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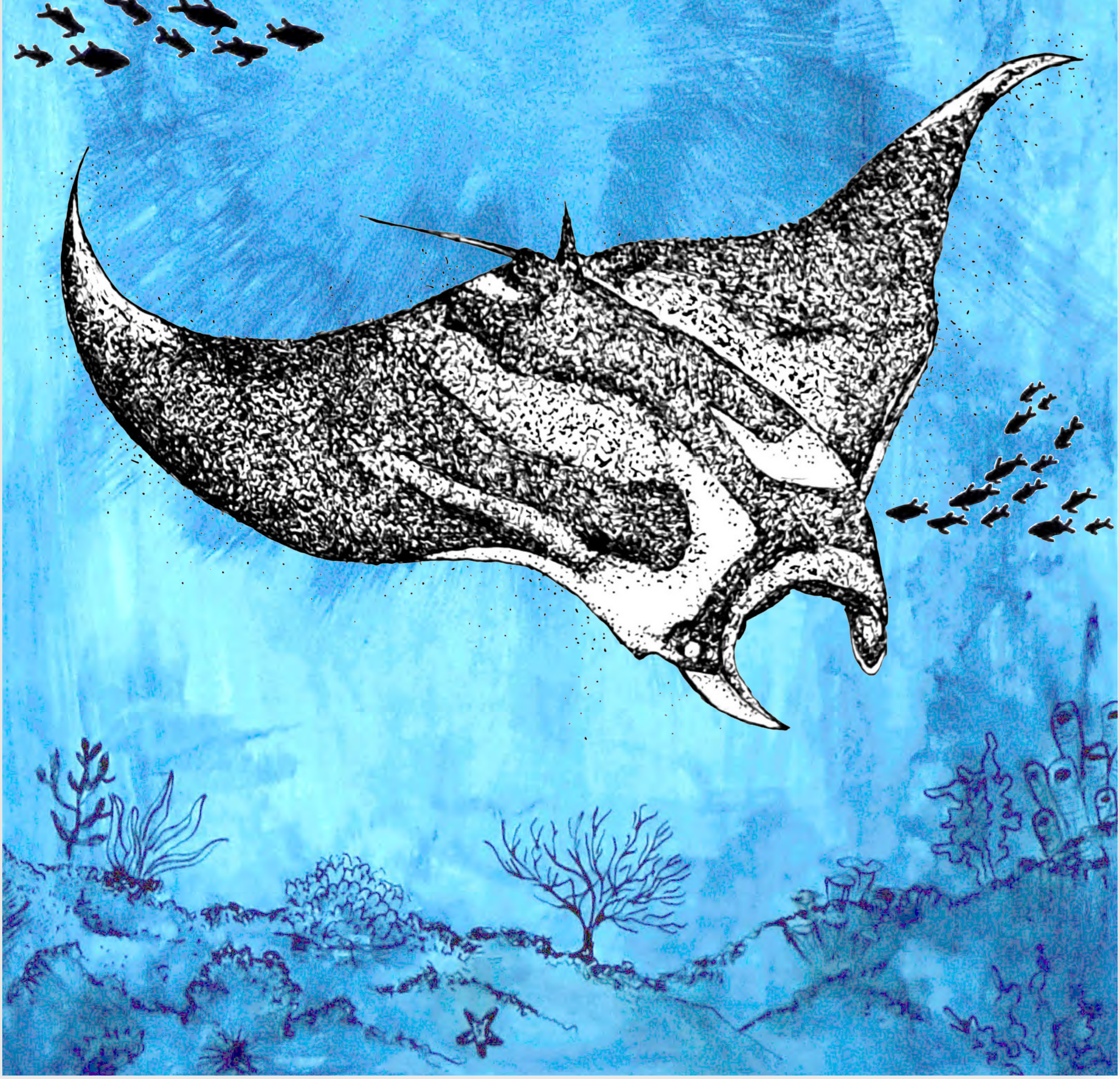

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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Giant Oceanic Manta Ray *Mobula birostris* in ink on acrylic wash by Elakshi Mahika Molur adapted from scientific illustration by Roger Hall.

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ARTICLE

Effect of ecological factors on the grass dynamics at Point Calimere Wildlife Sanctuary, India

Selvarasu Sathishkumar [1], Subhasish Arandhara [2] & Nagarajan Baskaran [3]

[1,2,3] Mammalian Biology Lab, Department of Zoology, A.V.C. College (Autonomous) (affiliated to Bharathidasan University, Tiruchirappalli), Mannampandal, Tamil Nadu 609305, India.
[1] ksathish605@gmail.com, [2] subhasisharandhara@gmail.com, [3] nagarajan.baskaran@gmail.com (corresponding author)

Abstract: Grass dynamics play a major role in the density and diversity of grazing mammals. To understand the drivers of grass quality and quantity, we assessed the height, cover, soft-texture, green leaves, and reproductive phase of grass species in relation to 13 ecological covariates belonging to climate, vegetation, human disturbance, and wild herbivores at Point Calimere Wildlife Sanctuary, southern India during November 2018–September 2020. From the 1,024 quadrates, we recorded 22 grass species and 10 sedges. The grass parameters varied significantly among habitats and between seasons. The grass height and grass cover were more in open scrub, while the soft-textured green grasses were more in grasslands. All the grass parameters except reproductive stage were highest during the wet season. The general linear model (GLM) based analysis on the covariate effect on grass quantity and quality demonstrated that among the 13 covariates compared, *Prosopis*, an alien invasive species, is the major driver, with negative influence on both grass quantity; the cover, and grass quality; soft-texture and greenness of grass. The feral horse, an alien invasive, negatively influenced grass height. Earlier studies have also shown the devastating effects of these exotics on native flora and fauna at Point Calimere, and measures suggested by these studies are recommended to safeguard natural communities in the area.

Keywords: Dry evergreen, grasslands, grass quality, greenness of grass, invasive threat, open scrub, soft-textured grass, southern India, species composition, Tamil Nadu.

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Author details: Selvarasu Sathishkumar is presently a PhD scholar in A.V.C. College (Autonomous), (affiliated to Bharathidasan University, Tiruchirappalli), Mayiladuthurai, Tamil Nadu, India. Subhasish Arandhara is presently a PhD scholar in A.V.C. College (Autonomous), (affiliated to Bharathidasan University, Tiruchirappalli), Mayiladuthurai, Tamil Nadu, India. Nagarajan Baskaran is an assistant professor at the Department of Zoology, A.V.C. College (Autonomous) since 2011. Worked as senior scientist at Asian Elephant Research & Conservation Centre, Centre for Ecological Sciences, Indian Institute of Science, Bangalore during 2002–2011. Research Interest: Studying the behavioural ecology of Wild Asian Elephants and their habitats in southern Indian, east-central Indian (Eastern & Western Ghats) and parts of northeastern India (eastern Himalaya), since 1990. Also studying other large mammals like antelopes, squirrels, sloth bears and assessing biodiversity and impact of developmental activities on conservation of biodiversity in India.

Author contributions: SS—data collection and analyses, draft preparation. SA—data collection, pruning, and analyses and draft preparation. NB—conceptualizing, supervising, data analyses, and final draft preparation.

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INTRODUCTION

In grassland environment grass phenology regulates the life cycles of grasses, which has a direct impact on biodiversity and trophic levels associated to herbivory (Auken 2009; Fischer et al. 2013). Phenology of grass species such as fledgling grass, soft shoots, soft, and green leaves determine herbivore nutrients (Hughes et al. 1993). Leaf length, leaf size, and spruce growth are unique features of each species (Ahsan et al. 2010; Huijser & Schmid 2011; Wang et al. 2011). The growth rate depends on the life cycle of the grass species. At the vegetative phase, cellulose and hemicellulose are present in large quantities for energy supply (Islam et al. 2003; Hussain & Durrani 2009). The budding, flowering, fruiting to seed dispersal stages are the reproductive phases (Sherry et al. 2011). Many factors, including rainfall, soil type, season, access to water, and the availability of open habitat play a role in determining the quantity and quality of grass that can grow (Ganskopp & Bohnert 2001; Sawyer et al. 2005; Hagenah et al. 2008; Hussain & Durrani 2009; Zeng et al. 2010).

Grasslands are significant global reservoirs of biodiversity and important food sources for herbivores (Jing et al. 2014; White et al. 2000; Bardgett et al. 2021). Natural grasslands are also vital to climate and water regulation, and to biogeochemical cycles like carbon balance, hence their degradation has serious consequences (White et al. 2000; O'Mara 2012; Cai et al. 2015). Natural grasslands cover regions with sufficient precipitation for grass to grow. Climatic, human-caused, and other environmental factors influence grasslands and alter grass phenology (Boval & Dixon 2012). Worldwide, grasslands have been disappearing for the greater part of a century (Egoh et al. 2016). In a short amount of time, grassland can be negatively affected by a shift in land use. Specifically, a major issue with grasslands is the growth and succession of forests (Liu et al. 2013).

This study focuses on the grass species of Point Calimere Wildlife Sanctuary, which acts as the major food source to the Blackbuck, an iconic species of the reserve, and other ungulates. Multiple pressures, from the invasion of *Prosopis* to over-grazing by cattle and feral horse on the grasslands habitat, would result in decline in grass biomass needed to support the Blackbuck population in the study area (Baskaran et al. 2016; Arandhara et al. 2020, 2021). Although grasses have wide ecological amplitude and several adaptations to withstand trampling, grazing, fire, food, and drought, they face severe competition for light and nutrients from aggressive wood species and invasive plants in tropical forests (Ashokkumar et al. 2021). This study assessed grass species parameters representing quantity: height & cover, and quality: grass soft-texture, green grass, & reproductive phase, across three habitats and two seasons between 2018–2020 to identify the ecological drivers of grass quantity and quality.

METHODS

Study area

The research was carried out at the Point Calimere Wildlife Sanctuary in Tamil Nadu, which is located between 10.30–79.85 ^{0}N and 10.35–79.42 ^{0}E at the confluence of the Bay of Bengal and the Palk Strait, near Nagapattinam (Figure 1). The reserve encompasses 30 km^2 of dry evergreen forest, grassland, open scrub, sandy coastline, salt marshes, and backwaters (Ali 2005). The grasses in the sanctuary's southernmost region cover 17% (4.49 km^2) of the total sanctuary area. The sanctuary's native and flagship species of Blackbuck live in grasslands that also serve as a foraging ground for other herbivores like feral horses, Chital, and domestic cattle. The average annual rainfall in Point Calimere is 1,366 mm, with temperatures ranging 23–37 ºC. The grasslands are especially vulnerable to invasion by *Prosopis juliflora*. Anthropogenic pressures on the sanctuary include firewood collection, fishing, and cattle grazing.

Data collection

Assessment of Grass dynamics and other variables: Data were collected between November 2018 and October 2020 covering two seasons (dry season: February–August and wet season: September–January) and three habitats (Dry evergreen, open scrub, and grasslands). The study area was overlaid with 1 km^2 grids and placed with a 1-km line transect at each grid. The grass availability and parameters were evaluated on a monthly interval. Four 1 m^2 quadrates were placed at 5 m intervals on the north, south, east, and west directions at every 250 m interval along these transects. Quadrates of this size have previously been widely used in studies of grass abundance (Menut & Ceaser 1979; Hacker 1984; Sivaganesan 1991). In total, 1,024 quadrates were laid (dry evergreen—453, open scrub—272, and grasslands—299) (Image 1). All grass dynamic parameters were recorded in each quadrat following methods described in Table 1 Grass specimens were collected and preserved in order to create herbariums for each grass species for species identification and confirmation (Rangel et al. 1999; Shaw 2008; Shankar & Shashikala 2010). The vouchered

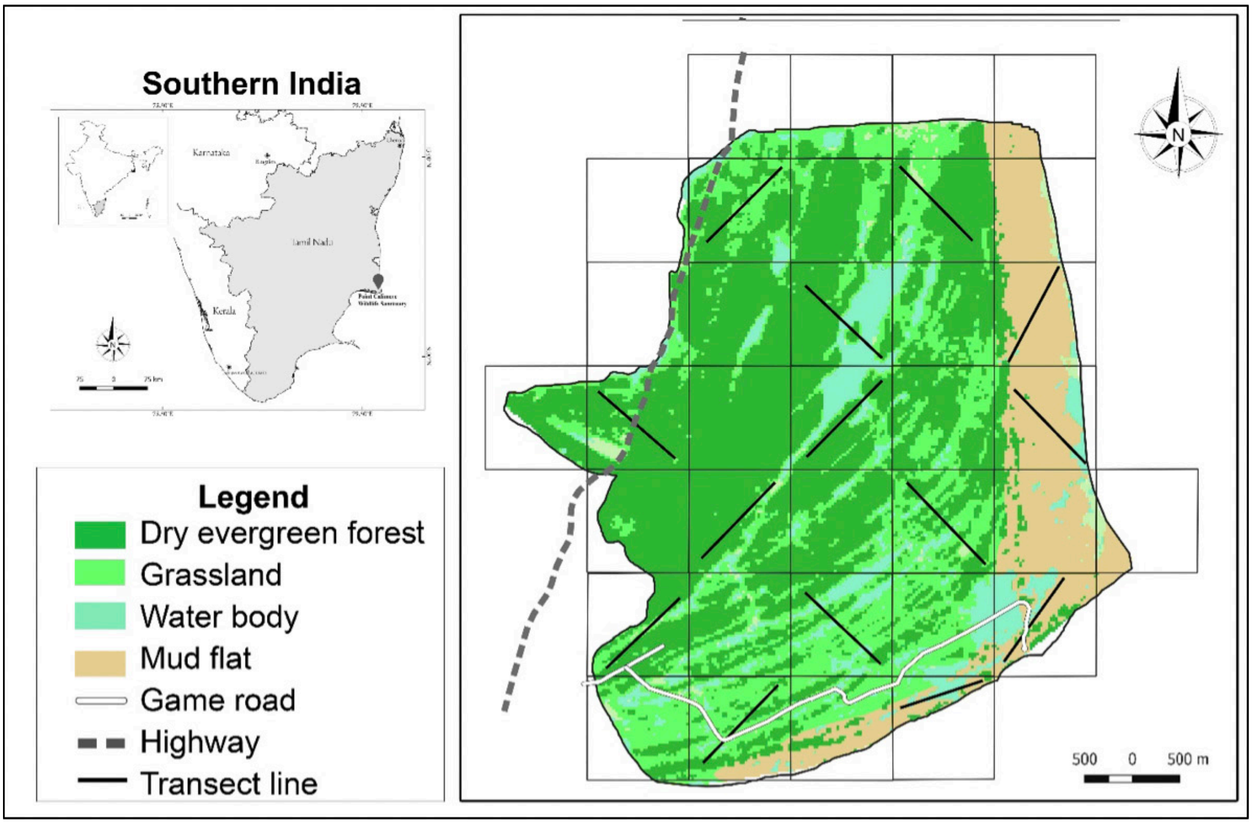

Figure 1. Map showing the study area at Point Calimere Wildlife Sanctuary, India.

Image 1. Grassland at Point Calimere Wildlife Sanctuary, India.

herbarium was deposited at mammalian biology lab, department of Zoology in A.V.C. College (Autonomous).

Data analysis

Statistical analysis: Prior to performing a detailed analysis, the compiled data were examined for normality and variance homogeneity. The Kolmogorov-Smirnov (KS) test used on grass parameter such as, height (KS: 0.35; p = <0.05), cover (KS: 0.19; p = <0.05), soft texture (KS: 0.23; p = <0.05), green leaves (KS: 0.16; p = <0.05), and reproductive phase (KS: 0.37; p = <0.05) of grass species was neither normal, nor could be transformed to normal with four different transformations (Arsin, Log10 (LG10), Inverse log, and Exponential). Therefore, the difference in the selection of this species between seasons were tested using non-parametric Mann-Whitney U-test and Kruskal-Wallis H test. SPSS V.23 software package was used for the statistical test and the general linear model (GLM) was used to identify the covariates influencing on grass dynamics characteristics and all parameter models were ranked by their small-sample Akaike information criterion (AICc) and inferences were taken from models with ΔAICc ≤ 2. However, in results are comprehensively shows that top two models of lowest ΔAICc. Model comparison were calculated by the *R* package 'MuMIn' (Barton et al. 2018) by in R Library, in R Software Version 3.3.3 (R Core Team 2019). This model was ranked first due to lowest AIC. Also, the proportion of the total predictive power found in the model was sorted to be the highest at weight value. The analysis was carried out for each grass parameter separately.

RESULTS

In total, the study identified 22 grass species and 10 species of sedges at Point Calimere (Table 2). The grass species dominated the stand in all parameters studied compared to sedges. *Aeluropus lagopoides* had the highest mean height, percentage of cover, soft texture, and green leaves. *Chloris barbata* had the highest percentage of reproductive phase. *Dactyloctenium aegyptium* was the second highest in terms of cover, soft texture green leaves, followed by *Cyperus compressus*.

Variation in grass parameters between season and among habitats

The grass parameters varied significantly among the three habitats: grassland, open-scrub, and dry evergreen. Among the five grass parameters, grass height, percentage cover, and reproductive phase were significantly more in open-scrub followed by grasslands and dry evergreen (Figure 2). On the other hand, soft-textured grass and green leaves were significantly higher in grasslands than the other two habitats. In relation to season, grass height, percentage cover, soft texture, and green leaves were significantly higher in the wet compared to dry season. While the reproductive stage was significantly higher during dry compared to wet season (Table 3).

Influence of covariates on grass parameter - GLM Model

Grass height: GLM to test the influence of covariates on grass height showed a model with covariates viz feral-horse density, *P. juliflora* cover, rainfall, spotted deer density, shrub % cover, and distance from water bodies turned out as the best model with lower delta AIC and higher weightage, influencing the grass height (Table 4). However, the covariates, viz., feral-horse with negative influence and rainfall with positive influence were alone turned out to be the significant predictors of grass height (Table 5).

Grass cover: Although the GLM showed that covariates with feral-horse density, grasslands, *P. juliflora* cover, rainfall and distance from water bodies entered as the best model with lower delta AIC and higher weightage influencing the grass cover (Table 4), covariates, viz., feral-horse, P. *juliflora* cover, distance from water with negative influence, and rainfall and wet season with positive influence turned out to be the significant predictors of grass cover (Table 5).

Grass soft-texture: A model with open habitat, *P. juliflora* density, rainfall and distance from shade entered as the best model with lower delta AIC and higher weightage influenced the soft-texture of grass (Table 4). Interestingly, all the four covariates had significant effect on the soft-texture with rainfall, open habitat, and distance from shade were having positive influence, while the *P. juliflora* density had negative influence (Table 5).

Grass green leaves: Although a model with blackbuck density, open habitat, *P. juliflora* density, and rainfall entered as the best model with lower delta AIC and higher weightage influencing the green leaves availability (Table 4), covariates, viz., density of *P. juliflora* and blackbuck with negative effect and open habitat with positive effect were alone significantly influencing the percentage of green leaves in the grass species (Table 5).

Grass reproductive phase: Although a model with covariates such as feral-horse density, open habitat extent, P. *juliflora* density, and rainfall entered as the

Table 1. Details of grass dynamics parameters and covariates sampled at Point Calimere Wildlife Sanctuary, India.

	Grass dynamics parameters	Description
Dependent variables		
1	Grass height (cm)	Grass height was measured using a measuring scale, from the ground level to the highest leaf blade bend, at five points (one each at four corners and one at the center) of the quadrate.
2	Grass cover/m^2	Assessed visually assuming 100% for the entire quadrat and estimating the proportion of area within a quadrat covered by each grass.
3	Soft texture (%)	Examined crushing the leaves by hands, if leaf's structure could be squashed into a ball—proportion of such leaves for a given grass species in quadrat was rated in % rating.
4	Green leaves (%)	Assessed visually quantifying the proportion of leaves in a given species with green grass, assuming 100% for all the leaves of the same species.
5	Reproductive phase (%)	Evaluated visually quantifying the proportion of a given grass with flowers and fruits in % rating.
Covariates		
6	Open habitat extent (km^2)	At every plot laid, habitat visibility on all four directions of north, south, east, and west.
7	Distance to water (m)	Measured as the distance from a given quadrate to the water source using a rangefinder or obtained from land-use land-cover map.
8	Distance to shade (m)	Measured as the distance from a given quadrat to the nearest canopy cover area using a rangefinder.
9	Distance to road (m)	Measured as the distance from a given quadrat location to the nearest road or obtained from land-use land-cover map.
10	Ambient temperature (°C)	Measured using a generic digital thermometer-cum-hygrometer device (model: HT01) at each observation at the feeding site.
11	Humidity (Relative %)	As described above.
12	Weather	Recorded visually as cloudy or sunny weather at the start of each feeding site examination.
13	Rainfall (mm)	Rainfall data arrived from the secondary sources (https://www.soda-pro.com/web-services/meteo-data/merra)
14	*Prosopis juliflora* cover/25 m^2	*Prosopis* density were arrived from 5 x 5 m quadrates in the study area
15	*Prosopis juliflora* density/25 m^2	*Prosopis* cover were obtained from 5 x 5 m quadrates in the study area
16	Blackbuck density	Density was obtained by the line transect survey method in the study area.
17	Feral horse density	As described above
18	Chital density	As described above.

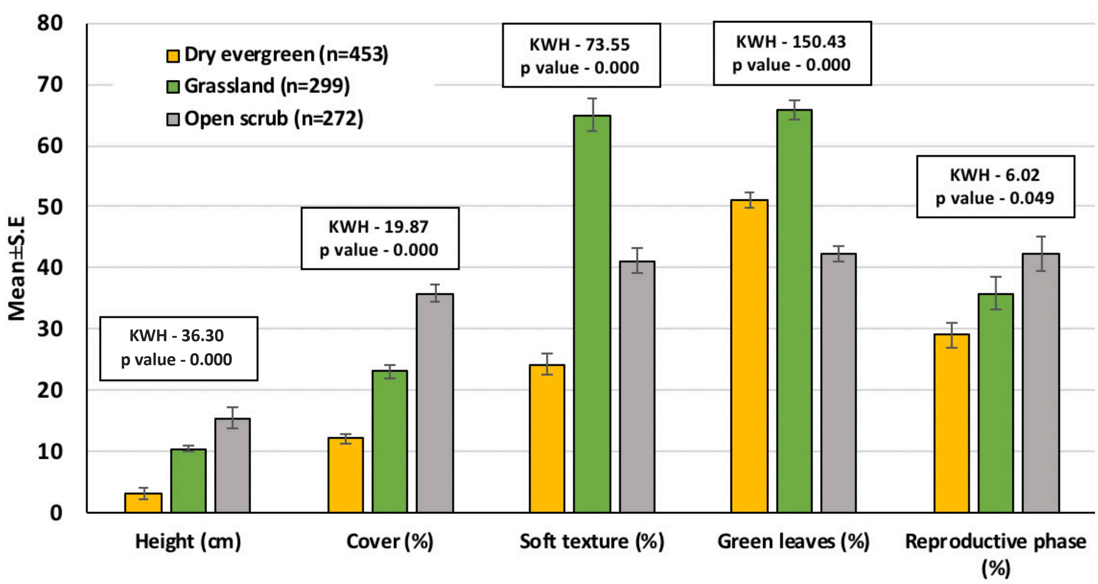

Figure 2. Variation in grass dynamics parameters among the habitats at Point Calimere Wildlife Sanctuary, India.

best model with lower delta AIC and higher weightage influencing the reproductive phase of the grass (Table 4), covariates, viz., *P. juliflora* density and open-scrub with positive effect and rainfall with negative effect had significant influence on the amount of grass reproductive phase (Table 5).

Table 2. Overall list of grass and sedge species and their parameter recorded at Point Calimere Wildlife Sanctuary, India.

	Grass and sedge species	Height (cm)	Cover (%)	Soft texture (%)	Green leaves (%)	Reproductive phase (%)
Grasses						
1	*Aeluropus lagopoides* (L.)	**13.2 ± 0.9**	**20.3 ± 1.5**	**20.3 ± 1.5**	**20.4 ± 1.5**	6.1 ± 0.4
2	*Aristida adscensionis* (L.)	1.0 ± 0.4	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.3 ± 0.1
3	*Aristida setacea* (Retz.)	1.4 ± 0.4	1.3 ± 0.4	1.3 ± 0.4	1.2 ± 0.4	0.0 ± 0.0
4	*Brachiaria ramosa* (L.) Stapf.	2.4 ± 0.4	3.8 ± 0.6	3.8 ± 0.6	3.8 ± 0.6	1.3 ± 0.2
5	*Cenchrus ciliaris* (L.)	1.5 ± 0.6	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	1.4 ± 0.6
6	*Chloris barbata* Sw.	**10.6 ± 1.2**	7.6 ± 0.9	7.5 ± 0.9	7.4 ± 0.9	**13.0 ± 1.5**
7	*Chrysopogon aciculatus* (Retz.) Trin.	4.8 ± 1.1	1.7 ± 0.4	1.7 ± 0.4	1.7 ± 0.4	4.6 ± 1.1
8	*Chrysopogon fulvus (Spreng.) Chiov.*	2.6 ± 0.8	1.1 ± 0.3	1.1 ± 0.3	1.0 ± 0.3	2.9 ± 0.9
9	*Cynodon dactylon* (L.) Pers.	0.1 ± 0.1	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.2
10	*Cyrtococum trigonum* (Retz.) A.Camus	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.3	0.6 ± 0.3
11	*Dactyloctenium aegyptium* (L.) Willd.	5.8 ± 0.5	**12.4 ± 1.2**	**12.6 ± 1.2**	**12.8 ± 1.2**	**12.2 ± 1.1**
12	*Dichanthium annulatum* (Forssk.) Stapf	3.6 ± 1.1	1.1 ± 0.3	1.1 ± 0.3	1.1 ± 0.3	0.6 ± 0.2
13	*Digitaria longiflora* (Retz.) Pers.	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.4	1.3 ± 0.4	1.9 ± 0.5
14	*Eragrostiella bifaria* (Vahl) Bor.	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.9 ± 0.4
15	*Eriochloa procera* (Retz.) C.E.Hubb.	0.7 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.9 ± 0.3
16	*Hemarthria compressa* (L.f.) R.Br.	0.6 ± 0.4	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2
17	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	2.7 ± 1.3	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.1
18	*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs, 2003	1.9 ± 0.8	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.6 ± 0.2
19	*Oplismenus composites* (L.) P. Beauv.	1.9 ± 0.5	1.6 ± 0.4	1.5 ± 0.4	1.5 ± 0.4	3.1 ± 0.8
20	*Paspalum paspaloides* (L.)	1.3 ± 0.6	0.5 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	0.0 ± 0.0
21	*Perotis indica* (L.)	**10.0 ± 1.6**	4.1 ± 0.7	4.0 ± 0.7	4.0 ± 0.6	9.0 ± 1.5
22	*Trachys muricata* (L.) Pers.	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3
Sedges						
23	*Bulbostylis barbata* (Rottb.) C.B.Clarke	2.9 ± 0.5	3.8 ± 0.6	3.8 ± 0.6	3.8 ± 0.6	6.2 ± 1.0
24	*Cyperus compressus* (L.)	5.5 ± 0.6	**10.2 ± 1.0**	**10.2 ± 1.0**	**10.1 ± 1.0**	5.6 ± 0.6
25	*Cyperus kyllingia* (L.)	1.8 ± 0.3	3.3 ± 0.6	3.4 ± 0.6	3.4 ± 0.6	1.2 ± 0.2
26	*Cyperus polystachyos* Rottb.	2.4 ± 0.4	3.3 ± 0.6	3.2 ± 0.6	3.2 ± 0.6	2.5 ± 0.4
27	*Cyperus rotundus* (L.)	0.9 ± 0.3	1.3 ± 0.4	1.4 ± 0.4	1.4 ± 0.4	0.3 ± 0.1
28	*Cyperus squarrosus* (L.)	1.2 ± 0.3	1.8 ± 0.4	1.8 ± 0.4	1.8 ± 0.4	0.6 ± 0.1
29	*Fimbristylis cymosa* R.Br.	8.9 ± 1.1	6.9 ± 0.8	7.0 ± 0.9	7.0 ± 0.9	**11.3 ± 1.4**
30	*Fimbristylis ovata* (Burm.f.) J.Kern	0.3 ± 0.1	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3
31	*Fimbristylis triflora* (L.) K.Schum.	3.0 ± 0.6	2.2 ± 0.5	2.2 ± 0.5	2.2 ± 0.5	4.6 ± 1.0
32	*Kyllinga nemoralis* (J.R.Forst. & G.Forst.) Dandy ex Hutch. & Dalziel	4.9 ± 0.7	4.9 ± 0.7	4.9 ± 0.7	5.0 ± 0.7	6.8 ± 1.0

DISCUSSION

This study observed 22 species of grasses and 10 sedges in the study area, similar to what Arandhara et al. (2021) and Frank et al. (2021) reported for the same area. On the basis of cover, species such as *A. lagopoides*, *D. aegyptium,* and *C. compressus* are the three dominant grasses recorded in the coastal habitats, open-scrub, and dry-evergreen in this study. These findings also support earlier studies elsewhere for *A. lagopoides* (Khan & Gulzar 2003; Ahmed et al. 2013), *D. aegyptium* (Rojas-Sandoval 2016), and *C. compressus* (Ravi & Mohanan 2002; Bryson & Carter 2008).

Table 3. Seasonal variation among the grass parameter at Point Calimere Wildlife Sanctuary, India.

Grass dynamics parameters	Wet season (n = 592)	Dry season (n = 432)	Mann-Whitney U	p
Height (cm)	13.4 ± 1.43	10.1 ± 0.26	17224	0.000
Cover (%)	24.7 ± 0.78	21.6 ± 0.89	40389	0.000
Soft texture (%)	67.1 ± 1.75	47.6 ± 1.58	24379	0.000
Green leaves (%)	75.7 ± 0.80	37.6 ± 0.82	69701	0.000
Reproductive phase (%)	36.4 ± 1.82	43.5 ± 2.24	31091	0.001

Table 4. Top two best models extracted from GLM to characterize relationship among the grass parameter and the covariates sorted according to AIC.

Dependent variables	Model	df	Log *L*	AICc	ΔAICc	weight
Grass height (cm)	Feral-horse density + *Prosopis juliflora* cover + rainfall + Spotted deer density + Shrub percentage cover + Distance from water bodies	5	-3258	6527	0.00	0.099
	Feral-horse density + Spotted deer density + Shrub percentage cover	4	-3259	6527	0.20	0.090
Grass cover (%)	Feral-horse density + Grassland habitat + *Prosopis juliflora* cover + rainfall + Distance from water bodies	8	-4544	9105	0.00	0.091
	Feral-horse density + Grassland habitat + *Prosopis juliflora* cover + rainfall + Shrub percentage cover + Distance from water bodies	9	-4543	9106	0.28	0.079
Grass soft texture (%)	Open habitat availability+ *Prosopis juliflora* density + rainfall + Distance from shade	5	-4995	10001	0.00	0.996
	Open habitat availability+ *Prosopis juliflora* density + rainfall	4	-5002	10013	1.51	0.002
Grass green leaves (%)	Blackbuck density + Open habitat availability + *Prosopis juliflora* density + rainfall	6	-5496	11004	0.00	0.650
	Blackbuck density + Open habitat availability + *Prosopis juliflora* density	5	-5498	11006	1.60	0.292
Grass reproductive phase (%)	*Prosopis juliflora* cover + rainfall + Open-scrub	5	-4965	11098	0.00	0.880
	Prosopis juliflora cover + rainfall + Open-scrub	4	-4910	11088	1.04	0.652

Independent factors influencing the grass parameters

Rainfall, wet season, open habitat availability, distance from shade, and open-scrub habitat all had a positive impact on the grass parameters measured at Point Calimere. In contrast, *Prosopis juliflora*, the density of feral horse and Blackbuck, and the distance from water negatively influenced the grass parameters studied.

Predictors of grass height

The density of feral horses, a non-ruminant bulk feeder (Arandhara et al. 2020), had the greatest negative effect on grass height among the 13 covariates compared. According to Maron & Crone (2006), the effects of herbivory on grassland are more severe than those on woodland. Rainfall, widely regarded as the most effective factor in promoting plant growth, was a major predictor influencing positively on height of the grass species (Derner & Hart 2007; Parton et al. 2012). Increased rainfall during the growing season has been shown to improve soil water use, which in turn promotes healthy root development and grasses as well as other plant growth (Wan et al. 2002).

Predictors of grass cover

The study showed that percentage of grass cover decreased with feral horse density, *P. juliflora* cover and distance from the waterbody. The feral-horse is a large herbivore with predominant grazing nature and a bulk-feeder (Baskaran et al. 2019; Arandhara et al. 2020). Their intensive grazing pressure is thus negatively influencing the grass cover, as grazing mostly occurs during the growing season (Hao & He 2019). In this study, a decrease in grass cover was observed with the *Prosopis* cover. *Prosopis* is an alien invasive species at Point Calimere, which grow taller and tap the sunlight at canopy level. Sunlight is an essential factor for the photosynthesis of all plants including grass species and thus the increase in *Prosopis* cover reduces the intensity of sunlight available to the grass species found at the ground level. Therefore, grass cover decreased with *Prosopis* cover (Baskaran et al. 2019; Murugan et al. 2019; Arandhara et al. 2021). Like the sunlight, soil nutrient, soil moisture is also another important factor influences the plant growth and productivity and moisture in the soil is required during the wet season to promote CO_2 absorption and plant growth (Morgan et al. 2016). Therefore, the grass

Table 5. The best model showing the relationship between each grass variable and the significant covariates.

Dependent variable	Covariate	Estimate ± S.E.	z value	Pr(>|z|)
Grass height (cm)	(Intercept)	10.6 ± 0.59	17.95	0.000
	Feral horse density	-0.0 ± 0.01	3.28	0.001
	Rainfall	0.1 ± 0.00	0.64	0.022
Grass cover (%)	(Intercept)	42.2 ± 0.02	251.41	0.000
	Feral horse density	-0.0 ± 0.00	11.40	0.000
	P. juliflora cover	-0.0 ± 0.01	14.65	0.000
	Rainfall	0.0 ± 0.02	3.21	0.001
	Wet season	0.1 ± 0.01	4.28	0.000
	Distance from water	-0.0 ± 0.02	2.80	0.005
Grass soft texture (%)	(Intercept)	4.0 ± 1.79	223.28	0.000
	Rainfall	0.0 ± 0.02	4.97	0.000
	P. juliflora density	-1.1 ± 0.12	-9.70	0.000
	Open habitat availability	0.0 ± 0.02	3.83	0.000
	Distance from shade	0.0 ± 0.02	-3.80	0.000
Grass green leaves (%)	(Intercept)	4.0 ± 0.02	223.64	0.000
	Rainfall	0.0 ± 0.02	4.16	0.000
	P. juliflora density	-1.0 ± 0.12	-8.62	0.000
	Open habitat availability	0.0 ± 0.02	3.52	0.000
	Blackbuck density	-512 ± 179.3	-2.86	0.004
Grass reproductive phase (%)	(Intercept)	39.4 ± 5.29	7.44	0.000
	P. juliflora cover	0.82 ± 0.33	2.46	0.013
	Rainfall	-0.10 ± 0.01	-6.25	0.000
	Open scrub	1.8 ± 0.89	0.04	0.048

cover increased significantly with rainfall and during wet season compared to dry season as reported elsewhere (Wan et al. 2002; Zhang et al. 2020; Xu et al. 2021). Since soil moisture decreases with increase in distance from waterbody, the grass cover decreased significantly with distance from the waterbody.

Predictors of soft-texture and green grass

The study showed that grass soft-texture increased with rainfall, open habitat, and distance from the shade, but it decreased with *Prosopis* density. Similarly, the green grass availability increased with rainfall, and open habitat, but it decreased with *Prosopis* and blackbuck densities. Studies have shown that rainfall by increasing the soil moisture, triggering the growth of fresh, and green grasses (Hermance et al. 2015; Moore et al. 2015; Morgan et al. 2016; Post & Knapp 2020). The fact that fresh grown plants parts are softer than the old-grown parts due to low fiber and cellulose content (de Jong 1995; Treydte et al. 2011; Kunwar et al. 2016). Thus, rainfall increases significantly both soft-texture and green leaves of grasses. The open habitat provides the ideal sunlight intensity and temperature for promoting photosynthesis in grass species (Solofondranohatra et al. 2018) and thus the soft-textured green grasses increased significantly with extent of open habitats. In contrast, with increase in *Prosopis* density, which exploits both sunlight at canopy level and the available soil moisture more efficiently (Shiferaw et al. 2021), reduces the soft-texture and greenness of the grass species through reduced growth. The negative effect of shade on grass soft-texture also follows the above concept as explained for *Prosopis*. Blackbucks are a species of ruminant that is known for eating the tips of young, tender grass leaves, which are richer nutrients and water content (Jhala 1997; Baskaran et al. 2016) and thus green grass availability decreases with the density of blackbucks.

Predictors of grass reproductive phase

The study shows that the grass species reproductive phase increased with *P. juliflora* cover and open-scrub. As stated in earlier studies that the open-scrub predominantly with woody plants that are typically less than 3 m tall and relatively open, offers excellent support for grasses and plants that are shorter than them (Wardle 1971; Solofondranohatra et al. 2018). Likewise, *P. juliflora* is the most common woody plant in open-scrub at Point Calimere (Arandhara et al. 2021). Since, grazers are unable to access the grass species found between and beneath the bushes, the grazing intensity is lower in open-scrub compared to grasslands. Thus, the grass species with less grazing pressure in the open-scrub or with more density of *Prosopis*, with better growth as found in this study, had more reproductive phases than that of in grasslands. These findings are similar to earlier study that states the grass species in the open-scrub were shielded from overgrazing (Popay & Field 1996). As a result, the grass species reaches its maximum potential for growth and reproduction. As the mean annual precipitation across space increased, flowering time pushed back for most grass species, as documented by Munson & Long (2017).

CONCLUSIONS AND RECOMMENDATIONS

Point Calimere supports grasses and sedges which provide ideal food sources for mammalian grazing communities. Both grass species quantity and quality varied among habitats and between seasons. Among the 13 covariates compared, *Prosopis*, an alien invasive species, is the major driver that negatively influences on both grass quantity and quality. The feral horse, an alien invasive, negatively affected grass height. The devastating effect of these exotics on native flora and fauna at Point Calimere have been already documented by various studies (Ali 2005; Baskaran et al. 2019; Arandhara et al. 2020, 2021). Thus, to safeguard the natural communities of plants and animals of Point Calimere, effective measures are needed as suggested by earlier studies.

REFERENCES

Ahmed, M.Z., T. Shimazaki, S. Gulzar, A. Kikuchi, B. Gul, M.A. Khan, H.W. Koyro, B, Huchzermeyer & K.N. Watanabe (2013). The influence of genes regulating transmembrane transport of Na+ on the salt resistance of *Aeluropus lagopoides*. *Functional Plant Biology* 40(9): 860–871.

Ahsan, N., T. Donnart, M.Z. Nouri & S. Komatsu (2010). Tissue-specific defense and thermo-adaptive mechanisms of soybean seedlings under heat stress revealed by proteomic approach. *Journal of Proteome Research* 9(8): 4189–4204.

Ali, R. (2005). Field studies for the conservation and management of Point Calimere Complex. Foundation for ecological research, advocacy and learning. A Report for the Tamil Nadu Forest Department, 40 pp.

Arandhara, S., S. Sathishkumar & N. Baskaran (2020). Modelling the effect of covariates on the detectability and density of native Blackbucks and invasive feral-horse using multiple covariate distance sampling at Point Calimere Wildlife Sanctuary, Southern India. *Mammalian Biology* 100(2): 173–186.

Arandhara, S., S. Sathishkumar, S. Gupta & N. Baskaran (2021). Influence of invasive *Prosopis juliflora* on the distribution and ecology of native blackbuck in protected areas of Tamil Nadu, India. *European Journal of Wildlife Research* 67(3): 1–16.

Ashokkumar, M., S. Swaminathan & R. Nagarajan (2021). Grass species composition in tropical forest of southern India. *Journal of Threatened Taxa* 13(12): 19702–19713. https://doi.org/10.11609/jott.7296.13.12.19702-19713

Auken, O.W. (2009). Causes and consequences of woody plant encroachment into western North American grasslands. *Journal of Environmental Management* 90(10): 2931–2942.

Bardgett, R.D., J.M. Bullock, S. Lavorel, P. Manning, U. Schaffner, N. Ostle, M. Chomel, G. Durigan, L. Fry, D. Johnson & J.M. Lavallee (2021). Combatting global grassland degradation. *Nature Reviews Earth & Environment* 2(10): 720–735.

Barton, H., G. Mutri, E. Hill, L. Farr & G. Barker (2018). Use of grass seed resources c. 31 ka by modern humans at the Haua Fteah cave, northeast Libya. *Journal of Archaeological Science* 99: 99–111.

Baskaran, N., K. Ramkumaran & G. Karthikeyan (2016). Spatial and dietary overlap between blackbuck (*Antilope cervicapra*) and feral horse (*Equus caballus*) at Point Calimere Wildlife Sanctuary, southern India: Competition between native versus introduced species. *Mammalian Biology* 81(3): 295–302.

Baskaran, N., S. Arandhara, S. Sathishkumar & S. Gupta (2019). Assessing the changes in land use and land cover by invasive species and its influence on native flora & ungulates in selected protected areas of Tamil Nadu, India using GIS and remote sensing. Technical report submitted to SERB, Government of India.

Boval, M & R.M. Dixon (2012). The importance of grasslands for animal production and other functions: A review on management and methodological progress in the tropics. *Animal* 6(5): 748–762.

Bryson, C.T. & R. Carter (2008). The significance of Cyperaceae as Weeds, pp. 15–102. In: Naczi, R.F.C. & B.A. Ford (eds.). *Sedges: Uses, Diversity, and Systematics of the Cyperaceae, 1st ed*. Missouri Botanical Garden Press, 298 pp.

Cai, H., X. Yang & X. Xu (2015). Human-induced grassland degradation/restoration in the central Tibetan Plateau: the effects of ecological protection and restoration projects. *Ecological Engineering* 83: 112–119.

De Jong, T.J. (1995). Why fast-growing plants do not bother about defence. *Oikos* 74(3): 545–548.

Derner, J.D. & R.H. Hart (2007). Grazing-induced modifications to peak standing crop in northern mixed-grass prairie. *Rangeland Ecology & Management* 60(3): 270–276.

Egoh, B.N., J. Bengtsson, R. Lindborg, J.M. Bullock, A.P. Dixon & M. Rouget (2016). The importance of grasslands in providing ecosystem services: opportunities for poverty alleviation, pp. 421–441. In: Routledge handbook of ecosystem services, Routledge.

Fischer, L.K., M. von der Lippe & I. Kowarik (2013). Urban grassland restoration: which plant traits make desired species successful colonizers*? Applied Vegetation Science* 16(2): 272–285.

Frank, S.J.D., G.V. Gopi, K. Sankar & S.A. Hussain (2021). Dry season resource selection among sympatric ungulates in a tropical coastal landscape: implications for conservation and management. *Tropical Ecology* 62(3): 418–426.

Ganskopp, D & D. Bohnert (2001). Nutritional dynamics of 7 northern Great Basin grasses. *Rangeland Ecology & Management/Journal of Range Management Archives* 54(6): 640–647.

Hacker, J.B. (1984). Genetic variation in seed dormancy in *Digitaria milanjiana* in relation to rainfall at the collection site. *Journal of Applied Ecology* 21: 947–959.

Hagenah, N., H. Munkert, K. Gerhardt & H. Olff (2008). Interacting effects of grass height and herbivores on the establishment of an encroaching savanna shrub, pp. 189–202. In: Valk, A.K. (ed.). Herbaceous Plant Ecology. Recent Advances in Plant Ecology.

Springer, 367+VII pp. https://doi.org/10.1007/978-90-481-2798-6

Hao, Y. & Z. He (2019). Effects of grazing patterns on grassland biomass and soil environments in China: A meta-analysis. *PloS One* 14(4): p.e0215223. https://doi.org/10.1371/journal.pone.0215223

Hermance, J.F., D.J. Augustine & J.D. Derner (2015). Quantifying characteristic growth dynamics in a semi-arid grassland ecosystem by predicting short-term NDVI phenology from daily rainfall: a simple four parameter coupled-reservoir model. *International Journal of Remote Sensing* 36(22): 5637–5663.

Hughes, L., M. Westoby & A.D. Johnson (1993). Nutrient costs of vertebrate-and ant-dispersed fruits. *Functional Ecology* 54-62 pp.

Huijser, P. & M. Schmid (2011). The control of developmental phase transitions in plants. *Development* 138(19): 4117–4129.

Hussain, F. & M.J. Durrani (2009). Nutritional evaluation of some forage plants from Harboi rangeland, Kalat, Pakistan. *Pakistan Journal of Botany* 41(3): 1137–1154.

Islam, M.R., C.K. Saha, N.R. Sharkar, M. Jahilil & M. Hasanuzzamam (2003). Effect of variety on proportion of botanical fraction and nutritive value of different Napier grass (*Pennisetum puporeum*) and relationship between botanical fraction and nutritive value. *Asian-Australasian Journal of Animal Sciences* 16: 177–188.

Jhala, Y.V. (1997). Seasonal effects on the nutritional ecology of blackbuck Antelope cervicapra. *Journal of Applied Ecology* 34(6): 1348–1358.

Jing, Z., J. Cheng, J. Su, Y. Bai & J. Jin (2014). Changes in plant community composition and soil properties under 3-decade grazing exclusion in semiarid grassland. *Ecological Engineering* 64: 171–178.

Khan, M.A. & S. Gulzar (2003). Light, salinity and temperature effects on the seed germination of perennial grasses. *American Journal of Botany* 90: 131–134.

Kunwar, A., R. Gaire, K.P. Pokharel, S. Baral & T.B. Thapa (2016). Diet of the four-horned antelope *Tetracerus quadricornis* (De Blainville, 1816) in the Churia hills of Nepal. *Journal of Threatened Taxa* 8(5): 8745–8755. https://doi.org/10.11609/jott.1818.8.5.8745-8755

Liu, L., S. Bestel, J. Shi, Y. Song & X. Chen (2013). Paleolithic human exploitation of plant foods during the last glacial maximum in North China. *Proceedings of the National Academy of Sciences* 110(14): 5380–5385.

Maron, J.L. & E. Crone (2006). Herbivory: effects on plant abundance, distribution and population growth. *Proceedings of the Royal Society B: Biological Sciences* 273(1601): 2575–2584.

Moore, L.M., W.K. Lauenroth, D.M. Bell & D.R. Schlaepfer (2015). Soil water and temperature explain canopy phenology and onset of spring in a semiarid steppe. *Great Plains Research* 25(2): 121–138.

Morgan, J.A., W. Parton, J.D. Derner, T.G. Gilmanov & D.P. Smith (2016). Importance of early season conditions and grazing on carbon dioxide fluxes in Colorado shortgrass steppe. *Rangeland Ecology & Management* 69(5): 342–350.

Morgan, J.W., J.M. Dwyer, J.N. Price, S.M. Prober, S.A. Power, J. Firn, J.L. Moore, G.M. Wardle, E.W. Seabloom, E.T. Borer & J.S Camac (2016). Species origin affects the rate of response to inter-annual growing season precipitation and nutrient addition in four Australian native grasslands. *Journal of Vegetation Science* 27(6): 1164–1176.

Munson, S.M. & A.L. Long (2017). Climate drives shifts in grass reproductive phenology across the western USA. *New Phytologist* 213(4): 1945–1955.

Murugan, R., I. Djukic, K. Keiblinger, F. Zehetner, M. Bierbaumer, S. Zechmeister-Bolternstern & R.G. Joergernsen (2019). Spatial distribution of microbial biomass and residues across soil aggregate fractions at different elevations in the Central Austrian Alps. *Geoderma* 339: 1–8.

O'Mara, F.P. (2012). The role of grasslands in food security and climate change. *Annals of Botany* 110(6): 1263–1270.

Parton, W., J. Morgan, D. Smith, S. Del Grosso, L. Prihodko, D. LeCain, R. Kelly & S. Lutz (2012). Impact of precipitation dynamics on net ecosystem productivity. *Global Change Biology* 18(3): 915–927.

Popay, I. & R. Field (1996). Grazing animals as weed control agents. *Weed Technology* 10(1): 217–231.

Post, A.K. & A.K. Knapp (2020). The importance of extreme rainfall events and their timing in a semi-arid grassland. *Journal of Ecology* 108(6): 2431–2443.

Rangel, A.A., D.D. Rockemann, F.M. Hetrick & S.K. Samal (1999). Identification of grass carp haemorrhage virus as a new genogroup of aquareovirus. *Journal of General Virology* 80(9): 2399–2402.

Ravi, N. & N. Mohanan (2002). Common Tropical and Sub-tropical Sedges and Grasses. *Science Publishers*, Inc., Enfield, New Hampshire

Rojas-Sandoval, J. (2016). *Dactyloctenium aegyptium* (crowfoot grass). Invasive Species Compendium, 19321 pp.

Sawyer, H., F. Lindzey & D. McWhirter (2005). Mule deer and pronghorn migration in western Wyoming. *Wildlife Society Bulletin* 33(4): 1266–1273.

Shankar, N.B. & J. Shashikala (2010). Diversity and structure of fungal endophytes in some climbers and grass species of Malnad region, Western Ghats, Southern India. *Mycosphere* 1(4): 265–274.

Shaw, R.B. (2008). *Grasses of Colorado*. University Press of Colorado, Boulder, CO, 650 pp.

Sherry, R.A., X. Zhou, S. Gu, J.A. Arnone III, D.W. Johnson, D.S. Schimel, P.S. Verburg, L.L. Wallace & Y. Luo (2011). Changes in duration of reproductive phases and lagged phenological response to experimental climate warming. *Plant Ecology & Diversity* 4(1): 23–35.

Shiferaw, H., T. Alamirew, S. Dzikiti, W. Bewket, G. Zeleke & U. Schaffner (2021). Water use of Prosopis juliflora and its impacts on catchment water budget and rural livelihoods in Afar Region, Ethiopia. *Scientific Reports* 11(1): 1–14.

Sivaganesan, N. (1991). The ecology of the Asian Elephant in Mudumalai Wildlife Sanctuary, with special reference to habitat utilization. Unpublished PhD Thesis. Bharathidasan University, Tiruchirapalli.

Solofondranohatra, C.L., M.S. Vorontsova, J. Hackel, G. Besnard, S. Cable, J. Williams, V. Jeannoda & C.E. Lehmann (2018). Grass functional traits differentiate forest and savanna in the Madagascar central highlands. *Frontiers in Ecology and Evolution* 6: 184.

Treydte, A.C., J.G. van der Beek, A.A. Perdok & S.E. van Wieren (2011). Grazing ungulates select for grasses growing beneath trees in African savannas. *Mammalian Biology* 76(3): 345–350.

Wan, C., I. Yilmaz & R.E. Sosebee (2002). Seasonal soil-water availability influences snakeweed root dynamics. *Journal of Arid Environments* 51: 255–264.

Wang, T., X. Jin, Z. Chen, M. Megharaj & R. Naidu (2011). Green synthesis of Fe nanoparticles using eucalyptus leaf extracts for treatment of eutrophic wastewater. *Science of the Total Environment* 466: 210–213.

Wardle, J. (1971). The forests and shrublands of the Seaward Kaikoura Range. *New Zealand Journal of Botany*, 9: 269–292

White, R.P., S. Murray, M. Rohweder, S.D. Prince & K.M. Thompson (2000). *Grassland Ecosystems*. World Resources Institute, Washington, DC, 81 pp.

Xu, W., X. Deng, B. Xu, J.A. Palta & Y. Chen (2021). Soil Water Availability Changes in Amount and Timing Favor the Growth and Competitiveness of Grass Than a Co-dominant Legume in Their Mixtures. *Frontiers in Plant Science* 12: 723839.

Zeng, D.H., L.J. Li, Z.Y. Yu, Z.P. Fan & R. Mao (2010). Soil microbial properties under N and P additions in a semi-arid, sandy grassland. *Biology and Fertility of Soils* 46(6): 653–658.

Zhang, Y., Q. Wang, Z. Wang, Y. Yang & J. Li (2020). Impact of human activities and climate change on the grassland dynamics under different regime policies in the Mongolian Plateau. *Science of the Total Environment* 698: 134304.

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