POPULATION STATUS, DISTRIBUTION AND LOCATING NESTING SITES OF GREAT SLATY WOODPECKER, *Mulleripicus pulverulentus* (TEMMINCK, 1826) IN SUKLAPHANTA NATIONAL PARK, NEPAL

Dinesh Raj Joshi

T.U. Registration No: 5-2-37-624-2010

T.U. Examination Roll No: 112/2071

Batch: 2071

A thesis submitted

In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Ecology

Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

Nepal

May 2018

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author (s) or institution (s).

.....

Date: 21 May, 2018 Dinesh Raj Joshi

TRIBHUVAN UNIVERSITY ☏ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

RECOMMENDATION

This is to recommend that the thesis entitled **"Population status, Distribution and Locating Nesting sites of Great Slaty Woodpecker, *Mulleripicus pulverulentus* (Temminck, 1826) in Suklaphanta National Park, Nepal"** has been carried out by Dinesh Raj Joshi for the partial fulfilment of Master's Degree of Science in Zoology with special paper Ecology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

Date: 21 May, 2018

……

Prof. Dr. Nanda Bahadur Singh
Supervisor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY ☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

LETTER OF APPROVAL

On the recommendation of supervisor "Dr.Nanda Bahadur Singh" this thesis Submitted by Dinesh Raj Joshi **"Population status, Distribution and Locating Nesting sites of Great Slaty Woodpecker, *Mulleripicus pulverulentus* (Temminck, 1826) in Suklaphanta National Park, Nepal"** is approved for the examination and submitted to the Tribhuvan University in partial fulfilment of the requirements for Master's Degree of Science in Zoology with special paper Ecology.

Date: 21 May, 2018

……..

Prof. Dr. Ranjana Gupta
Head of Department
Central Department of Zoology
Tribhuvan University
Kritipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY ☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Dinesh Raj Joshi entitled **"Population status, Distribution and Locating Nesting sites of Great Slaty Woodpecker, *Mulleripicus pulverulentus* (Temminck, 1826) in Suklaphanta National Park, Nepal"** has been accepted as a partial fulfilment for the requirements of Master's Degree of Science in Zoology with special paper Ecology.

EVALUATION COMMITTEE

……
Supervisor
Dr.Nanda Bahadur Singh
Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

……..
Head of Department
Dr.Ranjana Gupta
Professor
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

……
External examiner
Mr. Juddha Gurung
President, CODEFUND
Kathmandu, Nepal

……..……..
Internal Examiner
Dr. Hari Prasad Sharma
Lecturer
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Date: 1st June, 2018

ACKNOWLEDGMENTS

I would like to express my sincere thanks as well as gratitude to my respected supervisor Prof. Dr. Nanda Bahadur Singh, Central Department of Zoology, T.U. for his continuous supervision, guidance and encouragement throughout my study. His constructive comments, untiring help and practical suggestions inspired me to accomplish this work successfully. Without his support and guidance, the study wouldn't possible in current form

I am especially thankful to **Ann Marie Gage** Ma'am and **IDEA WILD** for the valuable and important Equipment, without which my research work seems difficult. I would like to thanks to Department of National Parks and Wildlife Conservation (**DNPWC**) for Permission to conduct the research project and cooperation during the field visit. I am equally thankful to the staff of suklaphanta national park for their support and guidance during my field visit.

I am grateful to Prof. Dr. Ranjana Gupta, Head of Central Department of Zoology, T.U., for her kind support and the Central Department of Zoology for providing required research permission and equipment. I am equally thankful to all teaching and other staffs of the Department for their encouragement.

Special thank goes to my friends Seejan Gyawali, Arjun khanal and Ashok Chaudhary for their tireless support during the field work. My sincere thank goes to senior brother Pradeep Joshi and Bird guide Krishna Bidari. I am much thankful to Jay raj Binadi for GIS mapping and statistical analysis.

I am indebted to my family members for making my research field so ease. At last but not least my heartfelt thank goes to the entire unmentioned person who helped directly and indirectly during the study.

Mr. Dinesh Raj Joshi
Email: - joshidinesh155@gmail.com
Exam Roll No: 112/2071
T.U. Registration No. 5-2-37-624-2010
Enrolled year: 2071/2072

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviated form	Details of abbreviations
BCN	Bird Conservation Nepal
DNPWC	Department of National Park and Wildlife Conservation
DBH	Diameter at Breast Height
EN	Endangered
GPS	Global Positioning System
GSW	Great Slaty Woodpecker
SNP	Suklaphanta National Park
TAL	Terai Arc Landscape
IUCN	International Union for the Conservation of Nature and Natural resources
VU	Vulnerable

ABSTRACT

Great Slaty Woodpecker *Mulleripicus pulverulentus* (GSW) is the largest surviving woodpecker in Asia and it is distributed in Terai Arc Landscape (TAL) from central (Chitwan) to far-western Nepal (Kanchanpur) and this species has already upgraded as Endangered (En) and Vulnerable (Vu) in IUCN Red list nationally and globally respectively. The present study was carried in the year of 2017 in two different seasons (summer-May-June and winter-January) focused on the population estimation, distribution, and nesting sites of the GSW in Suklaphanta National Park (SNP) using Line Transect, and call playback methods. A total of 43 individuals were observed in winter season whereas 16 in summer season. The number of GSW's detected in two different seasons was found to be varied by 45.76% where maximum numbers were detected in winter season (72.88%). Similarly, the mean percentage of male was comparatively higher (61.01%) than percentage of female (38.99%). The distribution of GSW was mainly observed in Sal forest (91.52%). Out of total 14 laid transects, the nest cavities of GSW was observed in 5 transect, recording a total of 21 nests which was further categorized as 4 active nests and 17 as passive nests. An ecological monitoring of this species over a longer time period is necessary in order to get robust information for the survival of the species.

1 INTRODUCTION

Woodpeckers belong to family Picidae and subfamily Picinae. Family Picidae represented by nearly 215 species composed of 30 genera around the world (Sharma *et al.,*, 2015). A total of 871 bird species has been recorded in Nepal among which regular species of Woodpecker are 26 (BCN and DNPWC, 2011). Many of these species are facing enormous pressure from increasing human population in the country. A total of 149 species of birds has been identified as nationally threatened in 2010 (BCN and DNPWC, 2011). According to a recent study, the global population of this species has reduced by 90% during the last 100 years, primarily due to habitat lost to logging (Lammertink *et al.,*, 2009). IUCN has elevated the critical status of Great Slaty Woodpecker to 'Vulnerable' in 2010 (BirdLife International, 2010). The Nepalese population of this species is estimated from 190 to 250 (IUCN Red list, 2015).

Great Slaty Woodpecker (GSW) has a length of 48–58 cm (19–23 in) and a weight of 360–563 g (0.794–1.241 lb) (Dunning, 1992). It has a very long, strong chisel-tipped bill, an elongated neck and a long tail (Winkle *et al.,* 1995). This species plumage is almost entirely dark grey or blackish Slaty-grey overlaid with small white spots. The throat is paler grey and males have small red moustache. Normally, the nominate subspecies is the darkest, most Slaty gray race. Male has a more pale throat with a greater amount of whitish feather tips forming small spot and is slightly paler below than the nominate, sometimes appearing almost whitish on the belly (Watson and Shaw, 2018). The size and structure readily distinguishes this bird from almost any other species, including other woodpeckers. Occasionally, at first glance, the Great Slaty Woodpecker is mistaken for a hornbill but, obviously, such a resemblance is slight at best (Winkler *et al.,*, 1995).

The Great Slaty Woodpecker (*Mulleripicus pulverulentus*) is the largest in Asia and is perhaps the largest surviving Picid in the world (Mikusiński, 2006 and Lammertink *et al.,*, 2009). Trees, snags and logs are primary substrates providing nesting sites, shelter, and food for the majority of woodpeckers (Winkler *et al.,*, 1995). Few nests of the species have been described in detail, but at least occasionally nests are raised cooperatively by groups (Lammertink, 2004) known nests, at anywhere from 9 to 45 m in height in the trees, were located in very large trees (Melletti and Penteriani, 2003). When excavating the nest hole, both parents participate but reportedly the male does the majority of the work. The nest hole entrance will be around 10 cm across, but much wider inside the tree (Lammertink and Estrada, 1995. The pair will only use a nest from a prior year if competition is too overbearing for a newly constructed hole. The nesting season, in Malaysia at least, appears to be from March to August. The clutch reportedly consists of 2 to 4 eggs, which are incubated by both parents. Both parents also feed and generally brood the young. The young great Slaty woodpeckers probably stay with their parents until the next breeding season.

It is a fairly gregarious species McMahon *et al.,* (2015). Great Slaty woodpeckers (GSW) are mostly seen in groups consisting of 3 to 6 individuals, which consist of a breeding pair and their young from prior years. Kumar *et al.,* (2011). Groups often feed social insects like ants, termites, wood-boring beetles and stingless bees. Ants seem to be

generally favored in the diet, though larvae of other species may be eaten quite regularly as well (Ali and Ripley, 1983; Jha, 2017). Occasionally, small fruit may supplement the diet (Lammertink, 2004). Females spend more time searching for feeding sources and males, which have slightly larger bills, spend more time opening the sources. Preferred feeding sources are mostly found in large branches or trunks of large, living trees. The groups will travel considerable distance to access these trees and, as such, the home ranges of the species are quite large (Angelstam and Mikusinski, 1994).

One striking feature of woodpeckers is their ability to excavate cavities in living and dead trees (Winkler and Christie, 2002). Due to this "engineering activity", woodpeckers have been proposed as key-stone species in several communities with large numbers of secondary cavity nesters (Daily *et al.*,1993; Conner *et al.,* 2004; Martin *et al.,* 2004; Ojeda, 2004).Woodpeckers are highly sensitive to changes in woody vegetation attributable to anthropogenic causes, including those related to forest management and exploitation. Operations like logging, systematic manipulation for forest structure, plantations and fuel wood extraction are therefore likely to have an impact on the extant woodpecker community (Mikusiński, 2006).

Woodpeckers tend to have very specific habitat requirements, such as abundance of large trees and trees with decay, as shown by studies in Europe (Wiktander *et al.,* 2001, Melletti and Penteriani, 2003; Pasinelli, 2007) and North America (Block, 1991; Setterington *et al.,* 2000; Bevis and Martin 2002) but do not generally visit heavily disturbed areas (Paakkala *et al.,* 2017). Also found in mature Sal forests, swamp forest and mangroves with tall, mature trees (Lammertink, 2009). The species usually occurs below an elevation of 600 m and occasionally ranging up to 2,000 m (Wrinkler *et al.,* 1995). Similarly, in Peninsular Malaysia the Great Slaty Woodpecker does not occur above the 200-m foothill boundary (Grimmett *et al.,* 1998). Great Slaty Woodpecker is a resident, inhabiting Sal (*Shorea robusta*) and broadleaved forests of the lowlands and is dependent on the presence of mature trees (Grimmett *et al.,* 1998). In these tropical forests, the woodpecker community encompasses up to 14 or 15 species. Because of this high diversity, one may expect narrow specialization and thus high sensitivity to forest disturbance by some of these Asian woodpeckers Dominguez *et al.,* (2017). The species breeds cooperatively and have been observed in groups of up to 12 individuals (Lammertink, 2004).The highest diversity of sympatrically occurring woodpecker species in the world is found in the lowland rainforests of Borneo, Sumatra and Peninsular Malaysia (Watson and Shaw, 2018).

The Great Slaty Woodpecker is distributed widely, extending from Greater Sundas, through Indo-China, Myanmar, Bangladesh, Nepal, Bhutan, Brunei, Cambodia, India, Indonesia, Loas, Malaysia, Philippine, Singapore, Thailand and Vietnam (Winkler *et al.,* 1995; Birdlife International, 2012).

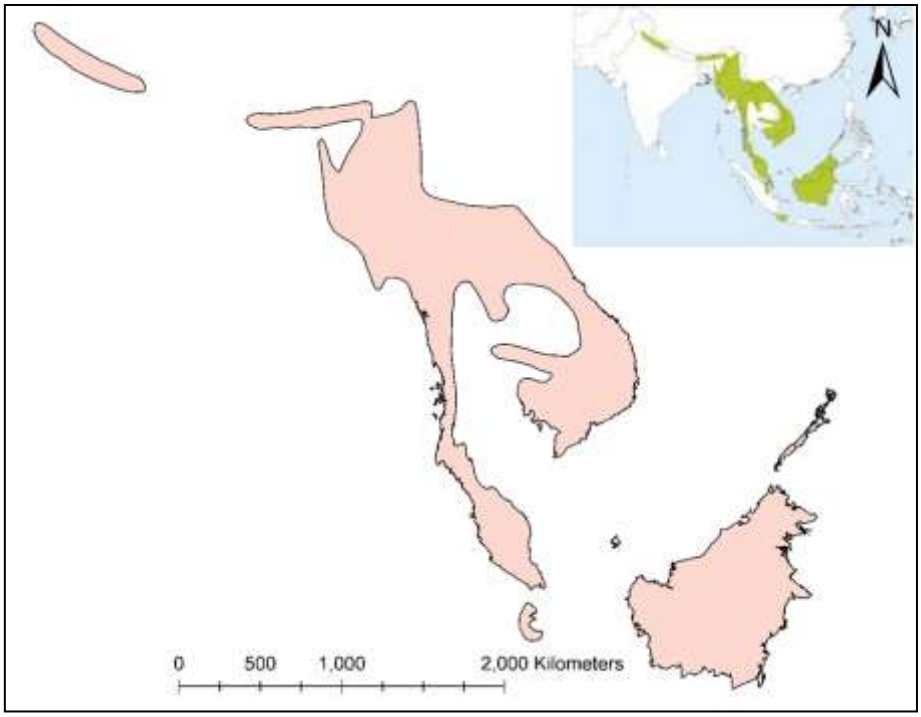


Figure 1: World wide Distribution of Great Slaty Woodpecker

In Nepal Great Slaty Woodpecker has been recorded in Suklaphanta National Park, Bardia National Park, Banke National Park and Chitwan National Park and in the forests of Kailali, Kapilbastu and Nawalparasi districts (Baral, 2011).

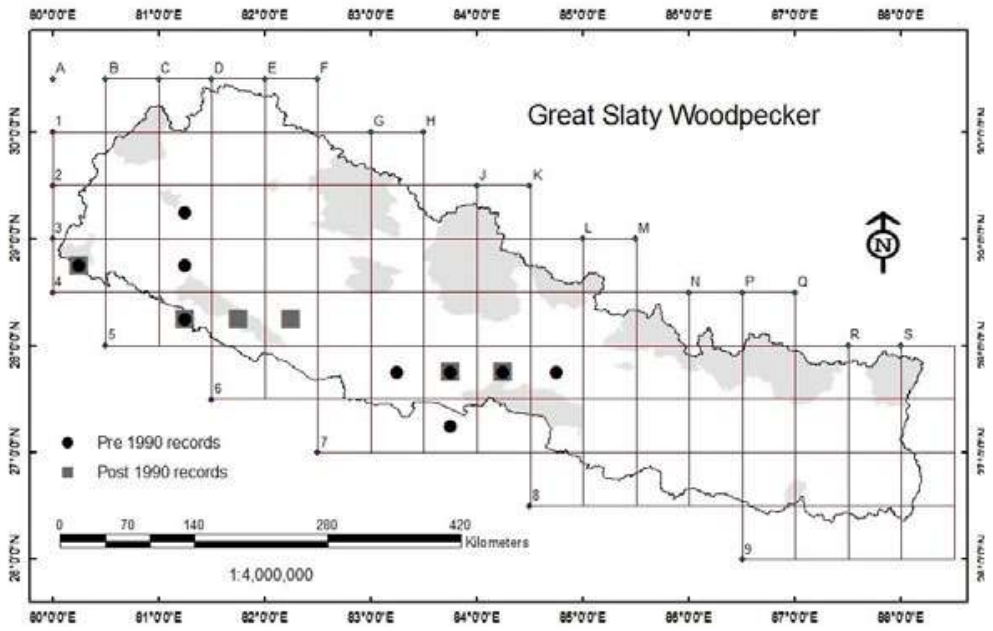


Figure 2: Distribution of Great Slaty Woodpecker in Nepal
(Source: Insipp *et al.*, 2016)

Great Slaty Woodpecker is threatened by the loss and degradation of lowland forests, notably the loss of mature trees (Ghazala and Kumar, 2011). Decline of old-growth forests are believed to be the main causative factors for the probable extinction of two of the world's largest woodpecker species such as the Imperial Woodpecker (*Campephilus imperialis*) and the Ivory-billed Woodpecker (*Campephilus principalis*) in the Americas. Being strongly tied to wooded areas, woodpeckers are particularly sensitive to forest degradation and modification by forestry operations that alter the natural structure and composition, usually through removal of larger trees, establishment of exotic plantations (Thompson *et al.,* 2003; Mikusinski, 2006) and extraction of dead wood (Lindenmayer and Noss, 2006). Woodpeckers are also important targets for conservation as several large or specialized species are facing population declines, and some have even become critically endangered or possibly extinct (Mikusinski, 2006). While tropical and subtropical forests of Asia have high picid diversity, not much is known about the ecology of woodpeckers there (Mikusinski, 2006). These forests are undergoing rapid changes in land use, the ecological impacts of which, particularly on woodpeckers, remain largely unstudied. An example of one such region is the tarai region of Nepal which is covered by tropical moist deciduous dipterocarp forests dominated by Sal trees.
Persistence of woodpecker populations in protected areas requires sufficient availability of old-growth forests (Lammertink, 2004) that provide woodpeckers with coarse woody debris, snags, as well as large living trees suitable for foraging and nesting (Angelstam and Mikusinski, 1994; Vergara and Schlatter, 2004; Drever and Martin, 2010, Lorenz *et al.,,* 2016; Vergara *et al.,* 2016).Woodpeckers are particularly important for conservation because of their ability to create cavities that are crucial for many other organisms (Martin and Eadie, 1999). Diversity of woodpeckers is a reliable predictor of the general avifaunal diversity both at the stand level (Drever *et al.,* 2008 and Kumar *et al.,* 2011) and at the landscape scale (Mikusinski *et al.,* 2001). Hence, picids are useful in assessing the status of bird diversity and ecological health of a forest (Drever and Martin, 2010).

1.1 Objectives

1.1.1 General Objective

To find Population status, distribution and locating nesting sites of Great Slaty Woodpecker in Suklaphanta National park.

1.1.2 Specific Objectives

- To determine the population status of Great Slaty Woodpecker.
- To map the distribution of Great Slaty Woodpecker.
- To locate the nests of Great Slaty Woodpecker.

1.2 Rationale of the Study

It was found that very few explorations on Great Slaty Woodpecker have been carried out in the world so as scarce data from the study area. Thus this project updates the scientific ecological information on this species and covers the research gap. Similarly, this work locate the nests, feeding site and nesting site of this species which is the first study in the study area which ultimately enhance the conservation modality development from government level through conservation recommendation. Birdlife International (2016) GSW has been listed as Vulnerable as it has suffered a rapid population decline over the past 20 years due to loss of primary forest cover throughout much of its range and the true rate of decline may be greater than currently estimated, and evidence of such declines would result in the species being uplifted in the future.

1.3 Limitations

Spatial Limitation: Not all the core area were visited and sampled because of the risks of wildlife like Elephant and Tiger.

Temporal Limitation: Because of the limitation of time, a total of 20 days were only spent in the field.

Economic Limitation: The study was self-funded so had a limited budget.

2 LITERATURE REVIEW

2.1 National context

The first historical record of Great Slaty Woodpecker in Nepal was in Butwal, Rupandehi District, in 1952 (Rand and Fleming, 1957). This species is a local resident occasionally seen in Suklaphanta Wildlife Reserve (Inskipp and Inskipp, 1991). A population survey carried out by the Nepalese Ornithologists Union in 2011 estimated a total of 190 birds comprising estimates of 50 individuals of GSW in Suklaphanta National Park and concluded that the large proportion of the species' population occurs in protected areas (Baral, 2011; Inskipp *et al*., 2016). Similarly, Parajuli (2068) recorded 2% picidae family in the Kamala River Basin, Lowland Nepal.

2.2 Global context

Lammertink *et al.,* (2009) found the global population of GSW has reduced by 90% primarily due to habitat lost by logging during the last 100 years in west Borneo, Lingga Island (Riau Archipelago, Indonesia), Tenasserim (Myanmar), and west-central Myanmar and found preference for large diameter trees for foraging and nesting by GSW. Martin and Eadie (1999) studied the Grouping and Cooperative Breeding in the Great Slaty Woodpecker along 4.4km of north-central BC, Canada, and located GSW primarily on logged-over forest on lowland plains, below 70m elevation. Similarly, Mikusiński (2006) explained the distribution, conservation, and research in woodpeckers in a global perspective and recorded 216 species of picidae family including Great Slaty Woodpecker. Lammertink, *et al.,* (2009) found the densities of Great Slaty Woodpecker related positively and significantly with density of large trees of DBH 31-120 cm and also stated the global population of Great Slaty Woodpecker is declining. Kumar and Shahabuddin (2012) conducted a study to survey the distribution of Great Slaty Woodpecker in the Sal forests of western Uttarakhand and to search for breeding sites by using call playback assisted survey and stated extremely rare. The cavity nester in mixed forests of interior British Columbia, Canada used full range of live and dead trees for nesting, but strong preference was given to the live trees with decay (Martin *et al.,*, 2004). He also found the black woodpecker (*Dryocopus martius*) that provided the largest cavities in Europe and both the northern flicker (*Colaptes auratus*) and great spotted *(Dendrocopos*) woodpeckers that provided the majority of cavities for secondary cavity nesters in North America and Europe, respectively.

Kumar and Singh (2010) found 11 species of woodpecker in the *Shorea robusta*-dominated moist deciduous forests of northern India. Similarly, Birand and Pawar (2004) studied forest bird species at nine sites in north-east India with low- to mid-elevation tropical evergreen forest and recorded Great Slaty Woodpecker from Disturbed, regular cane/palm extraction and heavy non-timber forest product collection site. Similarly, Javed and Rahmani (1998) recorded Great Slaty Woodpecker from Sal forest in Dudwa National Park, India.

Kotaka and Matsuoka (2002) examined old nest cavities excavated by Great Spotted Woodpeckers (GSW) *Dendrocopos major* in two study areas (urban and suburban forests) in Sapporo, northern Japan and found five avian and one mammalian secondary cavity user (SCU) species occupied 47 of 101 GSW cavities inspected. Segura (2017) found positive association between Great Spotted Woodpecker and both dead-tree density and large mature African Maamora cork oak forest trees having DBH>60 cm. Wightman *et al.,* (2010) found total of 11 nest-trees, averaging 18.5 (± 4.2) m tall, and 59.1 (± 14.5) cm diameter at breast height and nest cavities were 11.7 (± 2.3) m high, and the diameter at nest height was 37.6 (± 11.5) cm for White-bellied Woodpecker in Western Ghats, India. Similarly, Ojeda and Cgazarraeta (2014) recorded the abundances of large live trees and coarse of woody debris strongly correlated with home range and habitat use by Magellanic Woodpeckers in an old-growth forest of Patagonia but, Macey *et al.,* (2016) documented five variables; shrub height, diameter at breast height (DBH) of pine midstory, canopy closure, density of pine midstory, and density of hardwood midstory negatively impact foraging probability of Red-cockaded Woodpecker (*Picoides borealis*) in East Texas. Dominguez *et al.,* (2017) examined the habitat selection of Middle Spotted Woodpecker (*Leiopicus medius*) at southwestern boundary range of Izki Natural Park, northern Spain during the non-breeding season (October–December) and found lower forest cover and fewer large trees with a greater abundance of dead trees more preferred compared to breeding season (April–May). Bergner *et al.,* (2016) in Taurus Mountain of Turkey recorded nesting trees for Picidae family were taller and had a higher proportion of dead wood. Similarly, Rota *et al.,* (2014) also found Black-backed Woodpeckers (*Picoides arcticus*) of Black Hills, South Dakota most likely to use larger and disturbance-killed trees in relatively high Sal area stands.

Crucial cavity-producers like woodpeckers are often considered as keystone species, because they create nest-sites for numerous other cavity-nesting animals and, thus, maintain ecological webs of cavity-breeders. Iisoe *et al.,* (2017) found strong positive relationship between woodpecker species richness and current tree cover and annual precipitation globally. Mikusinski and Angelstam (1998) showed negative correlation between the degree of urbanization and woodpecker diversity in central Europe. Habitat selection can be envisaged as a hierarchical spatial process, from choice of home range to choice of dietary item. The green woodpecker (*Picus viridis*) is described as being closely bound to cultivated land and deciduous forests of south-central Scandinavia, mainly due to its summer diet composed of ants (Hymenoptera: Formicidae) found on meadows and pastures (Rolstad *et al.,,* 2000). Choice of cavity site is also related with the species of the Woodpecker. Conner *et al.,* (1975) in forest areas of Virginia found, common flickers (*Colaptes auratus*) nested only in dead snags in 1 to 12year-old clear-cuts; Pileated woodpeckers (*Dryocopus pileatus*) nested in mature, dense stands with high basal area, and downy woodpeckers (*Dendrocopos pubescens*) nested in sparsely stocked stands with lower basal area. Conner *et al.,* (1976) found, woodpeckers were apparently able to detect the presence of the heart rots and select suitably infected trees for nest excavations, thus

reducing the energy expenditure necessary to excavate nest cavities. Different nest-cavity sizes and wood-chiseling capabilities of the woodpecker species limit the vertical range over which nest cavities can be excavated. McAuliffe and Hendricks (1988) in Sonoran Desert found; Gilded Flickers (*Colaptesauratu schrysoides*) and Gila Woodpeckers (*Melanerpes uropygialis*) excavate nest cavities within the giant sahuaro cactus where, Flicker cavities are usually restricted to within 3 m of the stem apex but Nest cavities excavated by Gila Woodpeckers are found over a considerably broader vertical range of heights; their average height is also lower. Kerpez and Smith (1990) measured and compared the dimensions and height of Gila Woodpecker (*Melanerpes uropygialis*) and Northern Flicker (*Colaptes auratus*) nest cavities and found Gila Woodpecker nest cavities had smaller entrances, were shallower in the vertical plane of the saguaro, and were deeper in the horizontal plane of the saguaro than Northern Flicker nest cavities.

3 MATERIALS AND METHODS

3.1 Study Area

The Suklaphanta National Park (28°50′25″N and 80°13′44″E) is a protected area in the Terai of the Far-Western Region, Nepal, covering 305 km^2 (118 sq mi) of open grassland, forests, riverbeds and tropical wetlands at an altitude of 174 to 1,386 m (Bhuju *et al.*,, 2007). It lies in the extreme south-western section of Nepal's Terai in Kanchanpur District.

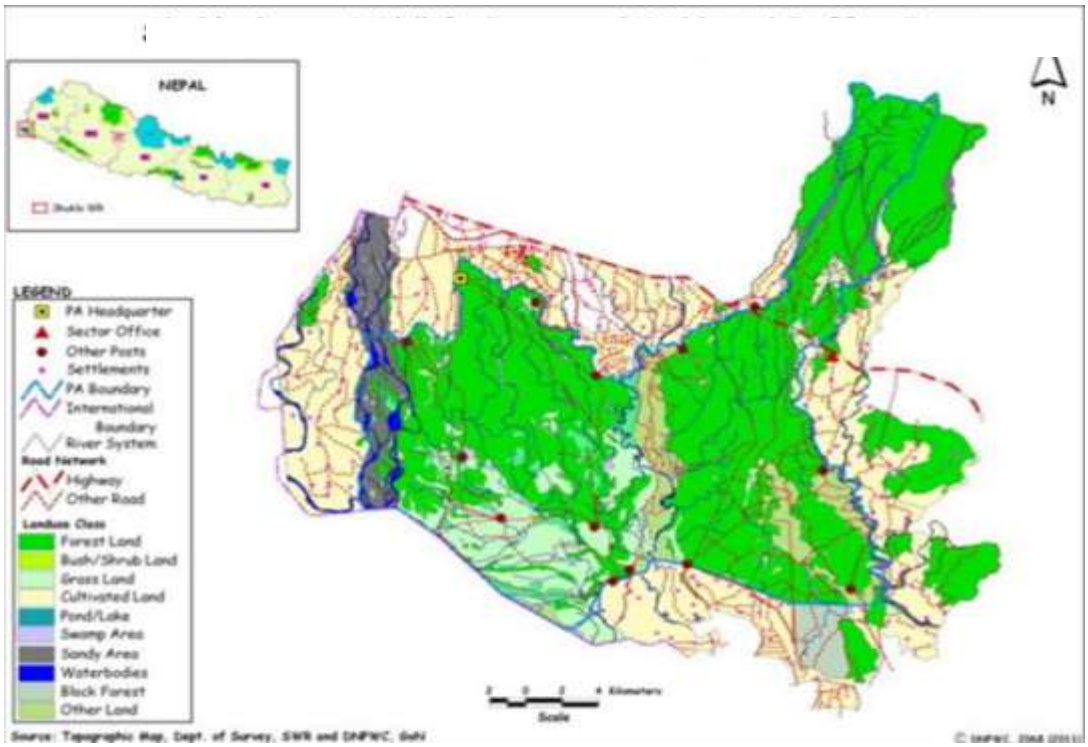


Figure 3: Suklaphanta National Park

The National Park shares a common boundary with the Indian state of Uttar Pradesh in the south and west which is formed by the Mahakali (Sarda) river, a major tributary of the Ganges. It is bordered on the eastern side by the Chaudhar River and to the north by a forest belt and cultivations. The international border between Nepal and India demarcates the southern and western boundaries of the reserve. The Luggabugga Florican Reserve in India lies adjacent to the southern boundary of SuklaPhanta. The Syali and Radha rivers form the eastern and western boundary respectively for the part of the reserve that extends north of the east-west highway (Baral and Inskipp, 2009).The reserve was a famous hunting area for many years and was declared as a Royal Hunting Reserve in 1969 with an area of about 155 km2. The reserve was gazetted as the Suklaphanta Wildlife Reserve in 1976. Later the reserve was extended eastwards by an area of about 150 km^2 to create more habitat and a corridor from the terai into the Churia hills for the seasonal migration of wildlife.

3.1.1 Climate

The climate of the region is subtropical monsoonal with mean annual rainfall of 1,579 mm (62.2 in) that occurs from June to September and is highest in August. The winter months of December and January are fairly cold with daytime temperatures of 7–12 °C (45–54 °F) and occasional frost. From February onwards temperatures rise up to 25 °C (77 °F) in March and reach 42 °C (108 °F) by end of April. When the first pre-monsoon rains reach the area in May, humidity increases (Majupuria and Kumar, 1998; Timilsina and Heinen, 2008)

3.1.2 Flora

Some 700 species of flora are estimated in the park including 553 vascular plants, 18 pteridophytes, 410 dicots and 125 monocots (Bhuju *et al.*, 2007). SuklaPhanta is important both nationally and internationally for its extensive grasslands or phantas that constitute almost half the reserve's vegetation. The main grassland, Suklaphanta proper, is the largest protected patch of continuous grassland in Nepal. It is approximately 16 km^2 in area. The main grass species include *Imperata cylindrica* and *Heteropogon contortus*. Some 54.7% of the reserve is covered by broadleaved forests of Sal (*Shorea robusta*) with forests of Sissoo (*Dalbergia sissoo*) and Khair (*Acacia catechu*) along rivers, and grassland and marsh in the southwest where soils are of recent alluvium. The rest consists of forests of Sal, Sissoo and Khair and savannah, supported by better-drained soils on higher terrain in the northeast (Baral and Inskipp, 2009).

3.1.3 Fauna

The park supports the highest population of Bengal floricans in Nepal. It is the western limit of swamp francolin, Jerdon's bushchat, rufous-rumped grass bird, chestnut-capped babbler and Jerdon's babbler; the north-western limit of yellow-eyed babbler; the eastern limit of Finn's weaver and the most important regular wintering site of Hodgson's bushchat. Forest birds include spot-bellied eagle owl, dusky eagle owl, rufous-bellied eagle and Oriental pied hornbill. The forests are also important for Great Slaty Woodpecker and white-naped woodpecker. The white-rumped vulture, slender-billed vulture, lesser adjutant, grey-headed fish eagle, darter and rufous-rumped grass bird are breeding residents. Sarus crane, painted stork and bristled grass bird are summer visitors. Greater racquet-tailed drongo, white-capped water redstart, rusty-tailed flycatcher and rufous-gorgeted flycatcher are uncommon winter visitors. (Baral and Inskipp, 2009). A total of 30 species of mammals has been recorded on the reserve. Globally threatened mammals include the Tiger (*Panthera tigris*), Swamp Deer (*Cervus duvauceli duvauceli*), Asian Elephant (*Elephas maximus*), the recently introduced Greater One-horned Rhinoceros (*Rhinoceros unicornis*) and Hispid Hare (*Caprolagus hispidus*) which are all resident (Baral and Inskipp, 2009; IUCN, 2009). Large reptiles including the Indian Rock Python (*Python molurus*) and Marsh Mugger (*Crocodylus palustris*) both globally threatened (IUCN, 2009) are also found here. A total of 27 fish species has been recorded in rivers, lakes and ponds of the reserve (Bhatt and Shrestha, 1977). Not much) is known about the herpetofauna of the reserve.

3.2 Materials

GPS, Nikon camera (500 mm), Topo-map (1:50,000), Measuring tape (100 m), Binocular (8x42 mm), Speaker (JBL) and Silva-compass

3.3 Methods

3.3.1 Preliminary survey

One week preliminary survey was done from 20 October 2016 to 27 October. During initial filed visit interaction was done among the park people, Staff and Guards to locate and to identity the probable and potential are of Great Slaty Woodpecker.

3.3.2 Line Transect

Line transects survey (Bibby *et al.*, 2000) was used to identify the population status, distribution and nesting sites. Open width transect was selected and birds on each transect was recorded through observation. Two Bikes were used at the speed of 20km/hr from early morning time (07:00 hrs) to evening (17:00 hrs) for data collection. The line transect count was adopted as the main method for surveying the bird populations. Where possible, such linear transects were laid out in different terrain types in the study site. Total 14 transects, 5km each were served. Call play back was done at the sighting point of Grey Slaty Woodpecker to congregating the bird to make count easy. The observed woodpeckers were noted down along with other details such as Co-ordinate, habitat type, activities and time. Similarly, the sighted nests were categorized as active and passive and are counted with above mentioned details. Canopy cover, DBH, Nest height from the ground level and tree conditions were also noted down for each tree in which nests were recorded.

Table 1: Transects sampled in the study area

Transects	Start	End
T1	Majgaun	Pipraiya
T2	Pipraya	Hattisar
T3	Pipraya	Barkaula post
T4	Phata	Bahune khola
T5	Bahune khola	Singpur post
T6	Singpur post	Singpal baba
T7	Singpal baba	Ranital
T8	Ranital	Dudhiya camp chowk
T9	Dudhiya camp chowk	Baba taal
T10	Arjuni	Hattithala
T11	Hattithala	Hirapur
T12	Badnikheda army post	Badnikheda national park post
T13	Badnikheda national park post	Lalpani
T14	Lalpani	Beldadi

3.3.3 Data Collection/ Actual field work

This study was done in two time field visits i.e. winter and summer season. Winter visit was done from 18 January 2017 to 28 January (10days) and summer visit from 30 May 2017 to June 10 (10 days).

3.3.4 Call Playback

GSW are gregarious bird and are highly sensitive to the call playback. Call play back method was deployed after spotting the individuals in order to make them aggregate and make the individual counting easier. Furthermore, the aggregation helps to determine the sex.

3.3.5 Distribution

Distribution pattern was identified on the basis of direct field observation. GPS points of Great Slaty Woodpecker distribution area was interred in digitizing Topo-Map of study area and prepared the GSW distribution map by using GIS software Arc View 10.4 version.

.

3.4 Data Analysis

The gathered data were analyzed on the basis of objectives. Sexes were differentiated on the basis beak and also on the presence and absence of small red moustache in the throat region. Male had a prominent small red moustache whereas female devoid of red moustache. Male to female ratio, density and abundance were also calculated using following formulae

$$\text{Crude density} = \frac{Total\ Woodpecker\ found}{\text{Total area survyed}} \quad \ldots\ldots (1)$$

$$\text{Ecological density} = = \frac{Total\ Woodpecker\ found}{\text{Total area of National park}} \quad \ldots\ldots (2)$$

Estimated population = crude density x total area of National Park…… (3)

Student's T-test, was done with R-studio version 3.4 to judge the significant associations among the number of woodpecker recorded in each season in different transect and among the sex recorded in two seasons. Number of Great Slaty Woodpecker recorded in each habitat type was used to determine distribution pattern. The distribution pattern of the Woodpecker was calculated by variance to mean ratio (Odum, 1971) which is based on the fact that in Poisson distribution, the variance (S^2) is equal to the mean.

Distribution pattern (DP) = ($S^2/\bar{X}$)

If,

($S^2/\bar{X}$)=1, distribution is random, (S2/$\bar{X}$)> 1, distribution is clumped,

(S2/$\bar{X}$)< 1, distribution is uniform

Where, S^2= Variance, $\bar{x}$= Mean

Seasonal mean focal size was calculated using formula:

Seasonal Mean Focal size (SMFS) $= \frac{Total \text{ numbers of woodpecker observed } (N1)}{Number of focal observed \text{ in particular season } (N2)}$

The correlation was done to check the significant association between different nesting site parameters.

4 RESULTS

4.1 Population status

A total of 59 great slaty woodpecker were recorded in two seasons, 72.88% were in winter and 27.12% in the summer. Significant different was found among individuals recorded (p-value = 0.03616) in two season. Male number was abundant in both seasons, 60.46% male and 39.53% female in winter; 62.50% male and 37.50% female in summer. The mean focal size was 3.07 and ranged from 5 to 17 individuals in the winter, whereas the mean focal size was 1.14 in summer and ranged from 4 to 7. No significant difference was obtained among male and female in winter (p-value = 0.04339) and summer (p-value = 0.09175).

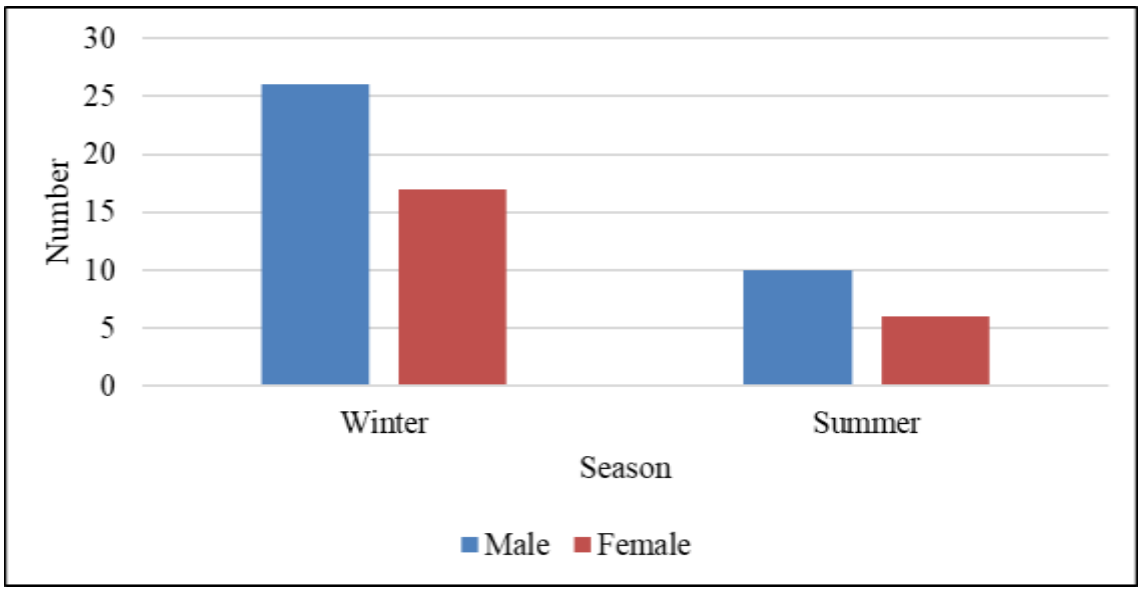


Figure 4: Great Slaty Woodpecker male and female numbers in different months

Overall male and female were 36 and 23; respectively, with sex ratio (Female: Male) 1:1.56. Which, significantly varied from 1:1 sex ratio (t = 3.0838, df = 13, p-value = 0.008715). Among 14 surveyed transect (Table 1) woodpecker were noted in 6 transect (T1, T2, T8, T5, T6, T13). Five flocks were recorded in the winter and three in the summer (Table 1). The single flock had maximum 17 woodpeckers in the winter season, and minimum 4 individuals in summer. Maximum 21 birds were found in T1 and minimum 5 found in T2, T6, and T8. The sex ratio slightly differed in the transect, in winter maximum sex ratio (Female: Male) of 1:1.5 was found in T6,T8,T13 and in summer maximum sex ratio (Female: Male) of 1:3 was found in T1.The minimum sex ratio (1:1.429) in winter was in T1 whereas in summer it was 1:1.33 recorded in T13 (Table 1). The ecological and crude density was found to be 0.19 individual/km^2 and 0.84 individuals/km^2 respectively.

Table 2: Sighting of Great Slaty Woodpecker in Suklaphanta National Park, 2017

Transects	Winter					Summer				
	Flock	TW	WM	WF	M:F	Flock	TS	SM	SF	M:F
T1	1	17	10	7	1.429	1	4	3	1	3
T2	0	0	0	0	0	1	5	3	2	1.5
T3	0	0	0	0	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	1	6	4	2	2	0	0	0	0	0
T6	1	5	3	2	1.5	0	0	0	0	0
T7	0	0	0	0	0	0	0	0	0	0
T8	1	5	3	2	1.5	0	0	0	0	0
T9	0	0	0	0	0	0	0	0	0	0
T10	0	0	0	0	0	0	0	0	0	0
T11	0	0	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	0	0	0	0
T13	1	10	6	4	1.5	1	7	4	3	1.333
T14	0	0	0	0	0	0	0	0	0	0
Mean focal size		8.6					5.33			
TOTAL	5	43	26	17	1.52	3	16	10	6	1.66

TW= Total Winter, WM= Winter Male, WF= Winter Female, SM= Summer Male, SF= Summer Female, M=Male, F=Female, TS=Total

4.2 Distribution of Great Slaty Woodpecker in relation to habitat characteristics

Distribution of woodpecker was found to be significant (X-squared = 80.769, df = 3, p-value < 2.2e-16) among the surveyed habitat. Maximum 91.52% Great Slay Woodpeckers were found in Sal forest, 8.47%in riverine forest.

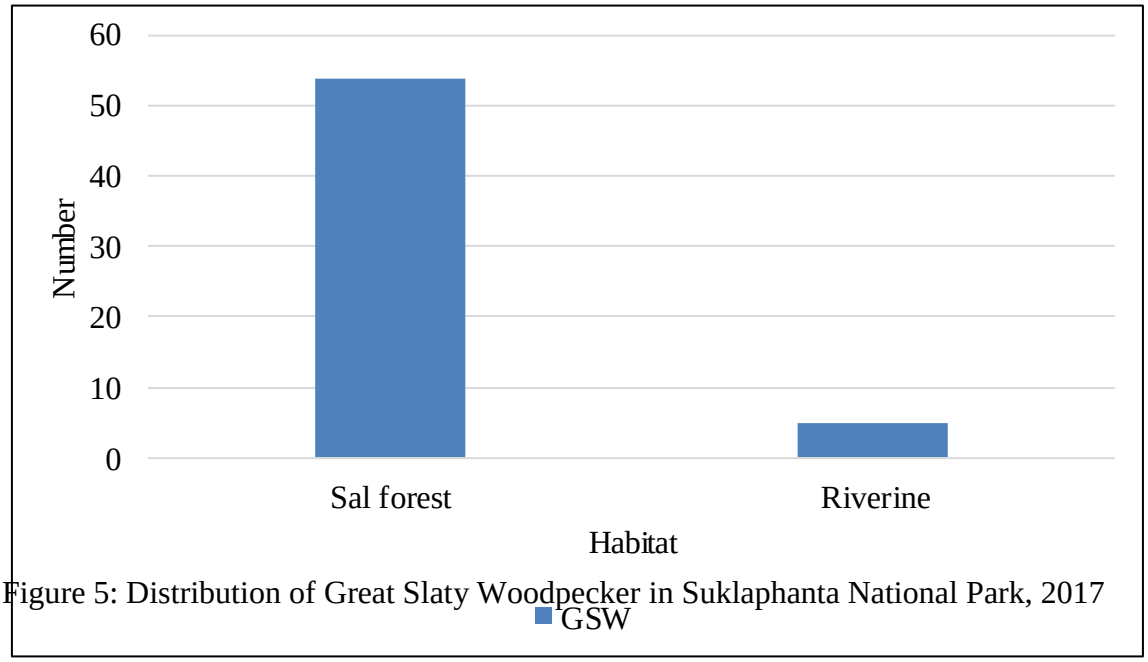


Figure 5: Distribution of Great Slaty Woodpecker in Suklaphanta National Park, 2017

Most of the Great Slaty Woodpeckers detections were in dense Sal forest. Distribution pattern was found to be Uniform (Variance/mean=0.93<1) in both season.

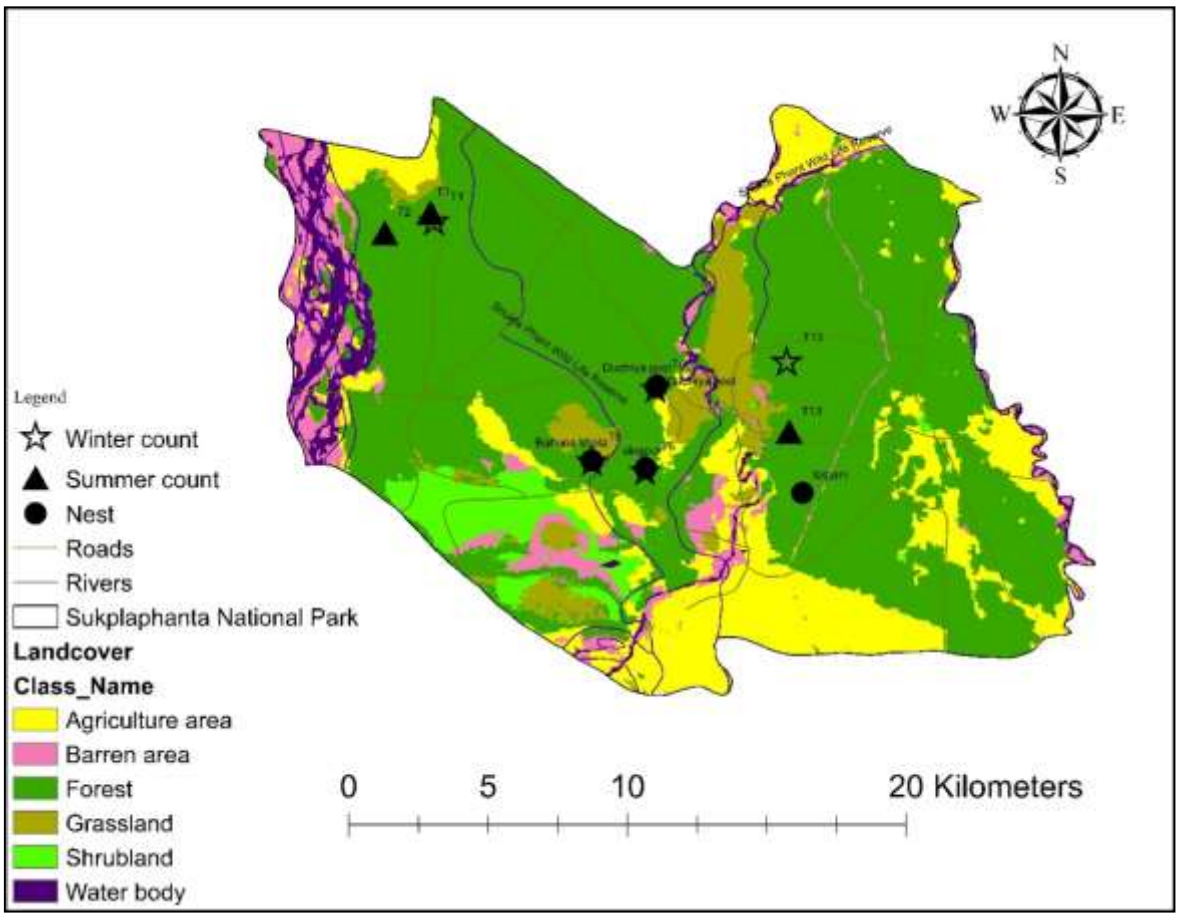


Figure 6: Great Slaty Woodpecker citing sites in Suklaphanta National park

4.3 Locating the nesting sites of Great Slaty Woodpecker

Total 21 nest cavities were observed in surveyed area. Among them 19.04% were active nest cavities and remaining 80.96% were passive nest cavities with mean 4.2 cavities per site (Figure 7). Active nest cavities were found in Dudhiya camp A and Dudhiya camp B whereas passive nests were found in Bahune khola, Singpur post and Lalpani. Almost all cavity trees had multiple cavities arranged in a vertical formation. The number of cavities ranged from 2 to 8 in a tree. The distribution of the cavities was found to be not significant (p-value = 0.06478).

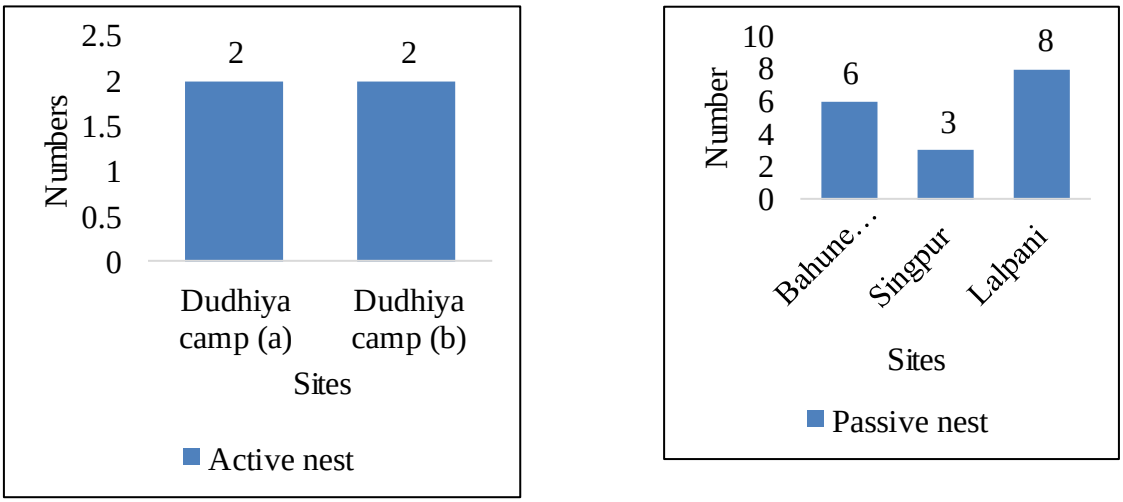
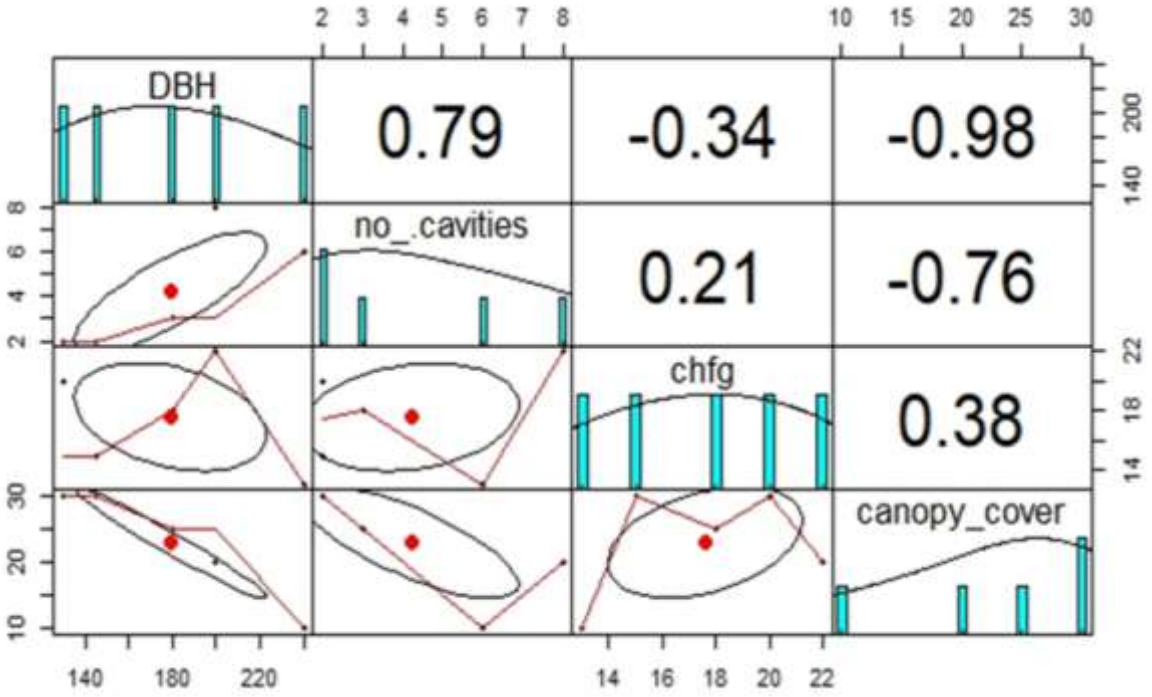


Figure 7: Great Slaty Woodpecker Nest cavities found at various site

4.3.1 Great Slaty Woodpecker detection in relation to habitat characteristics

Positive correlation was found between Cavities numbers and cavity height from ground(r = 0.21), DBH and number of cavities (r = 0.79), Canopy cover and crown height from ground level (r = 0.38), but negative correlation was found between DBH and cavity height from ground level (r = -0.34), canopy cover and DBH (r = -0.98), canopy cover and number of cavities (r = -0.76).



DBH= Diameter at Breast Height, Chfg=Cavity height from ground level

Figure 8: Correlation coefficient between different variables of the study site

The cavity (nest) was found in the Sal forest only, maximum were found in the live bent Sal tree followed by snag, live broken top and live tree. The DBH ranged from 130 to 240 cm with average 179cm, suggesting that only mature trees were suitable for excavating cavities. While almost all the cavities were in live trees, it was observed that many of these trees were deformed otherwise infested. Cavity height from the ground level ranged from 13-22 m and canopy cover ranged from 10%-30%.

Table 3: Cavity detail of Great Slaty Woodpecker in Suklaphanta National Park

Location	Tree species	Tree condition	DBH (Cm)	Number of cavities	Nest status	cavity height from ground level(m)	Canopy cover (%)
Bahunekhola	Sal	Snag	240	6	Passive	13	10
Dudhiya camp chowk (a)	Sal	Live	145	2	Active	15	30
Dudhiya camp chowk (b)	Sal	live, biforked	130	2	Active	20	30
Lalpani	Sal	live, bent	200	8	Passive	22	20
Singpur post	Sal	live, broken top	180	3	Passive	18	25
Total			895	21		88	
Average			179	4.2		17.6	

5 DISCUSSION

5.1 Demographic structure

The present study found total 59 Great Slaty Woodpecker in two seasons (summer and winter) with the ecological and crude density 0.19 individual/km^2 and 0.84km^2 respectively. However, in most count places where the species was detected, had multiple sightings, which suggested that it could be locally abundant at that particular site. Maximum 72.88% Great Slaty Woodpecker were found in winter and 27.12% in the summer. Significant different was found among individuals recorded in two season (p-value = 0.036). The high number of the GSW in the winter season might be due to the starting of the breeding season at that time they wander in the search of mate and therefore sighting was more. But, summer, being the incubation period most of the couple might be in the cavity of the tree, this might had made less sighting. GSW were detected at 8 sites (5 sites in winter + 3 sites in summer) in two season with flock size ranging from 4 to 17. Baral (2011) estimated 50 Great Slaty Woodpecker in the Suklaphanta National park in 2010.This study and the present study shows that the population of GSW is stable. The possible reason of stable population of GSW is because of small homerange.

Male number was abundant in both seasons. The mean focal size was 8.6 and ranged from 5 to 17 individuals in the winter, whereas the mean focal size was 5.33 in summer and ranged from 4 to 7. Kumar and Shahabuddin (2012) located *Mulleripicus pulverulentus* at 7 sites with mean group size 3 and ranged from 1 to 5 individuals in Sub-Himalaya Uttarakhanda, India which differed to the mean group size of the winter of present finding. Similarly, Lammertink (2004) noted group size of 5-6, which was less than present finding.

Great Slaty Woodpeckers appear to be highly social woodpeckers that group into the same associations on consecutive days. Group members forage in close proximity, often exploiting one food source with several group members of woodpeckers (Koenig and Mumme, 1987 and Conner *et al.*,, 2001). Instead, the grouping of Great Slaty Woodpeckers might be a strategy to collectively locate and exploit sparse but highly profitable food sources: nests of termites, ants, and stingless bees in cracks and natural cavities of branches and trunks. Once located, such as food source offered sufficient food for several individuals. A smaller number of Great Slaty Woodpeckers could be expected to find fewer food sources per unit time and may not be able to fully exploit a food source once located.

5.2 Distribution

Distribution of woodpecker was found to be significant (p-value < 2.2e-16) among the surveyed habitat. Maximum 91.52% Great Slay Woodpeckers were found in Sal forest and 8.47% in riverine forest. Distribution pattern was found to be uniform in the both seasons. Kumar *et al.,* (2011) found apparent differences in woodpecker number between seasons and which significantly differed across habitat types which matched with present finding. Similarly, Dominguez *et al.,* (2017) found *Leiopicus medius* preferred habitat

with greater abundance of dead trees during the non-breeding season. But, McMahon *et al.,* (2015) found the number of Acorn Woodpeckers and woodpecker territories increased over the study period with the increase in percent canopy cover, differed from the present finding. The distribution of great slaty woodpecker was found in the lowland Sal forest. Suklaphanta National Park being lowland National park and had dense Sal forest as majority (91.51%) of the woodpeckers were found in Sal forest. Similar finding was recorded by Lammertink (2004), who stated, great slaty woodpecker was absent from hill sites, which implied that hill reserves were not an option for conservation of this logging-sensitive species thus, the responses of this species in population density might serve as an indicator in forest management. The distribution pattern of GSW in present finding was uniform. Watson and Shaw (2018) also found White-headed Woodpeckers (*Picoides albolarvatus*) as uniformly distributed and restricted to interior dry coniferous forests. The probable reason behind the uniform distribution of GSW is due to the availability of food resources distributed evenly in the mature Sal forest.

The present results indicated that Sal forest had high number of great slaty woodpecker as compared to other forests. This showed Sal forest had its own bird community. According to Wesolowski *et al.,* (2005), each forest type had its own species composition. The abundance of great slaty woodpecker was more in Sal forest. In this study it was found that insectivore species were dominant in forest habitats, indicating rich abundance and easy availability of insects. The variation in bird abundance, consistent with the distribution of food resources was also reported by (Sheldon *et al.,*, 2010). Some studies conducted in the Indian Subcontinent (Welsolowski *et al.,*, 2005) have also shown that the insectivore guild is dominant in forest habitats. Present study had found species abundance fluctuated across seasons among habitat types and maximum diversity was found in winter season. Very few studies have been conducted in this area and knowledge of the great slaty woodpecker is virtually unknown.

5.3 Nesting sites details

Primary cavity-producers like woodpeckers are often considered as keystone species, because they produce nest sites also for several other cavity-nesting animals and, thus, maintain ecological webs of cavity-breeders (Andersson *et al.,*, 2018). However, the detailed temporal dynamics of cavities and their lifetime occupancy rates and survival are not usually known which makes it difficult to assess the actual significance and full impact of primary cavity breeders (Paakkala *et al.,*, 2017). In the present study total 21 cavities with average 4.2 were found. Almost all trees had multiple cavities arranged in a vertical formation. The number of cavities ranged from 2 to 8 in a tree. The distribution of the cavities was found to be not significant (p-value = 0.06478) among sites. Kumar and Shahabuddin (2012) found nesting trees at six sites in Uttarakhanda, India; Lammertink (2004) recorded two nests in south East Asia. Similarly, Lammertink *et al.,* (2009) found great slaty woodpeckers preferred large diameter trees for foraging and nesting concede with present finding where the mean DBH was 179cm and showed positive correlation (r =0.97) with the cavity numbers. Similarly, the positive relationship between habitat characteristics and DBH has been demonstrated by a number of studies (Wines, 1992; Raphael and White, 1984; Wilson and Comet, 1996). Sedgwick and Knopf (1990) also

found Cavity-nesting birds preferred DBH >69 for nesting. Raphael and White (1984) studied nesting and foraging habitat selection by cavity-nesting birds (CNB) and found overall, 72% of the nests were in standing dead trees (snags) which differed with present finding as only 28.5% nest were found in the snags. Wightman *et al.*, (2010) also stated maximum nest of White-headed woodpecker in snags differs from present finding. Present study found average mean height of cavity 17.6m from the ground level and maximum nest were found in 20% canopy cover which differs from Milne and Hejl (1989) who found Nest of White- headed Woodpecker (*Picoides albolarvatus albolarvatu*) at mean height of 3m from ground level and maximum nest cavity in 45% canopy cover. Similarly, Wightman *et al.*, (2010) found Nest cavities of White-bellied Woodpecker in Western Ghats, India 11.7 (± 2.3) m high, and the diameter at nest height was 37.6 (± 11.5) cm for White-bellied Woodpecker in Western Ghats, India which is less than present finding. During present study, Positive correlation was found between Cavities numbers and cavity height from ground, DBH and number of cavities, Canopy cover and crown height from ground level, but negative correlation was found between DBH and cavity height from ground level, canopy cover and DBH, canopy cover and number of cavities. Renken and Wiggers (1989) record percent forest over story canopy cover, percent saw timber cover, and log and stump volume within territories were negatively related to territory size of Pileated Woodpecker (*Dryocopus pileatus*) in Missouri differed from present finding. Bergner *et al.*, (2016) found nesting trees for Picidae family of woodpecker in Taurus Mountains, Turkey were taller and had a higher proportion of dead wood. Similarly, Rota *et al.*, (2014) also found Black-backed Woodpeckers (*Picoides arcticus*) of Black Hills, South Dakota most likely to use larger, disturbance-killed trees in relatively high basal area stands. Woodpeckers (Picidae) are closely associated with trees and woody habitats because of multiple morphological and ecological specializations (IIsoe *et al.*,, 2017). Pakkala *et al.*, (2018) recoded the annual occupancy history of 655 old cavities of the Three-toed Woodpecker in 86 territories in a 170-km^2 area in southern Finland during 1987–2017 and found significant negative correlation between the occupancy and the age of the cavity. Hebda *et al.*, (2017) analyzed data on nest sites of Great Spotted Woodpeckers *Dendrocopos* major and found woodpeckers excavated breeding holes in 11 tree species, but species used in individual habitats varied greatly. But, Segura (2017) found positive association between Great Spotted Woodpecker and both dead-tree density and large mature Maamora cork oak forest trees (>60 cm DBH). Ojeda and Cgazarraeta (2014) recorded the Abundances of large live trees and course of woody debris strongly correlated with home range and habitat use by Magellanic Woodpeckers in an old-growth forest of Patagonia which concede with present finding. The Sal has large DBH, hard wood and thick bark which serve as the home for many insects, termites in which the woodpecker feeds. Woodpecker excavates their nests out of solid wood, and because their nests are often well protected against predators and the environment, other species use and compete for their old, vacant nests. Kumar and Shhabuddin (2012) observed GSW mainly in mature Sal-dominated forests in sloping terrain. Most trees in which cavities were found were deformed or diseased and had a median diameter at breast height (DBH) of 53.5 cm.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Maximum great slaty woodpeckers were recorded in the winter season which indicate the congregation nature of woodpecker in the winter for mate selection. The mean focal size was 3.07 and ranged from 5 to 17 individuals in the winter season, whereas the mean focal size was 1.14 in summer and ranged from 4 to 7; which also conclude the aggregation nature of great slaty woodpecker in the winter. Male number was maximum in both season compared to female, which show the co-operative breeding behavior of great slay woodpecker.

Sal forest is preferred by great slaty woodpecker when compared to riverine forest. The distribution pattern of GSW was found to be uniform due to the availability of food resources evenly distributed in mature Sal forest.

Passive nests were found more than active nests. Almost all cavity trees had multiple cavities arranged in a vertical formation. The number of cavities ranged from 2 to 8 in a tree. Great slaty woodpecker form multiple cavities in the vertical direction of the tree having mean DBH 179 cm; suggest that only mature trees are suitable for excavating cavities.

6.2 Recommendations

- Sustainable monitoring of GSW should be done for the exact status of the species. The use of robust technique such as satellite transmitters should be deployed to get more detail information on the ecology of GSW.
- Sal tree with average 179 cm DBH must be stopped logging as Great Slaty Woodpecker preferred old live *Shorea robusta* forest for cavity making.
- Baseline survey should be done at fixed intervals through the relevant organizations and researchers.
- The study of relationship between logging disturbances along with more nest location, feeding ecology, movement ecology and breeding success of GSW is recommended to upcoming researchers.

7 REFERENCES

Ali, S. and Ripley, S.D. 1983. Handbook of the birds of India and Pakistan: together with those of Bangladesh, Nepal, Bhutan and Sri Lanka, Compact Edition. Oxford University, 36 pp.

Andersson, J., Domingo Gómez, E., Michon, S., and Roberge, J.M. 2018. Tree cavity densities and characteristics in managed and unmanaged Swedish boreal forest. Scandinavian Journal of Forest Research, **33**(3): 233-244.

Angelstam, P. and Mikusinski, G. 1994. Woodpecker assemblages in nature and managed boreal and hemi boreal forest-a review. Annales Zoologici Finnici, **31**: 157-172.

Baral, H. 2011.Status and conservation of Great Slaty Woodpecker *Mulleripicus pulverulentus* in Nepal. Preliminary report to Department of National Parks and Wildlife Conservation, Government of Nepal and Rufford Small Grants Foundation, UK. Unpublished.

Baral, H. S. and Inskipp, C. 2009.The birds of Suklaphanta Wildlife Reserve, Nepal. Our Nature, **7**: 56-81.

Parajuli, K. 2068. Survey of bird species richness in Kamala river basin, lowland nepal.M.sc Thesis. Central Department of Zoology, Tribhuvan University Kathmandu, Kiritpur, Nepal.

BCN and DNPWC. 2011. The state of Nepal's Birds 2010 Kathmandu Bird Conservation Nepal and Department of National Parks and Wildlife Conservation, 54pp.

Bergner, A., Sunnergren, A., Yeşilbudak, B., Erdem, C. and Jansson, N. 2016. Attributes of trees used by nesting and foraging woodpeckers (Aves: Picidae) in an area with old pollarded Oaks in the Taurus Mountains, Turkey. Zoology in the Middle East, **62**(4): 288-298.

Bevis K.R. and Martin S.K. 2002. Habitat preferences of primary cavity excavators in Washington's East Cascades. *In*: Laudenslayer, W.F.Jr., Shea, P.J., Valentine, B. E., Weatherspoon, C.P., Lisle T. E. (eds). Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Reno, NV, pp. 207-221.

Bhatt, D. D. and Shrestha, T. K. 1977. The Environment of Suklaphanta: A Study Report, Sponsored by the National Planning Commission of Nepal. Tribhuvan University, Curriculum Development Centre.

Bhuju, U.R., Shakya, P.R., Basnet, T.B. and Shrestha, S. 2007. Nepal Biodiversity Resource Book. Protected Areas, Ramsar sites and World Heritage Sites. International Centre for Integrated Mountain Development, 128pp.

Bibby, C., Jones, M. and Marsden, S. 2000. Expedition Field Techniques: Bird Surveys. Birdlife International. Expedition advisory center, UK, 34 pp.

Birand, A. and Pawar, S. 2004. An ornithological survey in north-east India. Forktail, **20**: 15-24.

BirdLife International. 2010. Species factsheet: *Mulleripicus pulverulentu*s. Acessed on 21 June, 2017

BirdLife International. 2012. "*Mulleripicus pulverulentus*". IUCN Red List of Threatened Species. Version 2013.2. International Union for Conservation of Nature. Retrieved 26 November 2013.

Block, W.M. 1991. Foraging ecology of Nuttall's woodpecker. Auk, **108**: 303–317.

Conner, R.N., Rudolph, D.C. and Walters, J.R. 2001.The red-cockaded woodpecker: surviving in a fire-maintained ecosystem (Vol 49). University of Texas Press, USA, 365pp.

Conner, R.N., Hooper, R.G., Crawford, H.S., and Mosby, H.S. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. The Journal of Wildlife Management, **4:**144-150.

Conner, R.N., Miller, O.K. and Adkisson, C.S. 1976. Woodpecker dependence on trees infected by fungal heart rots. The Wilson Bulletin, 575-581.

Conner, R.N., Saenz, D. and Rudolph, D.C. 2004. The red-cockaded woodpecker: interactions with fire, snags, fungi, rat snakes and pileated woodpeckers. Texas Journal of Science **56**: 415–426.

Daily, G.C., Ehrlich, P.R. and Haddad, N.M. 1993. Double keystone bird in a keystone species complex. Procedding of National Academy Science, **90**: 592–594.

Domínguez, J., Carbonell, R. and Ramírez, A. 2017. Seasonal changes in habitat selection by a strict forest specialist, the Middle Spotted Woodpecker (*Leiopicus medius*), at its southwestern boundary: implications for conservation. Journal of Ornithology, **158**(2): 459-467.

Drever, M.C., Aitken, K.E.H., Norris, A.R. and Martin, K. 2008. Woodpeckers as reliable indicators of bird richness, forest health and harvest. Biology Conservation, **141**: 624–634.

Drever, M.C. and Martin, K. 2010. Response of woodpeckers to changes in forest health and harvest: Implications for conservation of avian biodiversity. Forest Ecology Management, **259**: 958–966.

Dunning, J. B. 2007. CRC handbook of avian body masses, 2nd ed. CRC press, London New York, 579pp

Ghazala, S. and Kumar, R. 2011. Assessing Conservation Threat in an Endemic Bird Area: The Great Slaty Woodpecker in Sub-Himalayan Uttarakhand, India. Final report for WWF-small grant India.

Grimmett, R., Inskipp, C. and Inskipp, T. 1998. Birds of the Indian Subcontinent 1st ed. Christopher Helm, London, UK, 107 pp.

Hebda, G., Wesołowski, T. and Rowiński, P. 2017. Nest sites of a strong excavator, the Great Spotted Woodpecker (*Dendrocopos major*) in a primeval forest. Ardea, **105**(1): 61-71.

Ilsøe, S.K., Kissling, W.D., Fjeldså, J., Sandel, B. and Svenning, J.C. 2017. Global variation in woodpecker species richness shaped by tree availability. Journal of Biogeography, **44**(8): 1824-1835.

Inskipp, C. 1989. Forest birds of Nepal: their status and conservation. International Council for Bird Preservation, Cambridge press, UK, 187 pp.

IUCN. 2009. IUCN Red List. Accessed on 1st June, 2017.

Inskipp, C. and Inskipp, T.P. 1991. A guide to the birds of Nepal 2nd ed.Christopher Helm, London, 123pp.

Inskipp, C., Baral, H.S., Phuyal, S., Bhatt, T.R., Khatiwada, M., Inskipp, T. and Poudyal, L. 2016. The status of Nepal's Birds: The national red list series. Zoological Society of London, UK, 614pp.

Javed, S. and Rahmani, A. R. 1998. Conservation of the avifauna of Dudwa National Park, India. Forktail, **14**: 55-64.

Jha, P.K. 2017. Common Birds of Chitwan National Park, Nepal. Journal of Advanced Academic Research, **1**(2): 19-26.

Jones, C.G., Lawton, J.H. and Shachak, M. 1994. Organisms as ecosystem engineers. Oikos, **69**: 373–386.

Kerpez, T.A. and Smith, N.S. 1990. Nest-site selection and nest-cavity characteristics of Gila Woodpeckers and Northern Flickers. The Condor, 193-198.

Koenig, W.D. and Mumme, R.L. 1987. Population ecology of the cooperatively breeding Acorn Woodpecker. Princeton University Press, Princeton, 397pp.

Kotaka, N. and Matsuoka, S. 2002. Secondary users of Great Spotted Woodpecker (*Dendrocopos major*) nest cavities in urban and suburban forests in Sapporo City, northern Japan. Ornithological Science, **1**(2): 117-122.

Kumar, R., Shahabuddin, G. and Kumar, A. 2011. How good are managed forests at conserving native woodpecker communities? A study in sub-Himalayan dipterocarp forests of northwest India. Biological conservation, **144**(6): 876-1884.

Kumar, R. and Shahabuddin, G. 2012. Assessing the status and distribution of the Great Slaty Woodpecker *Mulleripicus pulverulentus* (Temminck, 1826) in sub-Himalayan Uttarakhand, India. Journal of Bombay Natural History Society, **109**: 17-22.

Kumar, R. and Singh, P. 2010. Determining woodpecker diversity in the sub-Himalayan forests of northern India using call playbacks. Journal of Field Ornithology, **81**(2): 215-222.

Lammertink, M. 2004. Grouping and cooperative breeding in the Great Slaty Woodpecker. The Condor, **106**(2): 309-319.

Lammertink, M. 2004. A Multiple-Site Comparison of Woodpecker Communities in Bornean Lowland and Hill Forests. Conservation Biology, **18**(3): 746-757.

Lammertink, M., Prawiradilaga, D.M., Setiorini, U., Naing, T.Z., Duckworth, J.W. and Menken, S.B. 2009. Global population decline of the Great Slaty Woodpecker (*Mulleripicus pulverulentus*). Biological Conservation, **142**:166-179.

Lammertink, J.M. and Estrada, A.R. 1995. Status of Ivory-billed Woodpecker *Campephilus principalis*in Cuba: almost certainly extinct. Bird Conservation International, **5**:53-59.

Lindenmayer, D.B. and Noss, R.F. 2006. Salvage logging, ecosystem processes, and biodiversity conservation. Conservational Biology, **20**: 949–958.

Lorenz, T.J., Vierling, K.T.,Kozma, J.M. and Millard, J.E. 2016. Foraging plasticity by a keystone excavator, the white-headed woodpecker, in managed forests: Are there consequences for productivity? Forest Ecology and Management, **363**:110-119

Macey, J.N., Brent Burt, D., Saenz, D. and Conner, R.N. 2016. Habitat use and avoidance by foraging red-cockaded woodpeckers in east Texas. Southeastern Naturalist, **15**(9): 76-89.

Majupuria, T.C. and Kumar, R. 1998. Wildlife, National Parks and Reserves of Nepal. S. Devi, Saharanpur and Tecpress Books, Bangkok, 410pp.

Martin, K. and Eadie, J.M. 1999. Nest webs: A community-wide approach to the management and conservation of cavity nesting forest birds. Forest Ecology Management, **115**: 243–257.

Martin, K., Aitken, K.E.H. and Wiebe, K.L. 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. The Condor, **106**: 5–19.

McAuliffe, J.R. and Hendricks, P. 1988. Determinants of the vertical distributions of woodpecker nest cavities in the Sahuaro cactus. The Condor, **67**:791-801.

McMahon, D.E., Pearse, I.S., Koenig, W.D. and Walters, E.L. 2015. Tree community shifts and Acorn Woodpecker population increases over three decades in a Californian oak woodland. Canadian Journal of Forest Research, **45**(8): 1113-1120.

Melletti, M. and Penteriani, V. 2003. Nesting and feeding tree selection in the endangered white-backed woodpecker, *Dendrocopos leucotoslilfordi*. Wilson Bull, **115**: 299-306.

Mikusinski, G. 2006. Woodpeckers: distribution, conservation, and research in a global perspective. Woodpeckers: distribution, conservation, and research in a global perspective. Annales Zoologici Fennici, **43**: 86-95.

Mikusinski, G., Gromadzki, M. and Chylarecki, P. 2001. Woodpeckers as indicators of forest bird diversity. Conservation Biology, **15**: 208–217.

Mile, K.A. and Hejl, S.J. 1989. Nest-site characteristics of white-headed woodpecker. The journal of Wildlife Management, **20:**50-55.

Odum, E.P. 1971. Fundamental of ecology 3rd ed. Nataraj Publishers, Dehradun, India, 574 pp.

Ojeda, V.S. 2004. Breeding biology and social behavior of Magellanic woodpeckers (*Campephilus magellanicus*) in Argentine Patagonia. European Journal of Wildlife Research, **50**: 18-24.

Ojeda, V. and Chazarreta, L. 2014. Home range and habitat use by Magellanic Woodpeckers in an old-growth forest of Patagonia. Canadian Journal of Forest Research, **44**(10): 1265-1273.

Ouellet-Lapointe, U., Drapeau, P., Cadieux, P. and Imbeau, L. 2012. Woodpecker excavations suitability for and occupancy by cavity users in the boreal mixed wood forest of eastern Canada. Ecoscience, **19**(4): 391-397.

Pakkala, T., Tiainen, J. and Kouki, J. 2017. The importance of nesting cavity and tree reuse in the three-toed woodpecker *Picoidestri dactylus* in dynamic forest landscapes. Annales Zoologici Fennici, **544**(4): 175-191.

Pakkala, T., Tiainen, J., Piha, M. and Kouki, J. 2018. Three-toed Woodpecker cavities in trees: A keystone structural feature in forests shows decadal persistence but only

short-term benefit for secondary cavity-breeders. Forest Ecology and Management, **413**: 70-75.

Pasinelli, G. 2007. Nest site selection in middle and great spotted woodpeckers *Dendrocopos medius*and *D. major*: implications for forest management and conservation. Biodiversity and Conservation, **16**(4): 1283-1298.

Raphael, M. G. and White, M. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildlife Monographs, **8**:3-66.

Renken, R.B. and Wiggers, E.P. 1989. Forest characteristics related to Pileated woodpecker territory size in Missouri. Condor, 642-652.

Robles, H., Ciudad C., Vera, R., Olea, P.P., Purroy, F. J. and Matthysen, E. 2007. Sylvo pastoral management and conservation of the middle spotted woodpecker at the south-western edge of its distribution range. Forest Ecology Management, **242**: 343-352.

Rolstad, J., Løken, B. and Rolstad, E. 2000. Habitat selection as a hierarchical spatial process: the green woodpecker at the northern edge of its distribution range. Oecologia, **124**(1), 116-129.

Rota, C.T., Rumble, M.A., Millspaugh, J.J., Lehman, C.P. and Kesler, D.C. 2014. Space-use and habitat associations of Black-backed Woodpeckers (*Picoides arcticus*) occupying recently disturbed forests in the Black Hills, South Dakota. Forest Ecology and Management, **313:** 161-168.

Santharam, V. 2003. Distribution, ecology and conservation of the White-bellied Woodpecker *Dryocopus javensis* in the Western Ghats, India. Forktail, **19**: 31-38.

Sedgwick, J.A. and Knopf, F.L. 1990. Habitat relationships and nest site characteristics of cavity-nesting birds in cottonwood floodplains. The Journal of Wildlife Management, 112-124.

Segura, A. 2017. How does vegetation structure influence woodpeckers and secondary cavity nesting birds in African cork oak forest? Acta Oecologica, **83**: 22-28.

Setterington, M.A., Thompson, I.D. and Montevecchi, W.A. 2000. Woodpecker abundance and habitat use in mature balsam fir forests in Newfoundland. Journal of Wildlife Management, **64**: 335–345

Sharma, V., Lawaniya, N.K., Yadav, D., Jangid, A.K., Dhawal, O., Yadav, O. *et al.*, 2015. Records of White-napped Woodpecker from Todgah Raoli Wildlife Sanctuary, Rajsthan. Journal of New Biological Reports, **4**(3): 243-246.

Sheldon, F.H., Styring, A., Hosner, P.A. 2010. Bird species richness in a Bornean exotic tree plantation: A long-term perspective. Biology Conservation, **143**: 399-407.

Thompson, I.D., Baker, J.A. and Ter-Mikaelian, M. 2003. A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. Forest Ecology Management, **177**: 441-469.

Timilsina, N. and Heinen, J.T. 2008. Forest Structure under Different Management Regimes in the Western Lowlands of Nepal. Journal of Sustainable Forestry, **26**(2): 112-131.

Vergara, P.M., Soto, G.E., Moreira-Arce, E., Rodewald, A.D., Meneses, L.O. and Pérez-Hernández, C.G. 2016. Foraging behaviour in Magellanic Woodpeckers is consistent with a multi-scale assessment of tree quality. PLoS ONE, **11**(7): 12-26.

Watson, D.M. and Shaw, D. 2018. Veiled Polypore (*Cryptoporus volvatus*) as a foraging substrate for the White-Headed Woodpecker. Northwestern Naturalist, **99**(1): 58-62.

Wesołowski T., Czeszczewik D. and Rowinski P. 2005. Effects of forest management on Three-toed Woodpecker *Picoides tridactylus* distribution in the Bialowieza Forest (NE Poland): conservation implications. Acta Ornithology, **40**: 53-60.

Wightman, C.S., Saab, V.A., Forristal, C., Mellen-McLean, K. and Markus, A. 2010. White-headed woodpecker nesting ecology after wildfire. Journal of Wildlife Management, **74**(5): 1098-1106.

Wikramanayake, E. D., Dinerstein, E., Robinson, J. G., Karanth, K.U., Rabinowitz, A., Olson, D. *et al.,* 1999. Where can tigers live in the future? A framework for identifying high-priority areas for the conservation of tigers in the wild. *In* Riding the Tiger. Tiger Conservation in human-dominated landscapes, Seidensticker, J., Christie, S., Jackson, P. (eds.). Cambridge University Press, Cambridge., 255-272

Wiktander U., Olsson O. and Nilsson S. G. 2001. Seasonal variation in home-range size, and habitat area requirement of the lesser spotted woodpecker (*Dendrocopos minor*) in southern Sweden. Biological Conservation, **100**: 387–395.

Willson, M.F. and Comet, T.A. 1996. Bird communities of northern forests: patterns of diversity and abundance. The Condor, 337-349.

Wines, J.A.1992. Ecology of Bird Communities. Cambridge: Cambridge University Press, UK, 469 pp.

Winkler, H. and Christie, D.A. 2002 Family Picidae (woodpeckers). *In* Handbook of the birds of the world, vol. 7, jacamars to woodpeckers, del Hoyo, J., Elliott, A. and Sartagal, J. (eds.). Lynx Edicions, Barcelona., pp. 296–555

Winkler, H., Christie, D.A. and Nurney, D. 1995 Woodpeckers. A guide to woodpeckers, piculets and wrynecks of the world. Pica Press, Russel Friedman Books, South Africa, 212pp.

Zoological Society of London. 2015, National Red List of Nepal's Birds Volume 3rd. Regent's Park, London, UK, 189 pp.

Appendix I: Photo plate

Plate 1: Female responding to male call

Plate 2: Male calling

Plate 3: Measuring DBH of tree

Plate 4: Using calls play back

Plate 5: Habitat of Great Slaty Woodpecker

Plate 6: Woodpeckers in group

Plate 7: Active nest in *Shorea robusta*

Plate 8: Passive nest cavity on the snag Sal tree

APPENDIX II: DATA SHEET

Date: Latitude:

Place: Longitude:

Transect	Start time	End time	Start point		End point		Sex			Habitat	Nest Cavity					
			East	North	East	North	Total	Male	Female		East	North	Number	DBH	Canopy cover	Cavity height from ground level
T1																
T2																
T3																
T4																
T5																
T6																
T7																
T8																
T9																
T10																
T11																
T12																
T13																
T14																