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INSIGHTS

Native mammals disperse the highly invasive *Senna spectabilis* in the Western Ghats, India

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Abstract

Senna spectabilis, a native tree of tropical America is rapidly colonizing the forests of Western Ghats. We identified the Asian elephant (*Elephas maximus*) as the major disperser of *Senna*, with the dung facilitating germination of the species. The study provides critical information for the management of *Senna* in tropical Asia.

KEYWORDS
Asian elephant, seed dispersal, *Senna spectabilis*, Western Ghats

1 | INTRODUCTION

Biological invasions are one of the major conservation challenges in the current time, threatening the native biodiversity, causing extinctions, and hampering natural evolutionary processes worldwide (IPBES, 2019; Seebens et al., 2017). Several invasive plants use animal vectors for colonization, establishment, and spread by dispersing their diaspores through ingestion and defecation of seeds (Gosper et al., 2005; Richardson et al., 2000). Such mechanisms can effectively disperse seeds over large distances from the parent plant and increase germination chances (Vittoz & Engler, 2007). When alien plants interact with animal-mediated dispersal of native plants, it will disrupt native mutualisms that evolved over evolutionary time (Farwig & Berens, 2012; Traveset & Richardson, 2014). Hence, an understanding of invasive plants' dispersal mechanisms and identifying the native seed dispersers are important for their future management (Richardson et al., 2000).

Invasive trees are long-lived, large, and capable of dominating and altering the native vegetation by hampering the ecological processes badly when compared to other plant growth forms like herbs and shrubs (Wilgen & Richardson, 2014). *Senna spectabilis* (DC.) H.S. Irwin & Barneby (Fabaceae) is an exotic ornamental tree native to tropical America (Jothy et al., 2012). It was widely introduced outside its native range, including Africa, Asia, North America, and Oceania (Randall, 2012). Life history traits such as fast growth rate, ability to produce a large number of seeds, thick canopy cover, lack of natural enemies, and capability to propagate from stems or roots make *S. spectabilis* an aggressive invasive tree, although it does not fix nitrogen (Maclean et al.,1992; Wakibara, 1998; Wakibara & Mnaya, 2002).

In India, *S. spectabilis* was introduced in the Western Ghats without proper knowledge about its potential to become an invasive species. After the introduction, it started establishing itself extensively in the new areas, and its management has become a challenging task (Vinayan et al., 2020). For example, it was introduced in the Wayanad

Wildlife Sanctuary by the early 1980s and has now covered over 23% of the sanctuary area in 40 years (Figure 1). To map the spatial pattern of spread and abundance of *S. spectabilis*, the study area was overlaid with 500 × 500 m grid cells as spatial sampling units (1702 grids). The abundance of *S. spectabilis* in each grid was categorized into different classes ranging from high to absent. For this purpose, two trained observers walked along the available roads and forest trails in each grid and categorized different abundance classes of *S. spectabilis* based on visual estimation of abundance. The grids with no *S. spectabilis* was classified as "absent," "low" (≤10% of the total stems), "medium" (10–40%), and grids with a high abundance of *S. spectabilis* was categorized as "high" (≥40% of all the stems) (See Vinayan et al., 2020).

The fruits of *S. spectabilis* are long, cylindrical, pendulous pods, with brown seeds (Satyanarayana & Gnanasekaran, 2013). The nutrient content, taste, and smell of the pods might have been the major drivers attracting the herbivores. However, the seed dispersers of *S. spectabilis* from its native and introduced range are unavailable. One possibility for its rampant spread over several forest types in the Western Ghats in a short period is by adapting to active dispersal mechanisms. In this context, we hypothesized that native wide-ranging animals are capable of dispersing their seeds over large spatial scales thereby facilitating its spread.

To test this hypothesis, we carried out this study in the Wayanad Wildlife Sanctuary (76°02′ and 76°27′ E longitude and 11°35′ and 11°51′ N latitude) located in the Wayanad district of Kerala state, India. The study area extends over 344.44 km^2 and is part of the contiguous Nilgiri Biosphere Reserve (NBR). The sanctuary's principal vegetation is southern moist deciduous and dry deciduous forests interspersed with monoculture plantations of teak and eucalyptus. The sanctuary is also known for large herbivores; the Asian elephant (*Elephas maximus*), chital (Axis axis), gaur (*Bos gaurus*), sambar deer (*Rusa unicolor*), and carnivores like tiger (*Panthera tigiris*), leopard (*P. pardus*), and wild dog (*Cuon alpinus*).

Our field observations showed that the fruiting phenology of *S. spectabilis* in the Western Ghats spans from January to April. The sampling was restricted to the areas with a high density of *S. spectabilis* and was done when mature pods were available (February-March 2020) to identify its potential mammalian dispersers. Two observers walked along the available trails and roads through dense patches of *S. spectabilis* in the sanctuary. But, the droppings of chital were selected randomly from open grassland patches. The observers examined all fresh feces of mammals to detect the presence of seeds (Table 1). The feces were identified based on their characteristic size and shape following Jhala et al. (2009). Once seeds of *S. spectabilis* were found in the feces, they were collected and placed on white paper to retrieve and count

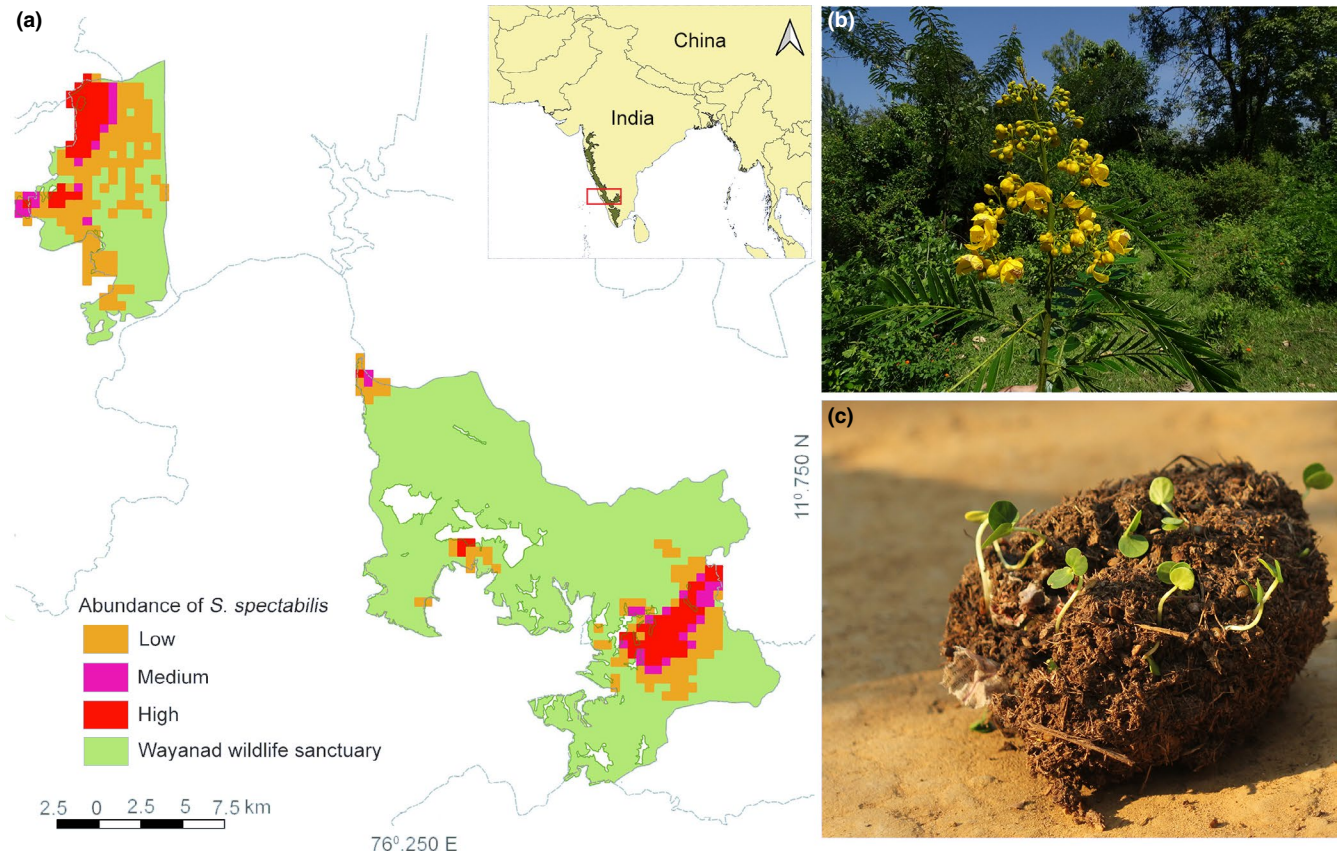

FIGURE 1 (a) Map showing the distribution of *S. spectabilis* in Wayanad Wildlife Sanctuary (source: Vinayan et al., 2020), (b) flower of *Senna spectabilis*, and (c) seedlings of *S. spectabilis* in an elephant dung pile

TABLE 1 Number of seeds recorded from the feces of different species of mammals during the study

Sl no	Species	Number of feces examined	Feces with seeds	Number of seeds recorded in the feces (min-max)
1	Elephant	55	28	1–2164
2	Chital	196	37	1–3
3	Indian crested porcupine	14	12	1–22
4	Gaur	9	0	0
5	Indian hare	40	0	0
6	Asian palm civet	9	0	0
7	Livestock	32	0	0

the seeds. The seeds were identified using a reference collection prepared by collecting pods from adult trees. We examined the feces of seven species of herbivores; elephant (n = 55), gaur (n = 9), Livestock (cattle) (n = 32), Chital (n = 197), Indian crested porcupine (n = 14), Asian palm civet (n = 9), and Indian hare *Lepus nigricollis* (n = 40).

Our study found that *S. spectabilis* seeds were dispersed by three of the seven mammal species sampled. These were elephant, chital, and Indian crested porcupine while no seeds were recorded from the feces of livestock, Indian hare, gaur, and Asian palm civet. Interestingly, we found that elephants dispersed a large number of seeds (of the 55 dungs sampled, four dungs had >500 seeds) compared to other species. The fruiting of *S. spectabilis* coincides with high elephant density in Wayanad because there is an influx of elephants toward this region during summer (March-May) from other parts of the Nilgiri Biosphere Reserve (Anoop & Ganesh, 2020). Hence, there is a high chance that the *S. spectabilis* will spread fast in the landscape, especially in the micro-habitats of elephants including riparian forests and swamps. The number of seeds reported from the droppings of chital was less, but it is also a potential dispersal agent given its high abundance. Except a few studies, the role of chital as a seed disperser is less investigated (Prasad et al., 2004). Indian crested porcupine is a generalist herbivore and often a seed predator but seeds were intact in their droppings. Studies elsewhere have reported their pivotal role as dispersal agents of various native and invasive plant species (Akram et al., 2017; Hafeez et al., 2011; Mori et al., 2017).

Being a wide-ranging species with poor digestive ability, elephants can transport viable seeds over considerable distances (Campos-Arceiz & Blake, 2011) and we feel this will strongly determine the present and future distribution of *S. spectabilis* in the elephant inhabited regions of the Western Ghats. In addition, as multiple mammals forage on *S. spectabilis* fruits, the seeds will reach diverse vegetation types and agriculture landscape around the conservation areas. The passage of the seeds of *S. spectabilis* through the gastrointestinal tract of herbivores may facilitate seed germination (Shiferaw et al., 2004). Therefore, we collected three elephant dungs with seeds (200 seeds) and left these dungs to germinate at a coffee plantation close to the study area. The dung was watered every morning. After one and half weeks of watering, 120 seeds were found germinated from the dung. Hence, we suggest carrying out detailed work on the germination capacity of the ingested seeds of *S. spectabilis* by different animals and how they affect the population dynamics and spread in the landscape. We could not do this experiment on the other two species because of logistic reasons.

Other invasive plants distributed in India have also shown to use native vertebrates for their seed dispersal. For example, Jackal (*Canis aureus*) and wild boar (*Sus scrofa*) actively disperse seeds of the invasive tree *Prosopis juliflora* in the Kachchh Desert of Gujarat (Karthik et al., 2009). Native birds are the primary disperser of *Lantana camera* in the Western Ghats (Ramaswami et al., 2016). Besides, sloth bears (*Melursus ursinus*) also disperse *Lantana* seeds in small quantities (Ramesh et al., 2009). Even though native vertebrates play a significant role in successfully spreading invasive plants in most ecosystems, this aspect of invasion ecology has gained little research attention. Understanding the mutualistic associations between native vertebrates and invasive plants and how that facilitates seed dispersal can provide vital information for process-based management of invasives (Westcott & Fletcher, 2011).

We acknowledge that our study did not identify all possible seed dispersers of *S. spectabilis* in the landscape, which will require an extensive survey. Based on our result, one way to contain the spread of *S. spectabilis* can be the constant removal of adult trees and pruning of branches that will lower flowering and fruiting to reduce the dispersal of seeds to new areas by the dispersers and reduce soil seed bank. Studies conducted in Mahale Mountains National Park in western Tanzania found that girdling and felling of trees in combination with removal of seedlings and sprouts are an effective way to control *S. spectabilis* (Lukosi, 1997; Wakibara & Mnaya, 2002). We also suggest extending the management of *S. spectabilis* in the agricultural landscape where it is used as shade trees for coffee and as support for pepper plants. Many of the protected areas in the Western Ghats are already threatened by the spread of various other invasive alien plant species (Muniappan & Viraktamath, 1993; Prasad, 2012; Sundaram & Hiremath, 2012). Thus, the spread of *S. spectabilis* is an added threat to the biodiversity of the Ghats. Hence, we suggest an urgent survey in the Western Ghats to map areas where the species is present and monitor changes of the existing populations. The information presented in this paper will contribute toward devising an effective management plan to curb the future spread of *S. spectabilis* in the Ghats.

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CONFLICT OF 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.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.wstqjq2mk (Anoop et al., 2021).

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