OCCURRENCE OF INVASIVE ALIEN PLANT SPECIES (IAPS) IN THE HABITAT OF SWAMP DEER (*Cervus duvaucelii* Cuvier, 1823) OF SHUKLAPHANTA NATIONAL PARK, NEPAL

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Submitted to

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu

Nepal

September, 2019

DECLARATION

I hereby, declare that this thesis work entitled **"Occurrence of Invasive Alien Plant Species (IAPS) in the Habitat of Swamp Deer (*Cervus duvaucelii* Cuvier, 1823) of Shuklaphanta National Park, Nepal"** is my own otherwise as acknowledged. I have not submitted it or any parts of it to any other academic institutions for any degree.

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RECOMMENDATION

This is to recommend that the thesis entitled **"Occurrence of Invasive Alien Plant Species in the Habitat of Swamp Deer (*Cervus duvaucelii* Cuvier, 1823) of Shuklaphanta National Park, Nepal"** has been carried out by Renu Bhandari for the partial fulfillment 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.

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LETTER OF APPROVAL

On the supervision of Associate Prof. Dr. Bishnu Prasad Bhattarai, this dissertation submitted by Renu Bhandari entitled **"Occurrence of Invasive Alien Plant Species in the habitat of Swamp Deer (*Cervus duvaucelii* Cuvier, 1823) of Shuklaphanta National Park, Nepal"** is approved for the examination to the Tribhuvan University in partial fulfillment of the requirement for Master's Degree of Science in Zoology with special paper Ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Renu Bhandari entitled **"Occurrence of Invasive Alien Plant Species in the habitat of Swamp Deer (*Cervus duvaucelii* Cuvier, 1823) of Shuklaphanta National Park, Nepal"** has been accepted as a partial fulfillment for the requirement of Master's Degree of Science in Zoology with special paper Ecology.

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LIST OF ABBREVIATIONS

DFO	District Forest Office
DNPWC	Department of National Parks and Wildlife Conservation
gm	Gram
GPS	Global Positioning System
ha	Hectare
IUCN	International Union for Conservation of Nature
km	Kilometer
m	Meter
NTNC	Nepal Trust for Nature Conservation
^{o}C	Degree Celsius
SNP	Shuklaphanta National Park

ABSTRACT

The present study was conducted during October 2018 to April 2019 with an aim to assess the floral diversity, status and distribution of invasive alien plant species and its impact on swamp deer habitat in seven research sites within the grasslands of Shuklaphanta National Park. The quadrats of 5*5m were laid so as to collect the data for native and invasive species in the park. The number of native and invasive alien plants species within the quadrats were counted and noted. The invasive floral diversity indices, Shannon- Weiner index (H) and Simpson Index of species (SI) diversity were calculated using Ms Excel 2016. Out of 20 plant species recorded in the study area, grass species were nine, and invasive plant species were eleven. The abundance of IAPS was higher in Tintale area and least in Barkaula. The Shannon- Weiner diversity index for Tintale are, Singhapur, Barkaula, Silalekh, Pillar 24, Pillar 26 and Sundarpur were 1.051, 1.275, 0.085, 1.309, 0.953, 0.905 and 0.541 respectively whereas the Simpson Index diversity was 0.573, 0.692, 0.033, 0.683, 0.563, 0.547 and 0.355 respectively. The abundance of invasive alien plants was higher in open grasslands and those having less distance from the village and roads. The invasive species cover was low in the areas where there was high native species cover. The overall impact of IAPS was seen low in the grasslands of the park to create impact on the habitat of the swamp deer however the threats due to invasion cannot be neglected. The buffer zone and the wetlands were highly invaded, which can become a major contributor to encourage the invasion in the core areas of the park which can eventually lead to the decline of Swamp Deer population in the park. Therefore, proper management of IAPS before it completely invades the park and Swamp Deer Conservation action plan is needed in the park.

1. INTRODUCTION

1.1. Background

Invasive Alien Species (IAS) are species, native to one area or region, that have been introduced into an area outside their normal distribution, either by accident or on purpose, and which have colonized or invaded their new home, threatening biological diversity, ecosystems and habitats, and human well-being (CBD 1992). Species invasion is profoundly altering communities and ecosystem worldwide (Gurevitch and Padilla 2004). The invasive species have some specific traits like high reproductive and dispersal rate, noble weapons, phenotypic plasticity and they are generalists. These traits provide them the capability to adapt in the multiple types of environmental conditions. The immense widespread of these invasive species in a non-native range brings out the serious condition, biological invasion. The biological invasion is the unchecked phenomena of spread and proliferation of the species that are non-indigenous/exotic including plants, arthropods, plant pathogens and even vertebrates (Lowe et al. 2000). The invasions, today, have come to become the burning issues at the global scenario as they are the prime reasons for the global change (Vitausek et al.1997) and the major cause of loss of native biodiversity (Ricciardi et al. 1998, Kohli et al. 2004). It is reported that biological invasion is one of the most significant driver of environment change and degradation (Vitousek et al. 1997, Pimental 2002), affecting the delivery of ecosystem goods and services and consequently human wellbeing (Pejchar and Mooney 2009). It has been recorded that about 42% of the species listed as threatened and endangered are at risk mainly due to the invasive species (Pimentel et al. 2000). Similarly, the accession of invasive species creates an enormous economic loss for the countries hosting it. The economic loss by the invasive species is thought to be around US$ 138 billion per year (Pimentel et al. 2000). Invasive species besides being one of the major reasons of the faunal extinction and also affect the ecosystem services negatively (Pejchar and Mooney 2009).

Nepal, a link between the various trade oriented Asian countries is blessed with the diverse climatic conditions and the wide range of geomorphology (Dobremez 1976 as cited in TISC 2002). The concern on invasive species started in Nepal in 1950 AD. There are around 219 invasive plant species in Nepal (Tiwari et al. 2005, Siwakoti 2012., Sukhorukov 2014). Altogether, 21 species are prioritized for assessment of invasiveness character in Nepal. Among them, six species are considered as high threat to the native species habitats and ecosystems. These include *Ageratina adenophora, Chromolaenaodorata, Lantana camara, Mikania micrantha, Eichhornia crassipes* and *Ipomoea carnea ssp. fistulosa*. Following three species are recorded as medium threat: *Alternanthera philoxeroides, Myriophyllum aquaticum*and Parthenium *hysterophorus*. Similarly, low threat causing species are *Ageratum conyzoides, Amaranthus spinosus, Argemone mexicana, Cassia tora, Hyptis suaveolens, Pistia stratiotes* and *Leersia hexandra*. There are five species with insignificant threats, which include *Bidens pilosa, Xanthium strumarium, Cassia occidentalis, Oxalis latifolia* and *Mimosa pudica* (IUCN

2005). The distribution of *Mikania micrantha* is common and problematic from central to eastern Nepal especially from Chitwan to Jhapa districts (Tiwari et al. 2005). The habitat of One Horned Rhinoceros is a serious threat caused due to the invasion of *Mikania micrantha* in Chitwan National Park. The spread of these invasive species can drastically change the structure of the ecosystem (Gurevitch and Padilla 2004) and hence affecting the natural habitat of the wildlife.

Swamp Deer

The Barasingha (*Rucervus duvaucelii* syn. *Cervus duvaucelii*), is also called swamp deer. The Barasingha is currently found in isolated localities in north and central India, and southwestern Nepal. It is extinct in Pakistan and Bangladesh (Qureshi et al. 2004). Barasingha is assessed as Vulnerable under criterion C1 because the estimated total population lies between 3,500 and 5,100 animals (not all of which will be mature individuals) and outside of several key populations, the protection status is not secure. Thus, the species is assumed to still be in decline by at least 10% over 24 years (three generations) mostly due to habitat conversion and degradation (IUCN 2015).

1.2. Objectives of the study

1.2.1. General Objective

The main objective of the study was to explore the impacts of invasive alien plant species (IAPS) on the grassland habitat of swamp deer in Shuklaphanta National Park, Farwestern Nepal

1.2.2. Specific Objectives

- To assess the native and invasive alien floral diversity in grasslands
- To assess the impact of Invasive alien plants on Swamp Deer habitat

1.3. Significance of the study

Invasion is an uncontrolled and an extreme issue. The major impacts of invasion are seen to be on grasslands, riverine forests and even the woodlands to some extent. *Acacia catechu* (Khayer), *Dalbergia sissoo* (Sissoo*) and Bombax ceiba* (Simal) are mainly found to be affected and among grasses, *Themeda triandra* (Khar), *Imperata cylindrica* (Siru), *Eragrotis unioloids* (Banso) are affected at a greater extent. Though, a number of efforts are being carried out but yet it is a challenge for all the ecologists and biodiversity conservationists to control the invasion once they get established. Various workshops are being carried out on controlling the invasion in Nepal by different organizations at National and International level. Study of *Mikania micrantha* in Chitwan National Park and the observed results have pulled everyone's attention on invasion. Similar threat is experienced by Shuklaphanta National Park. The invasion has already started affecting the grasslands of the park. This study "Impact of invasive plant species on Swamp Deer of Shuklaphanta National Park" is significant / justifiable here because it will explore the

threat generated to the ungulates of the park due to invasion, extent of invasion and the ideas of local people on invasion along with mitigation measures being carried out.

1.4. Research Questions

1. What is the status of IAPS on grassland, in Shuklaphanta National Park?
2. What types of habitat is preferred by Swamp Deer?
3. What is the impact of IAPS on Swamp Deer habitat?

2. LITERATURE REVIEW

2.1. Invasion of Alien Plants in Nepal

Biological invasion has been considered as an important component of global environmental changes (Vitousek et al. 1997) and a leading cause of decline and/or loss of native biodiversity (Ricciardi et al. 1998, Kohli et al. 2004) and ecosystem services (Pejchar and Mooney 2009). With steady increase in human movement and global trade, the intensity of biological invasion has been increasing in all ecosystems and landscapes. The negative impact of invasive species is further exacerbated by ongoing climate change because the later has been projected to increase both frequency (Clavero and Berthau 2005) and intensity of biological invasion (Simberloff 2000).

The problem of invasive species is prevalent both in developed as well as developing countries, but their impact is likely to be higher in developing countries like Nepal due to lack of expertise and limited resources available for their management. Nepal lies at the cross-road of six floristic provinces of Asia (Sino-Japanese, Southeastern Asiatic, Indian, Sudano-Zambian, Irano-Turranean and Central Asiatic) and the floral elements of all provinces are represented in Nepal (Dobremez 1976, TISC 2002). With the widest elevation gradient and heterogeneous geomorphology, organisms from anywhere of the world may find suitable habitat and climatic condition in Nepal. There are at least 219 alien species of flowering plants (Tiwari et al. 2005, Siwakoti2012, Sukhorukov 2014) and 64 species of animals (Budha 2015) that are naturalized in Nepal. An assessment of invasive alien plant species (IAPS) was undertaken for the first time by IUCN Nepal during 2002- 2003 and reported 21 naturalized (i.e. alien species with self-sustaining population) flowering plant species to be invasive in Nepal (Tiwari et al. 2005). Community consultation and field observations showed that at least four additional naturalized plant species can be considered invasive in Nepal. Though the Nepalese scientific community was aware of the arrival of IAPS since long, scientific study of the problems related to them got momentum only after 2000 and the Central Department of Botany, Tribhuvan University is playing a leading role in IAPS related research in Nepal (Poudel and Thapa 2012). In this communication, an overview of diversity of the IAPS in Nepal, their distribution, dispersal, impacts, management, legal provision, and future prospects have been presented.

2.2. Distribution

2.2.1 Distribution in Nepal

There is high concentration of IAPS on the southern half of the country (which includes Tarai, Siwalik and Mid Hills running east-west) with tropical to subtropical climate (Table 2). This is not surprising because more than 3/4th of the naturalized plant species (which also includes IAPS) of Nepal are native to tropical and subtropical region of the world (Tiwari et al. 2005, Bhattarai et al. 2014). Until now, the most troublesome species such as *Chromolaena odorata, Eichhornia crassipes, Lantana camara and Mikania micrantha* are confined to this region. However, northward movement of these species cannot be ruled out. Some species of tropical origin like *Ageratina adenophora and*

Parthenium hysterophorus started their invasion from the southern part and have already reached to northern border crossing through Low Mountain region. Only a few invasive species like *Erigeron karvinskianus and Galinsoga quadriradiata* are confined to Mid Hills and Low Mountains, and absent in warm regions such as Terai and Siwalik. The IAPS has not been reported from High Mountain regions of Nepal.

2.3. Ecology of IAPS

Introduction of alien species exclusively depends on human activities while the subsequent dispersal of naturalized species occurs both by natural process as well as human activities. The IAPS that belongs to Asteraceae such as *Ageratina adenophora, Chromolaena odorata and Mikania micrantha* are mostly dispersed by winds but some other species of the same family are dispersed by animals (e.g., *Xanthium strumarium, Bidens pilosa*), vehicles and agriculture produces (e.g., *Parthenium hysterophorus*). Dispersal by vehicles and as contaminant of transport materials often result in the formation of satellite populations at isolated geographic locations (e.g., valley with warm climate amid high hills). Seeds of *Lantana camara*are mainly dispersed by birds but this species is still being transported to new locations for ornamental purposes due to its attractive flower. Wetland IAPS are mostly dispersed by water but species like *Eichhornia crassipes and Pistia stratioites* are also transported to new locations for their ornamental values. *Ipomoea carnea*, a wetland species common in Terai region has been introduced to hilly region for controlling soil erosion along roadside and also as hedge plant in agroecosystem. However, this species is less likely to be problematic in hilly region due to lack of suitable habitat. Species that is dispersed mainly by natural process (e.g., *Chromolaena odorata*) often has low spread rate than other species which is dispersed by human activities (e.g., *Parthenium hysterophorus*). For example, *Chromolaena odorata* with minimum residence time (MRT) of 190 years has not been reported from the Tarai region west of Karnali river but *Parthenium hysterophorus* with only 48 years MRT is found not only from eastern to western Nepal but also from southern border with India to northern border with China (Timbure of Rasuwa district).

2.4. Impacts

Because of the inherent linkage with human activities, the IAPS are more common, and hence have more impacts in anthropogenic landscape than in intact natural landscape. The impact of IAPS in anthropogenic landscape mainly includes the economic losses due to decline in agriculture production, increased labor to remove the weeds, suppression of useful species, and health hazard to human and livestock. From anthropogenic landscape, some of the IAPS expand to natural landscape such as forest, grassland and wetland where they not only compete with native species for resources but also degrade the habitats thereby making the ecosystems hostile to native species and increasing the rate of human-induced biodiversity loss. Therefore, globally the biological invasion has been considered as the second major cause of biodiversity loss next to habitat degradation (Glowka et al. 1994). In Nepal, the IAPS are already common and spreading rapidly both in anthropogenic as well as in natural landscape but their impacts – economical, ecological and evolutionary have not been evaluated comprehensively. Limited

researches and case studies have shown that the impacts of IAPS ranges from habitat degradation of endangered wildlife (e.g., one-horned rhinoceros, Murphy et al. 2013) to negative effects on the livelihood of rural communities (Rai et al. 2012). Murphy et al. (2013) reported that 44% of the habitat of endangered one-horned rhinoceros in Chitwan National Park has been negatively affected by *Mikania micrantha* by suppressing growth of grasses and regeneration of trees.

Another IAPS *Parthenium hysterophorus* has significantly altered species composition and soil chemistry of grasslands (Timsina et al. 2011). The cases of bitter taste in milk produced by cattle that grazed in *P. hysterophorus* invaded grassland, and allergic dermatitis due to this weed to human have been also reported (Shrestha et al. 2015). Other IAPS of the terrestrial ecosystems such as *Ageratina adenophora*, *Lantana camara* and *Chromolaena odorata* are also widespread and form monoculture stands displacing native species and disrupting ecosystem processes. They have reduced carrying capacity of rangelands, increased the risk of fire damage, and prevented regeneration of other species including trees. However, these impacts are largely anecdotal due to lack of risk assessment and impact study.

In wetlands of Tarai, Siwalik and Mid Hills, *Eichhornia crassipes* is the most troublesome IAPS threatening all the Ramsar sites and most of the other lake systems. This species not only smothers the wetland biodiversity but also negatively affects the livelihood of wetland dependent local communities. For example, in Begnas lake of Pokhara valley, boating and fishing are important economic activities of the local communities residing near the lake. Boating is both means of transportation as well as source of income from tourism, and about 200 individuals are involved in boating profession (Buddhi Sagar Kandel, staff of Boat Entrepreneur's Association of Begnas Lake, personal communication, Nov 15, 2015). Similarly, livelihood of at least 60 households depends on fishing in the lake. Livelihood of both these boating and fishing communities has been threatened due to rapid expansion of the *E. crassipes* in the lake since last 8-10 years. Review of available references showed that a limited number of studies have evaluated the impacts of a few IAPS (e.g., Timsina et al. 2011, Rai et al. 2012, Murphy et al. 2013) while most of the perceived impacts of IAPS is largely anecdotal. There is a need of systematic and comprehensive studies on the ecological and economic impacts of invasive alien species in Nepal. The Government of Nepal has targeted to evaluate ecological and economic impacts of at least five invasive alien species by 2020 (MFSC 2014a). Some research activities are being initiated in this direction by different institutions such as the Central Department of Botany (Tribhuvan Unversity), International Center for Integrated Mountain Development (ICIMOD), and National Trust for Nature Conservation (NTNC).

2.5 Distribution of Swamp Deer

The Barasingha is currently found in isolated localities in north and central India, and southwestern Nepal. It is extinct in Pakistan and Bangladesh (Qureshi et al. 2004, Md Anwarul Islam in litt. 2008). Into the early twentieth century, the Barasingha was widely distributed in areas of suitable habitat throughout the Indo–Gangetic plain and the

lowlands flanking the southern Himalaya. The range formerly extended eastward across the Terai of southern Nepal through the Sundarbans as far as Assam. Barasingha occurred west to the River Indus, into Pakistan, and as far south as the River Godavari area of east-central India (Schaller 1967, Groves 1982, Sankaran 1989). The only known population in Bangladesh was in the Sundarbans, where it has been extinct for perhaps a century. The species may also have been in the northeast of Bangladesh, given its distribution in adjacent India (Md Anwarul Islam in litt. 2008).

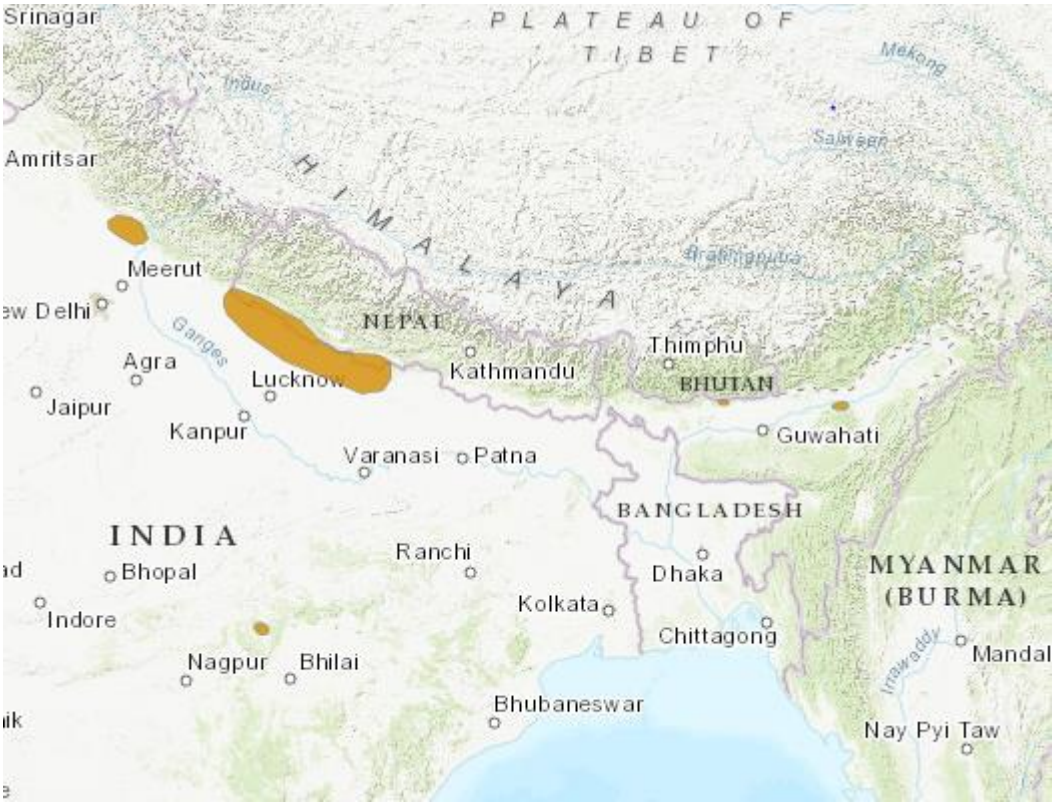

Figure 1. Geographical range of Swamp deer (Source: IUCN 2008).

2.6 Morphology and ecology

The Swamp deer (Barasingha) is a large deer with a shoulder height of 44 to 46 in (110 to 120 cm) and a head-to-body length of nearly 6 ft (180 cm). Its hair is rather woolly and yellowish brown above but paler below, with white spots along the spine. The throat, belly, inside of the thighs and beneath the tail is white. In summer the coat becomes bright rufous-brown. The neck is maned. Females are paler than males. Young are spotted. Average antlers measure 30 in (76 cm) round the curve with a girth of 5 in (13 cm) at mid beam (Blanford 1888). A record antler measured 104.1 cm (41.0 in) round the curve (Prater 1948). Swamp deer are mainly grazers (Lydekke 1888). They largely feed on grasses and aquatic plants, foremost on *Saccharum*, *Imperata cylindrica*, *Narenga porphyrocoma*, *Phragmites karka*, *Oryza rufipogon*, *Hygroryza* and *Hydrilla*. They feed throughout the day with peaks during the mornings and late afternoons to evenings. In

winter and monsoon, they drink water twice, and thrice or more in summer. In the hot season, they rest in the shade of trees during the day (Qureshi et al. 2004).

2.7 Ecology and behavior

The herds comprise, on average, about 8–20 individuals, with large herds of up to 60. There are twice as many females than males. During the rut they form large herds of adults. The breeding season lasts from September to April, and births occur after a gestation of 240–250 days in August to November (Schaller 1967). They give birth to single calves. When alarmed, they give out shrill, baying alarm calls (Prater 1948).

2.8 Swamp deer habitat

Swamp deer lives in the swampy grasslands and floodplains of Indian sub-continent, and also utilizes surrounding riverine forests and woodlands. It is highly dependent on the availability of water. Swamp deer is mainly a grazer, eating grass and leafy aquatic vegetation. It feeds mainly in the morning and evenings, and in the midday heat it retreats to the shade or rest in the open. Where there is substantial human disturbance, the swamp deer is mainly nocturnal. Swamp deer is listed by IUCN, with the few remaining populations declining or already affected by habitat fragmentation due to expansion of agriculture, habitation and various other land use practices (Duckworth et al. 2008). The total world population of swamp deer is estimated less than 5,000 animals, occupying an area of less than 2,000 km² in India and Nepal.

3. MATERIALS AND METHODS

3.1 Study area

3.1.1 Geographical location

Shuklaphanta National Park is situated between longitudes 80^0 06' 04" and 80^0 21' 40" E; latitudes 28^0 45' 16" and 28^0 57' 23"N, altitudinal range from 80m-600m and covers an area of 305 sq. km. The area of 243.5 sq. km. surrounding the reserve was declared as the buffer zone in 2004. The Park is bounded by the Syali River in the east, Mahakali River in the west, Siwalik Hills in the north and east and Luggabhugga Florican Reserve of India in the south (DNPWC 2017). The park contains many different ecosystem and habitat types, that includes the Siwalik hills, grasslands, and flood plains created by various river systems (Mahakali, Bahuni, Syali and Chaudhar). The Siwalik ridge links the hills with the Terai forests by maintaining a natural corridor and allows for vertical migration of wild animals.

3.1.2 Shuklaphanta National Park

The Suklaphanta National Park is situated in the southwestern corner of Nepal in the lowland of Terai in Kanchanpur district of Nepal. The Park that was originally a hunting area was later converted to the wildlife reserve to protect swamp deer. In 1976, the area was gazetted as Royal Suklaphanta Wildlife Reserve. After the people's revolution in 2006, the reserve was renamed as SWR. In 2017 it was upgraded as Suklaphanta National Park. The area of 243.5 sq.km. surrounding the reserve was declared as the buffer zone in 2004. The reserve extends up to the Syali River in the eastern boundary southward to the international border with India which demarcates the reserve's southern and western boundary. A small part of the reserve extends north of the East-West Highway to create a corridor for seasonal migration of wildlife into the Sivalik Hills. Suklaphanta grassland is important both nationally and internationally for its extensive habitat of different species. It is the habitat of 700 floral species, 28 Fishes, 12 reptiles, 46 mammals (18 protected under CITIES), and 423 species of birds. The park is well known for its large grassland tracts known as 'Phantas'. Among these Phantas, Shuklaphanta is the largest one having an area of 54 sq. km² (Yadav et al. 2000). The major attraction of this park is the Swamp deer. It also serves a shelter to spotted deer, royal Bengal tiger, Bengal florican, hog deer and blackbuck at a higher extent. The grasslands of the park mainly consist of *Imperata cylindrical, Themeda triandra, Saccharum bengalensis* and *Desmostachya bipanata* which provides a suitable habitat for various ungulates. Shuklaphanta National Park is an important part of the Terai Arc Landscape (TAL) and a biological corridor that helps maintain a balance of herbivores and carnivores.

3.1.3 Grasslands

The grasslands are the most important ecosystems in nature in order to support a huge biodiversity that inhibits in it. The grasslands of SNP covers approximately half of the

vegetation of the park. The protected area is part of the Terai-Duar savanna and grasslands ecoregion. It is one of the best-conserved examples of floodplain grassland (Dinerstein 2003). It is included in the Terai Arc Landscape (Bhattarai 2013). The grasslands are commonly called as "phanta". The major grassland of the SNP is Shuklaphanta grassland. The other grasslands comprise of Barkaula phanta, Singhapur phanta, Sundarpur phanta, Hirapur phanta. The main grass species of the phantas include *Imperata cylindrica* and *Heteropogan contortus* which are used for thatching. The largest herd of Swamp deer in the whole world is seen in the grasslands of SNP. Grassland seems to be invaded by tree and shrub saplings which pose major threats to the long-term existence of the main phantas.

3.1.4 Climate

The climate of the region is sub-tropical monsoon type. The mean annual rainfall in this area is 1,579 mm (62.2 inch). The rainfall occurs from June to September and is highest in August. The winter months of December and January are fairly cold. The daytime temperature during this time of year is 7–12 °C (45–54 °F). Sometimes frost can also be seen. From February onwards temperatures rise up to 25 °C (77 °F) in March. The temperature reaches upto 42 °C (108 °F) by end of April. When the first pre-monsoon rains reach the area in May, humidity increases (Timilsina and Heinen 2008).

3.1.5 Vegetation

DNPWC (2006) studied about the area of the park and found that it is composed of forest (65.02%), left agriculture land (7.87%), grassland (16.1%), shrubland (3.76%) and water bodies (7.25%). Around 700 species of plants are there in the park. They include 553 vascular plants, 18 pteridophytes, 410 dicots and 125 monocots (Bhuju et al. 2007). The grasslands of Shuklaphanta National Park cover almost half of the vegetation of the park. The main grass species are *Imperata cylindrica*, *Phragmites karka*and *Saccharum spontaneum*. They grow in the marshes around the seven small lakes. The main forest type is Sal (*Shorea robusta*) in association with Khair (*Acacia catechu*) and Sissoo (*Dalbergia sissoo*) that grow by the side of rivers. The grassland being invaded by trees is a major threat to the long-term existence of the main plants. Trees outcompete any grasses growing under them, especially those that need plenty of sunlight, e.g. *Bombax ceiba*. Trees cover any grasses growing under them, mainly those that need more sunlight. Tree seeds are spread all over the grasslands. They mostly germinate near existing trees. Also, trees help in the growth of shade-loving grasses and prevent the growth of sun-loving species. This process of succession usually converts grassland into woodland over time (Baral and Inskipp 2009).

3.1.6 Fauna

The open grasslands and wetlands covers large area around the lakes. This area is home to different kinds of animals (Majupuria and Kumar 1998). In the rivers, lakes and ponds 28 fish species 5 reptile species and 12 amphibian species were recorded (Baral and

Inskipp 2009). These include Mahaser, Rohu, Magar Crocodile, Indian Rock Python, Monitor Lizard, Indian Cobra, Common Krait and Oriental Ratsnake (Baral and Inskipp 2009). The current checklists include 46 mammal species. Among them 18 are protected under CITES such as the Bengal Tiger, Indian Leopard, Sloth Bear, Swamp Deer, Asiatic Elephant and Hispid Hare. Great One Horned Rhinoceros were moved from Chitwan National Park (Bhuju et al. 2007). The gathering of Swamp deer in the grasslands of the park is the largest in the world. The population of Hispid Hare may be of international significance (Baral and Inskipp 2009). In spring 2016, a Rusty Spotted Cat was photographed by a camera trap for the first time in the protected area (Lamichhane et al. 2016). In case of birds a total of 423 species has been recorded. The park supports the highest population of Bengal floricans in Nepal. It is the western limit of Swamp Francolin, Jerdon's Bushchat, Rufous Rumped Grassbird, Chestnut Capped Babbler and Jerdon's Babbler. For Yellow Eyed Babbler, it is the north-western limit and it is the eastern limit of Finn's Weaver. It is also 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 Grassbird are breeding residents. Sarus Crane, Painted Stork and Bristled Grassbird are summer visitors. Greater Racquet Tailed Drongo, White Capped Water Redstart, Rusty Tailed Flycatcher and Rufous Gorgeted Flycatcher are winter visitors but they are not common (Baral and Inskipp 2009).

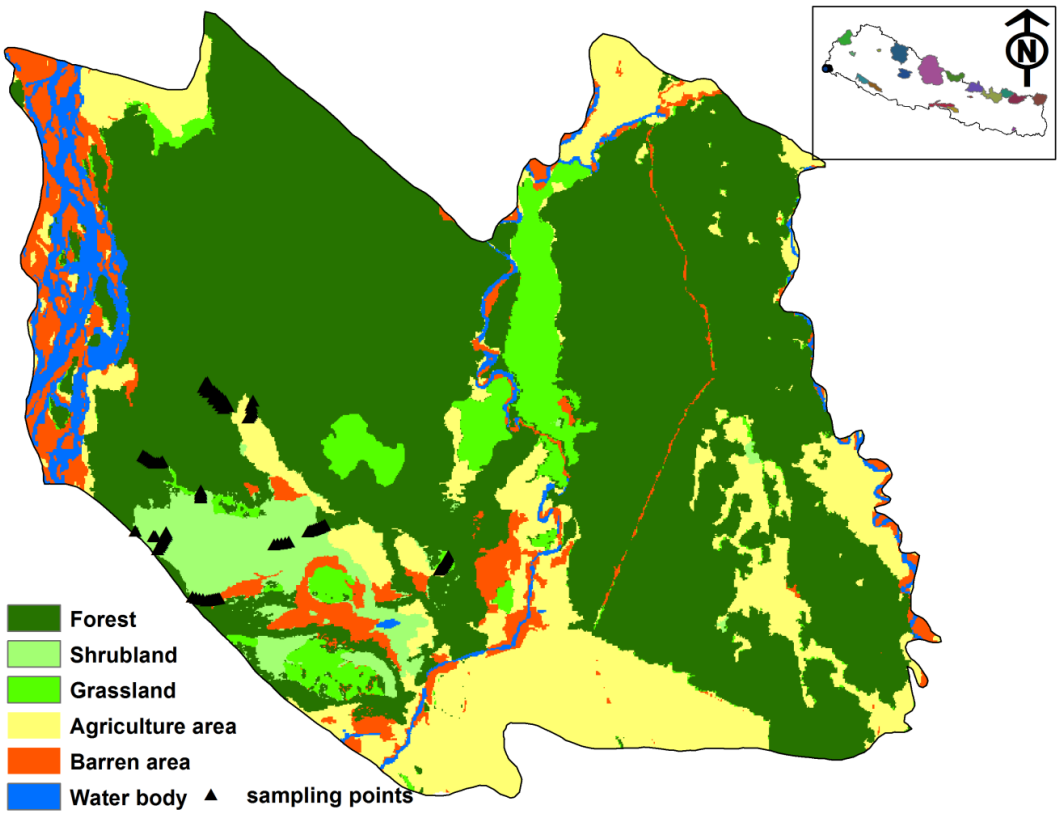

Figure 2. Location of sampling sites in the Shuklaphanta National Park, Kanchanpur.

3.2 METHODS

3.2.1 Site Selection

After the survey we knew about the habitat preference, invasion site, and finally assigned the research sites. The research sites cover the swamp deer preferred habitat invaded by the invasive plant species. The research sites were of the grasslands since swamp deer prefers the grassland. The random sample plots sized 5m*5m were laid. The study was carried out in nine research sites, viz: Tintale area, Singhapur, Silalekh, Barkaula, Pillar 24, Pillar 26 and Sundarpur.

3.2.2Method of data collection

3.2.2.1 Qualitative data collection

Primary data collection: The primary data collection included the view from local key person, farmers, nature guides, park personnel and field observation. Open interview was used to know their ideas on control and management of the weeds.

Secondary data collection: The secondary data includes the existing research literature and document survey. Related INGOs such as IUCN, and ISSG, DNPWC annual report

etc. were consulted to receive literature and document on impact of invasive species on swamp deer habitat.

3.2.2.2 Quantitative data collection

i. Identification of invasion area: In survey, we identify the area of invasion and swamp deer preferred habitat. Reconnaissance field visits were made on foot and by motor and the invaded areas allocated into blocks according to its habitat.
ii. Block division and sample intensity: Each block was divided into various quadrates of 5*5m randomly in the transects at 100m distance for the shrubs and invasive plants biomass.
iii. Data collection: All plant species within each quadrate were identified and counted. The plant species were identified with the help of standard literature of plant identification in Nepal and visual inspection by taxonomists. For further identification, the friends at Central Department of Botany were consulted.

3.2.3 DATA ANALYSIS

3.2.3.1 Diversity indices

To compare the distribution pattern in different blocks, either there is heterogeneous or homogenous & even or uneven distribution, Simpson's index was calculated using following formula Simpson's Index of diversity (Simpson 1949 as described by Krebs 1989) was applied for measuring floral diversity.

$1\text{-}D = 1\text{-} \sum(p_i)_2$

Where,

D = Simpson Index of diversity

Pi = Proportion of individual species in the community

3.2.3.2 Simpson's Index (D)

Simpson index measures the probability that two individuals randomly selected from a sample in to the same species (or some category other than species). There are two versions of the formula for calculating D. Strictly speaking; the first formula (1) should only be used to estimate an infinite population. The second version (2) is an adaptation of the formula to estimate a finite population. However, with a large sample there is practically no difference between these equations. Either is acceptable, but be consistent.

a) $D = \sum (n/N)_2$ b) $D = \sum n(n-1)/N(N-1)$

Where, n = the total number of organisms of a particular species N = the total number of organisms of all species

The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give the species diversity.

3.2.3.3 Simpson's Index of Diversity (1 – D)

The value of this index also ranges between 0 and 1, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample long to different species.

3.2.3.4 Shannon-Weiner index

Shannon-Weiner (S-W) provides a means of comparing the diversity between two or more ecosystems which goes beyond the most basic species-per-unit-area metric. While this simpler metric is useful, in some cases it is desirable to evaluate the equitability of the distribution of the species. An example is a disturbed habitat heavily dominated by a small number of species, but with a few individuals of the original habitat persisting at low numbers. In a more natural system, the native species could be more abundant and the ecosystem more balanced and resilient, despite comparable numbers of species. S-W takes advantage of the mathematical properties of logarithms which can weight components of a system differently based on the numbers of individuals within a group. While you do not need to understand the theory that underlies this, it is helpful to remember that groups with small numbers contribute less to the S-W index than do more abundant groups.

If all groups contribute the same number of individuals to a community, S-W will be equal to the simpler species per unit area index. As soon as the species become unevenly distributed the Index goes down, depending on the scale of the inequality.

$H' = \sum p_i \ln p_i$

H'= index of species diversity

S= species richness (total number of species present)

Pi = proportion of total sample belonging to the i^{th} species

ln= natural log (base e = not the same of log!)

3.2.3.5 Frequency and relative frequency

Frequency of a species is the percentage of quadrates in which the particular species occurs. It gives an index on the spatial distribution of a species and is a measure of relative abundance (Krebs 1978).

Frequency = Total number of quadrates in which a particular species occurs / Total number of quadrates sampled × 100

Relative Frequency = (Frequency of a species / Sum of frequency values for all species) × 100

3.2.3.6 Impact analysis of IAPS

Based on the invasive species intensity, and the presence of the swamp deer evidences the impact of invasion was predicted.

4. RESULTS

4.1 Distribution of IAPS in Shuklaphanta National Park

The invasion in Shuklaphanta National Park is at the pace of gradual increase. The grasslands have low invasion so far however, if the invasion continues, it may also suffer the problem as Chitwan National Park. Invasion by invasive species was seen low but by the woody perennials, *B. ceiba* was significant in grasslands. The invasion was seen higher in buffer zone where the human and livestock disturbance was high. People are dependent on the park for fodder and thatch collection which contributes to the distribution of the IAPS inside the park. Due to such disturbances invasive alien plant species got opportunity to enter the park. Also the invasion was significantly higher in the wetlands of the park.

4.2 Diversity of invasive alien plant species

4.2.1 Simpson's Index of Diversity (1-D)

Simpson's Index of Diversity (1 – D) and value ranges between 0 and almost 1, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species. The details are given below presented by the graph:

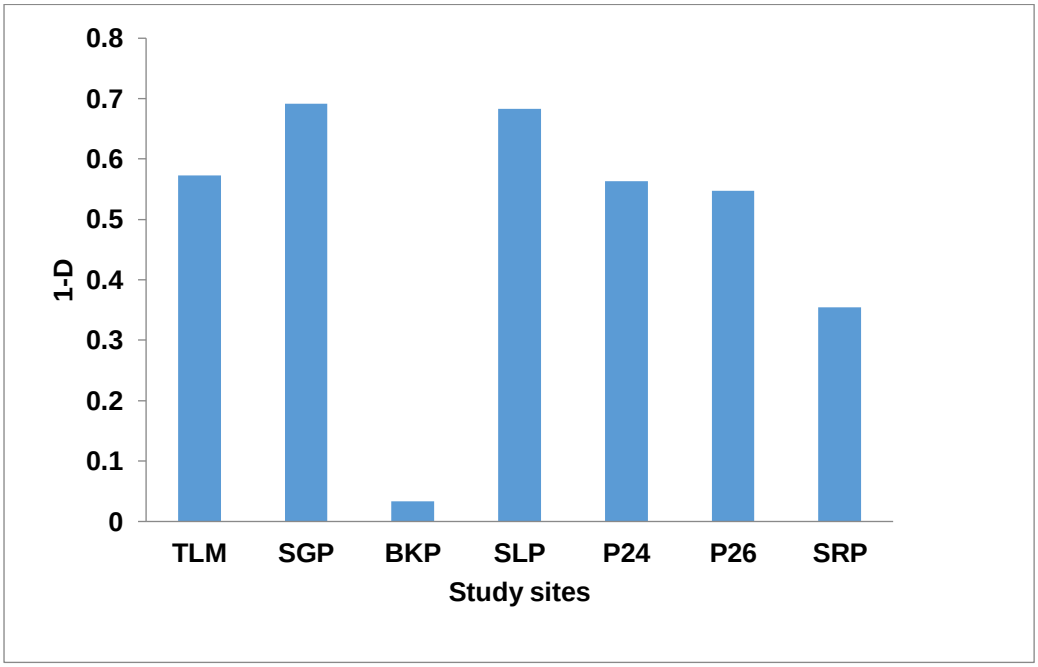

Figure 3. Graph displaying site-wise Simpson Diversity Index (1-D)

From the above figure it is clear that SGP has high Simpson diversity index (SI=0.692) followed by SLP (SI=0.683) and TLM (0.573). It was also seen that BKP has lesser Simpson diversity index value (SI=0.033). As we know, greater the SI value the greater the diversity of abundance of the species, therefore it is clear that SGP/SLP area has greater diversity and BKP has lesser diversity.

4.2.2. Shannon-Weiner index of diversity (H')

The diversity of species in each habitat types was calculated by using the Simpson diversity index and Shannon - Weiner diversity index. Shannon-Weiner (S-W) provides a means of comparing the diversity between two or more ecosystems which goes beyond the most basic species-per-unit-area.

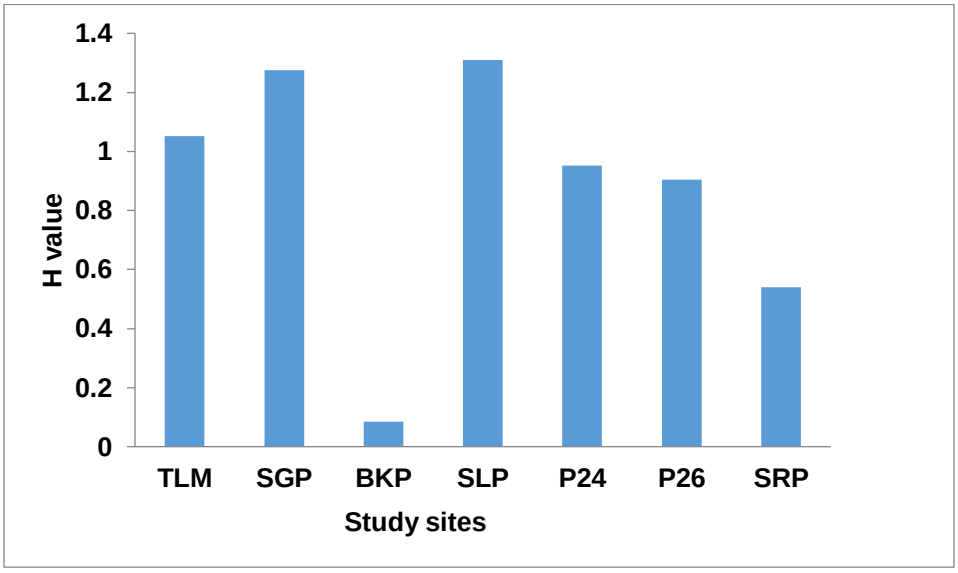

Figure 4. Graph displaying site-wise Shannon-Weiner Diversity Index (H)

Shannon-wiener index diversity (H') varied from BKP (H'=0.085) to SLP (H'=1.309). It was much higher in three different study sites SLP, SGP and TLM. The maximum diversity was recorded (H'=1.309) in SLP and Minimum (H'=0.085) for BKP.

4.2.3 Species richness

It signifies the number of species per sample. Following graph was obtained from the present study for IAPS richness.

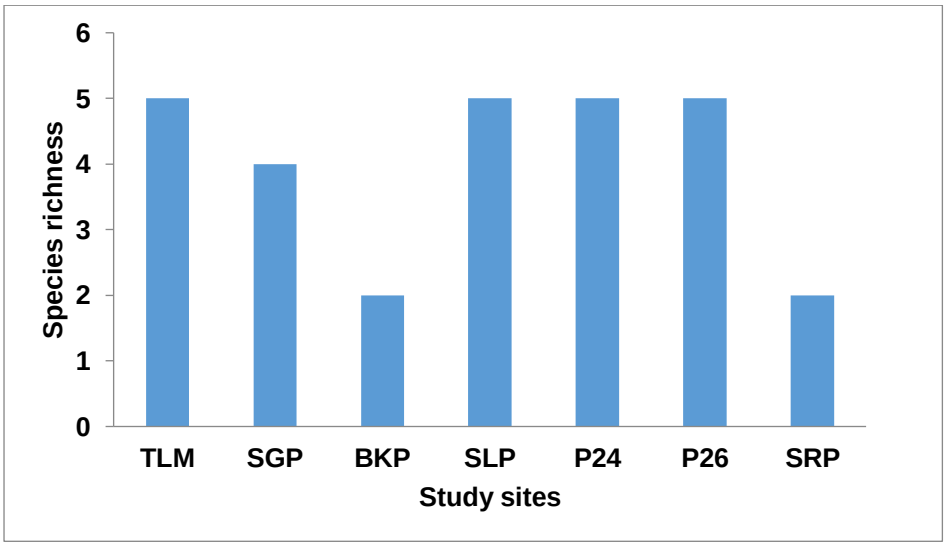

Figure 5. Graph showing site-wise Species Richness

Table 1. Study area wise Invasive alien plant species diversity and dominance indices in SNP.

Sites	Species richness	Abundance	Dominance_D	Simpson_1-D	Shannon_H	Evenness_e^H/S	Equitability_J
TLM	5	589	0.427	0.573	1.051	0.572	0.653
SGP	4	68	0.309	0.692	1.275	0.895	0.919
BKP	2	119	0.967	0.033	0.085	0.545	0.123
SLP	5	165	0.317	0.683	1.309	0.741	0.813
P24	5	308	0.437	0.563	0.953	0.519	0.592
P26	5	302	0.453	0.547	0.905	0.494	0.562
SRP	2	13	0.645	0.355	0.541	0.858	0.779

Table 2. Study area wise native grass frequency, relative frequency, density, relative density and coverage in SNP.

Name of the grass species	Frequency	Relative frequency	Density/m²	Relative density/m²
Sacchharum munj	56.7	12.67	1.46	10.8
Narenga porphyrcoma	61.85	13.82	1.59	24.59
Impereta cylindrical	54.63	12.21	1.4	12.46
Sacchharum spontaneum	48.45	10.83	1.24	5.55
Demostachys binnata	42.26	9.44	1.08	3.59
Grewia asiatica	12.37	2.76	0.31	0.56
Cynodon dactylon	72.16	16.12	1.85	20.1
Cymbopogan flexuosus	26.8	5.99	0.69	1.13

4.3 Impact assessment of IAPS

4.3.1 Area of invasion

a) Tintale area

A total of 16 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 2000m and 453m respectively. Entire grassland of this site was comprised of only a few number of native species and was open since it had recently been burnt. The abundance of native species and invasive species recorded in this area was 310 and 589 respectively and the species richness for Native and invasive species was found to be eight and five respectively. The native flora of these sites were *Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia, Ipomea carnea, Ageratum conyzoides, Xanthium strumarium and Amaranthus*

*spinous*were recorded in this site during the study. The IAPS cover in this site was found to be 15.201% signifying low impact in the grassland.

The frequency, relative frequency, density and the relative density and coverage of IAPS in the site was calculated to compare the IAPS in each site.

Table 3. Density, relative density, frequency, relative frequency and coverage of IAPS in Tintale area.

Scientific Name	**Common Name of Species**	**Sites**	**D**	**RD**	**F**	**RF**	**C**
Oxalis latifolia	Chari amilo	TLM,SGP,BKP, SLP,P24.P26	0.083	0.297	75	37.5	29.71
Cassia tora	Chakmake	BKP,P26,SRP	0	0	0	0	0
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	4.286	0.045	6.25	3.125	4.58
Lantana camara	Banphanda	SLP,P24	0	0	0	0	0
Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0	0	0	0	0
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0.008	0.073	12.5	6.25	7.3
Amaranthus spinous	Kande saag	SLP,P26	0	0	0	0	0
Xanthium strumarium	Bhede kuro	TLM,SRP	0.003	0.008	6.25	3.125	0.084
Argimone maxicana	Gaide kada	TLM,SGP,BKP, SLP,P24.P26	0.161	0.576	100	50	57.55

b) Singhapur

A total of 10 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 3000m and 309m respectively. This grassland was still to be burnt and had the old dried Narenga in higher number making it dense and difficult to work in. The abundance of native species and invasive species recorded in this area was 322 and 68 respectively and the species richness for Native and invasive species was found to be eight and four respectively. *The native flora of this site were Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia, Ipomea carnea,Solanum viarum and Amaranthus spinous* were recorded in this site during the study. The IAPS cover in this site was found to be 1.756% signifying no impact in the grassland.

Table 4. Density, relative density, frequency, relative frequency and coverage of IAPS in Singhapur.

Scientific Name	Common Name of Species	Sites	D	RD	F	RF	C
Oxalis latifolia	Chari amilo	TLM,SGP,BKP, SLP,P24.P26	0.056	0.983	20	95.23	98.31
Cassia tora	Chakmake	BKP,P26,SRP	0	0	0	0	0
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	0.008	0.26	10	14.28	26.47
Lantana camara	Banphanda	SLP,P24	0	0	0	0	0
Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0.005	0.16	20	28.57	16.18
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0	0	0	0	0
Amaranthus spinous	Kande saag	SLP,P26	0	0	0	0	0
Xanthium strumarium	Bhede kuro	TLM,SRP	0	0	0	0	0
Argimone maxicana	Gaide kada	TLM,SGP,BKP,SLP, P24.P26	0.01	0.44	20	28.57	44.11

c) Barkaula

A total of 20 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 5000m and 442m respectively. This grassland was also unburnt. This site had the highest native floral abundance. The abundance of native species and invasive species recorded in this area was 697 and 119 respectively and the species richness for native and invasive species was found to be eight and two respectively. The native flora of this site were *Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia and Solanum viarum* were recorded in this site during the study. The IAPS cover in this site was found to be 3.071% signifying no impact in the grassland.

Table 5. Density, relative density, frequency, relative frequency and coverage of IAPS in Barkaula.

Scientific Name	Common Name	Sites	D	RD	F	RF	C
Oxalis latifolia	Chari amilo	TLM,SGP,BKP,SLP, P24, P26	0.05	0.98	100	95.23	98.31
Cassia tora	Chakmake	BKP,P26,SRP	0.0009	0.01	5	4.76	1.68
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	0	0	0	0	0
Lantana camara	Banphanda	SLP,P24	0	0	0	0	0

Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0	0	0	0	0
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0	0	0	0	0
Amaranthus spinous	Kande saag	SLP,P26	0	0	0	0	0
Xanthium strumarium	Bhede kuro	TLM,SRP	0	0	0	0	0
Argimone maxicana	Gaide kada	TLM,SGP,BKP,SLP, P24, P26	0	0	0	0	0

d) Silalekh

A total of 12 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 2000m and 309m respectively. This grassland was partially burnt and the soil was moist. The abundance of native species and invasive species recorded in this area was 329 and 165 respectively and the species richness for Native and invasive species was found to be eight and five respectively. The native floras of these sites were*Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia, Lantana camara, Ageratum conyzoides, Argimone maxicana and Amaranthus spinous* were recorded in this site during the study. The IAPS cover in this site was found to be 4.749% signifying no impact in the grassland.

Table 6. Density, relative density, frequency, relative frequency and coverage of IAPS in Silalekh.

Scientific Name of Species	**Common Name of Species**	**Sites**	**D**	**RD**	**F**	**RF**	**C**
Oxalis latifolia	Chari amilo	TLM,SGP,BKP, SLP,P24.P26	0.03	0.4	100	63.3	40.21
Cassia tora	Chakmake	BKP,P26,SRP	0	0	0	0	0
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	0	0	0	0	0
Lantana camara	Banphanda	SLP,P24	0.005	0.04	16.7	10.5	4.34
Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0	0	0	0	0
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0.01	0.14	8.33	5.27	14.67
Amaranthus spinous	Kande saag	SLP,P26	0.005	0.04	16.7	10.5	4.34
Xanthium strumarium	Bhede kuro	TLM,SRP	0	0	0	0	0
Argimone maxicana	Gaide kada	TLM,SGP,BKP, SLP,P24.P26	0.02	0.26	16.7	10.5	26.08

e) Pillar 24

A total of 12 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 2500m and 192m respectively. This grassland was burnt and was open which made it easy for the direct sighting of the swamp deer. The larger herds of Swamp deer were observed in this site. The abundance of native species and invasive species recorded in this area was 220 and 308 respectively and the species richness for Native and invasive species was found to be eight and fiverespectively. The native flora of this site were *Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia, Ipomea carnea, Solanum viarum and Argimone maxicana* were recorded in this site during the study. The IAPS cover in this site was found to be 7.950% signifying no impact in the grassland.

Table 7. Density, relative density, frequency, relative frequency and coverage of IAPS in Pillar 24.

Scientific Name of Species	**Common Name of Species**	**Sites**	**D**	**RD**	**F**	**RF**	**C**
Oxalis latifolia	Chari amilo	TLM,SGP,BKP,SLP, P24, P26	0.07	0.48	100	44.4	48.7
Cassia tora	Chakmake	BKP,P26,SRP	0	0	0	0	0
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	0	0	0	0	0
Lantana camara	Banphanda	SLP,P24	0.001	0.012	8.33	3.7	1.29
Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0.001	0.009	8.33	3.7	0.97
Agertum conyzoides	Gandhe	TLM,SGP, SLP,P24	0.006	0.04	8.33	3.7	4.54
Amaranthus spinous	Kande saag	SLP,P26	0	0	0	0	0
Xanthium strumarium	Bhede kuro	TLM,SRP	0	0	0	0	0
Argimone maxicana	Gaide kada	TLM,SGP,BKP, SLP,P24.P26	0.065	0.44	100	44.44	44.44

f) Pillar 26

A total of 12 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 1500m and 260m respectively. This site was also open. The abundance of native species and invasive species recorded in this area was 218 and 302 respectively and the species richness for native and invasive species was found to be eight and fiver respectively. The native flora

of this site were *Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Oxalis latifolia, Cassia tora, Parthenium hysterophorus,Hyptis sauveolen, argimone maxicana and Amaranthus spinous* were recorded in this site during the study. The IAPS cover in this site was found to be 7.796% signifying no impact in the grassland.

Table 8. Density, relative density, frequency, relative frequency and coverage of IAPS in Pillar 26.

Scientific Name of Species	**Common Name of Species**	**Sites**	**D**	**RD**	**F**	**RF**	**C**
Oxalis latifolia	Chari amilo	TLM,SGP,BKP, SLP,P24.P26	0.07	0.49	100	42.91	49
Cassia tora	Chakmake	BKP,P26,SRP	0.002	0.01	8.33	3.57	1.98
Hyptis sauveolens	Tulsi jhaar	SRP	0	0	0	0	0
Ipomea carnea	Besharam	TLM, SGP	0	0	0	0	0
Lantana camara	Banphanda	SLP,P24	0	0	0	0	0
Parthenium hysterophorus	Kanike ghaans	P24	0.001	0.09	8.33	3.57	0.99
Solanum viarum	Not known	P24,P26	0.003	0.02	8.33	3.57	2.31
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0	0	0	0	0
Amaranthus spinous	Kande saag	SLP,P26	0.009	0.06	8.33	3.57	0.66
Xanthium strumarium	Bhede kuro	TLM,SRP	0	0	0	0	0
Argimone maxicana	Gaide kada	TLM,SGP,BKP, SLP,P24.P26	0.066	0.46	100	3.57	46.02

g) Sundarpur

A total of 8 plots were assessed in this site during the study. The mean distance from the village and road from the center of the site was approximately 3500m and 550m respectively. The abundance of native species and invasive species recorded in this area was 214 and 13 respectively and the species richness for native and invasive species was found to be eight and two respectively. The native floras of these sites were *Impereta cylindrica, Narenga porphyrcoma, Cynodon dactylon, Saccharum munj, Saccharum spontanium. Demostachys binnata, Grewia asiatica and Cymbopogan flexus* whereas the invasive species like *Cassia tora and Xanthiumstrumarium* were recorded in this site during the study. The IAPS cover in this site was found to be 0.413% signifying no impact in the grassland.

Table 9. Density, relative density, frequency, relative frequency and coverage of IAPS in Sundarpur.

Scientific Name of Species	Common Name of Species	Sites	D	RD	F	RF	C
Oxalis latifolia	Chari amilo	TLM,SGP,BKP, SLP,P24.P26	0	0	0	0	0
Cassia tora	Chakmake	BKP,P26,SRP	0.004	0.18	12.5	0.33	18.75
Hyptis sauveolens	Tulsi jhaar	SRP	0.004	0.18	12.5	0.33	18.75
Ipomea carnea	Besharam	TLM, SGP	0	0	0	0	0
Lantana camara	Banphanda	SLP,P24	0	0	0	0	0
Parthenium hysterophorus	Kanike ghaans	P24	0	0	0	0	0
Solanum viarum	Not known	P24,P26	0	0	0	0	0
Agertum conyzoides	Gandhe	TLM,SGPSLP,P24	0	0	0	0	0
Amaranthus spinous	Kande saag	SLP,P26	0	0	0	0	0
Xanthium strumarium	Bhede kuro	TLM,SRP	0.004	0.62	12.5	0.33	62.5
Argimone maxicana	Gaide kada	TLM,SGP,BKP, SLP,P24.P26	0	0	0	0	0

4.3.2 Invasion ability

It was found that the invasion, though less, was seen high in open areas and where there was low abundance of native grasses. The invasion ability on each studies grasslands was assessed and tabulated below:

Table 10. Site-wise invasion condition.

Sites	IAPS cover	Invasion Condition			
		None	Low	Medium	High
TLM	15.201		√		
SGP	1.756	√			
BKP	3.071	√			
SLP	4.749	√			
P24	7.950	√			
P26	7.796	√			
SRP	0.413	√			

Impact of IAPS in the habitat of swamp deer

The invasion of the weed decreases with the increase of coverage by native flora and canopy closure, which shows the intolerance of shade. Nevertheless, the grassland with sparse trees and shrub is observed to be highly prone to invasion by the invasive plants.

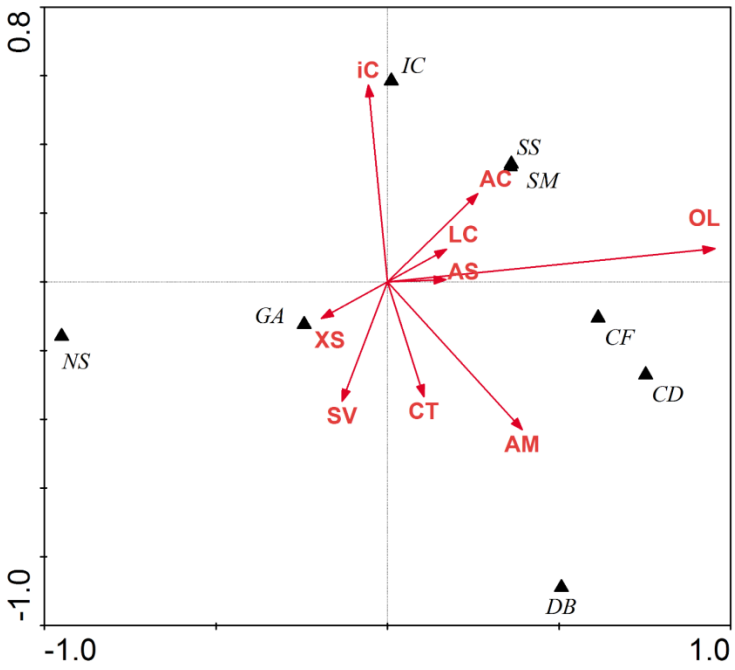

Figure 6. CCA ordination diagram (biplot) showing native species relationship with invasive alien plant species in grassland habitat of swamp deer. Monte-Carlo permutation test of significance of all canonical axes: Trace = 0.294, F = 2.447, P = 0.02 (with 499 permutations). First two axes are displayed. The first axis accounts for 66.2% and the second axis 19.8% of the variability. Here, the plants name in red color shows the invasive species and the black represent the native flora of the study area. The details of species codes are given below:

Invasive Species

iC: *Ipomea carnea*
AC: *Ageratum conyzoides*
LC: *Lantana camara*
AM: *Argimone maxicana*
SV: *Solanum viarum*
CT: *Cassia tora*
OL: *Oxalis latifolia*
XS: *Xanthium strumarium*
AS: *Amaranthus spinous*

Native Species

IC: *Imperata cylindrica*
SS: *Saccharum spontanium*
SM: *Saccharum munj*
CF: *Cymbopogan flexus*
CD: *Cynodon dactylon*
NS: *Narenga porphyrcoma*
DB: *Demostachys binnata*
GA: *Grewia asiatica*

Population trend of swamp deer in Shuklaphanta National Park

The number of swamp deer, has decreased in the Shuklaphanta National Park (SNP) in the last couple of years, according to a recent census conducted by the SNP administration. The species also witnessed a steep decline in the population during the 1970s. One of the major causes for swamp deer habitat loss is shrinkage of grassland, riverine forest and wetland due to invasion by the invasive alien plants and by the perennial invasion. With the increase in habitat alteration due to invasion, the number might have decreased. Therefore, it was also seen an indirect impact on swamp deer by invasive species. However, due to the managing efforts the Swamp deer population can gradually be restored to a relatively safer status.

Table11. Showing the population trend of Swamp deer in Shuklaphanta National Park.

Year	**Number**	**Source**
1968	1250	Bhatta and Shrestha, 1977
1978	1000	Schaaf, 1978
1994	1850	Hensaw, 1994
2003	1607	Gyawali, 2003
2006	1639	SWR, 2006
2007	1674	SWR, 2007
2014	2301	SWR, 2014
2019	2246	SNP, 2019

4.3.3. Threat due to IAPS

Total area of Shuklaphanta grassland is gradually decreasing as a result of various native shrubs and trees encroachment especially on northern and southern aspects of the grassland. The plant species widespread in and around the environment were the key encroachers of this ecosystem. *Bombax ceiba*, *Butea monsoperma*, *Sterculia villosa*, *Acacia catechu*, and *Dalbergia sissoo* were main tree species while shrub species were *Ficus palmata, Zizyphus mauritiania, Grewia sapida*. Some invasive alien plant species (IAPS) observed in both terrestrial and wetland ecosystems. Already listed as worst all over the world, *Lantana camara*and *Parthenium hysterophorus*was observed in the park. Similarly, another notorious IAPS *Echhornia crassipes*and Pistia was significantly high in wetland ecosystem causing serious impact in Rani Lake. The perennial invasion is also a matter of concern in the park since the increment in the tree species in the grassland

lowers its area making it less suitable for grassland species. *B. cieba* is mostly seen in the patches of the grassland. Due to the shadow of the trees the grass species cannot grow underneath and this causes the decrease in the grassland area creating the direct impact on the grassland species.

4.3.4. Control and management

Shuklaphanta National Park has grasslands locally called as Phantas and some of the grasslands are managed by grazing, some due to climatic climax, some due to repeated fires and some due to management interventions (Poudel 2007). However, management of invasive species involves three basic strategies: prevention, eradication and control (Radocevich et al. 2009). Prevention involves restriction to the introduction of potentially invasive alien species and requires strict quarantine and regular monitoring. It is the first and the best strategy for invasive species management but its implementation, even partial at best, cannot be effective in the context of globalization of trade and increasing human mobility. Because of the open border with India and high trade dependency, prevention of the entry of invasive species to Nepal is almost impossible. Eradication is the complete removal of invasive species from the habitat or region and this is possible only when the species occurs in a small area. However, in most of the cases, by the time when managers acknowledge the problem and prepare for action, it is often too late for eradication to be possible due to rapid spread of the invasive species covering large areas. Control involves reducing the abundance of invasive species in the invaded habitat or region and preventing further spread, thereby minimizing their impacts to ecosystem and economy. It does not necessarily result in elimination of species from any particular region. Due to a large number of IAPS and their widespread occurrence, 'control' is the only strategy left to manage them across landscapes. The control of the IAPS requires the integration of physical, chemical and biological methods. One important lesson learned from the management efforts of IAPS is that a single method is no more effective in controlling these weeds. A carefully selected set of intervention methods is required to successfully manage the IAPS. Before any strategy is developed to manage IAPS, their ecological and economic impacts need to be analyzed, and the underlying mechanisms need to be understood. In Nepal, the number of IAPS, and their ecological and economic impacts – which are often irreversible – are increasing over the time. These facts are reflected in the recently prepared biodiversity related national documents such as the Nepal Fifth Report to Convention on Biological Diversity (MFSC 2014b) and Nepal

National Biodiversity Strategy and Action Plan 2014-2020 (MFSC 2014a). Unfortunately, systematic and science-based management of the IAPS has not been initiated yet in Nepal. However, some efforts have been made by communities and development partners to manage a few IAPS by using their biomass to meet demand of energy and organic manure. For example, *Ageratina adenophora and Chromolaena odorata* have been used as animal bed and subsequently for preparing organic manure by farmers in Nepal. In districts like Makawanpur (Hetaunda area) and Bajhang (Rayal village), the stem of *Lantana camara* is used as fire wood. Biomass of all these three

IAPS has been also used for preparing bio-briquette to substitute fire wood. Community Forest Users' Groups near Kathmandu valley have initiated commercial production of bio-briquette and supply to the Valley. Biomass of *Ageratina adenophora and Eichhornia crassipes* has been also used, together with animal dung, in biogas plant. At some locations fire is also used to control IAPS in grassland and shrub lands. In wetlands, physical removal of IAPS has been practiced. For example, *Eichhornia crassipes* is being periodically removed from Beeshajari Lake system (a Ramsar site) of Chitwan, Taudaha of Kirtipur Municipality in Kathmandu valley, Phewa and Begnas lakes of Pokhara valley, etc. with limited success. In Pokhara valley, the biomass of *E. crassipes* has been used for preparing handicraft items (e.g., pen holder, hand-bag, dust bin, etc.) by local women's group (Anonymous 2015a).

Biomass removal has been also practiced for other species such as *Leersia hexandra* in Bishajari lake (Chitwan) and *Myriophyllum aquaticum* in Taudaha (Kirtipur). The Hario Ban Program, which is being implemented by WWF Nepal, has supported local communities to remove *E. crassipes* and *Pistia stratioites* from Tikauli lake (a part of Bishajari lake system) of Chitwan (WWF Nepal 2013). One important approach of biological method of IAPS management is the use of biological control agents. In Nepal, biological control agents are present only for two IAPS: leaf feeding beetle *Zygogramma bicolorata Pallist*er and winter rust *Puccinia abrupta var. partheniicola* (Jackson) Parmelee for *Parthenium hysterophorus* (Shrestha et al. 2015), and stem galling fly *Procecidochares utilis*. Stone and leaf spot fungus *Passalora ageratinae Crous* and A.R Wood for *Ageratina adenophora* (Winston et al. 2014). However, these biological control agents were not introduced officially after quarantine screening but spread naturally into Nepal from India and other Asian countries.

Recently, Nepal Agriculture Research Council (NARC) has imported two weevils *Neochetina eichhorniae Warner* and *N. bruchi Hustache* from USA (Florida) as an effort to biological control of *Eichhornia crassipes* and both these weevils are under laboratory trial (Anonymous 2015b). It is not clear whether a standard quarantine screening will be performed before releasing them into natural habitats as was done by India when *N. eichhorniae* was released there in 1984 (Jayanth 1988). Effectiveness of the biological control agents in controlling target IAPS has not been evaluated systematically but field observations showed that the effect is only marginal. Distribution of fungal control agents (*Puccinia abrupt var. partheniicola and Passalora ageratinae*) of both species is much localized with apparently no effect to the target species. *Zygogramma bicolorata* seems to be the most effective biological control agent of IAPS present in Nepal but its population is still small and their effectiveness is erratic with year to year variation (Shrestha et al. 2015). For effective control of *P. hysterophorus*, it seems necessary that the control by Z. bicolorata need to be complemented by other biological control agents, displacement by competitive plant species, and other cultural, physical and chemical measure (Adkins and Shabbir 2014). *Procecidochares utilis* entered Nepal naturally from India and established population by 1972 in eastern part of Nepal (Ilam, Terhathum and Dhankuta districts) (Sharma and Chhetri 1977, as cited by Muniappan et al. 2009). The fly, originally from Mexico, has already established its populations in Hawawii (USA), Asia, Africa,

Australia, New Zealand, etc. (Muniappan et al. 2009). In Nepal, the fly has reached to almost all areas where *A. adenophora* is present but its impact on the weed is insignificant (BB Shrestha, unpublished data). In China and Africa too, the damaging effect of the fly on *A. adenophora* is only marginal (Xiao-yu et al. 2004, Heystek et al. 2011).

5. DISCUSSION

Out of plant 20 species recorded in the study area grass species were 9, and invasive plant species were eleven. *Oxalis latifolia* and *Argimone maxicana* were observed in almost all the plots surveyed. Oxalis was not seen only in Sundarpur whereas *Argimone maxicana* was not seen in Barkaula and Sundarpur. The Tintale area near Shuklaphanta post had *Lantana camara and Parthenium hysterophorus* which are considered to be the worst invasive plants worldwide. *Lantana camara* was also seen in Silalekh in two plots. *Hyptis sauveolens* was observed only in one plot in Sundarpur whereas *Solanum viarum* was observed in four plots in Singhapur, Pillar 24 and Pillar 26. The Tintale area, Silalekh, Pillar 24 and Pillar 26 had the higher species richness and abundance value for IAPS. Most of the parts of these sites were open and near to village and road as compared to other sites. Open and more disturbance contributed in the higher diversity for IAPS in these sites. *Oxalis latifolia, Argimone maxicana, Solanum viarum and Ipomea carnea* were repeatedly observed in each of these sites. The soil was moist in Pillar 24, Pillar 26 and Tintale area had sufficient water bodies near to flourish *Ipomea carnea*. The present extent of the invasion was low in the grasslands so as to create any significant impact on the habitat of the Swamp deer but if the trend of invasion goes on, it may soon create problem for Swamp deer. Since, the buffer zone and wetlands of the park was highly invaded by *Ageratum conyzoides, Cassia tora, Parthenium hysterophorus, Lantana camara and Eichornnia crassipes and Pistia stroites* respectively, the invasion inside the park cannot be ignored. Further, the perennial invasion by *Bombax Ceiba* was observed in all the grasslands but it was higher in the Pillar 24, Pillar 26 and Tintale area. The invasion by woody plants provides shades which limits the growth of the grass species suitable for the Swamp deer.

a. Diversity of native and invasive alien flora in the study area

Bhattarai (2012) studied the threats on the grassland of Shuklaphanta National Park and found out that the major ecosystem change observed was due to anthropogenic actions such as, excessive land use, deforestation, species invasion, and even the lack of sustainable management within and beyond protected area. Invasion of woody perennials and invasive alien species, human intervention together with improper management practices possibly generated substantial impacts on all major ecosystems of Shuklaphanta grassland. The further results showed that the importance value index (IVI) and prominence value (PV) of woody perennials were high coupled with significant PV of invasive species. Ecosystem services change was prevalent in the study area and high possibility to change into forest vegetation. Invasive species, shrubs, and large trees encroachment consequently invited alteration challenge on preferable habitats formed on assemblage of major grass species. The disrupted ecosystem services amplified pressure on both prey and prey base species including swamp deer, antelope, one-horned rhinoceros, Asiatic elephant, royal Bengal tiger, Bengal florican and other threatened

species. The results are similar to the present study. The pace of invasion by invasive alien plant species and perennial invasion is continuously going on.

Results from a study done by Peet et al (1999) made classification of the grasslands in four protected areas in Nepal as; Two hundred and forty-six plant species were recorded and nine species assemblages, with eight phases, were identified. Chitwan National Park contained the greatest diversity of assemblages, whilst Bardia National Park and Suklaphanta National Park, were of conservation significance for the occurrence of an *Imperata cylindrica* assemblage and its associated fauna. Early successional assemblages dominated by *Saccharum spontaneum and Phragmites karka* predominated in Koshi Tappu Wildlife Reserve. The spatial and temporal distribution of grassland assemblages was found to be primarily influenced by fluvial processes but also by fire, cutting and grazing. Changes in the impact of these disturbances, for example as a result of dam building or a change in the fire regime, would alter the diversity and distribution of the plant assemblages together with their associated fauna.

The vegetation of the park is the mosaic of great expenses of grasslands primarily of tall, dense grasses interspersed with deciduous forests, interconnected streams and swamps making the park suitable for many of the rare and endangered species. There are eight type of vegetation in the park (Schaaf 1987). Sal forest, Sal savanna, mixed deciduous forest, Khair-sissoo forest, dry grasslands, seasonal wet grasslands, lowland savanna and marsh. The grassland water bodies are very critical for swamp deer. The important grass species of the grassland are, *Impereta cylindrica, Eulaliopsis binnata, Saccharum munj, Sachharum spontanium, Cynodon dactylon, Themeda triandra and Narenga porphyrcoma* (Poudel 2007). Similar results for the grassland species was observed during the present study in which *Narenga* dominated the most of the grassland.

b. Impacts of IAPS on the habitat of Swamp deer

The major threats to the swamp deer are habitat conversion, livestock grazing, poaching, conflict and other anthropogenic disturbances (Paul et al. 2018). Present study also revealed that due to human and livestock disturbances the habitat of swamp deer is in threat. Invasion is also driven by such disturbances.

A small population of swamp deer was recently rediscovered in Uttarakhand state at Jhilmil Jheel. The habitat around this Conservation Reserve is heavily fragmented due to expansion of agriculture, habitation and various other land use practices. The reserve provides an area of only 0.009 km^2 per animal, which is insufficient in maintaining a viable population of swamp deer (Tiwari and Rawat 2013). From information through the park personnel during the present study, the walking trails inside the grasslands, thatch collection and the frequent visitors also contribute to the fragmentation.

Habitat degradation is still problematic within protected areas supporting Barasingha. Grass, timber and fuelwood cutting by local people degrade the surviving habitat, which lies mostly within protected areas, and external threats include change in river dynamics due to human developmental activities, increase in siltation and reduced flow of water during critical periods of summer. Protected area management practices are sometimes

questionable, e.g. the current practice of grassland burning to control woody succession needs to be done in form of a mosaic, and harrowing should be discouraged as it seems to deteriorate grassland condition and promote occupation by unpalatable grass species like *Cymbopogon* spp. Many grasslands and woodlands have weed infestation (Qureshi et al. 1995, 2004). Similar results were drawn from this study.

Ahmed and Khan (2008) studied the status, distribution, social organization and the conservation problems faced by endangered swamp deer (*Cervus duvuaceli duvuaceli*) in Dudhwa Tiger Reserve (DTR). We estimated total population to be 1016 (578 in Dudhwa National Park (DNP) and 438 in Kishanpur Wildlife Sanctuary (KWS)). The mean group size in DNP and KWS was 21.40±1.71 and 11.89±1.72, respectively. Overall mean group size in DTR was 18.37±1.71 animals/group. Group size showed significant difference across difference habitat types ($F = 28.3$, d.f. = 2, $P<0.01$). Adult females formed major share of population in the study area. The male: female: fawn ratio in DNP and KWS was 57:100:28 and 62:100:19, respectively. Overall sex ratio in DTR was 58:100:26. All male groups were larger than female groups but the group size was highest for mixed groups. The major threat to swamp deer conservation throughout DTR is the destruction of its habitat and illegal poaching. As a result, it has become locally extinct from many areas. We recommend restriction on grass cutting in Satiana area, creation of some artificial Taals (lakes) for wallowing, protection of Taals for aquatic vegetation, relocation of Ghola and Ghajrola villages and intensive patrolling of these areas during monsoons. Similarly, the invasion of aquatic weeds (e.g. *Eichornnia crassipes and Pistia stroites*) could also become the prime reasons for the species endangerment in Shuklaphanta National Park soon.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

It was also concluded that the invasion is lessen the grasslands of the Shuklaphanta National Park. The overall impact of invasion was not seen significant enough to create impact on the habitat of the Swamp deer. Finally, it in concluded that though the invasion in the grassland is low but it is very obvious that the invasion soon creates problems for the habitat of the target species. Invasion in wetlands and bufferzone which are also the important factors for Swamp deer population is observed to be highland it is serious threat for Swamp deer habitat management and maintaining the Swamp deer population.

6.2 Recommendations

1. Community driven conservation and management of Swamp deer habitat in the park to ensure survival of this species.

2. Further research regarding the management of the invasive alien plant species in Shuklaphanta National Park

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APPENDICES

1. GPS CORDINATES

S.N.	SITES	LAT	LON
1	TINTALA	28.82272	80.187333
2	TINTALA	28.822521	80.186919
3	TINTALA	28.82233	80.186445
4	TINTALA	28.822078	80.18601
5	TINTALA	28.821881	80.185551
6	TINTALA	28.821783	80.185027
7	TINTALA	28.821527	80.184606
8	TINTALA	28.821381	80.184114
9	TINTALA	28.821214	80.183631
10	TINTALA	28.821134	80.183108
11	TINTALA	28.820903	80.182648
12	TINTALA	28.818249	80.177323
13	TINTALA	28.817931	80.176303
14	TINTALA	28.817763	80.175257
15	TINTALA	28.817595	80.174209
16	TINTALA	28.81737	80.173225
17	SINGHPUR	28.815943	80.222496
18	SINGHPUR	28.815556	80.222276
19	SINGHPUR	28.81516	80.222049
20	SINGHPUR	28.814764	80.221812
21	SINGHPUR	28.81433	80.221619
22	SINGHPUR	28.813944	80.221351
23	SINGHPUR	28.813567	80.221062
24	SINGHPUR	28.81317	80.220805
25	SINGHPUR	28.812802	80.220514
26	SINGHPUR	28.812472	80.220126
27	BARKAULA	28.85594	80.151888
28	BARKAULA	28.85592	80.152944
29	BARKAULA	28.85547	80.153916
30	BARKAULA	28.85503	80.154888
31	BARKAULA	28.85444	80.155694
32	BARKAULA	28.85392	80.156444
33	BARKAULA	28.85342	80.157222
34	BARKAULA	28.85267	80.158166
35	BARKAULA	28.851833	80.158666
36	BARKAULA	28.851361	80.159027
37	BARKAULA	28.850888	80.157722

38	BARKAULA	28.851527	80.156972
39	BARKAULA	28.852194	80.15625
40	BARKAULA	28.853083	80.155166
41	BARKAULA	28.853625	80.154722
42	BARKAULA	28.854722	80.153277
43	BARKAULA	28.85525	80.1525
44	BARKAULA	28.85535	80.15263
45	BARKAULA	28.85696	80.15241
46	BARKAULA	28.857197	80.152934
47	SILALEKH	28.837107	80.140857
48	SILALEKH	28.836857	80.140496
49	SILALEKH	28.836774	80.13983
50	SILALEKH	28.836774	80.13933
51	SILALEKH	28.836718	80.13877
52	SILALEKH	28.836885	80.138246
53	SILALEKH	28.837246	80.137691
54	SILALEKH	28.837496	80.13719
55	SILALEKH	28.837802	80.13677
56	SILALEKH	28.838028	80.136272
57	SILALEKH	28.838255	80.13583
58	SILALEKH	28.838453	80.135367
59	PILLAR24	28.815277	80.140468
60	PILLAR24	28.81587	80.140751
61	PILLAR24	28.816314	80.140943
62	PILLAR24	28.816674	80.14123
63	PILLAR24	28.817052	80.1415
64	PILLAR24	28.817515	80.141629
65	PILLAR24	28.817892	80.14194
66	PILLAR24	28.818288	80.142133
67	PILLAR24	28.818637	80.142477
68	PILLAR24	28.819035	80.142724
69	PILLAR24	28.81955	80.142675
70	PILLAR24	28.819662	80.133941
71	PILLAR26	28.80375	80.150611
72	PILLAR26	28.803527	80.151638
73	PIILLAR26	28.803333	80.152666
74	PILLAR26	28.803277	80.153666
75	PILLAR26	28.802972	80.154638
76	PILLAR26	28.803057	80.155145
77	PILLAR26	28.803142	80.15566
78	PILLAR26	28.803236	80.156175
79	PILLAR26	28.803311	80.15669

80	PILLAR26	28.803442	80.157173
81	PILLAR26	28.803537	80.157678
82	PILLAR26	28.80365	80.158174
83	SUNDARPUR	28.852944	80.165916
84	SUNDARPUR	28.851916	80.1655
85	SUNDARPUR	28.851138	80.165583
86	SUNDARPUR	28.85025	80.165722
87	SUNDARPUR	28.849854	80.165539
88	SUNDARPUR	28.849461	80.16526
89	SUNDARPUR	28.849066	80.165028
90	SUNDARPUR	28.848719	80.16475

1. List of photographs

Photo 1. Herd of Swamp deer in Shuklaphanta National Park

Photo 2. *Argimone maxicana* in Tintale area. Photo 3. Perennial invasion by *B. ceiba*.

Photo 4. *Lantana camara*, Shuklaphanta post. Photo 5. *Aretatum conyzoides*, buffer zone

Photo 6. *Eicchornia crassipes*, Rani Taal.

Photo 7. *Parthenium hysterophorus*