Invasive alien plant species and their effect on the occurrence of mammal species in Shuklaphanta National Park, Nepal

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Research Article

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Abstract

The introduction and colonization of invasive alien plant species (IAPS) is one of the major threats to the conservation of native flora and fauna. These species are noticed within several protected areas, including lowlands of Nepal, causing adverse effects on both the species and ecosystem services. The effects of IAPS on threatened mammalian species, especially with regards to their occurrences, remains little known. We identified the effects of IAPS on the occurrence of threatened mammalian species at Shuklaphanta National Park (ShNP), Nepal from 11 November 2020 to 11 June 2021. We categorized ShNP into IAPS invaded and non-invaded habitat. We recorded the occurrence of threatened mammal species from 210 plots of 10 m X 10 m along the line transect. Altogether, we recorded 11 invasive alien plant species. Among them blue billygoat weed (*Ageratum houstonianum*) had the highest abundance in the study area. We recorded 25 mammal species in the study area, whereas 11 were threatened. Among the threatened species, 10 were found in the habitats invaded by IAPS, while all 11 were identified in non-invaded habitats. We found the higher occurrence of threatened mammal species closer to the forest where the abundance of IAPS was observed to decrease. In addition, we observed the occurrence of mammal species increased as the distance from the water source, road, human settlement, and agricultural land increased, indicating that the abundance of IAPS also decreased with increasing distance to water source, road, human settlement and agricultural land. Our findings suggest that the threatened mammal species tend to utilize the non-invaded habitat of IAPS over the invaded habitats. For developing a more suitable habitat for threatened mammal species, we recommend the removal or control of IAPS from ShNP.

Introduction

The species that move away from their native areas, either accidentally or deliberately, are alien species (Pysek et al. 2004). These alien species, which include both plants and animals, are invasive alien species due to their high reproductive rate and the potential for rapid spread over the large areas (Lowe et al. 2000, Pysek et al. 2004). The rapid spreading of invasive alien plant species (IAPS) is increasing especially on various land uses in the context of a changing climate (Meyerson and Mooney 2007) and infrastructure development such as road and transportation (Adhikari et al. 2020). In addition, the spreading of IAPS has escalated with globalization, through trade, tourism, travel and other human disturbances or activities (Lahkar et al. 2011), which are particularly conducive to IAPS (Mack et al. 2000, Knight et al. 2009). Furthermore, many tourism-related activities had contributed to the distribution of IAPS (Pathak et al. 2021). In particular, the promotion of tourism in protected areas like Chitwan National Park has substantially increased human activities in these areas, leading to the rapid spread of IAPS into these protected area (Pathak et al. 2021). In addition, various non-native species are intentionally introduced outside of their natural range to enhance tourism (Arismendi and Nahuelhual 2007). For example, sports fish species such as salmon and trout are introduced into non-native habitats to strengthen the possibilities of recreational fishing (Arismendi and Nahuelhual 2007).

Typically, IAPS tend to produce a large number of viable seeds (Brooks et al. 2004), and exhibit early sexual maturity (Pysek et al. 2003). This strategy reduces competition from native species and enhances the survival chances of IAPS (Mack et al. 2000, Knight et al. 2009). Moreover, the IAPS can cause remarkable negative impacts on native flora and fauna (Mooney et al. 2005, Hardesty-Moore et al. 2020). These impacts include the loss of native species and biodiversity (Kohli et al. 2006), habitat alteration (Murphy et al. 2013), and the deterioration of ecosystem productivity and nutrient cycling (Charles and Dukes 2008, Vila et al. 2011). After the several generations, the IAPS are capable of adapting to their introduced habitat (Baker 1986). This adaptibility is facilitated by their ability to adjust to new climatic conditions (Hellmann et al. 2008), which can lead to negative impacts on the ecosystem (Vila et al. 2011, Shrestha and Shrestha 2021). Several studies had demonstrated that IAPS, such as Parthenium, exhibit allelopathic nature due to the presence of water soluble phenolic and sesquiterpene lactones like parthenin (Timsina et al. 2011). This leads to the inhibition of the growth of other plants through the soil contamination (Belz et al. 2007, Rashid et al. 2008). Consequently, IAPS become dominant in the introduced habitat (Khaniya and Shrestha 2020).

In certain localities, some IAPS are used for food, medicine, fuel, or fodder as a means of control (Kull et al. 2007). For examples, silver wattles (*Acacia dealbata*), black wattles (*A. mearnsii*) and green wattles (*A. decurrens*) are used globally for economic, environmental and ornamental purpose (Kull et al. 2007). Sometimes IAPS have been used as alternative sources of fodder for livestock (Shrestha et al. 2018). Despite their potential areas, IAPS have negative impact on agricultural production, forest regeneration (Shrestha et al. 2018), livestock grazing (Lahkar et al. 2011, Khaniya and Shrestha 2020), and human health (Rai and Singh 2020). For example, the Indian Muntjac (*Muntiacus muntjak*) in Baluran National Park, Java, was found to avoid IAPS invaded habitat (Tyson 2007).

Biological invasions can have impacts on pollinator communities, as they attract pollinators and dispersers away from native species (Aravind et al. 2010). For example, the berries of lantana (*Lantana camara*) attract frugivorous birds and mammals, leading to the dispersal of its seeds and hindering the reproductive success of native species (Aravind et al. 2010). Although Nepal provides habitats for species from various parts of the world due to physiographic and climatic variation (Brown et al. 2002; Chaudhary et al. 2020), the effects of IAPS invasion have been limited. Therefore, we aimed to assess the abundance of IAPS and their effects on the occurrence and habitat utilization of threatened mammal species in Shuklaphanta National Park, Nepal. These data will be immensely helpful for the park managers devising a robust management strategy for controlling the invasive.

Methods

Study area

We conducted this study in Shuklaphanta National Park (ShNP; 28°45'–28°57'N to 80°07'–80°21'E), which is located in a lowland of Sudur Paschhim Province of Nepal (Fig. 1). It comprises 305 km^2 with 243.5 km^2 of buffer zone. The park was established in 1976 as a Shuklaphanta Wildlife Reserve for the conservation of barasingha (*Rucervus duvaucelii*) population in Nepal. The ShNP's main habitat includes forest, grassland and wetland (Shrestha and Pantha 2018). The species composition of the forest are sal (*Shorea robusta*), kadam (*Adina cordifolia*), kumkum (*Mallotus philippinensis*), jamun (*Syzygium cumini*), pitalu (*Trewia nudiflora*), crape myrtle (*Lagertroemia parviflora*), bahera (*Terminalia bellirica*), and chebulic myrobalan (*Terminalia chebula*). Shuklaphata is the largest grassland with an area of approximate 16 km^2 dominated by congon grass (*Imperata cylindrical*), baruwa sugarcane (*Saccharum bengalensis*), wild sugarcane (*Saccharum spontaneum*), and halfa grass (*Desmostachya bipinnata*). A total of 56 mammal species has been recorded from the ShNP (Poudyal et al. 2020). This park is a home to endangered wildlife species including bengal tiger (*Panthara tigris*), asian elephant (*Elephas maximus*) and greater one-horn rhino (*Rhinoceros unicornis*). barasingha, spotted deer (*Axis axis*), hog deer (*Axis porcinus*), samber deer (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*), and nilgai (*Boselaphustrago camelus*) are the main species of ungulates. The people in the buffer zone are mainly engaged in agriculture and animal husbandry, and rely heavily on the park for cattle grazing and firewood food lumber and grass collection (Bot 2003).

Data collection

We identified the invasive alien plant species (IAPS) presence and absence sites within the park in our preliminary study from 28 October to 3 November 2020. Intensive field study was carried out between 11 November 2020 and 11 June 2021. We categorized as IAPS invaded (if any invasive plant species cover the area > 10%) and IAPS non-invaded habitat (if the area is without invasive plant species or sparsely distributed i.e. less than 10% coverage) in grassland and forests of ShNP. We established a total of 42 transects, and each transect was approximately 250 m length. The interval between two transects was at least 250 m. Sometimes, the variation in length was made due to the presence of rivers, streams or lakes. Along each transect, we established five plots of 10 m X 10 m, alternately at the interval of 50 m. In each plot, we established five nested subplots with 1 m X 1 m: four at the corners and one at the center of the plot. In the plot, presence/absence of IAPS, individual of each IAPS species (in IAPS presence habitat), forest canopy (in the forest sites), sign of herbivores and carnivores mammal species such as foot prints, scratches, burrows, and fecal were recorded. In addition, the elevation and latitude and longitude of each plot were also recorded by Global Positioning System (Garmin Etrex 10). Furthermore, the nearest distance to the forest, agricultural land, road, household, and water sources were also recorded with GPS from the center of each plot, however, the distance > 250 m was measured with Geographic Information System. Three nested subplots were used diagonally for observation. The IAPS number was counted from the nested subplots. IAPS abundance of individual species was identified by counting the numbers in each plot. The sign of each mammal species was identified in the field.

Data analysis

We calculated a Chi-square and Mann-Whitney U Test to determine the difference in IAPS invaded and non-invaded habitat for categorical and continuous data, respectively. Logistic regression was performed to determine the effects of IAPS on threatened mammal species in the study area. Five variables including invasive alien plant species abundance, distance to nearest forest (m), distance to nearest water source (m), distance to road (m) and tree canopy (%) were used as predictive and presence absence of threatened mammal species as response variable. All statistical test were performed in R Program (R Core Team 2023).

Results

Invasive Alian Plant Species composition

We established altogether 210 plots (IAPS invaded habitat: 105; IAPS non-invaded habitat: 105) during this study period. We found a total of 11 invasive alien plant species under seven families. Among the recorded species, 36.37% (n = 4) species belongs to Asteraceae, and followed by Fabaceae (18.18%, n = 2), and single species of each family Papaveraceae, Amaranthaceae, Verbenaceae, Lamiaceae, and Convolvulaceae.

In IAPS invaded habitat, the abundance of blue billygoat weed (*Ageratum houstonianum*) was highest i.e. 41.47%, and followed by sickle senna (*Senna tora*) 40.20%,, parthenium (*Parthenium hysterophorus*) 9.48%,, bushmint (*Mesosphaerum suaveolenes*) 1.76%, coffee senna (*Senna occidentalis*)0.31%,, lantana (*Lantana camara*) 0.29%, billygoat (*Ageratum conzyoides*) 0.25%, rough cocklebur (*Xanthium strumarium*) 0.15%, Mexican poppy (*Argemone mexicana*) 0.11%, spiny pigweed (*Amaranthus spinosus*) 0.068% and bush morning glory (*Ipomea carnea*) had 0.02% (Fig. 2).

The IAPS abundance was increased with increasing distance to forest (Fig. 3A) but decreased with increasing distance to water (Fig. 3B), road (Fig. 3C), and settlement area (Fig. 3D).

Mammal species composition

We recorded the presence of altogether 23 mammal species from seven orders and 14 families during this study (Supplementary Table 1). Among these the order carnivora had the highest diversity (10 species; 40%; five families), and followed by artiodactyla (seven species; 23.33%; three families), rodentia (two species; 6.67%; two families), lagomorpha and primates (two species; 6.67%; one family) and proboscidea and perissodactyla (one species; 3.30%; one family). Among them, nine mammals species have been included in IUCN Redlist of Threatened Species (IUCN 2023; Supplementary Table 1).

In IAPS non-invaded habitat, the mammal species were recorded in 88.57% (n = 93 of 105) of plots; order Artiodactyla was recorded in 91.40% (n = 85 of 93) of plots and followed by Carnivora 54.84%, Proboscidea 30.11%, Perissodactyla and Rodentia 15.05%, Primates 10.75% and Lagomorpha 6.45%, whereas the threatened mammal species were recorded from 63.81% (n = 67 of 105) of plots; order Proboscidea was recorded from 41.79% (n = 28 of 67) of plots and followed by Artiodactyla 37.31%, Carnivora 28.35%, Perissodactyla 20.90% and each Lagomorpha and Primates had 1.49%.

In IAPS invaded habitat, the mammal species were recorded from 84.76% (n = 89 of 105) of plots; order Artiodactyla was recorded from 94.38% (n = 84 of 89) of plots and followed by Carnivora 51.69%, Proboscidea 21.35%, Rodentia 19.10%, Primates 13.48%, Perissodactyla 8.99% and Lagomorpha 7.87%

of plots, whereas the threatened mammal species were recorded from 50.48% (n = 53 of 105) of plots. The occurrence of threatened mammal species was reduced as compared to IAPS non-invaded plots. In these plots, order Proboscidea was recorded from 35.85% (n = 19 of 53) of IAPS presence plots, which was followed by Artiodactyla 43.59%, Carnivora 13.30%, Perissodactyla 15.09%, Lagomorpha 5.13% and Primates 2.56% of plots.

Proportionally, more threatened mammal species occurrences were found in IAPS non-invaded habitat than IAPS invaded habitat, but there was no variation in their occurrence between invaded and non-invaded habitats ($\chi^2 = 0.767$, df = 1, $p = 0.382$). More threatened mammal species occurrence was found near to the forest, and had variation in their occurrence between IAPS invaded and IAPS non-invaded habitat ($p < 0.001$; Table 1). The average distance of IAPS non-invaded habitat to the nearest forest was 535.49 m (range: 0 to 1197.39) and 512.30 m (range: 0 to 1199.67) in IAPS invaded habitat (Table 1**)**. More threatened mammal species occurrence was found far from the water sources, but no variation in their occurrence between IAPS invaded and IAPS non-invaded habitat ($p = 0.808$; Table 1). The average distance of IAPS non-invaded habitat to the nearest water sources was 1387.61 m (range: 66.85 to 3622.49 m), and 1589.52 m (range: 37.87 to 6496.98 m) in IAPS invaded habitat (Table 1).

Table 1
Average distance of threatened mammal species occurrence in IAPS presence and absence habitats of Shuklaphanta National Park, Kanchanpur, Nepal 2021. Range of reported values are given in parentheses. *Significant effects are in bold.

Variables	**IAPS presence habitat**	**IAPS absence habitat**	**Statistics** **(Mann-Whitney test)**
Distance to forest	512 (0-1200)	535 (0-1197)	U = 5543; p < **0.001**
Distance to water	1590 (38-6497)	1388 (67-3623)	U = 5619; p = 0.808
Distance to road	793 (11-2352)	813 (55-2211)	U = 5729; p = 0.624
Distance to human settlement	1868 (117–7354)	2116(296–4696)	U = 7186; p < **0.001**

More threatened mammal species occurrence was found far from the road, however, there was no variation in their occurrence between IAPS invaded and non-invaded habitat ($p = 0.624$; Table 1). The average distance of IAPS non-invaded habitat to the nearest road was 813.07 m (range: 54.53 to 2210.88 m), and 792.80 m (range: 11.02 to 2351.72 m) in IAPS invaded habitat (Table 1). Fewer threatened mammal species occurrence was found near the settlement area, and had significant difference between IAPS invaded and non-invaded habitat ($p < 0.001$; Table 1). The average distance of IAPS non-invaded habitat to the nearest settlement area was 2115.6 m (range: 295.9 to 4696.3 m) and 1867.7 m (116.9 to 7353.5) in IAPS invaded habitat (Table 1).

The occurrence of threatened mammal species was influenced by distance to forest and distance to water sources. Threatened mammal species occurrence was higher at close to forest and increased with increasing distance to water sources (Table 2).

Table 2
Model averaged variables estimates describing the threatened mammal species presence in the IAPS invaded habitat of Shuklaphanta National Park Nepal in 2021. Model variables include invasive alien plants species abundance, distance to forest (m), canopy cover (%), distance to water (m), distance to road (m). Estimates were averaged from all models.

Variables	**Estimate**	**SE**	**z**	**p**
(Intercept)	-0.4389	0.3867	-1.135	0.256
Invasive plant species abundance	-0.0008	0.0008	-1.091	0.275
Distance to forest	-0.0018	0.0008	-2.306	0.021
Distance to water source	0.0005	0.0001	3.754	0.001
Distance to road	0.0000	0.0003	0.155	0.877
Tree canopy cover	-0.0010	0.0037	-0.271	0.787

Discussion

We document the abundance of IAPS in the Shuklaphanta National Park (ShNP) and their impact on the habitat utilization of threatened mammal species in ShNP. Among 11 IAPS invaded species in the park, the blue billygoat weed is most abundant species, followed by sickle senna, parthenium, bushmint and other species. The effect of IAPS invasion on the overall mammal species is not remarkable, however, the threatened mammal species avoids their invaded habitat. Their effect to the threatened mammal species might be mainly due to habitat loss and lack of palatable plant species by the IAPS invasion (Murphy et al. 2013). It might decrease the spatial detectability and distribution of mammal species (Arandhara et al. 2021).

The highly invaded habitat of study area was avoided by threatened mammal species. Like in Chitwan National Park (Murphy et al. 2013), Bardia National Park (Bhatta et al. 2020) and Parsa Wildlife Reserve (Chaudhary et al. 2020), a lot of principal habitats of threatened species were encroached by IAPS in Shuklaphata National Park too. The ShNP has important habitat for threatened species such as Swamp Deer and Spotted Deer, seems reduced as a result of invasion of unpalatable plant species. The impacts associated with the encroachment comprised the loss of preferable habitat for ungulates (Thapa et al. 2018).

We recorded more threatened mammal species close to forest, it might be due to availability of more grazing area near the forest. Forest seem less affected by the invasion of IAPS, this could be due to the formation of dense wall from adjacent vegetation. This reduces the interior lighting and wind speeds, which might lower the probability of IAPS establishment in the interior of the forest (Hansen and Clevenger 2005).

The abundance of IAPS is higher near the water sources, this might be due to the flow of propagules along the current of water, as river served as corridors for the dispersal of IAPS (Parendes and Jones 2000). Besides, the rivers provide suitable habitat and act as reservoir of propagules for further invasions (Parendes and Jones 2000). The IAPS abundance was higher at nearer to water sources. Furthermore, IAPS affected water supply in different way, such as, increased disease vector, increased microbial activities, and biochemical oxygen demand (Howard and Matindi 2012). Therefore, these areas might be avoided by the threatened mammal species. Thus, the occurrence of threatened mammal species decreases at nearer to the water source in IAPS invaded habitat.

There was no significant effects of IAPS abundance on threatened mammal species occurrence during this study, however their higher occurrence was noticed at lower abundance of IAPS. The abundance of IAPS is higher nearer the road, this might be due to the dispersal of seed through vehicles as well as contaminant of transport materials. Thus road facilitates the dispersal of seed to new site (Shrestha et al. 2019). In addition, the road edges provide suitable microhabitats for IAPS establishment and serve as dispersal corridor for species like Parthenium (Shrestha 2018). Furthermore, a number of direct road connect thousands of vehicles, through these road various IAPS thought to have dispersed. Besides, there was significant relationship between type of road and the frequency of the weed’s occurrence (Nath et al. 2019). But the level of invasion from IAPS nearer to roads might be different, expected for more invasion in frequently used road tracks than in infrequently used road tracks (Parendes and Jones 2000). Therefore, the threatened mammal species occurrence was higher at far from the road, as it possessed low abundance of IAPS.

Conclusions

In conclusion, our study in Shuklaphanta National Park highlighted the negative impact of IAPS on abundance of native species and the avoidance of invaded habitats by threatened mammal species. The proximity to forests positively influenced the occurrence of threatened mammal species, while habitats near water sources, roads, and human settlements exhibited higher abundance of IAPS and were less preferred by the threatened species. It is crucial to develop a targeted management plan to mitigate the threat of IAPS and conserve the diverse mammal species in the park, considering their near threatened, endangered, and vulnerable statuses. This study emphasizes the need for increased awareness and collaborative efforts among managers, policymakers, researchers, and the public to address this biodiversity challenge effectively.

Declarations

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Author Contributions

Conceptualization— C.C., H.P.S; Data collection— C.C.; Supervised— H.P.S.; Data Analyzed—C.C. and H.P.S. writing—review and editing— C.C. and H.P.S.

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Declarations Conflict of interest

The authors declare no conflict of interest.

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Figures

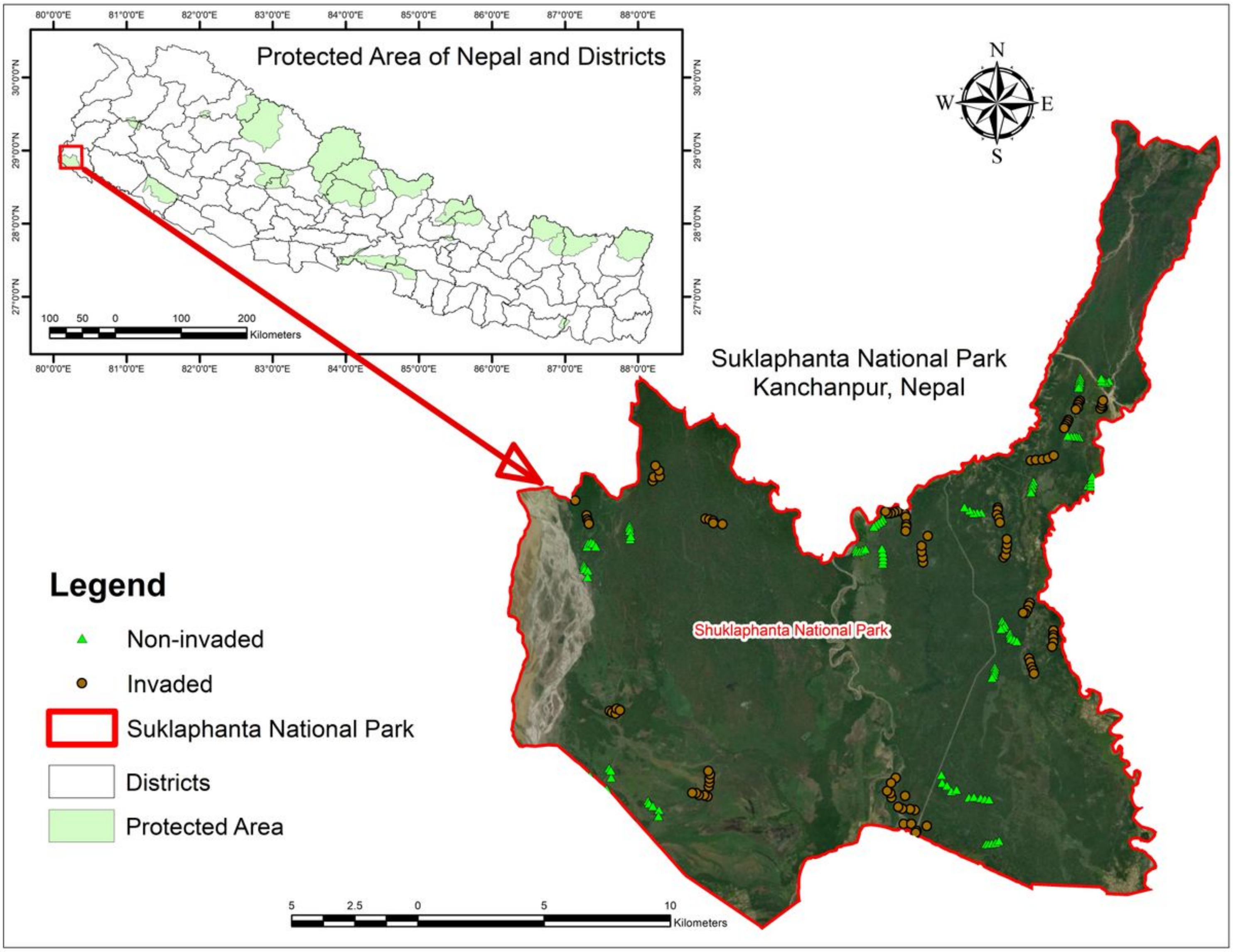

Figure 1

Invasive Alien Species invaded and non-invaded area in Shuklaphanta National Park, 2020-2021.

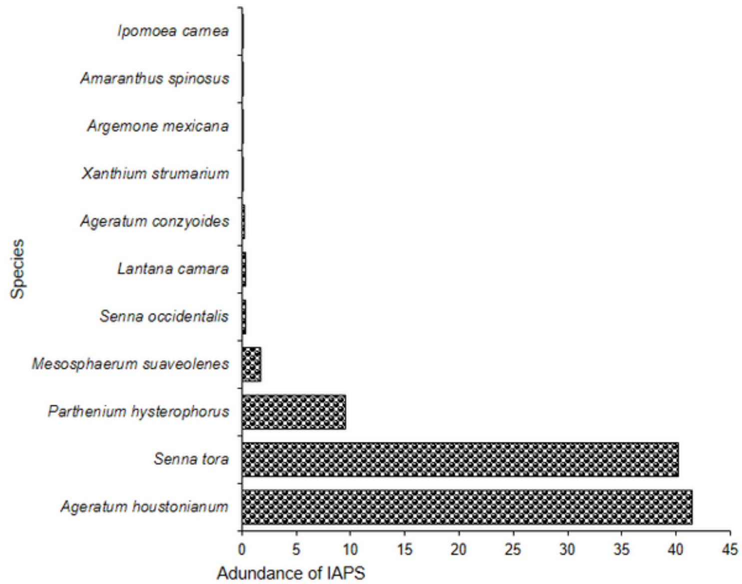

Figure 2

Abundance of Invasive Alien Plant Species in Shuklaphanta National Park, Nepal, 2020‒2021

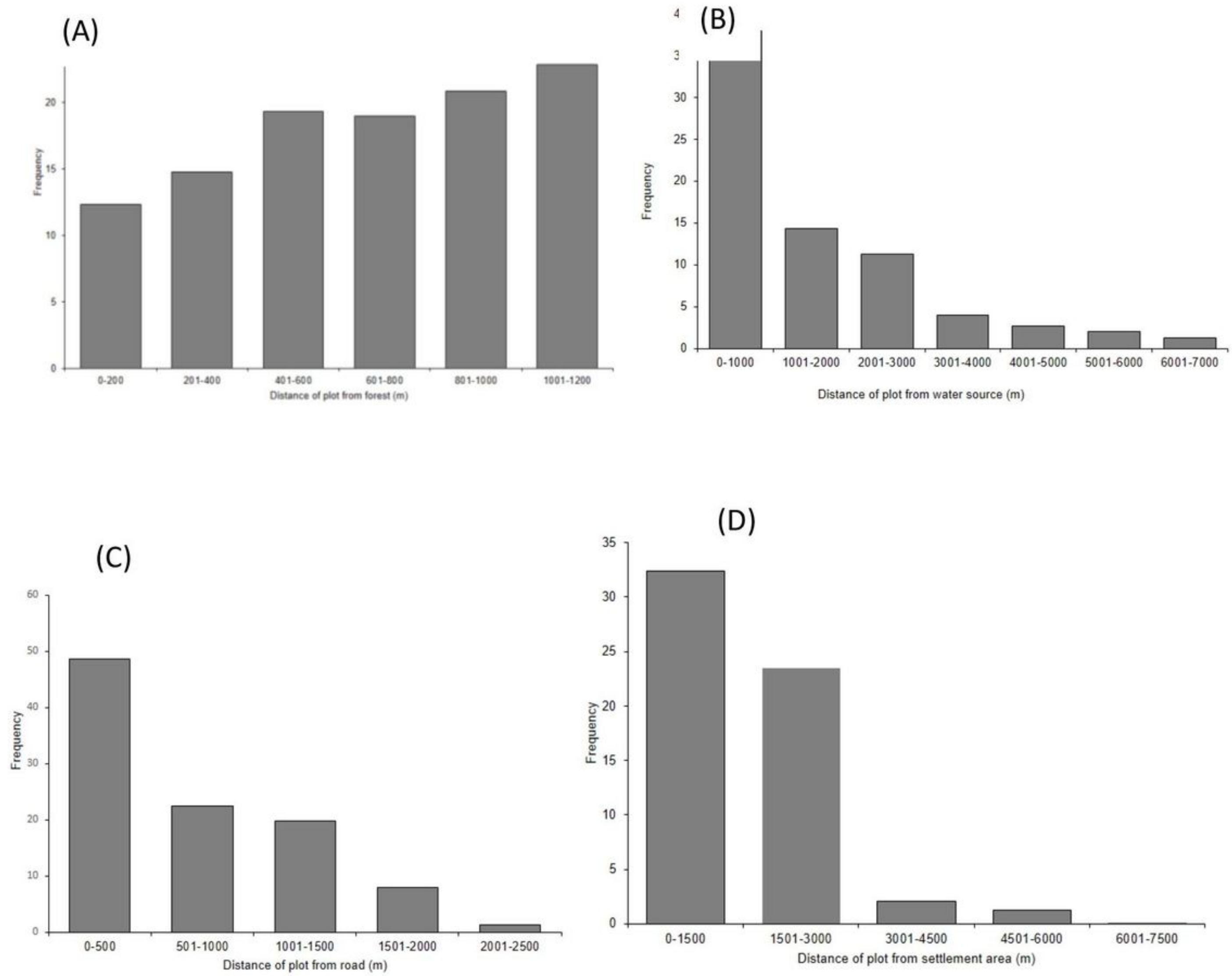

Figure 3

Occurrence of Invasive Alien Plant Species nearest to (A) forest, (B) water, (C) road, (D) settlement area in Shuklaphanta National Park, Nepal, 2020–2021

Supplementary Files

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- SupplementaryTable1.docx