International Journal of Ecology and Environmental Sciences 44 (3): 319-329, 2018
ISSN: 2320-5199 (Online)

Wild Ungulates in A Human Dominated Landscape: Their Population Structure, Density and Biomass in Western India

DHAWAL MEHTA *[1] AND V.C. SONI[2]

Department of Biosciences, Saurashtra University, Rajkot 360005, Gujarat, India and
Wildlife Institute of India, Chandrabani, Dehradun 248002, Uttarakhand, India

Email ID: [1] dhawalbmehta@hotmail.com; [2] vcsoni2009@gmail.com
Corresponding author; Present address: *33, Shiv Ganesh-2, Opp. Zydus Hospital, Thaltej, Ahmedabad 380059, Gujarat, India*

ABSTRACT

The population structure, density and biomass of three species of ungulates-Nilgai (*Boselaphus tragocamelus*), Wild Pig (*Sus scrofa*) and Chinkara (*Gazella bennetti*) were studied in ten grasslands of Central Saurashtra, Western India during 2011-12 using the distance sampling method. The total transect length involving all the study sites was 38.44 km which was walked for a total of 16 times resulting in a sampling effort of 615.04 km. The mean group size at all the sites for Nilgai, Wild Pig and Chinkara were 5.403±0.95 (SE), 7±0.63 (SE) and 5.4±0.63 (SE) respectively. Average estimated densities of 40.52 Nilgai km^{-2}, 50.58 Wild Pig km^{-2} and 1.64 Chinkara km^{-2} were recorded from all sites. The sex ratios were usually biased towards females except in some cases in Nilgai. The Nilgai and Chinkara were usually seen to be solitary or form small herds while Wild Pigs were more gregarious forming herds of more than 6 individuals. The group size in all three species did not vary between sites and between seasons. The average wild ungulate biomass at all the studied grassland sites was computed to be 4569.95 kg km^{-2}.

Key Words: Saurashtra; Grassland; Group Size; Line Transect; Nilgai; Wild Pig; Chinkara

INTRODUCTION

Several studies have emphasized on estimating prey densities of large herbivores in different parts of the world with evidences suggesting that ungulate depletion is a major factor driving the current decline of predators (Ramakrishnan et al. 1999, Karanth and Stith 1999). Large herbivores, particularly, are very difficult to conserve due to several factors: inherently low population densities, unique habitat requirements, tendency to raid crops, and in several cases, their consumption by local people (Karanth and Sunquist 1992). Estimation of ungulate abundance in various protected areas in India has been ongoing since over half a decade, few examples would include Schaller (1967), Berwick (1974), Johnsingh (1983), Sankar (1994), Varman and Sukumar (1995), Khan et al. (1996), Khan (1997), Karanth and Sunquist (1992, 1995), Karanth and Nichols (1998, 2000), Kumar (2000), Biswas and Sankar (2002), Jathanna et al. (2003), Bagchi et al. (2004), Andheria et al. (2007), Mondal et al. (2011), Jhala et al. (2008, 2011). These studies have been confined to well managed protected areas and are usually forested habitats. A major part of wild fauna is solely dependent upon grasslands (Groombridge 1992). Yet grassland ecosystems have not received the desired attention and have been largely neglected in terms of conservation and proper management, except grazing lands, especially in developing countries including India (Rahmani 1989). The current study was carried out in grasslands of Central Saurashtra in the Gujarat state, India. These grasslands form a mosaic along with an otherwise human and agriculture dominated landscape. The ungulate populations here are considered over abundant by locals

as well as the management and hence a detailed study was necessitated to generate baseline information to further assist in conservation and management of the study area.

STUDY AREA

The Saurashtra peninsula forms a rocky tableland dominantly composed of Deccan lava. It is flanked by the Gulf of Kutch and coastal plains in the North, Arabian Sea towards the West and South, demarcated by the Gulf of Khambhat on the South East and alluvial plains to its East (Figure 1). It comprises of seven districts namely Surendranagar, Rajkot, Jamnagar, Porbandar, Junagadh, Amreli and Bhavnagar covering 47,000 km^2 representing 24% of the state of Gujarat (Jadav 2010). It is bound between the latitudes 20^0 50' N and 23^0 5' N and longitudes 69^0 20' E and 72^0 10' E. Biogeographically, the whole area falls under the biotic province 4B- Gujarat Rajputana of the 4-Semi Arid biogeographic zone (Rodgers et al. 2000). The major habitat of Saurashtra is represented by an open thorny scrub forest with graminoid ground cover, commonly referred to as tropical scrubland savanna which gradually changes to a dry savanna in the process of continuous degradation and is locally called *Vidi* (grasslands for hay) (Mehta 2015). The *vidis* historically were protected and maintained by the erstwhile princely states as private game reserves, community grasslands or pastures by local authorities and then transferred to and maintained by the State Forest Department since 1959-60 (Sugoor and Ande 2001). In 1962, the *vidis* were classified as reserved and non reserved depending upon their annual grass production; grasslands with an annual outcome of more than 93000 kg were given the status of reserved *vidis* and the ones with lower production were called non reserve *vidis* (Sugoor and Ande 2001). In case of reserve *vidis*, the entire management rests with the Forest Department and collected grass is supplied to Revenue Department for distribution. The non reserve *vidis* are auctioned annually to local bodies in the month of June-July to fulfil the local needs. If none of the local bodies are keen, then these are put to open auction for collection of grass.

Central Saurashtra is a human dominated landscape predominated by the Rajkot district of Gujarat state. The region experiences a semi arid climate in the aridity index range of 20-40 per cent indicating a general deficiency of soil moisture for major part of the year. The mean annual temperature is 26-27^0C with mean maximum and minimum of 40^0C and 11^0C and range of extremes being 46^0C and 5^0C. The relative humidity is 65-70 per cent. Three distinct seasons occur: Winter, summer and monsoon. Winter starts from November and continues till February with January being the coldest month. The average temperature ranges from 10^o to 15^o C. Summer is usually dry and hot and extends from March to June. May is the hottest month with the mean maximum temperature of 40^o C. Monsoon extends from July to October and rain fall is confined to monsoon season only and marked by high relative humidity ranging from 80% to 92% and an annual mean rainfall of 661.57 mm. The area stands at an average 160 metres above mean sea level.

The major vegetation of the *vidis* in Central Saurashtra includes grasses like *Sehima nervosum* (Rottler) Stapf, *Dichanthium annulatum* (Forssk.) Stapf., *Andropogon pumilus* Roxb., *Apluda mutica* L., *Aristida adscensionis* L., *Cenchrus ciliaris* L., *Cymbopogon martinii* Roxb., *Heteropogon contortus* L., *Cynodon dactylon* L., *Iseilema laxum* Hack., *Chrysopogon fulvus* Spreng. with scattered growth of mostly thorny species of trees like *Acacia nilotica* L., *A. senegal* L., *A. leucophloea* Roxb., *Balanites aegyptiaca* L. and *Zizyphus nummularia* (Burm.f.) Wight & Arn. (Mehta 2015). The exotic mesquite (*Prosopis juliflora* Sw.) hasn't invaded the *vidis* in this part, thus keeping the grassland ecosystem intact with its indigenous vegetation community.

We conducted our sampling in 10 reserved and non reserved *vidis* located over six *tehsils* (Lodhika, Padadhari, Rajkot, Gondal, Jamkandorna and Jasdan) of Rajkot range namely Khirasara (reserved *vidi,* area-400 ha), Khambhala-Ishvariya (reserved *vidi,* area-91.13 ha), Hirasar (reserved *vidi,* area-241.34 ha), Bhandariya (reserved *vidi,* area- 167.04 ha), Vanathali (reserved *vidi,* area-156 ha), Rampar (reserved *vidi,* area-98.33 ha), Meghavad (reserved *vidi,* area-28.12 ha), Nani Kanesara (reserved *vidi,* 241.78 ha), Umath (reserved *vidi,* 1455 ha) and Modhuka-Chadika (non reserved *vidi,* 116.88 ha). All these grasslands are surrounded by agricultural lands (Figure 2). These grasslands act as day refuges for the ungulates and these species are known to raid crops in the night.

The wild ungulates found in these grasslands include three species, namely the Nilgai (*Boselaphus tragocamelus* Pallas), Chinkara (*Gazella bennetti* Sykes) and the Wild Pig (*Sus scrofa* L.)

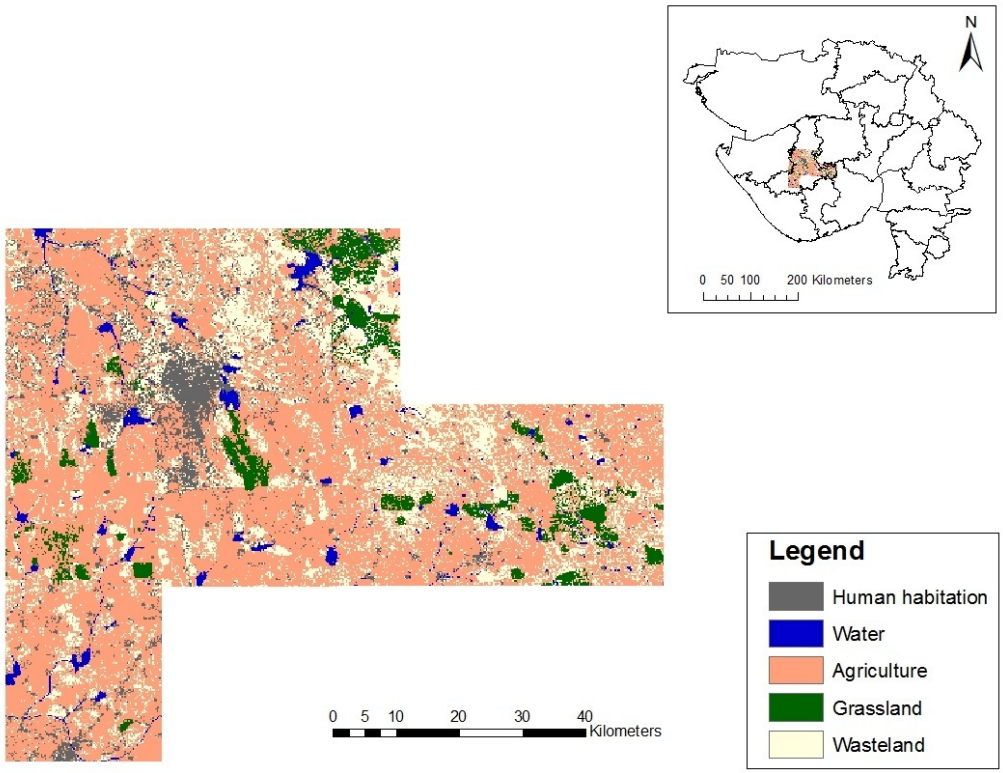

Figure 1. Map of the study area

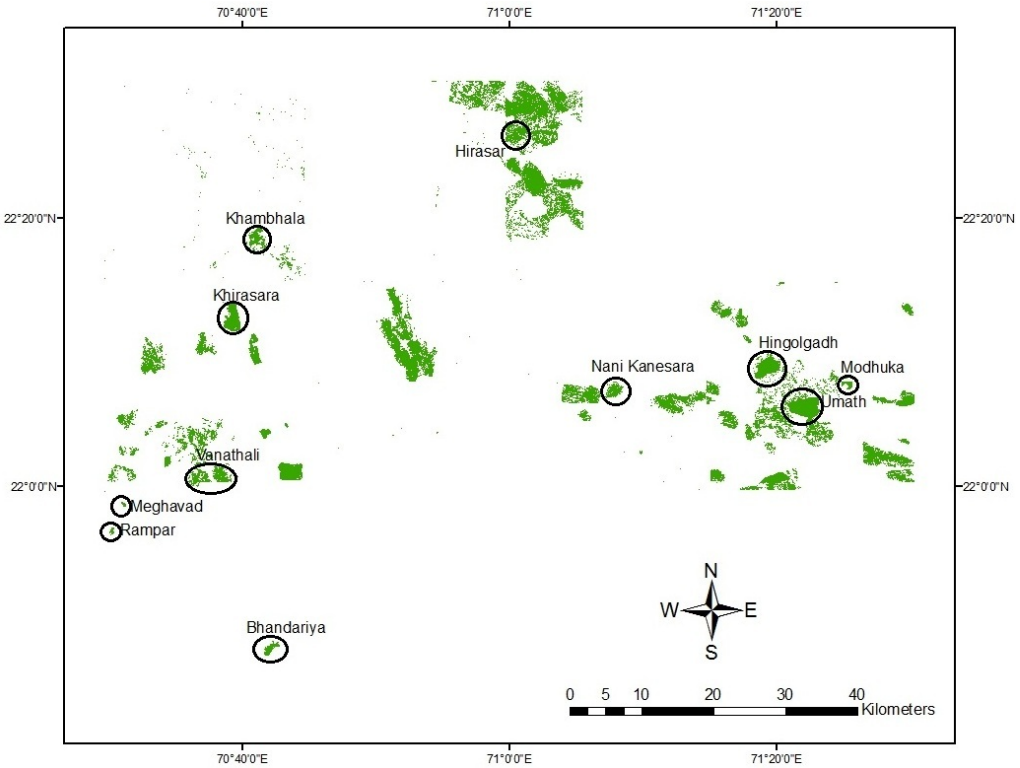

Figure 2. Locations of the grasslands in the study area

METHODS

The ungulate populations were systematically sampled starting 1st October, 2011 till 31st January, 2013 (thus covering 4 seasons-2 winters, 1 summer and 1 monsoon), using permanently marked foot transects to determine group sizes, grouping tendencies, and densities using the distance sampling method. Adult mortalities were observed to be very low and calves or piglets after the birth season were not included in the data set as data collected over a period of one year and four seasons would inevitably cause a variation in the densities. The densities collected over different seasons were averaged to minimize the coefficient of variation. The abundance estimation was carried out by collecting data on the line transects. Animal counts and associated distance data are used to model visual detection probabilities as a decreasing function of distance from the line transect. Nevertheless, a large number of observations are often required to calculate detection function precisely (Ramesh 2010). The detection probability of an object depends solely on its perpendicular distance from the line. This modelling and the subsequent estimation of population densities and their variances are accomplished by using the program DISTANCE (Thomas et al. 2010). Since estimating animal densities using Distance Sampling method corrects the bias of non-detection, this method is preferred over others (Karanth and Nichols 1998).

The data on sighting distance, sighting angle and accurate group size were recorded for each detection. Data was collected during 06.30-09.30 a.m. and 15.30-18.30 p.m. The length of the transects varied from 1.14 km to 3.88 km in different *vidis* covering the entire stretch of the *vidis*. The total transect length involving all the study sites was 38.44 km which was walked for a total of 16 times resulting in a sampling effort of 615.04 km. The sampling effort was uniform for different seasons of the year. The hypotheses we tested were (1) Do the group sizes of the ungulates vary between seasons and (2) What governed the differential density at the grassland study sites. A two-way ANOVA using seasons as block level was used to test for differences in mean group size of each species between all the study sites (Sokal and Rohlf 1995). Generalized linear models using area of the grassland, distance to human habitation, distance to water, distance to road, distance to farms, ground cover, tree density, terrain, cattle density and rainfall as predictors were run to understand differential densities at the different grassland sites.

Whenever possible, animals were also assigned to appropriate age-sex categories. Mean group sizes obtained from line transect counts actually indicate the size of 'clusters' (Burnham et al. 1980) of animal species being sampled, rather than of social groups. Though these clusters are not always identical to social groups, we believe our estimates are adequate for population analyses. For population estimates, the mean group size was multiplied with the density of clusters to obtain density of animals in the study sites as suggested by Karanth and Sunquist (1992). The data were analyzed using the software DISTANCE 6.0 (Thomas et al. 2010). The best fit models were chosen depending on the minimum AIC values to determine densities. The accuracy of density estimates depends on how well the underlying assumptions were met (Buckland et al. 2001). Counting errors and biases (Broten and Said 1995, Jolly 1969, Caughley 1974, Norton-Griffiths 1978, Ottichilo and Sinange 1985) may contribute to fluctuations in the population estimates. However, one of the main factors that contributes significantly to counting errors is visibility, which in turn is influenced by vegetation cover (Watson and Tippett 1981).

For biomass estimation, the average body weights of species mentioned in available literature (Biswas and Sankar 2002, Bagchi et al. 2004) were used.

RESULTS

Group Size and Grouping Tendencies

The total data from all the study sites were used to analyze grouping tendencies. The results of two way ANOVAs showed no significant difference in the mean group size in case of all species between seasons and between all the sites ($P>0.05$ in all cases) except for the mean group size of the Nilgai only in case of Umath because the animals detected were always solitary and showed marginal variation ($p=0.06$) (Table 1).

Nilgai were found to be solitary or forming small groups; at times large groups of males (bachelor herds) constituted of about 26-29 individuals. Solitary Nilgai accounted for about 29.33% of the groups and these were usually adult males. Wild Pig congregated in larger herds of 6-10 individuals constituting of males, females and young ones (Table 2). A group size of 35 individuals of Wild Pigs might have been temporary congregation of several groups. The Chinkara were found to occur in small family units of about 5 individuals and very seldom were seen in groups of more than 7.

Table 1. Results of a two-way ANOVA, comparing group size of three ungulates across three seasons (winter, summer and monsoon) and study sites during 2011-12.

Species	Effect	F	p
Nilgai	Season	F_{125}=0.7292	0.48436
	Site	F_{125}=2.0866	0.05935
	Interaction	F_{125}=0.7805	0.63465
Wild Pig	Season	F_{17}=0.0190	0.9812
	Site	F_{17}=1.6664	0.1419
	Interaction	F_{17}=0.6964	0.7496
Chinkara	Season	F_{11}=1.9558	0.1876

Table 2. Group size proportionate (%) distribution of the study species in Central Saurashtra. n=number of groups detected

Group size	Nilgai (n=148)	Wild Pig (n=92)	Chinkara (n=14)
1-5	60	28.26	75
6-10	22.66	61.95	25
11-15	12	6.52	0
16-20	2.66	1.086	0
21-25	2	0	0
26-30	0.66	0	0
31-35	0	2.173	0

Density Estimates

An average density of 40.52 individuals km^{-2} of Nilgai was recorded from eight grasslands. No animals were sighted in two grasslands (Meghavad and Rampar) and hence weren't used in the analysis (Table 3). The uniform/cosine model gave the least AIC and eventually the best fit throughout all the study areas for all species. Wild Pigs were recorded from 7 out of 10 sites and the average density was 50.58 individuals km^{-2}. Chinkara was recorded from only one site-Umath and the density was 1.64 individuals km^{-2} (Table 3).

The estimates of group sizes and densities at each site for all three species are given in Table 3. The data was collected through the course of the year (2 winters, 1 summer and 1 monsoon) which would thus reflect variability because of varying detection conditions and consequently account for the larger coefficient of variation than recommended (%CV <10-15%) in spite of having a sample size larger than recommended by Burnham et al. (1980). The densities have been derived from such data and should be considered as averages for the period as mentioned by Karanth and Sunquist (1992). Density estimates show that both Nilgai and Wild Pig are abundant in all the areas while the Chinkara is found only at one site with half the density of the Nilgai and one-eleventh that of Wild Pig at the same site.

None of the predictor variables (proximity to human habitation, proximity to water, proximity to road, proximity to farms, ground cover, tree density, terrain, cattle density and rainfall) showed any significant effect on the differential densities of the wild ungulate species in the study area.

A comparison of the density estimates from other forests of India is shown in Table 4. The average density of Nilgai and Wild Pig in the study area is much higher than Protected Areas falling under the same biotic province in India.

Population Structure

Nilgai and Chinkara were classified as adult males (AM), adult females (AF), yearling males (YRM), yearling females (YRF) and young (YG), while the Wild Pigs were classified as adult males (AM), adult females (AF) and young (YG). We could assign sex and age group to all the Nilgai and Chinkara recorded and 82% of all the Wild Pigs detected (Table 5). The young ones of Chinkara were not recorded during the study period. The adult sex ratios appeared biased towards females in case of the Nilgai except for Khirasara (122.75:100), Vanathali (106.25:100), Nani Kanesara (375:100) and Umath (150:100). This might be due to lesser detection of females especially in Nani Kanesara and Umath. Khirasara (108:100) and Kanesara (300:100) followed the same pattern in case of ratios of yearling males to yearling females while the rest of the sites either showed a female yearling bias or else no detection, which could also be accountable to erroneous classification of some yearlings as adults.

The adult sex ratios in case of Wild Pigs and Chinkara depicted a bias towards females at all the sites.

Biomass Estimates

The biomass at each site was computed based on the mean densities at different sites (Table 6). The average

Table 3. Estimated numerical density (individuals km^{-2}) of three ungulate species in Central Saurashtra. Dg and Di = estimated density of groups and individuals respectively; GS = estimated mean group, SE = estimated standard error, CV Di = estimated coefficient of variance of density of individuals, CI Di=95% confidence intervals of density estimates of individuals

	Nilgai					Wild Pig					Chinkara				
Site	Dg	GS ± SE	Di	CV Di	CI Di	Dg	GS±SE	Di	CV Di	CI Di	Dg	GS±SE	Di	%CVDi	CI Di
Khirasara	12.39	6.08±0.507	69.36	38.77	38.93-99.80	3.5	10.4±1.83	35.91	27.33	22.31-49.52	--	--	--	--	--
Khambhala-Ishvariya	7.395	8.004±0.67	55	23.47	42.34-67.65	6.19	6.77±0.04	42.02	22.06	29.17-54.86	--	--	--	--	--
Hirasar	6.95	5.89±0.837	39.26	30.84	25.55-52.97	6.29	7.4±0.98	48.04	48.7	15.61-80.47	--	--	--	--	--
Bhandariya	12.1	5.31±0.694	55.46	31.12	35.93-74.99	12	7.2±0.14	86.65	15.75	67.73-105.56	--	--	--	--	--
Vanathali	4.82	9.16±1.29	41.1	23.05	27.96-54.23	--	--	--	--	--	--	--	--	--	--
Nani Kanesara	8.38	2.28±0.505	17.35	2.03	16.86-17.83	10.49	6.29±0.02	65.94	26.13	42.05-89.83	--	--	--	--	--
Umath	3.95	1±0	4.035	2.97	3.86-4.20	3.46	5.69±0.39	19.49	4.06	18.4-20.59	0.31	5.4±0.63	1.645	5.58	1.51-1.77
Modhuka	7.74	5.5±0.353	42.59	13.55	34.59-50.59	10.65	5.25±0.176	56.03	12.19	46.56-65.5	--	--	--	--	--

Table 4. Density (individuals km^{-2}) of three wild ungulates in Central Saurashtra with different study sites falling under the same biotic province in India. The density estimates are the mean of all the sites

	Central Saurashtra*	Rampara[1]	Hingolgadh[1]	Velavadar[1]	Gir[2]	Ranthambhore[3]	Sariska[4]
Habitat type	Tropical Dry savannah	Tropical Dry savannah *Acacia senegal* forest	Tropical Dry savannah *Acacia senegal* forest	Tropical Grassland	Tropical dry deciduous forest	Tropical dry deciduous forest	Tropical Dry deciduous forest
Nilgai	40.52	10.86	12.61	13.17	0.4	6.6	18-36
Chinkara	1.64	1.53	14.52	--	1.2	1.2	--
Wild Pig	50.58	--	--	5.05	2.1	3.61	5.2-11.1

*-Present study, 1-Gujarat State Forest Department census (Singh 2001), 2- Khan (1997), 3- Bagchi et al. (2004), 4-Sankar (1994).

Table 5. Proportions (%) of different age and sex classes among different ungulate species

Site	Nilgai (N=809)					Wild Pig (N=543)			Chinkara (N=43)			
	% AM	% AF	% YRM	% YRF	% YG	% AM	% AF	% YG	% AM	% AF	% YRM	% YRF
Khirasara	40.98	33.38	8.28	7.67	9.66	22.48	61.24	16.27	--	--	--	--
Khambhala-Ishvariya	26.72	54.65	--	6.38	12.23	23.11	63.31	13.56	--	--	--	--
Hirasar 24.56	51.92	--	11.57	11.92	25	67.85	7.142	--	--	--	--	
Bhandariya	15.69	47.67	12.2	19.18	5.23	22.64	67.92	9.43	--	--	--	--
Vanathali	51.51	48.48	12.12	--	--	--	--	--	--	--	--	--
Nani Kanesara	55.55	14.81	22.22	7.4	--	28.57	71.42	25.71	--	--	--	--
Umath 60	40	--	--	--	22.22	61.72	16.049	27.06	49.62	12.03	11.27	
Modhuka	26.15	79.45	--	--	--	30.23	48.83	20.93	--	--	--	--

Table 6. Density (Di, km^{-2}) and Biomass (kg km^{-2}) estimates of three species of ungulates in Central Saurashtra.

Site	Nilgai		Wild Pig		Chinkara	
	Di	Biomass	Di	Biomass	Di	Biomass
Khirasara	69.36	12762.24	35.91	1364.58	--	--
Khambhala-Ishvariya	55	10120	42.02	1596.76	--	--
Hirasar	39.26	7223.84	48.04	1825.52	--	--
Bhandariya	55.46	10204.64	86.65	3292.7	--	--
Vanathali	41.1	7562.4	--	--	--	--
Nani Kanesara	17.35	3192.4	65.94	2505.72	--	--
Umath 4.035	742.44	19.49	740.62	1.645	19.74	
Modhuka	42.59	7836.56	56.03	2129.14	--	--

ungulate biomass contributed by Nilgai and Wild Pig in Central Saurashtra were 7455.56 kg km^{-2} and 1922.14 kg km^{-2} respectively. The biomass contributed by Chinkara was 19.74 kg km^{-2} at Umath.

DISCUSSION

Group Size and Grouping Tendencies

Our results show that the mean group size did not vary between seasons and among study sites. This thus implied that temperature, availability of food or mating period did not play a significant role in group formation of the study species. The antelopes i.e. Nilgai and Chinkara usually formed smaller groups while the Wild Pig had a higher frequency of groups of 6-10 individuals. Nilgai has been known to occur in small groups in other areas as well (Dinerstein 1980, Khan et al. 1995), Biswas and Sankar 2002, Bagchi et al. 2008). The males of the species were found to occur solitarily or form small herds along with females and fawns. Only seldom were they found to occur in herds of more than 20 individuals, thus forming a bachelor herd. Females formed small individual herds along with yearlings and calves or with a few males. The herd size composition in case of the Nilgai follows a pattern reported from other forests of the country thus indicating their basic tendency to form not so large herds even though the habitat of the study area (savannah) intermingled with agriculture differs drastically from these forests.

The Wild Pig frequently formed groups of 5-10 individuals in all sites from where it was recorded. Biswas and Sankar (2002) have reported similar group sizes in Pench Tiger Reserve in Central India.

The Chinkara has also been reported to form small herds, pairs or family units (Rahmani 1990, Khan et al. 1996, Bagchi et al. 2004). Chinkara was found only to occur at one grassland site i.e. Umath. This can be attributed to Umath's proximity to the Hingolgadh Nature Education Sanctuary that holds a substantial population of the species (Figure 2). The Chinkara herds thus encountered here may be transiting between the two areas, thus Umath stands as a suitable habitat and one of the strongholds to support a viable population of the Chinkara. The Chinkara has not been reported from other sites even in earlier literature. This might be due to relatively smaller sizes of the *vidis* as compared to Umath and higher disturbance.

Density Estimates

The results show that the population densities in all these areas were relatively high as compared to any of the national parks or sanctuaries in South Asia. Chauhan et al. (2010) described the population of the Nilgai in Rajkot as over abundant. The densities are higher relative to Wildlife Sanctuaries (Hingolgadh and Rampara) in proximity to the study sites with similar vegetation, hence contributing to a higher biomass. This shows the Nilgai's preference to open and cultivated areas (Blanford 1888, Prater 1971).

Wild Pig showed similar results and their densities were higher than in protected areas in other parts of the country and the state of Gujarat. The Wild Pigs are a constant source of human-wildlife conflict in the landscape. The Wild Pig has always been associated with man, and successfully utilises the human altered landscape (Fadeev 1981, Erkinaro et al. 1982).

The Chinkara occurred at only one site and its density was similar to that of Gir forest as reported by Khan (1997). However, its density was relatively low as compared to other Wildlife Sanctuaries in India (Bagchi et al. 2004) from the same biogeographic province. The density in the adjoining Hingolgadh sanctuary is 8.85 times higher. Umath hence may serve as a potential habitat in the near future once the carrying capacity is reached at Hingolgadh. The landscape between Umath and Hingolgadh needs to be conserved to serve as a viable corridor to ensure long term conservation of the Chinkara in this area.

No predictor variables showed any significant effect on the differential densities of these ungulates indicating that animals existed in areas that acted as refuge patches in an otherwise human dominated landscape and exhibits their high adaptability to coexist with humans and justifies their dependence on cultivated crops as food resource.

Population Structure

The adult sex ratios appeared biased towards females in case of the Nilgai except for some areas. Khan et al. (1995) reported Nilgai to have an approximate even sex ratio 89-97 males:100 females in Gir. Biswas and Sankar (2002) and Bagchi et al. (2008) have reported a male biased sex ratio in Pench and Ranthambhore Tiger Reserves respectively thus, indicating that it was not unusual in this species.

The adult sex ratios in case of Wild Pigs depicted a bias towards females at all the sites as also reported by Karanth and Sunquist (1992) and Biswas and Sankar (2002) at Nagarhole National Park and Pench Tiger Reserve.

The Chinkara showed a bias towards females as reported by Rahmani (1990) in Rajasthan. Bagchi et al. (2008) reported a ratio of 119.8 males per 100 females in Ranthambhore National Park. There is a slight possibility of encountering the same individuals during successive transect walks due to the territoriality of the species as highlighted by Bagchi et al. (2008).

Biomass Estimates

The biomass estimates computed from the average weights of the three study species show that the ungulate biomass in these areas is very high. The herbivore biomass in the study area is sufficient to sustain a substantial population of predators. Biomass in some grasslands even exceeds that of tropical African savannahs like Serengeti and Nairobi National Park (Eltringham 1979).

CONCLUSION

These animals occur in a human dominated landscape and hence are a constant source of human-herbivore conflict resulting in huge economic loss to the farming community. The farmers are tolerant to the presence of the Chinkara in their farmlands. The populations are thriving chiefly due to the religious and socio-ethical sentiments of the local communities. There is no natural predator in these areas to control the population of these animals which thus implies a need to manage populations by non-biological means. However, some adjoining wildlife sanctuaries do hold populations of natural predators like the wolf (*Canis lupus pallipes*) but the habitat needs to be managed and corridors need to be conserved for movement of these carnivores which could possibly control the population densities of these ungulates. There is evidence of wolves predating on the Nilgai and Wild Pig from the *Bhal* region of Gujarat (Jethva and Jhala 2004). Section 11(b) of the Indian Wildlife (Protection) Act 1972 empowers the Chief Wildlife Warden (CWLW) of the state or an authorized officer to permit any person to hunt a wild animal or group of animals (specified in Schedule II, III and IV) if it is found to be causing damage to standing crops. The Nilgai and Wild Pigs are categorized as schedule-III in the Wildlife (Protection) Act and can hence be allowed to hunt on a legal basis. The village Sarpanchs declared as the honorary wildlife wardens are considered "subordinate" officers to the CWLW and hold the authority to allow hunting of Nilgai (Chauhan et al. 2010). Considering the religious and ethical sentiments of the locals, non lethal methods like chemical or immunocontraception can be opted. Immuno-contraception has proven as an effective population control tool in a multitude of species (Liu et al. 1989, McShea et al. 1997, Kirkpatrick 1995, Kirkpatrick et al. 1990, 1992, 1995; Turner and Kirkpatrick 2002, Kirkpatrick and Turner 2008). The confinement of the wild animals in the *vidis* by corralling them is an unfavourable option since it would interrupt their population dynamics (McCollough 1997). Site specific plans include managing the grasslands based on sound scientific principles. The grass should be harvested in a systematic manner leaving a considerable proportion as

forage for wildlife and also planting good browse species like *Zizyphus nummularia* in the grasslands which is likely to reduce crop depredation (Mehta et al. 2013, Mehta 2014). Also, pulsating fencing using solar power with government support or subsidy around the agricultural lands could be the most viable option (Chauhan and Sawarkar 1989, Mehta 2014).

ACKNOWLEDGEMENTS

We are thankful to the Deputy Conservator of Forests and office staff of the Rajkot Forest Division and Gujarat State Forest Department for their constant support and help in conducting this study.

The data were collected and analyzed by the first author. Both the authors contributed equally to the preparation of the manuscript. We declare no conflict of interest

REFERENCES

Andheria, A.P.; Karanth, K.U. and Kumar, N.S. 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. Journal of Zoology 273: 169-175.

Bagchi, S.; Goyal, S.P. and Sankar, K. 2008. Social organisation and population structure of ungulates in a dry tropical forest in western India (Mammalia, Artiodactyla). Mammalia 72 : 44–49.

Bagchi, S.; Goyal, S.P. and Sankar, K. 2004. Herbivore density and biomass in a semi-arid tropical dry deciduous forest of western India. Journal of Tropical Ecology 20: 475–478.

Berwick, S.H. 1974. The Community of Wild Ruminants in the Gir Forest Ecosystem, India. PhD thesis, Yale University, New Haven, CT. 226 pages.

Biswas, S. and Sankar, K. 2002. Prey abundance and food habit of tigers (*Panthera tigris tigris*) in Pench National Park, Madhya Pradesh, India. Journal of Zoology, London 256:411–420.

Blanford, W.T. 1888. The Fauna of British India, including Ceylon and Burma. Mammalia. Taylor and Francis. London. England. 617 pages.

Broten, M.D. and Said, M. 1995 Population trends of ungulates in and around Kenya's Masai Mara Reserve. Pages 169-193, In: Sinclair, A.R.E. and Arce, S.E.R (Editors) Serengeti II: Dynamics, Management and Conservation of an Ecosystem. The University of Chicago Press, Chicago.

Buckland, S.T.; Anderson, S.T.; Burnham, K.P.; Laake, J.L.; Borchers, D.L. and Thomas, L. 2001. Introduction to Distance Sampling. Estimating Abundance of Biological Populations. London: Oxford University Press. 446 pages.

Burnham, K.P.; Anderson, D.J. and Laake, J.L. 1980. Estimation of density from line transect sampling of biological populations. In Wildlife Monographs 72. Washington, DC: The Wildlife Society. 202 pages.

Caughley, G. 1974. Bias in aerial survey. Journal of Wildlife Management 38: 921-933.

Chauhan, N.P.S. and Sawarkar, V.B. 1989. Problems of over abundant populations of Nilgai and blackbuck in Haryana and Madhya Pradesh and their management. Indian Forester 115: 488-493.

Chauhan, N.P.S.; Chowdhury, S.; Qureshi, Q.; Malik, K.; Nigam, P. and Sinha, P.R. 2010. Managing Blue Bull (*Boselaphus tragocamelus*) in Human and Agriculture Dominated Landscapes: Challenges and Options for Mitigation. Wildlife Institute of India, Dehradun, India. 38 pages.

Dinerstein, E. 1979. An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part II; Habitat/animal interaction. Biological Conservation 16: 265–300.

Eisenberg, J. F. and Lockhart, H. 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. Smithsonian Contributions to Zoology 101: 1–118.

Eltringham, S.K. 1979. The Ecology and Conservation of Large African Mammals. University Park Press, Baltimore, 286 pages.

Erkinaro, E.; Kalevi, H.; Lindgren , E.; and Sulkava , S. 1982. Occurrence and spread of Wild Pigs (*Sus scrofa*) in the eastern FinnoScandia. Memoranda 58: 39-47.

Fadeev, E.V. 1981. Dynamics of the northern limits of the area of distribution of the wildboar, *Sus scrofa* in Eastern Europe. Biologicheskie Nauki (Moscow) (9): 56-64.

Groombridge, B. 1992. IUCN Red List of Threatened Mammals. IUCN Gland, Switzerland, and Cambridge, UK. 286 pagees.

Jadav, R.D. 2010. Ecological Status and Importance of Grasslands (Vidis) in Conservation of Avian Fauna in Saurashtra. PhD thesis. Saurashtra University, Rajkot. 272 pages.

Jathanna,D.; Karanth, K.U. and Johnsingh, A.J.T. 2003. Estimation of large herbivore densities in the tropical forests of southern India using distance sampling. Journal of Zoology, London 261: 285–290

Jethva, B.D. and Jhala, Y.V. 2004. Foraging ecology, economics and conservation of Indian wolves in the Bhal region of Gujarat, Western India. Biological Conservation 116:351–357.

Jhala, Y.V.; Gopal, R.; and Qureshi, Q. (Eds) 2008. Status of tigers, co-predators and prey in India. National Tiger Conservation Authority, Govt.; of India, New Delhi and Wildlife Institute of India, Dehra Dun. TR 08/001. 151 pages.

Jhala, Y.V.; Qureshi, Q.; Gopal, R. and Sinha, P.R. (Eds.) 2011. Status of the Tigers, Co-predators and Prey in India, 2010. National Tiger Conservation Authority, Govt. of India, New Delhi and Wildlife Institute of India, Dehradun. TR 2011/003. 302 pages.

Johnsingh, A.J.T. 1983. Large mammalian prey–predators in Bandipur. Journal of Bombay Natural History Society 80: 1–57.

Jolly, G.M. 1969. Sampling methods for aerial censuses of wildlife populations. East African Agriculture and Forestry journal 34 (Special Issue): 46-49.

Karanth, K.U. and Nichols, J.D. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology. 79: 2852– 2862.

Karanth, K.U. and Nichols, J.D. 2000. Ecological Status and Conservation of Tigers in India. Final Technical Report to the Division of International Conservation, US Fish and Wildlife Service, Washington DC and Wildlife Conservation Society, New York. Bangalore, India: Centre for Wildlife Studies. 124 pages.

Karanth, K.U. and Sunquist, M.E. 1992. Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. Journal of Tropical Ecology 8: 21–35.

Karanth, K.U. and Sunquist, M.E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology 64: 439–450.

Karanth, K.U. and Stith, B.M. 1999. Prey depletion as a critical determinant of tiger population viability. Pages 100-113, In: Seidensticker, J.; Christie, S. & Jackson, P. (Editors) Riding the Tiger. Cambridge University Press, Cambridge, U.K.

Khan, J.A. 1997. Estimation of ungulate densities by line transect method in Gir forest, India. Tropical Ecology 38: 65-72.

Khan, J.A.; Chellam, R.; Rodgers, W.A. and Johnsingh, A.J.T. 1996. Ungulate density and biomass in the tropical dry deciduous forests of Gir, Gujarat, India. Journal of Tropical Ecology 12: 149–162.

Khan, J.A.; Chellam, R. and Johnsingh, A.J.T. 1995. Group size and age-sex composition of three major ungulate species in Gir lion sanctuary, Gujarat, India. Journal of Bombay Natural History Society 92: 295–302.

Kirkpatrick, J.F. 1995. Management of Wild Horses by Fertility Control:The Assateague Experience. National Park Service Scientific Monograph, National Park Service, Denver, CO. 60 pages.

Kirkpatrick, J.F. and Turner, A. 2002. Reversibility of action and safety during pregnancy of immunization against porcine zona pellucida in wild mares. Reproduction 60: 197-202.

Kirkpatrick, J.F. and Turner, A. 2008. Achieving population goals in a long-lived wildlife species (*Equus caballus*) with contraception. Wildlife Reseatch 35: 513-519.

Kirkpatrick, J.F.; Liu, I.K.M. and J.W. Turner, Jr. 1990. Remotely delivered immunocontraception in feral horses. Wildlife Society Bulletin 18: 326-330.

Kirkpatrick, J.F.; Liu, I.K.M.; J.W. Turner, Jr.; Naugle, R. and Keiper, R. 1992. Long-term effects of porcine zonae pellucidae contraception on ovarian function in feral horses (*Equus caballus*). Journal of Reproductive Fertility 94: 437-444.

Kirkpatrick, J.F.; Naugle, R.; Liu, I.K.M.; Bernoco, M. and Turner, J.W. Jr. 1995. Effects of seven consecutive years of porcine zona pellucid contraception on ovarian function in feral mares. Biology of Reproduction, Monograph Series 1 (Equine Reproduction VI): 411-418.

Kumar, N.S. 2000. Ungulate Density and Biomass in the Tropical Semi-arid Forest of Ranthambore, India. MSc thesis, Pondicherry University, Pondicherry. 72 pages.

McCollough, D. R. 1997. Irruptive behaviour in ungulates. Pages 69-98, In: McShea, W.J.; Underwood, H.B. and Rappole, J.H. (Editors) the Science of Overabundance: Deer Ecology and Population Management. Smithsonian Institution Press, Washington, D.C.

Liu, I.K.M.; Bernoco, M. and Feldman, M. 1989. Contraception in mares heteroimmunized with porcine zonae pellucidae. Journal of Reproductive Fertility 89: 19-29.

McShea, W.J.; Monfort, S.L.; Hakim, S.; Kirkpatrick, J.; Liu, I.; Turner Jr, J.W.; Chassy, L. and Munson, L. 1997. The effect of immuno-contraception on the behavior and reproduction of white-tailed deer. The Journal of Wildlife Management 61 (2): 560-569.

Mehta, D.; Soni, V.C. and Sankar, K. 2013. Food habits of Nilgai (*Boselaphus tragocamelus*) as determined by pellet analysis in a human-dominated landscape, Western Gujarat, India. Scientific Transactions in Environment and Technovation. 7(1): 7-13.

Mehta, D. 2014. Study on the Ecology of Nilgai (*Boselaphus tragocamelus*) in Saurashtra. Ph.D. thesis. Saurashtra University, Rajkot. India. 216 pages.

Mehta, D. 2015. The *Vidis* of Saurashtra. Pages 54-63, In: Rawat, G.S. and Adhikari, B.S. (Editors) Ecology and Management of Grassland Habitats in India. ENVIS Bulletin: Wildlife and Protected Areas, Wildlife Institute of India, Dehradun, India.

Mondal, K.; Gupta, S.; Qureshi, Q. and Sankar, K. 2011. Prey selection and food habits of leopard (*Panthera pardus fusca*) in Sariska Tiger Reserve, Rajasthan, India. Mammalia 75: 201-205.

Norton-Griffiths, M. 1978. Counting Animals. Handbook No. 1. African Wildlife Leadership Foundation, Nairobi, Kenya. 139 pages.

Ottichilo, W.K. and Sinange, R.K. 1985. Differences in the Visual and Photographic Measurements in the Estimation of Strip Widths for Aerial Censuses of Animal Populations. Department of Resource Surveys and Remote Sensing (DRSRS), Ministry of Planning and National Development, Nairobi, Kenya.

Prater, S.H. 1971. The Book of Indian Animals. Bombay Natural History Society, Bombay. 324 pages.

R Core Team 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Rahmani, A. R. 1989. Grassland birds of the Indian subcontinent: A review. Pages 187-204, In: Goriup, P.D. (Editor) Ecology and Conservation of Grassland Birds. International Council for Bird Preservation (ICBP) Technical Publication No. 7. BirdLife International, Cambridge, U.K.

Rahmani, A.R. 1990. Distribution, density, group size and conservation of the Indian gazelle or Chinkara *Gazella bennetti* (Sykes 1831) in Rajasthan, India. Biological Conservation 51: 177-189.

Ramakrishnan,U.; Coss, R.G. and Pelkey, N.W. 1999. Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Biological Conservation 89: 113-120

Rodgers W.A.; Panwar H.S. and Mathur, V.B. 2000. Wildlife Protected Area Network in India: A Review. Wildlife Institute of India. Dehradun: 44 pages.

Sankar, K. 1994. The Ecology of Three Large Sympatric Herbivores (Chital, Sambar and Nilgai) with Special Reference for Reserve Management in Sariska Tiger Reserve, Rajasthan. PhD thesis, University of Rajasthan, Jaipur. 190 pages.

Schaller, G.B. 1967. The Deer and the Tiger. University of Chicago Press, Chicago. 370 pages.

Seidensticker, J. 1976. Ungulate populations in Chitawan Valley, Nepal. Biological Conservation 10: 183–210.

Singh, H.S. 2001. Natural Heritage of Gujarat. Published by Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar. 262 pages.

Sokal, R.R. and Rohlf, F.J. 1995. Biometry. W.H. Freeman, New York, USA. 887 pages.

Sugoor, R.K. and Ande, D.B. 2001. Conservation strategy for grasslands of Suarashtra and Kachchh region of Gujarat state. Indian Forester 127(12): 1408-1414.

Thomas, L.; Buckland, S.T.; Rexstad, E.A.; Laake, J.L.; Strindberg, S.; Hedley, S.L.; Bishop, J.R.B.; Marques, T.A. and Burnham, K.P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

Varman, K.S. and Sukumar, R. 1995. The line transect method for estimating densities of large mammals in a tropical deciduous forest: an evaluation of modes and field experiments. Journal of Bioscience 20(2): 273–287.

Watson, R. and Tippett, C.I. 1981. Examples of Low-level Aerial Surveys Conducted in Africa from 1968 to1979: One Firm's Experience. ILCA Monograph 4. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. 243 pages.

Received 20 March 2018
Accepted 31 May 2018