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Population Structure of Blue Sheep (*Pseudios nayaur*) in Shimshal Valley Gilgit-Baltistan Pakistan

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RHK collected data, analyzed and wrote the manuscript. HA assisted in data analysis. ER assisted in data collection. MAN designed project and redrafted the manuscript.

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ABSTRACT

Blue sheep is a key species and found in Tibetan Plateau and the bordering massif through Central Asia. In Pakistan the distribution range of species is restricted to higher altitude areas of Northern Areas including Khunjerab and Shimshal. The present study was conducted from 25 September 2014 to 23 October 2014, to estimate the population size of blue sheep in Shimshal and Socterabad Community Controlled Hunting Areas, by employing recently developed double observer-based Capture Mark Recapture method (CMR). A population of 834 ±356 were estimated in Shimshal and Socterabad CCHAs, with an estimated density of 0.6 sheep/km^2. The present study showed a female-biased sex ratio (80 male/100 females), probably due to ongoing trophy hunting. The young to female ratio (0.5) indicated ongoing recruitment of young. The trophy hunting operates on a sustainable use approach, as limited animals are harvested to generate economic revenues for poor mountain communities, which in turn protects the entire population and associated ecosystem from illegal massive hunting. The present study successfully tested CMR method, and produced reliable and accurate estimate of the population, which could help in determining sustainable trophy quota.

INTRODUCTION

Ungulates play a key role in upholding ecosystems through influencing flora structure, plants species composition and nutrients cycling (Bagchi and Ritchie, 2010). Robust and enduring studies of population dynamics are vital for the better understanding of population ecology, wildlife management and conservation (Zhang *et al*., 2012). Population size can be used as best indicator for the conservation of many large herbivores species (Gaillard *et al*., 1998). However, conducting such large-scale and long-term surveys in the remote areas is difficult due the budget and human resource limitations (Gusset and Burgener, 2005; Singh and Gulland, 2011). For better conservation and management of wild ungulates it is necessary to study its different population parameters (Shackleton, 1997), as they are the main prey for the endangered species i.e., snow leopard (*Uncia uncia*) (Wegge *et al*., 2012). Blue sheep or bharal is a medium size wild goat (Bhatnagar, 2003), having (head to body length = 115-160 cm, tail = 10-15 cm, shoulder height = 69-91 cm and weight = 35-75 kg) (Sheikh and Molur, 2004).

The blue sheep (*Pseudois nayaur*) is an alpine ungulate characterized by its sociability, resides on the Tibetan Plateau and the bordering massif through Central Asia i.e. Bhutan, Nepal, China, India and Pakistan, Possibly in Tajikistan (Harris, 2003; Namgail *et al*., 2004). They live in groups ranging from 10-50, but sometimes the herd size may reach up to 200 individuals (Schaller, 1977; Wegge, 1979; Wilson, 1984; Fox *et al*., 1986). The distribution range of the blue sheep occurs at an elevation of 4550-5480 m (Chetri and Pokhare, 2005). In Pakistan the blue sheep populations are endemic to the northern most province Gilgit-Baltistan (Roberts, 1997; Ablimit *et al*., 2011; Khan *et al*., 2012), as it is confined to the Khunjerab National Park (KNP) (Namgail *et al*., 2004) and neighboring parts of the upper Hunza i.e. Shimshal which perhaps represents the western most population of the sheep in the Karakorum Range (Wegge, 1988).

Blue sheep is declared as least concern globally (IUCN, 2015). One of the major threats to blue sheep populations in Pakistan is poaching (Shackleton, 2001). To minimize this threat trophy hunting has been adopted

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as a conservation tool (Lindsey *et al*., 2007; Nawaz *et al*., 2016). It allows to cull some of selected individuals from a population that can be beneficial for the rest of population to be hunted as a whole (Gunn, 2001). But without having scientific knowledge about the age of individuals in a population, the hunters target the males which in general are those facing stout sexual selection pressures (Short and Balaban, 1994). In order to make the trophy hunting a valuable tool for conservation of blue sheep and other ungulates it must be based on scientific data regarding the population size and demographic parameters of that species (Palazy *et al*., 2012). Another factor which is contributing towards the population downfall is the deficiency of reliable scientific data for allocation of hunting quotas (Anderson, 2001; Whitman *et al*., 2004; Packer *et al*., 2009). For estimating blue sheep population in an area, it is important to study the different parameters like group number, group size and classification by sex and age. To find the sustainability of a population it is very important to study the young to female ratio in that population (Thapa, 2013). Range number of progenies for blue sheep is 1-2 with an average of 1.5 (WII, 2014). In case of gregarious ungulates most productive populations are considered those with a female-biased sex ratio (Caughley, 1977). Another major parameter in blue sheep population dynamics is to study the presence of trophy rams because many populations with low male-to-female ratios face the problem of lower fecundity (Solberg *et al*., 2002; Aryal *et al*., 2010b). Comparison of population size in different zones within range of that population is also very important for conservation (Aryal *et al*., 2010a). Fitness of a population returns from social behaviors such as group size giving many advantages like minimizing predation risks (Hamilton, 1971). Group number and group size of blue sheep increases in an area with increase in the population density (Zhang *et al*., 2012). Trophy hunting is basically sport hunting in which those animals are hunted having large weapons like antlers, horns or tusks. Thus, trophies are usually males, and the animals which are usually considered as trophy are ungulates species. In trophy hunting usually the hunter looking for the largest animal in a taxon or geographic area (Frisina *et al*., 2000). Trophy hunting is being practiced in Gilgit-Baltistan since 1991 (Jingfors, 2000), and the first blue sheep trophy hunt was auctioned in 2004 (Jackson, 2004). Assessment of the blue sheep population with a credible method is required for management of the declining population in Gilgit-Baltistan, and to rationalize trophy hunting quota.

MATERIALS AND METHODS

Study area

The study was conducted in Shimshal and Socterabad Community Controlled Hunting Areas (CCHAs) (Fig. 1). Both areas were notified CCHAs in 2006 under section 22 of Northern Areas Wildlife Act, 1975 (WWF, 2009). Shimshal CCHA lies in the extreme north of Hunza-Nagar in Shimshal valley, in Hunza-Nagar District, at an altitude of 3,100 m above sea level (36º 26' 16.5'' N, 75º 19' 05.8'' E) (Khan *et al*., 2012). Along east and north, Shimshal CCHA is surrounded by the Khunjerab National Park (KNP). It is the major settlement in the District, comprising of four hamlets i.e. Khizarabad, Farmanabad, Aminabad and central Shimshal, with a population of approximately 2500 living in 300 households (Ali and Khan, 2007). Shimshal Pass (4,735 m) rises above the village. It lies on the watershed between the Indus River and Tarim River basins, and leads to the valley of the Shimshal Braldu River, a tributary of the Shaksgam River on the border with China. Socterabad CCHA lies in west of Shimshal CCHA, bounded by the KNP in north, at an elevation of 2,500 m (36° 10' 29.82'' N, 74° 58' 2.45'' E). It was legally notified as CCHA in 2006 and was re-notified in 2010 to adjust boundaries by Government of Gilgit-Baltistan (WWF, 2010). There are five villages in Socterabad CCHA; Shachktar, Bili, Ukulgar, Gircha and Luwarchevis, (Knudsen, 1999), which lie along the Karakoram Highway, and are socially organized in Khunjerab Villagers Organization (KVO). The KVO is mainly inhabited by Wakhi people. A conservation program with in a 30 km buffer zone outside the KNP border was initiated by KVO in 1996 (Khan, 1996).

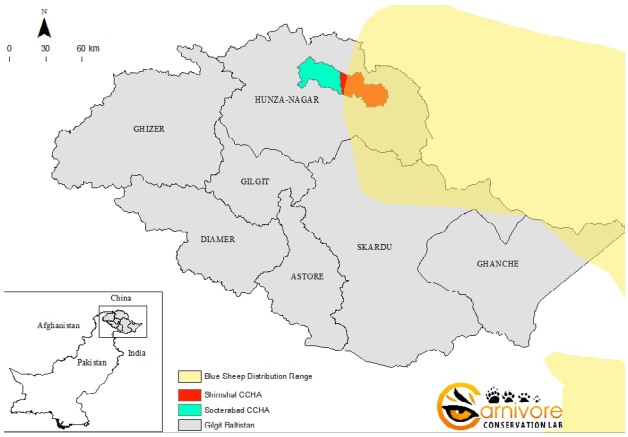

Fig. 1. Map showing distribution range of blue sheep in Pakistan including study area.

Study method

The double observer survey method was used for estimating the blue sheep population, which is considered an effective method for estimating the population of ungulates in the mountainous areas of Central Asia and Himalayas (Suryawanshi *et al*., 2012; Tumursukh *et al*., 2015). This technique had been used for estimating abundance of Himalayan tahr (*Hemitragus jemlahicus*) in New Zealand (Forsyth and Hickling, 1997). This method involves two observers looking for and counting animals simultaneously. It is must to ensure that they will not cue each other if they sight animals. Both the CCHA's were divided into blocks. Depending on the area and topography, higher ridges and watersheds were considered boundaries where there is less possibility for animals to cross the block. All the blocks were scanned simultaneously. The survey was conducted from 25 September 2014 to 23 October 2014. Most sighting was done in morning (7.00 am- 10.00 am) and afternoon (3.00 pm- 6.00 pm) because blue sheep are more active during this time (Liu *et al*., 2005).

Twelve members participated in the survey out of which six were researchers and remaining six were wildlife watchers. The observers were divided into three teams. Each team consisted first observer and second observer. Owing to the terrain of the area both observers were temporally separated by 1 hour. Both the observers scanned these blocks and the surrounding areas moving through the predetermined trails. A spotting scope (20×60 Swarovski) and binoculars (10×50) Pentax (XCF) were used for taking observation of blue sheep. Nikon Cool Pix L10 Digital camera was used to take photographs, and data was recorded on prescribed forms. After sighting a group, it was tried best to demographically categorize the animals in female, young, class I, class II and class III males (Schaller, 1977). Males were classified on the basis of horns structural appearance. The class I young males (2-3) years old have straight emerging horns, in class II males (4-6) years old the horns bends downwards while the class III trophy males (≥7) years have cylindrical horns which are very broad at base and curving almost horizontally outwards. Moreover, the class III males have distinct dark black shade in chest (Robert, 1997). It was difficult to distinguish the yearlings and young's so both were kept in a single category of young (less than 2 years old). To avoid double counting of groups both the observers matched their data at end of day. The groups having same number of demographic categories were considered same. In order to identify the herds on the basis of location the Global Positioning System (GPS) (GPSMAP 62s Garmin) was used to record the coordinates that were marked on the map in the field (Namgail, 2006).

Statistical analysis

Population was estimated by using Capture Mark-Recapture Method in (Specific MS Excel-2013 formats) based on the formulas (Forsyth and Hickling, 1997).

$$\hat{G} = \frac{(B + S_1 + 1)(B + S_2 + 1)}{B + 1} - 1$$

$$N = \hat{G}\hat{U}$$

$$Var(\hat{G}) = \frac{S_1 S_2 (S_1 + B + 1)(S_2 + B + 1)}{(B + 1)^2 (B + 2)}$$

Where B is Number of groups seen by both observers, S_1 is groups seen by observer first, S_2 is groups seen by observer second, $\hat{G}$ is estimated number of groups, $\hat{U}$ is mean group size and N is estimated population.

RESULTS

Population structure

A total of 754 blue sheep were counted in 17 sightings made in Shimshal and Soctarabad Community Controlled Hunting Areas (Fig. 2). The whole area was keen-sighted by both observers with detection probability of 0.78 for observer one and 0.47 for observer two. The population was estimated at 834 ± 356 (95% CI) animals. The composition of recorded population included 42.7% females, 34.1% males and 23.21% young. The percentage of female was high in each CCHA with respect to male and young. Ratios for female to young, female to male and adults to young which were 1:0.5, 1:0.8 and 1:0.3 respectively. Among males the highest percentage was of class III trophy size males followed by class II and class I. The overall density for study area was 0.6 animals' km^{-2}. The highest density was found in Shimshal CCHA (1.06 animals' km^{-2}) as compared to Soctarabad CCHA (0.2 animal km^{-2}).

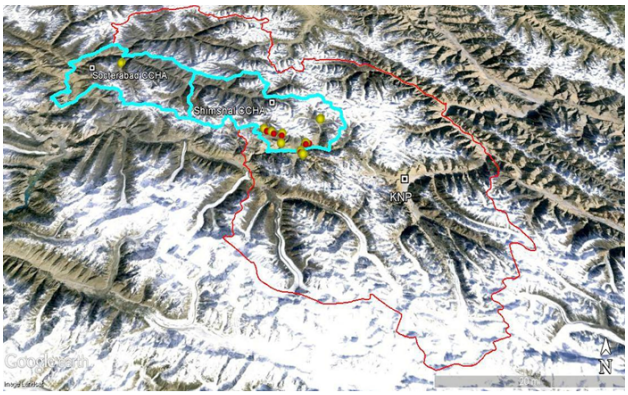

Fig. 2. Map showing locations of blue sheep sightings. Yellow and red dots indicate sightings made by observer 1 and 2, respectively.

Herd composition

A total of 17 herds were sighted in all study blocks during this survey. Out of which 14 were mixed groups containing female, male and young while the remaining 3 were only consisting males (Fig. 3). The average herd size was (mean44.5 ± SE 10.8). Significant variation was observed in herd sizes in both conservancies. The average herd size in Shimshal CCHA was (46.4 ± SE 12.8) and compared to (34.7 ± SE 16.9) in Soctarabad CCHA.

Fig. 3. Blue sheep sighted at Shimshal.

DISCUSSION

Blue sheep is a highly coveted trophy for foreigners and source of economic benefits, for impoverished remote communities of Gilgit-Baltistan since 2004 (Jackson, 2004; Khan *et al*., 2014). Since the inception of trophy hunting in 2004, 27 animals have been harvested. Annually 8 blue sheep could be harvested by acquiring permit at a reserve price of 8000 US$ per animal (GOP, 2014), 80% of this revenue is being used for public activities and wildlife conservation activities in the custodian communities while 20% is used by Wildlife Department for Conservation of Wildlife of Gilgit-Baltistan. Quotas for trophy hunting are supposed to be based on population data (Shackleton, 2001). Therefore, proper monitoring programs are necessary to evaluate the effectiveness of conservation (Singh and Gulland, 2011).

There are several methods available for population estimation, but most of them are not suitable for rugged areas (Singh and Gulland, 2011). One of the commonly used methods for ungulates surveys in rugged areas is vantage count developed by Jackson and Hunter (1996), but owning to need of huge manpower and financial resources it is mal suggested. Suryawanshi *et al*. (2012) developed a more robust and rigorous method of double observer based on CMR to address the loopholes in monitoring of ungulates in rugged mountains of subcontinent. However, in this method detection probability of observer 1 appears to be higher. This phenomenon was recorded in the present study as well as in many previous studies on blue sheep and ibex in India and Mongolia (Suryawanshi *et al*., 2012; Tumursukh *et al*., 2015). The lower detection probability for observer two in these studies indicate the escaping behavior of wild mountain ungulates on sighting humans or any other threat (Tumursukh *et al*., 2015). According to Thompson (2004) the detection probability of observers is also affected by activity pattern of animals and other factors like climate, terrain, survey time and observer efficiency.

In Pakistan very, limited work has been done regarding census and estimation of population size of blue sheep. A total of 1,036 blue sheep were reported in a survey from Soctarabad, Khunjerab pass and Shimshal with a density of 0.523 animals per km^2 (Khan *et al*., 2014). In a recent survey conducted in Shimshal a total of 67 blue sheep are reported with a density of 0.016 per km^2 (Khan *et al*., 2015).

The present survey revealed an estimated population of 834 (±365 95%CI) blue sheep in both CCHA's of Shimshal and Socterabad which were formerly included in KNP (Knudsen, 1999) with an estimated density of 0.6 animal's km^{-2}. In earliest surveys, conducted by Rasool (1976, 1986), reported 35 and 170 blue sheep in 1976 and 1986 respectively from the same area. Later, Wegge (1988) reported a population of 1500 to 2000 blue sheep with an estimated density of 2-5 animals per km^2 from Shimshal. This indicates that the population of blue sheep was increased after establishment of KNP in 1975. However, later Rasool (1990) reported 600 blue sheep in 1989 from the same area, indicating a drastic decrease in the population due to fatal *Sarcoptes scabiei* infection. Dagleish *et al*. (2007) confirmed that the *Sarcoptes scabiei* infection existed in blue sheep population of Shimshal and caused mortalities in 2000. The downfall in the blue sheep population in the area is also because of competition with the livestock for food, and excessive poaching for meat and trophies, besides disease caused mortalities (Schaller *et al*., 1987; Wegge, 1988; Shafique and Ali, 1998). More recently in 2005-2010, 1036 blue sheep were reported by Khan *et al*. (2014) from Shimshal, Socterabad and Khunjerab pass with an estimated density of (0.5 animals km-^{2}), suggesting recovery in the population. The estimates by Khan *et al*. (2014) are higher than the present study because they are based on the long term and repeated field survey was conducted by Zhang *et al*. (2012) in Ningxia

Helan mountains china (Zhang *et al*., 2012). In present study a population of 730 and 104 was estimated from Shimshal and Socterabad CCHA's, respectively, which shows higher estimate than 15 and 52 blue sheep (0.063 animals km^{-2}) from Socterabad and Shimshal respectively reported by (Khan *et al*., 2015). According to Roberts (1997) blue sheep were considerably numerous in these remote areas especially of Shimshal where the hunting pressure from the locals was fairly low. The present study revealed that still a good population of blue sheep is present in the study area. Density for Shimshal estimated in the present study was (1.06 animals km$^{-2)}$ which indicated that blue sheep's main stronghold is in Shimshal.

The ratio for female to young in the present study is lower than that 1:1 reported by khan *et al*. (2014) from the same area. Low ratio of young's in present study is due to the season of survey as it was conducted after six months (September – October) of lambing season. The earlier study by Khan *et al*. (2014) reported high ratio of young as it was conducted in lambing season (April – July, Roberts, 1997). Lu *et al*. (1994) reported same ratio of 1:0.5 for female to young in Qomolangma Nature Reserve China and declared it satisfactory recruitment in blue sheep population. The low ratio of young to females is possibly due to mass mortalities caused by harsh climate and food scarcity (Wegge, 1988, 1997). According to Dagleish *et al*. (2007) the young mortalities occurs because of diseases transmitted by livestock, to which the young ones are more susceptible. Festa *et al*. (2006) and Haller (1992) reported that stochastic killing of young ones by specialist predators also results in low ratio of young's in a population. In the present study the ratio reported for female to young was 1:0.5, which is lower than earlier reports (Khan *et al*., 2014). The present survey reported a female biased sex ratio like the other studies khan *et al*. (2014) in Shimshal, Zhang *et al*. (2012) in Ningxia Helan Mountains National Nature Reserve China, Aryal *et al*. (2010a) in Dhorpatan Hunting Reserve Nepal, Bhardwaj *et al*. (2010) in Gangotri National Park western Himalaya India. In case of gregarious ungulates most productive populations are considered those with a female-biased sex ratio (Caughley, 1977). According to Wegge (1979) in ungulates populations the females are usually predominant because the males are selectively hunted for trophies.

According to Aryal *et al*. (2010a) selective hunting of males in a population results in a low ratio of males to females. In the present survey about 45.5 % of the total male population were trophy size, while Khan *et al*. (2014) reported 58 % of males exceeding the trophy size. Low number of males in population was probably because of survey timing which was conducted in September 2014 to October 2014 before rut season. Schaller (1980) reported rut season of blue sheep from late November to January. Two isolated groups of eight and one group of five trophy size males were reported in the present study at elevation of 4351 m along the snow line. According to Roberts (1997) before rut season the mature male's lives in small groups of five to six individuals away from females and young mixed herds at high elevations as close as possible to the permanent snow line. Both in Shimshal and Socterabad CCHA's trophy is being practiced. In order to make trophy hunting valuable for conservation quota allocation must be made on the basis of population status. Jackson (2004) reported that one trophy quota can be set if a population containing fifty individuals with minimum four trophy size animals in two consecutive surveys. If the population reaches 150 individuals with minimum eight trophy males in two consecutive surveys, the quota could be increased to two animals.

In the present survey 17 herds were sighted with average herd size of 44.5 ± SE10.8. The largest herd consisting of 150 individuals was recorded from Maidoor in Shimshal CCHA. According to Stockley (1928), Schaller (1973), Roberts (1997), blue sheep lives usually in form of small groups consisting of 10–40 individuals but sometimes may unite in large groups of up to 400 individuals. The herd size reported in this study is significantly large than other studies, Manang, Nepal (15.6 ± SE1.3, Oli *et al*., 1996), Dhorpatan Hunting Reserve, Nepal (7 ± SE5.5, Aryal *et al*., 2010), Ningxia Helan mountains china (8.48 ± SE5.5, Zhang *et al*., 2012), and Upper Mustang, Nepal (8.4, Tapha, 2013). Both the CCHA's are low disturbed areas. According to Wilson (1981) the herd sizes are usually large in least disturbed areas.

CONCLUSION AND RECOMMENDATIONS

The population reported in this survey afford maximum eight animals for hunt. For sustainable harvest of blue sheep regular census should be made annually in future by using Double observer method based CMR. Granting hunting permits need to be conditional with a population assessment, made through a reliable estimate, and double observer based CMR is a promising technique. The IUCN should revise and update distribution range of blue sheep in Pakistan using data collected during this study and other recent studies carried out in the habitat of blue sheep. Comparing with previous studies population seems stable, trophy hunting should be continued in future.

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Statement of conflict of interest

Authors have declared no conflict of interest

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