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Full Length Article

Seasonal Variation in Population Structure of Himalayan Ibex (*Capra sibirica*) in Central Karakoram National Park, Pakistan

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Abstract

Lack of information on seasonal population dynamics is a challenge for devising conservation strategies for *Capra sibirica* in Central Karakoram National Park (CKNP). In 2015–2016 we surveyed the spring and winter populations of *C. sibirica* in five major catchments of the park, through direct count method, using specific vantage points. Over 2,859 ibex were observed including 830 adult males, 1062 adult females, 384 yearlings, 430 kids and 153 undetermined individuals. The density increased from spring to winter in all valleys, except in Hoper. The occurrence of adult male and adult females did not vary significantly across the seasons, while for kids and yearling it varied significantly (Mann-Whitney; U=2592, α=0.000 for kids and U=3792, α=0.040 for yearlings). Sex ratio between male to female, kids to female and yearling to female varied across the seasons. Male to female sex ratios decreased from spring to winter in all valleys, (P = 0.350), except Hushey while kids to female it increased in Hisper, Hoper and Thaley, but remained unchanged in Basha and decreased in Hushey (P = 0.433). Typical group size increased in winter across all valleys whereas the mean group size also increased in all valleys, except in Basha. Group density also increased in three valleys from spring to winter. The distribution of various sex classes among various group types across the seasons changed significantly (Kruskal-Wallis test, α=0.000 for males, α=0.000 for females, α=0.007 for yearling and α=0.043 for kids). Area based multiple comparisons and linear regression (R^2) indicated that group size and density are linear in relation indicating high group size in high-density area than that of in mid and low-density areas. A strong correlation was observed among typical group size and habitat type (r = 0.286, P = 0.000). A positive correlation was observed among habitat type and weather (r = 0.296, P = 0.000). Seasonality as an important determinant of population dynamics should be taken into account while studying abundance and population structure of mountain ungulates. © 2020 Friends Science Publishers

Keywords: *Capra sibirica*; Population density; Sex ratio; Group dynamics; CKNP

Introduction

Himalayan ibex (*Capra sibirica*) is the most abundant species of wild *Caprinae* in Pakistan (Schaller 1977) and inhabit the arid and precipitous mountain ranges, above the tree-line in Karakoram, Himalaya and Hindu Kush (Roberts 1997; Anwar 2011). Globally *C. sibirica* is distributed in Afghanistan, China, India and Mongolia (Macdonald 1984), also found in the mountains of Central Asia, Tien Shan and Koh Altai (Rovero *et al*. 2018). In Pakistan *C. sibirica* is found in northern mountain, usually inhabiting the rugged terrain at elevation of 3660 to 5000 m in Gilgit-Baltistan, Swat Kohistan, Chitral and some area of Azad Jammu & Kashmir (Roberts 1997; Usman *et al*. 2007; Anwar 2011). In Gilgit-Baltistan *C. sibirica* populations are widely distributed almost in all the major valleys with greater abundance in upper Hunza, Baltistan, Ishkoman, Yasin, Haramosh and Deosai (Roberts 1997). The Himalayan ibex has been listed as “Least Concern” in the Red List of Pakistan’s Mammals (Sheikh and Molur 2005). However, they face shortage of forage due to sparse vegetation and dietary competition with domestic ungulates including sheep, goats, yak and cattle (Anwar 2011). Other factors such as severe winters, excessive hunting and natural predation pressure (Fox *et al*. 1992) and death from avalanches on snow bound slopes also affect population and group dynamics (IUCN 2009). Sometimes the excessive number of livestock grazing in shared pastures

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may force the animals move to undesired locations (Usman *et al*. 2007).

Large mammalian herbivores form recognizable groups consisting of individuals located a short distance from one another and most often engaged in a common activity such as feeding, walking or resting. Like other members of the Caprinae subfamily, ibex are gregarious species, which prefer to live in herds of females with kids and yearlings or in all male groups, with an open social organization system (Schaller 1977). The size and structures of group differ in different seasons when individuals get separate or mix to get new groups (Habibi 1997). Factors affecting grouping behavior of wild ungulates include population size (Sokolov 1959), type of habitats (Alados 1985; Khan *et al*. 2014a) and seasons (Raman 1997). Group size increases directly in relation to availability of food (Mishra 1982; Schaller 2009).

Little information is available about population dynamics of wild ungulates inhabiting northern mountainous areas of Pakistan (Khan *et al*. 2014a, b). Lack of reliable data on the species abundance and group dynamics across different seasons is a key challenge for conservation and management of biological diversity (IUCN 2009). Systematic and long-term monitoring of key species in protected areas has been greatly emphasized for effective conservation and management (Spellberg 1994; Boddicker *et al*. 2002). Following a thorough review of trophy hunting program in Pakistan, Shackleton (2001) has recommended allocating hunting permits primarily based on advocate population data. Therefore, this study was designed to investigate seasonal population dynamics of *C. sibirica*, inhabiting five valleys of Central Karakoram National Park (CKNP), using important parameters such as species abundance and density, ratios among different age and sex classes, group size and structure. Specifically the study aimed at to: a) determine seasonal variation in the species abundance, density and sex ratios among various demographic groups; and b) investigate and correlate various factors responsible for seasonal variation in population structure.

Materials and Methods

Study area

Central Karakoram National Park (CKNP-74.406963 to 76.728595 E and 35.178868 to 36.454163 N) measuring 10,000 km^2 is located amidst the lofty peaks of Karakoram Mountains in Pakistan (Fig. 1), spanning partly in five of the ten districts of Gilgit-Baltistan (Hagler Bailly-Pakistan 2005). The Park is a refuge area not only for threatened species, such as musk deer, markhor, Ladakh urial and snow leopard, but also for not threatened but important “flagship” species, such as Himalayan ibex, blue sheep and gray wolf (Roberts 2005; IUCN 2009, Lovari and Bocci 2009). Most of the CKNP areas are characterized by vegetation with species like *Artemesia* spp., *Juniper* spp., *Rosa webbiana* and *Polygonum* spp., *Myricaria germanica* and *Hippophae rhamnoides*, along the streambeds. Conifer mainly includes *Junipererus* spp. and Pinus *wallichiana*, which are found mixed with grasses at high altitude (WWF–Pakistan 2008). The narrow inter-mountain valleys surrounding the Park are characterized by semi-arid ecosystems providing home to about 100,000 people of unique customs and traditions (WWF–Pakistan 2007). Majority of the local communities (>80%) depend upon subsistence agriculture and livestock herding.

Survey

Five CKNP valleys, reported to be abundant in *C. sibirica* (Khan *et al*. 2014b; Ali *et al*. 2015) including; Hisper, Hoper, Hushey, Basha and Thaley (Fig. 1) were selected to conduct seasonal population assessments. In winters the surveys were conducted from 15 to 31 December 2015 and spring from 15–31 May 2016. We applied fixed-point direct count method (Feng *et al*. 2007; Usman *et al*. 2007; Khan *et al*. 2014a, b) on transacts with specific vantage points. The surveys were conducted during dawn and dusk when the animals were more active for feeding and drinking (Fox *et al*. 1992). Across all the valleys and sub-catchments the vantage points were selected keeping in view the maximum sightings potentials and the same points were used in the subsequent surveys. We used binoculars (Nikon 12 x 50) and spotting scope (Swarovski ATM 80 HD) to count animals. For distribution mapping, the vantage points were geo-referenced with the help of a hand-held GPS (Garmin 78); a compass was used to note down bearings (angle), while distance from vantage points to location of herds was estimated approximately. The data were noted down in a tally sheet that also included information on weather and habitat conditions. Each herd seen was classified into age and sex groups based on the criteria defined by Schaller (1977) and Lovari and Bocci (2009), whereas trophy size males (>7 years old) were recorded separately.

Data analysis

SPSS 20 was used to analyze data. In addition to mean group size, typical group size was also calculated based on animal-centered measurements (Jarman 1974), by squaring the sizes of groups, summing across all groups and dividing the sum by total number of individuals observed. The typical group size was calculated because the former is an observer-centred measurement that gives equal weightage to groups of all sizes, and may not reflect the experience of the average individual species in the same manner as done by the later (Raman 1997). Density was estimated using total counts divided by the surveyed area (Fox *et al*. 1992). Mann-Whitney U test was applied to compare reliability of sample means between different survey timings (seasons). Kruskal-Wallis H test was used to determine difference in sex ratio between different density areas. Pearson chi-square test was used to compute ratios among different sex and age classes. A three-way analysis of variance with valleys/area, habitat type and weather was used to examine whether typical group size differed under the influence of any of the factor or interaction among factors (Raman 1997). To measure the effect of age class within as well as against weather and habitat type on ibex population distribution, we used Spearman's correlation (r). Linear regression (R^2) was used to look for the relationship between group size and density.

Results

Seasonal abundance

Seasonal counts of Himalayan ibex in five valleys of CKNP (Table 1), over spring-winter comprised of 538–618 in Hisper, 243–252 in Hoper, 173–229 in Thalay, 102–192 in Basha and 78–434 in Hushey. An annual sum of 2,892 ibex encounters was recorded during spring and winter, with maximum encounters in Hisper (n = 1156) followed by Hushey (n =512) > Hoper (n = 495) > Thaley (n = 402) and Basha (n = 294), respectively. Also, a total of 292 trophy-sized ibex were also counted across all five valleys in both the seasons, with maximum in Hisper and minimum in Basha (Fig. 1).

The density increased from spring to winter in all valleys, except in Hoper where it slightly decreased (Fig. 2). According to our estimates, it swelled to 82% in Hushey, 46.8% in Basha, 24.4% in Thaley over spring to winter. However, the population estimate in Hoper valley was not significantly different indicating only 3% decrease during winter.

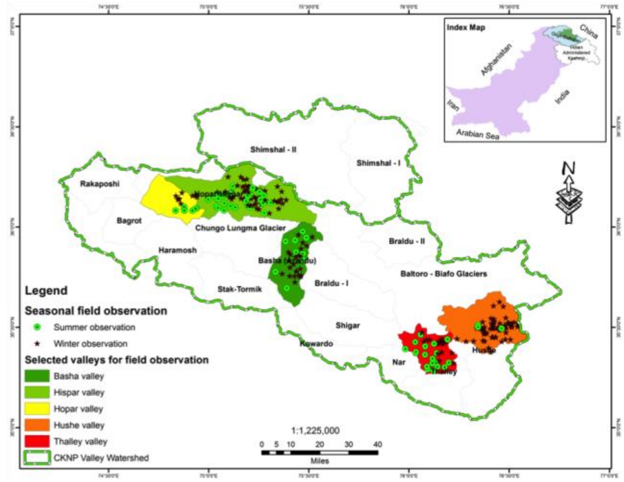

Fig. 1: Central Karakoram National Park, Pakistan showing seasonal distribution of Himalayan ibex in the survey sites (Source: WWF-Pakistan 2008)

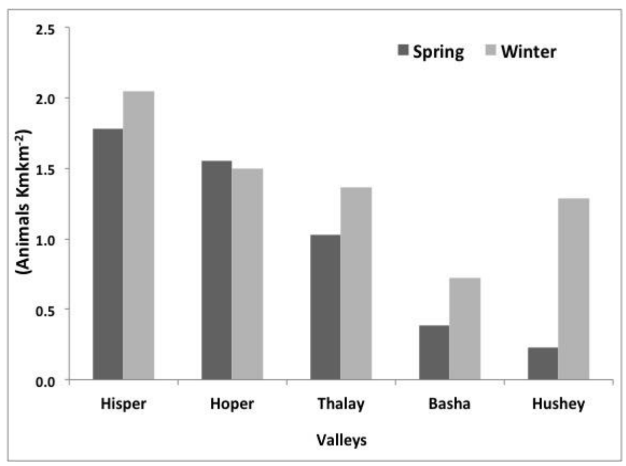

Fig. 2: Winter and spring density of Himalayan ibex in selected valleys of CKNP

Demographic composition

The occurrence of adult male and adult females did not vary significantly across the seasons, while for kids and yearling it varied significantly (Mann-Whitney; U=2592, α=0.000 for kids and U=3792, α=0.040 for yearlings). A highly positive correlation between female and yearlings (r = 0.970, P = 0.006), adult males and trophy-sized males (r = 0.957, P = 0.011), yearlings and not determined individuals (r = 0.938, P = 0.018) was measured for the counts in spring. However, strong correlation in winter season was recorded among female and kids (r = 0.960, P = 0.040), kids and males (r = 0.993, P = 0.007), male and female (r = 0.970, P = 0.030), female and trophy sized male (r = 0.947, P = 0.053).

Sex ratios

Sex ratio between male to female, kids to female and yearling to female varied across the seasons (Table 2). Male to female sex ratios decreased from spring to winter in all valleys (χ^2 = 10.0, df = 9, P = 0.350), except Hushey while kids to female ratio increased in Hisper, Hoper and Thaley, remained same in Basha and decreased in Hushey (χ^2 = 8.00, df = 8, P = 0.433). However, ratio between yearling and female decreased from spring to winter except in Hoper valley (χ^2 = 10.0, df = 9, P = 0.350) (Table 2).

Group dynamics

According to our surveys, most of the animals were found in mixed herds. The typical group size increased in winter across all valleys (spring: 20, range=9–42; winter: 31, range=13–76, Fig. 3). Mean group size also increased in all valleys (except in Basha) (spring: 14, range=8–24; winter 17, range=10–34). However, distribution of various sex classes among various group types across the seasons changed significantly (Kruskal-Wallis test, α=0.000 for

Table 1: Seasonal distribution of Himalayan ibex population in selected valleys of the CKNP, Pakistan

Valley	Season*	Male	Female	Yearling	Kid	Undetermined	Total	Trophy size male
Hisper	S	153	184	122	51	28	538	65
	W	146	210	63	143	56	618	46
Hoper	S	111	92	26	19	4	252	65
	W	64	97	34	48	0	243	11
Thaley	S	54	67	36	0	16	173	17
	W	66	99	11	34	19	229	23
Basha	S	34	50	11	7	0	102	5
	W	45	102	16	14	15	192	20
Hushey	S	22	36	7	11	2	78	7
	W	135	125	58	103	13	434	33
Total		830	1062	384	430	153	2859	292

*S= spring, W= winter

Table 2: Ratio among multiple age groups and sex ratio within the population of Himalayan ibex

Valley	Season	Male-female ratio	Kids-female ratio	Yearlings-female ratio
Hisper	S	0.83:1	0.28:1	0.66:1
	W	0.7:1	0.68:1	0.30:1
Hoper	S	1.21:1	0.21:1	0.28:1
	W	0.66:1	0.49:1	0.35:1
Thaley	S	0.81:1	0.00:1	0.54:1
	W	0.67:1	0.34:1	0.11:1
Basha	S	0.68:1	0.14:1	0.22:1
	W	0.44:1	0.14:1	0.16:1
Hushey	S	0.61:1	0.31:1	0.19:1
	W	1.08:1	0.82:1	0.46:1

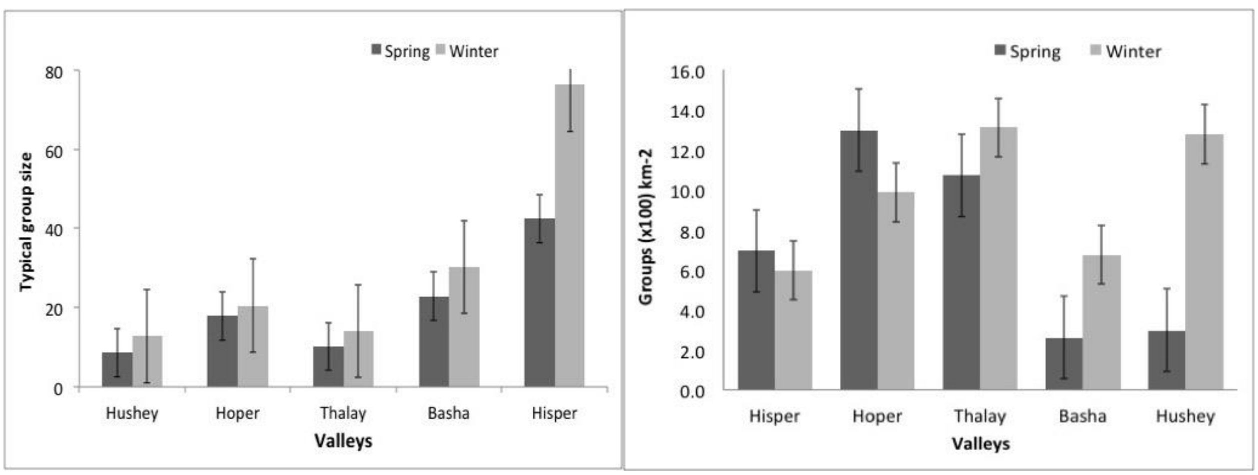

Fig. 3: Typical group size (no of animals) (left) and group density (number of groups per100 km^2) (right) of Himalayan ibex during spring and winter in selected valleys of CKNP, Pakistan

males, α=0.000 for females, α=0.007 for yearling and α=0.043 for kids).

Maximum average group size was recorded in Hisper followed by Hoper and Hushey > Thaley > Basha. Moreover, average group density did not vary significantly across the seasons (χ^2 = 20.0, *df* = 16, *P* = 0.220, Fig. 3). Results showed that group density increased from spring to winter in Hushey (3.0 to 12.8 group 100 km^{-2}), Thaley (10.7 to 13.1 groups km^{-2}) and Basha valley (2.6 to 6.7 groups km^{-2}). Area based multiple comparisons and linear regression (R^2) indicated that group size and density are linear in relation indicating high group size in high density area than that of in mid and low density areas (Table 3).

In addition, a three-way analysis of variance (ANOVA) indicated no statistically significant effects of habitat, weather and season on typical group size of Himalayan ibex (Table 4). Other two-way interactions and the three-way interaction between valley/area, habitat type, and weather, were not significant. A strong correlation was observed among typical group size and habitat type (r = 0.286, *P* = 0.000), whereas no significant correlation was observed between typical group size and weather. Whereas, a positive correlation was observed among habitat type and weather (r = 0.296, *P* = 0.000), indicating that weather is somehow indirectly affecting the typical group size.

Table 3: Results of linear regression of Himalayan ibex mean group size measures in five valleys of CKNP across spring and winter season, 2015–2016

Valleys	Season	R^2 (adjusted)	*F*	*Sig.*
Hushey	Spring	0.766	30.4	0.001
	Winter	0.680	88.0	0.000
Thaley	Spring	0.650	32.5	0.000
	Winter	0.487	21.0	0.000
Basha	Spring	0.402	5.03	0.075
	Winter	0.206	5.40	0.034
Hoper	Spring	0.600	30.9	0.000
	Winter	0.309	7.70	0.015
Hisper	Spring	0.564	28.1	0.000
	Winter	0.235	6.23	0.024

*Dependent variable: Mean group size, Independent variable: group density

Table 4: Results of three-way analysis–Influence of season habitat and weather on average group size (typical) of Himalayan Ibex in CKNP

Source	*df*	Mean Square	F	*Sig.*
Season	1	196.300	.676	.412
Weather	4	30.193	.104	.981
Habitat	2	180.918	.623	.537
Season × Weather	1	195.172	.672	.413
Season × Habitat	2	82.687	.285	.753
Weather × Habitat	3	407.913	1.405	.243
Season × Weather × Habitat	1	55.275	.190	.663
Error	178	290.388		

Discussion

The results revealed that Himalayan ibex are widespread in CKNP valleys, as confirmed previously by Hess (1990) in Hoper; Khan *et al.* (2014b) and Ali *et al.* (2015) in Hisper and Hushey; Hagler Bailly-Pakistan (2005) in Thaley and Basha. The animals were more abundant in winters as appeared from the minimum counts, which increased up to 82% in winters, compared to spring. Greater congregation of wintering populations of *C. sibirica* has also been observed in similar range area, *e.g.* Ladakh (Fox *et al.* 1992). In mountainous landscapes snowfall in upper catchments limits the distribution of wild ungulates in lower catchments with concentrated populations leading to greater abundance estimation. In spring with melting of snow the animals start to venture upward in search of fresh plant growth, sporadically distributing, hence there is a chance of less abundance estimation. Another reason of low abundance estimation in spring is poor accessibility to upper catchments due to avalanches, leading to less chances of encounter with ibex populations.

Overall in the surveyed areas the adult sex ratios skewed towards female, except in Hushey and Hoper, where it was almost at unity, presumably due to long-term community-based conservation efforts, which has also been previously observed in case of Hushey (Khan *et al.* 2014a). Male to female sex ratios decreased in winters, presumably due to factors such as greater mortality of young males; trophy hunting, death of old males due to weakness after rut; relatively more killing of males than females by predators such as snow leopard and wolf (Fedosenko and Savinov 1983; Geptner *et al.* 1988) and unfavourable range conditions (Hoefs and Nowlan 1994). Kids to female sex ratios increased in three valleys probably due to the new cohort but in one valley it reduced. Reduction in kids to female ratios can be attributed to uptake of young ones by mammalian and avian predators (Bhatnagar 1997). The sex ratios differed according to habitat type and range conditions, *e.g.*, the female to male ratio after birth in Tian Shan, Dzhungarskiy Alatau and Himalayas was recorded to be 1.09:1, 1.21:1 and 1.11:1, respectively (Fedosenko and Savinov 1983; Fox *et al.* 1992). Moreover, in Mongolia and west Sanjay the female bias was also greater in populations *i.e.*, 2.13:1 and 1.87:1, respectively (Dzieciolowski *et al.* 1980; Zavatskiy 1989). The greater female bias is attributed to various factors like nutrition and range conditions that affect ratio of females to males after birth, *e.g.*, female produce more male offspring in unfavourable range conditions (Hoefs and Nowlan 1994).

Like other members of Caprinae, Himalayan ibex are highly gregarious and prefer to live in different types and sizes of groups, determined by various factors, *e.g.*, seasonality (Raman 1997), habitat type (Khan *et al.* 2016), and overall population size (Sokolov 1959). In CKNP valleys, the animals were distribution into mixed herds both in spring and winter populations, but demographic variations were greater in winter herds. As compared to spring the winter populations represented well-mixed sex and age classes. Although the occurrence of adult males and adult females did not vary significantly across seasons but kids were more frequent in winter populations and yearlings in spring populations. We found a correlation in the occurrence of females and yearlings and adult males and trophy-sized males in spring populations. The greater male segregation has also been observed by Fox *et al.* (1992) in summer ibex populations in Ladakh. Similarly, in our study a strong correlation was observed between female and kids, kids and males, male and female, female and trophy sized males in the winter populations. The correlations between the occurrence of females and trophy-sized males together in winters can be attributed to the rutting period. Well-mixed herds in wintering populations of ibex correspond to the previous assessments (Dzieciolowski *et al*. 1980; Habibi 1997).

In our seasonal assessment, no significant change was observed in the mean group size of ibex across four valleys except in Hisper where mean group size increased significantly from spring to winter. However, a significant increase in typical group size was recorded across both seasons. Occurrence of larger groups in Hisper, Basha and Hoper can be attributed to the vast alpine pastures as compared to other valleys. Greater abundance and concentrated population in winters may lead to larger group sizes as compared to spring.

Another aspect that emerged during this study is significant effect of habitat type on mean group size (Fig. 2). The mean group size and group density was smaller in all four villages *i.e*., Hushey, Thaley, Basha and Hoper during spring season. It was recorded that the ibex group density increased significantly in all valleys except Hoper where it decreased from 13.0 groups 100 km^{-2} to 9.9 groups 100 km^{-2}. In contrast to the positive relationships between ibex density and group size within a given season, it was observed that during winter, smaller group size is due to unseen factors affecting the group size. In addition to varying habitat type and weather, no significant effect of season on mean group size of Himalayan ibex was observed (Table 4). A strong correlation among habitat type and mean group size was found, which indicated that the mean group size varied according to habitat type. It can be deduced from the results that habitat types of a species determine for its food, shelter and overall survival is a major factor affecting population structure of Himalayan ibex across season. Moreover, strong correlation between weather and habitat type indicated that weather indirectly affects the ibex group size in addition to habitat type. Previous literature provides the evidence of effect on *C. sibirica* population due to various habitat factors (Khan *et al*. 2016; Peterson 2016).

Conclusion

Population structure of Himalayan ibex varies across seasons, with a marked difference in density, sex ratios and grouping tendencies. Such variations can be attributed to various factors including habitat types, weather and reproductive activities. Therefore, while determining the abundance estimations and population structure of *C. sibirica* in mountainous landscapes seasonality must be taken into account. In mountainous terrain variation in weather conditions greatly affect such estimation due to the resultant habitat conditions and accessibility to surveying areas. In winters with snowfall wild animals descend down to more accessible area in valley bottoms giving a better chance of encounter and the populations are well mixed of all age and sex classes. Therefore, population structure can be reliably determined in winter surveys.

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