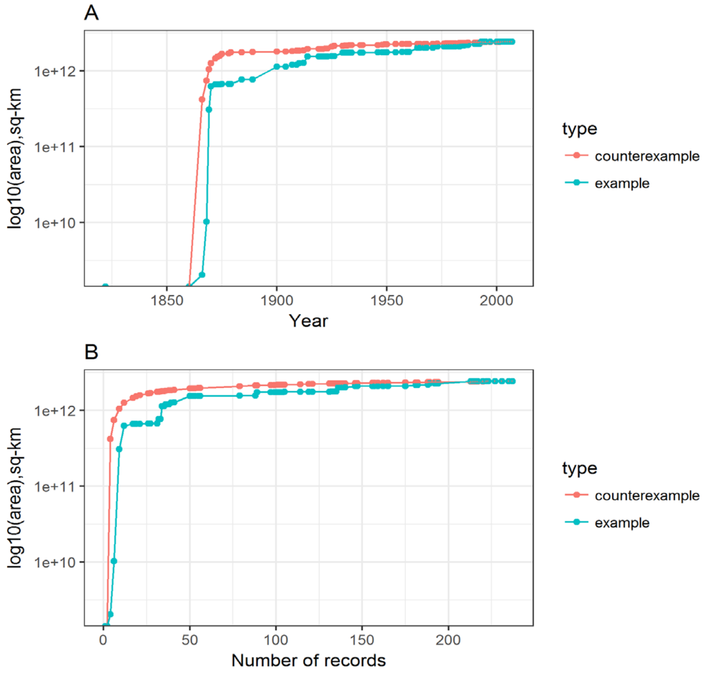

Figure A.18: **Range accumulation curves for snow partridge (*Lerwa lerwa*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

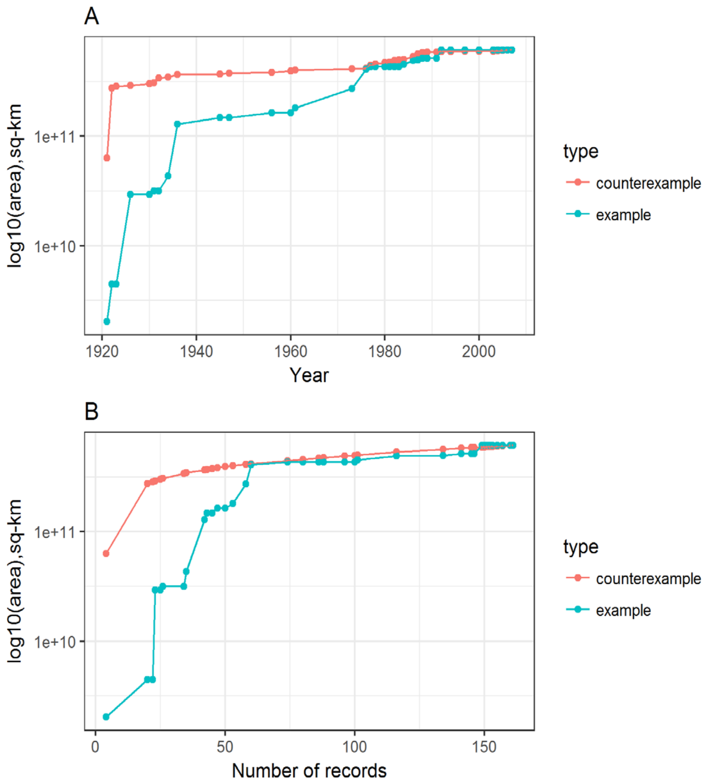

Figure A.19: **Range accumulation curves for buff-throated partridge (*Tetraophasis szechenyii*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

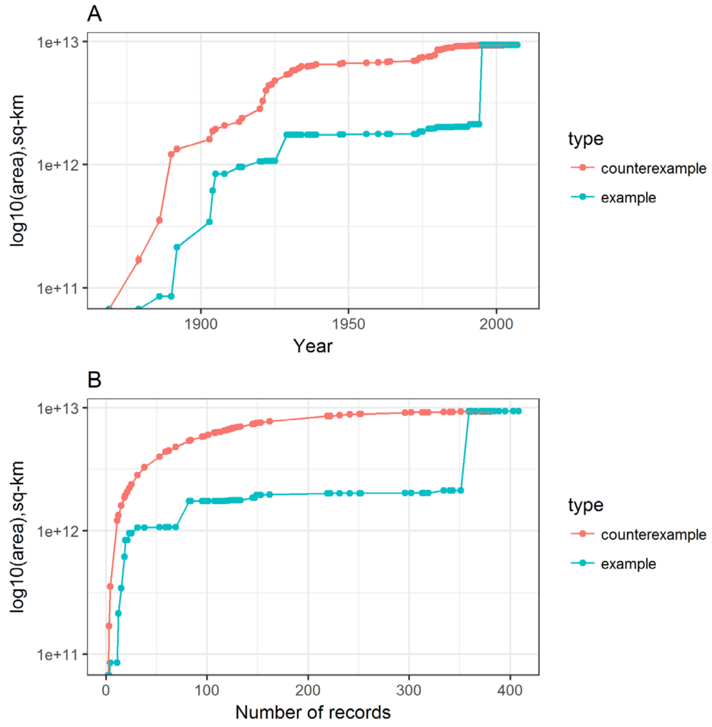

Figure A.20: **Range accumulation curves for Temminck's tragopan (*Tragopan temminckii*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

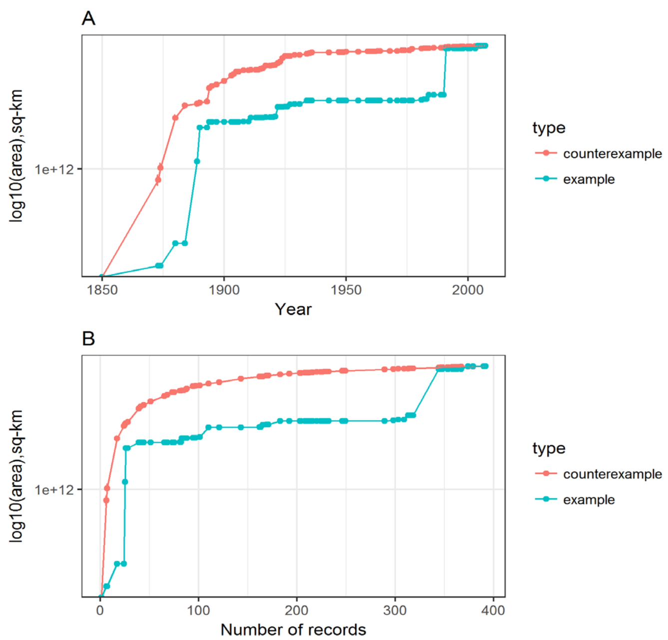

Figure A.21: **Range accumulation curves for Tibetan partridge (*Perdix hodgsoniae*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

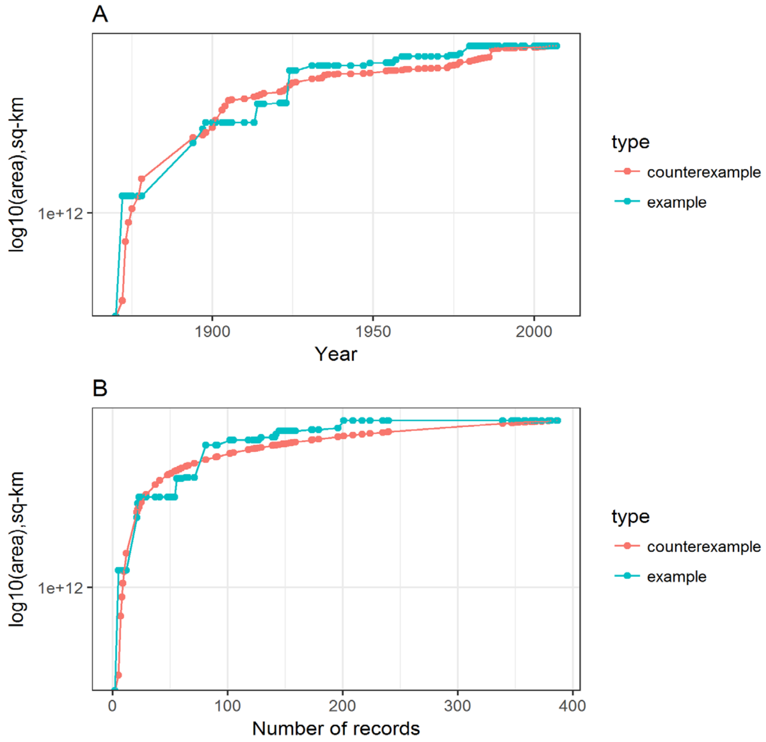

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Figure A.22: **Range accumulation curves for Tibetan snowcock (*Tetraogallus tibetanus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

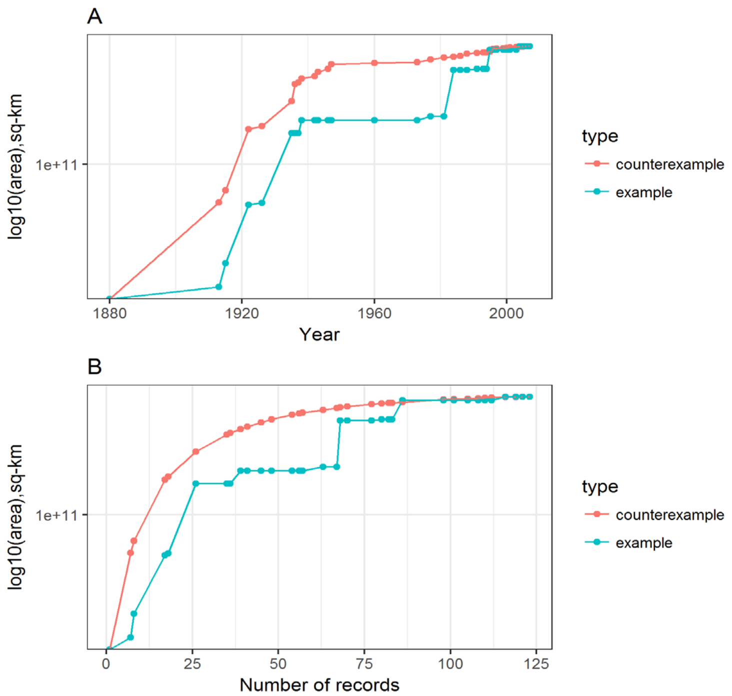

Figure A.23: **Range accumulation curves for Tibetan-eared pheasant (*Crossoptilon harmani*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

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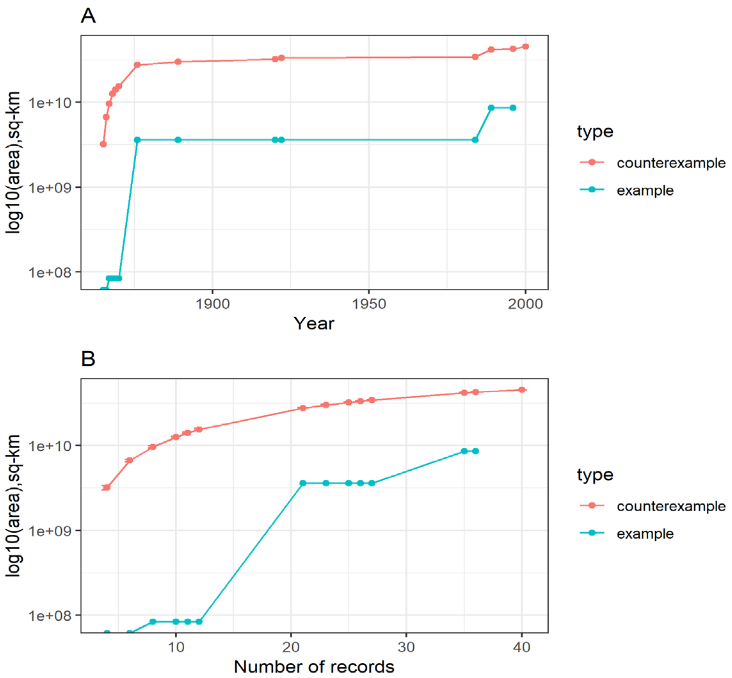


Figure A.24: **Range accumulation curves for Himalayan quail (*Ophrysia superciliosa*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

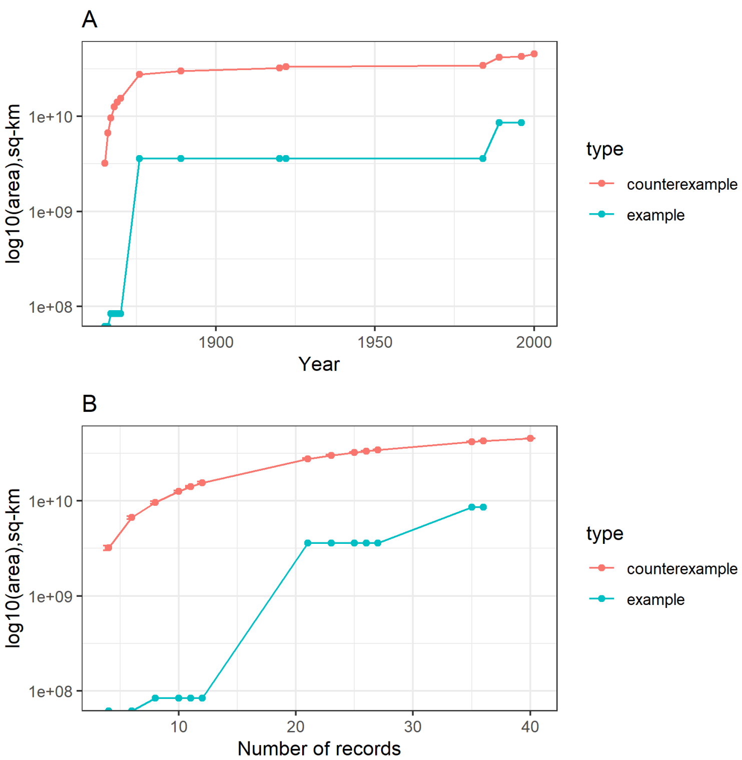


Figure A.25: **Range accumulation curves for kalij pheasant (*Lophura leucomelanos*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

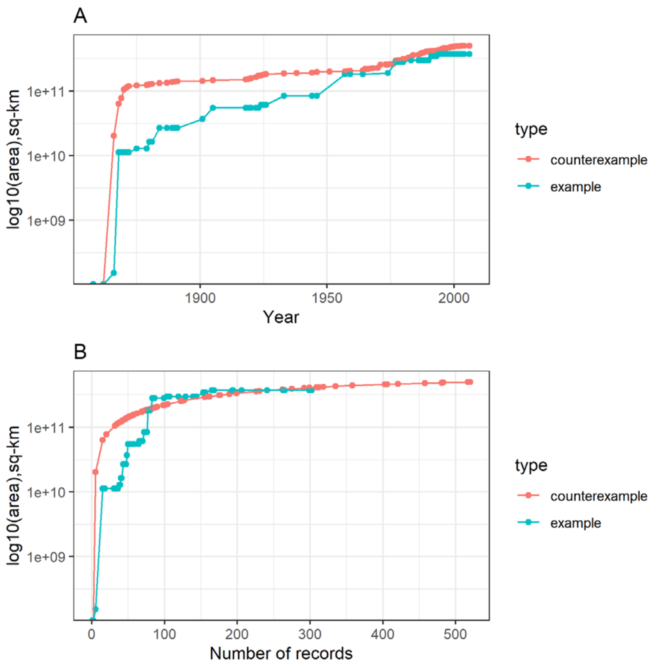


Figure A.26: **Range accumulation curves for western tragopan (*Tragopan melanocephalus*).** A, Comparison of historical (red) and simulated (green) area accumulation curves for year. B, Comparison of historical (red) and simulated (green) area accumulation curves for year.

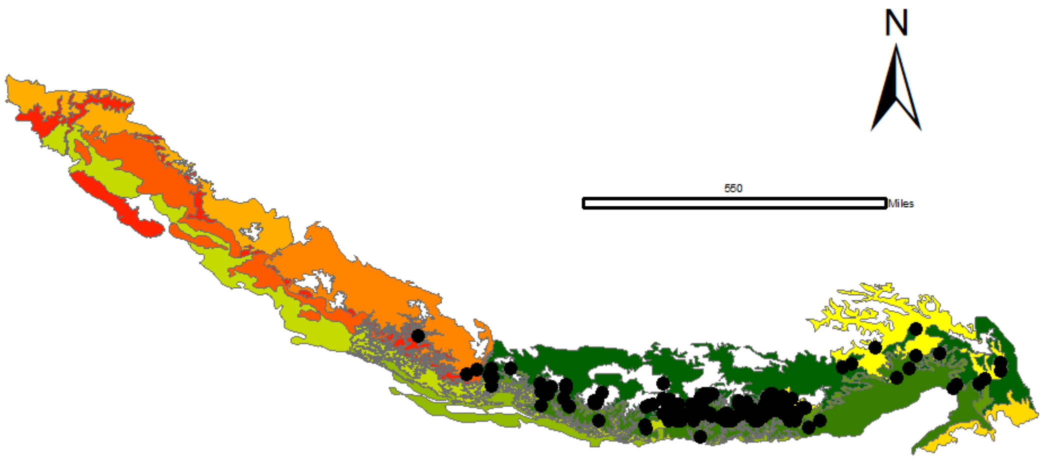
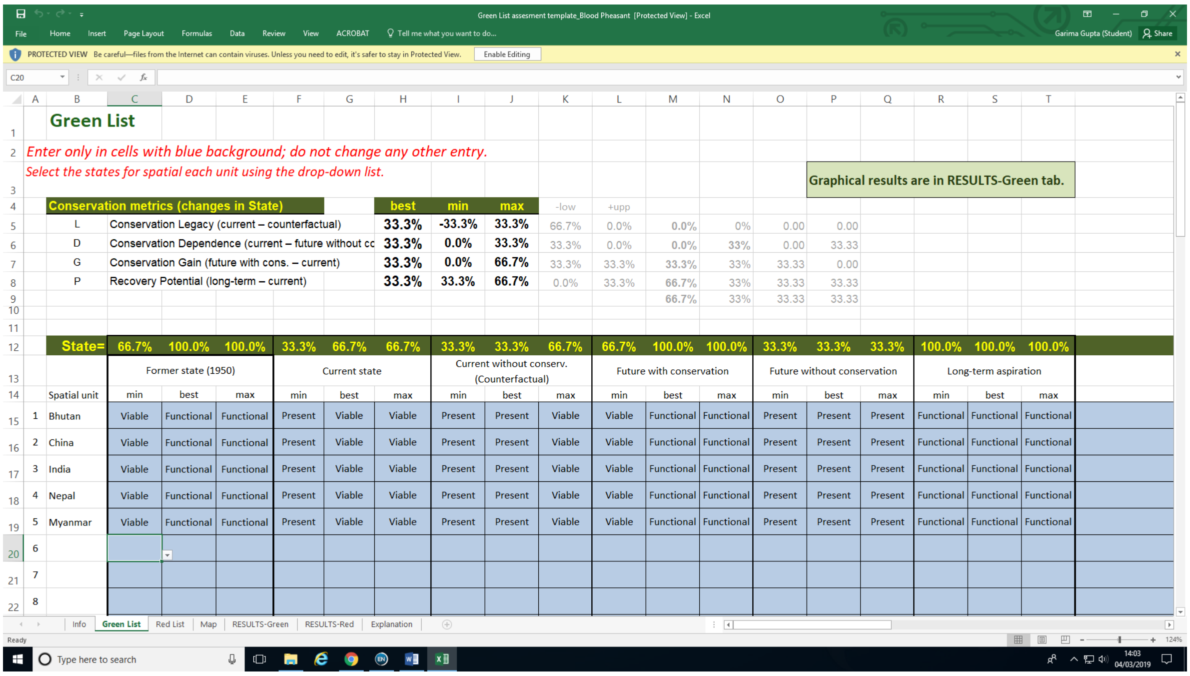


Figure A.27: Map showing the distribution of blood pheasant (*Ithaginis cruentus*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for blood pheasant which were collected from GALLIFORM: WPA Eurasian Database v 1.0.



Green List

Enter only in cells with blue background; do not change any other entry.

Select the states for spatial each unit using the drop-down list.

Graphical results are in RESULTS-Green tab.

Conservation metrics (changes in State)		best	min	max	-low	+upp				
L	Conservation Legacy (current – counterfactual)	33.3%	-33.3%	33.3%	66.7%	0.0%	0.0%	0%	0.00	0.00
D	Conservation Dependence (current – future without cc	33.3%	0.0%	33.3%	33.3%	0.0%	0.0%	33%	0.00	33.33
G	Conservation Gain (future with cons. – current)	33.3%	0.0%	66.7%	33.3%	33.3%	33.3%	33%	33.33	0.00
P	Recovery Potential (long-term – current)	33.3%	33.3%	66.7%	0.0%	33.3%	66.7%	33%	33.33	33.33
							66.7%	33%	33.33	33.33

		Former state (1950)			Current state			Current without conserv. (Counterfactual)			Future with conservation			Future without conservation			Long-term aspiration		
	State=	66.7%	100.0%	100.0%	33.3%	66.7%	66.7%	33.3%	33.3%	66.7%	66.7%	100.0%	100.0%	33.3%	33.3%	33.3%	100.0%	100.0%	100.0%
	Spatial unit	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max
1	Bhutan	Viable	Functional	Functional	Present	Viable	Viable	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
2	China	Viable	Functional	Functional	Present	Viable	Viable	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
3	India	Viable	Functional	Functional	Present	Viable	Viable	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
4	Nepal	Viable	Functional	Functional	Present	Viable	Viable	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
5	Myanmar	Viable	Functional	Functional	Present	Viable	Viable	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
6																			
7																			
8																			

Figure A.28: Screen shot of the template used to assess the IUCN Green List status of blood pheasant (*Ithaginis cruentus*).

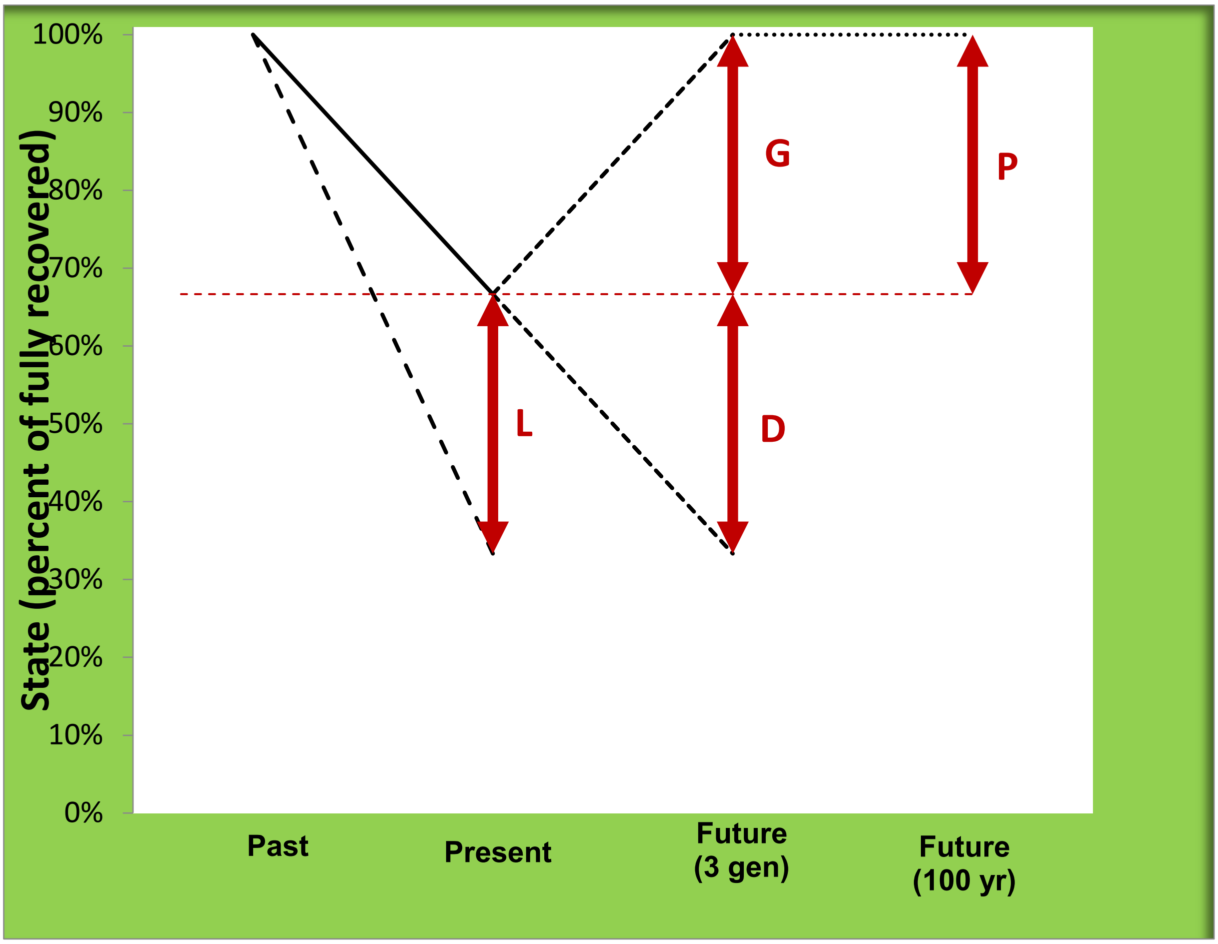


Figure A.29: Conservation metrics for blood pheasant (*Ithaginis cruentus*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

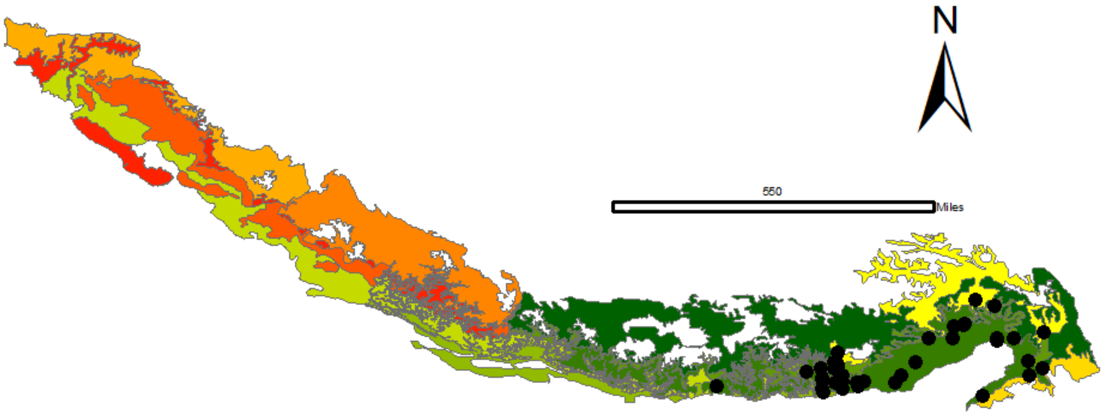
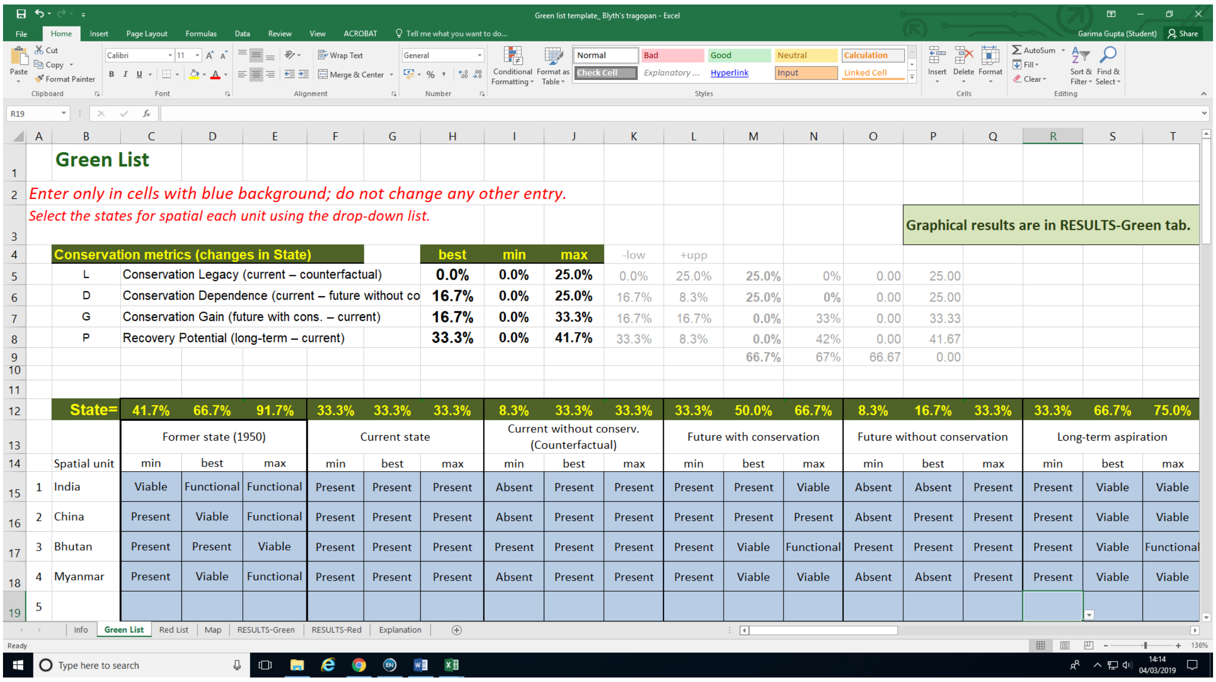


Figure A.30: Map showing the distribution of blyth's tragopan (*Tragopan blythii*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for blyth's tragopan which were collected from GALLIFORM: WPA Eurasian Database v 1.0.



Green List

Enter only in cells with blue background; do not change any other entry.

Select the states for spatial each unit using the drop-down list.

Graphical results are in RESULTS-Green tab.

	Conservation metrics (changes in State)	best	min	max	-low	+upp				
L	Conservation Legacy (current – counterfactual)	0.0%	0.0%	25.0%	0.0%	25.0%	25.0%	0%	0.00	25.00
D	Conservation Dependence (current – future without co	16.7%	0.0%	25.0%	16.7%	8.3%	25.0%	0%	0.00	25.00
G	Conservation Gain (future with cons. – current)	16.7%	0.0%	33.3%	16.7%	16.7%	0.0%	33%	0.00	33.33
P	Recovery Potential (long-term – current)	33.3%	0.0%	41.7%	33.3%	8.3%	0.0%	42%	0.00	41.67
							66.7%	67%	66.67	0.00

State=	41.7%	66.7%	91.7%	33.3%	33.3%	33.3%	8.3%	33.3%	33.3%	33.3%	50.0%	66.7%	8.3%	16.7%	33.3%	33.3%	66.7%	75.0%
	Former state (1950)			Current state			Current without conserv. (Counterfactual)			Future with conservation			Future without conservation			Long-term aspiration		
Spatial unit	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max
1 India	Viable	Functional	Functional	Present	Present	Present	Absent	Present	Present	Present	Present	Viable	Absent	Absent	Present	Present	Viable	Viable
2 China	Present	Viable	Functional	Present	Present	Present	Absent	Present	Present	Present	Present	Present	Absent	Present	Present	Present	Viable	Viable
3 Bhutan	Present	Present	Viable	Present	Present	Present	Present	Present	Present	Present	Viable	Functional	Present	Present	Present	Present	Viable	Functional
4 Myanmar	Present	Viable	Functional	Present	Present	Present	Absent	Present	Present	Present	Viable	Viable	Absent	Absent	Present	Present	Viable	Viable
5																		

Figure A.31: Screen shot of the template used to assess the IUCN Green List status of Blyth's tragopan (*Tragopan blythii*).

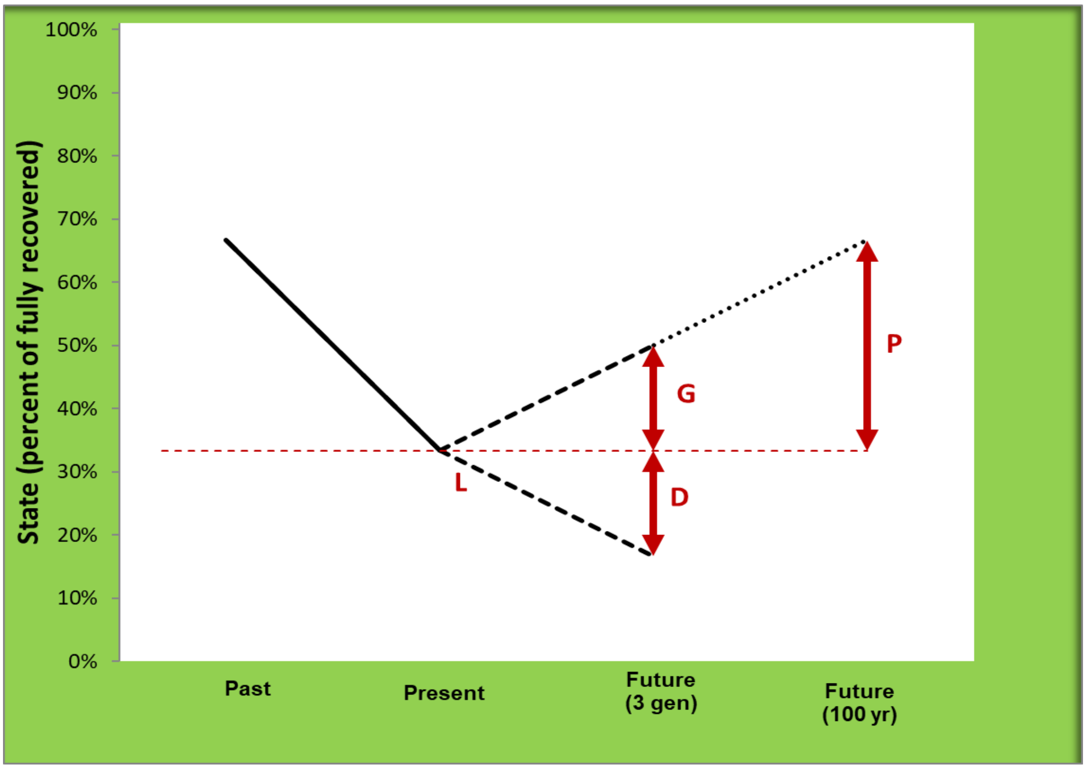


Figure A.32: Conservation metrics for Blyth's tragopan (*Tragopan blythii*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

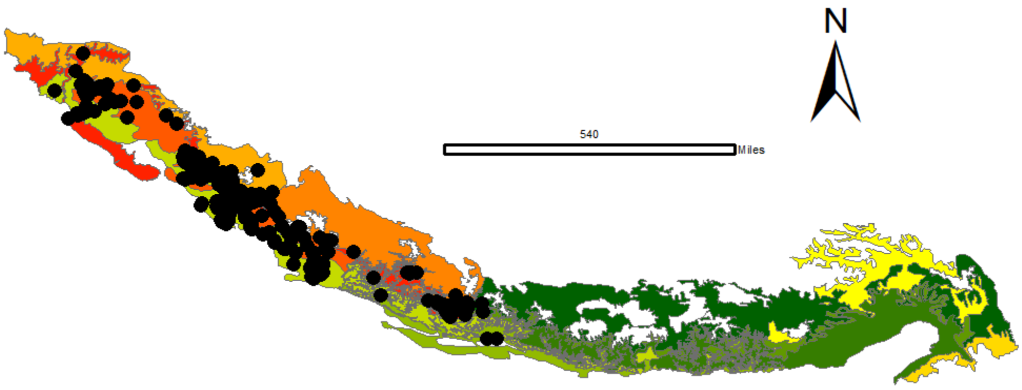


Figure A.33: Map showing the distribution of cheer pheasant (C*atreus wallichii*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for cheer pheasant which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

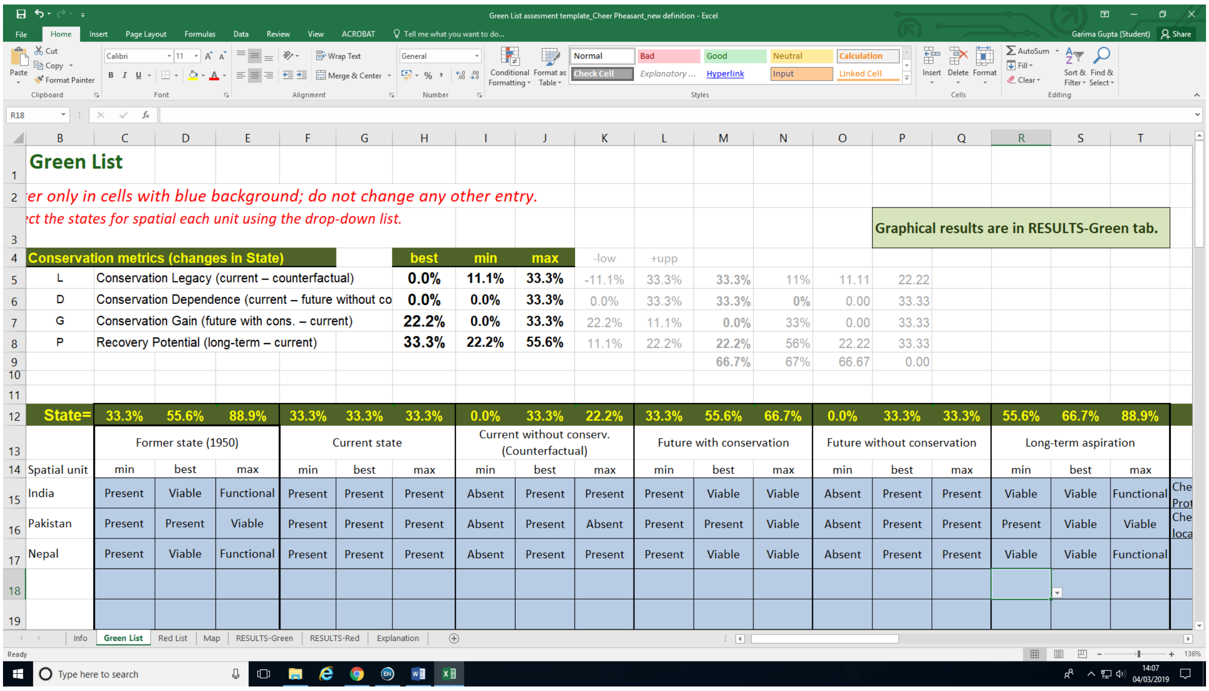


Figure A.34: Screen shot of the template used to assess the IUCN Green List status of cheer pheasant (*Catreus wallichii*).

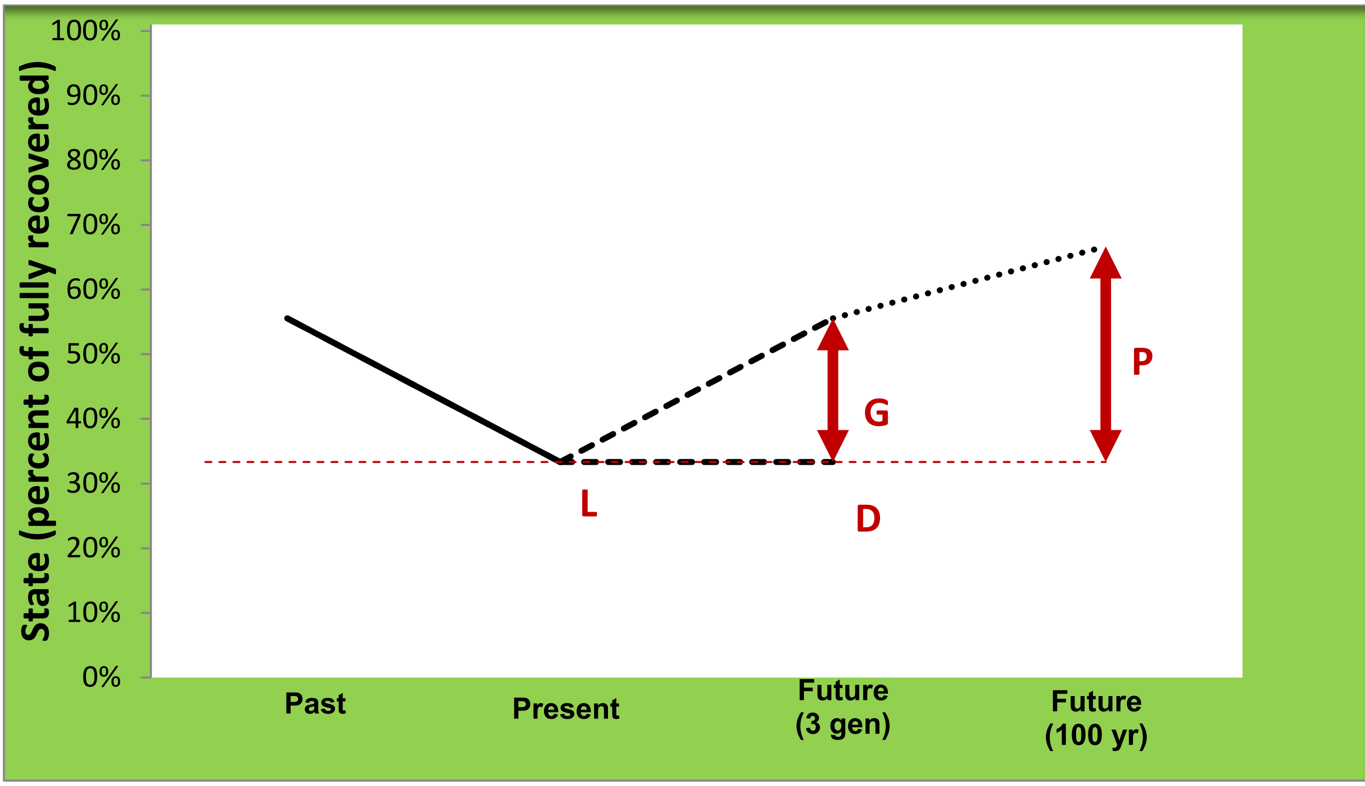


Figure A.35: Conservation metrics for cheer pheasant (*Catreus wallichii*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

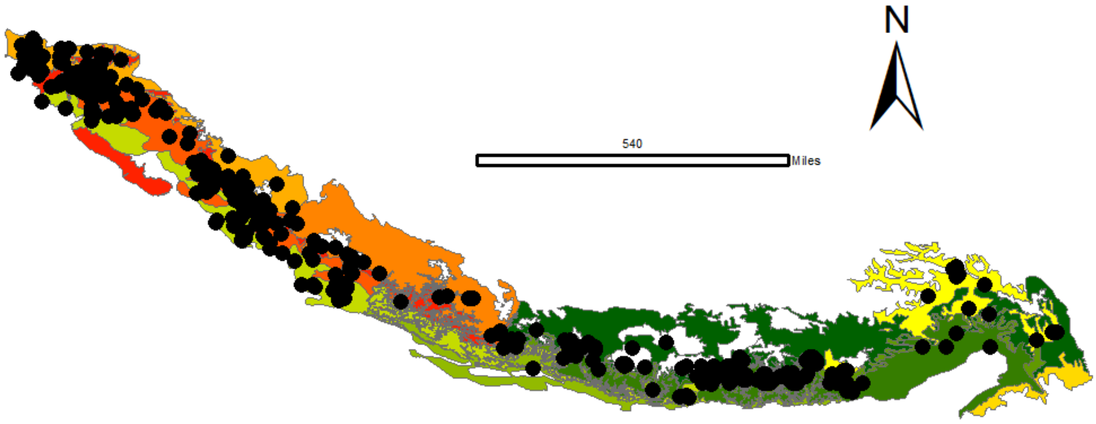
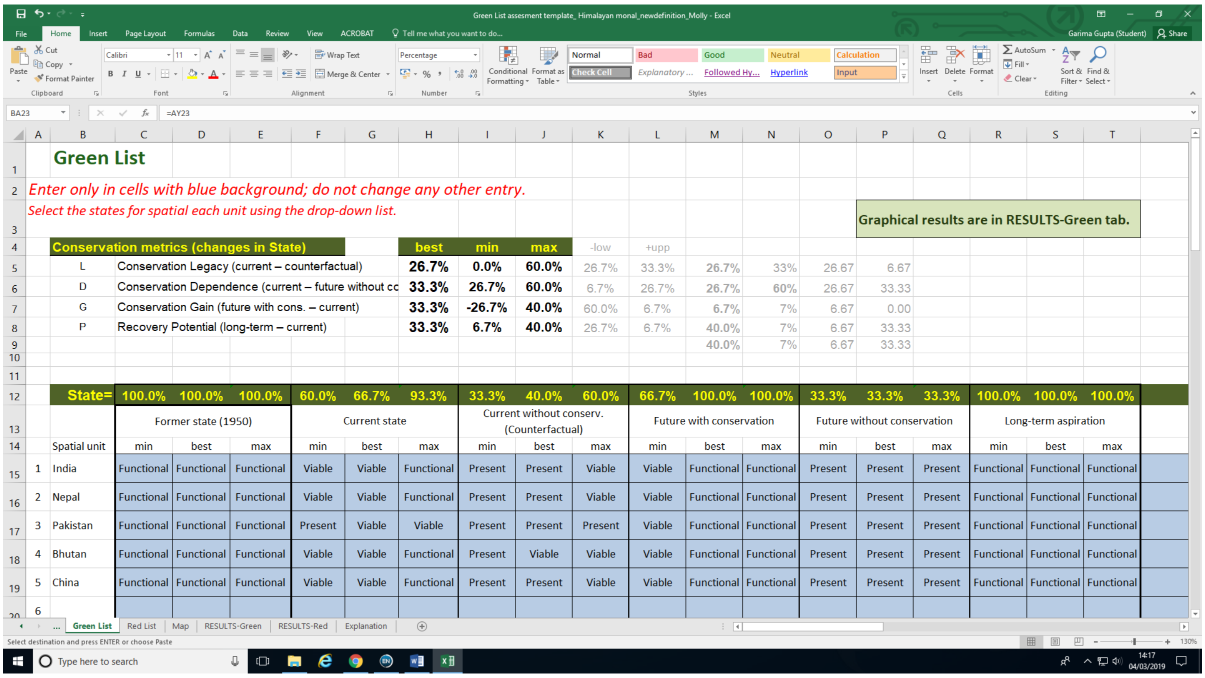


Figure A.36: Map showing the distribution of Himalayan monal (*Lophophorus impejanus*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data.for Himalayan monal which were collected from GALLIFORM: WPA Eurasian Database v 1.0.



Green List

Enter only in cells with blue background; do not change any other entry.

Select the states for spatial each unit using the drop-down list.

Graphical results are in RESULTS-Green tab.

	Conservation metrics (changes in State)	best	min	max	-low	+upp				
L	Conservation Legacy (current – counterfactual)	26.7%	0.0%	60.0%	26.7%	33.3%	26.7%	33%	26.67	6.67
D	Conservation Dependence (current – future without cc	33.3%	26.7%	60.0%	6.7%	26.7%	26.7%	60%	26.67	33.33
G	Conservation Gain (future with cons. – current)	33.3%	-26.7%	40.0%	60.0%	6.7%	6.7%	7%	6.67	0.00
P	Recovery Potential (long-term – current)	33.3%	6.7%	40.0%	26.7%	6.7%	40.0%	7%	6.67	33.33
							40.0%	7%	6.67	33.33

	State=	100.0%	100.0%	100.0%	60.0%	66.7%	93.3%	33.3%	40.0%	60.0%	66.7%	100.0%	100.0%	33.3%	33.3%	33.3%	100.0%	100.0%	100.0%
		Former state (1950)			Current state			Current without conserv. (Counterfactual)			Future with conservation			Future without conservation			Long-term aspiration		
	Spatial unit	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max
1	India	Functional	Functional	Functional	Viable	Viable	Functional	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
2	Nepal	Functional	Functional	Functional	Viable	Viable	Functional	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
3	Pakistan	Functional	Functional	Functional	Present	Viable	Viable	Present	Present	Present	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
4	Bhutan	Functional	Functional	Functional	Viable	Viable	Functional	Present	Viable	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
5	China	Functional	Functional	Functional	Viable	Viable	Functional	Present	Present	Viable	Viable	Functional	Functional	Present	Present	Present	Functional	Functional	Functional
6																			

Figure A.37: Screen shot of the template used to assess the IUCN Green List status of Himalayan monal (*Lophophorus impejanus*).

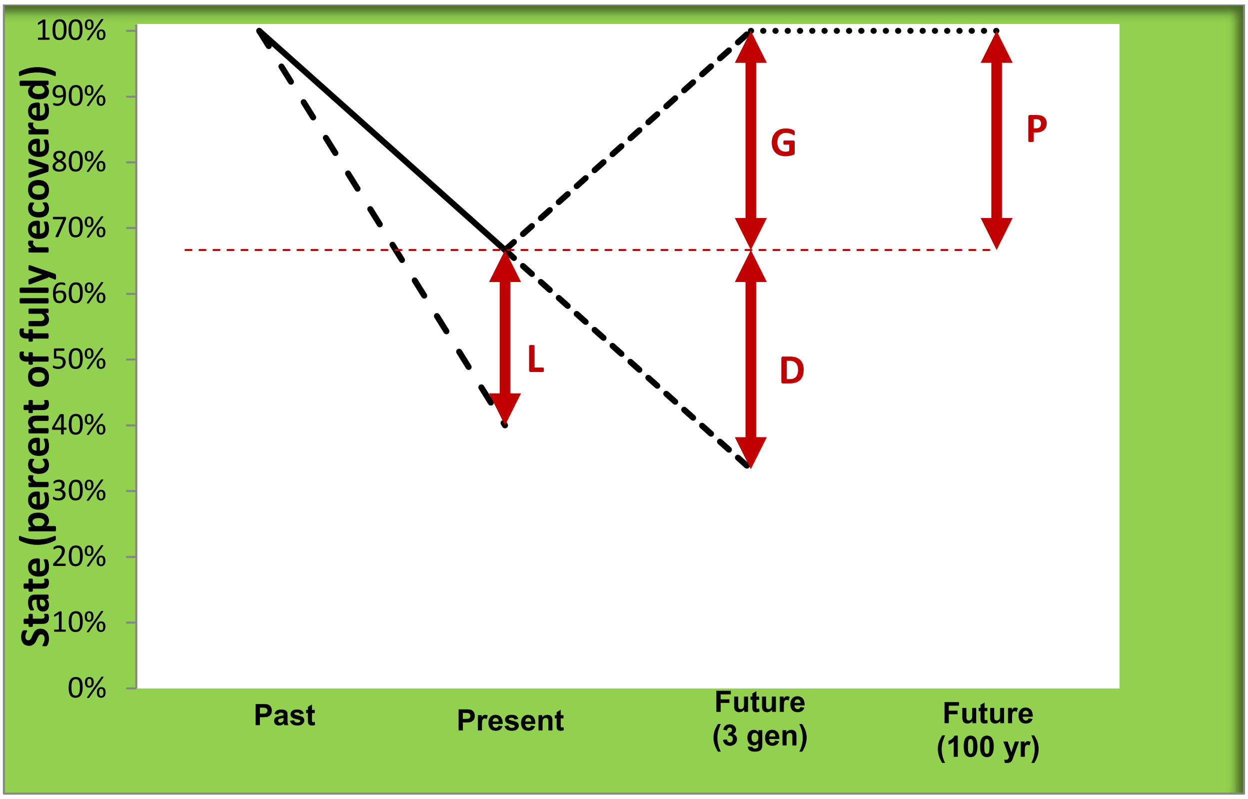


Figure A.38: Conservation metrics for Himalayan monal (*Lophophorus impejanus*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

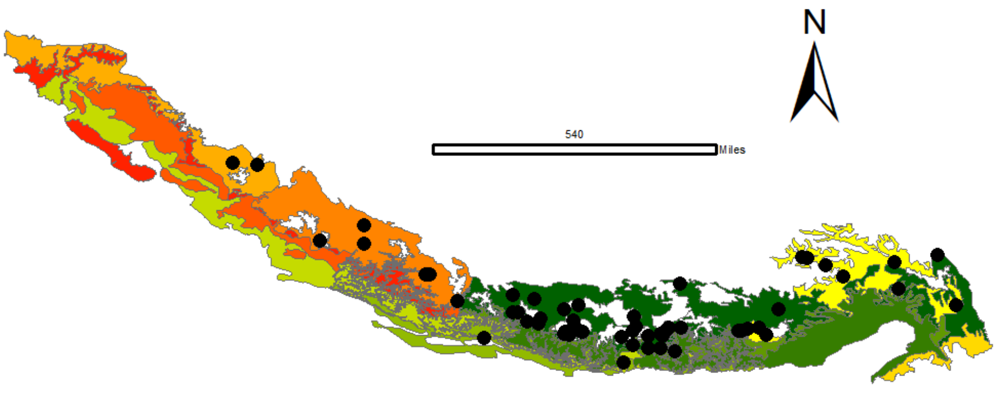


Figure A.39: Map showing the distribution of Tibetan snowcock (*Tetraogallus tibetanus*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for Tibetan snowcock which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

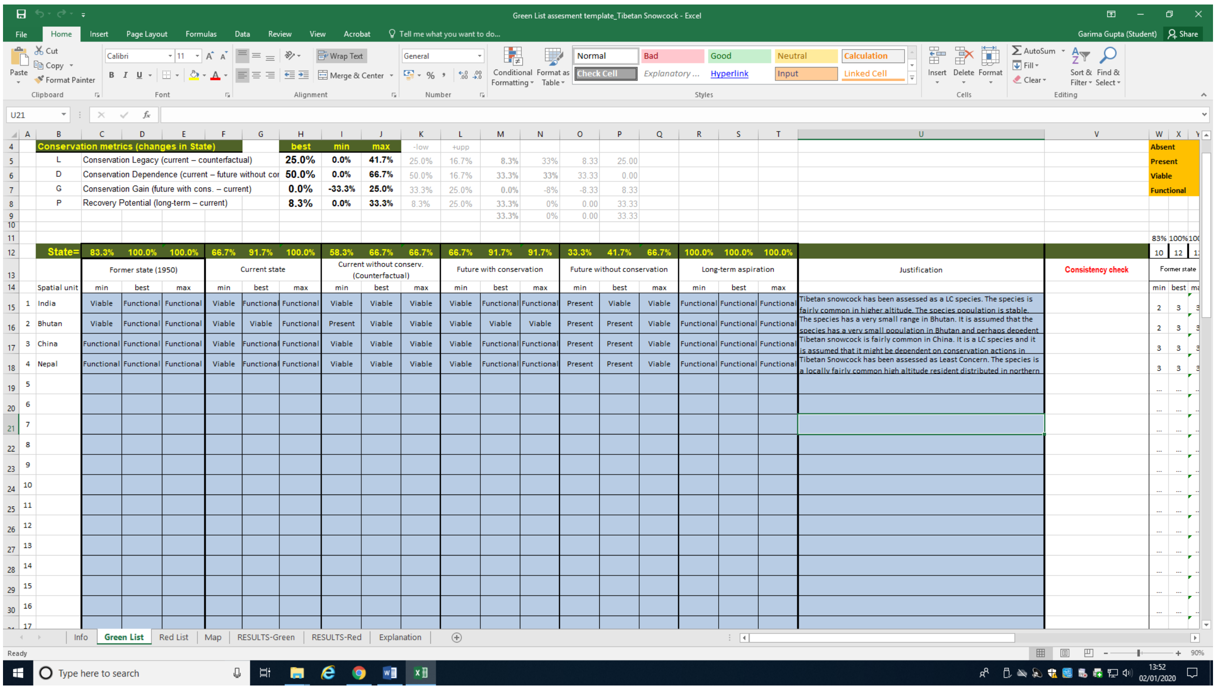


Figure A.40: Screen shot of the template used to assess the IUCN Green List status of Tibetan snowcock (*Tetraogallus tibetanus*).

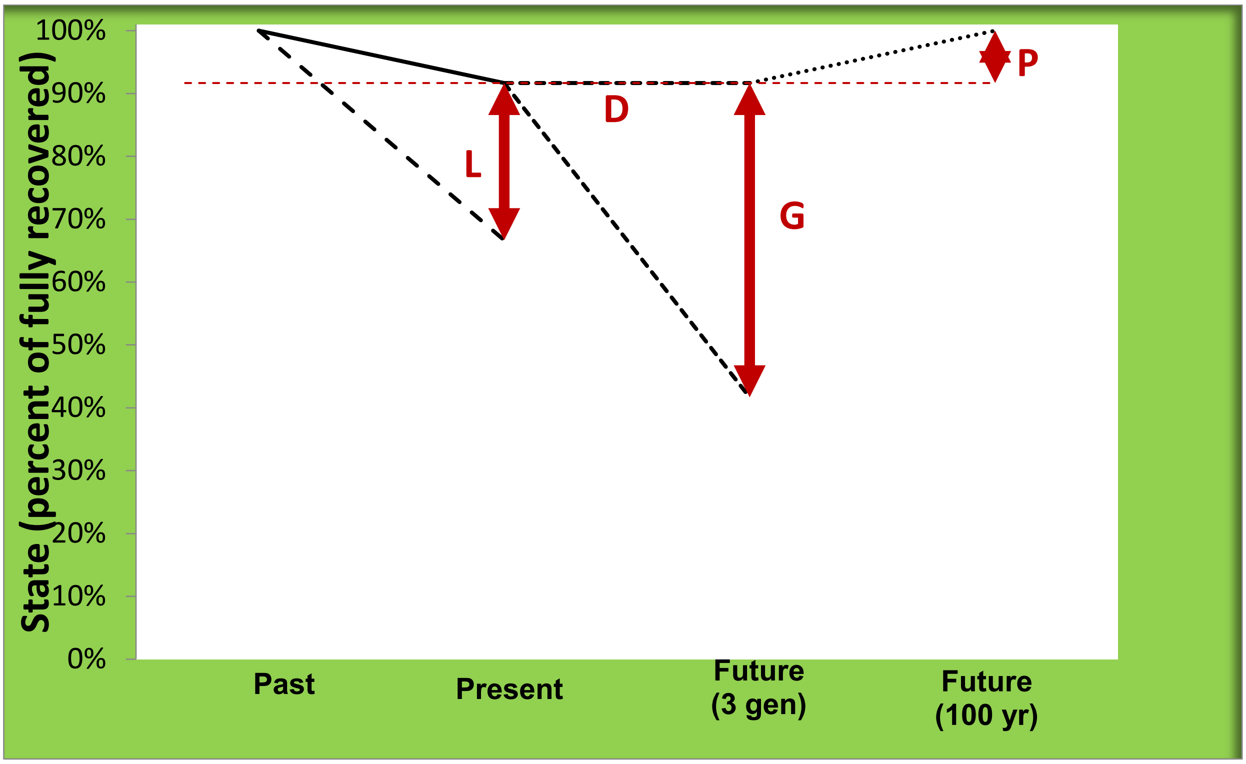


Figure A.41: Conservation metrics for Tibetan snowcock (*Tetraogallus tibetanus*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

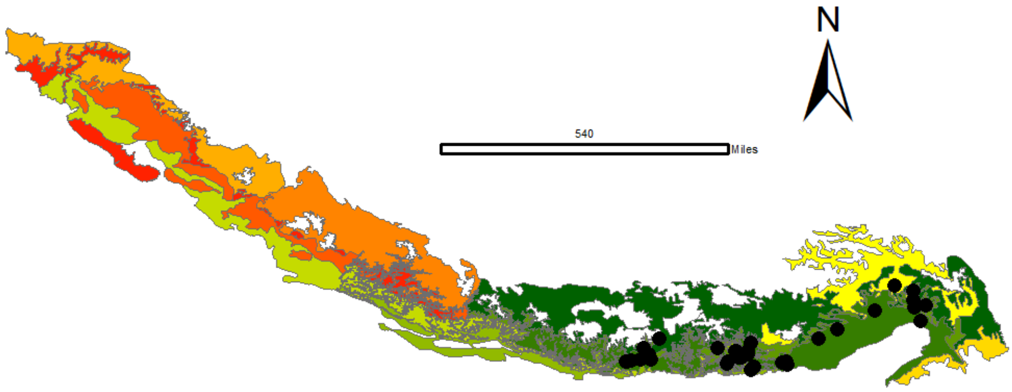
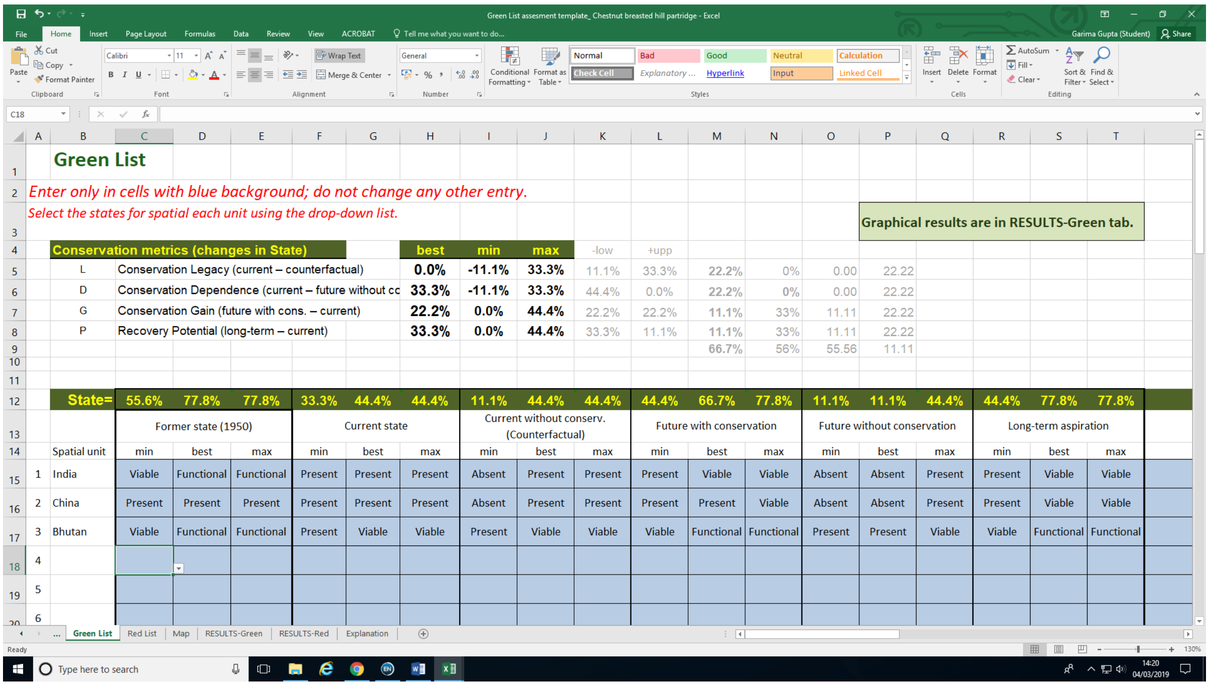


Figure A.42: Map showing the distribution of chestnut- breasted hill partridge (*Arborophila mandellii*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for chestnut- breasted hill partridge which were collected from GALLIFORM: WPA Eurasian Database v 1.0.



Green List

Enter only in cells with blue background; do not change any other entry.

Select the states for spatial each unit using the drop-down list.

Graphical results are in RESULTS-Green tab.

	Conservation metrics (changes in State)	best	min	max	-low	+upp				
L	Conservation Legacy (current – counterfactual)	0.0%	-11.1%	33.3%	11.1%	33.3%	22.2%	0%	0.00	22.22
D	Conservation Dependence (current – future without cc	33.3%	-11.1%	33.3%	44.4%	0.0%	22.2%	0%	0.00	22.22
G	Conservation Gain (future with cons. – current)	22.2%	0.0%	44.4%	22.2%	22.2%	11.1%	33%	11.11	22.22
P	Recovery Potential (long-term – current)	33.3%	0.0%	44.4%	33.3%	11.1%	11.1%	33%	11.11	22.22
							66.7%	56%	55.56	11.11

	State=	55.6%	77.8%	77.8%	33.3%	44.4%	44.4%	11.1%	44.4%	44.4%	44.4%	66.7%	77.8%	11.1%	11.1%	44.4%	44.4%	77.8%	77.8%
		Former state (1950)			Current state			Current without conserv. (Counterfactual)			Future with conservation			Future without conservation			Long-term aspiration		
	Spatial unit	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max
1	India	Viable	Functional	Functional	Present	Present	Present	Absent	Present	Present	Present	Viable	Viable	Absent	Absent	Present	Present	Viable	Viable
2	China	Present	Present	Present	Present	Present	Present	Absent	Present	Present	Present	Present	Viable	Absent	Absent	Present	Present	Viable	Viable
3	Bhutan	Viable	Functional	Functional	Present	Viable	Viable	Present	Viable	Viable	Viable	Functional	Functional	Present	Present	Viable	Viable	Functional	Functional
4																			
5																			
6																			

Figure A.43: Screen shot of the template used to assess the IUCN Green List status of chestnut- breasted hill partridge (*Arborophila mandellii*).

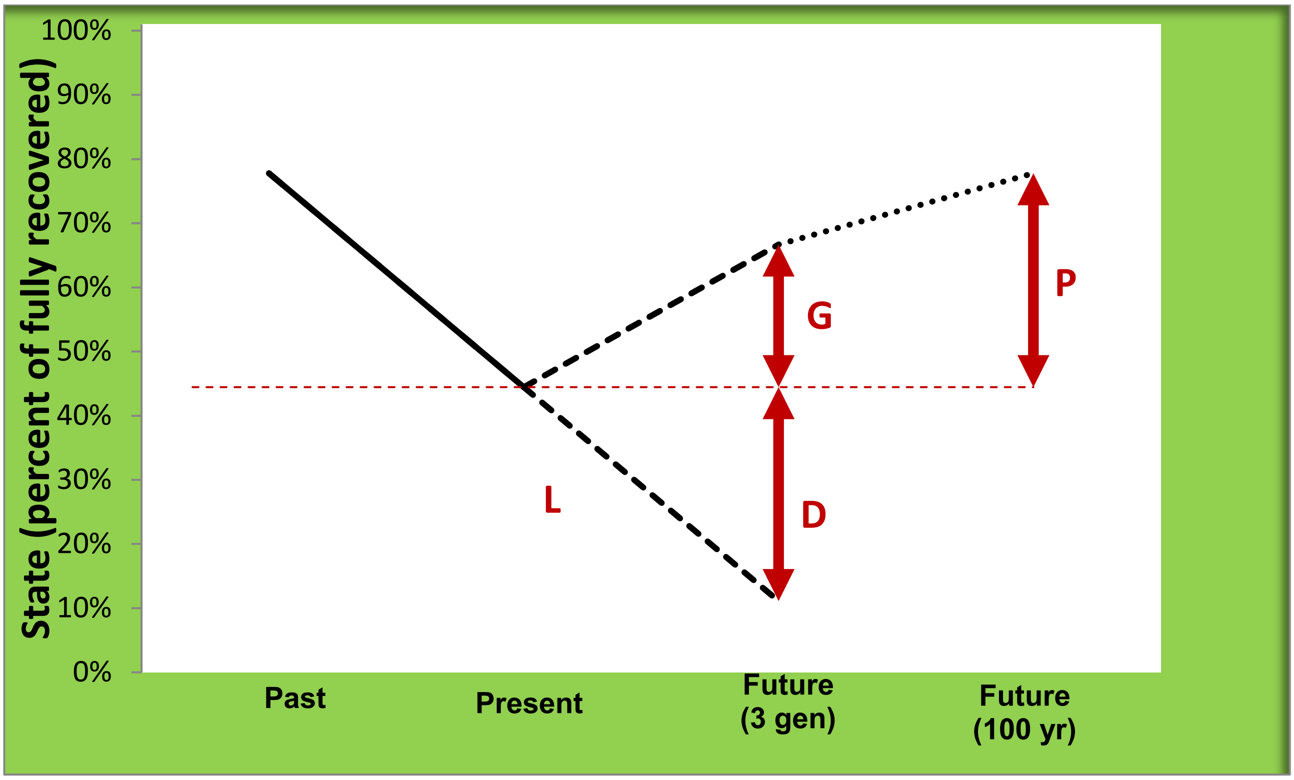


Figure A.44: Conservation metrics for chestnut- breasted hill partridge (*Arborophila mandellii*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

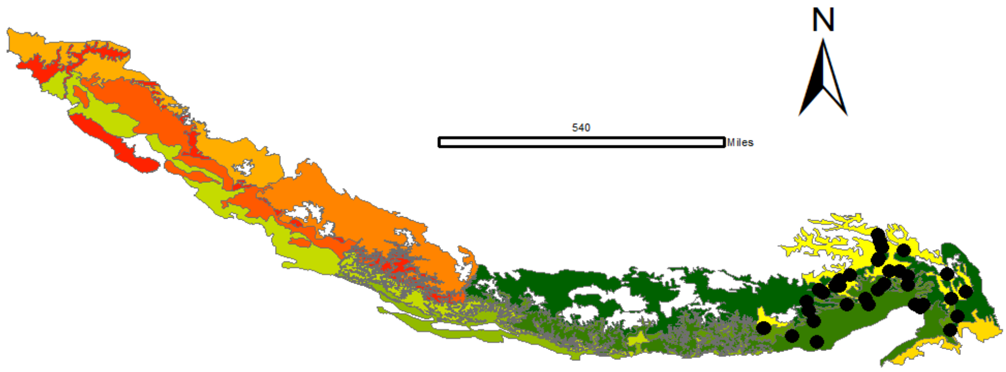


Figure A.45: Map showing the distribution of Sclater's monal (*Lophophorus sclateri*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for Sclater's monal which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

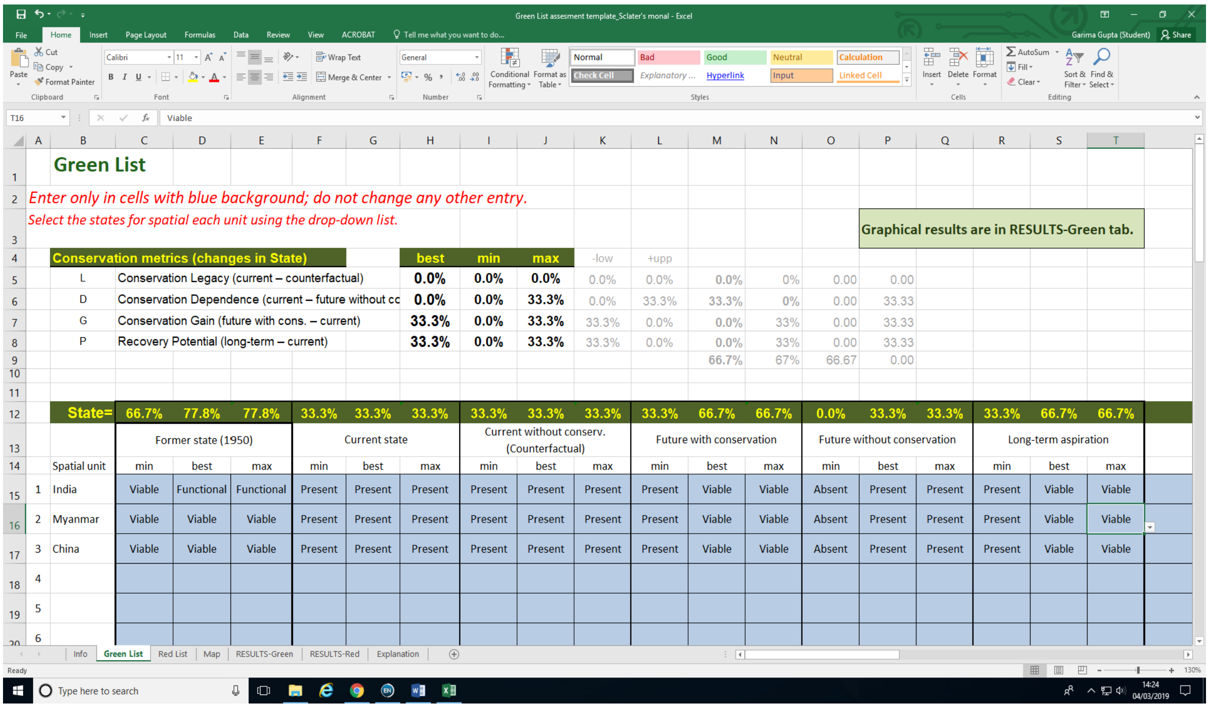


Figure A.46: Screen shot of the template used to assess the IUCN Green List status of Sclater's monal (*Lophophorus sclateri*).

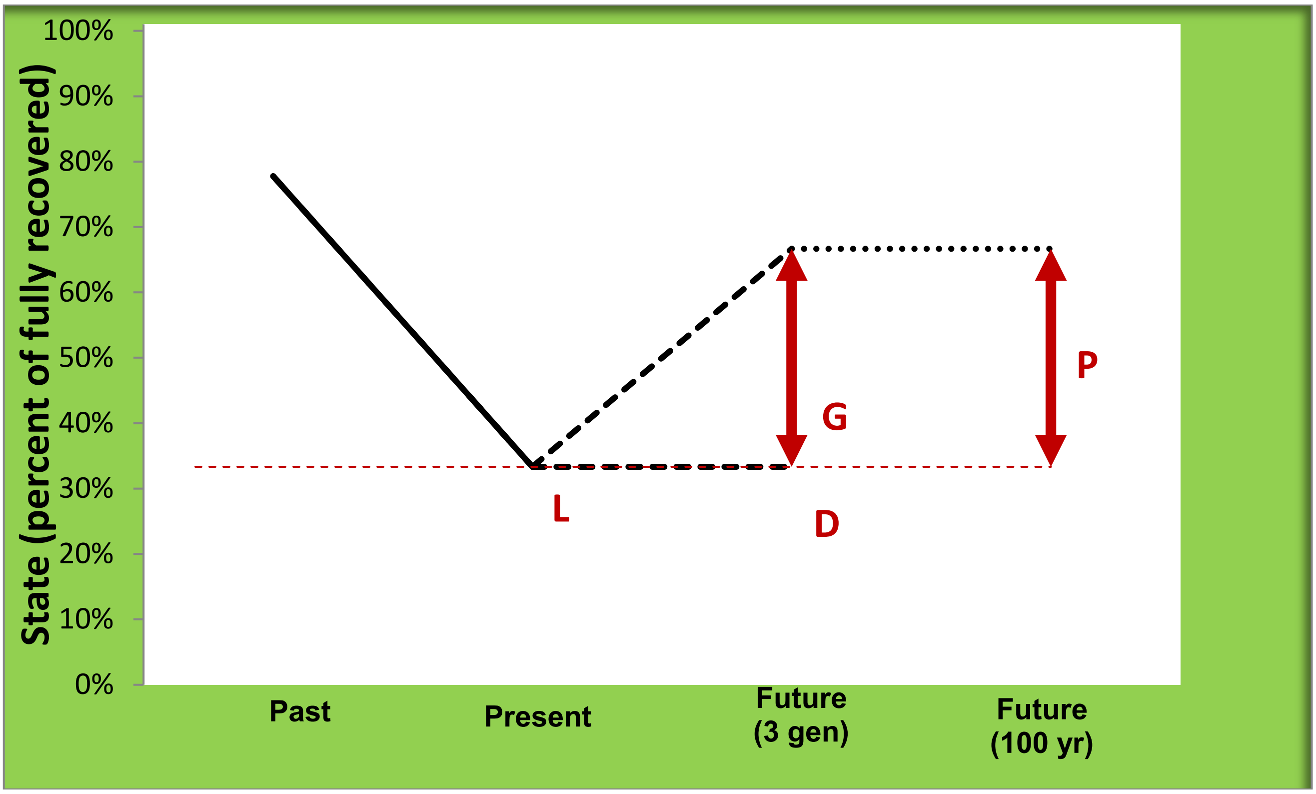


Figure A.47: Conservation metrics for Sclater's monal (*Lophophorus sclateri*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

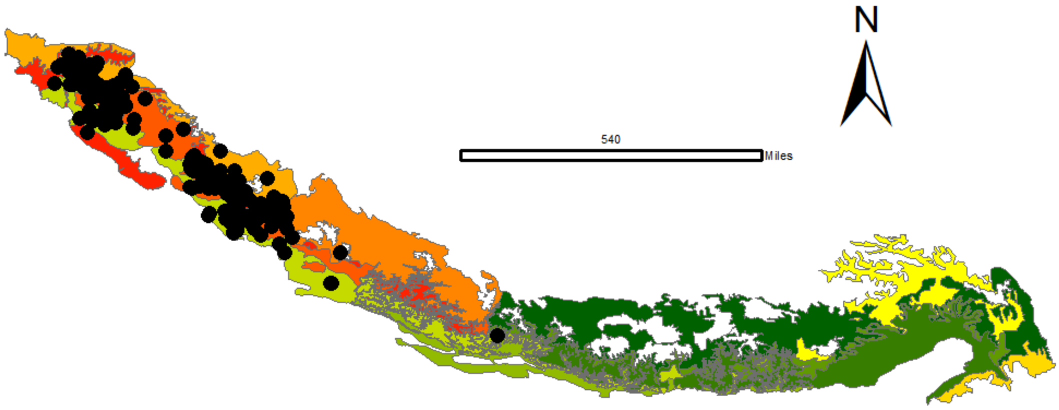


Figure A.48: Map showing the distribution of western tragopan (*Tragopan melanocephalus*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for western tragopan which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

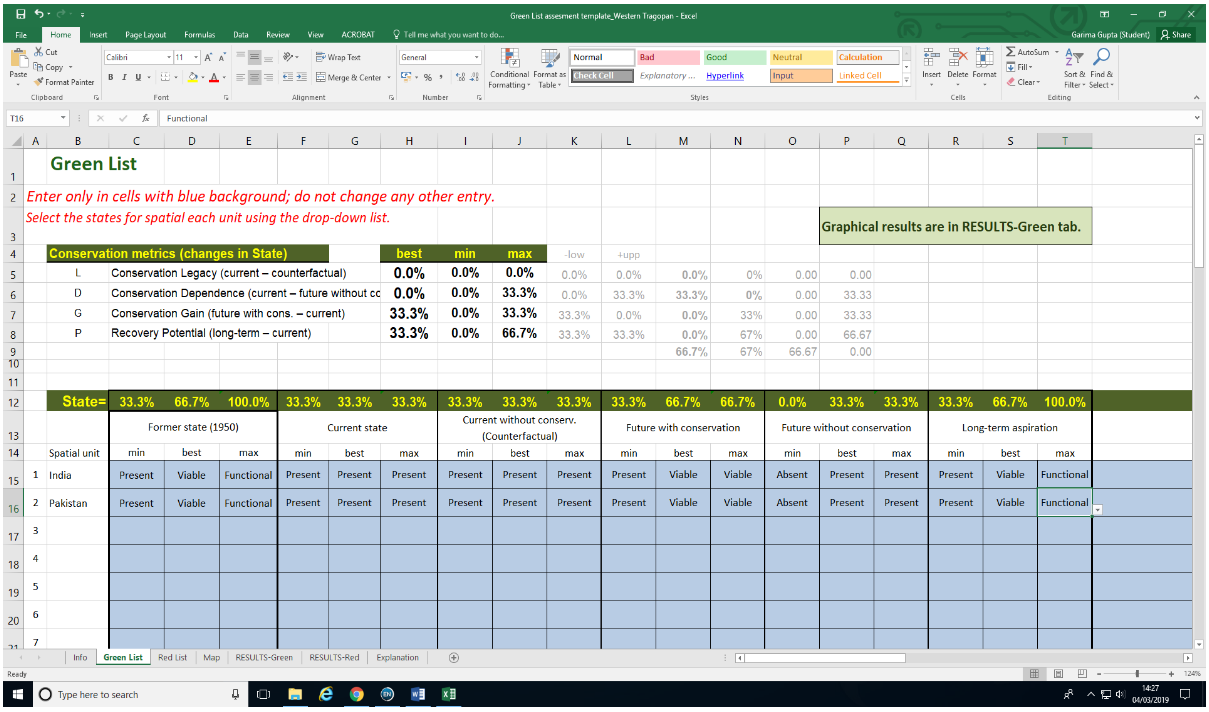


Figure A.49: Screen shot of the template used to assess the IUCN Green List status of western tragopan (*Tragopan melanocephalus*).

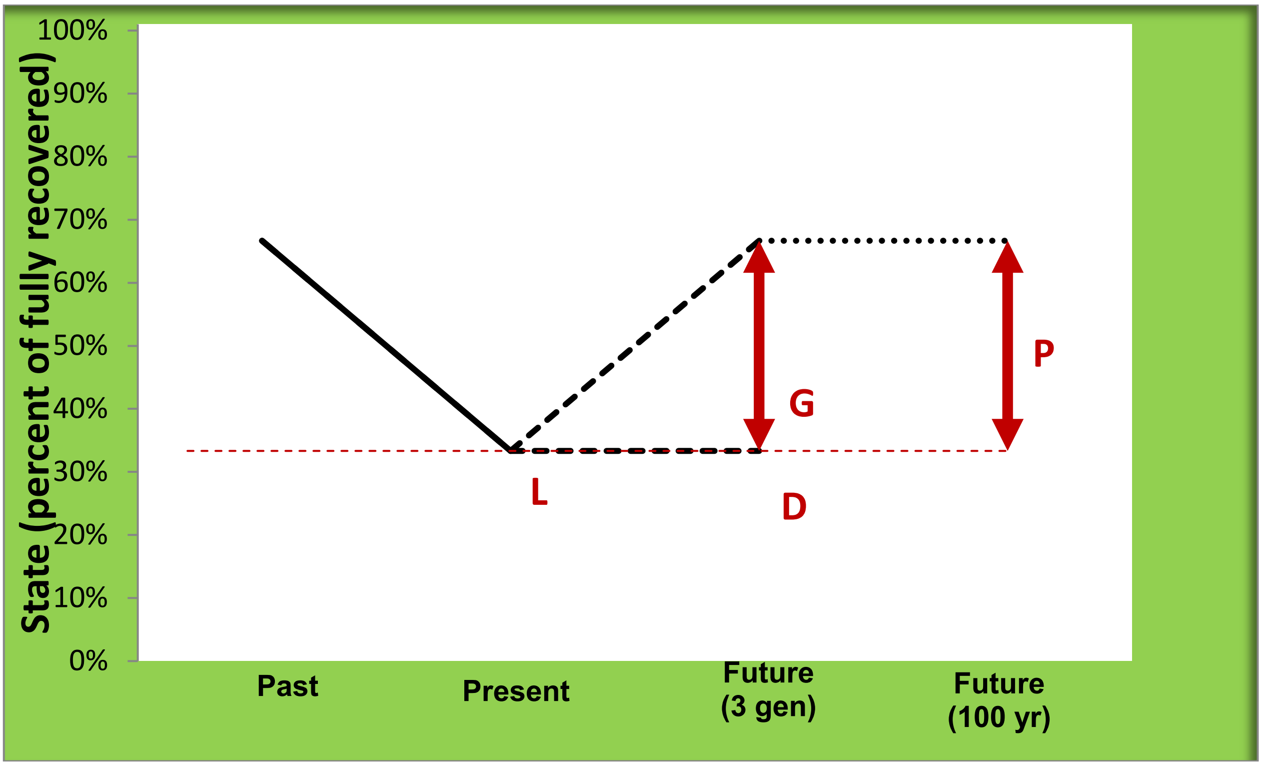


Figure A.50: Conservation metrics for western tragopan (*Tragopan melanocephalus*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

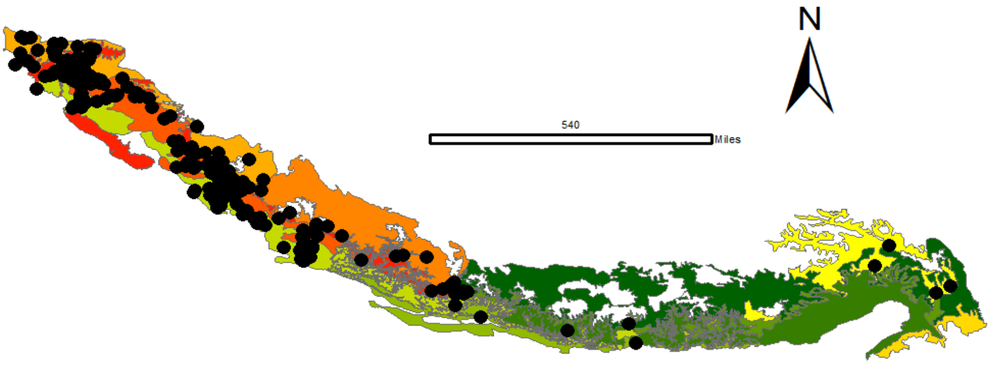


Figure A.51: Map showing the distribution of koklass pheasant (*Pucrasia macrolopha*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for koklass pheasant which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

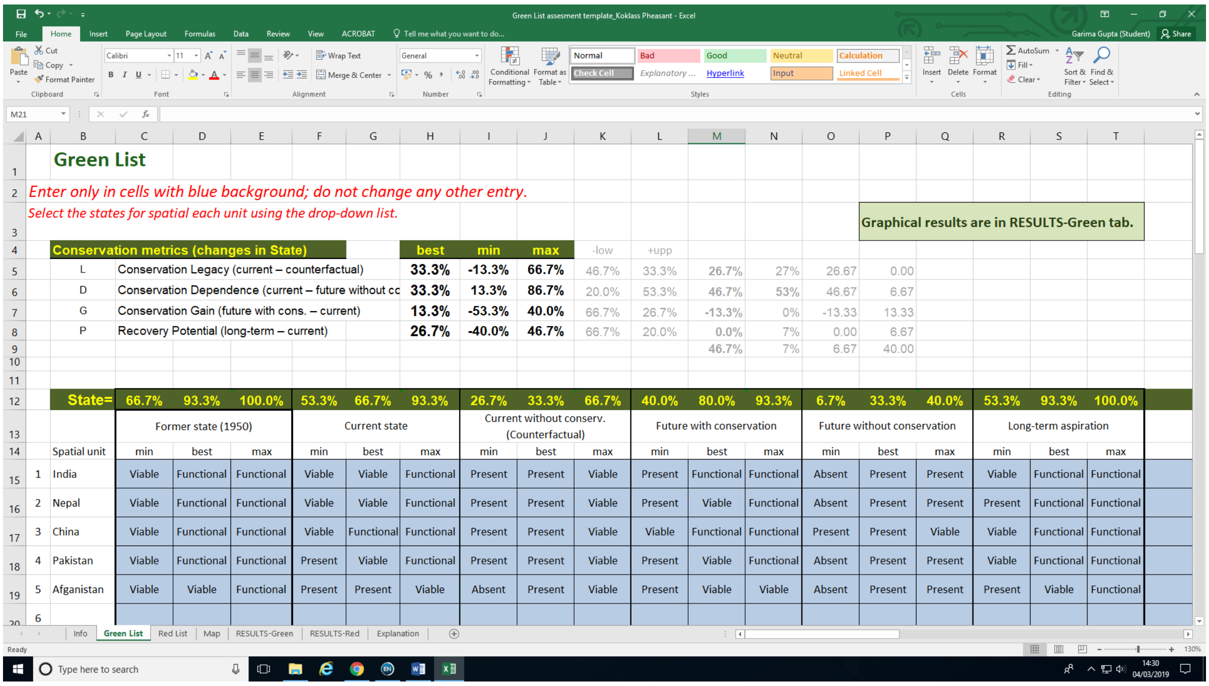


Figure A.52: Screen shot of the template used to assess the IUCN Green List status of koklass pheasant (*Pucrasia macrolopha*).

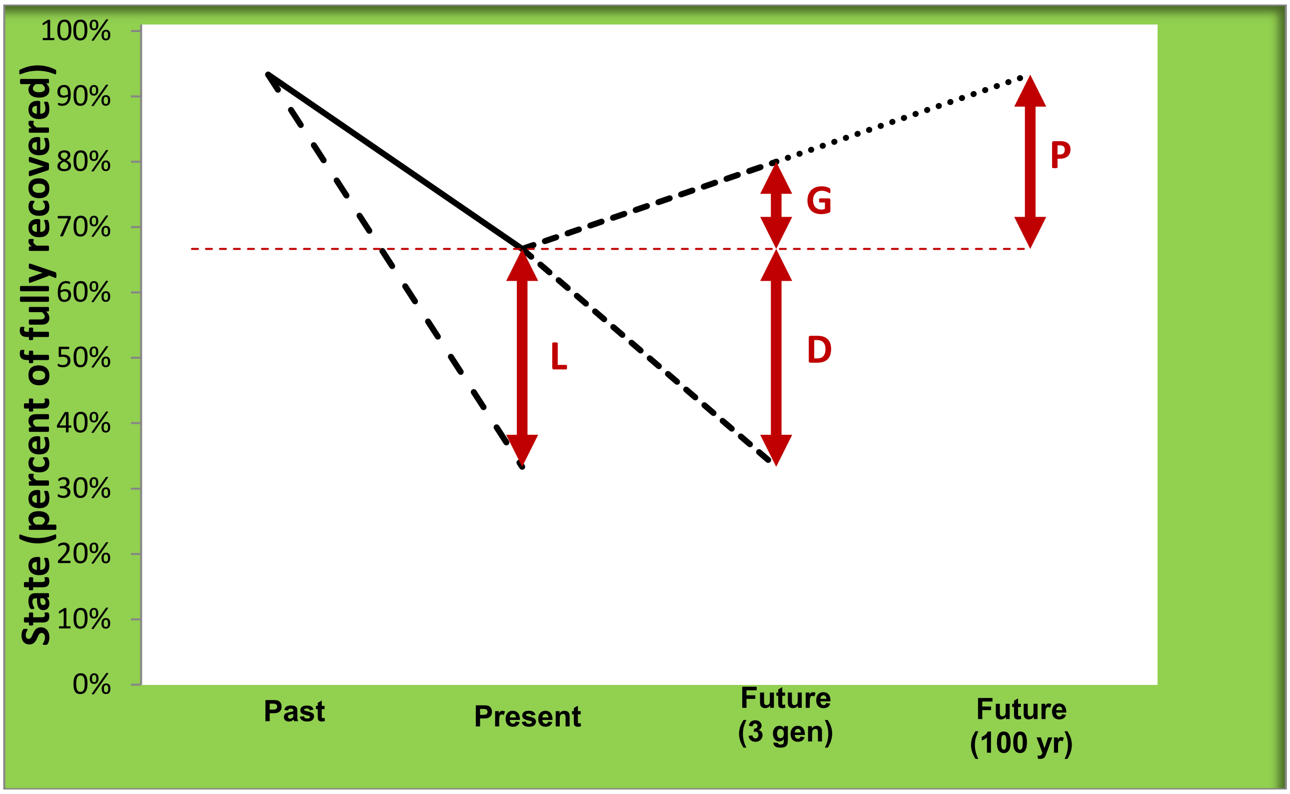


Figure A.53: Conservation metrics for koklass pheasant (*Pucrasia macrolopha*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

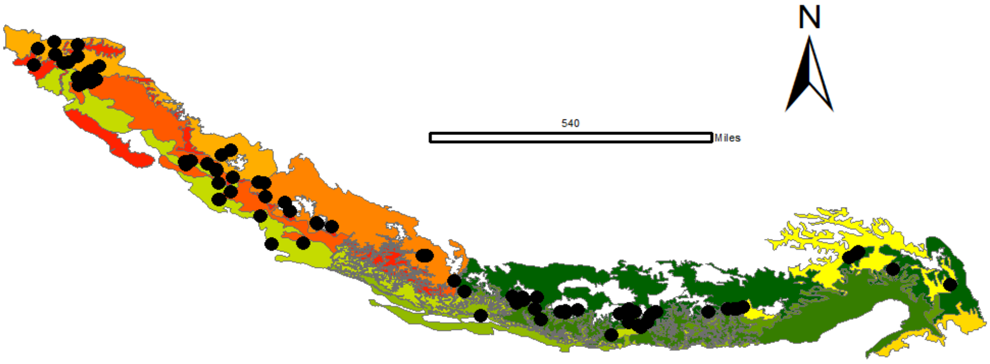
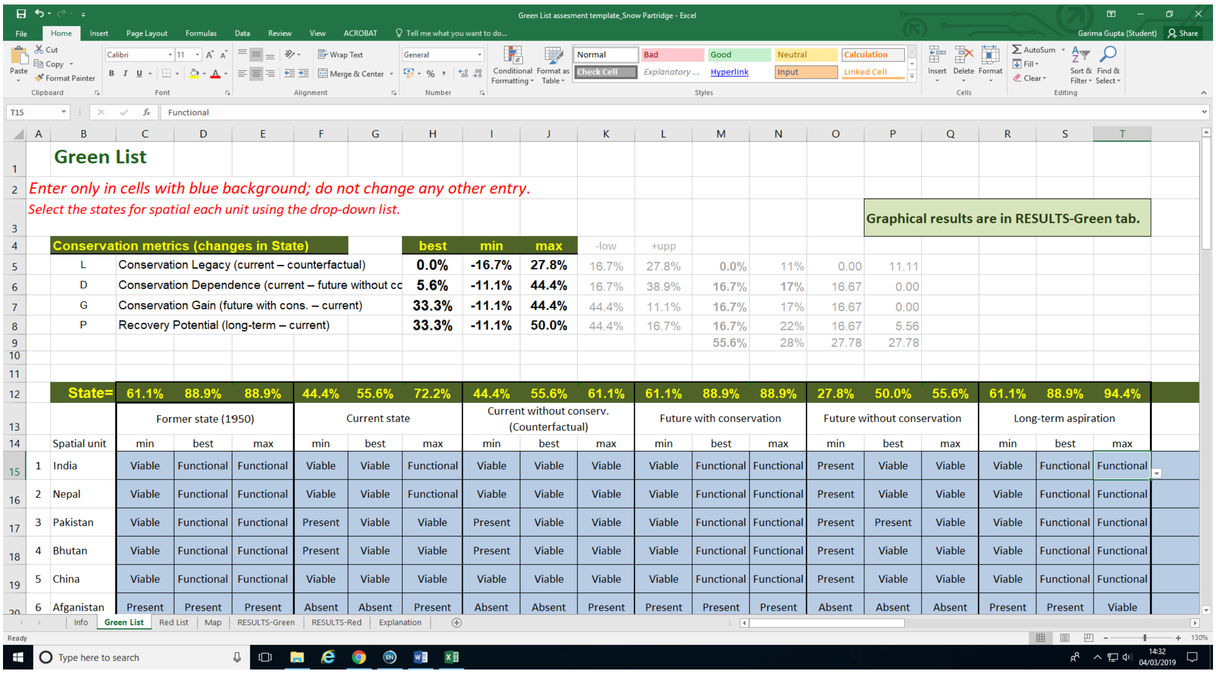


Figure A.54: Map showing the distribution of snow partridge (*Lerwa lerwa*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for snow partridge which were collected from GALLIFORM: WPA Eurasian Database v 1.0.



Green List

Enter only in cells with blue background; do not change any other entry.

Select the states for spatial each unit using the drop-down list.

Graphical results are in RESULTS-Green tab.

	Conservation metrics (changes in State)	best	min	max	-low	+upp				
L	Conservation Legacy (current – counterfactual)	0.0%	-16.7%	27.8%	16.7%	27.8%	0.0%	11%	0.00	11.11
D	Conservation Dependence (current – future without cc	5.6%	-11.1%	44.4%	16.7%	38.9%	16.7%	17%	16.67	0.00
G	Conservation Gain (future with cons. – current)	33.3%	-11.1%	44.4%	44.4%	11.1%	16.7%	17%	16.67	0.00
P	Recovery Potential (long-term – current)	33.3%	-11.1%	50.0%	44.4%	16.7%	16.7%	22%	16.67	5.56
							55.6%	28%	27.78	27.78

	State=	61.1%	88.9%	88.9%	44.4%	55.6%	72.2%	44.4%	55.6%	61.1%	61.1%	88.9%	88.9%	27.8%	50.0%	55.6%	61.1%	88.9%	94.4%
		Former state (1950)			Current state			Current without conserv. (Counterfactual)			Future with conservation			Future without conservation			Long-term aspiration		
	Spatial unit	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max	min	best	max
1	India	Viable	Functional	Functional	Viable	Viable	Functional	Viable	Viable	Viable	Viable	Functional	Functional	Present	Viable	Viable	Viable	Functional	Functional
2	Nepal	Viable	Functional	Functional	Viable	Viable	Functional	Viable	Viable	Viable	Viable	Functional	Functional	Present	Viable	Viable	Viable	Functional	Functional
3	Pakistan	Viable	Functional	Functional	Present	Viable	Viable	Present	Viable	Viable	Viable	Functional	Functional	Present	Present	Viable	Viable	Functional	Functional
4	Bhutan	Viable	Functional	Functional	Present	Viable	Viable	Present	Viable	Viable	Viable	Functional	Functional	Present	Viable	Viable	Viable	Functional	Functional
5	China	Viable	Functional	Functional	Viable	Viable	Viable	Viable	Viable	Viable	Viable	Functional	Functional	Present	Viable	Viable	Viable	Functional	Functional
6	Afganistan	Present	Present	Present	Absent	Absent	Present	Absent	Absent	Present	Present	Present	Present	Absent	Absent	Absent	Present	Present	Viable

Figure A.55: Screen shot of the template used to assess the IUCN Green List status of snow partridge (*Lerwa lerwa*).

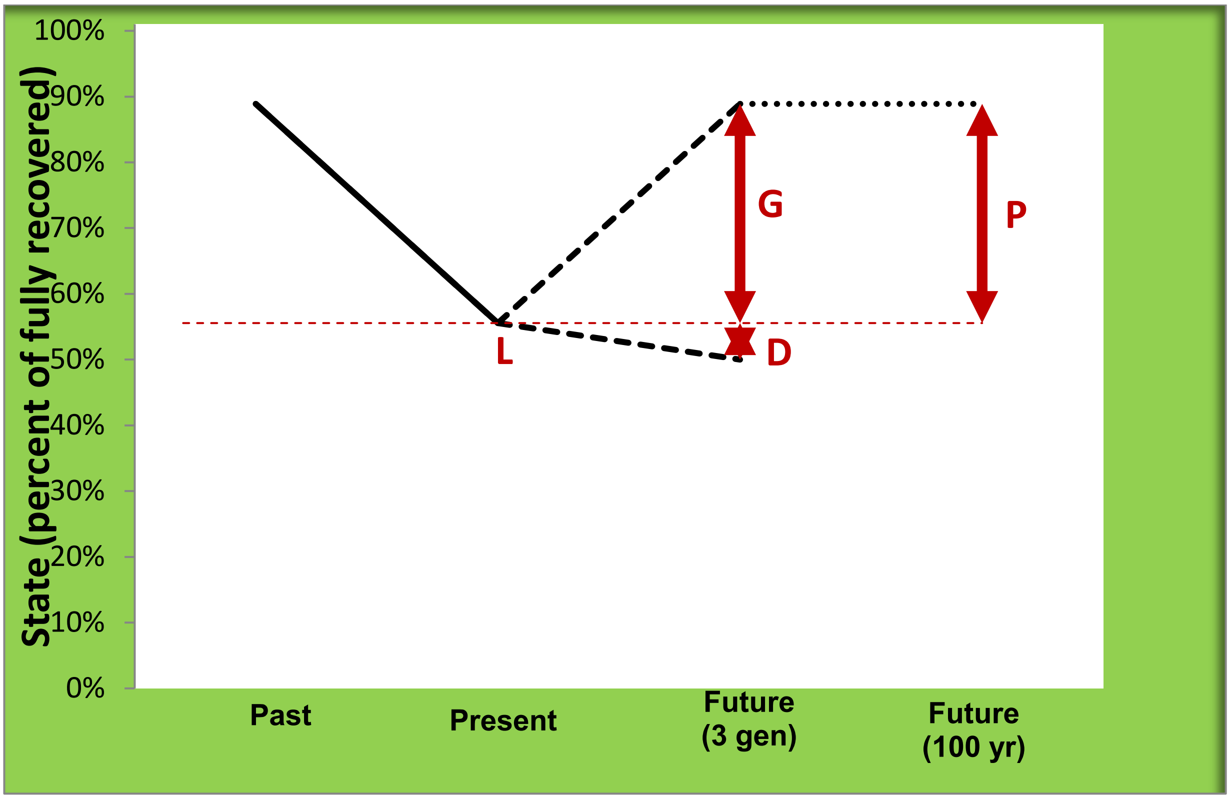


Figure A.56: Conservation metrics for snow partridge (*Lerwa lerwa*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

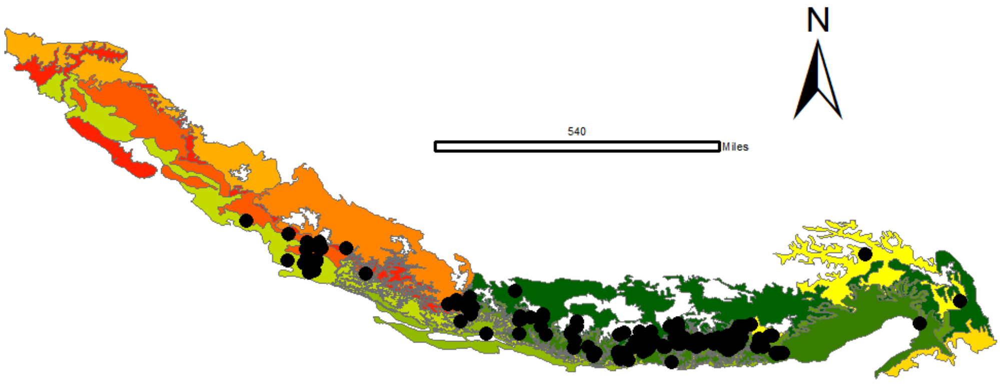


Figure A.57: Map showing the distribution of satyr tragopan (*Tragopan satyra*) in the WWF Himalayan ecoregions. Black dots in the map represents the point locality data for satyr tragopan which were collected from GALLIFORM: WPA Eurasian Database v 1.0.

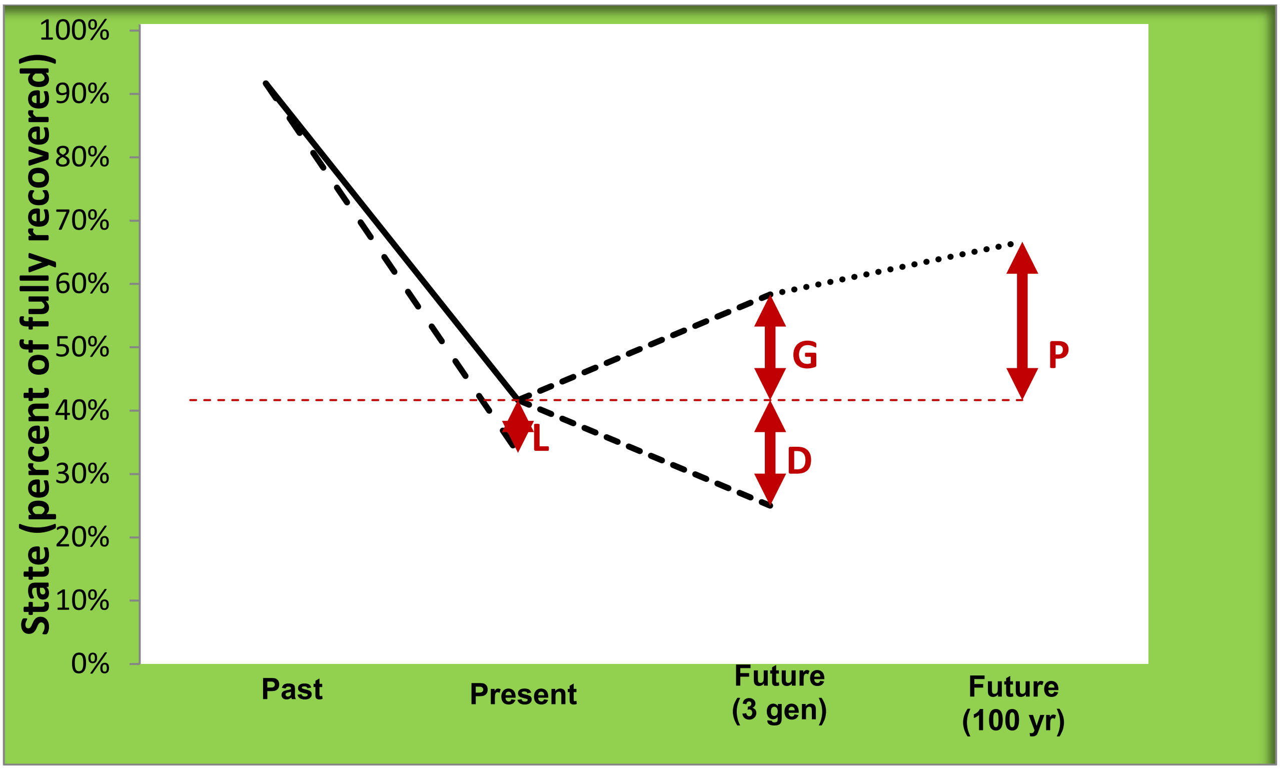


Figure A.58: Conservation metrics for satyr tragopan (*Tragopan satyra*) expressed as a percentage of fully recovered state. (For figure details see Figure 5.1).

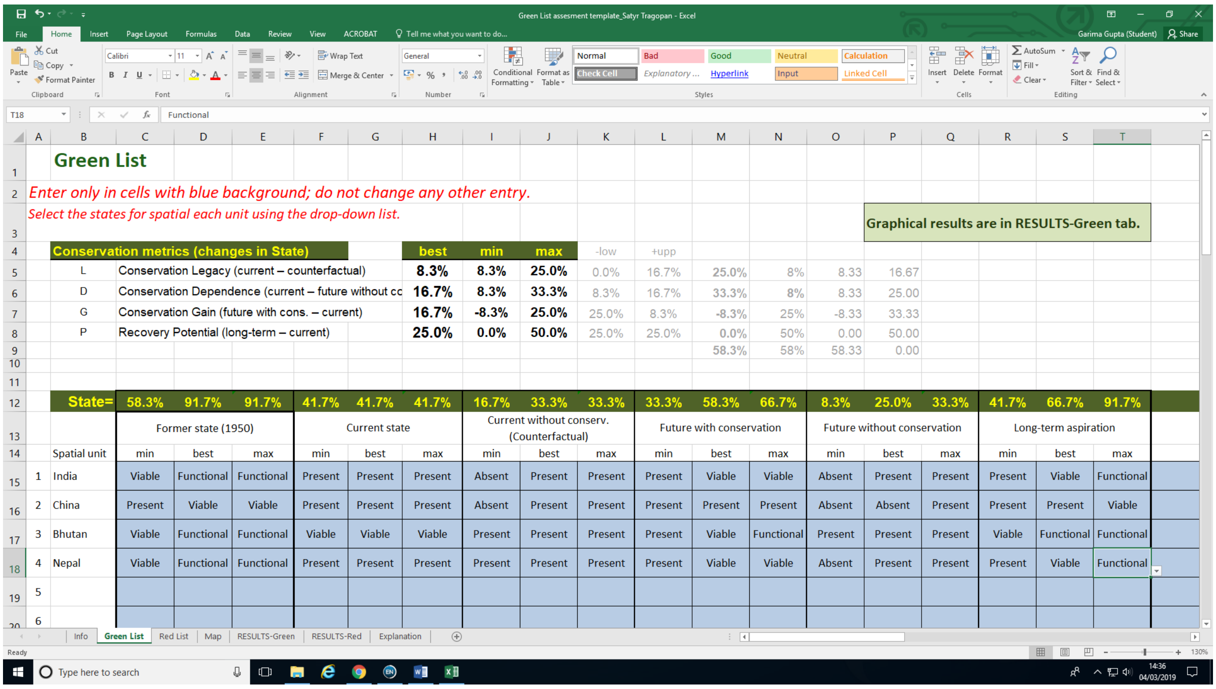


Figure A.59: Screen shot of the template used to assess the IUCN Green List status of satyr tragopan (*Tragopan satyra*).