Ecology, Biodiversity and Approaches for Management of Specialthang Grassland in Royal Manas National Park.

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Specialthang Grassland, Royal Manas National Park

Abstract

Grasslands represent an important habitat in the Royal Manas National Park, occupying 1191.18 hectares of its geographical area. The condition of most of the grasslands has degraded over the years due to the invasion of woody perennials. A biodiversity assessment of Specialthang grassland, covering 240 acres under Manas Range, was conducted to assess the status of the grasslands and to provide insights for developing scientific grassland management regimes. The quadrat sampling method, point count, and modified pollard walk methods were used for vegetation, avifauna, and butterfly surveys respectively. Encounter rate from line transects and photographic capture rate index from camera traps were used for mammal survey.

A total of 71 plant species, 14 butterfly species, 61 bird species, and 13 mammal species were recorded from the study area.

The study showed a high dominance of *Chromolaena odoratum* (24084.3 per hectare) followed by *Clerodendrum viscosum* (1270), *Leea asiatica* (1232.8), and *Urena lobata* (1232.3).

Species such as cogon grass (*Imperata cylindrica*), lemongrass (*Cymbopogon pendulus*), elephant grass (*Saccharum narenga*), *Penicum auritum* and *Arundinella bengalensis* had high important value index (IVI).

The mean encounter rate and photographic capture rate for large and medium mammals

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such as Elephant (*Elephus maximus*), Sambar (*Rusa unicolor*), Wild Pig (*Sus scrofa*), and Barking Deer (*Muntiacus muntjak*) were high. Conversely, small mammal encounter rate was recorded significantly low. Long-term assessment of biodiversity of grasslands shall be pivotal in planning, development, and adaptive management of grasslands. We recommend the use of patch mosaic burning technique, based on sound knowledge of grassland ecology, for the protection and restoration of grasslands in the Royal Manas National Park.

Keywords: Biodiversity; Grassland; Habitat Management; Royal Manas National Park.

Introduction

Grasslands form a major part of the global ecosystem, covering 37% of the earth's terrestrial area (Loveland et al.2000; Mara 2012). Tropical Savannahs, Temperate Grasslands, and Steppes are the three unique grasslands of the world (Chandran 2015). They are deemed as key sites for biodiversity conservation and provide many essential ecosystem services underpinned by rich biodiversity and diverse ecosystem processes (Bezbarua et al. 2008; SANBI. 2013). Grasslands of the Eastern Himalayas, which comprises mainly of coastal grasslands, riverine alluvial grasslands, montane grasslands, sub-Himalayan tall grasslands, tropical savannahs, and wet grasslands are remarkably rich in biodiversity providing refuge for a large number of endemic and endangered species (Landsberg and Lehmkuhl 1995; Chandran 2015). These grasslands also have the highest densities of tiger, rhinos and ungulate biomass in Asia (Wikramanayake et al. 1998, Lahkar 2008). The sub-tropical, tall wet grasslands in the foothills of the Himalayas have been referred to as 'Terai' grasslands (Lehmkuhl 2000; Mathur 2000). These grasslands are among the most productive terrestrial ecosystems in the world, which supports a high biomass of grazing ungulates (Seidensticker et.al. 2010; Ghosh 2015). However, steady increase in human and livestock populations, changes in land use practices, heavy infestation by unpalatable and alien invasive plants have degraded the grasslands resulting in the loss of biodiversity and ecosystem services, decline in quality and quantity of forage species, loss of pastoral livelihoods, and desertification (Faber-Langendoen & Jose 2010; FAO 2013).

The Royal Manas National Park (RMNP) has an incredible mosaic of habitat diversity, ranging from significant grassland savannahs in the southern plains to vast expanses of old growth tropical monsoon, subtropical and temperate forests along wide altitudinal ranges. The grasslands of RMNP which represent the Terai grassland occupy about 1191.18 hectares along the southern foothill of the National Park and are home to some of the globally endangered species such as Royal Bengal Tiger (*Panthera tigris*), Asian Elephant (*Elephus maximus*), Asiatic Wild Buffalo (*Bubalus bubalis*), Gaur (*Bos gaurus*) and Hispid Hare (*Caprolagus hispidus*). However, the condition of grasslands has waned over the years mainly because of improper management through the indiscriminate use of fire giving way to invasion by alien species such as siam weed (*Chromolena odoratum),* crepe flower *(Lagerstroemia parviflora),* wolly dyeing rosebay *(Wrightia arborea),* caesarweed (*Urena lobata)*, asian leea (*Leea asiatca)* etc. causing extensive damage to grassland habitats (DoFPS 2015).

The management of some of the grasslands through annual burning, which started since the inception of first conservation management plan 1995-2000 was carried out in the absence of scientific assessment and proper management regimes leading to further increase in the invasion of woody perennials. Uncontrolled and unsystematic burning retards the natural process of ecological succession and instead facilitates woody succession (Lehmkuhl 1989, 1994; Giora & Osborne 2014).

Sound management of grasslands based on their proper ecological knowledge will form an important benchmark of the potential for the long-term protection and, where possible, the restoration of the grassland ecosystem. Determining the status of grassland community structure and long-term ecological studies on various grasslands will be fundamental in systematic planning and development of scientific grassland management regime (Rawat & Adhikari 2015). Therefore, this Study attempted to establish baseline data on the biodiversity of Specialthang grassland for developing proper scientific management recommendations. Our specific objectives were:

1. To estimate the Relative Frequency (RF), Relative Density (RD) and Relative Cover (RC) of grassland community including invasive species using quadrat sampling method.
2. To estimate the diversity and abundance of mammals using encounter rate from line transects and photographic capture rate index from camera traps.
3. To estimate the diversity and abundance of avifauna and butterfly using the point count method and modified pollard walk method respectively.
4. To examine the implications of our results for the development of proper scientific grassland management regimes in the Royal Manas National Park

Methods

Study Area

The Royal Manas National Park (RMNP) is situated in the south-central foothills of Bhutan (90°35' E to 91°13' E and 26° 46' N to 27° 08' N). Spanning an area of 1057 sq. km, the national park falls within the political jurisdiction of three *dzongkhags* viz., Zhemgang, Sarpang, and Pemagatshel. The elevation of the RMNP ranges from as low as 97masl at the southern foothills up to 2714masl in the north. The Park has a moist subtropical to cool temperate climate with four distinct seasons. Summer lasts from May to August with annual maximum temperature ranging from 20° C to 40° C. The rainfall ranges from 200mm to 4400mm

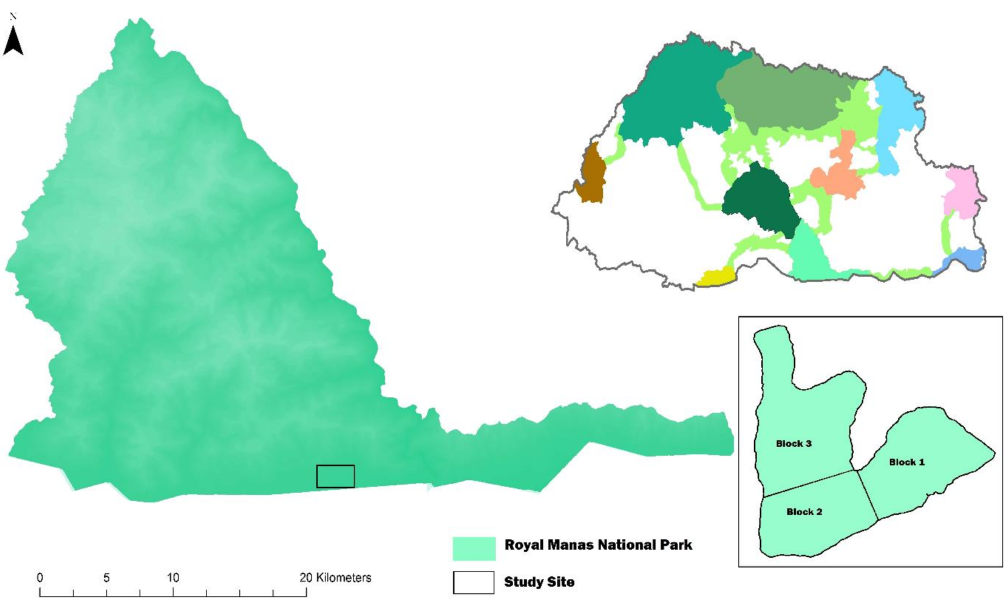

Figure 1: Location of study site within the Royal Manas National Park

annually (RMNP 2015). The total grassland area of 240 acres in Specialthang is located about 8km from Manas Range at an elevation range of 240masl to 275masl (Figure 1).

The forest types of the RMNP are broadly classified into four eco-floristic zones such as Tropical monsoon forests (< 500m), Sub-tropical forests (500 -1000m), Warm broadleaved forests (1000 – 2000m) and Cool broadleaved forests (2000-2714m) (DoFPS 2015).

Methodology

The biodiversity assessment survey was carried out from 13th February 2016 to 18th March 2016. A grassland area of 240 acres was stratified into 3 blocks of 79.5, 70 and 89.5 acres respectively (Figure 1).

Vegetation survey

A total of 15 line transects with a maximum length of 2 km were laid in each block. Quadrats of sizes 20m x 20m for trees, 5m x 5m for shrubs, and 2m x 2m for herbs, grasses, and regeneration with a total of 89 plots were laid systematically along each line transect at every 100m interval. The identification of plant specimens was referred from the Flora of Bhutan (Grierson & Long 1983,1984,1987,1991,1999,2002 and Noltie 2000) and Weeds of Bhutan (Parker 1992). Relative Frequency (RF), Relative Density (RD) and Relative Cover (RC) were used to calculate the Important Value Index (IVI) (Lahkar 2008). One-way ANOVA test was used to compare the mean difference in the dominance of invasive and grassland species across the three blocks. All analyses were conducted using R version 3.3.1 (R Foundation for Statistical Computing).

Mammal survey

An index of encounter rate from line transects and index of prey density from camera traps were adopted for assessing their diversity and abundance (Karanth & Nichols 2002). A total of 14 transects with a random stating point were placed between a minimum width of 100m interval in all three blocks. The length of the transects, ranging between 0.5km to 1.4km were walked at an average speed of less than 1km per hour. Indirect signs such as pellets, scats, footprints, scrapes, resting/wallow sites of wild animals within 1m on either side of the transect line were recorded.

For deriving indices of species abundance based on trapping rate, a total of 24 camera traps were placed at potential sites based on species signs and convergence of game trails for increasing the probability of capture rate (Karanth & Nichols 2002). The camera traps were spaced at a minimum distance of 200-300m in twelve camera stations. At each location, two cameras were installed on a suitable trail of which one camera was mounted at a height of about 40-50cm and other at 5-15cm, which helped in obtaining clear photographs of both large and small mammals. All the cameras were kept operational for 24 hours a day for a minimum of 35 days. Following O' Brien et al. (2003), we calculated the photographic capture rate index (PCRI) using consecutive camera trap images of individuals of the same species taken with more than 30 minutes time interval (O' Brien et al. 2003). The camera trap survey generates a simple quantitative index, consisting of the number of independent events per unit sampling effort, which is a good predictor of absolute density of a species in an area (Carbone et al. 2001). One-way ANOVA test was used to compare the mean difference in photographic capture rate index abundance indices (PCRI) of mammals across the three blocks. All analyses were conducted using R version 3.3.1 (R Foundation for Statistical Computing).

Avifauna and Butterfly Survey

For avifauna survey, the point count method was used for assessing the diversity of birds in

Specialthang grassland (Ralph et al. 1995). In each block, series of points at approximately 200m distance interval were laid along the transects. We spent ten minutes at each point interval in identifying and recording the birds from the centre of the point. Opportunistic bird sightings from point to point were also recorded. For butterfly survey, a modified ‘Pollard walk’ method was used (Sundufu & Dumbuya 2008; Singh 2012, Nidup et. 2015) primarily based on vegetation cover and geographical feature. Butterflies observed within 5m either side of transect line and 5m to the front of observer were only recorded (Leyanoni et al. 2011; Mayur et al. 2013). Every effort was made to avoid counting butterfly more than once. Identification of butterfly species followed Kehimkar (2008) and Nidup (2015).

Results

Vegetation diversity

A total of 71 plant species representing 46 families were recorded from the study area, out of which, 19 were tree species, 18 shrub species, 17 grass species and 17 herb species. The grass species were dominated by the sub-family of Andropogoneae with 17 species, followed by Paniceae with 6 species.

Comparative assessment of grass species

The comparative analysis of grass species from the three blocks showed the highest species richness in block 1(N=14), followed by block 2(N=11), and the lowest in block 3 (N=7). The Shannon diversity index was found to be higher in block 1 (3.9) as compared to block 2 (3.1) and block 3 (2.5). *Imperata cylindrica, Cymbopogon pendulus, Saccharum narenga* [add common name] were the dominant grass species in all the three blocks with high IVI values. Grass species with low IVI values were recorded for *Neyraudia arundinaceum, Penisetum* sp. and *Eulalia fastigiata* (Figure 2) [add common name]. There was a statistically significant difference in the IVI value between the blocks as determined by one-way ANOVA (F (2,29)=

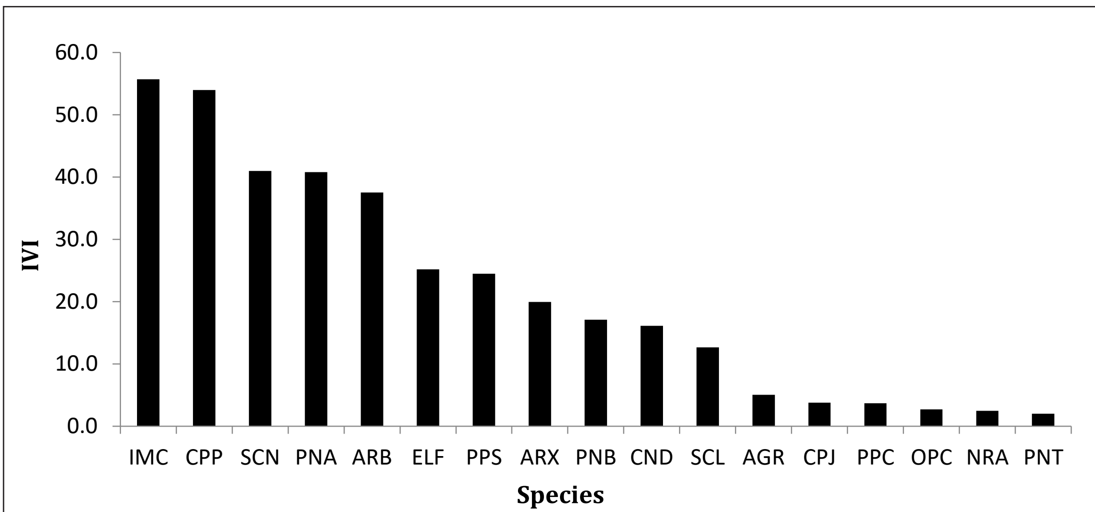

Figure 2: Important value index (IVI) of grass species. *(AGR=Agrostis sp., ARX=Arthraxon sp., ARB=Arundinella bengalensis, CPJ= Cymbopogon jwarancusa, CPP=Cymbopogon pendulus, ELF=Eulalia fastigiata, IMC=Imperata cylindrica, SCL=Saccharum longesetosum, SCN=Saccharum narenga, CND= Cynodon dactylon, NRA= Neyraudia arundinaceum, OPC=Opliminus composites, PPC= Paspalum conjugatum, PPS= Paspalum scrobiculatum, PNA= Penicum auritum, PNB=Penicum brevifolium, PNT= Penisetum sp.)*

3.168, p=0.04).

Distribution of invasive shrub and herb species

[For all of these plants, can you get common names?] A total of 19 invasive shrubs were identified, of which the highest density (per hectare) was recorded for *Chromolaena odoratum* in block 1 (43000) followed by block 3 (27817.1) and block 2 (1435.8). Other co-dominant shrubs included *Crotolaria pallida, Clerodendrum viscosum, Urena lobata, Leea asiatica* and *Colebrookea oppositifolia* (Table 1). The overall highest density of invasive shrub species (per hectare) was recorded for *Chromolaena odoratum* (24084.3), followed by *Leea asiatica* (1232), *Urena lobata* (1032.2), *Crotalaria pallida* (946.1), *Clerodendrum viscosum* (846.7), *Clebrookia oppositifolia* (593.7), *Flemingia macrophylla* (378.8), *Tsilanthes bengalensis* (354.4) and the lowest density (per hectare) was recorded for *Damnacanthus indicus* (242.2). There was statistically no significant difference in the density of invasive shrub species between the blocks (F (2,111) =0.8103, p=0.44).

A total of 17 invasive herb species were recorded in all the three blocks of which *Spermacoce latifolia, Mikania micrantha, Ageratum conyzoides, Lygodium japonicum* and *Aster* sp. were found commonly distributed in all the three blocks (Figure 3).

Table 1: Comparative density of invasive shrub species in three blocks

Shrub species	Block 1	Block 2	Block 3
	Density per hectare		
Cassia tora	0.0	0.0	148.6
Chromolaena odoratum	43000.0	1435.8	27817.1
Clerodendrum viscosum	2300.0	0.0	240.0
Colebrookea oppositifolia	0.0	318.3	1462.9
Crotolaria pallida	2450.0	22.5	365.7
Damnacanthus indicus	250.0	21.7	457.1
Desmos dumosus	816.7	15.8	0.0
Eranthemum griffithii	0.0	0.0	22.9
Flemingia macrophylla	483.3	0.0	194.3
Leea asiatica	933.3	250.8	2514.3
Maesa macrophylla	33.3	0.0	0.0
Melastoma normale	783.3	90.8	80.0
Melilotus indica	0.0	4.2	0.0
Murraya cunighii	50.0	0.0	0.0
Phlogacanthus thyrsiformis	33.3	0.0	34.3
Psilanthus bengalensis	583.3	0.0	480.0
Sida acuta	666.7	0.0	11.4
Tabernaemontana divaricata	150.0	0.0	0.0
Urena lobata	2250.0	12.5	834.3

Distribution of tree species

The tree richness was highest in Block 1 (N=16), followed by Block 3 (N=14) and Block 2 (N=11). *Wrightia arborea and Lagerstroemia parviflora* were the dominant tree species with high tree densities (per hectare) recorded in all the three blocks (Table 2). The overall tree species abundance was *Lagerstroemia parviflora* with 16.4 trees (per hectare), followed by *Wrightia arborea* (14.8), *Grewia sepiaria* (8.1), *Callicarpa arborea* (7.0), *Phyllanthus emblica* (5.0), and

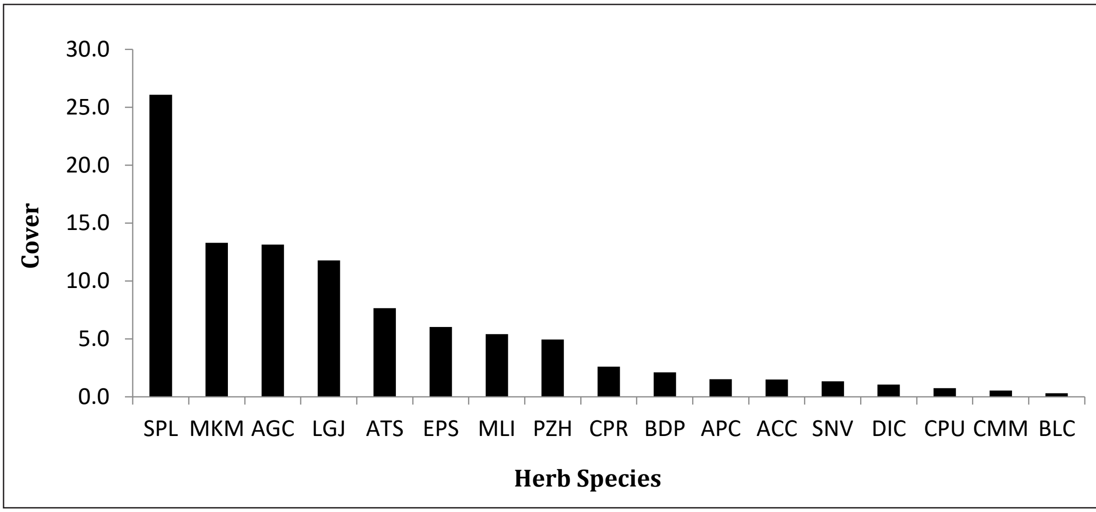

Figure 3. Percentage cover of invasive herb species in three blocks. *AGC= Ageratum conyzoides, APC= Apioscarnea, ACC=Asclepias curassavica, ATS=Aster sp., BLC=Barleria cristata, BDP= Bidens pilosa, CPU= Clinopodium umbrosum, CMM= Commelina sp., CPR= Cyperus sp. ,DIC=Dioscorea sp., LGJ= Lygodium japonicum, MLI= Melilotus indica, MKM= Mikania micrantha, SPL=Spermacoce latifolia, EPS= Euphorbia sp.,PZH= Poulzolzia hirta, SNV= Solanum viarum Stereospermum colais* (0.2)

Table 2: Comparative density of tree species in three study blocks

Tree species	Block 1	Block 2	Block 3
	Density per hectare		
Acacia rugata	1.0	0	0
Alstomia scholaris	1.0	0	0
Bombax ceiba	1.0	0.8	0.7
Bridelia tomentosa	2.1	0.0	0.7
Callicarpa arborea	8.3	4.2	8.6
Careya arborea	5.2	0.8	8.6
Casearia graveolens	2.1	0.8	12.1
Dillenia pentagyna	3.1	2.5	18.6
Grewia sepiaria	2.1	0.0	1.4
Lagerstroemia parviflora	7.3	12.5	29.3
Phyllanthus emblica	8.3	5.0	3.6

Schima wallichii	1.0	0.0	0.0
Sterculia villosa	4.2	0.0	0.0
Syzygium cumini	3.1	0.0	0.7
Terminalia bellirica	2.1	7.5	5.7
Wrightia arborea	19.8	11.7	12.9
Holarrhena pubescens	0.0	0.8	0.0
Zizyphus mauritiana	0.0	1.7	0.7
Sterospermum colais	0.0	0.0	0.7

Mammal Diversity

A total of 13 mammal species were recorded from the survey. Amongst the 13 species of mammals recorded, high frequency of indirect signs were observed in elephant (*Elephus maximus*)(N=179), sambar (*Rusa unicolor*) (N=91), wild pig (*Sus scrofa*)(N=74) and barking deer (*Muntiacus muntjak*)(N=54). Conversely, the evidence of small mammals like a Himalayan crestless porcupine (*Hystrix brachyura*) (N=2), Indian hare (*Lepus nigricollis*)(N=1), small Indian civet (*Viverricula indica*)(N=1) and Indian gray mongoose (*Herpestes edwardsii*)(N=1) were low in all the three blocks. There was statistically no significant difference in frequency of mammals recorded between the three blocks as determined by one-way ANOVA (F (2,33)=0.3175, p=0.96).

Encounter rate and photographic capture rate of mammal species

The survey results showed a higher mean encounter rate (per km) for elephant (*Elephus maximus*), sambar (*Rusa unicolor*), wild pig (*Sus scrofa*), and barking deer (*Muntiacus muntjak*). Contrarily, all the small mammal species such as Himalayan crestless porcupine (*Hystrix brachyura*), Indian hare (*Lepus nigricollis*) and small Indian civet (*Viverricula indica*) had low encounter rate (Table 3).

The photographic capture rate index (PCRI) was highest for barking deer (*Muntiacus muntjak*) and sambar (*Rusa unicolor*). Among the carnivore species, large Indian civet (*Viverra zibetha*) had the highest PCRI of 2.7 independent events per 100 trap nights followed by tiger (*Panthera tigris*) and common leopard (*Panthera pardus*) at PCRI of 0.9 and 0.5 independent events per 100 trap nights respectively. Small mammal species such as Indian gray mongoose (*Herpestes edwardsii*), small Indian civet (*Viverricula indica*) and Himalayan crestless porcupine (*Hystrix brachyura*) had as low as 0.5 independent events per 100 trap nights (Table 4).

Table 3: Mean encounter rate of mammals in Specialthang, grassland. n= Total number of signs encountered, I= Mean number of scat/dung/pellet encountered/km walked

Species		Mean encounter rate of species (per km)		
Common Name	Scientific Name	**N**	**I**	**SE**
Sambar	*Rusa unicolor*	91	7.07	2.44
Barking Deer	*Muntiacus muntjak*	54	4.19	1.88
Elephant	*Elephus maximus*	179	13.90	3.42
Wild Pig	*Sus scrofa*	74	5.75	2.20
Guar	*Bos gaurus*	11	0.85	0.85

Water Buffalo	*Bubalus bubalis*	7	0.54	0.68
Indian Hare	*Lepus nigricollis*	1	0.08	0.25
Himalayan crestless porcupine	*Hystrix brachyura*	9	0.09	0.15
Large Indian Civet	*Viverra zibetha*	2	0.16	0.25
Small Indian civet	*Viverricula indica*	1	0.08	0.25

Table 4: Photographic capture rate index of mammals in Specialthang, grassland. n= Total number of independent events, I=Photographic capture rate index (independent events/100 trap nights)

Species		Photographic capture rate index	
Common Name	Scientific Name	**n**	**I**
Tiger	*Panthera tigris*	2	0.9
Common Leopard	*Panthera pardus*	1	0.5
Sambar	*Rusa unicolor*	11	5.5
Barking Deer	*Muntiacus muntjak*	11	5.5
Large Indian Civet	*Viverra zibetha*	6	2.7
Small Indian Civet	*Viverricula indica*	2	0.5
Wild Pig	*Sus srofa*	2	0.9
Indian Gray Mongoose	*Lepus nigricollis*	4	0.5
Himalayan Crestless Porcupine	*Hystrix brachyura*	6	2.7
Water Buffalo	*Bubalus bubalis*	1	0.5

Bird and Butterfly Diversity

A total of 61 bird species were recorded from one-time single season count in 21-point count stations and opportunistic bird sightings. Red-vented Bulbul (*Pycnonotus cafer*) was counted the highest with 117 individuals in the survey area. The density of bird was calculated in three distance band viz., 254 birds in 0-15 m band, 71 birds in the 16-30m band, and 7 birds in 31-50m band. From the survey, three species viz., Chestnut-capped Babbler (*Timaliapileata*), Siberian Ruby Throat (*Luscinia calliope*), and White-tailed Ruby throat (*Luscinia pectoralis*) were new records for RMNP, making the total bird list to 489 species. Critically Endangered bird species such as White-rumped Vulture (*Gyps bengalensis*) and Near Threatened Himalayan Vulture (*Gyps himalayensis*) were also recorded from the survey area. A total of 14 species of butterflies belonging to 4 families viz., Hisperidae, Lycenidae, Peridae, and Nymphalidae were recorded of which family Nymphalidae had the maximum record of species. Out of 14 species recorded, one species viz., Painted Jezebel (*Delias hyparete*) was a new record for RMNP, making the total butterfly list to 198 species.

Discussion

This is the first known grassland study carried in the lower altitudes of the Royal Manas National Park. Similar studies were conducted in Manas National Park, in India by Lahkar (2008), Malnad region (Karnataka) by Puyravaud et al. (1994), Nepal, Peet et al. (1997) and Jaldapara Wildlife Sanctuary by Biswas and Mathur (2003). Result for the dominant grass assemblage in this study is in concurrence with at least one of the grass assemblages described in the Manas National Park and the Jaldapara Wildlife Sanctuary. Similar to the findings of Lahkar (2008) and Shrestha and Dangol (2006), the grassland community of Specialthang was dominated by *Imperata cylindrica* which was found to be the most abundant species with IVI value of 55.70. *Imperata cylindrica* thrives in areas disturbed by human activities and frequent fire affected areas, as the rhizomes of this species are very resistant to fire which triggers flowering and seed production in the species to spread vegetatively (Wilcut et al.1988; FIPR 1997; MacDonald 2004).

A high coverage of grassland by invasive species such as *Chromolaena odoratum* at 24,084.3 (per hectare) was found and is now clearly one of the major challenges for the habitat management in RMNP. *Chromolaena odoratum* is considered one of the obnoxious invasive species, which tolerates a wide range of soil conditions, severe drought, and fire and is also highly allelopathic which suppresses neighbouring vegetation (Munniapan & Bamba 2000). Uncontrolled burning impacts the composition of grasslands from palatable species to non-palatable species making it less suitable for herbivore species and further retards the natural process of ecological succession by facilitating woody succession (Lehmkuhl, 1989, 1994; Chandran 2015).

Further, results of this survey showed high coverage of trees species such as *Lagerstroemia parviflora*, *Wrightia arborea,* and *Grewia sepiaria*. These trees species show remarkable coppicing growth and are mostly grown in comparatively open habitats, in disturbed forests and grassland, and along rivers and are also highly resistant to fire (Orwa et al. 2009). The unsystematic grass management regimes mainly through uncontrolled burning and to an extent climate change are reported as major factors in the reduction of native perennial grasses from their formal range (DoFPS 2015). This is also evident from the land use land cover maps of 1972 and 2010 showing a notable decline in the area coverage of grasslands in RMNP. Identifying the processes that led to degradation and factors governing the rehabilitation processes is essential for habitat management (Vasu & Singh 2015).

Apart from invasive species being one of the major threats of grasslands, climate change is now increasingly recognized as one of the global environmental challenges, which affects the productivity of vegetation and the composition of grassland species causing a shift to less productive, more drought-tolerant plant and tree species (Weddell 1996; Grime et al. 2008). Although the empirical data to forecast the historical changes in temperature and rainfall and other climatic variables are not available to substantiate the cause of grassland degradation in RMNP, studies have shown that the global increase in temperature will impact grasslands to undergo significant shrub invasion (Van Auken, 2000).

The PCRI and encounter rate of small mammal species from the survey were found low which could be mainly attributed to the indiscriminate burning of grassland area yearly. Studies elsewhere show that the major effects of fire on small mammals are related to vegetation modification, loss of food, and cover and increased exposure to predation (Witz et al.1988; Letnic et al. 2005). There is strong evidence that widespread uncontrolled burning has a detrimental impact on less mobile grassland-dependent species (Oliver 1980). Conversely, there was a high abundance of large and medium mammals in the grassland. The large mammals escape from the fire easily, which makes them less susceptible to extinction due to impact from fire (Singer & Schullery 1989). Large predators like tigers (*Panthera tigris*) and common leopard (*Panthera pardus*) are territorial prey dependent animals, commonly found to use grasslands in RMNP as evidenced by their high photographic capture rates. The main prey base of these predators consists of mainly large and medium mammals like sambar (*Rusa unicolor*), barking deer (*Muntiacus muntjak*), gaur (*Bos gaurus*) and wild pig (*Sus scrofa*). The ungulates upon which these predators are dependent are in turn dependent on grasslands for their survival (Sunquist & Sunquist 1988; Landsberg & Lehmkuhl1997). Research by Lehkuhl (1994) indicates utilization of prescribed fire or patch mosaic burning technique in grassland habitats of tigers can increase the amount of biomass produced and productivity of grasses. Patch mosaic burning technique is an efficient grassland management tool which involves setting aside some of the blocks for burning while the remaining blocks are intercepted from burning regime providing breeding and escape cover for grassland dependent species (Lahkar 2008). The decision on how to burn a portion of grassland must always be founded on a clearly defined set of management objectives of the grassland, and knowledge of the nature of ecosystem and its ecological requirements (SANBI 2013).

Our assessment shows that the status of grasslands in Specialthang is relatively poor. A systematic grassland management regime based on proper scientific assessment will be imperative in the perpetuation of healthy grasslands and of their threatened and endangered fauna in RMNP.

Management recommendations

The grasslands form one of the significant components of diverse ecosystems and are rich in biodiversity. The condition of the Specialthang grassland has deteriorated as a result of the invasion of woody perennials. The high prevalence of invasive species which are aggressive colonizers coupled with the unsystematic burning of grasses annually have impacted the state of native grassland species and diversity and abundance of small mammals. Proper understanding of plant species composition structure is crucial for assimilating the succession and change in vegetation structure over time due to natural and anthropogenic impacts.

Given the deteriorated state of grasslands in RMNP, the grassland management needs to focus on maintaining and recovering the existing grasslands for faunal biodiversity and in ensuring availability of palatable grasses to herbivores. Habitat management shall form an integral component of protected area management for conserving, protecting and restoring habitat for grassland reliant species and to prevent fragmentation of grassland habitats. Based on the findings of the present study, following recommendations for management of the grassland are made:

Patch mosaic burning technique

Patch mosaic burning technique is recommended for an efficient grassland management in RMNP. Ideally, some of the intact grassland areas having higher native species should be left unburned throughout the larger burned area, leaving nesting sites, alternative food sources, and refuge cover for wildlife.

Determining the best time to burn and fire line width

The early season burning (Nov-Dec) is more beneficial in terms of production response relative to mid (Jan –Feb) and late burning

(March-April) (Gillon 1983). As per Lehmkuhl, (1989) grasses burned in December or January was found to grow substantially by April, if unburned grasses follow a similar phenology, late-season fires would likely reduce production. Further, the timing of burn within a day and biomass available governs the impact of fire on grasslands. The midday in the late burning period (Mar- April) is the most harmful, where the time required for the spread of fire is the fastest compared to the early and mid-burning period (Lahkar 2008). Firebreak/firelines using mechanical method should be prepared along the area of interventions. The width of the fire line shall depend on the amount and type of vegetation present as well as the size of the grassland and as a rule of thumb, the fire line should be at least three times the height of adjacent vegetation (Hanselka 2006).

Clearing and Habitat enrichment

Mechanical removal method through slashing and uprooting of invasive species such as *Chromolaena odoratum* and trees with high coppicing growth after the burning operation should be carried immediately. The other invasive herb species which includes *Spermacoce latifolia, Lygodium japonicum* and *Mikania micrantha* should also be removed through uprooting as these species were found predominating in all the three blocks. Transplanting of native grass saplings from the unburned areas should be carried in addition to developing nursery for the grass species that will help in rehabilitating the grasslands.

Monitoring of ecological parameters and future research

The long-term assessment of biodiversity and primary productivity of grasslands shall be pivotal in planning, development, and adaptive management of grasslands based on sound ecological knowledge of the grassland ecosystem. Monitoring of invasive and grass species diversity is required periodically. Establishment of control plots will be imperative for a long-term ecological study on the impact of burning on the plant succession grassland dynamics, nutrient cycling, and soil development over time. The areas of intervention should be methodically assessed regularly from the onset of prescribed burning to habitat enrichment. Resource selection of grassland reliant wildlife species and inventory of small mammals, herpetofauna, and invertebrate groups in grasslands and their associations with grassland species assemblage could be studied to better manage the grasslands in RMNP.

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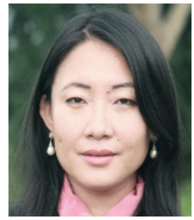

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