Mammalian Biology 87 (2017) 27–35

Contents lists available at ScienceDirect

Mammalian Biology

journal homepage: www.elsevier.com/locate/mambio

Original investigation

Large herbivore populations outside protected areas in the human-dominated Western Ghats, India

Girish Arjun Punjabi [a,*], M.K. Rao [b]

[a] Wildlife Research & Conservation Society, Sus Road, Pashan, Pune, India
[b] Office of the Additional Principal Chief Conservator of Forests (Wildlife), Borivali, Mumbai, Maharashtra, India

ARTICLE INFO

Article history:
Received 24 August 2016
Accepted 15 May 2017
Handled by Juan Carranza
Available online 17 May 2017

Keywords:
Wild ungulates
Group density
Abundance-occupancy
Livestock
Tropical forests

ABSTRACT

Large terrestrial wild herbivores are threatened globally, but scarce information exists on their populations outside of protected areas in South and Southeast Asia. India supports 39 species of wild herbivores, nearly two-thirds of which are threatened. While the protected area network still forms the backbone of large mammal conservation, it occupies less than 5% of India. Yet, remnant habitats outside of parks have received sparse attention to conserve threatened wild herbivores. Our study examined the effects of livestock occurrence, human proximity (distance to nearest village), and habitat factors (percentage habitat available and mean slope) on populations of large wild ungulates in a tropical forest outside of protected areas in the Western Ghats of India. We used a sign-based abundance-occupancy modelling approach to assess the effects of these variables on animal group density ($\hat{\lambda}$) and animal group-specific detection probability (r) of three large wild ungulates (gaur *Bos gaurus*, sambar *Rusa unicolor*, and wild pig *Sus scrofa*). Our results reveal that in human-dominated tropical forests, gaur group density increases with larger available habitat and lower occurrence of livestock, while sambar group density increases with higher mean slope and lower occurrence of livestock. Contrary to expectation, sambar group density was higher in smaller available habitat. No variable could reliably explain wild pig group density, but the species is a known generalist. Our results have important implications for conservation of threatened large herbivores and management of remnant tropical forest habitats outside protected areas, especially Reserved Forests in the Indian context. Remnant habitats can support significant populations of large herbivores and need to be protected in developing South and Southeast Asian countries. Gradual improvement in livestock management practices will benefit large herbivore populations in priority regions outside of protected parks in India.

Introduction

Terrestrial large wild herbivores play critical roles in forests and ecosystems globally (Ripple et al., 2015). However, large herbivores in the tropics face manifold threats and extinction risks are high for the majority of species in rapidly-developing South and Southeast Asian countries (Ahrestani and Sankaran, 2016; Ripple et al., 2015). India, a mega-diverse country in South Asia, supports 39 species of wild herbivores, two-thirds of which are threatened with extinction (Ahrestani and Sankaran, 2016). Loss of habitat has significantly reduced the distribution range of many large herbivores across the country (Karanth et al., 2010), while hunting is still widespread (Gubbi and Linkie, 2012; Madhusudan and Karanth, 2002; Velho et al., 2012). Moreover, the country's high human population growth (Cohen, 2003) and largely agrarian economy have resulted in a sizeable population of livestock (*c.* 500 million, Ministry of Agriculture, Govt. of India, 2012), which create severe resource limitation for many native wild herbivores (Madhusudan, 2004; Mishra et al., 2004; Suryawanshi et al., 2010).

Of the 21% of land area in India under forest cover, less than 5% is under the protected area network (ENVIS Centre on Wildlife and Protected Areas, 2016). Almost 60% of these protected areas had resident human populations and were grazed by livestock in the past (Kothari et al., 1989; Singh, 1999), although this has marginally reduced in recent years due to better management of Tiger Reserves in India. Well-protected parks are critical to harbour high densities of large wild herbivores and carnivores (Karanth et al., 2004). Yet, substantial amount of functionally-important forest habitats remain outside of protected reserves in India.

* Corresponding author.
E-mail address: girisharjunpunjabi@gmail.com (G.A. Punjabi).

http://dx.doi.org/10.1016/j.mambio.2017.05.004
1616-5047/

These habitats include government-controlled Reserved Forests which connect parks (Bennett, 2003; Sharma et al., 2013) and enhance resources for wide-ranging mammalian species (Karanth, 2016; Woodroffe and Ginsberg, 1998). However, these forest commons are also subject to variable intensities of resource use by resident communities of people and their livestock (DeFries et al., 2010). Remnant habitats are increasingly recognized to be important for wide-ranging wildlife (Punjabi et al., 2017; Qureshi et al., 2014; Seidensticker, 2016; Silori and Mishra, 2001), but have received limited conservation focus. This is especially of concern in the context of declining large herbivore populations in 'multiple-use' landscapes, which suffer from intense pressures of local hunting and livestock grazing as they are not explicitly managed for wildlife conservation (Harihar et al., 2014; Pillay et al., 2011).

Land managers require robust assessments of where and how wild herbivore populations can persist in such multiple-use, human-dominated landscapes of South and Southeast Asia (Ripple et al., 2015). Indeed, management efforts to stem the decline in large herbivore populations are constrained by insufficient scientific knowledge for most species in remnant habitats (Sankaran and Ahrestani, 2016). Still, practical limitations (poor sightability, undulating terrain) limit the application of conventional methods such as distance sampling (Buckland et al., 2001) to reliably assess populations of cryptic and low-density herbivores from such habitats, which are important benchmarks for species conservation and management. Also, biotic impacts on wild herbivore populations are difficult to study experimentally across large scales due to multiple constraints (Madhusudan, 2004; Ritchie et al., 2009). From this perspective, newer developments in robust scientific approaches which permit assessments of low-density or cryptic herbivores from sub-optimal habitats are especially valuable (Gopalaswamy et al., 2012; Rovero and Marshall, 2009; Vongkhamheng et al., 2013).

We conducted a study in the Western Ghats of India to understand how anthropogenic and ecological factors affect populations of large wild ungulates in human-dominated tropical forest landscapes. We used a sign-based occupancy-abundance sampling approach (Gopalaswamy et al., 2012; Royle and Nichols, 2003) to specifically examine the effects of livestock occurrence, human proximity (distance to the nearest village), and habitat factors (percentage habitat availability and slope) on populations of three large wild ungulates (gaur *Bos gaurus*, sambar *Rusa unicolor*, and wild pig *Sus scrofa*) in a region outside any protected area. Based on known biology and available information, anthropogenic and ecological factors were expected to explain population-level responses of gaur and sambar more reliably as compared to wild pig which is known to be a generalist species and resilient to anthropogenic impacts (Steinmetz et al., 2010).

Material and methods

Study area

Our study site spanned an area of *c.* 325 km^2 around the Tillari river valleys, part of the northern Western Ghats landscape in India. The intensive study area in the state of Maharashtra comprised of Reserved Forests and private forest land, bordering the states of Karnataka and Goa. Majority of forest habitats in our study region are safeguarded as Reserved Forests to prevent illegal tree-felling, but there are minor restrictions on access for resident people and their livestock. The region comprises of Tropical moist deciduous and semi-evergreen forests (Champion and Seth, 1968), and the terrain is undulating with steep escarpments along the main crest of the Western Ghats, with elevation ranging from 50 m to 1030 m a.s.l. Average rainfall from June to September is *c.* 3000 mm in the region, and temperatures vary from 16° to 35 °C from the winter to summer months. The region is an important pinch-point in a large mammal corridor between Kali Tiger Reserve in the state of Karnataka and the Radhanagari Wildlife Sanctuary in Maharashtra, the latter being one of the 39 serial sites inscribed in the UNESCO World Heritage list.

Preliminary camera-trapping in the region revealed the presence of the tiger *Panthera tigris*, dhole *Cuon alpinus*, sloth bear *Melursus ursinus*, leopard *Panthera pardus*, and seven species of wild ungulates, which include gaur, sambar, wild pig, Indian muntjac *Muntiacus muntjac*, four-horned antelope *Tetracerus quadricornis*, Indian chevrotain *Moschiola indica* and chital *Axis axis*. Gaur, sambar, and four-horned antelope are categorized as Vulnerable as per the IUCN Red List (Duckworth et al., 2016; Mallon, 2008; Timmins et al., 2015), while the other ungulate species are Least Concern. Four-horned antelope and chital were rarely photographed using camera-traps, indicating that they are particularly uncommon in the region.

Close to 40 villages occur in the study region, with village sizes ranging from 10 to 400 households. A few settlements belong to Gavli dhangars, a traditional resident pastoral community, who rear large number of goat, buffalo, and cattle and rely on communal and Reserved Forest land for grazing (Gadgil and Malhotra, 1982). Six villages were relocated about a decade ago from a part of our study area due to a large irrigation project, creating an inviolate region along one valley of the Tillari River. This gave us an interesting opportunity to assess wild ungulate population in a region devoid of human settlements and livestock, and compare it with other parts of our study region which have human settlements and livestock. Our study region overlapped two administrative districts and human population density varied from 160 people per km^2 to 327 people per km^2, while livestock density (cattle, buffalo, and goat together) ranged from 47 to 150 livestock per km^2 (Commissionerate of Animal Husbandry, 2012). High densities of livestock, found in much of our study region, graze within forests during day-time and are corralled in villages during night-time. Households in the study region mostly engage in agriculture and cash-crop plantations (sugarcane *Saccharum* sp., cashew *Anacardium occidentale*), and are dependent on forests for livestock grazing, firewood, minor forest produce, and medicinal plants. A few large estates in the study region grow cash crops such as rubber (*Hevea* sp.) and pine-apple (*Ananas comosus*).

Group density

Since many tropical forest-dwelling herbivores are cryptic, and often exist in low densities outside protected areas, they are notoriously difficult to count using conventional methods such as distance sampling (Buckland et al., 2001). We used an approach developed to assess the relative abundance of herbivores using sign-based occupancy surveys that relies on heterogeneity in detection probability of herbivore signs (Gopalaswamy et al., 2012; Royle and Nichols, 2003). The key assumption of the method is that heterogeneity in detection probability of signs (r) exists as a result of variation in animal abundance (Royle and Nichols, 2003). This modelling approach, termed AOS (abundance–occupancy–spatial), uses detection of herbivore signs on spatial replicates to estimate group density ($\hat{\lambda}$, Gopalaswamy et al., 2012) and not the density of individual animals per unit area, as is the standard. The method is useful to assess the effect of environmental variables on animal populations under certain sampling conditions as it accounts for imperfect detection, and is therefore superior to relative abundance indices (RAIs) which are rarely calibrated in practise (Hayward et al., 2015; Sollmann et al., 2013).