Mortality and poaching of wolverines in Sweden

Dödlighet och illegal jakt på järv i Sverige

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1. ABSTRACT

In this report, we assess causes of mortality and estimate annual survival for 234 wolverines (*Gulo gulo*) monitored for a total of 613 wolverine years in northern Sweden. The study area was located in a mountainous area in Norrbotten County in and around the Laponia World Heritage site. We found that poaching (including assumed poaching) was the main cause of mortality in adult wolverines (60 %). For adult wolverines the annual survival was 0.91 (0.88-0.95; 95% CI) when poaching was excluded, and 0.81 (0.76-0.86) when both confirmed and assumed poaching were included. The annual poaching rate in adult wolverines was 0.10 (0.06-0.14). Notably, the annual poaching rate was higher in adult males 0.21 (0.06-0.35) than females 0.08 (0.04-0.11; P = 0.031). Almost all poaching of adult wolverines (97 %) occurred during the snow-season (December-May), with a peak in March-May. In addition, three subadult wolverines were poached in March-May. Most juvenile mortality was caused by intraspecific predation and other natural factors (78 %). Both our assessment of subadult mortality causes and estimate of juvenile/subadult survival are presumably biased low because a high proportion of subadults disperse. Neither the annual survival, including all sex and age classes and all mortality causes nor the annual poaching rate differed between 1993-1999 and 2000-2011. Although poaching forms a significant part of wolverine population dynamics in Sweden, estimates of an increasing population suggest that the level of poaching is not high enough to halt population growth.

1. SVENSK SAMMANFATTNING

I denna rapport rapporterar vi åldersspecifika dödsorsaker, med fokus på illegal jakt, och årlig överlevnad hos 234 järvar (*Gulo gulo*)som följts under totalt 613 radio-år i norra Sverige. Studieområdet var låg i ett område med fjäll och fjällnära skogar i Jokkmokks kommun i Norrbottens län. Vi fann att illegal jakt (inklusive förmodad illegal jakt) var den viktigaste dödsorsaken bland vuxna järvar (60 %). Hos vuxna järvar var den årliga överlevnaden 91 % (88-95 %; 95 % CI) när illegal jakt var exkluderat från analysen. När illegal jakt inkluderades var den årliga vuxenöverlevnaden 81 % (76-86 %). Illegal jakt svarade för en årlig dödlighet på 10 % (6-14) vuxna järvar. Noterbart är att dödligheten orsakad av illegal jakt var högre hos hanar (21 % (0.06-0.35 %)) än hos honor (8 % (0.04-0.11 %; P = 0.031). Nästan all illegal jakt på vuxna järvar (97 %) skedde i under snösäsongen (december-maj), med en tydlig topp i mars-maj. De tre subadulta (1-2 år gamla) järvar som dödades illegalt dödades även de i mars-maj. Den viktigaste dödsorsaken bland järvungar (0-1 år gamla) var inomartspredation. Både våra beräkningar av dödsorsaker och årlig överlevnad bland subadulta järvar är troligen underskattningar eftersom en stor andel av djuren i denna åldersklass utvandrar och förlorades från studien innan vi kunde avgöra vad som hänt med dessa djur. Varken årlig överlevnad inkluderande alla åldersklasser och dödsorsaker eller nivån på illegal jakt tycks ha förändrats från perioden 1993-1999 till 2000-2011. Våra analyser visar att illegal jakt är en viktig del i järvars populationsdynamik i Sverige. Emellertid tyder inventeringsresultaten på att populationen i landet ökar och att illegala jakten inte är tillräckligt omfattande för att stoppa populationen från att växa som helhet.

2. INTRODUCTION

The wolverine is relatively scarce across its circumpolar range, with regional status ranging from secure to endangered and, in some locales, possibly extirpated. Globally, the wolverine is classified as Least Concerned (Abramov et al. 2009). There is also a diversity of conservation and management concerns in many areas where the wolverine occurs. These concerns include primarily habitat fragmentation, overexploitation, and depredation conflicts with sheep and reindeer husbandry (Landa et al. 2000, Slough 2007, Zhang et al. 2007). Recently, concern has also been raised about the potential negative impact of global warming on wolverine populations (Copeland et al. 2010). Some concerns about wolverine management/conservation are common to many areas of wolverine distribution, while some are more specific to particular regions.

The Scandinavian wolverine population size and distribution declined markedly during the 1900s (Flagstad et al. 2004). During the last 10 years the wolverine population has increased in both Sweden and Norway, and the total Scandinavian population size is estimated to be 880-1190 individuals, with 550-790 in Sweden (Persson et al. 2011). The distribution of wolverines in Sweden largely overlaps with that of semi-domestic reindeer (*Rangifer tarandus*), which is the predominant prey of wolverines (Persson, 2005). The recovery of the wolverine population has been accompanied by increasing depredation of free-ranging sheep grazing unattended on summer pastures in Norway and semi-domestic reindeer in Sweden and Norway, leading to conflicts and high compensation costs (Swenson and Andrén, 2005). Currently, the wolverine population is listed as vulnerable in Sweden (Gärdenfors, 2010) and endangered in Norway (The Norwegian Biodiversity Centre). Current attempts to manage conflicts in Sweden are mainly based on a system of compensation for damage caused by wolverines, but also lethal harvest of wolverines and law enforcement against poaching (Persson et al. 2009). Compensation is based on the number of wolverines and other large carnivores within the reindeer grazing community. Lethal control of wolverines is only allowed in special cases as a final conflict-mitigating measure and is presumably of limited importance on a population level. In Norway, conflicts are managed with compensation for livestock that is documented or assumed to be killed by wolverines, as well as an extensive annual harvest of wolverines. As a result of the conflict with animal husbandry, poaching and legal harvest forms a substantial part of wolverine population dynamics in northern Scandinavia (Persson et al. 2009). As wolverines typically occur at low densities and have a low reproductive potential (Persson, 2005; Persson et al. 2006), wolverine populations are expected to be sensitive to changes in survival rates (Weaver et al. 1996).

We have previously assessed age-specific mortality causes and estimated annual survival of wolverines (Persson et al. 2009). Therefore, the aim with this report is to update the knowledge about poaching of wolverines in Sweden.

3. STUDY AREA

The study area (8000 km^2) is located in the county of Norrbotten around Kvikkjokk (67°00' N, 17°40' E). Part of the area is within Sarek National Park (2 600 km^2) and the Laponia World Heritage Site. The study area ranges from coniferous forest (Norway spruce, *Picea abies* and Scots pine, *Pinus sylvestis*) in the eastern parts (about 300 m a.s.l.), through mountain birch forest (*Betula* sp.) and mountain meadows to high alpine areas with peaks around 2000 m a.s.l. The tree line is at about 800 m a.s.l. The area is located within the Sami reindeer husbandry area and includes the reindeer management units: mainly Tuorpon, Jåhkågasska, Sirges and Luokta-Mávas and Sörkaitum. The study area has reproducing populations of lynx (*Lynx lynx*) and brown bear (*Ursus arctos*) that are also studied. Reindeer (*Rangifer tarandus*) is the main prey for wolverines in the area. Data on wolverine survival for this study has been collected from 1993 to 2011.

4. METHODS

4.1. Capturing and monitoring

During the study period we captured 256 wolverines and of these, 234 were used in analyses. Of these, 163 were monitored as juveniles, 107 as subadult (1–2 years), and 104 adult (>2 years) wolverines for a total of 613 wolverine years (Table 1). Some animals are included in analyses of mortality causes, but not included in the survival analyses, e.g. because the monitoring frequency were too low to be included in the latter. We captured and equipped most juveniles with implanted VHF-transmitters at rendezvous sites in early May to early June (2–3 months old). Adults were captured on ground or were darted from helicopters (Arnemo and Fahlman, 2007) and equipped with implanted VHF-transmitters and in some cases GPS-collars. The study was approved by the Animal Ethics Committee for northern Sweden, Umeå. Fur details on capture and immobilization see Arnemo et al. (2011).

We detected death of radio-marked wolverines during biweekly radio-tracking from fixed-wing aircraft with supplemental ground tracking. When we detected a mortality signal the site was investigated to determine the cause of death. We estimated the time elapsed from the date last heard alive until death by the condition of the carcass and indications at the carcass site. When the state of a carcass indicated that the animal had died recently, we designated the date of death at 80% of the time between the date last heard alive and the date when mortality was detected. When there were no indications of how long the animal had been dead, we fixed the date of death at 40% (cf. Johnson, 1979) of the time between the last time the animal was known to be alive and the date when mortality was detected. We classified animals that we lost contact with into two different categories; assumed poaching and lost (i.e., unknown disappearance) using additional information. Assumed poaching was when the lost animal was a resident adult equipped with a transmitter with at least half of the expected battery life remaining, the transmitter showed no signs of technical problems (e.g., strange signals), and the study area was searched extensively for the animal on ground and from the air (cf. Andrén et al., 2006; Persson et al. 2009).

Furthermore, in several cases we documented that a new individual had taken over the territory the winter following the disappearance of a resident individual, suggesting that the latter had been killed. Date of assumed mortality and censoring of lost animals were assigned the same way, i.e. one week after the last date the animal was heard alive (i.e., approximately intermediate between the last time heard and the next radio-tracking event).

4.3 Methods for estimating survival

Survival rates of radio-marked wolverines were calculated using the staggered entry design, which is a modified Kaplan-Meier estimate (Pollock et al. 1989, R-development core team 2010, R library *survival*). We estimated survival for two age classes; a) juveniles and subadults pooled, and b) adults. The juvenile/subadult age class included wolverines from approximately 3 months of age to the age of 2 years, and adults are wolverines older than 2 years. We also estimated survival separately for adult males and females. We estimated two survival rates. The first one includes all mortality and the second one excludes poaching and assumed poaching. The effect of poaching and assumed poaching on survival rate was estimated using competing risk models and cumulative proportional hazard (R library *cmprsk)*. If nothing else is mentioned, poaching includes both confirmed and assumed poaching in the text below.

5. RESULTS

5.1. Cause of mortality in radio-marked individuals.

In our study area in Sarek, northern Sweden, we monitored 234 individual wolverines. We documented 68 mortalities, distributed on 33 adult, 5 subadult and 32 juvenile mortalities. In addition, we documented 22 cases of assumed poaching of adult wolverines. We lost contact with 120 individuals for which the fate could not be determined.

Confirmed adult mortality was dominated by hunting (i.e. lethal control) and poaching (Table 1). A third (33 %) of confirmed adult mortality was caused by poaching. If we include assumed poaching, poaching caused 60 % of adult mortality (Fig. 1). Poaching caused 94 % of adult male mortality and 46 % of adult female mortality (Fig. 2). Natural adult mortality was caused by disease, intraspecific strife, starvation, avalanche and unknown natural causes.

We documented mortality of 5 subadult individuals during the study (Table 1). Poaching was confirmed as the cause of death of three individuals. Another wolverine presumably killed one male. Cause of death for one female was unknown.

We monitored 163 juvenile wolverines and documented 32 mortalities (Fig. 1). The predominant cause of death was intraspecific predation (44 %; n = 14). Other causes of juvenile mortality were lethal control, poaching, drowning, starvation and unknown causes. Human caused mortality represented 15 % of juvenile mortality, while 78 % of mortality was caused by natural factors.

5.3. Seasonal distribution of mortality

In adults, 97 % of confirmed and assumed poaching occurred during December-May, and 73 % occurred during March-May (Fig. 3). In contrast, 40 % of natural and unknown adult mortality occurred during December-May. All three cases of poached subadults occurred in March-May. In juveniles 94 % of the mortality occurred in May-September, but juveniles were not monitored in March-April.

5.2 Annual survival for radio-marked individuals
Annual survival for all sex and age classes pooled (Fig. 5) was significantly higher ($P<0.05$) when poaching was excluded 0.87 (0.84-0.91), compared to when poaching was included (0.78; 0.74-0.83).

For adult wolverines the annual survival was 0.91 (0.88-0.95) when poaching was excluded. If we included poaching the annual adult survival was 0.81 (0.76-0.86). When we analyzed adult survival separated on males and females, we found that female and male annual survival was 0.82 (0.77-0.88) and 0.77 (0.66-0.90), respectively, when all mortality causes were included.

Pooled annual survival for juveniles and subadults was 0.81 (0.75-0.87) including poaching, and 0.75 (0.68-0.83) when poaching was excluded.

If we look at the level of poaching separately, the overall level of poaching is 0.08 (0.05-0.11) when all age and sex classes are pooled. The annual rate of poaching was 0.03 (0.01-0.06) for juveniles and subadults combined, whereas the annual poaching rate was 0.10 (0.06-0.14) for adult wolverines. The annual poaching rate was higher in adult males 0.21 (0.06-0.35) than females 0.08 (0.04-0.11) (Competing Risk Regression; $P = 0.031$).

Overall annual survival, including all sex and age classes and all mortality causes, did not differ between the two periods 1993-1999 and 2000-2011 ($\chi^2 = 0$, $df = 1$, $P = 0.93$; Fig. 6). Similarly, the annual poaching rate did not differ between 1993-1999 and 2000-2011 (0.07 and 0.08, respectively; Competing Risk Regression, $P = 0.54$).

6. Discussion

We focus the discussion on adult survival because; a) adult survival is the demographic parameter that has most influence on population growth, b) adults is the age class that is most influenced by human caused mortality, c) we have the most robust data on adults and juveniles, but the latter age class is exposed to human caused mortality only for a limited time, e.g. not monitored in March-April and rarely in May.

Adult survival and mortality causes
Poaching, including assumed poaching, was the most important cause of adult wolverine mortality in northern Sweden (60 %; Fig. 1.). If we include lethal control, human caused mortality represent 71 % of adult mortality. Annual survival both when all age classes were pooled and for adult wolverines were significantly lower when confirmed and assumed poaching was included compared to survival without poaching. This suggest that poaching is the most important limiting factor for the Swedish wolverine population, considering that adult survival is the most important parameter influencing population growth rate in long-lived mammals (e.g. Stearns 1992). For example, the influence of

adult survival on wolverine population growth is estimated to be 4.5 times larger than that of reproduction (Persson 2008). Importantly however, the level of poaching is not large enough to hinder the population from growing, as suggested by an increasing size of the population the last 10 years (Persson et al. 2011).

Notably, mortality caused by poaching was significantly lower in adult female wolverines than for adult males. We hypothesize that this difference is due to sex-specific differences in movement patterns and indirect protection. First, male home ranges in our study area are typically about four times larger than those of females (Persson et al. 2010). Wolverine males also appear to increase their movements before and during the mating season (April–August) (Hornocker and Hash, 1981; Magoun, 1985), which partly overlaps with the period when most poaching occurred. Hence, more extensive movements presumably make males more exposed to (incidental) poaching than females. Second, denning females may receive indirect protection from poaching by the monitoring of wolverine reproductions by the County Administration, i.e. increased activity of people around denning areas might deter poachers and inflate adult female survival rates. This might be further inflated in our study area by our research activity centered on female denning areas. In addition, that denning females have an economical value, as a result of the current compensation system, could also contribute to indirect protection. Adult females and their survival is the most important segment of the population. Thus, an important implication of this result is that the observed level of poaching on females is a better reflection of the influence of poaching on growth rate of the wolverine population than the pooled survival of females and males.

Seasonal differences in adult mortality

The number of poached wolverines was highest during the snow season, with a peak in March-April. This is the factor explaining why adult survival is lower during the snow season than during the snow-free season (Persson et al. 2009). Poaching is presumably facilitated by snow cover that facilitates tracking and hunting by snow-machines in remote areas with low risk of detection. This is especially true for the later part of the snow season (March–May) when snow conditions are ideal and daylight is longer, increasing the chances of spotting wolverines and their tracks. A similar temporal pattern is documented for poaching of lynx in our study area (Andrén et al. 2006).

Juvenile and subadult survival and mortality causes

Although we monitored 107 individuals as subadults, we could only confirm 5 mortalities in this age class (Table X). A high proportion of subadults disperse from the study area and it is therefore logistically hard and expensive to monitor these individuals and their destiny (establishment and/or death). Furthermore, dispersing carnivores are young, inexperienced animals that make extensive movements in new areas and are often subject to higher mortality than residents (Waser, 1996; Fuller et al., 2003; Blankenship et al., 2006). Therefore, it is likely that our results underestimate subadult mortality and particularly mortality caused by poaching. Our assumption is supported by that two subadults classified as lost were subsequently incidentally found poached. *It suggests that* *our estimates of adult survival could be biased high as well (i.e., animals classified as lost were in fact killed).*

Juvenile mortality (n = 32) was dominated by natural causes (78 %). Of these, 14 were confirmed and one was presumably killed by conspecifics. A thorough discussion about intraspecific predation on juvenile wolverines is provided in Persson et al. (2003). Only 6 % of juvenile mortality was caused by poaching. The low level of poaching is expected as they are monitored in most cases from early June and to 1 March. Thus, juveniles were mainly monitored outside the period when poaching is most frequent.

Pooled annual survival for juveniles and subadults was lower than that of adult wolverines when poaching was not included. This difference is primarily explained by the higher natural mortality in juvenile wolverines. When including poaching, juvenile/subadult survival was still lower than that of adults, but the difference was smaller because the level of poaching was low in juveniles and the fate of many subadults could not be determined.

Lost animals and reliability of our estimates

In total, we lost contact with 120 wolverines for which we could not determine their fate. These animals were censored from all survival analyses. The explanation for these disappearances could be dispersal, failure of radio-transmitters or poaching (with subsequent destruction of transmitters). It was primarily subadults that were lost from the study; 48 % (n = 57) of all lost animals were subadults and 54 % of subadults were lost from the study. The reason for this is that most wolverines that disperse do so when they are subadults (Vangen et al. 2001). A high proportion of dispersing animals are lost because of the difficulties to monitor dispersal. In addition, for animals that have not been determined as being established, it is hard to separate dispersal, poaching and transmitter failure. As mentioned above, young dispersers is the category that is expected to be most exposed to poaching, and other mortality factors, suggesting that we underestimate subadult mortality in general and poaching in particular.

Representativitet för population utanför studieområde

Our study area represents a small proportion of the distribution of the Swedish wolverine population. Our study area mainly consists of rugged terrain, and over time our study area is likely to have been influenced by survival of marked animals, i.e. a selection process where we monitor more individuals in areas where survival is relatively high. Furthermore, it is not unlikely that our research activity could inflate survival of marked animals. Altogether, this suggests that our estimates of poaching could be biased low. Furthermore, our study area is not representative regarding the level of lethal control. Since the start of the study our radio-marked wolverines constitute 32 % of all lethal control conducted in Sweden. Thus, the level of lethal control is lower on a national level than indicated by our estimates in this report.

6.5. Conclusions
Poaching is the main cause of mortality in adult wolverines. Almost all poaching occur during the snow-season with a peak in March-May. Most juvenile mortality is caused by intraspecific predation and other natural factors. Our estimate of subadult survival and mortality causes is presumably biased low because a high proportion of subadults disperse. Although poaching forms a significant part of wolverine population dynamics, estimates of an increasing population suggest that the level of poaching is not high enough to halt population growth.

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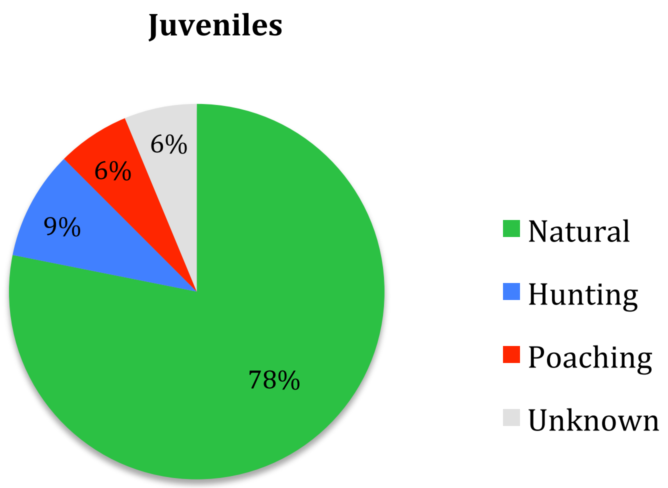
Table 1. Causes of mortality in radio-marked wolverines in northern Sweden.

Age (years)	N	Natural	Hunting	Poaching	Assumed poaching	Unknown cause	Unknown fate
<1	163	25	3	2	0	2	26
1-2	106	1	0	3	0	1	57
> 2	104	13	6	11	22	3	37
Total		39	9	16	22	6	120

* In addition four wolverines were confirmed to have died after we lost contact with them. One adult male was killed in intraspecific strife or injury from falling down a cliff. One adult. One adult female was killed illegally. One male and one female were lost as subadults and were subsequently found poached in a hydro power dam.



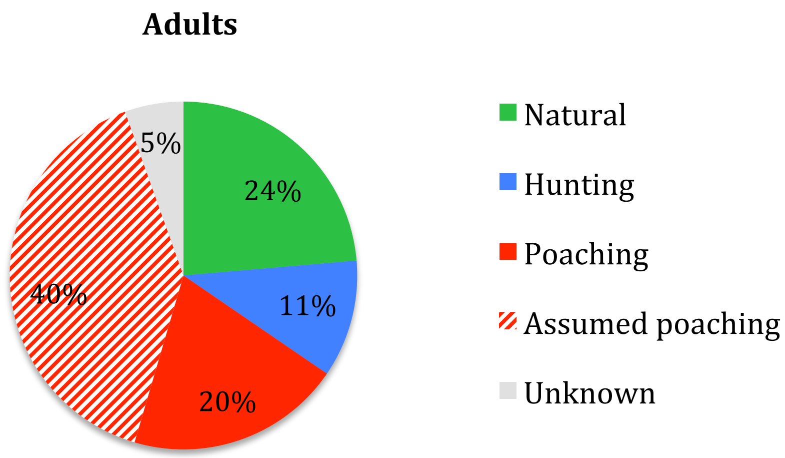
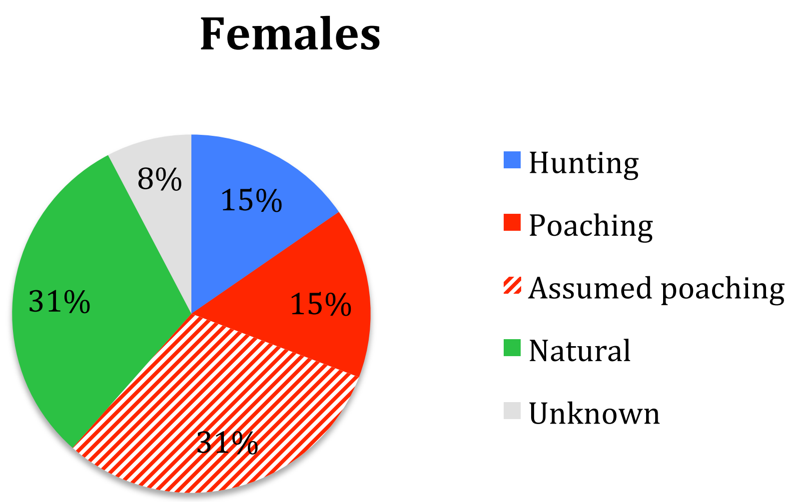


Figure 1. Causes of mortality in juvenile (upper chart) and adult (lower chart) wolverines in northern Sweden.



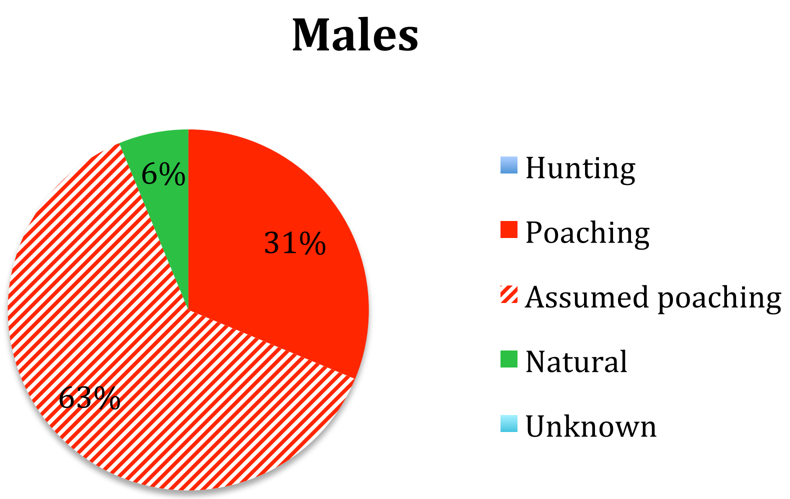


Figure 2. Causes of mortality in adult female (upper chart) and male (lower chart) wolverines in northern Sweden.

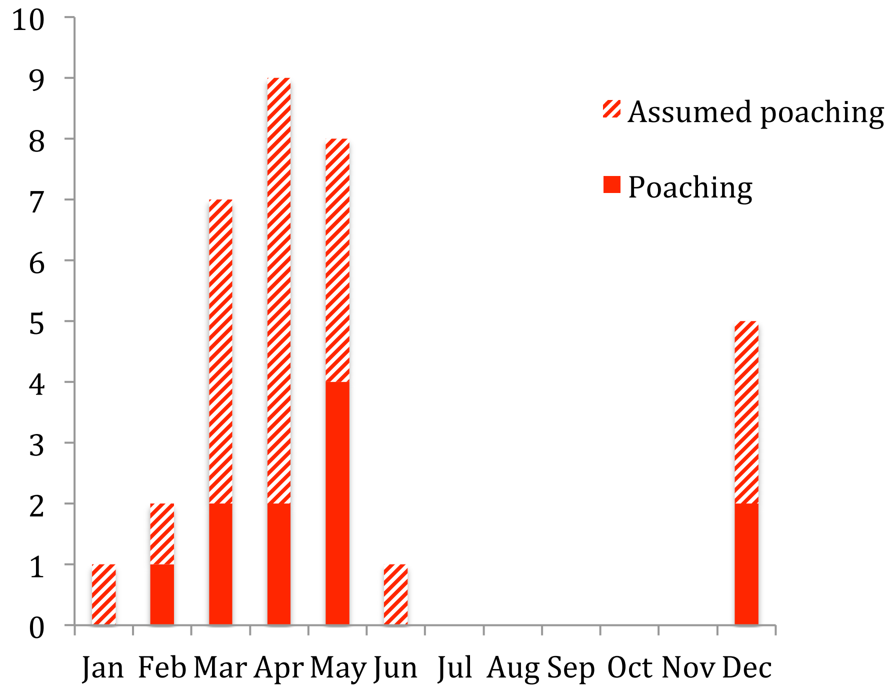


Figure 3. Number of radio-marked adult wolverines that died from confirmed poaching (red; n = 11) and assumed poaching (red-striped; n = 22) in relation to month of the year 1993–2011.

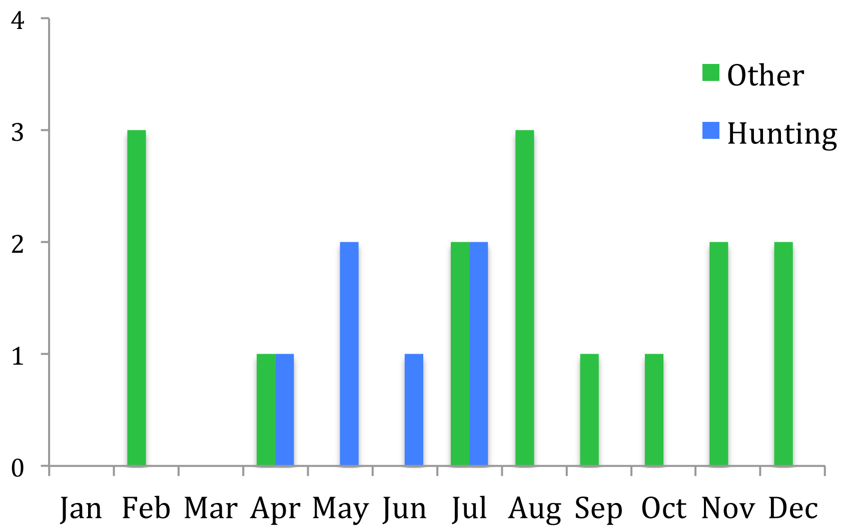


Figure 4. Number of radio-marked adult wolverines that died from natural and unknown causes (green bars; n = 15) and lethal control (blue bars; n = 6) in relation to month of the year 1993-2011.

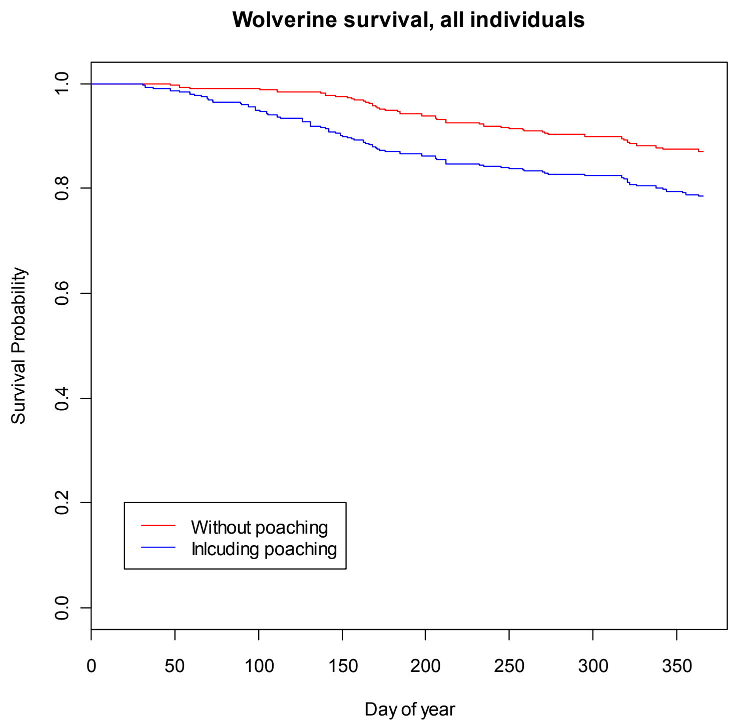


Figure 5. Survival curve illustrating survival probability for all sex and age classes pooled, with and without poaching included in the analysis. Survival is significantly lower when poaching (including assumed poaching) is included ($P < 0.05$).

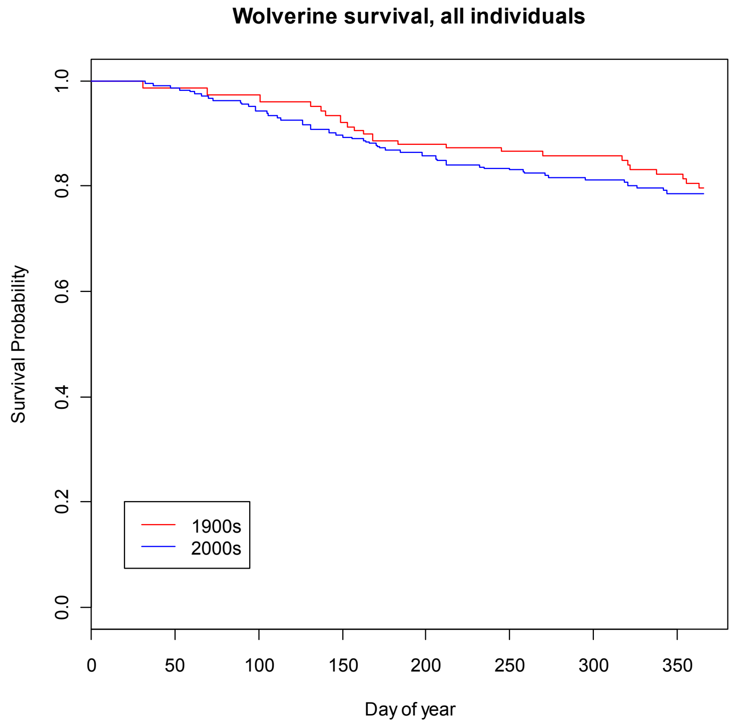


Figure 6. Survival curve illustrating survival probability for all sex and age classes pooled, 1993-1999 (1900s) and 2000-2011 (2000s) respectively, with poaching (including assumed poaching) included. The survival probability did not differ between the two periods.