ANIMAL BEHAVIOUR, 2004, 67, 1163–1165
doi:10.1016/j.anbehav.2003.07.009

Available online at www.sciencedirect.com
SCIENCE DIRECT®

COMMENTARY

Effect of chemical immobilization on social status of bighorn rams

FANIE PELLETIER*, JOHN T. HOGG† & MARCO FESTA-BIANCHET*
*Département de biologie, Université de Sherbrooke
†Montana Conservation Science Institute

(Received 3 March 2003; initial acceptance 5 May 2003; final acceptance 23 July 2003; MS. number: AS-1284)

Management programmes and research projects often require handling and marking of wild animals (Jorgenson et al. 1997; Gaillard et al. 2000). The consequences of capture on social behaviour, however, are often unknown, because they can only be determined through intensive monitoring of captured and control individuals (Berger & Kock 1988). Although a few studies have reported life history effects of chemical immobilization, for example, on female mountain goats, *Oreamnos americanus* (Côté et al. 1998), female moose, *Alces alces* (Ballard & Tobey 1981) and polar bears, *Ursus maritimus* (Ramsay & Stirling 1986), to our knowledge, no study has examined the impact of chemical immobilization on the behaviour and social organization of wild animals. Here, we report the effects of chemical immobilization on intrasexual combat and social dominance among bighorn sheep rams, *Ovis canadensis*.

Methods

Study area

The Sheep River Provincial Park is located in southwestern Alberta, Canada (50°N, 114°W) at an elevation of 1420–1740 m. The landscape includes cliffs and canyons used by sheep as escape terrain. The vegetation is characterized by open meadows and aspen, *Populus tremuloides*, forests. The population of bighorn sheep wintering in this area has been studied since 1981 (Festa-Bianchet 1986; Hogg & Forbes 1997; Hogg 2000). More than 95% of the sheep are marked with eartags.

Captures

For the purposes of the long-term study, we captured most bighorn sheep once, at 4–6 months of age and applied a unique eartag (All Flex) combination. In 2001 and 2002, respectively, we recaptured two and three adult rams aged 4–8 years, previously captured as lambs, using a dart gun (Paxarms Mk 21, Paxarms Co., Timaru, New Zealand) and a 3-ml syringe dart (Festa-Bianchet & Jorgenson 1985). Free-ranging sheep received an intramuscular injection of a mixture of xylazine hydrogen chloride (Rompun) and ketamine hydrogen chloride (Inoketam; Table 1). These rams were fitted with geographical positioning system collars (Telonics, Gen III TGW-3500 configuration) to monitor their movements before and during the rut (Hogg 2000). When manipulations were finished and most of the ketamine effect had gone (about 45 min), we reversed the effects of xylazine by idazoxan (RX 781094; Jorgenson et al. 1990).

Dominance

We located most males every day during the pre-rut and the rut (mid-September to mid-December), in both 2001 and 2002. Observations were made with binoculars and spotting scopes (15–45×). We recorded group size and composition, and all agonistic encounters between rams. We used six agonistic behaviours to assess male rank: front kick, rubbing, homosexual mount, clash, butt and non-contact displacement from bedding sites or foraging positions (Geist 1971; Hogg 1987). When a single encounter between two individuals involved repetition of the same behaviour (e.g. repeated front kicks), it was recorded as a single interaction.

We constructed dominance matrices using Matman 1.0 (Matrix Manipulation and Analysis, Noldus; de Vries et al. 1993) for 18 rams, 4 years of age and older, in both years (Table 2). Matman tests the linearity (h') of a social hierarchy (with $0 \leq h' \leq 1$ and $h' = 1$ being a perfectly linear hierarchy) based on the Landau index (Landau 1951) using a randomization process with 10 000 randomizations (de Vries 1995, 1998). Ranks assignments minimized first the number and then the strength of inconsistencies (de Vries 1998). Only males that interacted with at least

Correspondence: F. Pelletier, Département de biologie, Université de Sherbrooke, 2500 boulevard de l'université, Sherbrooke, PQ J1K 2R1, Canada (email: fanie.pelletier@usherbrooke.ca). J. T. Hogg, Montana Conservation Science Institute, 5200 Upper Miller Creek Road, Missoula, MT 59803, U.S.A.

0003–3472/03/$30.00/0
© 2004 The Association for the Study of Animal Behaviour. Published by Elsevier Ltd. All rights reserved.

Table 1. Bighorn rams captured in 2001 and 2002, Sheep River Provincial Park, Alberta, Canada

Ram ID	Age	Capture date	Weight (kg)	Xylazine dose (mg)	Ketamine dose (mg)	Idazoxan dose (mg)
269	6	29 October 2001	127.0	250	250	1.0
723	4	30 October 2001	—	250	250	0.9
772	8	18 October 2002	137.7	270	430	0.9
271	6	18 October 2002	129.0	270	430	1.0
280	5	19 October 2002	135.8	270	290	0.8

five other males were included in the matrix. Matrices were built in 2001 and 2002. Each year, two matrices were built: one based upon interactions seen before the capture of the rams (rams 269 and 723 were captured in 2001; rams 271, 772 and 280 in 2002) and one based upon interactions recorded after their capture (Table 2).

Results

The administration of idazoxan leads to a very rapid and apparently full recovery from the effects of xylazine (Jorgenson et al. 1990). Ketamine has no specific antagonist. However, reversal of xylazine appeared to proceed normally 45 min or more postinjection when most of the ketamine should have cleared (I. Ross, personal communication). All five captured rams appeared to regain full motor coordination within a few minutes of being released, and did not show any abnormal behaviour that could be detected by observers. Of the five adult males captured in 2001 and 2002, three (ram 269 in 2001 and rams 772 and 271 in 2002) were involved in one or more dominance fights within 18 h, 22 h and 7 h of release. Fights lasted for more than 1 h and involved, in all cases, more than two males. All three collared males lost these fights, and their rank decreased after their captures. In 2001, ram 269 lost two fights the day after capture, one to a ram that ranked one place below him and one to a ram that ranked three places below him. Ram 723 was not seen to fight after his capture; before capture, he was observed to have agonistic encounters with only four other rams. Therefore the estimated rank position of ram 723 before his capture is approximate. In 2001 the value of the h' was only 0.28 ($P_r = 0.075$) due to lack of observations for many dyads (Table 2). In 2002, ram 772 was the third-ranking male prior to capture (Table 3). The day after being caught and released, he fought for at least 4 h with three subordinates. The fight started when ram 772 rejoined the group after being captured. After 30 min of fighting, ram 772 attempted to leave the group but the three subordinate rams followed him over 8 km. That night, we found ram 772 alone, whereas all the other males had returned to the group. Ram 772 rejoined the group 15 days later and became the seventh-ranking male in the group (Table 3). Similarly, when ram 271 joined the group, the afternoon after his capture, he was involved in a 3-h-long fight with three subordinate males. Again, all subordinates won and 271 dropped from the rank 6 to the rank 12 (Table 3). Ram 280 also dropped from rank 11 to rank 17 (Table 3), having lost agonistic encounters with two low-ranking rams after its capture. Two other rams that ranked below ram 280 before his capture, rose several ranks above him after his capture because they had defeated ram 271 during his absence. All changes in rank following chemical immobilization remained stable over the pre-rut (approximately 25 days). The recaptured males were not observed to challenge other rams in an attempt to regain their former position.

Dominance fights increased in frequency after the captures of adult rams. In 2001, we saw no dominance fights during 216 h of observations from 20 September to 28 October. Within 24 h of recapturing rams 269 and 723, we recorded two fights: one involving ram 269 with two other rams and one between two other rams. In 2002, we observed bighorns for 192 h from 20 September to 17 October, and saw one dominance fight. On 18 October, rams 772 and 271 were recaptured, and within 24 h, we recorded two dominance fights: one involving ram 772 and three other males and one involving ram 271 and three other rams.

Table 2. Characteristics of dominance matrices for agonistic encounters among adult bighorn rams before and after some were captured, in 2001 and 2002, at Sheep River Provincial Park, Alberta, Canada

Matrix	Linearity index h'	Linearity test P	Number of encounters	Number of rams
2001 before capture	0.28	0.075	142	18
2001 after capture	0.40	0.003	311	18
2002 before capture	0.52	<0.001	260	18
2002 after capture	0.37	0.008	357	18

Two rams were captured in 2001 and three were captured in 2002.

Table 3. Pre-rut rank before and after the capture for five bighorn rams that were 4 years of age or older in 2001 and 2002, at Sheep River Provincial Park, Alberta, Canada

Ram ID	Rank before capture	Rank after capture	Absolute changes in rank*
269	9	10	−1
723	15	14	+1
772	3	7	−4
271	6	12	−6
280	11	17	−6

*Negative values indicate the number of positions lost by a ram after his capture and positive values indicate the number of positions gained.

Discussion

Chemical immobilization with xylazine and ketamine appears to negatively affect the fighting ability of bighorn rams despite their apparent full recovery. We were able to detect increases in the frequency of dominance fights and changes in rank because we monitored the behaviour of marked individuals. Subordinate rams appeared to detect some subtle 'vulnerability' in captured rams just after release, although it was unclear which rams initiated the encounters. We suggest that the drop in rank was unlikely to be a mechanical or visual effect of the radiocollar, because the collars remained on the rams for several months yet fights were more frequent only within 18–24 h of release. Nevertheless, our observations do not allow us to unequivocally conclude that the change in rank was due to chemical immobilization rather than to the collars. The fact that all captured rams that fought lost their fights suggests physical weakness and/or impaired mental state, possibly leading to a lower 'threshold' for giving up in a fight. Consortships (Hogg 1987) and mating success (Hogg & Forbes 1997) increase with increasing dominance rank, particularly among higher ranks. Therefore, chemical immobilization probably had a negative consequence on ram reproductive success in at least some cases.

Two rams (280 and 723) that were observed interacting with some of the rams that dominated them after they were captured were not seen interacting before their capture. Consequently, we could not establish with certainty that some dominance relationships were indeed reversed after the capture. For the three other rams (269, 772 and 271), the reversals in dominance rank were certain because they lost fights against rams that they had dominated before their capture.

Our results suggest that fighting skills and/or mental attributes are an important determinant for the outcome of fights for this species, and that social rank is not simply determined by body mass or horn size. Handling procedures that affect fighting ability may have undesired effects for social animals than normally have stable dominance hierarchies. A social organization based on dominance fights exists in other ungulates (e.g. *Cervus elaphus*, *Dama dama*). Chemical immobilization with xylazine and ketamine (and possibly other drugs) just before the rut may result in similar undesired effects for those species. It is our responsibility to minimize the impacts of research and management procedures. Therefore, capture plans for adult male ungulates should take into account the possible effects of drugs on social behaviour and on reproductive success. If negative impacts are likely to occur, captures should be avoided at times that are known to be crucial for the establishment of social relationships (e.g. in the few weeks preceding the rut) or otherwise modified to eliminate adverse effects.

We gratefully acknowledge the financial support of the Natural Sciences and Engineering Research Council of Canada (scholarships to F.P. and operating grant to M.F.-B.), the Challenge Grants in Biodiversity program (University of Alberta, grant to F.P.), Eppley Foundation for Research, the Charles Engelhard Foundation (grants to J.T.H.) and the Université de Sherbrooke. We thank Ian Ross for capturing the rams and Y. Gendreau, É. Viollet, K. A. Page and C. Feder for field assistance. We are grateful to the Kananaskis Field Stations (University of Calgary) for logistic support. We also thank Han de Vries and one anonymous referee for helpful comments on the manuscript.

References

Ballard, W. B. & Tobey, R. W. 1981. Decreased calf production of moose immobilized with anectine administered from helicopter. *Wildlife Society Bulletin*, **9**, 207–209.

Berger, J. & Kock, M. D. 1988. Overwinter survival of carfentanil-immobilized male bison. *Journal of Wildlife Diseases*, **24**, 555–556.

Côté, S. D., Festa-Bianchet, M. & Fournier, F. 1998. Life-history effects of chemical immobilization and radiocollars on mountain goats. *Journal of Wildlife Management*, **62**, 745–752.

Festa-Bianchet, M. 1986. Seasonal dispersion of overlapping mountain sheep ewe groups. *Journal of Wildlife Management*, **50**, 325–330.

Festa-Bianchet, M. & Jorgenson, J. T. 1985. Use of xylazine and ketamine to immobilize bighorn sheep in Alberta. *Journal of Wildlife Management*, **49**, 162–165.

Gaillard, J.-M., Festa-Bianchet, M., Yoccoz, N. G., Loison, A. & Toïgo, C. 2000. Temporal variation in fitness components and population dynamics of large herbivores. *Annual Review of Ecology and Systematics*, **31**, 367–393.

Geist, V. 1971. *Mountain Sheep*. Chicago: University of Chicago Press.

Hogg, J. T. 1987. Intrasexual competition and mate choice in Rocky Mountain bighorn sheep. *Ethology*, **75**, 119–144.

Hogg, J. T. 2000. Mating systems and conservation at large spatial scales. In: *Vertebrate Mating Systems* (Ed. by M. Apollonio, M. Festa-Bianchet & D. Mainardi), pp. 214–252. Singapore: World Scientific.

Hogg, J. T. & Forbes, S. H. 1997. Mating in bighorn sheep: frequent male reproduction via a high-risk 'unconventional' tactic. *Behavioral Ecology and Sociobiology*, **41**, 33–48.

Jorgenson, J. T., Samson, J. & Festa-Bianchet, M. 1990. Field immobilization of bighorn sheep with xylazine hydrochloride and antagonism with idazoxan. *Journal of Wildlife Diseases*, **26**, 522–527.

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.

Landau, H. G. 1951. On dominance relations and the structure of animal societies: I. Effect of inherent characteristics. *Bulletin of Mathematical Biophysics*, **13**, 1–19.

Ramsay, M. A. & Stirling, I. 1986. Long-term effects of drugging and handling free-ranging polar bears. *Journal of Wildlife Management*, **50**, 619–626.

de Vries, H. 1995. An improved test of linearity in dominance hierarchies containing unknown or tied relationships. *Animal Behaviour*, **50**, 1375–1389.

de Vries, H. 1998. Finding a dominance order most consistent with a linear hierarchy: a new procedure and review. *Animal Behaviour*, **55**, 827–843.

de Vries, H., Netto, W. J. & Hanegraaf, P. L. H. 1993. Matman: a program for the analysis of sociometric matrices and behavioural transition matrices. *Behaviour*, **125**, 157–175.