2-2012

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Abbas, F. -, Ruckstuhl, K. E., Mian, A., Akhtar, T., & Rooney, T. P. (2012). Distribution, Population Size, and Structure of Himalayan Grey goral *Naemorhedus goral bedfordi* (Cetartiodactyla: Bovidae) in Pakistan. *Mammalia*, 76 (2), 143-147.

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Distribution, population size, and structure of Himalayan grey goral *Naemorhedus goral bedfordi* (Cetartiodactyla: Bovidae) in Pakistan

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Abstract

Himalayan grey goral (*Naemorhedus goral bedfordi*) is a Red List (Near Threatened) member of Caprinae endemic to Asia, occupying the south-facing slopes of the Himalaya Mountains. The species is listed as Vulnerable on the National Pakistan Red List, but the distribution and abundance of the species within the nation is poorly known. We conducted a national census of Himalayan grey goral in Pakistan during 2002–2004, with the objective of documenting the geographic locations of populations, estimating population size, and describing group sizes and sex ratios. We conducted a direct count census in 98 sites distributed over the 4839 km² of suitable grey goral habitat. We counted 172 unique grey goral individuals: 143 adults and 29 subadults. We estimated a minimum of 370–1017 grey goral in Pakistan distributed in seven isolated populations. The adult sex ratio was female-biased nearly 2:1, and the mean size of social groups was 1.72±0.11 SE individuals. Our data support the National Red List status of Himalayan grey goral as Vulnerable, because no subpopulation probably contains >1000 individuals. We are unable to account for the sex ratio bias. Social group size is comparable with contemporary observations from India, but much lower than that reported a century ago. A national population viability analysis is needed for this species.

Keywords: caprinae; conservation status; group size; sex ratio; threatened.

Introduction

Himalayan grey goral *Naemorhedus goral bedfordi* (Lydekker 1905) is a small antelope-like goat in the subfamily Caprinae

(Hassanin et al. 1998, Fernández and Vrba 2005). This subspecies is endemic to Asia and occupies the south-facing slopes of the Himalaya Mountains. The geographic distribution range of Himalayan grey goral extends from northern Pakistan to Nepal, and includes Himachel Pradesh and Uttarakhnad in India (Prater 1980, Roberts 1997, Sathyakumar 2002). Roberts (1997) determined Swat (Pakistan) as the western limit of the distribution.

Over the past century, Himalayan grey goral has probably experienced population decline and range fragmentation, largely attributed to habitat loss, poaching, and possibly competition with livestock (Lydekker 1907, Anwar 1989). Reports from eastern parts of the Siwalik Hills in India suggest that viable populations of the species are now largely confined to sanctuaries and/or protected forest reserves (Pendharkar and Goyal 1995, Roy et al. 1995, Mishra and Johnsingh 1996, Ilyas 1998). Cavallini (1992) reported the absence of the species from 10 sanctuaries located in the Indian state of Himachal Pradesh.

In Pakistan, Himalayan grey goral historically extended from lower Swat to Indus Kohistan, through the Bonga Marg Valley of Hazara region, Margalla Hills and parts of Neelum Valley, and to Azad Kashmir beyond Athmuqam. Presently, there is uncertainty with respect to the current population size and range occupancy of Himalayan grey goral in Pakistan. Described as common a century ago (Lydekker 1907), it is thought to have experienced a rapid decline in recent decades (Grimwood 1969, Anonymous 1970). Government reports suggest a total of 331 individuals were present in the North-West Frontier Province (Anonymous 1988) and 40–60 in Margalla Hills National Park (Anwar 1989, Anwar and Chapman 2000). Himalayan grey goral was reported to be common in Azad Jammu and Kashmir (Anonymous 1984), but this was not based on any quantitative data (Anonymous 1988). A recent workshop organised by IUCN-Pakistan synthesised available information on mammal species of the country (Sheikh and Molur 2004). The National Red List status of Himalayan grey goral was designated as Vulnerable, based on two criteria C1 and C2a(i): the population is expected to undergo an additional decline of >10% over the next 10 years, and no subpopulation is known to contain >1000 individuals (Sheikh and Molur 2004).

To better characterise the status of Himalayan grey goral in Pakistan, we conducted a national population census in 2002–2004. The aims of this study were to document the geographic locations of populations and to provide a first order approximation of the number of animals present in these populations. We also report descriptions of group sizes and sex ratios.

Materials and methods

Grey goral census

To provide a current census of grey goral in Pakistan, we conducted surveys in the 13 districts identified by Roberts (1997) as being within the geographic range and providing suitable habitat for grey goral. These districts between the latitudes of 33°53'N to 36°07'N, and longitudes 70°55'E to 74°09'E, occur in the Himalayan foothills, and include parts of Islamabad (Margalla), North West Frontier Province (Chitral, Dir, Swat, Shangla, Mardan, Bunner, Kohistan, Batgram, Mansehra, Abbottabad and Nowshera), Azad Kashmir, and the Federally-Administered Tribal Areas (Orakzai, Bajur, and Mohmand). Elevations ranged from 773 to 3447 m a.s.l.

Within each district, we identified individual sites that contained potential goral habitat. The total area of goral habitat in each site was determined by mapping the contours of the hills and identifying areas that support *Pinus roxburghii* vegetation (Fakhar-i-Abbas et al. 2009). Data were mapped using a 1-cm to 2.62-km reference map (MapSend Worldwide V.1.00d 2002 by Thales Navigation, Magellan, USA). From the total habitat area, we excluded areas below 500 m or above 3000 m, reflecting the altitudinal range limits of the species. We further excluded areas without natural vegetation: human population settlements, active and fallow agricultural fields, and livestock grazing areas (Fakhar-i-Abbas 2006). This yielded 4839 km² of suitable grey goral habitat in 13 districts.

We surveyed a total of 98 sites that contained potential goral habitat, based on the presence of mixed *Pinus roxburghii* forests and grassy slopes (Anwar 1989, Pendharkar 1993, Fakhar-i-Abbas et al. 2009). These sites ranged in size from 12 to 123 km², except in Kohistan, where sites ranged from 113 to 265 km². Sites encompassed an altitudinal range of nearly 1000 m. Individual sites were several kilometres apart, most probably preventing free intersite movement of gorals. Each site was not exhaustively surveyed; typically 4–23 km² (23% of total) were surveyed. Each site was visited one to seven times each year between 2002 and 2004. The number of visits per site was constrained by accessibility; sites close to base camp or along main trails were visited more often, whereas remote sites were visited only once per year. Owing to logistical constraints, some sites were visited in summer, whereas others were visited in winter. Because the dominant tree (*P. roxburghii*) is evergreen, visibility is generally limited. In summer, visibility is further reduced by perennial vegetation. Visibility is slightly better in winter, but we did not detect more goral in winter than summer (Fakhar-i-Abbas 2006).

We observed goral using a telescope (Optolyth, Germany, 50×) from a fixed distance of 100–200 m. This distance was sufficient to avoid detection by animals; these did not show any signs of responding to the presence of the observer. Because gorals are crepuscular, we made observations either in the morning (from sunrise until 10:00 h) or the evening (from around 15:00 h until a half hour after sunset). We recorded all Himalayan grey goral visible within a variable-sized circular quadrat, which had a radius of 20–30 m. This plot size was a function of our telescope and the distance from the observer to

the animals. We recorded the shades of colour of the fur, and features of horns, muzzle and tails of most solitary individuals or a prominent individual when a group was present. This aided in individual identification. We maintained these records to avoid double counts of the individuals in the sampling area. The location of each site occupied by goral was recorded directly using a handheld GPS unit.

In addition to the number of goral present, we recorded the sex and age class of each animal. Subadults (<2 years of age) were identified by the absence of rings from the base of the horns. Males were distinguished from females through the larger size of their horns (Myslenkov 1992). When animals were seen grazing together within 20 m of each other, they were classified as a social group. These data were used to obtain sex ratios (male:female).

Our reliance on direct census methods introduces the potential pitfall of false absences. In other words, we cannot distinguish animals being absent from a site from animals being present but undetectable. We used two procedures to address the false absence problem. We interviewed local shepherds and hunters about the number and location of gorals living in their area. This enabled us to focus our efforts where goral had been detected. We also conducted surveys for signs (tracks, scats, hair, grazing marks, faecal pellets, etc.) along fixed vegetation transect lines used by Fakhar-i-Abbas et al. (2009) at sites where we observed no goral. Although these procedures do not eliminate the false absence problem, they reduced the probability of failing to detect animals actually present.

Population estimation

To estimate the grey goral population size in Pakistan (while incorporating uncertainty and variation in goral numbers among districts), we estimated the number of goral present in each district. Within a district, we first divided the number of individual gorals seen per site by the area of each site sampled to obtain a population density estimate. In cases where we had goral signs but no observations, we assumed one animal was present. We assumed zero animals in sites with no animal seen or signs detected. Using these population density estimates for each site, we calculated the arithmetic mean, SE, 95% confidence intervals (CIs) of goral density in all surveyed sites in a district (Sokal and Rohlf 1981). The upper and lower population density CIs were each multiplied by the area of unsurveyed suitable habitat in the district to estimate plausible density values of goral present in unsurveyed areas. In other words, we assumed that goral population densities at surveyed sites were representative of sites not surveyed. Finally, we converted goral density to goral individuals, combining estimates from surveyed and unsurveyed sites. This procedure provided us with a 95% CI estimate for the goral population in that district. We repeated this procedure for all 13 districts. By summing across all districts occupied by goral, we obtained a lower and upper confidence interval for population numbers in Pakistan. Because our population estimates are grounded in direct observations of animals, our population estimates are conservative. The actual population size could be larger.

Sex ratios and group size

We analysed sex ratios for deviation from an expected 1:1 for all of Pakistan and in each district using a χ^2 -test for goodness of fit (Sokal and Rohlf 1981). We reported the size of each social group seen in summer and winter, and identified the composition of these groups. We tested for significant differences in mean group sizes using the Mann-Whitney U-test, and significant differences between the distributions using a Kolmogorov-Smirnov two sample test (Sokal and Rohlf 1981).

Results

Between 2002 and 2004, we identified and sampled 1115 km² of the 4839 km² suitable grey goral habitat, and directly observed 172 unique grey goral individuals: 143 adults and 29 subadults. We observed goral at 41 of 78 sites distributed across seven districts (Figure 1). We found fresh goral signs in an additional six sites; total site occupancy was 60.3% in these districts. Extrapolating to suitable habitat in sites not surveyed, our 95% CI yields 370–1017 grey goral in Pakistan distributed throughout seven isolated populations (Figure 2). We estimated the largest population to occur in Azad Kashmir, which consisted of 91–263 individuals. Grey goral was not detected at any of the 20 sites located in the districts of Battagram, Swat, Shangla, Dir, Nowshera, and the Federally Administered Tribal Areas (Figure 3).

The adult sex ratio (49 males:94 females) appeared skewed towards females in Pakistan ($df=1$; $\chi^2=14.16$; $p<0.001$). Only four districts had >10 adults present: Mardan, Mansehra, Bunner, and Azad Kashmir. Sex ratios were significantly skewed towards females in Bunner (14 males:27 females; $df=1$, $\chi^2=4.12$; $p=0.04$), and Azad Kashmir (13 males:31 females; $df=1$, $\chi^2=8.02$; $p=0.005$). Sex ratios were not significantly skewed in Mardan (11 males:10 females; $df=1$,

Figure 1 Geographical area surveyed for *Naemoredus goral bedfordi* in each of 13 districts between 2002 and 2004 (bars), and total number of individual goral observed in each district (number above bars).

Figure 2 Estimated mean number of *Naemoredus goral bedfordi* present (circles) and 95% confidence intervals (whiskers) in each of seven districts where goral were detected, based on suitable habitat.

$\chi^2=0.05$; $p=0.82$) or Mansehra (6 males:13 females; $df=1$, $\chi^2=2.58$; $p=0.11$).

The mean group size was 1.72 ± 0.11 . This appeared larger in summer (1.91 ± 0.16) than winter (1.38 ± 0.10), but this was not statistically significant (Mann-Whitney U-test, $p=0.069$). In addition, group size distribution in summer was not significantly different than the group size distribution in winter (Kolmogorov-Smirnov two sample test, $p=0.09$). Solitary individuals were recorded in 58% of all sightings (Figure 4, Table 1). Animals were more likely to be seen in groups rather than as solitary individuals in summer (47.1%) than winter (32.4%), although this difference was not significant ($df=1$, $\chi^2=2.11$; $p=0.15$).

Figure 3 Map of northern Pakistan indicating surveyed districts with *Naemoredus goral bedfordi* present (dark grey) and absent (white). Medium grey shading indicates the district was not surveyed.

Figure 4 Distribution of *Naemorhedus goral bedfordi* group sizes observed in summer (white bars) and winter (black bars). The y-axis represents the number of groups of a given size (not individuals) observed.

Discussion

Our data suggest that a minimum of 370–1017 Himalayan grey goral individuals were present in Pakistan distributed over 4839 km² of suitable habitat. This estimate represents the first standardised national survey of Himalayan grey gorals in Pakistan. It is conservative in that it reflects detection bias in the form of undercounting. We did not attempt to quantify detection bias in this study. Despite these limitations, direct observations and minimum numbers known to be alive at the time of the study provide a reasonable index of population sizes in different districts (Slade and Blair 2000). Additionally, IUCN Red List evaluation allows for the use of data from direct observations. This study constitutes a baseline, although an imperfect one, against which future changes in population size can be judged.

Our data support the National Red List status of Himalayan grey goral as Vulnerable, based on the criterion that no subpopulation appeared to contain over 1000 mature individuals. Although our estimates are conservative, it seems unlikely

that we detected fewer than 20–25% of the animals present. Moreover, subpopulations exhibit areographic fragmentation, and it is not clear whether this reflects a typical geographical pattern for a species at its range limit or whether it is due to a recent history of overexploitation. Areographic fragmentation is not due to fragmentation of suitable habitat. Himalayan grey goral is mainly associated with the occurrence of *Pinus roxburghii* forest (Fakhar-i-Abbas 2006), which is well-distributed throughout Azad Kashmir, North West Frontier Province, and the Federally-Administered Tribal Areas. However, hunting, livestock grazing, and logging could be contributing to low goral numbers. Additional research is needed to ascertain the importance of these factors.

The female-biased sex ratios we observed were puzzling. We offer some plausible explanations in this regard. One possibility is that males exhibit higher mortality rates than females, due to extrinsic factors such as trophy hunting or sex-biased predation (Ginsberg and Milner-Gulland 1994). Male gorals were most often observed in prominent, conspicuous locations, whereas females were most often observed using vegetative cover. Sex-biased mortality from predators or trophy hunting could thus account for the sex bias we observed. A second possibility derives from the Trivers and Willard (1973) hypothesis: maternal investment in male offspring declines as maternal physiological condition declines. Goral compete for food with livestock, and it is unknown if they are subsisting on lower quality foods than they would select under more optimal conditions. Regardless of the cause, population decline due to sex ratio stochasticity can be of concern in small populations, even for polygamous species such as goral (Ginsberg and Milner-Gulland 1994).

The group sizes observed in this study are similar to those reported by Pendharkar and Goyal (1995) in India: 1.6 to 1.8 animals per group. Interestingly, Lydekker (1907) reported goral were almost always seen in groups of four to 12 animals. If Lydekker's observations are representative, this would suggest a major shift in social structure over the past century. Group size in some ungulates is known to increase with population size (Borkowski 2000), so the smaller groups seen today might reflect a population decline from a century ago. Alternatively, smaller group sizes today could reflect declines in predation risk (Hamilton 1971) or resource distribution (Jarman 1974).

In conclusion, we provide the first national census of the Himalayan grey goral in Pakistan, and support the Vulnerable National Red List status. Moving forward, we recognise the need for more precise population estimates and for a formal population viability analysis (PVA). Microsatellite loci can be combined with mark-recapture models to identify individuals and provide more reliable estimates of population size, as well as estimates of sex ratios, genetic diversity and dispersal distances. Combining faecal sample collection in occupied districts with presence-absence monitoring in unoccupied districts will aid in identifying population trends. A PVA will allow for a more rigorous assessment of vulnerability to extinction, and will allow researchers to predict the relative benefits of management aimed at hunting, livestock grazing or logging and thus help in boosting goral numbers.

Table 1 The size of *Naemorhedus goral bedfordi* social groups observed, sex composition of the group (M=male, F=female, S=subadult) and number of such groups observed.

Social group size	Social group composition	n
1	1 M	23
	1 F	31
	1 S	3
2	1 F, 1 S	13
	1 M, 1 S	1
	1 M, 1 F	11
	2 F	3
3	1 M, 1 F, 1 S	3
	2 F, 1 S	1
	1 M, 2 F	2
	3 F	1
4	1 M, 2 F, 1 S	4
	1 M, 3 F	1
6	2 M, 3 F, 1 S	1
7	2 M, 4 F, 1 S	1

Acknowledgements

We relied on the cooperation and field support of many individuals, for which we are grateful. We express special gratitude to Dr. Malik Mumtaz, Mr. Hassan Fatmi, Mr. Yusuf Qureishi, Mr. Awan, Mr. Ahmed Khan, Mr. Hashim, Mr. Ikmaiel Haidre, Mr. Saeed, Mr. Lodhi, Mr. Mazhar Hussain, Mr. Auliya Khan, and Mr. Sohail.

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Received April 7, 2011; accepted January 2, 2012; previously published online February 9, 2012

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