

Poaching, recruitment and conservation of Punjab urial *Ovis vignei punjabiensis*

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Poaching can accelerate extinction processes, particularly when driven by commercial gain. We studied Punjab urial *Ovis vignei punjabiensis*, an endangered wild sheep, in two areas of the Salt Range in Pakistan, with contrasting human population densities and management regimes. In the Eastern Salt Range (ESR), humans live adjacent to urial habitat and enforcement of antipoaching regulations is lax. In the Kalabagh Game Reserve (KGR), human population density is low and regulations are strictly enforced. In ESR, about a quarter of the lamb crop was removed by poachers, and all rams > 6 years old were eliminated by illegal shooting. In KGR, < 5% of lambs were removed and about 34% of adult rams were ≥ 6 years old. Yearly recruitment was only four yearling females per 100 ewes in ESR, compared to about 13 yearling females per 100 ewes in KGR. Recruitment was insufficient to maintain the population in ESR. Poaching of newborn lambs to be kept as pets appears to be the greatest short-term threat to Punjab urial, recently exacerbated by the granting of licences to legally possess pet urial. Over the long term, the increasing human population in the area presents additional challenges.

Key words: *Ovis vignei punjabiensis*, poaching, Punjab urial, recruitment, Salt Range, yearling females

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Many large herbivores in Asia are under threat from poaching, habitat fragmentation and competition with domestic livestock. Conservation of Asiatic ungulates is often hampered by poor knowledge of basic population dynamics and weak quantification of specific threats. Here we examine recruitment and survival in Punjab

urial *Ovis vignei punjabiensis* to assess the impacts of poaching on population persistence. We compare population structure, fecundity and lamb survival in two populations under different management regimes and levels of law enforcement.

The Punjab urial is distributed between the Jhelum and

Indus rivers in Pakistan, below an altitude of 1,500 m a.s.l. (Schaller & Mirza 1974). It is listed as endangered by the 2003 IUCN Red List. Like other wild sheep (Aleem 1977, Schaller 1977), Punjab urial are gregarious and highly sexually dimorphic: adult males weigh about 40 kg and their large curly horns can reach 100 cm in length. Adult females weigh 25 kg and their straight horns are only about 12 cm long. Females give birth to one or two lambs in early April. Although all harvesting of Punjab urial is illegal, mature males are a sought-after trophy while lambs are traditionally prized as pets. Ownership of a pet urial is a status symbol in Pakistan (Awan 2001). Awan et al. (2004) estimated a total population of about 860 urial in the Salt Range, suggesting a 56% decline from 1976, when Mirza et al. (1980) estimated 1,968 urial in the same area.

Methods

We studied Punjab urial in two areas of the Salt Range, Pakistan. The state-managed eastern section of the Salt Range (Lehri, Jalalpur and Kotal kund, referred to as ESR; 32°41'N, 73°23'E), covers about 518 km². The community-managed Kalabagh Game Reserve (KGR; 32°52'N, 71°39'E) extends over about 137 km². Protection against poachers is vigorously enforced in the KGR, where urial have been protected for the last 70 years by the reserve's private owners, who employ more than 30 game guards. Livestock grazing within the KGR is strictly prohibited in a core area of about 20 km² with the greatest urial density, and only a few head of cattle and sheep are allowed in other parts of the reserve where urial occur. Human access is limited to a few unpaved roads at low elevations where urial are rarely observed. Cutting of wood or grass is prohibited in the core urial habitat. In ESR, on the contrary, law enforcement is lax, lamb captures are common and adult urial are illegally hunted. ESR is heavily grazed by livestock and people commonly collect fuelwood and cut grass. Awan et al. (2004) reported that KGR supports about 500 animals, ESR only about 160.

Weather data (mean monthly temperature and precipitation) were obtained from Meteorological Department weather stations at Mianwali, 30 km southwest of KGR and Jhelum, about 20 km from ESR. The climate of the area is subhumid subtropical continental. Rain is strongly seasonal and 60% falls in summer. Monsoon rains start around mid-July and last to mid-September. Winter rains begin in January and persist to early March. January is the coldest and June the hottest month of the year. Maximum daily temperature is usually > 40°C in June.

In December and January the temperature often drops below zero. Average rainfall over 30 years (1961-1990) was 1,239 mm in ESR and 452 mm in KGR. The topography is similar in both areas, with an average elevation of 1,000 m a.s.l. The habitat type prevailing in the area is dry subtropical semi-evergreen scrub forest (Roberts 1991).

Data were collected during October 1999 - June 2002. Herd size and composition were assessed by repeated counts from established foot transects. We sampled 46 transects in ESR and 24 in KGR once in April, October and December each year. Foot transects varied in length from 3 to 7 km, for a total of 250 km in ESR and 140 km in KGR. To minimise sampling bias, transects were located in all habitats possibly occupied by urial. Additional observations were recorded during the rut, lambing season, summer and winter. Rut observations were made during 7-14 October, 20 October - 10 November and during 17-25 November 1999 in ESR and on the same dates in KGR in 2000. During the 2001 rut the same schedule was followed, but the number of days was divided equally between the two populations. Each population was sampled for 30 days during the lambing season over the course of the study. Summer and winter observations included five days per month for each population. Observations were made for seven hours each day. Sex ratios were calculated from observations obtained over the entire study period.

Peak parturition is during the first half of April (Awan 2001), and the rut is during the last week of October and the first week of November (Schaller & Mirza 1974). Observations were made primarily during early morning and late evening, using a Nikon 60x spotting scope and binoculars. Yearling females could only be distinguished from adult females at distances of < 200 m. Males ≥ 2 years old could easily be distinguished from females by body size and horn shape and size, and we made a special effort to identify yearling males through horn shape and presence of a scrotum. We used horn length, horn curl and neck ruff size (Schaller & Mirza 1974) to classify adult rams into four age classes: Class I (2 years old), Class II (3 years old), Class III (4-6 years old) and Class IV (> 6 years old). When possible, horn annuli were counted with a 60x spotting scope to estimate the exact age of rams. Because annuli are difficult to distinguish in older individuals, we pooled all rams > 6 years old (Schaller 1977) into class IV.

We used Analysis of Variance (ANOVA) to test for the effects of study area (ESR and KGR) and season on group size. We also calculated typical group size as the average group size experienced by all members of the population (Jarman 1974).

Fecundity was estimated from lamb:ewe ratios during 5-26 April (two weeks after the birth peak date) as recommended by Nichols & Bunnell (1999). Lambs found dead or poached soon after parturition were included when calculating lamb:ewe ratios. To assess lamb survival to nine months, we calculated January lamb:ewe ratios following Festa-Bianchet (1992) and Jorgenson (1992). To estimate survival to yearling age we compared the lamb:ewe ratio in April to the yearling:ewe ratio in July the following year. Lamb:ewe and yearling:ewe ratios were calculated only for groups observed from < 200 m, where yearling ewes could be classified. Yearling ewes were excluded from the calculation of lamb:ewe ratios. We marked 18 lambs (seven males and 11 females, all < 2 days old) in KGR in April 2002 with small Allflex coloured and numbered plastic ear tags. Newborn lambs were captured by hand. The survival of marked lambs was monitored until July 2003, during five surveys of KGR lasting three days each.

Information on poaching of newborn lambs was collected from the market and directly from persons involved in poaching, on the understanding that this information would be used only for study purposes. Documentation of illegal shooting of adult urial was collected from local people and confirmed by the hunter or a witness. Unconfirmed reports of poaching were not included, therefore we likely underestimated the prevalence of poaching. Dead urial were carefully examined to determine the cause of death. We observed eight predation attempts.

Results

A total of 3,508 urial sightings were classified into sex-age classes (Fig. 1) in KGR and ESR. Males ≥ 6 years old were absent from ESR, whereas in KGR they represented about 17% of the population. Adult sex ratio did not show much seasonal variation (0.90-1.27 in KGR and 0.56-0.65 in ESR; Fig. 2), but was consistently more female-biased in ESR.

Only 3 and 7% of the urial seen in KGR and in ESR, respectively, were solitary. Mean group size was 4.4 (SE = 0.30) in KGR and 3.2 (SE = 0.33) in ESR, with a

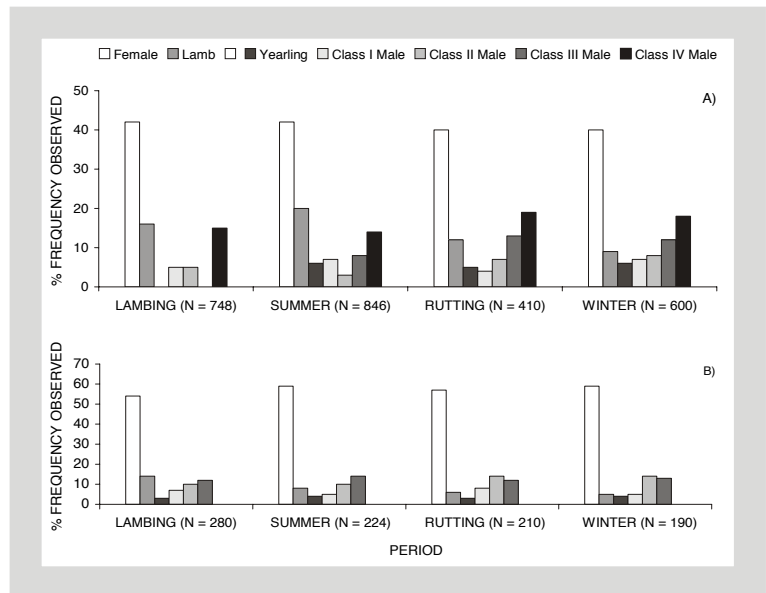


Figure 1. Sex and age composition of Punjab urial in A) the Kalabagh Game Reserve (KGR) and B) the Eastern Salt Range (ESR), Pakistan, during 1999-2002.

high coefficient of variation (Table 1). Group size varied seasonally (2-way ANOVA: $F_{3,859} = 10.21$, $P < 0.001$) and was smaller during the lambing season than in winter and summer. Groups were larger in KGR than in ESR ($F_{3,859} = 23.37$, $P < 0.001$) and the study area*season interaction was also significant ($F_{3,859} = 5.56$, $P = 0.001$) probably because the largest mean groups were seen during winter at KGR but during the rut at ESR (see Table 1). Typical group size was about seven urial and followed a pattern similar to mean group size (see Table 1). During the rut, the frequent occurrence of solitary rams accounted for the wide discrepancy between mean and typical group size (see Table 1).

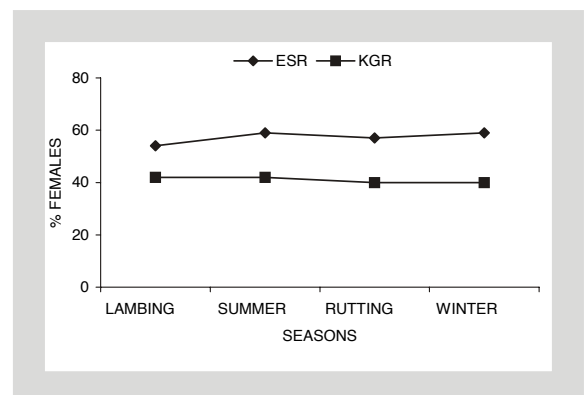


Figure 2. Seasonal variation in the percent females among adult Punjab urial seen in the Kalabagh Game Reserve (KGR) and the Eastern Salt Range (ESR), Pakistan, during 1999-2002.

Table 1. Mean, standard error (SE) and coefficient of variation (CV) of Punjab urial group size in Kalabagh Game Reserve (KGR) and Eastern Salt Range (ESR), Pakistan, during 1999-2002. The typical group size (the group size experienced by the average individual in the population) is also provided.

Season	N groups		Mean		SE		CV (%)		Range		Typical group size	
	ESR	KGR	ESR	KGR	ESR	KGR	ESR	KGR	ESR	KGR	ESR	KGR
Rutting	44	92	4.77	4.46	0.63	0.46	87.84	93.72	1-18	1-23	8.36	8.34
Winter	53	111	3.58	5.41	0.31	0.31	64.24	60.44	1-11	1-22	5.03	7.36
Lambing	104	215	2.69	3.48	0.18	0.17	70.26	74.13	1-11	1-13	4.00	5.38
Summer	81	167	2.77	5.07	0.23	0.28	75.81	73.37	1-13	1-19	4.33	7.77
Overall	282	585	3.21	4.45	0.33	0.30	74.53	75.41	1-18	1-23	6.5	7.21

Mixed groups (ESR: 38%, N = 106; KGR: 44%, N = 259) were the largest and most common social aggregation. All-male and nursery groups, including only ewes, lambs and yearlings each accounted for 22% of the groups seen in KGR and 14 and 25%, respectively, for ESR. Mixed groups were most common during the rut and least common during the lambing season (Fig. 3). The female:male adult sex ratio was close to unity in KGR, but it was biased towards females (1.7) in ESR.

To assess litter size at birth, we only considered 34 ewes at KGR whose lambs were captured soon after birth (12 ewes) or that were seen immediately after parturition (22 ewes), before they joined other ewes. Of these ewes, six (18%) had twins, leading to an average litter size of 1.18.

Mortality of marked lambs

Of 18 lambs marked in KGR within two days of birth, two died within three weeks, including a female that was eaten by a jackal *Canis aureus*. Two male lambs died in November. The mortality rate from birth to the following January was 22%, similar to the 25% estimated from changes in lamb:ewe ratio in KGR over the same peri-

od (Table 2). One female died as a yearling in June 2003. Of the surviving 13 lambs, nine (two males and seven females) were seen as yearlings; the other four were assumed to have died and were never seen during subsequent surveys up to October 2004. Minimum local survival of marked lambs to yearling age in KGR was therefore 50%, close to the 42% estimated from changes in lamb:ewe ratio observed in 2002 (see Table 2).

Changes in lamb:ewe ratio

Lamb production and mortality varied among years and areas (see Table 2). Lamb:ewe ratios declined substantially from April to the following January. Over three years, estimated mortality from birth to January averaged 65% in ESR and 35% in KGR. Yearling recruitment in July averaged seven yearlings per 100 ewes in ESR and 26 yearlings per 100 ewes in KGR (see Table 2).

Poaching of newborns and predation were the main causes of lamb mortality. Predators include leopard *Panthera pardus*, wolf *Canis lupus*, jackal, red fox *Vulpes vulpes*, yellow-throated marten *Martes flavigula* and steppe eagle *Aquila rapax*. Yellow-throated marten, eagle and jackal were documented to prey on lambs in early summer. We conducted six night-time surveys in both KGR and ESR. A goat's hide was first dragged behind a vehicle for 7 km, and then the same route was searched by spotlight. On average, for each kilometre of survey we saw 0.14 jackal and 0.28 foxes in KGR and 1.42 jackal and 0.57 foxes in ESR.

Of 62 cases where the cause of lamb death or disappearance could be determined, 16 were attributed to predators and 46 were due to poaching (Table 3). On average, more than a quarter of the lamb crop was known to be poached in ESR. The actual extent of lamb poaching was likely greater. Of the 10 adult urial known to be illegally shot during this study in ESR and

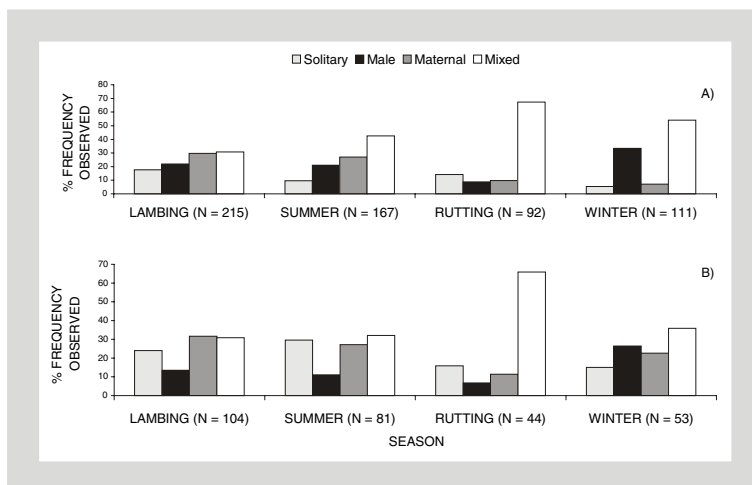


Figure 3. Seasonal frequency of different Punjab urial group types in A) the Kalabagh Game Reserve (KGR) and B) the Eastern Salt Range (ESR), Pakistan, during 1999-2002.

Table 2. Seasonal lamb:ewe and yearling:ewe ratios for Punjab urial in Kalabagh Game Reserve (KGR) and Eastern Salt Range (ESR), Pakistan, during 2000-2002.

Year	Area	April		January		Following July	
		Lamb:ewe	(N =)	Lamb:ewe	(N =)	Yearling:ewe	(N =)
2000	ESR	0.49	(N = 52)	0.22	(N = 59)	0.08	(N = 50)
	KGR	0.70	(N = 124)	0.43	(N = 118)	0.26	(N = 122)
2001	ESR	0.55	(N = 43)	0.15	(N = 39)	0.06	(N = 40)
	KGR	0.63	(N = 110)	0.37	(N = 106)	0.21	(N = 99)
2002	ESR	0.60	(N = 46)	0.19	(N = 42)	0.06	(N = 47)
	KGR	0.71	(N = 130)	0.53	(N = 123)	0.30	(N = 132)
Mean	ESR	0.55		0.19		0.07	
	KGR	0.68		0.44		0.26	

KGR, three rams were taken just outside KGR and seven (two females and five rams) in ESR.

Discussion

Punjab urial formed comparatively larger groups in winter and smaller groups in the lambing season than in other seasons. The smaller groups seen during the lambing season are likely due to the isolation of parturient females. In the winter when forage quality is low sheep use more open habitat and may decrease vigilance and increase bite rate by increasing group size (Jarman 1974, Risenhoover & Bailey 1985). Edge & Olson-Edge (1990) reported that group size of wild goats *Capra aegagrus* in Khirthar National Park, Pakistan, showed a similar seasonal trend.

Single births were much more common than twins. Jerdon (1874) suggested that urial usually have twins, and Prater (1965) suggested that one or two young are produced at birth. Schaller (1977, 1980) reported twins in fewer than 10% of births at KGR.

Schaller & Mirza (1974) and Schaller (1977) reported an even sex ratio for adult urial at KGR. Our study suggested a female-biased sex ratio for the ESR. In sexually dimorphic ungulates, male mortality is typically higher than female mortality, leading to female-biased adult sex ratios (Geist 1971, Clutton-Brock et al. 1982, Jorgenson et al. 1997, Loison et al. 1999). For Punjab urial,

however, the female-biased adult sex ratio may partly be due to the selective harvest of males as trophies. A comparison of average total rainfall suggests that vegetation productivity at KGR is not greater than in ESR. In addition, urial density is higher in KGR than in ESR. Thus, there is no obvious reason to expect a higher natural mortality of males in ESR, and the female-biased adult sex ratio may be explained by poaching. Hunting is strongly biased towards males with large horns, and has an important impact on population structure. Male lambs also fetch a higher price than female lambs. Because lambs are very difficult to catch, however, we suspect that all captured lambs are kept.

Lamb production rates in our study were similar to those reported for other wild sheep, but yearling recruitment was lower than for stable or increasing populations (Portier et al. 1998). The pet trade appears to be the greatest short-term threat to the survival of Punjab urial. While the protected KGR population seems relatively stable, numbers in the remainder of the Salt Range have declined to less than half what they were about 25 years ago (just over three urial generations). The two study areas are only about 100 km apart and have similar topography, but KGR is a community-managed game reserve, whereas ESR is managed by the state. It therefore appears highly likely that differences in population dynamics in these two areas are driven by differences in protection status.

The lamb:ewe ratio in April was not markedly differ-

Table 3. Documented Punjab urial predation and poaching in the Salt Range, Pakistan, during 1999-2002.

Predator	Observed predation attempts	Urial killed by predator	Prey sex/age
Leopard	-	3	Rams/1 class II ram and 2 class IV
Indian wolf	One wolf chasing a ram	2	Ram/class II and III
Asiatic jackal	Two unsuccessful pursuits	11	lambs
Yellow-throated marten	Two unsuccessful pursuits	3	lambs
Steppe eagle	Three predation attempts	2	lambs
Man (lambs captured to be kept as pets)	-	46	lambs

ent between KGR and ESR, suggesting that poor lamb production was not the source of population decline in ESR. We suggest that spatial and temporal changes in lamb survival, due mainly to different intensities of poaching, drive Punjab urial population dynamics. In ungulates, adult survival typically varies little over space and time (Gaillard & Yoccoz 2003) and changes in juvenile survival are often the key variable in population growth (Caughley 1977, Gaillard et al. 1998).

Lamb production in ESR and KGR varied little between years, but the disappearance rate of lambs from birth to January in ESR was about two times higher than in KGR. Lambs may die from many causes, particularly in the ESR, where a variety of potential predators exist. In particular, there may be more jackals in ESR than in KGR because human settlements in and near ESR provide food for jackals in the form of garbage. We estimate that about 25% of the lamb crop was poached in ESR, compared to 5% in KGR.

Schaller & Mirza (1974) and Schaller (1977) reported 75 and 65 lambs/100 adult females, and 35 and 42 yearlings/100 adult females in KGR in 1971 and 1973. We counted on average 68 lambs and 26 yearlings/100 adult ewes in KGR, but only 55 lambs and seven yearlings/100 adult ewes for ESR. Part of the difference could be explained by an increase in the trade of lambs as pets, although the number of predators may also have increased. Schaller & Mirza (1974) and Schaller (1977) reported that leopard and wolf were absent. During our study, leopard and wolf accounted for 24% of the known cases of predation. Over the last 50 years, however, the human population in the Salt Range has increased by a factor of 2.8 (Government of Pakistan 2000), greatly increasing the pressure to exploit natural resources in wild areas and accelerating the rate of habitat deterioration.

Estimated average survival to yearling age was about 12% in ESR and 38% in KGR. Gaillard et al. (2000) reported 27-45% post-weaning mortality for bighorn sheep *Ovis canadensis* and mean annual mortality of 11% for female bovines. Assuming a 10% annual mortality for adult ewes (Loison et al. 1999) and an equal sex ratio among yearlings, the recruitment of only four female yearlings a year appears insufficient to sustain the urial population at ESR. Consequently, the population will continue to decline if the existing levels of mortality and poaching are maintained. The 26 yearlings per 100 ewes seen in KGR are possibly enough to maintain numbers, assuming that 13 of them are females, although more information is required on other vital rates, particularly adult female survival.

Outside the KGR, in most of the Salt Range, most mature males were shot. Interviews with local people

revealed that urial poaching occurs with the tacit accord of wildlife officials. In ESR, 80% of males were aged 2-4 years and no ram > 6 years old was observed, suggesting a high level of illegal hunting.

In 1999, the government of Punjab granted permission to keep pet Punjab urial for an annual license fee of 50 US \$ per urial. Subsequently, the removal of lambs that are to be kept as pets appears to have increased. A supply chain of poachers and merchants has been established from the Salt Range to the major cities. The illegal trade in lambs is fuelled by their high price, ranging within 6,000-12,000 rupees or about 100-200 US \$. To place these prices in a local perspective, an unskilled labourer may earn as little as 80 rupees a day while low-ranking conservation officers are often paid < 6,000 rupees a month.

Because of the lucrative pet trade, some urial owners also interbreed them with domestic sheep, leading to a risk of genetic pollution if any hybrids were to escape. Despite the urial's protected status under the Punjab Wildlife Act of 1974, it enjoys little real protection outside the KGR. Commercial use of wildlife is a major threat to conservation (Geist 1994), particularly if it is culturally and politically sanctioned and the harvest is uncontrolled, as appears to be the case for Punjab urial.

The community-managed KGR currently constitutes the last remaining stronghold for wild ungulates in the Punjab Province, because it maintains sections of prime urial habitat with low human penetration. Most of the remaining range of this species is under continuously increasing human pressure. A reduction in poaching, increased law enforcement and a broader conservation awareness of the local people are urgently required. If strong measures are not taken, Punjab urial outside the KGR may soon become extinct.

Management recommendations

Existing legislation provides no means of community participation in wildlife management. Community participation in ESR should increase local interest in urial management. The practice of keeping urial as pets should be banned, and strict enforcement is required to curtail both the pet trade and cross-breeding of urial with domestic sheep.

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References

- Aleem, A. 1977: Punjab urial in Chak Jabbi area - Kala Chitta Range, Pakistan. - *Journal of Forestry* 27: 130-138.
- Awan, G.A. 2001: Pet trade threatened endangered urial. - *Caprinae, Newsletter. IUCN, Caprinae Specialist Group (CSG), Canada*, 9 pp.
- Awan, G.A., Ahmad, T. & Festa-Bianchet, M. 2004: Current status of Punjab urial. - *Islamabad Journal of Science* 14(1): 1-14.
- Caughley, G. 1977: Analysis of vertebrate populations. - John Wiley and Sons, New York, 234 pp.
- Clutton-Brock, T.H., Guinness, F.E. & Coulson, T. 1982: Red deer: behavior and ecology of two sexes. - University of Chicago Press, Chicago and London, 378 pp.
- Edge, W.D. & Olson-Edge, S.L. 1990: Population characteristics and group composition of *Capra aegagrus* in Kirthar National Park, Pakistan. - *Journal of Mammalogy* 71: 156-160.
- Festa-Bianchet, M. 1992: Use of age ratios to predict bighorn sheep population dynamics. - In: Emmerich, J. & Hepworth, W.G. (Eds.); Proceedings of the eighth biennial symposium Northern Wild Sheep and Goat Council 8: 227-236.
- Gaillard, J-M., Festa-Bianchet, M. & Yoccoz, N.G. 1998: Population dynamics of large herbivores: variable recruitment with constant adult survival. - *Trends in Ecology and Evolution* 13: 58-63.
- Gaillard, J-M., Festa-Bianchet, M., Yoccoz, N.G., Loison, A. & Toigo, C. 2000: Temporal variation in fitness components and population dynamics of large herbivores. - *Annual Review of Ecology and Systematics* 31: 367-393.
- Gaillard, J-M. & Yoccoz, N.G. 2003: Temporal variation in survival of mammals: a case of environmental canalization? - *Ecology* 84: 3294-3306.
- Geist, V. 1971: Mountain sheep: A study in behaviour and evolution. - Chicago University of Chicago press, 383 pp.
- Geist, V. 1994: Wildlife conservation as wealth. - *Nature* 368: 491-492.
- Government of Pakistan 2000: 1998 District census reports of Jhelum, Chakwal, Khushab and Mianwali. - Population census organization statistics division, Islamabad, 380 pp.
- Jarman, P.J. 1974: The social organization of antelope in relation to their ecology. - *Behaviour* 48: 215-267.
- Jerdon, T. 1874: The mammals of India. - London, John Weldon, 335 pp.
- Jorgenson, J.T. 1992: Seasonal changes in lamb: ewe ratios. - In: Emmerich, J. & Hepworth, W.G. (Eds.); Proceedings of the eighth biennial symposium Northern Wild Sheep and Goat Council 8: 219-226.
- Jorgenson, J.T., Festa-Bianchet, M., Gaillard, J-M. & Wishart, W. D. 1997: Effects of age, sex, disease and density on survival of bighorn sheep. - *Ecology* 78: 1019-1032.
- Loison, A., Festa-Bianchet, M., Gaillard, J-M., Jorgenson, J.T. & Jullien, J-M. 1999: Age-specific survival in five populations of ungulates: evidence of senescence. - *Ecology* 80(8): 2539-2554.
- Mirza, Z.B., Aslam, M., Asghar, M. & Mehal, A.Q. 1980: Distribution, status, habitat and food of the urial in the Punjab. - *Journal of Bombay Natural History Society* 76(3): 423-430.
- Nichols, L. & Bunnell, F.L. 1999: Natural history of Thinhorn sheep. - In: Valdez, R. & Krausman, P.R. (Eds.); Mountain Sheep of North America. The University of Arizona Press, pp. 23-77.
- Portier, C., Festa-Bianchet, M., Gaillard, J-M., Jorgenson, J. T. & Yoccoz, N.G. 1998: Effects of density and weather on survival of bighorn sheep lambs (*Ovis canadensis*). - *Journal of Zoology* 245: 271-278.
- Prater, S. 1965: The book of Indian animals. - Bombay Natural History Society, Bombay, 323 pp.
- Risenhoover, K.L. & Bailey, J.A. 1985: Foraging ecology of mountain sheep: implications for habitat management. - *Journal of Wildlife Management* 49: 797-804.
- Roberts, T.J. 1991: The birds of Pakistan. Volume 1. - Oxford University Press Karachi, 598 pp.
- Schaller, G.B. 1977: Mountain Monarchs-Wild Sheep and Goats of the Himalaya. - University of Chicago Press, 425 pp.
- Schaller, G.B. 1980: Stones of silence. - The Viking Press, New York, 292 pp.
- Schaller, G.B. & Mirza, Z.B. 1974: On the behaviour of Punjab urial (*Ovis orientalis punjabiensis*). - In: Geist, V. & Walther, F. (Eds.); The behaviour of ungulates and its relation to management, IUCN publications, pp. 306-323.