WOLVERINE CARCASS COLLECTION PROJECT: 2013 PROGRESS REPORT

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Acknowledgements

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Summary

- We collected basic biological information from trapper-submitted wolverine carcasses in order to examine the role of such projects to provide data useful for management purposes.
- Trapper submissions to the program were very good; about two-thirds of the annual harvest was received. Overall, Yukon trappers submitted 564 wolverine carcasses to the project (378 males, 186 females), spanning 7 trapping seasons (2005-2006 to 2011-2012).
- The program provides a cost effective means to monitor the composition of the wolverine harvest, and may allow for a statistical population reconstruction aimed at assessing the sustainability of the harvest. A continuation of the wolverine carcass collection program is recommended.

Key Findings

- The wolverine harvest was male-biased. On average, two-thirds of the wolverine carcasses submitted each year was males. This bias is desirable from a management perspective because it should have less impact on population dynamics than if reproductive females were removed from the population; thus, it is more sustainable.
- The relatively high percentage of adult females in the harvest in some years was unexpected and somewhat concerning from a harvest sustainability perspective because females are needed to produce litters and offset the loss to the population from harvest. A better understanding of, and monitoring for, these annual changes can prove invaluable for informing wolverine harvest management.
- Close to a third of the adult females harvested were very close to giving birth, and a few already had, when harvested. Harvesting females with dependent cubs in a den is a concern because the loss to the population is compounded. In addition, for some people, harvesting females with young is an ethical consideration. The data suggest that ending the wolverine harvest in late-February, rather than mid-March, would reduce the take of adult females that are close to parturition or post-partum.
- Early results suggest that snowshoe hare are a key item in the winter diet of wolverine in Yukon. This is in contrast to diet studies elsewhere, and it may have implications for the susceptibility of wolverine to harvest in years when the hare cycle is in the low phase.

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Introduction

Wolverines (*Gulo gulo*) are a species of special management interest across their circumboreal range because they are both a species at risk and a valued furbearer. Within Canada, wolverines are listed by the Committee on the Status of Endangered Wildlife (COSEWIC) as a species of *Special Concern*, and globally they are on the IUCN Red List as *Vulnerable*. Wolverines, generally, occur at low population densities (e.g. Golden et al. 2007), have large home ranges (Banci and Harestad 1990), and relatively low reproductive rates (Rausch and Pearson 1972, Banci and Harestad 1988). There is a concern that wolverines are sensitive to human disturbance and development, as well as overharvest (Ruggiero et al. 2007, Slough 2007).

Wolverines are harvested across much of their range in northern Canada and Alaska. Harvest reporting is in place in Yukon, where pelt sealing is compulsory for hides going into commercial trade (Slough 2007). Wolverines in Yukon can be harvested by hunting or trapping, with the vast majority (~ 98%) of animals harvested each year by fur trappers. In Yukon, Slough (2007) reported 2,162 wolverines harvested during the 1989–1990 to 2003–2004 trapping seasons; an average of 144 ± 40 (SD) wolverines per trapping season. The annual harvest during the same reported 15 years is marginally greater only in British Columbia, with an annual harvest of 152 ± 41 wolverines per year.

Given their global conservation concern, coupled with naturally low densities and relatively high harvest numbers, assessing the sustainability of wolverine is of particular interest to wildlife managers across the species range (e.g., Sæther et al. 2005, Lofroth and Ott 2007, Dalerum et al. 2008*a*). Such assessments, however, are difficult in many areas because the density or abundance of wolverine is often unknown. Methods to determine wolverine density or abundance include aerial survey (Golden et al. 2007, Magoun et al. 2007), mark-recapture studies using DNA obtained from hair-snagging grids (Mulders et al. 2007), and remotely-deployed camera traps (Magoun et al. 2011). However, wolverine are elusive and particularly difficulty to census. Consequently, methods currently available to inventory them are time-consuming and expensive, particularly for rugged and remote areas with limited access, such as Yukon.

In 2006, we initiated a program to assess the possibility of using readily available carcasses from fur trappers to monitor wolverine population status in Yukon, and evaluate the sustainability of the harvest. We reasoned that examination of readily available carcasses may provide a suitable means to gather demographic and population trend data in a cost-effective manner.

Similar wolverine carcass collection programs are underway in Nunavut, Northwest Territories (e.g., Lee 1994), as well as for other furbearers in other jurisdictions (e.g., Fryxell et al. 2001; Larivière et al. 2010). Our specific goals were to:

- **Examine the population characteristics of harvested wolverine**. Understanding the population composition of harvested animals and how that may change with time is essential for wildlife managers, as these data can be used to inform population modeling initiatives and establishing harvest restrictions (e.g. quotas), where necessary (e.g., Coe et al. 1980, Taylor et al. 1987, Larivière et al. 2010, Nilsen et al. 2011). We were primarily interested in obtaining the following key pieces of information from the carcasses: sex and age-class of harvested animals and reproduction by females, specifically, pregnancy rates, reproductive timing, and litter size.
- **Assess the sustainability of the harvest**. Here, we were interested in determining the feasibility of using age-at-harvest data to assess if the harvest was sustainable. Analyses of age-at-catch data have been commonplace in marine fisheries, but have not been widely applied for terrestrial mammals despite their potential as a cost-effective means of assessing harvest sustainability (e.g. Solberg et al. 1999, Fryxell et al. 2001, Nilsen et al. 2011). However, we recognized that a relatively long time series of harvest data were needed to conduct such analyses.
- **Explore aspects of the health of wolverine.** There is little information on the health of wolverine. Submitted carcasses provided an opportunity to grossly examine them for health issues and collect select tissues for disease sampling. Testing of readily-available carcasses of wolverine can provide a window into presence and prevalence of select diseases in the assemblage of carnivores in Yukon. Diseases of particular concern included trichinosis (Reichard et al. 2008) and rabies. We also had a specific interest in monitoring the body condition of wolverine, but first we needed to develop an accurate and easily-obtained index of body condition.
- **Enable research on wolverine biology**. Wolverines are one of the least studied carnivores in northern regions. Consequently, there is much still to learn about their basic biology and natural history. Banci (1987) and Rausch and Pearson (1972) provided the only biological studies of wolverine in Yukon. Given our access to a relatively large number of carcasses, we were interested in collecting biological samples that could be used to learn more about the basic biology of wolverine.

For example, DNA samples can be used to explore population genetics questions at regional (e.g. Wilson et al. 2000) or continental scales (e.g. Kyle and Strobeck 2001, 2002). Stomach contents and fat samples can be collected to examine seasonal diets (e.g. Magoun 1987, Lofroth et al. 2007). Additionally, morphological measurements can be collected to assess growth and developmental patterns (e.g., Wiig 1989, Bartareau et al. 2011). At the root of good wildlife management is knowledge of the basic biology of the species; a better understanding of this species will ultimately lead to better management.

Here, we provide a progress report on 7 years of wolverine carcass collections and preliminary results of the analyses of some of those data, with a focus on those that relate to the sustainability of the harvest in Yukon. We assess the feasibility of a carcass collection program to provide data of management interest for wolverine in Yukon.

Methods

In Yukon, Canada, wolverine may be legally harvested during winter (1 November to 10 March) by licensed fur trappers. We solicited licensed Yukon fur trappers to voluntarily submit the skinned carcasses of wolverine legally harvested in the 2005–2006 through 2011–2012 fur trapping seasons.

In return, trappers were compensated $30 per wolverine carcass. Animals were harvested by licensed fur trappers using industry-standard trap sets for wolverine. Carcasses were kept frozen at -20°C for 6–10 months prior to necropsy.

During necropsy, basic morphometric measures were taken, sex was determined, and various biological samples were collected. We attempted to calibrate our morphological measurements and biological sample collection with those being concurrently taken in the Northwest Territories in a similar wolverine carcass collection program conducted by the Northwest Territories Department of Environment and Natural Resources. Morphological measurements taken at the time of necropsy included total body length, neck circumference, and body mass (after removing stomach contents). We used cleaned skulls and skeletal material to measure skull length and width; and the lengths of humerus, femur, and baculum. Biological samples collected included: a premolar tooth (PM_1) for aging; female reproductive tracts to determine productivity; fat samples for the development of a body condition index; blood, tongue, and brain tissues to test for rabies, presence of *Trichinella*, and other diseases and parasites of concern; muscle tissue for DNA analyses; stomach contents and subcutaneous fat for diet analyses; and skull, baculum, and long bones for studies on body size and growth.

Age was determined via cementum analysis of a premolar tooth (Poole et al. 1994) at a commercial laboratory (Matson's Laboratory LLC, Milltown, Montana). Wolverine <1 years old were classified as juveniles, those that were 1 year old were yearlings, and those ≥2 years old were considered adults.

Sternal fat is considered a good indicator of total body fat (Robitaille et al. 2012). We developed a body condition index (BCI) that used body length (mm) to correct sternal fat measures (g) for differences in structural body size, using the equation: (sternal fat/body length)*1000.

Pregnancy was determined from the presence of a fetus, or in the case of animals harvested while early in pregnancy, the presence of corpora lutea (Banci and Harestad 1988). Corpora lutea, a mass of cells that forms after the release of a mature egg, were determined via microscopic inspection of uterine tracts. Where available, we obtained crown-rump length and mass of fetuses. To assess how close to term a pregnant female was we plotted crown-rump lengths and masses and visually compared those to published data for these values at parturition in captive wolverine (Mehrer 1976, Shilo and Tamarovskaya 1979).

We tested for statistical differences in the mean age and sex of harvested wolverine using 2-sample *t*-tests and 2-way analysis of variance (ANOVA).

We compared pregnancy rates among adults and yearlings with a 2-sample *t*-test. Differences in body condition between sexes and trapping seasons, and their interaction, was assessed with 2-way ANOVA. A general linear model, discriminant function analysis, and non-linear (quadratic) regression were used to analyze morphometric data to determine age and sex differences in the growth and size of wolverine. Data were visually examined for normality using box plots, prior to using parametric statistical tests. A *P*-value of ≤0.05 denoted statistical significance. SYSTAT (ver. 13) was used for statistical analyses.

Results and Discussion

Wolverine Carcass Submissions

Yukon trappers submitted 564 wolverine carcasses to the project (378 males, 186 females) spanning 7 trapping seasons (2005–2006 to 2011–2012). On average, 80.6 ± 11.9 (SD; range = 68–101) wolverine carcasses were submitted each trapping season. Wolverine carcass submissions represented 66.3 ± 9.1 % of the harvest each trapping season (range = 56.2–78.8%; Figure 1). The percent of the harvested wolverine submitted differed among months ($F_{4,60}$ = 23.316; P < 0.001; Figure 2) for both sexes, with no significant interaction between sex and month of harvest ($F_{4,60}$ = 0.265; P = 0.899).

All but 3.3 ± 2.2% (SD) of the wolverine carcasses submitted each year could be spatially attributed to a Game Management Zone (GMZ). Wolverine were submitted from most of the territory, with the exception of Ivvavik National Park and Reserve and Vuntut National Park and Reserve in the northeast, Kluane National Park and Reserve in the southwest, and GMZ 6, where wildlife harvest was restricted (Figure 3). The distribution among GMZs varied geographically ($F_{6,90}$ = 208.926, $P < 0.001$), with a disproportionate share of the wolverine carcasses submitted originating from GMZ 5. However, the distribution of carcasses submitted mirrored harvest patterns and likely did not create a geographic bias in our results.

Trapper submissions to the program were very good; we consistently received about two-thirds of the annual harvest. A similar Yukon-wide carcass collection program led by Banci (1987) conducted similar wolverine carcass collection programs during 3 trapping seasons (1982–1983 to 1984–1985) and collected a smaller percentage of the annual harvest (49.1 ± 3.3%) than this study.

However, the percentage of carcasses submitted in our study was low compared to a similar project in the Northwest Territories, where submission rate is generally believed to be >80% (Lee 1994; R. Mulders, GNWT, pers. comm.). The difference between the percent of the harvest represented in carcass collection programs in the Northwest Territories and Yukon may be a function of the remuneration to trappers offered by each territory.

Carcasses submitted to our program originated broadly across the territory. Because we received carcasses from a good percentage of the wolverines harvested and from a broad area across the territory, during all months of the harvest, we have fairly high confidence that our sample provides a good representation of the wolverine harvest in Yukon. We do not believe that there is any reason to suspect a bias in the submissions received.

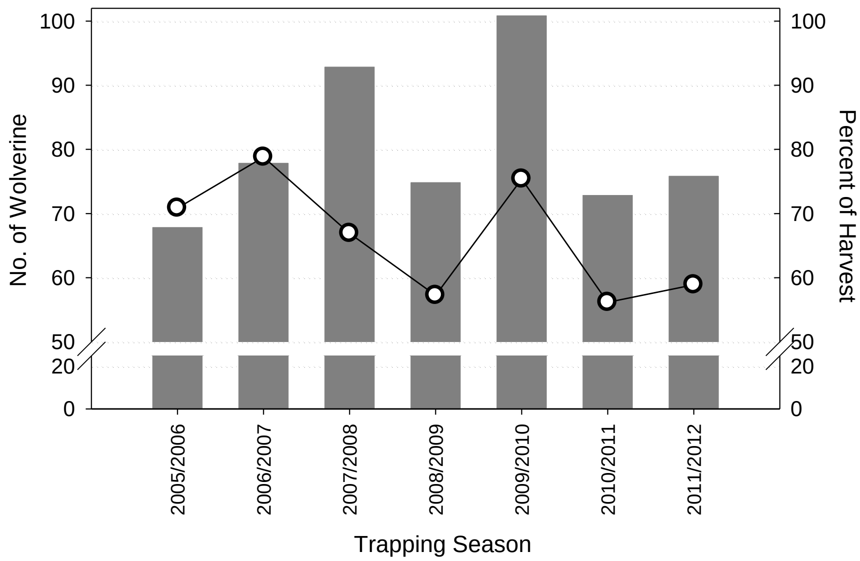

Figure 1. Number of trapper-killed wolverine carcasses submitted (vertical bars) and the percent of the annual harvest that these samples represent (dotted line), for each of 7 winter trapping seasons (2005–2006 to 2011–2012) in Yukon Canada.

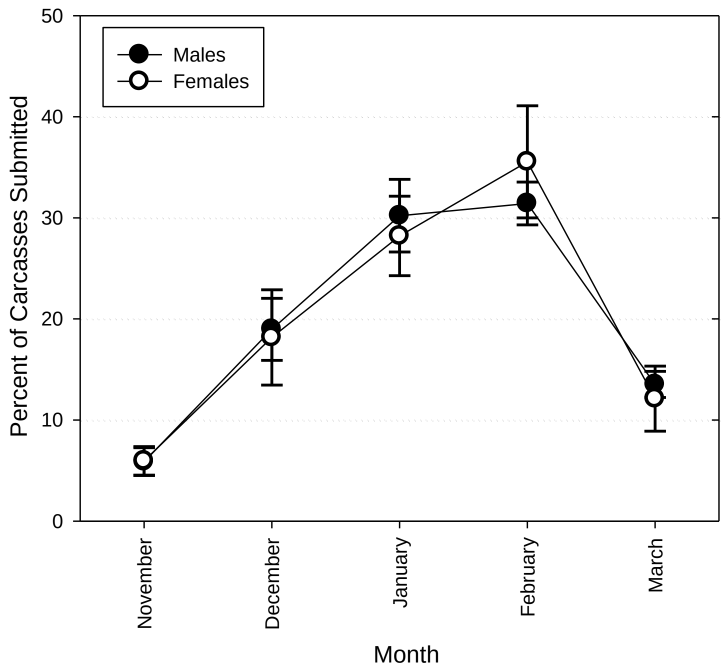

Figure 2. Mean (± SE) percent of the month of harvest of submitted (*Gulo gulo*) carcasses for 7 winter trapping seasons (2005-2006 to 2011–2012) in Yukon, Canada.

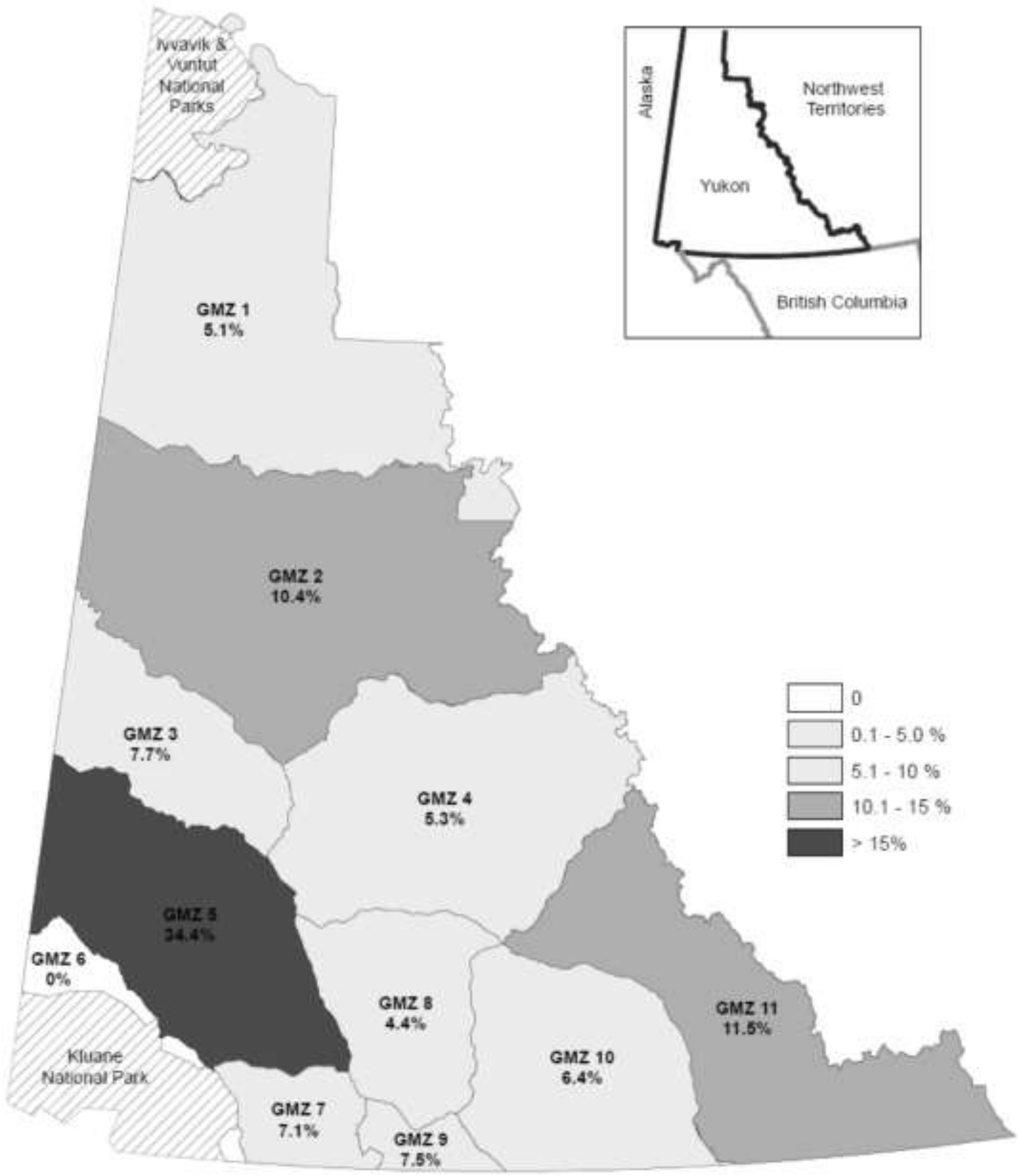

Figure 3. Spatial distribution of Wolverine (*Gulo gulo*) carcasses submitted from Game Management Zones (GMZ) in Yukon, Canada, during winter 2005–2006 to 2011–2012.

Sex and Age-class of Harvested Wolverine

The wolverine harvest was male-biased. On average, two-thirds of the wolverine carcasses submitted each year were males, a difference that was statistically significant (t_{12} = - 12.362; $P < 0.001$; Figure 4). This was not surprising as male-biased harvest is typical for mustelids (e.g. Buskirk and Lindstedt 1989, Fryxell et al. 2001, Larivière et al. 2010). A male-bias is likely because males occupy larger home ranges (Banci and Harestad 1990) and are more likely to encounter trap-sets than females (Buskirk and Lindstedt 1989). For wolverine, it is also likely that the harvest is male-biased because females likely den during February to April (Magoun and Copeland 1998, Inman et al. 2012) and their movements are likely restricted at this time, as they are attending to dependent pups. However, we have no Yukon data on the timing of wolverine denning or movements during the denning period. This bias is desirable from a management perspective because harvest should have less impact on population dynamics than if reproductive females were removed from the population; thus, it is more sustainable.

We obtained ages for 97.5% of the carcasses submitted. Ages of wolverine in our sample ranged from 0.6 to 12.9 years old, however the majority of harvested animals were >2 years old (Figure 5). The oldest male and female harvested were estimated at 11.9 and 12.9 years old, respectively.

The percent of harvested wolverine differed among age-class ($F_{2,36}$ = 5.617; P = 0.008: Figure 6). Males and females were harvested in the same proportion as juveniles, but more male yearlings were taken than females, and the opposite was true for adults. Most females taken were adults (Figure 6), and the percent of adult females harvested increased in the last 3 years of the study (Figure 7). Despite more females being harvested as adults than males, there was not a statistically significant difference in the interaction term ($F_{2,36}$ = 1.819; P = 0.177).

While the majority of harvest was of males, the percent of adult females in the harvest was unexpected; we would have predicted that most females harvested would be juveniles or yearlings, as seen in the data for males. This was the case for trapping seasons 2005–2006 to 2008–2009, however in the latter 3 trapping seasons a much larger percent of the females harvested were adults (Figure 7). A similar increase in the percent of adult males harvested was not seen in the data. Increased harvest of adult females is problematic from a population management perspective because adult females of most mammals contribute substantially more to the stability of natural populations. Loss of too many adult females would result in population declines, which would be difficult to reverse in the short-term, given the reproductive biology and life-history characteristics of the species (Persson et al. 2006).

For wolverine, several recent modeling exercises have demonstrated that the harvest of adult females has the largest impact on the sustainability of the harvest (Sæther et al. 2005, Lofroth and Ott 2007, Dalerum et al. 2008*a*). It is important to note that we do not know why more adult females were harvested, or how many adult females can be harvested in Yukon before an effect on the population trend occurs.

Nevertheless, this is a facet of the Yukon harvest that may warrant close attention, such as through continued monitoring of the age-sex characteristics of the harvest and perhaps some initial population modeling, as suggested by Lofroth and Ott (2007) for British Columbia.

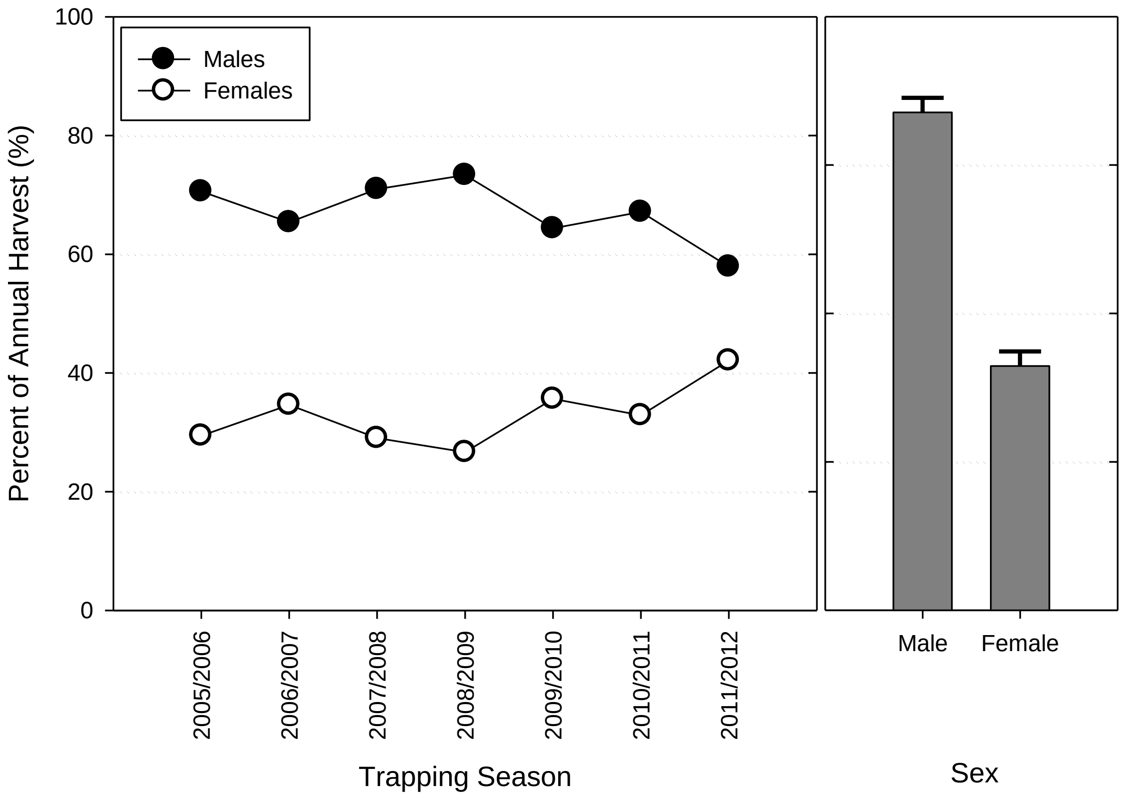

Figure 4. Sex of harvested wolverine in Yukon, Canada. Means (+ SE) are presented in the graph to the left (*n* = 378 males, 186 females). The Y-axis is the same for both panels.

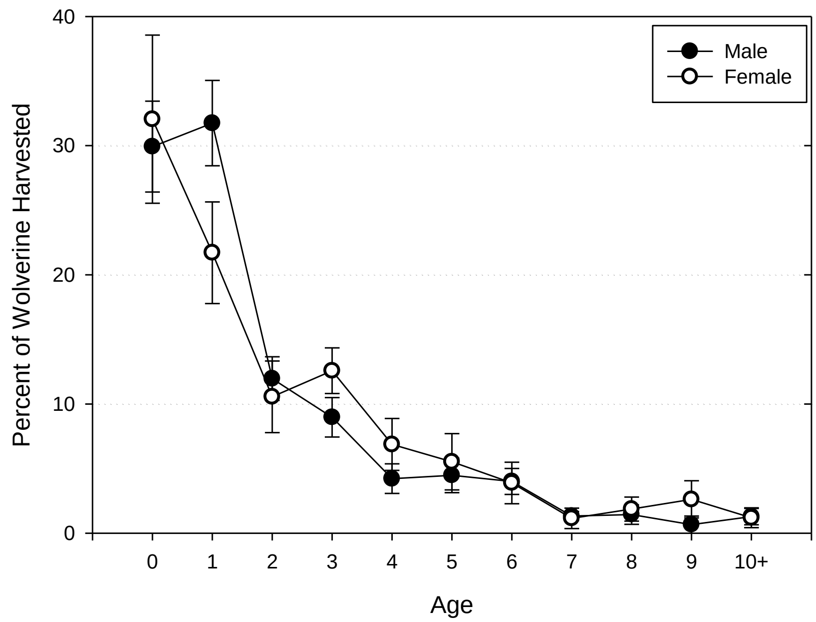

Figure 5. Mean (± SE) age-at-harvest of male (n = 363) and female (n = 182) trapper-killed wolverine (Gulo gulo) in Yukon, Canada, during 7 trapping seasons (2005–2006 to 2011–2012).

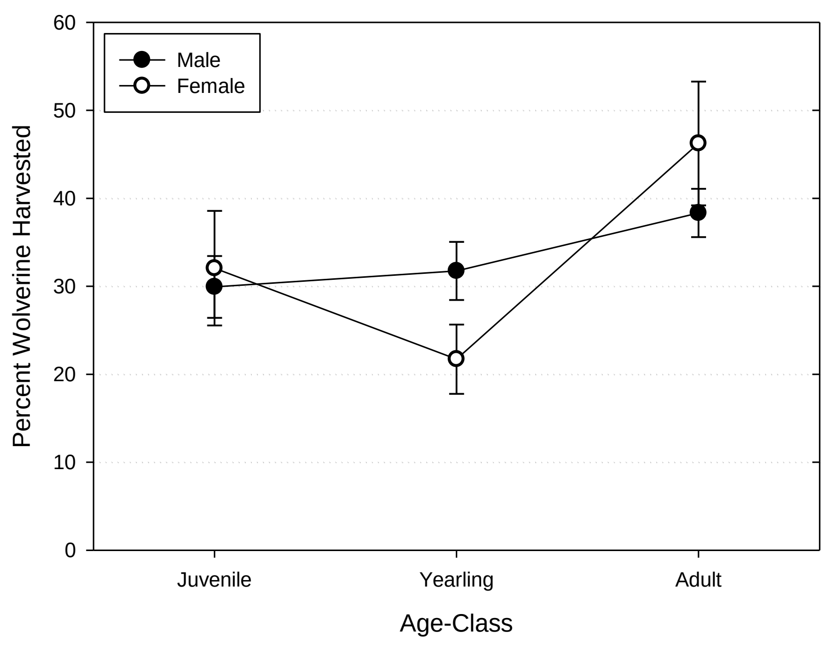

Figure 6. Mean percent (± SE) of wolverine (Gulo gulo) harvested in Yukon, Canada, from different age-classes, during the 2005–2005 to 2010–2011 winter trapping seasons.

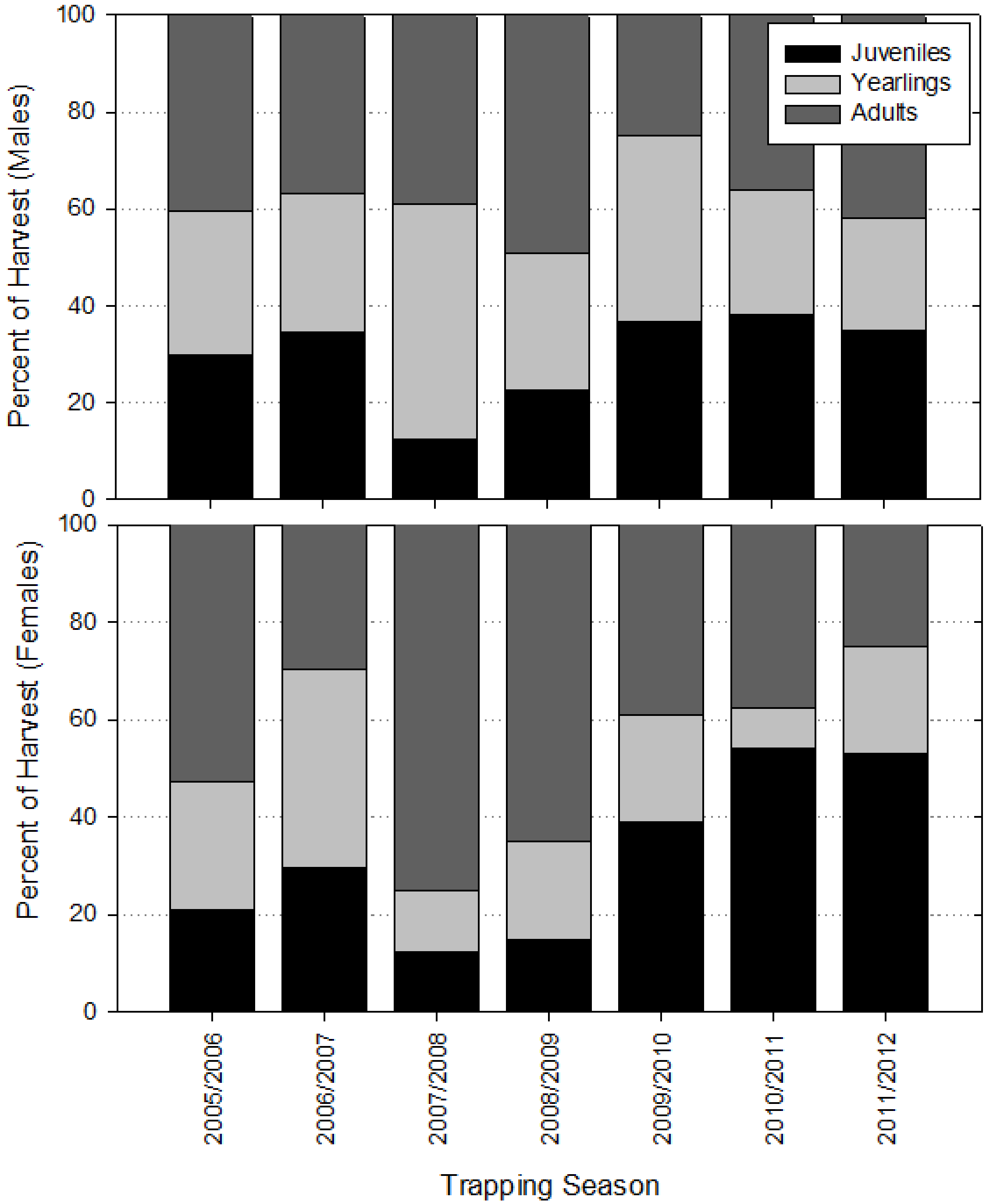

Figure 7. Percent of male (top) and female (bottom) wolverine (Gulo gulo) harvested in Yukon, Canada, from different age-classes, during the 2005–2005 to 2010–2011 trapping seasons.

Wolverine Reproduction

We examined 127 female wolverine for pregnancy status. Pregnancy rate was significantly different between age classes (t_8 = 5.453; P = 0.001), but not trapping seasons (t_2 = -0.615; P = 0.601; Figure 8). The pregnancy rate in the 2008–2009 trapping season was significantly lower than in the other 6 years of our sample (Figure 8). No juvenile females (n = 39) were pregnant, and 79.8 ± 3.1 % adults and 30.8 ± 10.3 % yearlings were pregnant (n = 54 and 27, respectively). Pregnancy rate increased from 0 in wolverine aged <1 year old and peaked in wolverine aged 3–5 years old (Figure 9). Wolverine 6 or more years old had decreased pregnancy rates. Of note, however, the oldest female in our sample was 12.9 years old, and she was pregnant.

Litter size could be discerned from 54 female wolverine carcasses, and ranged from 1 to 4, with most (44%) litters containing 3 fetuses (Figure 10). The mean litter size, as determined from corpora lutea and fetuses observed, was 2.6 ± 0.9 (SD) fetuses.

We found some variability in the estimated date of parturition of female wolverine in our sample, based on crown-rump lengths and mass. Using a range of crown-rump lengths of 121–160 mm, or fetus mass range of 83–108 g (Mehrer 1976, Shilo and Tamarovskaya 1979, Banci and Harestad 1988), it appeared that 8 of 27 (30%) wolverine in our study were very close to giving birth when harvested.

These animals were harvested in the final weeks of the trapping season, in late February or early March (Figure 11). Two wolverines had evidence of giving birth prior to being harvested. These animals were harvested within the last week of the harvest (9 March 2010 and 5 March 2012).

Our observations of wolverine reproductive activity are similar to that found by Rausch and Pearson (1972) and Banci and Harestad (1988) in their earlier studies of reproduction in wolverine from Yukon and Alaska. We also observed no reproductive activity in the first year of life, followed by low pregnancy rates in yearlings and 2 year olds. Most females 3–5 years old were pregnant, and females 6 years old or greater had reduced pregnancy rates. Thus, the reproductive potential of wolverine populations tends to be largely concentrated in the 3–5 year old females. The reasons for the depressed pregnancy rates we observed in 2008–2009 are not known, but could have a large impact on the number of young wolverine available for harvest in the subsequent 2 years. Litter sizes observed by Banci and Harestad (1988) and Rausch and Pearson (1972) were slightly larger (3.2 and 3.5, respectively) than our observations (2.9).

Earlier studies in Yukon and Alaska indicated that most wolverine give birth in February and March (Rausch and Pearson 1972, Banci and Harestad 1988, Magoun and Golden 1998).

We found ample evidence that close to a third of pregnant females harvested in Yukon were close to parturition when harvested, with all of these animals being harvested in late February or early March. Moreover, at least 2 females had given birth prior to being harvested. Banci and Harestad (1988) reported the harvest of 6 post-partum wolverine in their study. They reported that one of these animals was harvested in January and the remaining 5 were harvested in February. The implications of harvesting post-partum females is that it almost assuredly results in the loss of dependent cubs that are likely in their natal den at the time their mother is harvested. Thus, the loss to the population is greater than the one harvested individual.

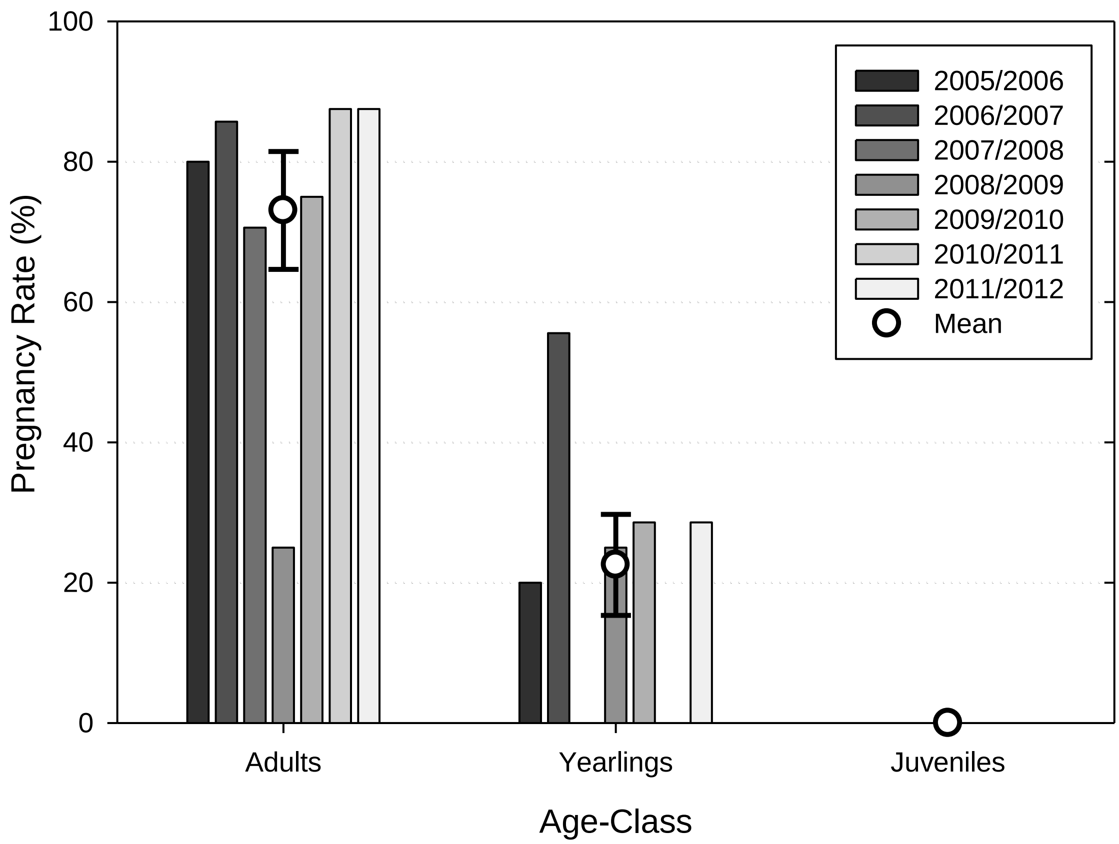

Figure 8. Pregnancy rate by age-class in each trapping season, for wolverine (Gulo gulo) harvested in Yukon, Canada, during the 2005–2006 to 2011–2012 trapping seasons. Bars indicate the percent harvested in each trapping season. Circles are the mean (± SE) percentage of the harvest per age-class.

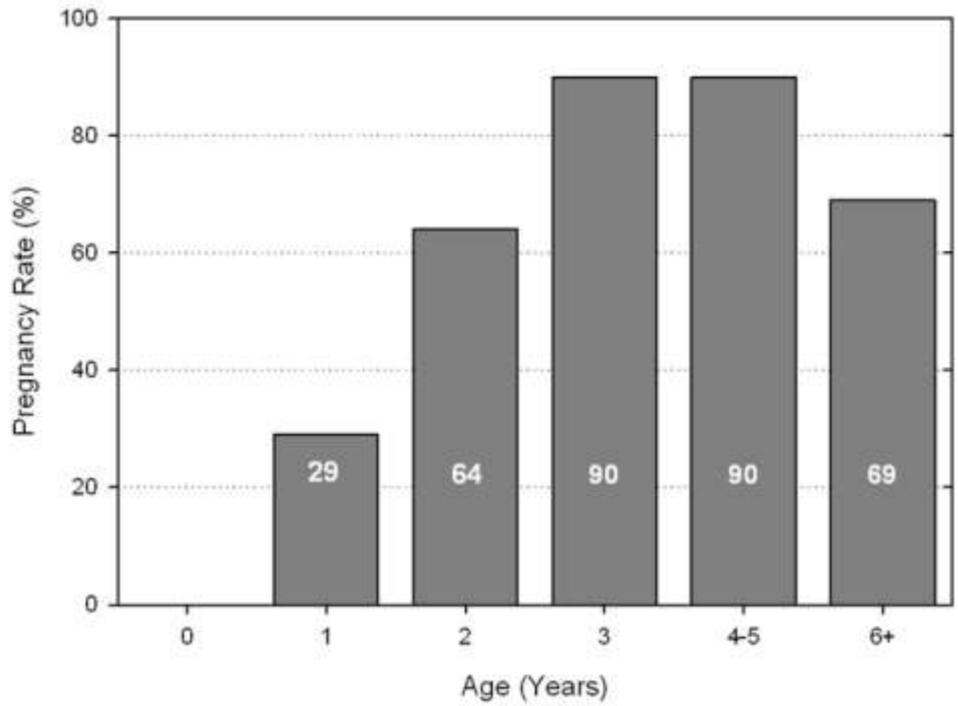

Figure 9. Percent of female wolverine (n = 127) in ages 0 to 6+ that were pregnant or post-partum. Animals in the 4–5 and 6+ age categories were combined due to small sample sizes.

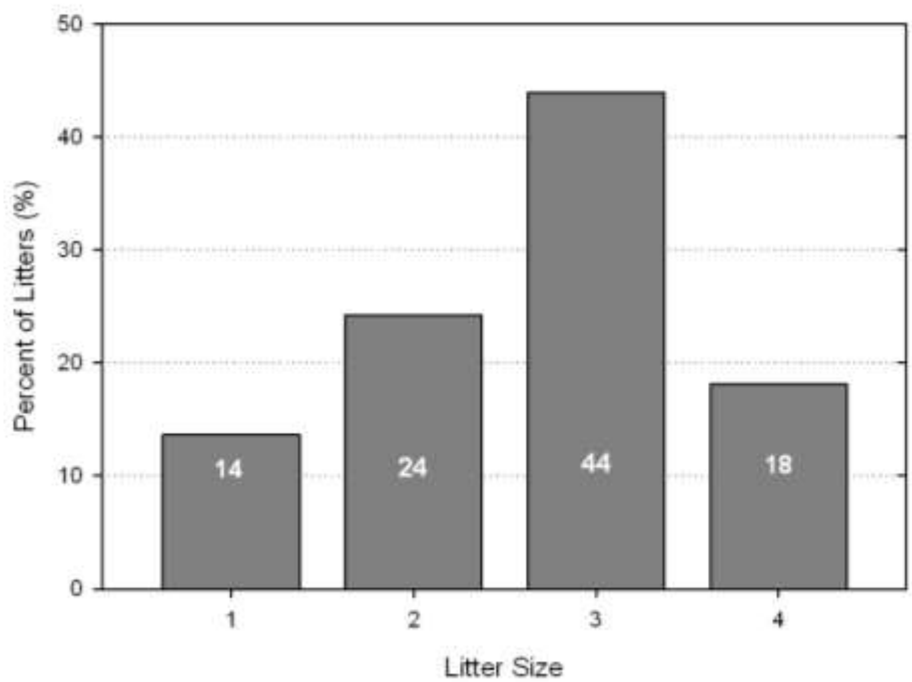

Figure 10. Litter size in wolverine from Yukon, Canada.

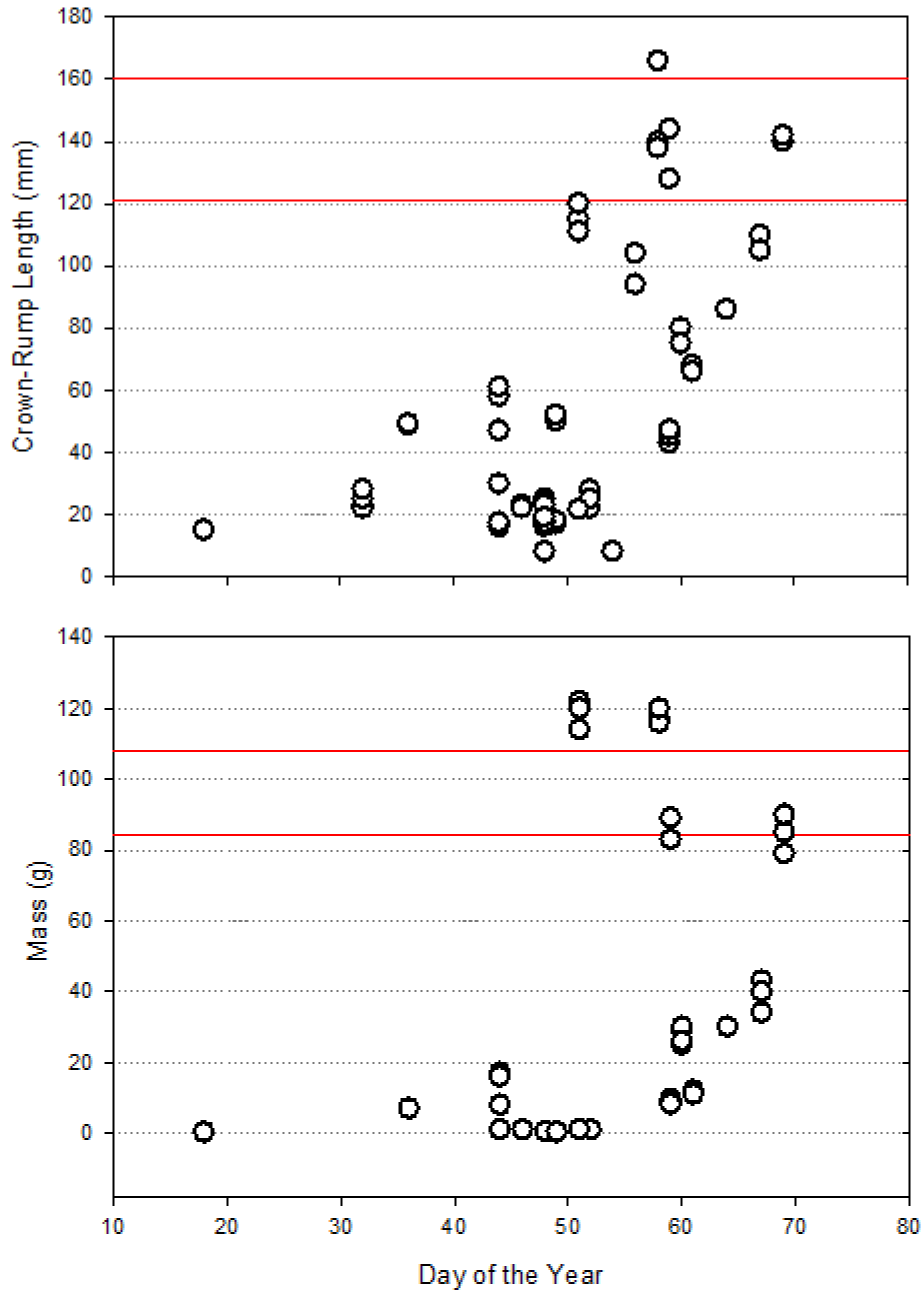

Figure 11. Fetus crown-rump length (mm; top panel) and mass (g; bottom panel) from harvested wolverine (Gulo gulo) from Yukon, Canada. Dashed red lines indicate the observed range of crown-rump length (top panel) and mass (bottom panel) reported for fetuses at birth.

Other: Wolverine Health, Morphometrics, and Diet

Wolverine Health. – At this time, we are only able to report on body condition and screening for rabies. However, samples have been taken to allow for testing for other diseases, parasites and other health-related conditions, as necessary.

Body condition index values varied between years ($F_{6,342}$ = 2.228, P = 0.040) and sex ($F_{1,342}$ = 5.124, P = 0.024), but the interaction term was not significant ($F_{6,342}$ = 1.226, P = 0.292). Thus, male and female wolverine had similar body condition index values in a given year, but these varied by year (Figure 12). This result suggests that there are "good" and "bad" years for wolverine, in terms of their ability to accumulate body fat. Persson (2005) determined experimentally that wolverine reproduction was dependent on late-winter food availability and body condition; during years when body condition is depressed it may be expected that reproduction will also be depressed.

For example, there was a sharp decrease in pregnancy rates in 2008–2009 (Figure 8), which was preceded in 2006–2007 and 2007–2008 by the lowest observed values for body condition (Figure 12).

In conjunction with the Animal Health Unit, 71 wolverine samples were submitted to the Canadian Food Inspection Agency (Ottawa, Ontario) to test for rabies, using the direct fluorescent antibody test of brain tissue. None of the samples submitted were positive. Recently, however, a wolverine in northern Alaska has tested positive for rabies (M. Vanderkop, Government of Yukon, personal communication). Further disease testing and parasite screening of Yukon wolverines may focus on health concerns identified in wolverine populations in neighbouring jurisdictions. These may include viral diseases such as rabies and canine distemper and parasites such as *Trichinella* and *Toxoplasma* (e.g., Dalerum et al. 2008*b*, Reichard et al. 2008*a,b*).

Wolverine Morphometrics. – Basic morphometric data from 488 animals were used to assess the difference in size and growth of wolverine. Wolverines were sexually dimorphic, with significant differences in mean values for all morphometric measures, regardless of age-class (Tables 1 and 2).

Wiig (1989) reported similar sexual size dimorphism in wolverine from Scandinavia.

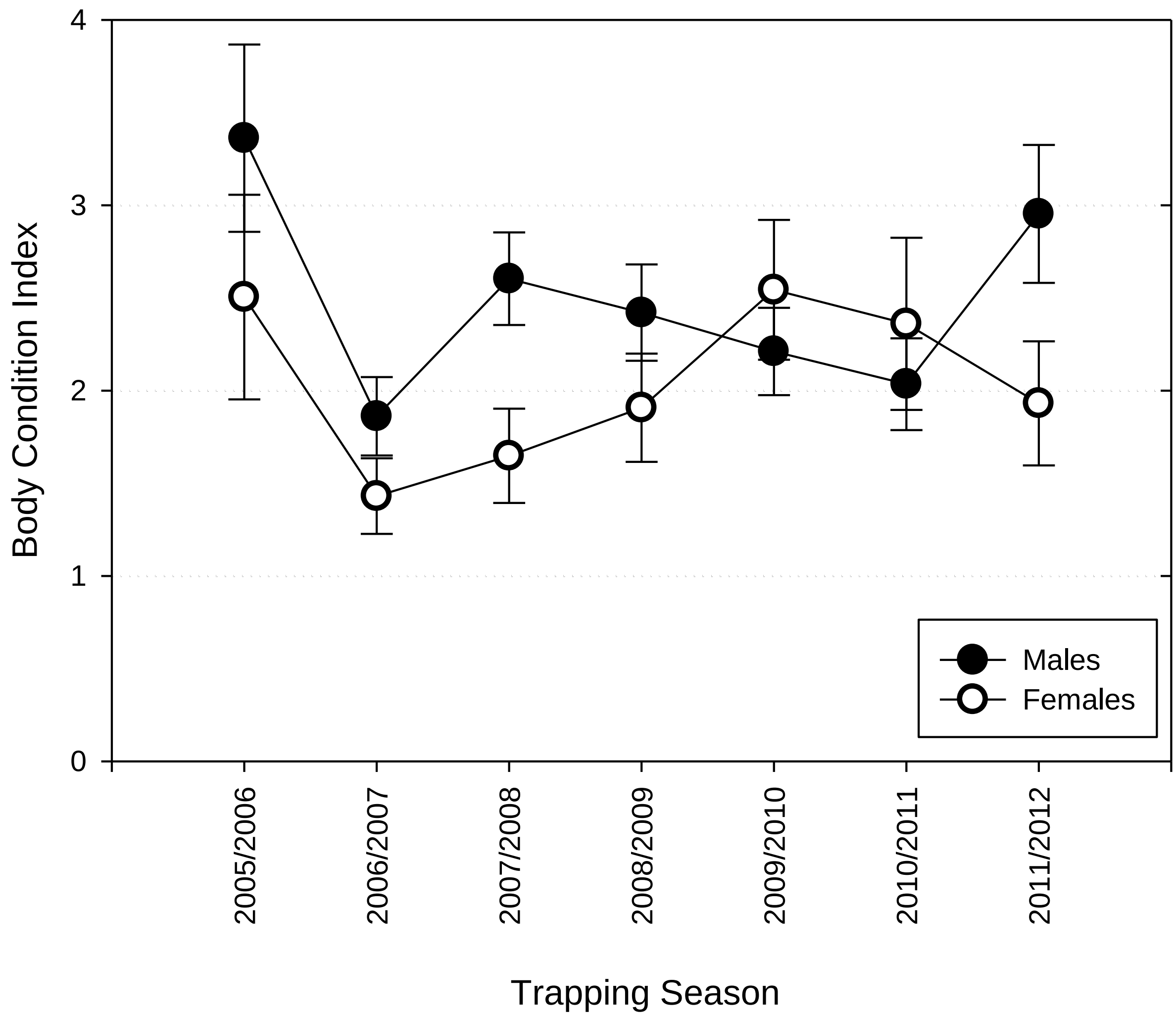

Figure 12. Annual variation in fat content of harvested wolverine, as indexed by a body condition index (see text for details). Data does not include juveniles in the sample.

Table 1. Mean (± SD) of selected morphological values for wolverine (Gulo gulo) collected from Yukon, Canada. Sample sizes are provided in parentheses.

Measurement	Sex	Age-Class		
		Adults	Yearlings	Juveniles
Skinned Mass (kg)	♀	6.9 ± 1.1 (72)	6.8 ± 0.9 (36)	6.6 ± 1.2 (44)
	♂	10.2 ± 1.7 (118)	9.8 ± 1.4 (108)	9.2 ± 1.8 (89)
Neck Circum. (cm)	♀	25.4 ± 2.2 (70)	25.5 ± 2.6 (33)	25.0 ± 2.2 (44)
	♂	30.3 ± 2.7 (118)	29.2 ± 3.0 (108)	28.2 ± 2.6 (89)
Body Length (cm)	♀	82.3 ± 7.6 (71)	82.0 ± 7.3 (35)	85.6 ± 8.5 (44)
	♂	91.2 ± 9.6 (119)	91.0 ± 8.8 (105)	90.1 ± 12.7 (88)
Skull Width (mm)	♀	93.2 ± 3.0 (54)	91.8 ± 3.2 (26)	89.6 ± 3.5 (36)
	♂	104.8 ± 3.6 (86)	101.9 ± 3.6 (70)	98.6 ± 4.3 (68)
Skull Length (mm)	♀	146.9 ± 5.8 (49)	147.2 ± 4.3 (25)	143.6 ± 4.7 (36)
	♂	163.2 ± 5.1 (82)	161.9 ± 5.1 (70)	157.1 ± 6.0 (67)
Femur Length (cm)	♀	13.3 ± 3.9 (62)	13.1 ± 4.1 (25)	13.3 ± 4.5 (39)
	♂	14.6 ± 5.2 (94)	14.6 ± 4.8 (98)	14.4 ± 4.9 (76)
Humerus Length (cm)	♀	12.7 ± 4.2 (62)	12.6 ± 4.0 (25)	12.6 ± 4.0 (39)
	♂	14.1 ± 4.8 (93)	14.1 ± 4.5 (97)	13.9 ± 4.5 (76)

Table 2. F-ratio and P values from general linear models (GLMs) for selected morphological traits for wolverine (Gulo gulo) collected from Yukon, Canada. (Sex = 2 levels: male, female; Age-class = 3 levels: juvenile, yearling, adult).

Measurement	Sex		Age-Class		Sex*Age-Class	
	***F*-ratio**[a]	***P***	***F*-ratio**[a]	***P***	***F*-ratio**[a]	***P***
Skinned Carcass Mass (kg)	419.2	<0.001	7.2	0.001	2.4	0.095
Neck Circumference (cm)	258.8	<0.001	10.0	<0.001	5.4	0.005
Skull Width (cm)	577.8	<0.001	49.9	<0.001	3.7	<0.001
Skull Length (cm)	560.2	<0.001	23.7	<0.001	1.9	0.153
Body Length (cm)	80.9	<0.001	0.1	0.890	1.2	0.305
Femur Length (cm)	633.2	<0.001	1.1	0.347	1.9	0.152
Humerus Length (cm)	782.6	<0.001	2.5	0.081	2.2	0.117

[a] degrees of freedom: sex = 1; age-class = 2; sex*age-class = 1, 2

Skull width, skull length, skinned carcass mass, and neck circumference all differed significantly among age-classes (Tables 1 and 2), regardless of sex. The measures of skeletal size (body length, femur length, and humerus length), however, did not differ among age-classes. These results indicate that wolverines were full-grown after the first 6 months or so of life, but that their skulls continued to grow, and that they had not yet attained their full body size in terms of muscle mass.

There was a significant interaction between sex and age-class for neck circumference and skull width, and a non-significant trend for body mass and skull length (Table 2), indicating that the difference in growth rates for these measures among age-classes was substantially greater for males than females. Non-linear (quadratic) regression was used to examine the relationship between growth and age. A significant regression was found for body mass and neck circumference, with growth increasing in males up to 4 years old and holding stable until about 6 years old, and declining thereafter. No such relationship was found for females, or for the body size measures (body length, and femur and humerus length), which were similar for all animals in our sample.

We used discriminant function analyses (DFA) to discriminate between sexes, based on skull characteristics. Our DFA, using all age-classes pooled, was significant (Wilk's Lambda = 0.382; $F_{2,321}$ = 259.3; $P < 0.001$) and correctly classified 94% of skulls as females and 88% as males (jackknifed classification matrix). When DFA were performed separately for each age-class (based on skull width and length), they were all significant as well, and the percent classified correctly increased for adults and yearlings, but not juveniles. The adult DFA (Wilk's Lambda = 0.247; $F_{2,128}$ = 195.4; $P < 0.001$) jackknife classification was 98% for both males and females. The yearling DFA (Wilk's Lambda = 0.341; $F_{2,89}$ = 85.8; $P < 0.001$) jackknife classification was 91% for males and 96% for females. The juvenile DFA (Wilk's Lambda = 0.412; $F_{2,98}$ = 69.825; $P < 0.001$) jackknife classification was 88% for males and 94% for females. These results are of interest because they confirm the observation by Flook and Rimmer (1965) that wolverine can be sexed based on skull measures with reasonable accuracy.

Further work on wolverine morphometrics from our sample will be conducted by Memorial University and Laurentian University, with an aim of better understanding sexual differences in growth and development in wolverine.

Winter Diet.– Diet is being investigated based on stable isotope characteristics (lead by the Carnivore Program) and stomach content analyses. Several students have been working on determining the diet of wolverine in Yukon from stomach contents (see Appendix). Interestingly, early results suggest that snowshoe hare (*Lepus americanus*) are a prominent feature in the winter diet of wolverine in Yukon (Kotipelto 2009, Blais 2011). This is in contrast to diet studies elsewhere which did not identify snowshoe hare as an important prey item (e.g. Magoun 1987, Lofroth et al. 2007). However, Banci (1987) noted in an earlier study that wolverine in Yukon ate snowshoe hare.

The implications of snowshoe hare being a prominent item in the diet of wolverine are 2-fold. First, it signals that perhaps we need to reconsider the long-standing classification of wolverine as a facultative scavenger (e.g. Myhre and Myrberget 1975, Magoun 1987, Lofroth et al. 2007, van Dijk et al. 2008, Dalerum et al. 2009), at least in some landscapes.

That is not to say that Yukon wolverine did not rely primarily on scavenging caribou and moose in winter – they did, but in some years they also made extensive use of snowshoe hare, which they likely hunted. Predation may be an important mode of securing food for some wolverine populations (e.g. Landa et al. 1999). Secondly, it is well established that snowshoe hare populations fluctuate on a 9–11 year cycle, including in Yukon (e.g. Boutin et al. 1995). If wolverine diet in Yukon is linked to the snowshoe hare cycle, then it follows that their populations may also oscillate to some degree, in tune with the snowshoe hare cycle. Data from the annual Yukon trapper questionnaire seems to confirm that there is a positive relationship between wolverine and snowshoe hare abundance (Jung et al., unpublished data). This has direct management implications: it may be that fewer wolverines are available for harvest in years that snowshoe hare are in the low-phase of their cycle. Moreover, trapping effort required to harvest wolverine may vary in response to the snowshoe hare cycle. On one hand, fewer wolverines on the landscape may require more effort from trappers to harvest a somewhat consistent number of wolverine each year. Alternatively, wolverine may have trouble securing food and are more readily trappable in years when snowshoe hares are scarce. In either case, the sustainability of the wolverine harvest may vary in response to snowshoe hare abundance.

A compilation of our 7 years of diet investigation is underway by Laurentian University.

However, more work is needed to determine the winter diet of wolverine in Yukon, particularly in relation to the snowshoe hare cycle and associated harvest management implications. It would be informative to examine wolverine diet throughout an entire cycle of snowshoe hare.

Management Implications and Recommendations

Population, Harvest, and Health Monitoring

Our experience thus far, as well as that from neighbouring jurisdictions, has amply demonstrated that carcass collection programs can provide a very cost-effective means of monitoring wolverine harvest and health. During the course of this project we were able to procure a large and representative sample of the wolverine harvest, thanks to the interest and cooperation of many Yukon trappers.

The project has provided some initial evidence that there is annual variation in body condition, the percent of pregnant females in the population, the percentage of adult females harvested, and that these may all be linked. The percentage of adult females in the harvest in some years was unexpected and somewhat concerning from a harvest sustainability perspective.

A better understanding of, and monitoring for, these annual changes can inform wolverine harvest management, including population modeling. This is particularly important if there is a future need to more closely regulate the number of wolverine harvested in some years or areas. More immediately, it provides a strong basis from which wildlife managers can use easily generated, quantitative information to communicate with trappers on changes they may predict in the annual availability of wolverine (harvest of wolverine in variable from year-to-year, see Figure 13).

Additional messages to trappers based on monitoring data my include the benefits of voluntarily reducing wolverine trapping effort in some years to avoid harvesting a large percent of adult females, or allow local populations to rebuild from year(s) of low reproduction.

Another area where the project has provided a significant finding of potential management interest is on the timing of the harvest in relation to wolverine parturition. We found that close to a third of the adult females harvested were very close to giving birth – and a few already had – when harvested. Harvesting females with dependent cubs in a den is a concern because the loss to the population is compounded. In addition, for some people, harvesting females with young is an ethical consideration (e.g. Parker and Rosell 2001).

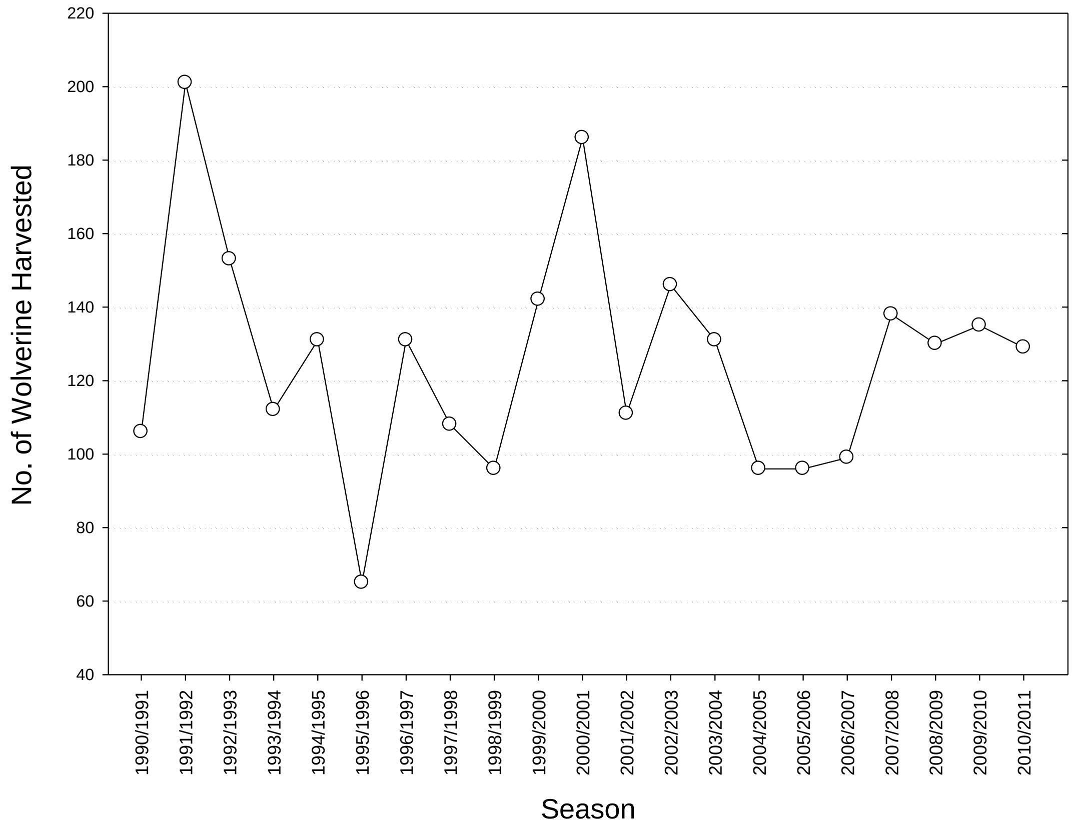

Figure 13. Annual variation in the harvest of wolverine from Yukon, 1990–1991 to 2010–2011.

Our data suggest that ending the wolverine harvest in late-February, rather than mid-March, would reduce the take of adult females that are close to parturition or post-partum. Most wolverine, however, are taken in January and February so the impact to trappers may be negligible (see Figure 2). Changes to the wolverine trapping season to protect females in the late stages of pregnancy and those with dependent cubs is also a consideration in the Northwest Territories (R. Mulder, Government of Northwest Territories, personal communication).

As an ancillary benefit, the wolverine carcass collection program provides an unparalleled opportunity to provide a wide spatial and temporal sample for testing for diseases of concern in Yukon carnivores.

Prevalence of diseases and parasites, such as *Trichinella*, *Toxoplasma*, rabies, canine distemper and parvovirus are of interest to assess and monitor, and wolverine carcasses can be incidentally used to collect reasonable large samples for testing on an annual basis.

A less tangible benefit of the wolverine carcass collection program is that it provided an opportunity for wildlife managers and some trappers to share information.

Like biologists, many Yukon trappers are very interested in learning more about the animals they focus on, and biologists and trappers can learn much from one another about wolverine by discussing findings from the carcass collection program.

Data from Yukon's wolverine carcass collection programs and similar programs in the Northwest Territories and Nunavut could be compared to allow for a pan-Northern assessment of the status of wolverine.

Assessing Harvest Sustainability

The main thrust of our carcass collection program is to provide a means of assessing the sustainability of wolverine harvest in Yukon. Given their global conservation concern, coupled with naturally low densities and relatively high harvest numbers, assessing the sustainability of wolverine is of particular interest to wildlife managers across the species range, including in Scandinavia (Saether et al. 2005), British Columbia (Lofroth and Ott 2007), and Alaska (Dalerum et al. 2008*a*). Such assessments, however, are difficult in many areas because they traditionally rely on knowing wolverine density or abundance, which are difficult information to obtain.

Methods to inventory wolverine include aerial survey (Golden et al. 2007, Magoun et al. 2007), mark-recapture studies using DNA obtained from hair snagging grids (Mulders et al. 2007), and camera traps (Magoun et al. 2011, Royle et al. 2011). However, these methods are time-consuming and expensive, particularly for remote areas with poor access.

Virtual population assessment (VPA; also known as cohort analyses) is a population modeling approach that was developed in marine fisheries where the only reliable data available for stock assessment was the catch (harvest) data (Pope 1972, Lassen and Medley 2001). This approach simply requires that information on a random sample of the age and sex of harvested animals each year is recorded, and that the total annual harvest is known. The model then backcasts (as opposed to forecast) the estimated population size in each year that data is available. It is a form of statistical population reconstruction (e.g. Skalski et al. 2007, 2011). As such, it is not used to forecast or predict the effect of potential future scenarios or management actions, such as is commonly done in a population viability assessment (PVA; e.g. Beissinger and Westphal 1998). Rather, the approach is to estimate the population size in previous years and evaluate whether the harvest has been sustainable and how changes in management may have affected harvest sustainability (Fryxell et al. 2001).

The main advantage of this approach is that it is cost-efficient and utilizes hunter-submitted samples – no additional field data collection is necessary. The disadvantage is that VPA requires a time series of data that extend beyond the span of one cohort of the population being studied, which would be the life span of an individual in the population (i.e. about 12 years for wolverine).

Using the data from the carcass collection program and overall harvest information for wolverine, this modelling approach holds great potential for answering the question of whether the Yukon harvest of wolverine is sustainable. It may also assist in evaluating changes in management strategies, if they occur. The VPA approach has only recently been used in wildlife management. The approach has been successfully used to answer important moose management questions in Newfoundland (Fryxell et al. 1988, Ferguson 1993) and Scandinavia (Solberg et al. 1999, 2000; Sæther et al. 2001; Uneo et al. 2009), as well as for marten (*Martes americana*) in Ontario (Fryxell et al. 2001) and lynx (*Lynx lynx*) in Norway (Nilsen et al. 2011), where long (≥15 years) time series of harvest data were available. Indeed, statistical reconstruction of populations to assess harvest management is currently an active area of research effort (e.g. Gove et al. 2002; Skalski et al. 2007, 2011; Millspaugh et al. 2009); it may become a method more relied upon in the future to formally assess harvest sustainability.

Yukon has one of the largest harvests of wolverine in the world, and while international trade in this species is not regulated under CITES (Convention on the International Trade in Endangered Species) it may become so, given their current listing as an endangered species in the EU and USA, where trade is already regulated.

Ensuring that we can quantitatively assess the sustainability of the Yukon harvest of wolverine should be a primary goal of a wolverine monitoring in Yukon. A virtual population analysis provides an opportunity to do so with minimal expense and effort. A minimum of 12 years of data of the age and sex of harvested wolverine are necessary to statistically reconstruct the population and assess harvest sustainability. The wolverine carcass collection program provides an initial 7 years of age-at-catch data that can form a solid basis for developing a database suitable for conducting a VPA. The analysis would be significantly strengthened if harvest effort is known, but it is not necessary.

Factors Affecting Harvest

In addition to monitoring the population and harvest, and assessing the sustainability of the harvest, another facet of wolverine harvest management that could be useful is a more fulsome understanding of the spatial and temporal trends in harvest.

An analysis of harvest trends should quantitatively assess factors that may influence harvest numbers, such as ecological (e.g. prey availability), environmental (e.g., weather, topography), and socio-economic (e.g. economic indicators) factors.

A better understanding of what factors drive harvest numbers from year-to-year may be useful in exploring means to guide trapping effort, where necessary. Similar analyses have recently been done for wolves (*Canis lupus*) in Alberta (Robichaud and Boyce 2010), bobcat (*Lynx rufus*) in Minnesota (Kapfer and Potts 2012), and wolverine in Alaska (Golden et al. 2007), for example. These studies have shown how powerful these analyses can be for better understanding the harvest of those species in those jurisdictions.

Excellent harvest data for wolverine in Yukon exist from 1981 to present, allowing a long time series to conduct analyses similar to that done by others (e.g. Golden et al. 2007, Robichaud and Boyce 2010, Kapfer and Potts 2012). A project on assessing the spatial and temporal trends of wolverine harvest in Yukon is currently being conducted by the University of Alberta. This study will explore socio-economic (e.g. pelt prices, gas prices) and environmental factors (e.g. hare cycle, snow accumulation, climate) as predictors of wolverine harvest in Yukon.

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Appendix: Outreach and Other Products

This appendix provides a listing of various communication products and initiatives undertaken.

School Group Presentations:

At least 2 presentations and demonstrations on the program and wolverine necropsies have been made to the Renewable Resource program students at Yukon College.

At least 4 presentations and demonstrations on the program and wolverine necropsies have been made to high school science class students.

Peer-reviewed Journal Papers:

Robitaille, J.-F., and T. S. Jung. in preparation. Variation in the winter body condition of wolverine (*Gulo gulo*) from northwestern Canada.

Oakley, M. P., T. S. Jung, M. Vanderkop, and J.-F. Robitaille. in review. Prevalence of nephrolithiasis in free-ranging wolverine (*Gulo gulo*) from Yukon.

Robitaille, J.-F., L. Villano, T. S. Jung, H. P. Slama, and M. P. Oakley. 2012. Fat dynamics and development of body condition indices for harvested populations of wolverine (*Gulo gulo*). Wildlife Biology 18: 35–45.

Student Thèses:

Blais, Angélique. 2011. Le régime alimentaire hivernal du carcajou (*Gulo gulo*) pendant les années 2010 et 2011 au Yukon. B.Sc. Honour's Thesis. Laurentian University, Sudbury, Ontario.

Conaty, Kathleen E. 2010. Ovulation rates in harvested wolverines, *Gulo gulo*, of the Yukon. B.Sc. Honour's Thesis. Laurentian University, Sudbury, Ontario.

Kotipelto, Mark. 2009. Le régime alimentaire du carcajou, *Gulo gulo*, au Yukon. B.Sc. Honour's Thesis. Laurentian University, Sudbury, Ontario.

Villano, Liane. 2008. Development of an index of physical condition in wolverine, *Gulo gulo*, using fat contents. B.Sc. Honour's Thesis. Laurentian University, Sudbury, Ontario.

Conference Presentations:

Robitaille, J.-F., T. S. Jung, and M. Kotipelto. April 2011. The relative importance and implications of snowshoe hare (*Lepus americanus*) in the winter diet of wolverine (*Gulo gulo*). 13th Northern Furbearer Conference: Whitehorse, Yukon. (Oral)

Robitaille, J.-F., L. Villano, T. S. Jung, M. P. Oakley, and H. Slama. April 2011. Trimming the fat: indices to estimate nutritional condition in harvested populations of wolverine (*Gulo gulo*). 13th Northern Furbearer Conference: Whitehorse, Yukon. (Poster)

Jung, T. S., J.-F. Robitaille, and M. Kotipelto. April 2010. The importance and implication of Snowshoe Hare (*Lepus americanus*) in the winter diet of Wolverine (*Gulo gulo*). Yukon Biodiversity Forum: Yukon College, Whitehorse, Yukon. (Poster)

Robitaille, J.-F., L. Villano, T. S. Jung, M. P. Oakley, and H. Slama. June 2009. Trimming the fat: indices to estimate nutritional condition in harvested populations of wolverine (*Gulo gulo*). 89th Annual Conference of the American Society of Mammalogists: University of Alaska Fairbanks, Fairbanks, Alaska. (Poster)

Jung, T. S., J.-F. Robitaille, M. P. Oakley, H. Slama, P. M. Kukka, R. Maraj, L. Villano, M. Kotipelto, M.-A. Durocher, and R. S. Rivard. April 2009. Natural history and status of an elusive carnivore: an overview of the wolverine carcass collection program. Yukon Biodiversity Forum: Yukon College, Whitehorse, Yukon. (Poster)

Robitaille, J.-F., L. Villano, M. P. Oakley, T. S. Jung, and H. P. Slama. November 2007. Indices des réserves énergétiques chez le carcajou, *Gulo gulo*. 32nd Annual Société Québécoise pour l'Étude Biologique du Comportement Congress: Université Laval, Québec. (Poster).

Robitaille, J.-F., M. Oakley, T. S. Jung, and H. Slama. April 2007. Indices to estimate fat deposits in wolverine, *Gulo gulo*. The Wildlife Society Annual Conference (Alaska Chapter): University of Alaska Southeast, Juneau, Alaska. (Poster).