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Original article

Seed dispersal by ungulates in the point calimere wildlife sanctuary: A scientific and perspective analysis

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ABSTRACT

Exotic woody weed plants are a very serious threat to seed dispersed by ungulate in the tropical forest of Asia. The ungulates in Point Calimere Wildlife Sanctuary (PCWS) are a significant role in native indigenous seed dispersal. The exotic woody weed tree *Prosopis juliflora* prevalence distributed in the PCWS and they might potentially alter the native medicinal plant species. In the present investigation, we have assessed the seed dispersal by ungulates in PCWS from January to March 2017. Four different ungulate species were selected to understand their seed dispersal rate of different plant species in selected sanctuary. This investigation was planned to confirm the seed dispersal by ungulates of blackbuck, spotted deer, wild boar and feral horse. Among the four different ungulates tested, the maximum numbers of pellets collected from blackbuck and no seed found in their pellets. The low quantities of pellets were collected from wild boar and this study has recorded medium-sized ungulates which dispersed variety of plant. However, the dispersal of the seed of medicinal plants were not considerably high and relatively moderate percentage of seeds dispersal occurred in medium-sized ungulates like wild boar and spotted deer. *P. juliflora* had 100% seed germination rate were observed from the faecal samples of wild boar and feral horse. The control seed achieved maximum seedling rate than the ungulates seeds.

1. Introduction

Plants are very less mobility in consequently their diverse of seeds dispersal are highly influencing through variety of biotic vectors. The majority of seeds are dispersing through animals by their digestive system, excreted seeds which fall on the ground and growing it naturally. Usually, that excreted seeds are getting higher potential chances to form new plants which could be far away from the mother plant (Jordano et al., 2010; Chapman et al., 2017; Susan Harrison, 2017; Chaves et al., 2018). Many birds are likely to eat diverse of fruits varieties which help to dispersing seeds to different locality by their dropping. The animals are doing seed dispersal and play a major role towards, success and wealth of environmental (Ingle, 2003; Lozada et al., 2007; Pejchar et al., 2008; Patrick David et al., 2015). The avian fauna are doing long-distance distribution of seed dispersal and accidentally these seeds are dispersed in uneven and critically important flora filling wild and epizoochoary (Gonzales et al., 2009; Chimera et al., 2010; Balasubramanian et al., 2011). Globally, the past three decades forest fire becomes major threat to wild ecosystem in various parts of the continents. As a result of forest fire, most of the indigenous/endemic flora species will become extinct as possible (Satendra and Kaushik, 2014). These problems are recently highlighted in many

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countries so that incidents cause more distraction of floral communities in wild ecosystem which can solve by migratory animal faecal seeds. This may help to improve and solve the falling of extinct flora community in various parts of world (Andresen and Leney, 2004; Auffret and Plue, 2014). The ecological studies have pointed out that the ungulate have been important role in seeds dispersal (Cosyns et al., 2005ab; Albert, et al., 2015a). However, only a very few studies reported on importance of seed dispersal by native ungulate species (Doucette et al., 2001; Bakker et al., 2007; Albert et al., 2015b).

The large herbivores mammals mostly preferred acacia plant species (*P. juliflora*). As a result, most of the wild regions disperse *P. juliflora* seed because mammalian herbivores faecal sample with huge amount of acacia seeds than other seeds (Miller, 1996; Gidske Leknaes Andersen et al., 2016). The animal faecal sample seeds dispersals were potential enough to germinate and grew on both endo and epizoochoary. It plays an important role in natural bio reforestation, regulates and maintains indigenous valuable plants in both wild and urban region. The indigenous or native vegetation provides food chain, food web of both herbivorous and carnivorous in forest ecosystem (Howe and Miriti, 2004; Kremen et al., 2007). The seed dispersal quality and quantity is directly proportional to abundance and richness of frugivorous animals (Schupp, 1993; Jordano et al., 2010; García et al., 2013).

More importantly, heterogeneity frugivore seed dispersal viability extensions are largely suffered by endurance of different anthropogenic disturbances (Martinez, et al., 2008; McConkey et al., 2012; Morales et al., 2013). Seed dispersal is an essential component of the plant colonization process which can be successfully done by many frugivorous (Rodriguez-Perez et al., 2012; Carlo and Morales, 2008; Cousens et al., 2010). Many studies of seed dispersal are carried out by farm ungulates but there is no detailed study report available in seed dispersal play by wild ungulate of Ramsar area of the South Coast India. The ungulates faecal have been potential for seed dispersal in wide range of forest area. Ecologist investigated the seed dispersal by many ungulates, in Eastern North America white-tailed deer noticeably 64% spread invasive floral species in which 95% seeds found great viability of germination by defecation (Gill and Beardall, 2001; Myers et al., 2004).

The exotic/weed plants are considerably causing major problems on many indigenous plants in both forest and wild region. Invading of *P. juliflora* extremely dense, impenetrable thick, with associated unfavourable impacts on cost-effective, millions of hectares of rangeland have already occupied in many continents (Pasiecznik, 1999). The extensive growth of *P. juliflora* not only altered fundamental important vegetation but also cause loss of underground water scarcity in different part of wild and human settle area. Continuous drastic climate change and ecological competitive surviving challenges which are major key factors for introduction of exotic/weed plants (Pasiecznik et al., 2001). Felker (1979) reported a mature tree could able to produce 630,000 to 980,000 seeds per year. *P. juliflora* fruits are highly sugary pods with seeds therefore all types of ungulates likely to attract and consuming that seed. Seeds while passing through the animal's digestive tract and moist faeces are these factors improving their germination power (Felker, 2003). The shade tolerant ground cover exotic/weed plants has detrimental effects on indigenous/endemic floral species, potentially altered forest construction, symphony and occupations (Wiser and Allen, 2006; Schulz and Thelen, 2000; Standish et al., 2001; Mc Alpine et al., 2015).

PCWS is one of the famous Ramsar wetland in Tamil Nadu, India, here a mix of salt swamps, mangroves, backwater, mudflats, grasslands and tropical dry evergreen forest. So far, 364 indigenous floral species (Climbers shrubs and trees) identified in which nearly, 198 plants are used for medicinal properties and essential food source of frugivorous mammals and birds. Middle canopy dominated by invasive and exotic species of *P. juliflora* which are major food for consumption of ungulate and seeds dispersal via to move by ungulate faecal samples (Baskaran et al., 2016). The major problems are highlighted by *P. juliflora* against natural biodiversity, ecological balance, loss of habitat for water birds, scarcity of fresh water and indigenous plant food for wild ungulates (black buck, spotted deer and wild boar), also insufficiency of grassland food (Pratiksha Patnaik, et al., 2017; Walter and Armstrong, 2014; Becker et al., 2016). Point Calimere ungulates (Black buck, spotted deer, wild boar, feral horse) consumed variety of food habitat and feral horse is free-roaming which overlapping feeding niche with black buck, spotted deer and wild boar (Baskaran et al., 2016). Here in the present study, we have evaluated seed dispersal by ungulates in PCWS with the following objectives:

- Evaluate the dispersal of various woody plants seeds by ungulates in PCWS.
- Find out the proportion of woody plant seeds in the fecal samples of various ungulates.
- Examine the germination and growth rate difference among the seeds dispersed by ungulates.

2. Materials and methods

2.1. Study area

The present study was carried out in the PCWS, Tamil Nadu, India. The Great Vedarnayam Swamp of the Point Calimere (10°18′N, 79°51′E) is located in East Coastal Line of Tamil Nadu, Nagapattinam District (Fig. 1). The forests of Point Calimere with an area of 24.17 km^2 were declared as the PCWS during 1967. The new Sanctuary, with a total area of 377 km^2 bears the name Point Calimere Wildlife and Bird Sanctuary.

2.2. Transects selection and pellet collection

The random faecal samples of ungulate collected twice an each transect consequently from 10 transects during December 2016 to April 2017. The control seeds were also collected separately to compare the seed germination test between ungulate pellets and control seeds. Transects (1000 × 3 m) was laid and walked fortnightly, searching for ungulates pellet. Every pellet found in transects identified to species level. For herbivores, all pellet clumps separated by at least 2 m considered as different pellets. Counting the number of different woody plant seeds found in each species of ungulate and the seed-dispersing ungulate species were identified (Lopez and Gonzalez, 2011).

2.3. Assessment of seed dispersal

Ungulate pellets/dung was collected using a belt transect method (1000 × 3 m) from various habitats of the study area. Before analysis, collected pellets were carefully dried in hot air oven at 30° C for 1 week which washed in a 0.5 mm × 0.5 mm fine-meshed sieve plate. All fresh/undamaged seeds were counted by hand lance which identified to species level with the help of a seed reference collection from the study area. Plants species whose seeds identified were listed to understand the woody plants dispersed by ungulates in the study area (Lopez and Gonzalez, 2011).

2.4. Evaluation of germination and growth rate

A sample of various wood plant seeds segregated from faecal samples of ungulates (Treated seeds) and a sample of various woody plants seeds collected from parent plants (Control seeds) and it was tested in green-house for germination and growth rate

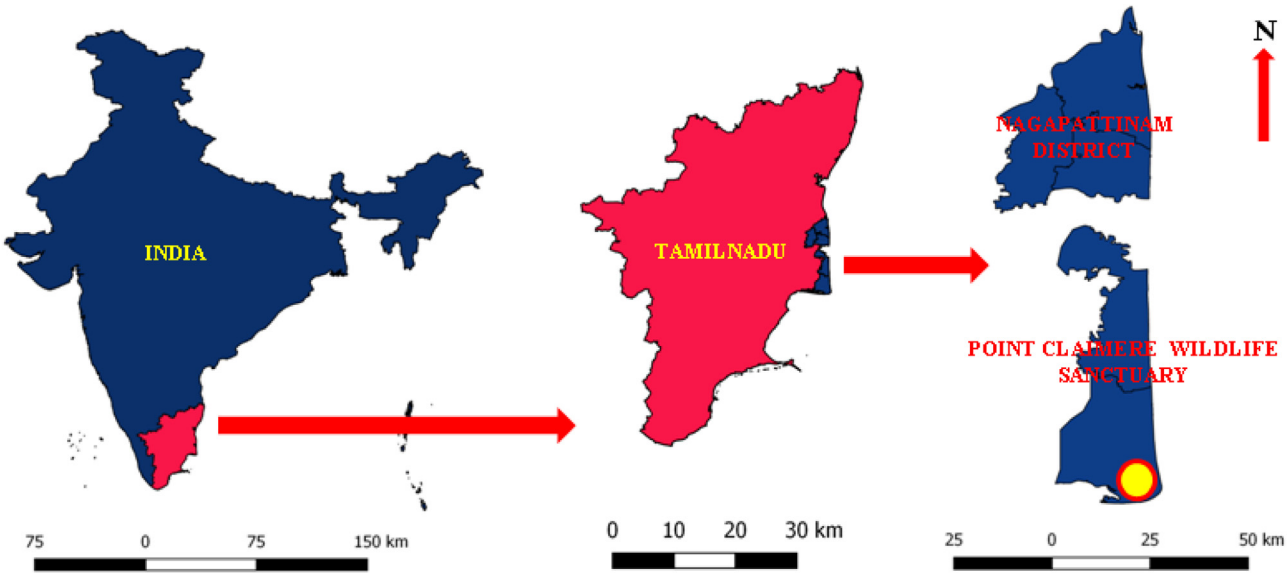

Fig. 1. Study area: Point Calimere Wildlife sanctuary (10°18′N, 79°51′E), Tamil Nadu, India.

on a weekly interval. Also, seeds samples of various woody plants along with various ungulate pellets was also placed under germination trail to find out the influence of ungulate faecal sample on germination and growth rate (Hitchcock and Cronquist, 1973).

3. Results and discussion

Present investigation provides the first hand of information on seed dispersal from ungulates in the PCWS at Nagapattinam District, Southern India. Present investigations confirm that the plant species are more in seed dispersals by ungulates in PCWS. The study was carried out from December 2016 to April 2017. Four different ungulate species were selected to understand the seed dispersal rate different plant species in the sanctuary. This study did not find any seed from the blackbuck among the four ungulate species, but the other three species showed the presence of seeds.

3.1. Ungulates pellets collection

Randomly ten sites were selected for pellets collection from ungulates in the Sanctuary. Maximum pellets were collected from the blackbuck than the other ungulates (Figs. 2 and 10). On the other hand least pellets were collected from the wild boar. But in the Ramarpatham, MPCA, Chemplast, Nandupallam and Muniyappan Lake the study did not record pellets of Black buck. Similarly, the collection and analysis of faecal samples were from blackbuck at Sathya Mangalam reserve forest at Erode District, showed very low and the study revealed that certain regions not recorded any pellets (Chandru, 1998). In general the current study reported that the blackbuck pellets did not show any plant species which was recorded during the study. It is emphasized that the blackbuck did not consume these plants in the sanctuary but we need to survey further intensive study to understand why the blackbuck did not have interest or consume the plant species. The low quantity of faecal sample defecated in wild boar might be due to the wild boar is one of the random dispersal defecated habits of animal and in addition to that the nature of the animals as small special group of herds. The similar finding was recorded in temporal and spatial pattern of defecation in wild boar (Ferretti et al., 2014).

3.2. Seeds in ungulates pellet samples

Seven different floral species found in different faecal samples of ungulates (Figs. 3–5 and 11) in which the *P. juliflora* seed was found maximum percentage in feral horse and followed by wild boar. It could be clearly examined the feral horse is free-roaming ungulate and it could consume over diet behaviour than the other ungulates. Similarly, previous researchers reported that the feral horse can consume heavy diet in variety of vegetation and PCWS feral horse was introduced species and it is regarded as semi-wild animal as well as the feral horse creates major problem of diet overlapping animals (Baskaran et al., 2016). The present study clearly noticed that the feral horse ungulate only disperses the unwanted and exotic plant species *P. juliflora* into the sanctuary

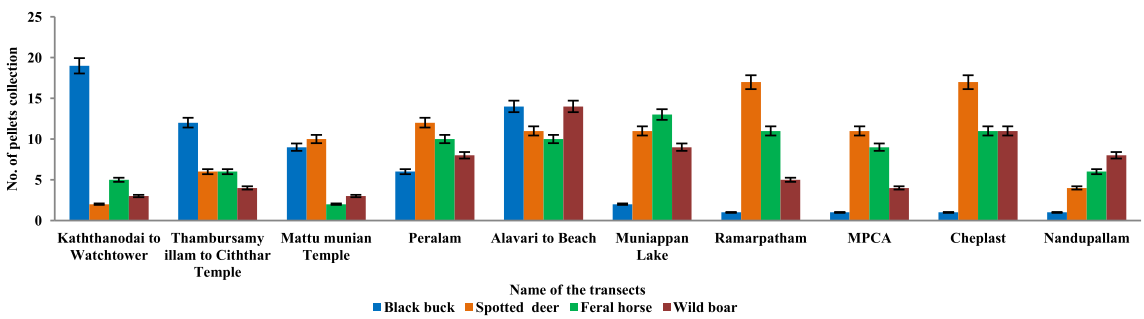

Fig. 2. The pellets collected from the different transects in the PCWS.

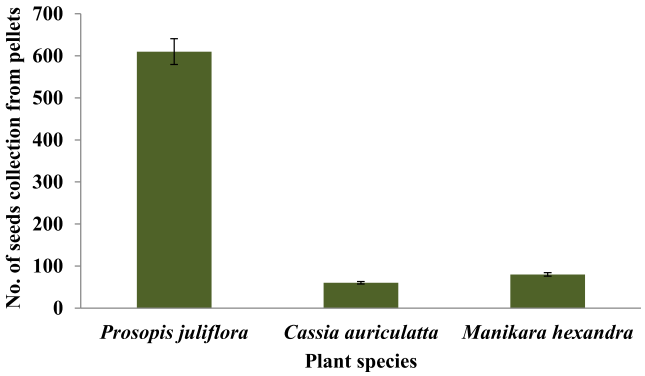

Fig. 3. Seeds collected from the pellets of feral horse in PCWS.

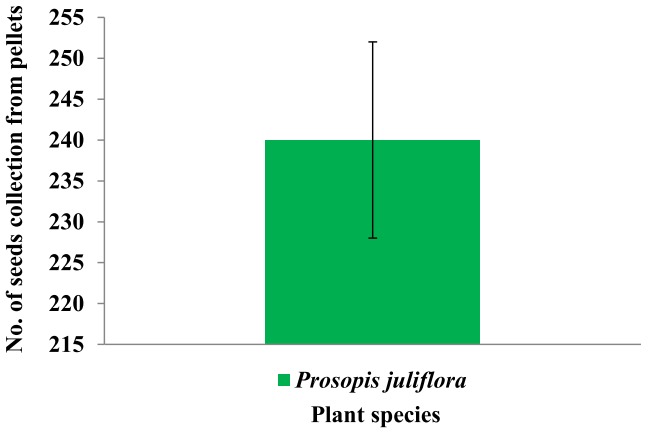

Fig. 4. Seeds collected from the pellets of wild boar in PCWS.

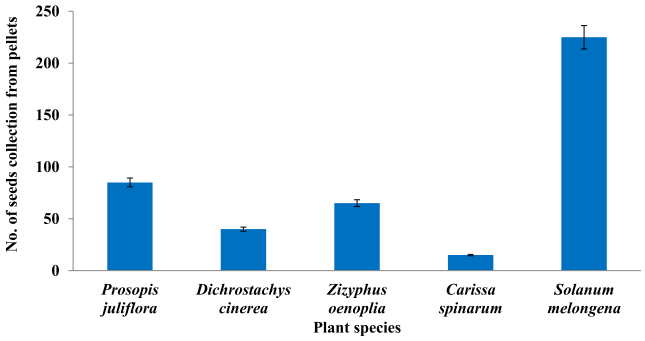

Fig. 5. Seeds collected from the pellets of spotted deer in PCWS.

as the results entire sanctuary threatened by that weed and nowadays it is very big management issues. The high rate of seed dispersal was recorded by small and medium-sized ungulates (Miller, 1996; Bartuszevige and Endress, 2008; Polak et al., 2014; Albert et al., 2015ab). The small ungulates animal is essential role in seed dispersal including variety of indigenous medicinal plants. The small ungulate in India is four types of antelope species such as blackbuck, Nilgai, Chowsingha, Chinkara. This is the above fact of previous study in antelope mediated seed dispersal has brought us closer to this goal seed fate pathways of antelope bitterbrush (Vander Wall, 1994). The PCWS the blackbuck is one of endemic species and does the major role in dispersal of medicinal seeds from the sanctuary.

3.3. Significant role of seed dispersal by small ungulates

Present investigation recorded medium-sized ungulate dispersed variety of plants species *(Dichrostachys cinerea, Zizypus, Carissa spinarum, Solanum melongena var insanum* and *Cassia auriculatta*) at PCWS. However, the seed dispersal of medium-sized spotted deer and wild boar ungulate were dispersed relatively moderate percentage of medicinal plants. The major reasons for indigenous native medicinal plants availability relatively are very less in blackbuck existing area of Sanctuary. Actively medicinal plants germination is caused by major occupation of *P. juliflora* and it is scattered entire region of sanctuary. The major roles of *Prosophis juliflora* dispersion have been done by large size of semi-wild ungulate feral horse. Many studies suggested about

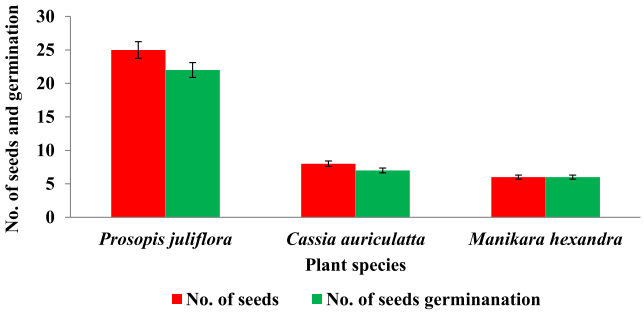

Fig. 6. Seeds and its germination rate of different species of seedlings in feral horse in PCWS.

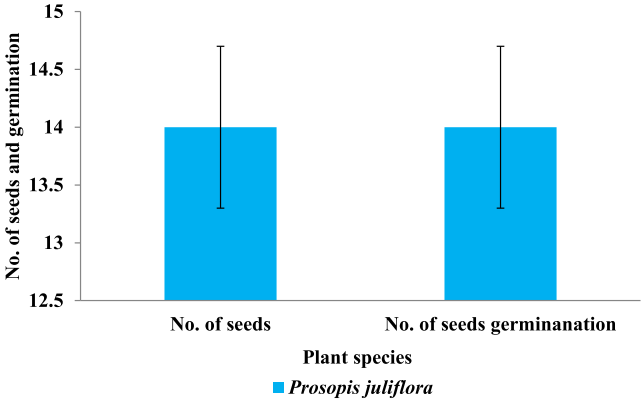

Fig. 7. Seeds and its germination rate of different species of seedlings in wild boar in PCWS.

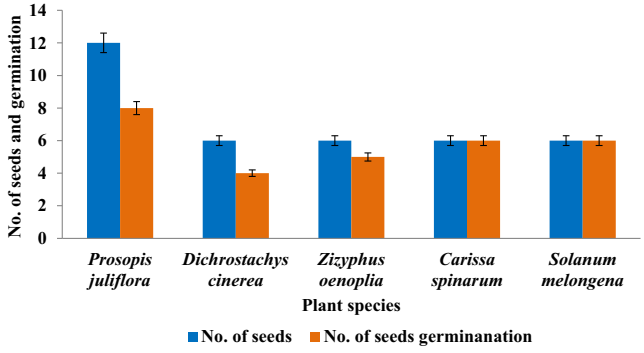

Fig. 8. Seeds and its germination rate of different species of seedlings in spotted deer in PCWS.

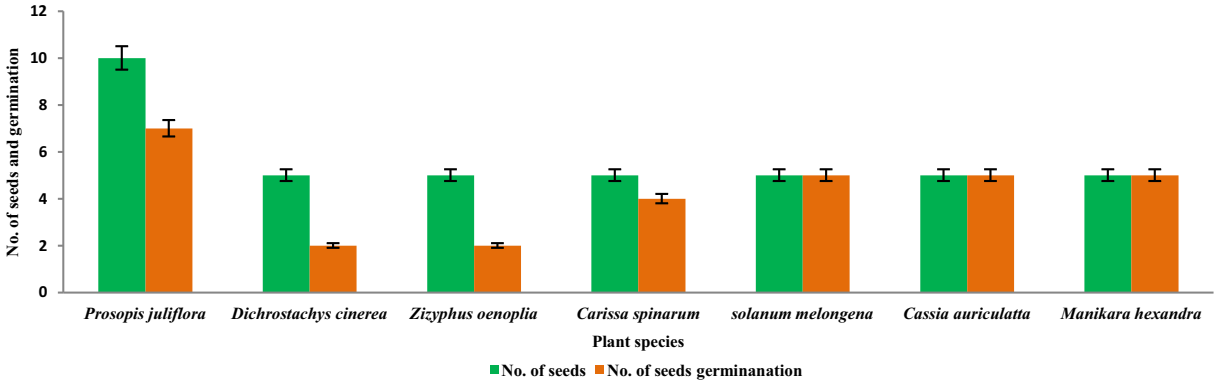

Fig. 9. Seeds and its germination rate of different species of seedlings in the control of PCWS.

Fig. 10. Different Ungulate pellets at PCWS. A: Spotted deer (*Axis axis*); B: Black buck (*Antilope cervicapra*); C: Wild boar (*Sus scrofa*); D: Feral horse (*Equus caballus*).

scenario of exotic and widespread, multi-branched tree of *P. juliflora* in Banni grassland of Kachchh desert of Gujarat, India (Karthik et al., 2009). In India most of the epizoochory areas were mostly occupied with many weeds of herbs, shrubs and trees which are dispersed by various modes of wind, avian groups and mammals.

Therefore, the natural habitat declined drastically in exo and endo zoochoary of PCWS as well as these problems are extending all biospheres of both protected and unprotected area of India and Indian subcontinents. The above reasons were discussed by several researchers and the exotic plants are significantly causing native ecosystem which is spreading drastically in across the landscape. It is pertinent to conserve of native ecosystem (Kumari and Choudhary, 2016; Baskaran et al., 2016; Junaedi et al., 2018). The present investigation revealed that the rate of seed germination test examined by faecal samples of ungulates. There was no seed found in the faecal samples of blackbuck. Generally, the blackbuck is browsing behaviour and they are living near sea shore boundary of PCWS. That's it the major reason for didn't find any seed in pellet/faecal samples of blackbuck as well as indigenous native herbs not much in the shoreline or blackbuck living area but exotic species of *P. juliflora* was more abundant in and around sanctuary. The endemic herbs of *Cassia auriculata, Zizypus, Carissa spinarum, Dichrostachys cinerea* and *Manikara hexandra* found in endo zoochoary zone. The problem of exotic woody weed plant could be altered the endemic herbal population at PCWS. In order to, the forest department implement the destruction of exotic woody weed trees (*P. juliflora*) from the blackbuck living zone. The major reasons are majority of endemic herbs are grazed and over diet consumed by feral horse and it gives the path for competition between the small and large ungulates including feral horse. Similarly, Baskaran et al. (2016) reported that the dietary competition,

Fig. 11. Different seeds Collection from different ungulate pellets at PCWS. A: *Cassia auriculata*; B: *Carissa spinarum*; C: *Prosopis juliflora*; D: *Dichrostachys cinerea*; E: *Manikara hexandra*; F: *Zizyphus oenoplia*; G: *Solanum melongena* var insanum.

Table 1
Seedlings growth rate recorded in the different ungulates faecal samples in PCWS.

S. No.	Ungulates	Seedling growth rate
1.	Feral horse (*Equus caballus*)	1.96 ± 0.332^{b}
2.	Wild boar (*Sus scrofa*)	2.02 ± 0.496^{c}
3.	Spotted deer (*Axis axis*)	2.05 ± 0.428^{d}
4.	Control seeds	1.00 ± 0.200^{a}

Values represent mean ± S.D. and different alphabets in the column are statistically significant at $p < 0.05$. (MANOVA; LSD -Tukey's Test). Control seeds: A fresh woody plants parent seeds. Treated seeds: A fresh seeds segregated from faecal samples of ungulates.

significance of exotic species and overlap among the ungulates in PCWS. Some earlier reports support that the blackbuck can consume and disperse the *P. juliflora* in an grassland ecosystem (Shivani et al., 2013) and another similar evidence reported that the blackbuck are dominant ungulate antelope species of many semi-arid grassland across in India (Ranjithshinh, 1989) but not reported as dominant dispersal of *P. juliflora*. We observed 100% germination rate of *P. juliflora* recorded in faecal samples of spotted deer, wild boar and feral horse (Figs. 6–9). The *P. juliflora* have unique characters which can suppress other plant growth, as well as considerably significant effects, create against sanctuary which is emerging and nuisance to the protected areas. Walter and Armstrong (2014) reported that the weed seeds have faster germination, nuisance to wild animals, fastest growth rate, suppress endemic plants species and spreading tropical forest of the world. On the other hand *Carissa spinarum* had maximum germination, high consumption and maximum level dispersed by spotted deer at PCWS. Farwig et al. (2007) suggested that the ungulates have seed predation and seeds dispersals, a significant process for conservation management of threatened plant species.

3.4. Seedling growth rate

The seed dispersal was mainly done by medium-sized ungulates which play significant role for dispersing medicinal plants at PCWS. Results were compared with control seedling the rate of growth was different from among the species. The control plant has achieved maximum growth than ungulates seeds (Table 1–3). In cause of control Zizypus seed had no germination because indigenous/native seeds are easily digested in rumen cattle, it compared with exotic seeds which are smaller and likely damaged in cattle remnant (Wisdom, 2005). In addition to that the previous recode support to us; the larger domestic/native ungulates have the potential to disperse the larger quantities of exotic seeds which are more responsible for threatening flora is protected and unprotected zones (Bogoni et al., 2018). This study noticed that there were significant variations between the rate of seedling growth of plant species and among the ungulate pellets (Table 2; $P < 0.001$).

4. Conclusion

The present study aims to conform of plant-seed dispersed by ungulates at PCWS. It is one of the important Ramsar wetland site in India which has plenty of medicinal values plants. Some of them

Table 2
The growth rate variation in seedlings among the ungulate species pellets in PCWS.

Sources	Sum of squares	df	Mean square	F	Sig.
Plant growth* Ungulates between groups	627.114	3	209.038	173.827	0.000
Within groups	4160.879	3460	1.203		
Total	4787.993	3463			

The growth rate variation of seedlings assessed among the ungulate species pellets, different statistical analysis like Sum of squares, degrees of freedom, Mean square, frequency and significance were calculated by IBM SPSS Statistics 25 version.

Table 3
Different plant seedlings growth rate of different ungulates seeds in PCWS.

S. No.	Ungulates	Plant speciied	Germination growth
1.	Feral horse	*Prosopis juliflora*	1.87 ± 0.381[b]
		Cassia auriculatta	2.37 ± 0.906[c]
		Manikara hexandra	1.92 ± 0.859[b]
2.	Wild boar	*Prosopis juliflora*	2.02 ± 0.496[c]
3.	Spotted deer	*Prosopis juliflora*	2.08 ± 0.601[c]
		Carissa spinarum	2.63 ± 0.103[c]
		Zizyphus oenoplia	2.64 ± 0.108[c]
		Dichrostachys cinerea	1.61 ± 0.955[b]
		Solanum melongena	0.84 ± 0.376[a]
4.	Control	*Prosopis juliflora*	0.99 ± 0.412[a]
		Cassia auriculatta	1.04 ± 0.535[b]
		Manikara hexandra	0.88 ± 0.379[a]
		Carissa spinarum	1.31 ± 0.661[b]
		Dichrostachys cinerea	1.45 ± 0.135[b]
		Solanum melongena var insanum	0.82 ± 0.324[a]

Values represent mean ± S.D. and different alphabets in the column are statistically significant at $p < 0.05$. (MANOVA; LSD -Tukey's Test). Control seeds: A fresh woody plants parent seeds. Treated seeds: A fresh seeds segregated from faecal samples of ungulates.

are extinct due to habitat destruction of overgrazing by exotic semi-wild ungulates of feral horse that is over diet consuming between the block buck, spotted deer and wild boar. The PCWS has associated another one major problems is exotic woody plant *P. juliflora.* Here, the weed tree *P. Juliflora* is a major threat to indigenous floral species. The majority of *P. juliflora* seeds are found in pellets of feral horse and wild boar. Our results will be helping the forest deportment to understand that for seed dispersal are mainly done by ungulates in PCWS. We want to give some vital suggestion to forest department. 1. Strictly prohibit non-native exotic plant species at PCWS. 2. Re-forestation steps have to be taken, particularly in black bulk territory. 3. The complete distraction of exotic woody weed plants of *P. juliflora* from PCWS is the need of the hour.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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