

Assessment of the Sustainability of Wolverine Harvest in British Columbia, Canada

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ABSTRACT Wolverines (*Gulo gulo*) are distributed across much of northern and western Canada and Alaska, USA, and they extend south into the mountainous western United States. Wolverines occur in most regions of British Columbia, Canada, with the highest population densities occurring in the interior mountainous areas. Wolverine populations in British Columbia have been primarily managed to provide a sustainable harvest for trappers and hunters. We used spatially based population estimates, population vital rate data, and spatially based harvest data to evaluate the sustainability of wolverine harvest (trapping and hunting) from 1985 to 2004. The median annual provincial wolverine harvest from 1985 to 2004 was 172 wolverines per year ($\bar{x} = 174.8$), which was less than the median simulated estimate of provincial recruitment (195.9 wolverines/yr; $\bar{x} = 209.7$). Harvests in individual population units ranged from 0 to 280 over the 20-year period. Spatially, wolverine harvest was likely to have been unsustainable in 15 of the 71 population units with wolverines, and it was likely to have been sustainable in the remaining population units. Harvest in 5 of the other 56 population units was marginally sustainable and thus of potential management concern. To improve harvest management of wolverines in British Columbia, wildlife managers should focus on improved data collection and monitoring at a provincial scale, and they should work with trappers and hunters at regional scales to address issues specific to individual population units. Further research is required to improve the reliability of wolverine vital rate and population data. (JOURNAL OF WILDLIFE MANAGEMENT 71(7):2193–2200; 2007)

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Wolverines (*Gulo gulo*) are currently distributed across much of northern and western Canada and Alaska, USA, and south into the mountainous western United States (Hash 1987, Banci 1994). This is substantially reduced from historic distributions (van Zyll de Jong 1975, Banci 1994, Aubry et al. 2007). Within extant wolverine range, genetic analyses suggest more pronounced population fragmentation in southern than in northern populations (Kyle and Strobeck 2001). Similar reductions in range have been documented in other parts of the wolverines' circumboreal range (Landa et al. 2000). Reasons for these range reductions are not completely understood, but they may include changing environmental conditions, changing food resources, human settlement and associated activity, harvesting, and persecution (Banci 1994, Clark et al. 1996, Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2003, Aubry et al. 2007). In the face of increasing pressures on wolverines and their habitat, an understanding of the relationship between these pressures and wolverine demographics is critical to effective conservation and management of this carnivore (Ruggiero et al. 1994, Weaver et al. 1996).

Wolverines' resilience to external pressures may be limited by their low densities, large home ranges, and low reproductive capacity (Weaver et al. 1996, Krebs et al. 2004, Sæther et al. 2005, Persson et al. 2006). Improved understanding of the effects of harvest on wolverine populations is key to understanding the effects of one stressor. In an analysis of survival rates for North American wolverines, Krebs et al. (2004) concluded that human-caused mortalities were not compensated by reductions in

natural mortalities and that sustainable harvests may depend on the establishment of refugia as source populations. Krebs et al. (2004) also demonstrated that, in areas with wolverine harvest, males (especially subadults) had lower survival than females, and they concluded that spatially explicit harvest planning and evaluation (McCullough 1996) were important components of a sustainable harvest system.

Wolverines in western Canada are considered a Species of Special Concern by COSEWIC (2003) and identified as a candidate for becoming threatened or endangered. Wolverines occur in most regions of British Columbia, with highest predicted population densities in the interior mountainous areas (Lofroth and Krebs 2007). Wolverines in mainland British Columbia (*G. g. luscus*) are blue-listed (Province of British Columbia 2005a) because they may be particularly sensitive to human activities or natural events and thus deserving of special management attention. The existence of the Vancouver Island wolverine (*G. g. vancouverensis*; red-listed) is uncertain. Provincial conservation lists (red and blue) are priority setting tools, and they confer no legal protection. By current policy, red-listed organisms are not harvested. Wolverine populations in British Columbia are contiguous to those in adjacent jurisdictions of Canada and the United States. Management of wolverines in British Columbia will likely influence wolverine populations in those jurisdictions and vice versa.

Wolverines are managed as a commercial furbearer species in British Columbia (Hatler 1989), and they have been harvested commercially for nearly 2 centuries (Novak et al. 1987). Annual harvest of wolverines has ranged from 40 to 634 since 1919 (Fig. 1). Management objectives include the conservation of the species across its current and historic

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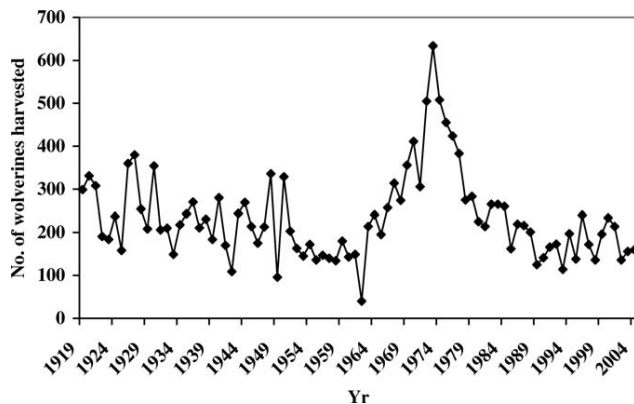


Figure 1. Annual wolverine harvests for British Columbia, Canada (1919–2004).

range in the province and the management of populations to provide a sustainable harvest for trappers and hunters.

British Columbia has a registered trapline system that confers the exclusive right to the trapline tenure owner to trap furbearers on a specified land base. The province has approximately 2,800 registered traplines. Wolverines are harvested by licensed trappers during regulated trapping seasons. Wolverines are also classified as small game and can be hunted during regulated seasons by licensed resident and nonresident hunters. Wolverine harvests are managed through the timing and length of trapping and hunting seasons and by annual bag limits for hunters. Timing and length of seasons vary geographically. Trapping seasons open 1 November and close between 31 January and 28 February. Hunting seasons open between 15 September and 15 October and close between 15 January and 31 January (Province of British Columbia 2005b). Trapping and hunting seasons exist for wolverines for the entire province, except for the Vancouver Island, Lower Mainland, and Okanagan regions and the Queen Charlotte Islands. Since 1985, total wolverine harvest has been reported at the level of the registered trapline, by licensed fur traders because furs are purchased from trappers and by government agents through royalty payments. In some regions, compulsory reporting of additional information for all wolverines harvested, including sex and age class, is required of trappers. To collect these data, hunters are required to have harvested wolverines inspected by government-approved inspectors.

To understand better the effect of harvest on wolverine populations, we use simulation modeling to evaluate the sustainability of wolverine harvest (trapping and hunting) in British Columbia from 1985 to 2004. We use spatially based population estimates, published population vital rate data, and spatially based harvest data to model net recruitment rates for wolverines and to identify population units that may warrant management attention.

STUDY AREA

British Columbia is a large (980,000 km²), ecologically diverse Canadian province with environments that range

from temperate coastal rain forest to interior deserts (Meidinger and Pojar 1991). Wolverines inhabit this landscape with 7 other medium and large carnivores (Nagorsen 1990) and substantial populations of 14 species of ungulates (Shackleton 1999).

METHODS

We divided British Columbia into 74 population units to facilitate the spatial evaluation of harvest (Fig. 2). We adapted population units from those used to assess grizzly bear (*Ursus arctos*) populations and harvest (Hamilton et al. 2004). The grizzly bear population units were established to identify similar ecotypes and subpopulations, and they were primarily based on watersheds or groupings of watersheds. We used features that potentially impeded dispersal (human settlement, transportation corridors, and large hydroelectric reservoirs) to delineate population units where appropriate. These impediments were more prevalent in the southern part of the province; therefore, population units in the south tended to be smaller than those in the north. Mean population unit size was 12,800 km² (range 2,690–47,080 km²). We estimated wolverine population size for each population unit using methods described by Lofroth and Krebs (2007).

We used survivorship estimates ($\bar{x}$, SE) for adults (0.88, 0.06) and subadults (0.85, 0.08) reported by Krebs et al. (2004) and juveniles (0.68, 0.06) reported by Persson et al. (2003). We set the age at first reproduction constant at 3 years (Magoun 1985, Banci and Harestad 1988, Copeland 1996, Persson 2003), and we applied a reproductive rate (0.397, 0.05) based on reported rates of Magoun (1985), Copeland (1996), and Persson (2003). We assumed an underlying normal distribution to these parameters, and we used the normal distribution randomization component of PopTools, version 2.7.5 (Commonwealth Scientific and Industrial Research Organization, Canberra City, Australia) to simulate each variable 5,000 times. For each realization, we estimated wolverine population growth rate by solving for lambda (λ) in the (cubic) Lotka equation (Eberhardt and Siniff 1977). We randomly simulated 5,000 estimates of population size (N) for each population unit assuming that each unit's estimate of $N^{-1\beta}$ was normally distributed (Sprott 1981). For each realization, we estimated annual recruitment (R) by multiplying λ by the population estimate. To reflect real recruitment, we assigned a rate of zero to negative values ($R = \max[N \cdot \lambda, 0]$).

We obtained spatially and temporally explicit data on total wolverine harvest and sex of a sample of harvested wolverines for the period from 1985 to 2004 by population unit from the British Columbia Wildfur, Compulsory Inspection, and Compulsory Reporting Data systems. Harvest data for 1 year (e.g., 1985) represented all known harvest from July 1985 to June 1986. For each population unit, we obtained bootstrapped estimates of the harvest (H) by randomly drawing one value from the harvest data 5,000 times. We calculated estimates of annual net recruitment (NR) for each population unit by subtracting H from R for

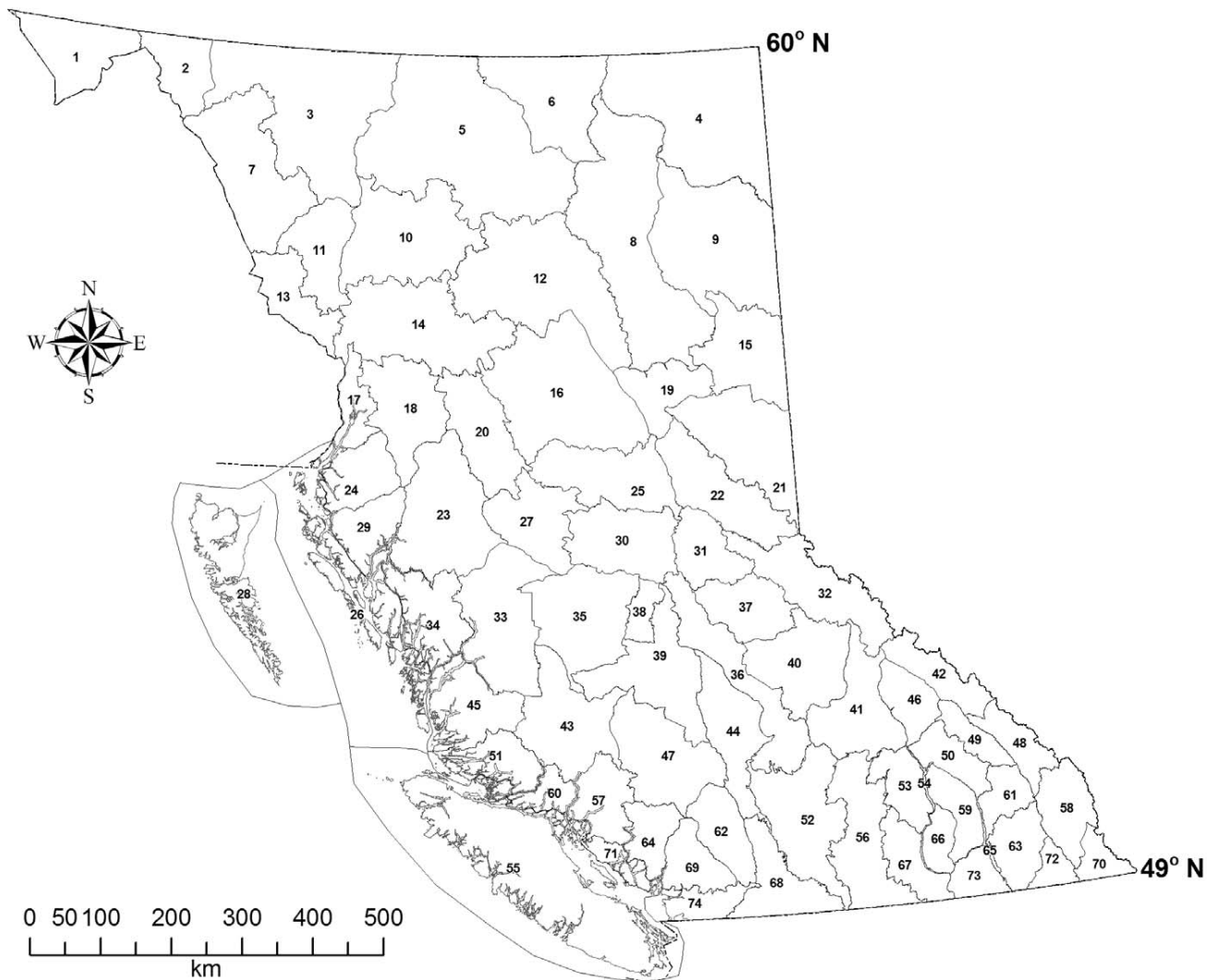


Figure 2. Wolverine population management units in British Columbia, Canada (2007).

each realization ($NR = R - H$). We reported median net recruitment rates for each population unit and for the province as a whole. To estimate the probability of overharvest for each population unit, we calculated the proportion of simulations with $NR < 0$ from the distribution of net recruitment estimates. For those population units where harvest was likely unsustainable (e.g., $>50\%$ of simulations had $NR < 0$, or equivalently the median NR was negative), we evaluated the relative severity of harvest by calculating the ratio of mean harvest to mean recruitment ($(\bar{R} - \overline{NR})/\bar{R}$).

We compared the effects of temporally asymmetric harvest on wolverine populations by simulating population growth for 20 years. We used mean population estimates and mean growth rate, for both reported and mean annual harvest, to build a simple model of population growth ($N_{t+1} = N \cdot \lambda - H$). We conducted this analysis on 10 population units 1) whose mean net recruitment rates were less than median net recruitment rates and 2) for which this difference was $>10\%$ of mean recruitment for that unit. We expected

these units to demonstrate best the effect of temporally asymmetric harvest on population growth, because they represented the most skewed distributions of simulated recruitment rates.

RESULTS

Population estimates (N) for individual population units ranged from 0 to 268 wolverines, and they were dependent on capability ratings and population unit size (Table 1). We eliminated 3 population units from any further analyses, because they had population estimates and harvests of zero (Queen Charlotte Islands, Arrow Lakes, and Kootenay Lakes).

We estimated mean population growth rate ($\bar{\lambda}$) at 1.06 ($SE = 0.06$; Fig. 3). Median R for population units ranged from 0.02 (Cariboo Basin Pavillion) to 15.71 (Muskwa) wolverines (Table 2). Median annual recruitment for the province as a whole was estimated to be 195.93 wolverines ($\bar{x} = 209.7$). Annual recruitment for each population unit was ≤ 0 in 16% of the recruitment realizations.

Table 1. British Columbia, Canada, wolverine population estimates ($\bar{x}$ 95% CI) and total reported wolverine harvest (1985–2004) by population unit.

Population unit	Unit no.	$\bar{x}$	95% CI	Wolverine harvest		
				Trapping	Hunting	Total
Tatshenshini	1	32	25–44	40	0	40
Tagish	2	33	24–46	70	1	71
Cassiar	3	208	144–316	181	6	187
Taiga	4	106	76–153	76	1	77
Muskwa	5	268	192–388	209	0	209
Hyland	6	89	67–122	76	2	78
Taku	7	78	60–104	73	0	73
Rocky	8	191	144–260	273	7	280
Alta	9	116	78–183	98	6	104
Spatsizi	10	132	91–203	123	5	128
Edziza	11	51	37–74	34	1	35
Finlay-Ospika	12	185	127–284	96	0	96
Lower Stikine	13	13	9–21	34	0	34
Upper Skeena-Nass	14	134	93–202	72	6	78
Lower Peace	15	25	16–41	18	0	18
Omineca	16	168	120–246	107	3	110
Stewart	17	10	7–15	9	1	10
Cranberry	18	71	52–101	77	1	78
Moberly	19	45	31–68	84	6	90
Babine	20	62	46–84	38	3	41
Hart	21	101	73–146	128	3	131
Parsnip	22	80	59–113	94	3	97
Bulkley-Lakes	23	93	70–126	118	8	126
Khutzeymateen	24	23	18–31	37	2	39
Nation	25	56	38–89	62	0	62
Outer Coast	26	6	2–28	0	0	0
Francois	27	44	29–70	92	0	92
Queen Charlotte Islands	28	0		0	0	0
North Coast	29	13	9–21	23	3	26
Nulki	30	45	32–66	48	0	48
Bowron	31	34	24–49	19	0	19
Robson	32	84	60–124	171	3	174
Tweedsmuir	33	77	58–103	18	2	20
Kitlope-Fiordland	34	18	12–32	0	2	2
West Chilcotin	35	48	34–70	65	0	65
Caribou Plateau	36	26	17–42	6	1	7
Quesnel Lake North	37	45	34–61	41	0	41
Blackwater	38	7	4–12	6	0	6
Southwest Chilcotin	39	19	12–34	13	0	13
Wells Gray	40	71	53–98	42	0	42
Columbia-Shuswap	41	58	44–78	51	1	52
Central Rockies	42	36	25–53	30	1	31
Klinaklini-Homathko	43	36	27–50	5	0	5
Caribou Basin Pavillion	44	0	0–1	8	0	8
Kwatna-Owikenno	45	16	9–31	0	0	0
North Selkirk	46	34	24–52	48	5	53
South Chilcotin Ranges	47	45	32–66	79	2	81
Rockies Park Range	48	31	22–45	28	0	28
Spillimacheen	49	20	15–29	40	0	40
North Purcell	50	32	22–49	30	0	30
Kingcome-Wakeman	51	10	6–19	0	0	0
South Thompson Nicola	52	5	2–16	3	0	3
Central Monashee	53	30	23–41	15	0	15
Arrow Lakes	54	0		0	0	0
Vancouver Island	55	9	0–35	0	0	0
Okanagan	56	11	7–16	3	0	3
Toba-Bute	57	12	7–34	1	0	1
Southern Rockies	58	39	29–54	81	2	83
Central Selkirk	59	32	22–49	36	0	36
Knight-Bute	60	4	2–8	0	0	0
Central Purcell	61	24	17–36	42	2	44
Stein-Nahatlatch	62	21	15–31	12	1	13
South Purcell	63	27	20–39	42	2	44
Squamish-Lillooet	64	10	6–20	2	0	2
Kootenay Lake	65	0		0	0	0
Valhalla	66	17	12–25	18	1	19

Table 1. Continued.

Population unit	Unit no.	$\bar{x}$	95% CI	Wolverine harvest		
				Trapping	Hunting	Total
Kettle Granby	67	11	6–21	15	0	15
North Cascades	68	14	8–27	5	0	5
Garibaldi-Pitt	69	12	7–24	1	0	1
Flathead	70	15	11–21	33	0	33
Sunshine Coast	71	3	2–6	0	0	0
Yahk	72	7	5–9	3	0	3
South Selkirk	73	10	7–14	0	1	1
Lower Mainland	74	2	1–5	0	0	0
British Columbia total	All	3532	2693–4759	3402	94	3496

Total harvest (trapping, hunting, known illegal kill, and reported road kill) during this time period was 3,496 wolverines (median annual harvest = 172; $\bar{x}$ = 174.8; Tables 1, 2). Trapping accounted for 97% of harvest. Harvests within individual population units ranged from 0 to 280 over the 20-year period (Table 1).

The *NR* for the province was 20.73 wolverines (Table 2). Median annual net recruitment for individual population units ranged from –3.05 (Robson) to 6.00 (Finlay Ospika) wolverines. Fifteen population units were likely to have been unsustainably harvested (e.g., >50% of simulations had *NR* < 0; Tables 3, 4). These unsustainably harvested population units represented 40.2% of total provincial wolverine harvest. Median annual net recruitment for these population units totalled –16.11 wolverines. The remaining 59.8% of total wolverine harvest during this period occurred in 56 population units, which were more likely to have been harvested sustainably (Table 3). Five population units that our analyses indicated were likely to have been harvested sustainably had a mean net recruitment of <0, but their median net recruitment rates were positive (Table 4). The estimated probabilities that harvest was unsustainable in these units were from 0.33 to 0.49. Harvests in these 5 population units were marked by peaks of more than double the mean harvest in 3–5 years of this time period (Table 5).

Mean annual harvest in population units with negative median *NR* varied from 99% (Hart) to 167% (Flathead) of

mean simulated annual recruitment (Table 4). This ratio varied from 102% (Kettle Granby) to 1,333% (Cariboo Basin Pavillion) among population units that simulations indicated were harvested sustainably but that had negative mean recruitment. Female wolverines made up ≤50% of the harvest reported in the compulsory reporting and inspection data in for all population units warranting management concern except Lower Stikine (57%), North Coast (67%), and West Chilcotin (75%; Table 4). Female composition for these units was based on samples of 35%, 21%, and 6% of their total harvest, respectively.

Populations declined less rapidly in population growth simulations using mean harvest rates in 6 of the 10 population units evaluated (Table 5). Harvests in these population units were marked by ≥2 consecutive years of harvest more than double the mean harvest for that unit. We were unable to model population decline in the Cariboo Basin Pavillion because the mean population estimate was zero. Harvest in the remaining units had ≥1 intervening year (and often more) of lower harvest between years of harvest that were more than double the mean harvest.

DISCUSSION

We demonstrated that the trapping and hunting harvest of British Columbia's wolverine population has likely been sustainable at a provincial scale from 1985 to 2004. Wolverine harvest in 15 of 71 population units was likely to have been unsustainable during this period. In addition, 5 other populations units were identified as warranting management attention. The component of female wolverines in the harvest of 17 of these 20 units was ≤50%, which would be expected given their lower vulnerability relative to males (Krebs et al. 2004). The percentage of females in 2 of the other units was based on small samples of the total harvest for those units. Compulsory reporting requirements have been inconsistent spatially and temporally during this time period. As a result, for some units this statistic was difficult to interpret and it may be of little value. Because population growth rate is very sensitive to adult female survival rates (Krebs et al. 2004), a more consistent approach to data collection and evaluation is warranted.

Our analyses demonstrated the importance of evaluating both median and mean net recruitment rates. Median net recruitment is a useful indicator of the likelihood of

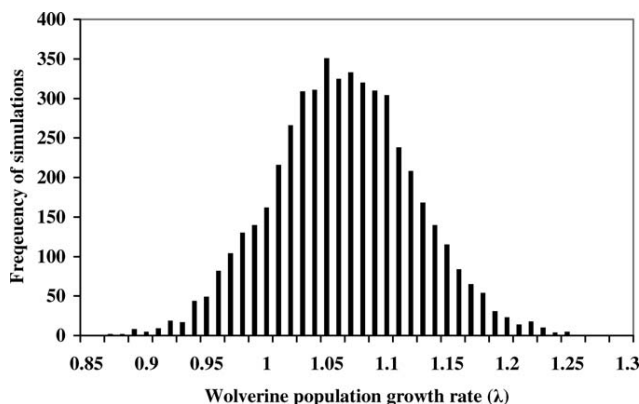


Figure 3. Frequency distribution of estimated wolverine population growth rate (λ) using simulation, British Columbia, Canada (2007).

Table 2. Recruitment and harvest statistics for wolverines in British Columbia, Canada, by population unit (1985–2004). *R* is simulated annual recruitment, *H* is resampled annual harvest, and *NR* is simulated net recruitment.

Population unit	Median <i>R</i>	Median <i>H</i>	Median <i>NR</i>	Proportion of simulations with <i>NR</i> < 0
Tatshenshini	2.04	1.87	0.10	0.43
Tagish	1.92	3.00	−1.00	0.62
Cassiar	11.60	8.00	2.38	0.42
Taiga	6.29	4.00	2.44	0.34
Muskwa	15.71	9.00	6.03	0.37
Hyland	5.23	2.00	2.07	0.34
Taku	4.59	2.00	1.40	0.36
Rocky	11.02	12.00	−2.48	0.57
Alta	6.76	5.00	1.54	0.43
Spatsizi	7.67	6.00	1.71	0.42
Edziza	3.02	1.00	1.25	0.29
Finlay-Ospika	10.58	4.00	6.00	0.30
Lower Stikine	0.72	1.00	0.00	0.46
Upper Skeena-Nass	7.71	3.00	3.98	0.31
Lower Peace	1.42	1.00	0.63	0.29
Omineca	9.82	5.00	4.32	0.33
Stewart	0.59	0.00	0.27	0.29
Cranberry	4.19	3.00	1.05	0.41
Moberly	2.61	4.00	−1.00	0.62
Babine	3.60	2.00	1.64	0.31
Hart	5.93	7.00	−0.61	0.53
Parsnip	4.69	4.00	0.16	0.49
Bulkley-Lakes	5.07	7.00	−1.01	0.57
Khutzeymateen	1.37	1.00	0.00	0.49
Nation	3.28	3.00	0.27	0.45
Outer Coast	0.33	0.00	0.33	0.00
Francois	2.54	4.00	−1.84	0.72
North Coast	0.78	1.00	0.00	0.43
Nulki	2.60	2.00	0.32	0.44
Bowron	1.96	1.00	1.05	0.26
Robson	4.92	8.00	−3.05	0.68
Tweedsmuir	4.20	1.00	3.25	0.16
Kitlope-Fiordland	1.08	0.00	0.98	0.04
West Chilcotin	2.78	3.00	−0.29	0.53
Caribou Plateau	1.49	0.00	1.15	0.14
Quesnel Lake North	2.63	1.00	0.75	0.37
Blackwater	0.38	0.00	0.22	0.23
Southwest Chilcotin	1.08	0.00	0.49	0.28
Wells Gray	4.15	1.00	2.10	0.28
Columbia-Shuswap	3.39	3.00	0.78	0.40
Central Rockies	2.10	1.00	0.79	0.32
Klinaklini-Homathko	2.00	0.00	1.77	0.08
Caribou Basin Pavillion	0.02	0.00	0.00	0.33
Kwatna-Owikenno	0.92	0.00	0.92	0.00
North Selkirk	1.98	3.00	−0.40	0.54
South Chilcotin Ranges	2.63	4.00	−1.10	0.62
Rockies Park Range	1.84	1.00	0.49	0.37
Spillimacheen	1.17	2.00	−0.56	0.58
North Purcell	1.84	1.00	0.52	0.37
Kingcome-Wakeman	0.54	0.00	0.54	0.00
South Thompson Nicola	0.29	0.00	0.22	0.13
Central Monashee	1.66	1.00	0.88	0.24
Vancouver Island	0.41	0.00	0.55	0.00
Okanagan	0.61	0.00	0.51	0.11
Toba-Bute	0.71	0.00	0.67	0.03
Southern Rockies	2.27	4.00	−1.30	0.63
Central Selkirk	1.82	1.00	0.21	0.43
Knight-Bute	0.22	0.00	0.22	0.00
Central Purcell	1.40	2.00	−0.18	0.52
Stein-Nahatlatch	1.23	0.00	0.69	0.23
South Purcell	1.50	2.00	−0.46	0.58
Squamish-Lillooet	0.59	0.00	0.54	0.05
Valhalla	0.97	1.00	0.21	0.38

Table 2. Continued.

Population unit	Median <i>R</i>	Median <i>H</i>	Median <i>NR</i>	Proportion of simulations with <i>NR</i> < 0
Kettle Granby	0.63	0.00	0.13	0.36
North Cascades	0.81	0.00	0.67	0.11
Garibaldi-Pitt	0.71	0.00	0.67	0.03
Flathead	0.87	1.00	−0.43	0.60
Sunshine Coast	0.17	0.00	0.17	0.00
Yahk	0.41	0.00	0.36	0.10
South Selkirk	0.54	0.00	0.51	0.04
Lower Mainland	0.14	0.00	0.14	0.00
British Columbia total	195.93	172.00	20.73	0.46

unsustainable harvest. Mean net recruitment can also indicate instances of potentially unsustainable harvest, particularly if population units are subjected to periodically high harvests in consecutive years.

Individual population units may not function entirely independently from adjacent units. There is some potential for dispersal from units with positive net recruitment to offset negative net recruitment in adjacent units. For example, the rate of overharvest in the Cariboo Basin Pavillion population unit seems extreme; however, it is based on a total harvest of only 8 wolverines. It is possible that these animals may have originated in adjacent population units. This potential may be limited by successful wolverine dispersal distance and the possibility that immigration and emigration may represent a small fraction of the wolverines in each population unit.

Our analyses provide a benchmark against which future harvests can be assessed and improvements to model parameters made. Our findings are the results of simulation modelling, and as such, they are limited by available data. Density estimates for habitat ratings are a synthesis of empirical estimates for high-capability habitats and predicted estimates for other habitat capability classes (Lofroth and Krebs 2007). Real litter size data (Magoun 1985, Copeland 1996, Persson 2003) are few but consistently much lower than those estimated from reproductive tract analyses (Rausch and Pearson 1972, Liskop et al. 1981, Banci and Harestad 1988). We assumed that vital rates remain constant between habitats of differing quality. This is improbable but untested. If vital rates decline with declining habitat quality, we would have overestimated productivity for lower quality habitat units. Most population units dominated by lower quality habitat are coastal, and they currently and historically have had little to no harvest.

Table 3. Wolverine harvest sustainability results for British Columbia, Canada (1985–2004). *NR* is simulated net recruitment.

	Proportion of simulations with <i>NR</i> < 0				
	0–20	21–40	41–50	51–60	61–100
No. of population units	19	25	12	9	6
Total wolverine harvest (%)	1.5	33.1	25.1	23.3	16.9

Table 4. Wolverine harvest data for British Columbia, Canada, population units that warrant management attention (1985–2004). Populations units with $NR < 0$ for $\leq 50\%$ of harvest simulations are in bold. NR is simulated net recruitment.

Population unit	Median NR	$\bar{x}NR$	% overharvest	% F ^a
Tagish	–1.00	–1.39	165	20
Rocky	–2.48	–1.60	114	44
Moberly	–1.00	–1.57	152	38
Hart	–0.61	0.10	99	29
Bulkley-Lakes	–1.01	–0.86	115	33
Francois	–1.84	–1.66	158	39
Robson	–3.05	–3.10	157	25
West Chilcotin	–0.29	–0.13	103	75
North Selkirk	–0.40	–0.41	117	50
Southern Chilcotin Ranges	–1.10	–1.09	137	38
Spillimacheen	–0.56	–0.69	152	13
Southern Rockies	–1.30	–1.62	162	39
Central Purcell	–0.18	–0.63	139	25
South Purcell	–0.46	–0.58	136	30
Flathead	–0.43	–0.68	167	50
Lower Stikine	0.00	–0.90	213	57
Khutzeymateen	0.00	–0.45	128	20
North Coast	0.00	–0.43	146	67
Cariboo Basin Pavillion	0.00	–0.37	1333	0
Kettle Granby	0.13	–0.02	102	na^b

^a % compulsory reporting harvest records that were F wolverines.

^b No compulsory reporting data available.

It is unlikely that lower productivity would have a significant influence on harvest sustainability results within these individual population units; however, it would result in reduced net recruitment for the province as a whole. Empirical density estimates for low and moderate capability classes and additional local vital rate data (particularly reproductive rates) would improve the evaluation process by enabling a more dynamic evaluation, such as population viability assessment (Sæther et al. 2005).

Wolverine harvest data may underreport the true harvest. Harvest data include all wolverines trapped for commercial purposes and harvested by licensed hunters. Wolverines harvested but kept for personal use by First Nations trappers are not included in the harvest data. The level of this and other harvest (poaching and unreported legal harvest) is unknown. The British Columbia Compulsory Inspection database contains only one record (of 1,045) of a poached wolverine. Provincially, an unreported harvest rate representing a 20% increase in current harvest could potentially be sustainable. Fifty-one (69%) population units could potentially sustain 15% more unreported harvest. The remaining units could sustain little to no unreported harvest.

MANAGEMENT IMPLICATIONS

Because provincial wolverine harvest is within sustainable limits, and because sustainability issues are limited to 20 of 71 population units, provincial-scale harvest management changes are likely not warranted. Overharvest issues in all population units of management concern can be addressed by reducing mean annual harvests by as little as 3 wolverines. Particular effort should focus on population units of concern in southern and eastern British Columbia that may be

Table 5. Simulated wolverine population decline rates for a sample of British Columbia, Canada, population units with temporally asymmetric harvests (1985–2004). We estimated rates by simulating population growth ($N_{t+1} = N \cdot \lambda - H$) using population estimates, mean growth rate, and reported and mean harvest rates. Reported rates are mean rates of decline in population estimates for 20 years for each population unit.

Population unit	$\bar{x}$ rate of population decline (% of population estimate)		Annual harvest exceeds twice $\bar{x}$ harvest	
	Evenly Reported distributed		Consecutive yr	Total yr
	harvest	$\bar{x}$ harvest		
Lower Stikine	0.11	0.13	0	4
North Coast	0.07	0.08	0	3
Tagish	0.10	0.09	2	4
Moberly	0.07	0.08	0	3
Central Purcell	0.09	0.06	3	4
Southern Rockies	0.12	0.09	2	3
Flathead	0.12	0.09	2	2
Khutzeymateen	0.06	0.05	2	3
Cariboo Basin Pavillion	na ^a	na ^a	2	5
Kettle Granby	0.05	0.02	2	3

^a Rates of decline could not be calculated because population estimate was zero.

important in the persistence or recovery of wolverine populations in Alberta, Canada, and the United States.

Wildlife managers should evaluate the appropriateness of closed seasons in light of recruitment rates for individual population units. They should also pay particular attention to consecutive years of harvest that greatly exceed both the mean harvest and recruitment rate for individual population units, due to the effect this may have on the rate of overall population growth. Wolverine populations have limited growth capability and are sensitive to overharvest; thus, managers may choose to re-evaluate harvest sustainability using simulation criteria appropriate to their own risk tolerance. Monitoring and reporting should be improved to provide better data on the female component of the harvest, a metric that should be integrated into annual harvest monitoring.

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