

Chapter 1

Introduction: The Large Herbivores of South and Southeast Asia—A Prominent but Neglected Guild

Farshid S. Ahrestani and Mahesh Sankaran

Abstract The large herbivores of South and Southeast Asia comprise an ancient and diverse guild with a long history of association with humans. To this day, our knowledge of the ecology of these herbivores, and the ecological roles they play in ecosystems, remains largely inadequate. In this edited collection of chapters, we attempt to synthesize and integrate ongoing research on large herbivores in the region, and highlight directions for future research that is critical for the management of large herbivores in South and Southeast Asia. Given the dramatic population declines and range contractions of large herbivores in the region, there is an urgent need for scientifically based management efforts to ensure both their continued persistence as well as the integrity of the ecological services they provide in ecosystems.

Keywords Artiodactyla • Biogeographic realms • Perisodactyla • Species richness and diversity • Ungulate ecology

As primary consumers, large (>5 kg) terrestrial mammalian herbivores are an integral component of nearly every ecosystem on Earth (Duncan et al. 2006). Besides their obvious and irreplaceable role in supporting viable populations of large carnivores, large herbivores also play other critical roles in ecosystems as regulators of energy and nutrient cycles, modulators of plant community composition and grassland-woodland transitions, and as agents of seed dispersal (Janzen

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1984; Olf and Ritchie 1998; Olf et al. 2002; Augustine and McNaughton 2004; Couvreur et al. 2004; Burns et al. 2009). Large herbivores are also recognized as ‘keystone’ species in many ecosystems, influencing not only the structure of vegetation but also the richness, abundance and distribution of several other taxa ranging from arthropods to birds (Duncan et al. 2006; Pringle et al. 2007; Palmer et al. 2008; Greenwald et al. 2008; Banks et al. 2010; Goheen et al. 2010; Foster et al. 2014). Their loss can thus have effects that cascade through ecosystems (Ripple and Beschta 2006; Beschta and Ripple 2012). Given that the majority of large herbivore species, particularly those in developing tropical countries, are undergoing dramatic population declines and range contractions, there is an urgent need for scientifically based management efforts to ensure both their continued persistence as well as the integrity of the ecological services they provide in ecosystems (Ripple et al. 2015).

For the general public, and many scientists alike, the term ‘large herbivore’ is synonymous with Africa, bringing to mind images of wide expanses of savannas teeming with ungulates. Indeed, Africa with 94¹ large herbivore species—the majority of which inhabit the Afrotropic biogeographic realm (Udvardy 1975)—is the most species rich of all continents. However, with 83¹ species (Table 1.1), the countries of South and Southeast Asia (SSEA; Fig. 1.1), which collectively comprise the bulk of Indo-Malayan biogeographic realm (Udvardy 1975), support more than twice as many large herbivore species per unit area when compared to Africa (8.22 vs. 3.11 species per million km²; also see Chap. 2). Further, many protected areas in South Asia also support biomass densities of large mammalian herbivores that are comparable to those found in many flagship parks in Africa (Karanth and Sunquist 1992). And yet, despite the global significance of SSEA in terms of its large mammalian herbivore diversity and abundance, our knowledge of the herbivores that inhabit its ecosystems, and the ecological roles they play in them, remains woefully inadequate.

The large herbivore guild of SSEA is both diverse and ancient. Evolutionary radiations of large herbivores occurred in Asia millions of years ago (see Chap. 2), and large herbivores in SSEA are today found across a wide range of habitats and environmental gradients, from deserts and arid lands to wet evergreen tropical forests, and from the plains to over 5000 m asl. Some species such as the sambar *Rusa unicorn*—arguably the most widely distributed large herbivore in SSEA—are found in a variety of habitats across wide precipitation, temperature, and altitudinal gradients, while there are species that are found on islands in Southeast Asia with highly restricted ranges. For example, no more than 300 tamaraw *Bubalus mindorensis* are left in the wild on Mindoro Island, Philippines.

Large herbivores in SSEA also have a long history of association with humans, perhaps more so than anywhere else on Earth. Species such as elephant, rhinoceros, gaur, water buffalo, markhor and ibex figure prominently as motifs on seals of the

¹The species list for large herbivores was drawn primarily from Wilson and Reeder (2005) while incorporating widely accepted updates by the IUCN.

Table 1.1 List of the large herbivore species found in South and Southeast Asia, their IUCN status, and their presence (X) in the different countries in the region

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
Order Cetartiodactyla (Artiodactyla)																
Family Bovidae																
Subfamily Bovinae																
<i>Bos gaurus</i> (gaur)	V				X		X	X	X	X	X	X	X	X		
Domestic form: <i>Bos frontalis</i> (gayal)																
<i>Bos javanicus</i> (banteng)	E								X	X	X	X	X	X	X	
Domestic form: <i>Bos javanicus</i>																
<i>Bos mutus</i> (wild yak)	V				X	X										
Domestic form: <i>Bos grunniens</i>																
<i>Bos sauveli</i> (kouprey)	CE											X				
<i>Boselaphus tragocamelus</i> (nilgai)	LC			X	X											
<i>Bubalus arnee</i> (water buffalo)	E				X	X		X	X	X		X				
Domestic form: <i>Bubalus bubalis</i>																
<i>Bubalus depressicornis</i> and <i>quarlesi</i> (lowland and mountain anoa)	E														X	
<i>Bubalus mindorensis</i> (tamaraw)	CE															X
<i>Pseudoryx nghethinhensis</i> (saola)	CE									X			X			
<i>Tetracerus quadricornis</i> (four-horned antelope, chousingha)	V				X	X										
Subfamily Antilopinae																
<i>Antelope cervicapra</i> (blackbuck)	NT				X											
<i>Budorcas taxicolor</i> (takin)	V				X			X	X							
<i>Capra aegagrus</i> (wild goat)	V		X	X												
Domestic form: <i>Capra hircus</i>																

(continued)

Table 1.1 (continued)

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
<i>Capra falconeri</i> (markhor)	E	X	X	X	X											
<i>Capra sibirica</i> (Himalayan ibex)	LC	X	X	X	X											
<i>Capricornis milneedwardsii</i> (Chinese Serow)	NT								X	X	X	X	X			
<i>Capricornis rubidus</i> (red serow)	NT				X		X		X	X						
<i>Capricornis sumatraensis</i> (southern serow)	V									X				X	X	
<i>Capricornis thar</i> (Himalayan serow)	NT				X	X	X	X	X							
<i>Gazella bennettii</i> (Indian gazelle/chinkara)	LC		X	X	X											
<i>Gazella subgutturosa</i> (goitered gazelle)	V	X	X	X												
<i>Hemirragus jemlahicus</i> (Himalayan tahr)	NT				X	X		X								
<i>Naemorhedus baileyi</i> (red goral)	V				X				X							
<i>Naemorhedus goral</i> (gray goral)	NT			X	X	X		X								
<i>Naemorhedus griseus</i> (Chinese goral)	V				X				X	X	X		X			
<i>Nilgiritragus hylocrius</i> (Nilgiri tahr)	E			X												
<i>Ovis ammon</i> (argali sheep)	NT	X	X	X	X											
<i>Ovis orientalis</i> (urial)	V	X	X	X	X											
Domestic form: <i>Ovis aries</i>																
<i>Pantholops hodgsonii</i> (Tibetan antelope, chiru)	E				X											
<i>Pseudois nayaur</i> (bharal, Himalayan blue sheep)	LC			X	X	X		X	X							

(continued)

Table 1.1 (continued)

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
Family Cervidae																
Subfamily Cervinae																
<i>Axis axis</i> (chital)	LC	X			X	X	X	X								
<i>Axis calamianensis</i> (Calamian deer)	E															X
<i>Axis kuhlii</i> (Bawean deer)	CE														X	
<i>Axis porcinus</i> (hog deer)	E			X	X	X	X	X	X							
<i>Cervus elaphus</i> (red deer, wapiti, American elk)	LC		X	X	X											
<i>Muntiacus altherodes</i> (Bornean yellow muntjac)	LC														X	
<i>Muntiacus crinifrons</i> (black muntjac)	V								X							
<i>Muntiacus feae</i> (Fea's muntjac)	DD								X	X						
<i>Muntiacus muntjak</i> (red muntjac)	LC	X			X	X	X	X	X	X	X	X	X	X	X	
<i>Muntiacus puhoatensis</i> (Pu Hoat muntjac)	DD										X		X			
<i>Muntiacus putaoensis</i> (leaf deer)	DD			X					X							
<i>Muntiacus rooseveltorum</i> (Roosevelt's muntjac)	DD									X	X	X	X			
<i>Muntiacus truongsonensis</i> (Annamite muntjac)	DD									X	X	X	X			
<i>Muntiacus vuquangensis</i> (giant muntjac)	E										X	X	X			
<i>Rucervus divuaceli</i> (barasingha, swamp deer)	V				X	X										
<i>Rucervus eldi</i> (Eld's deer, thamin)	E				X				X		X	X				
<i>Rusa affredi</i> (Philippine spotted deer)	E															X
<i>Rusa marianna</i> (Philippine sambar)	V															X

(continued)

Table 1.1 (continued)

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
<i>Rusa timorensis</i> (rusa)	V														X	
<i>Rusa unicorn</i> (sambar)	V	X			X	X	X	X	X	X	X	X	X	X	X	
Family Tragulidae																
<i>Moschiola indica</i> (Indian chevrotain)	LC				X											
<i>Moschiola meminna</i> (Sri Lankan chevrotain)	LC	X														
<i>Tragulus javanicus</i> (Javan chevrotain)	DD														X	
<i>Tragulus kanchil</i> (lesser Oriental chevrotain)	LC								X	X	X	X	X	X	X	
<i>Tragulus napu</i> (greater Oriental chevrotain)	LC								X	X				X	X	
<i>Tragulus nigrificans</i> (Balabac chevrotain)	E															X
<i>Tragulus versicolor</i> (silver-backed chevrotain)	DD												X			
<i>Tragulus williamsoni</i> (Yunnan chevrotain)	DD									X						
Family Moschidae																
<i>Moschus berezowskii</i> (Forest musk deer)	E												X			
<i>Moschus chrysogaster</i> (Himalayan musk deer)	E				X	X		X								
<i>Moschus capreus</i> (Kashmir musk deer)	E		X		X			X								
<i>Moschus fuscus</i> (black musk deer)	E				X	X		X								
<i>Moschus leucogaster</i> (white-bellied musk deer)	E				X	X		X								
Family Suidae																

(continued)

Table 1.1 (continued)

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
<i>Babyrussa babyrussa</i> (golden babirusa)	V														X	
<i>Babyrussa celebensis</i> (Sulawesi babirusa)	V														X	
<i>Babyrussa togeanensis</i> (Togian babirusa)	E														X	
<i>Porcula salvanius</i> (pygmy hog)	CE				X			X								X
<i>Sus ahoenobarbus</i> (Palawan bearded pig)	V															
<i>Sus barbatus</i> (bearded pig)	V													X		
<i>Sus bucculentus</i> (Heude's pig, Vietnam warty pig)	DD												X			
<i>Sus cebifrons</i> (Visayan warty pig)	CE															X
<i>Sus celebensis</i> (Sulawesi warty pig)	NT														X	
<i>Sus oliveri</i> (Mindoro warty pig)	E															X
<i>Sus philippensis</i> (Philippine warty pig)	V															X
<i>Sus scrofa</i> (Eurasian wild pig)	LC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
<i>Domestic form: Sus domesticus</i>																
<i>Sus verrucosus</i> (Javan warty pig)	E														X	
Order Perissodactyla																
Family Equidae																
<i>Equus hemionus</i> (Asiatic wild ass, kulan)	E			X												
<i>Equus kiang</i> (Tibetan wild ass, kiang)	LC			X	X											
Family Rhinocerotidae																
<i>Dicerorhinus sumatrensis</i>	CE														X	

(continued)

Table 1.1 (continued)

Species (Common name)	IUCN	SRI	AFG	PAK	IND	NPL	BNG	BHU	MYA	THD	LAO	CAM	VTN	MAL	IDO	PHI
(Sumatran rhinoceros)																
<i>Rhinoceros sondaicus</i> (Javan rhinoceros)	CE														X	
<i>Rhinoceros unicornis</i> (Indian rhinoceros)	V				X											
Family Tapiridae																
<i>Tapirus indicus</i> (Asian tapir)	E													X		
Order Proboscidea																
Family Elephantidae																
<i>Elephas maximus</i> (Asian elephant)	E	X			X	X	X	X	X	X	X	X	X	X	X	X

The countries in the region are: *SRI* Sri Lanka; *AFG* Afghanistan; *PAK* Pakistan; *IND* India; *NPL* Nepal; *BNG* Bangladesh; *BHU* Bhutan; *MYA* Myanmar; *THD* Thailand; *LAO* Laos; *CAM* Cambodia; *VTN* Vietnam; *MAL* Malaysia; *IDO* Indonesia; *PHI* The Philippines

IUCN status: *LC* Least Concern; *V* Vulnerable; *NT* Near Threatened; *E* Endangered; *CE* Critically Endangered; *DD* Data Deficient

Note The species list was drawn primarily from Wilson and Reeder (2005) while incorporating widely accepted updates by the IUCN. We confined the Phylogeny of the Orders and their subunits in accordance with Hassamini et al. (2012)

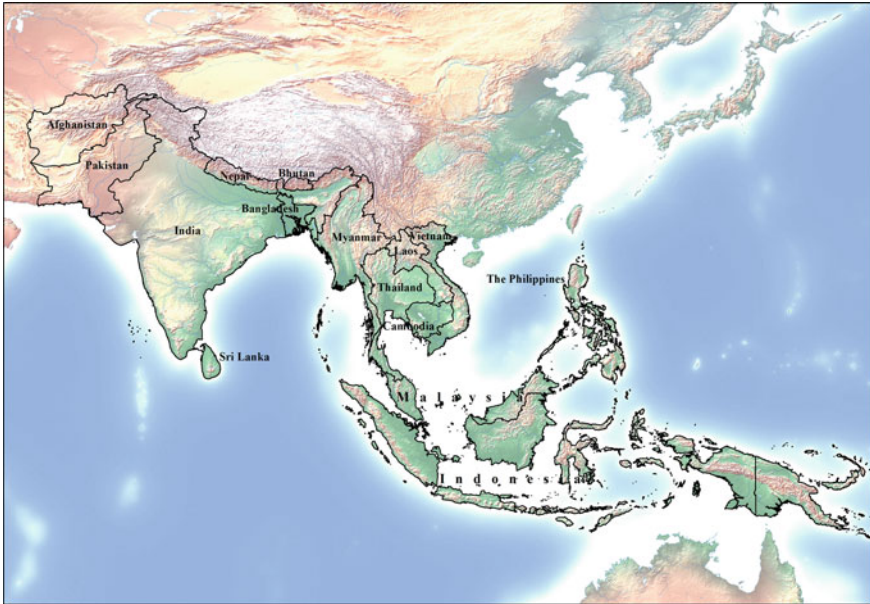


Fig. 1.1 Map showing the countries of South and Southeast Asia. (Map credit Sivakumar Sankar and Srinivas Vaidyanathan)

Indus valley civilization, dating back more than 5000 years. The Indus Valley region in Northwest India and Pakistan and westward to the Fertile Crescent (Southwest Asia) is also considered to be one of the principal centers of domestication of cattle (which resulted in the cattle breed *Bos indicus*), pigs, sheep and wild goats, while East Asia (China and countries south of it) is believed to have been a center for the domestication of buffalo, pigs and yak (Bruford et al. 2003; Chessa et al. 2009). Other large herbivores that have been domesticated or tamed in SSEA include the banteng *Bos javanicus*, Asian elephant *Elephas maximus*, and gaur *Bos gaurus*. Large herbivores have been, and continue to be an integral component of the fabric, culture, folklore, and religious practices of the region, and have also played important roles in ancient warfare in India and Central Asia. Despite this antiquity of association with humans, SSEA has the distinction of having one of the world's most recently discovered large herbivore species—the saola *Pseudoryx nghetinhensis*, a long-horned antelope native to dense forests in Laos and Vietnam was discovered for the first time by conservationists in 1992 (Dung et al. 1993).

Habitat loss, land-use change and hunting are pervasive threats to large herbivore populations worldwide, and nearly 60 % of all extant large herbivore species are today threatened with extinction (Ripple et al. 2015). The problem is particularly pronounced in SSEA, which is home to the highest number of threatened large herbivore species globally (Ripple et al. 2015). Over the past century, SSEA has lost nearly 50 % its forest cover (Houghton 1994; Richards and Flint 1994), and the

current rates of deforestation in SSEA are considered to be the highest among the world's major tropical regions (Zhao et al. 2006; Ripple et al. 2015). This loss has been particularly profound in Southeast Asia; for example, in just one decade, 1972–1982, peninsular Malaysia lost 18 % of its forested area (Brown et al. 1991), and it is estimated that if current trends continue, Southeast Asia could lose up to 75 % of its forests and 50 % of its biodiversity by the end of the century (Sodhi et al. 2004; Ripple et al. 2015).

Much of our current knowledge on the behavior, population dynamics, community ecology, and ecosystem impacts of large mammalian herbivores comes from studies carried out in other regions, particularly North America, Europe, and Africa. This body of work has contributed substantially to our general understanding of the ecological roles of large mammalian herbivores in ecosystems. However, because of differences between biogeographic realms in climate, edaphic factors, evolutionary history, and characteristics of large herbivore guilds, drawing inferences about the ecology and management of herbivores in SSEA, or making prescriptions for their conservation, based on studies from other regions may not always be straightforward. For example, while macropods, i.e., kangaroos and wallabies, exclusively occupy the terrestrial large mammalian herbivore niche in the Australasian biogeographical region, even-toed ungulates (Order Artiodactyla), odd-toed ungulates (Order Perisodactyla), and elephants (Order Proboscidea) dominate the large herbivore assemblages in the rest of the world. The range of body masses, as well as the modal body mass of the herbivore guild varies across biogeographic zones and continents. Compared to ungulates, macropods that dominate the Australasian realm have a more restricted body size range, as well as a lower modal body mass (Fritz and Loison 2006). SSEA and Africa are fairly similar in terms of their herbivore body mass range (SSEA: 5–3500 kg (chevrotain—elephant), Africa: 5–5000 kg (chevrotain/dik-dik—elephant)), but the range of body weights of ungulates in North America, South America, and Europe are more restricted (see Fritz and Loison 2006). Although SSEA and Africa support herbivore assemblages with similar body mass ranges, a key feature that distinguishes their large herbivore guilds is that 30 % of the species found in SSEA are deer species, while only one of the 94 large herbivore species found in Africa is a deer.

As both human population growth and the loss of natural habitat continue unabated, designing appropriate management strategies for the conservation of large herbivores in SSEA based on a sound knowledge of their ecology is becoming increasingly critical. Our objective in putting this edited volume together was twofold: (i) to showcase some of the current ongoing work on large herbivore ecology in SSEA and (ii) to highlight gaps in our knowledge base that catalyze future research on the ecology of large herbivores in SSEA. There is, however, a paucity of knowledge on large herbivores from SSEA. For example, a quick search on the ISI Web of Science database on published research on large herbivores in Asia unearthed 86 relevant peer reviewed publications between 2005 and February 2015, in comparison to 409 publications from the same period in Africa, where the large herbivores of SSEA find their closest analogues (Fig. 1.2; see figure title for details). Although by no means comprehensive, our search is nevertheless

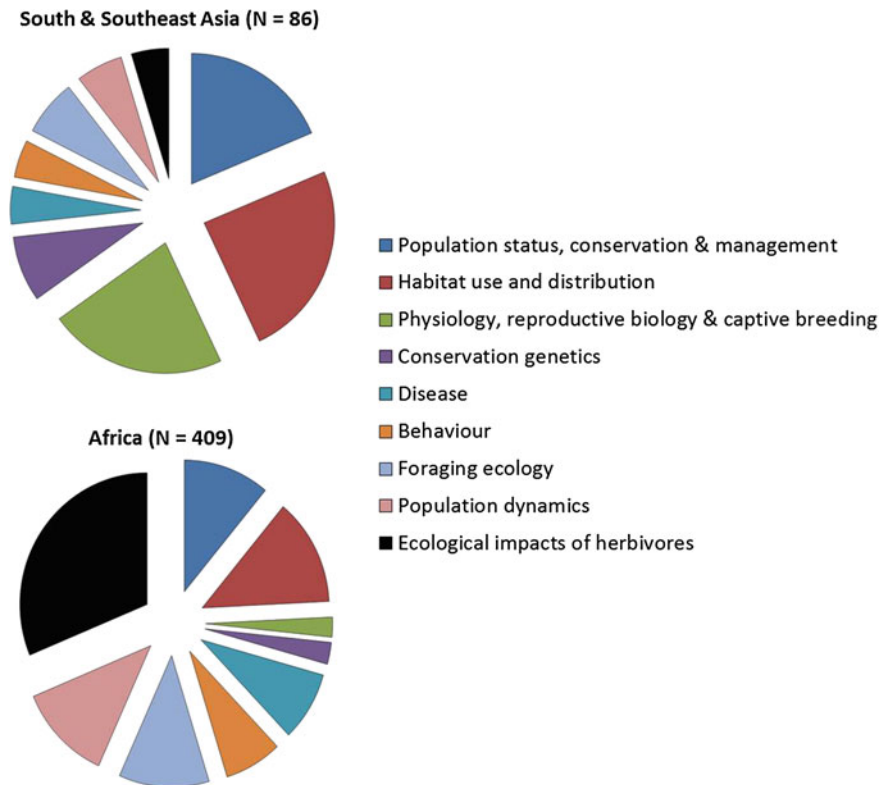


Fig. 1.2 A comparison of research efforts on native large herbivore species in South and Southeast Asia (SSEA) and Africa between January 2010 and February 2015. Data for the graphs were generated based on searching the ISI Web of Science database using the search string “topic = (ungulate OR herbivore OR grazing OR browsing) AND (continent OR countries) NOT (arthropod* OR fish* OR insect* OR butterfly*)”, where ‘continent’ and ‘countries’ represent Asia or Africa and their constituent countries, respectively. We excluded all studies that focused exclusively on domestic herbivores, those that only simulated herbivory under either field or greenhouse conditions, and those that focused primarily on the chemical analysis of browse species. For Asia, we only included studies that were carried out within the 15 countries (see Fig. 1.1 and Table 1.1) that comprise South and Southeast Asia. Studies were subjectively classified into different focal research areas based on the primary objectives of the study. Our final dataset included 86 studies from SSEA and 409 from Africa. While we are aware that the search is by no means comprehensive, we believe it is nevertheless reflective of the relative efforts expended on research on native large herbivore species in the two regions

illustrative of the dearth of research on herbivores in SSEA. Importantly, there are also critical differences in the nature of the research being carried out, and the kinds of questions being addressed, in both regions. The bulk of work in Asia focuses on quantifying population sizes (primarily for endangered species), habitat use, and distribution patterns of species, and studying the physiology and reproductive biology of species in captivity (Fig. 1.2). Only a small fraction of studies in SSEA

have investigated the factors that regulate herbivore populations, or have considered the consequences of herbivory for community and ecosystem level processes. This is in stark contrast to Africa, where the bulk of work has focused on elucidating the ecological impacts of herbivores in ecosystems and the factors regulating their dynamics in the long term, all of which are critical when it comes to managing herbivore populations. Clearly, there is not only a need for more research, but also different kinds of research on large herbivores in SSEA.

This book is not meant to be a comprehensive treatise on the ecology of large herbivores in SSEA, but a first step toward integrating ongoing research on large herbivores in the region. We have brought together research on herbivores at different spatial, temporal, and organizational scales ranging from the evolutionary history of large herbivores in Asia (Chap. 2), the importance of body size in influencing foraging strategies and species distribution patterns (Chaps. 3 and 4), the role of large herbivores as seed dispersers in SSEA (Chap. 5), behavior and long-term population dynamics of a widespread semiarid ungulate species (Chap. 6), consequences of herbivory for plant allocation patterns and ecosystem carbon and nutrient cycling (Chaps. 7 and 8), and the conservation and future of large herbivores in SSEA (Chaps. 9 and 10). We finally forge a synthesis and highlight directions for future research on large herbivores in SSEA that are particularly critical and urgent from a management and conservation perspective (Chap. 11). Ultimately, we want that this volume to serve as a key resource for scientists, students, and managers alike. Given that 31 of the 83 species (37 %) of large herbivores in SSEA are classified as either Endangered or Critically Endangered, and the population trends of practically all the species are considered by the IUCN to be decreasing (Table 1.1), we hope that this volume will inspire further research of the ecology of this prominent but understudied guild in SSEA.

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