Note

The Effect of Radio-Collar Weight on Survival of Migratory Caribou

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ABSTRACT Radio transmitters are widely used in wildlife management; therefore, it is essential to assess any effects that they may have on animal survival. We compared the survival of 269 randomly selected adult migratory caribou (*Rangifer tarandus*) fitted with either light very high frequency or heavy Argos satellite collars during the same period. Heavy collars reduced annual survival of caribou in a declining population with generally poor body condition by about 18%. Accurate estimates of survival are crucial for management decisions and possible effects of collars should be considered when calculating estimates.

KEY WORDS *Cervidae*, radio transmitter weight, *Rangifer tarandus*, satellite/VHF collars, survival, Ungava caribou.

Radio transmitters embedded in collars, backpacks, or ear tags are widely used in animal ecology and management to study habitat use (Massé and Côté 2013), behavior (Bleich et al. 1997), and survival (Fuller 1989). A crucial assumption often made, but rarely tested, is that the transmitter does not alter the behavior or vital rates of the subject (Bank et al. 2000, Venturato et al. 2009). Although all possible measures are normally taken by wildlife managers to minimize the risks associated with capture and wearing a radio transmitter, some detrimental effects may still persist for some species. Guidelines for the use of radio transmitters are often ambiguous and rarely species-specific. One frequently cited guideline is that they should weigh less than 3% of body mass of the animal instrumented (Kenward 2001), but the basis for that guideline is unclear. Regardless of the weight of radio transmitters, it is essential to consider their potential undesired effects, which may lead to biased vital rate estimates and erroneous management decisions. Although some studies have identified effects of radio transmitters on animal behavior (Brooks et al. 2008), mass loss (Legagneux et al. 2013), reproductive success (Demers et al. 2003), or survival (Swenson et al. 1999), much is still unknown and several results appear contradictory (e.g., Godfrey and Bryant 2003).

The size and weight of the radio transmitter, the species studied, and individual characteristics may affect the response to the radio transmitter. For example, heavier devices are more likely to have a negative impact than light ones (Brooks et al. 2008, Venturato et al. 2009). In addition, younger individuals may be more affected than adults (Cypher 1997, Swenson et al. 1999). Migratory species such as greater snow goose (*Anser caerulescens atlanticus*) or caribou (*Rangifer tarandus*) that travel hundreds or thousands of kilometers each year may be particularly susceptible to the effects of collars (Demers et al. 2003, Haskell and Ballard 2007), because the energetic costs of long migrations exacerbate the burden of wearing a transmitter.

Although technological advances have reduced the size and weight of radio transmitters, demand for newer and better tools has led to added functions, such as global positioning system (GPS) engines, 2-way communication, geofencing and proximity sensors, longer battery life, or onboard cameras, adding bulk and weight to the devices. Our objective was to evaluate the effect of radio-collar weight on survival of migratory caribou. We compared survival of adult females (≥2 years old) wearing a light very high frequency (VHF) collar (514 g) to that of females wearing a heavy satellite collar (1.63 kg) in a herd in northern Québec and Labrador over 5 years. Although these types of collars were consistently used throughout the 1990s, satellite collars used on migratory caribou today weigh approximately 500 g.

STUDY AREA

The range of the Rivière-George caribou herd extends over several thousand square kilometers in northern Québec and Labrador (Boulet et al. 2007). Over the last few decades, the herd's demography has changed. Estimated at about 60,000 caribou in 1963 (Des Meules and Brassard 1964), the herd

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experienced several decades of growth and was above 500,000 individuals for about 15 years, peaking in the late 1980s and early 1990s (Crête et al. 1996, Bergerud et al. 2008). The Rivière-George herd was photo censused at 823,375 individuals (±102,000) in 1993 (Couturier et al. 1996). It then declined to about 27,600 (±2,760) individuals in 2012 (Québec and Newfoundland-Labrador governments, unpublished data; Fig. 1). The recent decline was associated with poor body condition, likely due to overgrazing of the summer range and more extensive movements (Couturier et al. 1990, Crête and Huot 1993).

METHODS

Collar Data

In 1986, the governments of Québec and Newfoundland-Labrador initiated a satellite-monitoring program using Telonics (Mesa, AZ) Argos ST-3 satellite collars (hereafter satellite collars) on migratory caribou, mostly adult females. Animals were captured at various times of the year, mainly by net-gunning from a helicopter but also by boat at river crossings. The VHF and satellite collars were fitted on adult females (≥2-year olds) and both collar types provided large adjustment range so the fit on caribou neck was comparable. The Argos satellite collars used during our study provided a better fit than earlier versions of GPS satellite collars. Collar type did not differ between capture techniques and females to be fitted with each type of collar were selected randomly. Several new adults were captured and collared each year, maintaining a representative age structure of collared animals (Table 1). Actual age was not determined. Battery life for VHF collars was longer (4–9 years) than for satellite collars (2.5 years), but individuals with both collar types were consistently recaptured and fitted with new collars prior to the end of battery life. Observers monitored VHF radio-collars from fixed-wing aircraft or helicopter (see Crête et al. 1996). The herd's range was covered 6–8 times/year, with at least 1 field session between January and March over the winter range. We assumed that the chance of detecting live or dead individuals during these flights did not differ, because large proportions of the herd's range were covered during most flights. Some individuals with VHF collars may have died outside of these more frequented zones and were therefore not detected as deceased. Recent data, however, suggest that such bias, if present, was small. In 2011 and 2012, we found that the probability of finding a satellite collar in mortality mode using only the VHF was very similar to the probability of detecting mortality from functioning satellite collars. During this period, several satellite collars malfunctioned and could only be found using VHF transmitters. Out of 33 collar malfunctions of adult females, 3 were found dead and 30 alive, suggesting a survival rate of 91%, compared to 90% for individuals with functioning satellite collars (S. Rivard, Ministère des ressources naturels du Québec, personal communication). For VHF collars, mortality was determined using pulse rate of VHF frequency as the beats per minute (BPM) were higher (average 187 BPM) for collars in mortality mode than for those in active mode (average 49 BPM). Satellite monitoring provided the mortality date and location of each individual every ±5 days. For both VHF and satellite collars, mortalities were determined by visiting the presumed mortality site and locating evidence such as bones, fur, or blood on the collar. Unfortunately, in most cases exact time and cause of mortality was not determined because the carcass was visited up to a few months after death. We analyzed annual survival of caribou fitted with VHF and satellite collars in 1991–1994 and in 2000. The VHF collars were substituted for satellite collars after 1995, but many VHF collars were deployed prior to the 2001 aerial census (Couturier et al. 2004). A total of 195 adult females (>2 years) with VHF collars and 96 with satellite collars were monitored over these 5 years. The weight of the 2 collar types differed substantially; VHF collars weighed 514 g, whereas Argos ST-3 satellite collars weighed 1.63 kg.

Table 1. Number of new and active radio-collared caribou as well as number of mortalities between 1991–1994 and 2000 for caribou equipped with very high frequency (VHF) and satellite (Telonics Argos ST-3) collars from the Rivière-George herd.

	VHF collars	Satellite collars
Number of new radio-collared caribou		
1991	12	26
1992	10	2
1993	26	9
1994	9	14
2000	74	7
Number of active radio-collared caribou		
1991	76	29
1992	65	20
1993	67	23
1994	16	28
2000	74	22
Number of mortalities		
1991	15	10
1992	13	5
1993	12	8
1994	0	9
2000	9	7

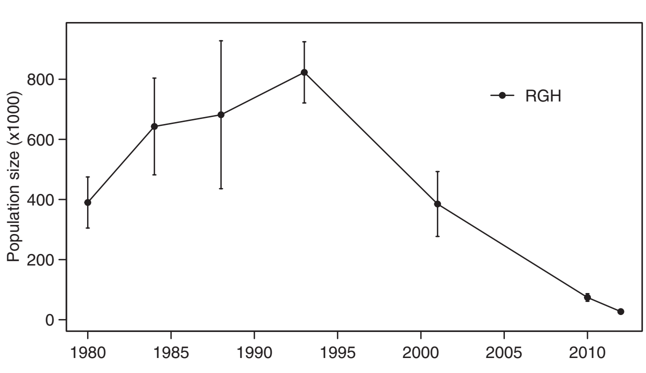

Figure 1. Population estimates from aerial censuses, with 95% confidence intervals when available, for the Rivière-George migratory caribou herd (RGH) in northern Québec and Labrador between 1980 and 2012. Note that the confidence interval in 2012 is too small to be seen on the graph.

Estimation of Survival Parameters

We compared survival of adult females over a biological year, 1 June to 31 May, according to collar type during the same period. We included individuals as of their first full year of monitoring (collared no later than 30 Jun) to eliminate potential biases due to the duration of monitoring during the first year. We censored individuals with satellite collars that were lost because of collar malfunction after the last transmission. However, we found no relation between collar malfunction and fate, as we explained above. We used a known-fate model in Program MARK version 6.1 (White and Burnham 1999) to estimate annual survival. We compared a general time-dependent model ($S_{g \times t}$, where S is survival, g is collar type and t is time), a simple time-dependent model (S_t) and a model with only collar type as the independent variable (S_g) and used the corrected Akaike's Information Criterion (AIC_c) to select the best model (White and Burnham 1999). We tested goodness-of-fit of each multistate dataset using Program U-Care version 2.3.2 (Choquet et al. 2009).

RESULTS

Females from the Rivière-George herd equipped with VHF collars had much higher annual survival rates (86%; $\hat{c} < 1$, SD = 9.79) than females with satellite collars (68.4%; $\hat{c} < 1$, SD = 5.78; Fig. 2) between 1991 and 1994 and in 2000. The best model included only collar type as an independent variable (95% CI = −1.4, upper 95% CI = −0.4), with no support for a time effect (Table 2).

DISCUSSION

We directly tested the effect of collar weight and size by comparing individuals with light and heavy collars that experienced the same pursuit, capture, and handling procedures during the same time period and over the same range. We found no difference in the locations of captures according to collar type. Our results suggested that heavy collars may reduce survival in migratory caribou. The average difference in point estimates of annual survival between individuals equipped with light VHF collars and those with heavy satellite collars was 17.7% (yearly range 5–32%) over 5 years. Only collar weight and size differed between these 2 groups. Survival of animals equipped with light VHF collars may be lower than survival of uncollared caribou, but we had no way to explore this possibility.

Although body condition measurements were not taken on captured individuals during this period, the herd was declining during the study period because of, in part, poor body condition in the late 1980s and early 1990s (Crête and Huot 1993; Couturier et al. 2009*a*, 2009*b*, 2010). Furthermore, the herd range had increased considerably during this period, resulting in annual migrations of over 1,000 km, likely decreasing body condition (Couturier et al. 2009*a*, 2010). This suggests that during a population decline, when demographic parameters such as survival and reproduction are already diminished, the added weight of a collar, even within the suggested <3% of total body mass (Kenward 2001), may have important implications. Although the satellite collars only weighed approximately 1.6% of the body mass of an adult female caribou (80–100 kg; Couturier et al. 2009*a*), compared to approximately 0.5% for the VHF collars, this difference was apparently enough to decrease survival during a population decline. In addition to the detrimental effect of weight, the size or shape of the collar may contribute to the cumulative effect of wearing a heavier radio collar. Although older caribou may be more affected by the added weight of a collar, age estimates of collared individuals were not available. The constant annual addition of newly marked random individuals of both collar types, however, should have maintained an age structure representative of the overall population for both collar groups. Thus, survival rate of animals fitted with each type of collar should not be biased by age. Further research with known age animals, however, is needed to address this question. Since 2000, caribou in the herd are no longer equipped with heavy collars. Recent satellite collars weigh approximately 500 g, similar to the weight of the VHF collars in this study.

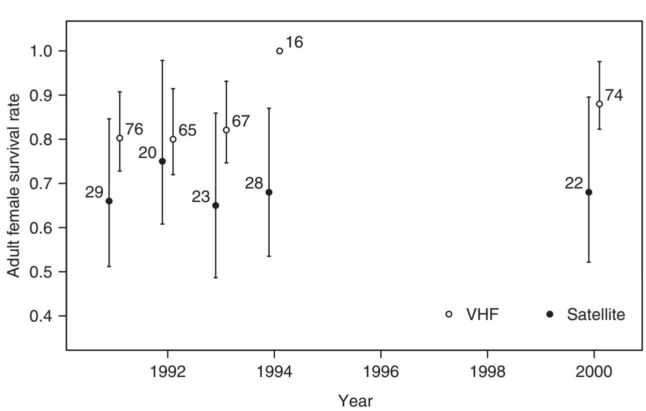

Figure 2. Annual survival rates with 95% confidence intervals of adult female caribou from the Rivière-George herd equipped with either light very high frequency (VHF) or heavy satellite collars (Argos) between 1991 and 2000. The number of individuals is indicated for each year.

MANAGEMENT IMPLICATIONS

Given the potential impact of satellite collars on individual survival, studies using heavy transmitter collars, for example, those including a video camera, should quantify the effect of these devices on survival, especially when body condition may be low. Ignoring this potential impact may bias results and lead to inappropriate management decisions. For example, an underestimate of adult female survival by only 5% (we found >15%) in migratory caribou demographic models will lead to an underestimate of projected population size by approximately 20% after only 5 years (A.L. Rasiulis, Université Laval, unpublished data). Such bias may lead to the establishment of inappropriate harvest strategies in management plans. We underscore, however, that potential effects of radio collars on individuals did not affect population demography, because a very small proportion (<0.0005%) of caribou carried radio collars during our study. Our results suggest that the interaction between collar

Table 2. Model selection results, based on Akaike's Information Criterion corrected for small sample sizes (AIC_c), for analyses examining adult female caribou survival (S) as a function of time and collar type in the Rivière-George herd, 1991–1994 and 2000; we considered 3 models.

Model[a]	AIC_c	ΔAIC_c	AIC_c weights	Model likelihood	No. of parameters	Deviance
S (collar)	423.3	0	0.98	1	2	194.42
S (collar × time)	431.4	8.1	0.02	0.0174	10	185.8
S (time)	439.7	16.4	0.00	0.0003	5	204.67

ΔAIC_c refers to the difference in AIC_c between the most supported and the given model.
[a] Collar = collar type, either very high frequency (VHF) or satellite; time = we considered each biological year (1 Jun to 31 May) as 1 occasion.

weight and individual body condition should also be considered.

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