Cougar predation on bighorn sheep in southwestern Alberta during winter

P. Ian Ross, Martin G. Jalkotzy, and Marco Festa-Bianchet

Abstract: Predation by cougars (*Puma concolor*) upon bighorn sheep (*Ovis canadensis*) was studied in southwestern Alberta during winters from 1985–1986 to 1993–1994. We examined 320 kills and found that ungulates provided >99% of the biomass consumed by cougars in November–April. All ungulate species found within the study area were taken by cougars. Predation on bighorn sheep varied greatly from year to year; cougars were known to kill 0–13% of the November sheep population, and 0–57% of over-winter sheep mortality consisted of known cougar kills. Of 29 bighorns killed by cougars, 13 were lambs. The remainder ranged in age from 1 to 17 years and included 9 ewes and 7 rams. Cougar predation on bighorn sheep appears to be largely an individual, learned behaviour; most cougars rarely killed sheep, but some preyed heavily upon them. One female killed 9% of the population and 26% of the lambs over a single winter. For mountain-dwelling ungulates that occur in small groups, the presence of one or a few individual specialist predators may strongly and unpredictably influence demography and behaviour.

Résumé : Nous avons mesuré la prédation exercée par les Cougars (*Puma concolor*) sur les Mouflons d'Amérique (*Ovis canadensis*) dans le sud-ouest de l'Alberta, au cours des hivers de 1985–1986 à 1993–1994. Nous avons examiné 320 proies tuées et constaté que les ongulés constituaient plus de 99% de la biomasse consommée par les cougars durant la période novembre–avril. Toutes les espèces d'ongulés présentes dans la zone d'étude ont servi de proies à des cougars. La prédation exercée sur les mouflons variait considérablement d'une année à l'autre; les cougars ont éliminé 0–13% de la population de mouflons en novembre et ont aussi été responsables de 0–57% de la mortalité en hiver. De 29 mouflons tués par des cougars, 13 étaient des agneaux. Les autres victimes étaient âgées de 1 à 17 ans et nous y avons dénombré 9 brebis et 7 boucs. La prédation sur les mouflons semble relever d'un comportement acquis, surtout individuel; la plupart des cougars tuent rarement des mouflons, mais certains individus les chassent plus particulièrement. Une femelle a tué 9% de la population et 26% des agneaux en un seul hiver. La présence d'un ou de quelques individus prédateurs spécialistes peut influencer fortement et de façon aléatoire la démographie et le comportement des ongulés de montagne qui vivent en petits groupes.
[Traduit par la Rédaction]

Introduction

Many bighorn sheep (*Ovis canadensis*) winter in isolated groups of fewer than 200 animals. They are therefore susceptible to stochastic influences, and possibly to intense predation pressure. The development of antipredator tactics such as gregariousness and traditional seasonal range-use patterns (Festa-Bianchet 1991) is likely a response to this vulnerability. However, gregariousness and tradition appear to be adaptations to avoid predation by coursing predators such as wolves (*Canis lupus*). Stalking predators like cougars (*Puma concolor*) may be able to circumvent these strategies, and predation losses in some herds may be high if individual cougars specialize in preying upon bighorns.

Harrison and Hebert (1988) reported selective predation by cougars on bighorn rams in British Columbia. Recent studies of some desert bighorn sheep (*O. c. nelsoni*) herds have indicated that cougar predation may strongly impact those populations (Wehausen 1996). However, the cryptic nature of cougar behaviour has, until recently, made it difficult to understand the relationships between cougars and their prey. We studied winter food habits of cougars in southwestern Alberta to determine the effects of cougar predation on a population of Rocky Mountain bighorn sheep.

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Materials and methods

Study area and study animals

The study area (Ross and Jalkotzy 1992) encompassed 780 km^2 in the foothills and Front Ranges of the Rocky Mountains in southwestern Alberta, and was centered on the Sheep River Wildlife Sanctuary (50°39'N, 114°38'W). A resident herd of bighorn sheep has been intensively studied there since 1981 (Festa-Bianchet 1986). Other ungulates include mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), elk (*Cervus elaphus*), and moose (*Alces alces*). Coyotes (*Canis latrans*) were the only other predator known to kill sheep. Between October and April, most sheep activity was confined to 6 km^2 encompassing two complexes of forage and escape terrain and 7 km of river canyon that linked them.

Cougar food habits

Winter food habits of cougars were studied between November–December and April from 1985–1986 to 1993–1994 by capturing

Table 1. Bighorn sheep killed by cougars in the Sheep River area, Alberta, from 1985–1986 to 1993–1994.

	Sheep class						
	Adult		Yearling	Lamb			
Cougar class	Female	Male	Male	Female	Male	Unknown	Total
Adult female	8	5	1	5	3	3	25
Subadult female					1		1
Adult male		1		1			2
Unknown class	1						1
Total	9	6	1	6	4	3	29

Table 2. Relative importance of cougar predation to the bighorn sheep population at Sheep River, based on numbers of known cougar kills.

	Sheep population				Over-winter percent decline	
Year	December	March	Over-winter sheep losses	Known cougar kills	All causes	Cougar predation
1985–1986	138	107	31	1	22	1
1986–1987	124	99	25	0	20	0
1987–1988	112	99	13	0	12	0
1988–1989	128	109	19	0	15	0
1989–1990	127	118	9	2	7	2
1990–1991	124	118	6	1	5	1
1991–1992	128	121	7	1	5	1
1992–1993	158	121	37	8	23	5
1993–1994	126	97	29	16	23	13

87 cougars and radio-collaring 60. Additional kills (n = 56) were located opportunistically during cougar-capture efforts from 1981–1982 to 1984–1985. Most cougars used home ranges that did not overlap sheep range, but we monitored 8 adult females and 3 adult males that did use portions of the sheep winter range. From 1985–1986 to 1988–1989, cougar kills (n = 61) were found by searching areas of concentrated activity (>1 day) of radio-collared cougars. Searching was facilitated by nearly complete snow cover during this period. This technique was biased towards finding carcasses of large (>15 kg) prey, as such carcasses would take longer to consume. However, since most ungulates required >1 day to consume, we presume that our ability to detect different ungulate species and age-classes was unbiased. The exception was lambs and fawns, which could be consumed by a family group in <1 day. Therefore, this cohort may be underestimated in our analyses. From 1989–1990 to 1993–1994, cougar kills (n = 259) were found by intensively searching all radiolocations (>1/day per cougar) of 3–7 adult and independent subadult cougars. When conditions permitted, we continuously snow-tracked cougars between radiolocations to search for kills. Cougars were considered the cause of death on the basis of necropsy results or when field sign indicated cougar predation. Ungulates killed by cougars normally showed extensive subcutaneous haemorrhage on the ventral or dorsal surface of the neck in conjunction with a collapsed trachea or fractured vertebral column. Winter was defined as the period between late November and early to mid-April during which we systematically tracked cougars.

Bighorn sheep census and measurements

The sheep population has been censused by ground survey several times annually since 1981, including early and late winter each year. Precise classified counts were possible because almost all sheep were marked. In early December from 1989 to 1993, ≥95% of the lambs, ≥98% of the ewes, and ≥67% of the rams were marked. All unmarked rams were individually recognizable (J.T. Hogg, Missoula, Mont., personal communication).

Live masses of sheep in winter were estimated to be as follows: lambs 32 kg, yearling rams and adult ewes 67 kg, 1/2-curl rams 80 kg, and 4/5-curl rams 120 kg (Festa-Bianchet et al. 1996). Edible biomass available to cougars at each kill was calculated by multiplying the appropriate live mass by a utilization factor of 0.79, determined in captive feeding trials (Ackerman 1982), then subtracting any estimated losses to scavengers. Scavengers were documented at <10% of cougar kills while the cat was still in attendance, and never accounted for more than an estimated loss of 2 kg of edible tissue.

Bighorn lambs were captured with tranquilizing drugs each year between late August and early December (Jorgenson et al. 1990). Chest girth was measured and adjusted to 6 October (the average date of lamb captures) with sex-specific linear regressions of chest girth on capture date, using data from all years. The adjusted chest girths of lambs killed by cougars were compared by means of t tests with those of lambs that survived to 1 year, using only data from years in which at least one lamb known to be killed by cougars was measured. We evaluated selection among classes of bighorn prey using a χ^2 goodness-of-fit test and the Bonferroni Z statistic (Neu et al. 1974; Alldredge and Ratti 1992) to test the null hypothesis that cougars killed bighorns of different age–sex classes in proportion to their availability within the population. For all tests, significance was established at α = 0.05.

Table 3. Winter kills (numbers and biomass consumed) by female cougars on bighorn sheep range at Sheep River, Alberta, 1985–1986 to 1993–1994.

Cougar ID No.	Bighorn sheep		Mule deer		Elk		Moose		Other		Total	
	n	Biomass (kg)	*n*	Biomass (kg)	*n*	Biomass (kg)	*n*	Biomass (kg)	*n*	Biomass (kg)	*n*	Biomass (kg)
F17	0	0	12	454	4	731	5	751	0	0	21	1936
F25	17	713	19	782	0	0	0	0	0	0	36	1495
F54	1	25	5	170	0	0	0	0	0	0	6	195
F69	0	0	19	723	7	1086	2	632	3[a]	71	31	2512
F84	5	247	28	1177	4	553	4	672	0	0	41	2649

[a]Includes 1 coyote, 1 snowshoe hare (*Lepus americanus*), and 1 white-tailed deer.

Table 4. Winter kills (numbers and biomass consumed) by female cougar F25 at Sheep River, Alberta, 1989–1990 to 1993–1994.

Year	Bighorn sheep		Mule deer	
	n	Biomass (kg)	*n*	Biomass (kg)
1990	0	0	6	356
1991	1	71	5	241
1992	1	32	2	111
1993	4	211	3	241
1994	11	494	2	71

Results

Prey species selectivity

Between 1985–1986 and 1993–1994, we examined 320 cougar kills. Twenty-nine bighorn sheep kills were found (Table 1). By comparison, we found 22 elk, 183 mule deer, 36 moose, and 19 white-tailed deer that had been killed by cougars. There was no relationship between the number of bighorn sheep present in December and the number of known cougar kills in 1985–1994 (Spearman's $r = 0.4$, $P = 0.26$; Table 2). During winters 1981–1982 through 1984–1985, we opportunistically located an additional 56 cougar kills; only 1 of these was a bighorn sheep.

Individual cougar selectivity

Of cougars with access to bighorn sheep range, not all preyed equally on sheep (Table 3). Of 5 females that we monitored intensively, 2 never killed a sheep and a third killed only 1. One female, F25, preyed heavily on bighorn sheep, but not consistently over the study period (Table 4). During 1993–1994, she alone killed 8.7% ($n = 11$) of the early-winter sheep population and 26.1% ($n = 6$) of the lambs.

Selection for classes of bighorn sheep

Of the 29 sheep killed by cougars, 13 (45%) were lambs and 16 were ≥1 year old (Table 1). Lambs constituted an annual average of 22.2% of the early-winter population (range 17.5–26.6%) between 1989–1990 and 1993–1994. Adult ewes represented 43.6% of the population and 31% of the kills, adult rams represented 23.8% of the population and 21% of the kills, and yearlings of both sexes constituted 10.4% of the population and 3.4% of the cougar kills. Cougars did not kill bighorn sheep of all classes according to their relative availability ($\chi^2 = 10.985$; $P < 0.05$, 3 df). The 95% confidence interval around the predicted occurrence of lambs in the population is $0.262 \leq P \leq 0.671$; therefore, cougars selected bighorn lambs. Other classes of sheep appeared in the kill sample in proportions predicted by the Bonferroni Z statistic.

More than one-third of cougar-killed bighorn sheep had apparent or possible disabilities. Two lambs had sustained debilitating injuries prior to their death, a third was alone several kilometres from other sheep when killed, and a fourth was a very late-born runt. Of the 9 adult ewes killed, 2 were >16 years old. A third ewe had been injured in a previous predation attempt. Another ewe had an opaque eye surface and may have been blind on that side. Three of the 6 adult rams were observed with a severe limp prior to their death.

Cougars did not, however, select small lambs. Chest girths adjusted to 6 October were similar for male lambs killed by cougars ($n = 6$, $\bar{x} = 75.6$ cm, SD = 3.75 cm) and for male lambs that survived to the following May ($n = 44$, $\bar{x} = 76.6$ cm, SD = 4.77 cm) ($t_{48} = 0.518$, $P = 0.6$). For female lambs, there were no differences in chest girth between those killed by cougars ($n = 7$, $\bar{x} = 73.0$ cm, SD = 2.10 cm) and those that survived to the following May ($n = 48$, $\bar{x} = 72.7$ cm, SD = 4.71 cm) ($t_{53} = 0.17$, $P = 0.9$).

Effects of cougar predation on bighorn sheep

Over-winter sheep losses due to all causes ranged from 5 to 23% each year (Table 2). The high losses in 1985–1987 were due to a pneumonia epizootic (Festa-Bianchet 1988). Between 1990 and 1994, the March population declined by 18% (Table 2). All of this decline occurred during the last winter, when known cougar predation accounted for 13% of the November sheep population and 57% of over-winter losses. The sheep population continued to decline slowly over the following 2 years (to 95 by March 1995 and 93 in 1996), possibly because of continued cougar predation. However, the rate of decline had slowed, concurrently with the death of cougar F25 in December 1994.

Discussion

Effects of cougar predation on bighorn sheep

The known annual cougar predation on bighorn sheep was highly variable during our study, ranging from 0 to 13% of the November population, and followed no predictable pattern. It seems unlikely that variability in cougar predation on bighorn sheep could be explained by changes in sheep density or the availability of alternative prey. There was no relation-

ship between sheep numbers and cougar predation. Given that sheep are highly gregarious and that a cougar would normally kill only one sheep when attacking a group, minor differences in total sheep numbers should not affect cougar predation, which would be more likely to be influenced by changes in group size, habitat-use patterns, or alertness levels. We have no accurate data on the availability of alternative prey, but our impression was that numbers of other ungulates did not decrease as cougar predation on sheep increased. If alternative prey were scarce, we would have expected all cougars to select bighorn sheep, but most of the sheep predation was by a single cougar. Wehausen (1996) recently reported that increases in cougar predation apparently led to steep declines in numbers of bighorn sheep in some California herds, but in his study areas there were fewer alternative prey species. Wehausen (1996) also recorded wide year-to-year differences in cougar predation on bighorn sheep.

Effects of individual cougar behaviour

Cougars employ a stalking approach to attack prey. Their most vulnerable prey, therefore, should be solitary animals in habitats that provide stalking cover yet are not dangerous areas in which to engage in a struggle. Because bighorn sheep are gregarious and usually found in open habitats, they may be less vulnerable to cougar predation than other ungulate species. A cougar that successfully hunts bighorn sheep must be able to stalk a group of ungulates in relatively open terrain. Predation in the precipitous terrain used by bighorn sheep is dangerous to the predator; one radio-collared cougar in our study fell to his death while attacking a bighorn sheep (Ross et al. 1995).

Female cougar F25 appeared to learn to hunt bighorn sheep in her later years (Table 4), even though her home range overlapped the sheep winter range for the >10 years that she was radio-monitored. In 1993–1994 she killed 11 sheep and 2 mule deer and her movements were essentially confined to the sheep winter range.

Selectivity for different classes of bighorn sheep

Harrison and Hebert (1988) found strong selection of bighorn rams by cougars in central British Columbia. Most rams in their study were killed in late fall – winter, when they were presumably weakened from rutting activities. We observed no apparent selection of mature rams in southwestern Alberta; only 3 (10%) of the sheep kills we found were of rams >3 years of age. Conversely, we found a preponderance of lambs in our kill sample. The home range used by cougar F25, responsible for most of the sheep predation during our study, did not overlap the area used by most of the adult rams during winter, therefore she had little opportunity to prey upon rams. We suggest that prey-class vulnerability to cougar predation, at least for bighorn sheep, is largely a function of the behaviour of individual cougars. Individual predator behaviour may be more important in determining vulnerability to predation than the anatomical or physiological characteristics of healthy prey. Disabilities may, however, predispose individual bighorn sheep to cougar predation. Presumably all lambs were relatively vulnerable because of their small body size, limited strength, and possibly reduced vigilance. Of those killed by cougars, 4 lambs (29%), 4 ewes (44%), and 3 rams (50%) had further anatomical or behavioural disabilities just prior to their death.

Management implications

The development of ecological theory has commonly failed to recognize the concept that individuals within populations vary, particularly in resource partitioning (Łomnicki 1988). As a result, many wildlife management strategies have similarly presumed that the functional ecological unit is the species, population, or group. Our study points to the significance of the role of individuals in predator–prey systems.

Successful cougar predation on bighorn sheep appears to be an individual skill that is learned over time. A few individual predators that specialize on a single prey type could have a strong effect upon the population dynamics of ungulates that live in small isolated groups, such as bighorn sheep or mountain goats (*Oreamnos americanus*; Festa-Bianchet et al. 1994). In California, cougar predation has led to drastic declines of some sheep populations (Wehausen 1996). We suggest that strategies for managing mountain ungulates that winter in herds of less than 200 individuals should incorporate the expectation that predation rates may vary widely and unpredictably from one year to another. Furthermore, we expect variations in predation rate to be very herd-specific, as they may depend not upon changes in either the prey or the predator population, but mostly upon learned behaviours of individual predators.

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