The Canadian Field-Naturalist

Volume 118, Number 2 April–June 2004

Morphology and Population Characteristics of Vancouver Island Cougars, *Puma concolor vancouverensis*

Steven F. Wilson[1], Apryl Hahn, Aaron Gladders, Karen M. L. Goh, and David M. Shackleton

Wildlife Research Group, Agroecology, Faculty of Agricultural Sciences, University of British Columbia, 270-2357 Main Mall, Vancouver, British Columbia V6T 1Z4 Canada

[1]Present address: EcoLogic Research, 406 Hemlock Avenue, Gabriola Island, British Columbia V0R 1X1 Canada

Wilson, Steven F., Apryl Hahn, Aaron Gladders, Karen M. L. Goh, and David M. Shackleton. 2004. Morphology and population characteristics of Vancouver Island Cougars, *Puma concolor vancouverensis*. Canadian Field-Naturalist 118(2): 159-163.

Cougars are a management concern on Vancouver Island because they are a top predator and because there have been frequent attacks on humans on the island. However, little is known about Cougar ecology in the Pacific Northwest of North America. We studied Cougar morphology and population characteristics as part of a larger study in two areas on Vancouver Island. We derived a multivariate measure of body size to describe changes with age and sex. Body size was similar in the two study areas. Survival rates for adult females were higher than those reported elsewhere; however, hunters avoided shooting females in general, and radio-collared Cougars in particular. Litter size at first detection was lower than reported in many other studies and may be related to food availability.

Key Words: Cougars, *Puma concolor vancouverensis,* morphology, survival, mortality, natality, Vancouver Island, British Columbia.

The Mountain Lion, or Cougar (*Puma concolor vancouverensis*), is one of the two main large predatory carnivores in the forests of Vancouver Island, British Columbia, Canada. It also has a long history of interactions with humans as a nuisance (livestock predation) and as a game species (Beier 1991). The incidence of Cougar attacks on humans in North America is also highest on the island. However, little is known about the ecology of Cougar in this part of its range, mainly because this subspecies inhabits dense forests typical of coastal British Columbia. We examined Cougar morphology and population characteristics in two study areas on Vancouver Island to investigate the effects of age, sex, and location on body size, and to determine survival rates and reproductive characteristics.

Methods

Research was conducted on a 700-km^2 area near Northwest Bay (NWB), British Columbia, and on a 1000-km^2 area centred on the Adam and Eve River valleys (AE) approximately 300 km northwest of NWB (Figure 1). Principal habitats at NWB consisted of different seral stages of Douglas Fir (*Pseudotsuga menziesii*), Western Hemlock (*Tsuga heterophylla*), and Western Redcedar (*Thuja plicata*) forests. The AE study area was more rugged and dominated by extensive stands of unlogged forest, particularly at higher elevations. Habitats at lower elevations were dominated by Western Hemlock and Western Redcedar while species at higher elevations included Mountain Hemlock (*Tsuga mertensiana*) and Yellow Cedar (*Chamaecyparis nootkatensis*). Understory vegetation on both study areas was typically dense and consisted of Salal (*Gaultheria shallon*), ferns (several genera) and *Vaccinium* species communities. Both study areas had cool summers and mild winters, with temperatures of 0-10°C for 4-6 months/year and annual precipitation of 1700-5000 mm/year (Meidinger and Pojar 1991). AE was cooler and wetter, with a greater proportion of precipitation falling as snow.

Cougars were captured between 4 March 1991 and 1 September 1996 at NWB and from 18 April 1997 to 12 September 1998 at AE. Local houndsmen were contracted to track and tree Cougars. Treed Cougars that could safely be immobilized were darted with a mixture of ketamine hydrochloride (3 mg/kg estimated total weight) and medetomidine hydrochloride (0.1 mg/kg). Cougars were sexed, measured (see below), and aged according to tooth replacement and wear, and by gum recession (Ashman et al. 1983; Laundré et al. 2000). Adult Cougars were fitted with VHF radio collars (Telonics, Inc., Mesa, AZ). Immobilizations were reversed with atipamezole (0.15 mg/kg). Morphological data from hunter-killed Cougars in and near AE were also included in our analyses.

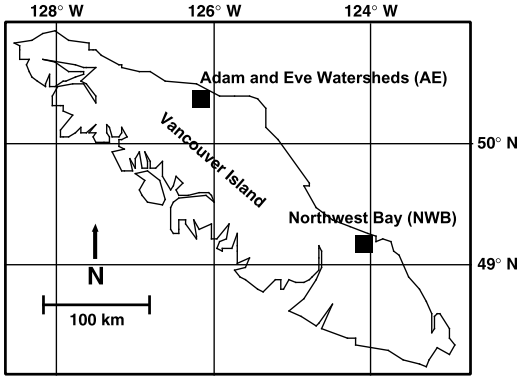

FIGURE 1. Location of cougar study areas on Vancouver Island, British Columbia, Canada.

Morphological measurements taken included: total weight (using a 100 kg spring balance to the nearest 1 kg), neck circumference at the base of the skull, chest circumference immediately behind the front legs, body length from nose to base of tail, tail length from base to tip of the last vertebrae (all to the nearest cm with a cloth tape measure), canine length from gumline to tip, and front and rear pad widths (to the nearest mm with a cloth tape measure; AE only).

We used principal component analysis (PCA) to derive a single variable to represent body size, based on the correlation matrix of morphological variables (Statistica 1995). We used this body size measure instead of total weight to describe the size of Cougars because it was less condition-dependent that using total weight alone. Where Cougars were captured >1 time, we included data from only the most recent capture. We used an analysis of covariance to test for differences in body size (log-transformed) between sex and study area, using age as a covariate. We also calculated means (±2 SE) for each morphological variable (by sex), but excluded Cougars <2 years old to minimize skews in distributions caused by the smaller body sizes of juvenile Cougars.

We calculated survival estimates with the staggered entry design of Pollock et al. (1989), which is based on the Kaplan-Meier product limit estimator (Kaplan and Meier 1958). This method estimates annual survival rate as the product of weekly survival rates ($1 - d/r$), where d is the number of animals that die and r is the number of animals "at risk" in a weekly period. Cougars carrying functioning radio collars comprised the "at risk" sample for each week. The design was "staggered entry" because not all Cougars carried collars at the same time. Cougars were added to the weekly sample as they were collared, and were removed as they died, had their collars removed, or when their collars stopped functioning. Analysis started with the collaring of the first Cougars in the two study areas. Annual survival estimates were based on 52 consecutive, seven-day periods.

There were sufficient data to analyse adult female Cougar survival; however, sample sizes were small, and the length of the study was relatively short in relation to the life expectancy of Cougars. Therefore, our estimates should be interpreted with caution.

We report the reproductive characteristics of collared females anecdotally because data were insufficient to calculate population growth rates; specifically, we had few data on birth intervals and survival to maturity. We report litter sizes (±2 SE) when they were first seen, so litter sizes at birth may have been larger, although in at least three litters, kittens were seen when <10 days old (eyes not open).

Results

Thirty Cougars were measured at NWB (17 females and 13 males) and 26 at AE (15 females and 11 males).

We used total weight, neck and chest circumference, and total length (body length + tail length) in the final PCA to derive a body size variable. All four variables loaded strongly and positively on the first axis, which explained 83% of the variation in the dataset. As a result, we used the first PCA axis as the index of body size (Table 1). We did not include canine length and body and tail lengths as separate variables in the analysis because doing so did not significantly increase the variation described in the first axis.

Body size differed between males and females ($P < 0.000$), but not between study areas ($P = 0.736$; Figure 2). Differences between males and females were also evident in univariate means of the morphological measurements (Table 2).

Mean survival rates were similar for collared Cougars on both study areas (Table 3). Known causes of female mortality at NWB included intraspecific killings (2) and animal control (3). The cause of one female mortality at NWB and both female mortalities at AE were unknown. Two mortalities of collared male

TABLE 1. Correlation between morphological variables and the first principal component axis (also known as "factor loadings"). The axis (based on the correlation matrix) was used as an index to describe body size of Vancouver Island Cougars in subsequent analyses.

Factor loadings of morphological variables					
Total Weight	Neck	Chest	Body length	Eigenvalue	% variation explained
0.994	0.889	0.927	0.878	3.314	82.8

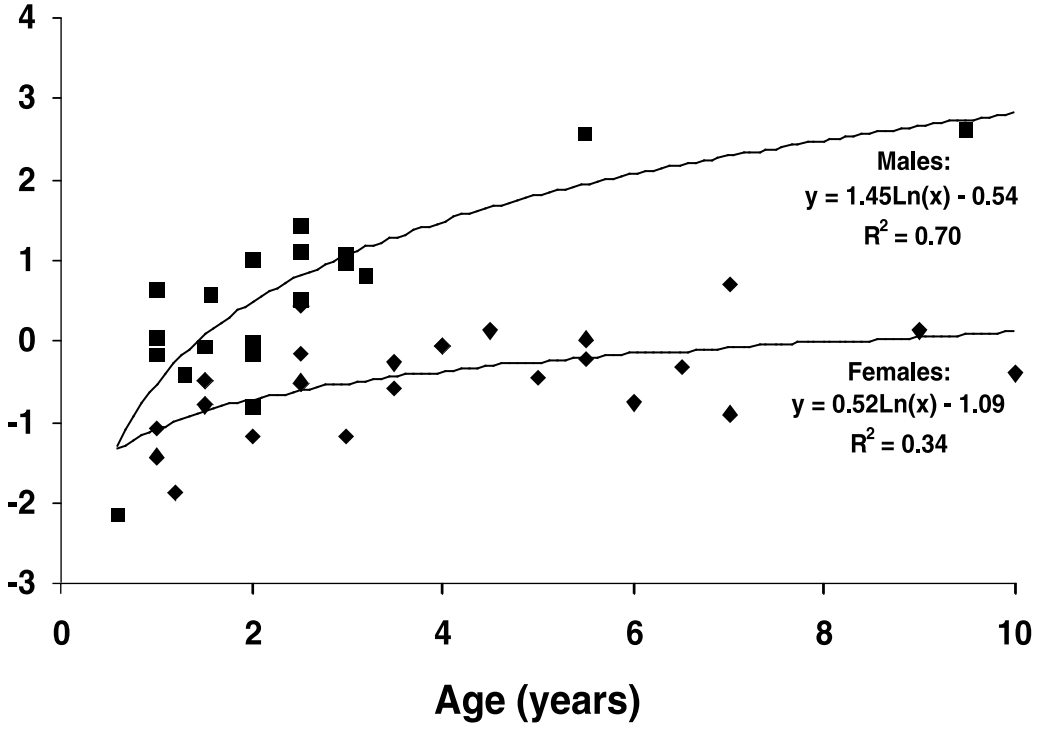

FIGURE 2. Relationship between body size (derived from the principal component analysis on morphological measurements, see text) and age for male and female Cougars in the two Vancouver Island study areas. Logarithmic trend lines are presented for males (squares ■) and females (diamonds ◆) , pooled by study area. The body size measurement was used because it was less condition-dependent than using total weight alone.

Cougars were investigated at AE; one was shot by hunters and the other was suspected to have been shot illegally.

At NWB, mean litter size at first detection was 1.9 ± 0.1 (n = 16). One female was known to have a litter of three kittens, and there were 12 other litters of two kittens and 3 of one kitten when first observed. Females were known or suspected to give birth during all months from March-October. Consecutive litters were recorded for two females; each had litters 21 and 23 months apart.

Litter size at AE was 1.8 ± 0.7 (n = 5). There was one litter of three, and two litters each of one and two kittens. Females gave birth in January, August, and September. No collared females at AE had more than one litter during the study period.

Discussion

Results presented in this paper are based on small absolute sample sizes; however, Cougars are rare and secretive, and inferences about their morphology and behaviour must often be based on few animals. The

TABLE 2. Means and standard errors of morphological measurements taken on captured Vancouver Island Cougars.

	Males			Females		
Measurement	n	Mean	2 SE	n	Mean	2 SE
Total Weight (kg)	13	51.3	5.7	22	39.1	2.1
Neck (cm)	12	39.5	3.0	23	35.1	1.3
Chest (cm)	12	72.5	3.5	23	65.4	1.6
Body length (cm)	13	128.2	6.6	23	120.9	3.1
Tail Length (cm)	13	73.0	4.5	23	70.1	2.3
Front pad Width (mm)	9	57.9	1.9	12	51.1	2.2
Hind pad Width (mm)	9	50.4	3.3	12	37.9	9.1
Canine Length (mm)	10	28.6	1.5	23	26.8	2.0

TABLE 3. Annual and mean survival rates of female Vancouver Island Cougars collared in two study areas: Northwest Bay (NWB) and Adam and Eve rivers (AE). Annual estimates were based on a staggered-entry design, starting with the first Cougars collared at NWB and AE in March 1991 and April 1997, respectively.

Study Area	Year	*n*	Survival	-2 SE	+2 SE	Mean
NWB	1991-1992	4	1			
	1992-1993	7	1			
	1993-1994	7	0.75	0.47	1	
	1994-1995	7	0.82	0.56	1	
	1995-1996	7	0.88	0.64	1	0.89
AE	1997-1998	7	0.80	0.53	1	
	1998-1999	7	1			
	1999-2000	4	0.83	0.50	1	0.88

densities of Cougars in our study areas also suggest that significant proportions of the populations were captured (2.6-7.3 Cougars/100 km^2 at NWB and 1.4-2.0 Cougars/100 km^2 at AE; S. Wilson, unpublished data). Our sample sizes were similar to, or larger than, those in many comparable studies (e.g., n = 22, Hemker et al. 1984; n = 68, Ross and Jalkotzy 1992; n = 76, Lindzey et al. 1994; n = 34, Spreadbury et al. 1996; n = 13, Franklin et al. 1999; n = 21, Pierce et al. 2000).

Few researchers have published Cougar morphological characteristics (*c.f.* Kohlmann and Green 1999; Grigione et al. 2002); however, mean measurements of Vancouver Island Cougars in this study were smaller than those reported by Cowan and Guiguet (1965) for 14 adult male (mean total length 241 cm, tail length 89 cm, mean total weight 73 kg) and 7 adult female (mean total length 206 cm, tail length 79 cm, mean total weight 46 kg). Vancouver Island Cougars are slightly smaller than those found elsewhere in British Columbia (Cowan and Guiguet 1965).

Survival estimates are critical for population management, but few studies report them. Using the same method and similar sample sizes, Lindzey et al. (1988) reported mean survival rates (S = 0.731) for female Cougars in a largely unhunted population in southern Utah that were lower than those we calculated for Vancouver Island Cougars (mean for both study areas S = 0.885). Hunting is an important component of mortality in Cougar populations where hunting is allowed (Hemker et al. 1984; Logan et al. 1986; Ross and Jalkotzy 1992). The Vancouver Island population is no exception; however, we were in frequent contacts with hunters in our study areas and know they often treed radio-collared cougars but chose not to shoot them, even though we did not request this. This might have inflated the survival rates calculated for radio-collared Cougars. Researchers and managers should be aware of this bias when calculating survival estimates from similar radio telemetry studies where hunters "lend a hand" by not shooting study animals. Animal control by British Columbia Wildlife Branch Control Officers was a significant source of human-caused mortality at NWB, where the human population density was higher than at AE. Intraspecific killing has been reported as an important source of mortality elsewhere (Lindzey et al. 1988; Spreadbury et al. 1996), but in our study it was detected only at NWB where Cougar population density was significantly higher than at AE.

Litters in both of our study areas were smaller than those reported in southeastern British Columbia ($\bar{x}$ = 3.1; Spreadbury et al. 1996), southwestern Alberta ($\bar{x}$ = 2.2; Ross and Jalkotzy 1992), Wyoming ($\bar{x}$ = 2.7; Logan et al. 1986), and southern Utah ($\bar{x}$ = 2.4; Lindzey et al. 1994). Other studies have recorded births in most months of the year (Ross and Jalkotzy 1992; Lindzey et al. 1994), with a peak in late summer and early fall (Lindzey et al. 1994). Our observations at AE were similar. The pattern was different at NWB, with no births recorded in winter and no obvious peaks in births during the spring-fall period.

Columbia Black-tailed Deer (*Odocoileus hemionus columbianus*) are the Vancouver Island Cougars' primary prey. Indices of deer abundance declined 55% from 1991-1996 at NWB and 38% from 1995-1999 at AE (British Columbia Ministry of Environment, Lands and Parks, unpublished data); therefore, small litter sizes among Vancouver Island Cougars may be a result of low food availability. Also, Black-tailed Deer are smaller than mainland Mule Deer (*Odocoileus hemionus*; Shackleton 1999). This highlights the importance of maintaining prey populations in management of Cougars on Vancouver Island.

Acknowledgments

This research was supported by Forest Renewal British Columbia, British Columbia Ministry of Environment, Lands, and Parks (MELP), Habitat Conservation Trust Fund, Science Council of British Columbia, MacMillan Bloedel Limited, TimberWest Limited, Western Forest Products Limited, BC Hydro, Mountain

Equipment Co-op, and the University of British Columbia. We thank M. DeLaronde, S. Foster, D. Koshowski, J. Leo, R. Ramcharita, H. Robinson, C. Wainwright, K. Wickert, and local houndsmen for assistance with fieldwork. For logistic support we also thank G. Brunham, K. Brunt, T. Hamilton, D. Janz, and H. Schwantje of MELP, as well as many staff of MacMillan Bloedel Limited in Nanaimo and Campbell River, British Columbia, and of TimberWest Limited in Nanaimo, B.C. S. Kohlmann, F. Scott and D. Nagorsen made helpful comments on the manuscript. This paper is dedicated to the memory of the late K. Atkinson, who conceived and supported the project from the outset.

Literature Cited

Ashman, D., M. Christensen, M. Hess, G. Tsukamoto, and **M. Wickersham.** 1983. The mountain lion in Nevada. Nevada Department of Fish and Game, Federal Aid in Wildlife Restoration Final Report W-48-15.

Beier, P. 1991. Cougar attacks on humans in the United States and Canada. Wildlife Society Bulletin 19: 403-412.

Cowan, I. McT., and **C. J. Guiguet.** 1965. The mammals of British Columbia. British Columbia Provincial Museum Handbook Number 11, Victoria, British Columbia. 414 pages.

Franklin, W. L., W. E. Johnson, R. J. Sarno, and **J. A. Ariarte.** 1999. Ecology of the Patagonia puma *Felis concolor patagonica* in southern Chile. Biological Conservation 90: 33-40.

Grigione, M. M., P. Beier, R. A. Hopkins, D. Neal, W. D. Padley, C. M. Schonewald, and **M. L. Johnson.** 2002. Ecological and allometric determinants of home-range size for mountain lions (*Puma concolor*). Animal Conservation 5: 317-324.

Hemker, T. P., F. G. Lindzey, and **B. B. Ackerman.** 1984. Population characteristics and movement patterns of cougars in southern Utah. Journal of Wildlife Management 48: 1275-1284.

Kaplan, E. L., and **P. Meier.** 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistics Association 53: 457-481.

Kohlmann, S. G., and **R. L. Green.** 1999. Body size dynamics of cougars (*Felis concolor*) in Oregon. Great Basin Naturalist 59: 193-194.

Laundré, J. W., L. Hernández, D. Streubel, A. Altendorf, and **C. L. González.** 2000. Aging mountain lions using gum-line recession. Wildlife Society Bulletin 28: 963-966.

Lindzey, F. G., Ackerman, B. B., Barnhurst, D., and **Hemker, T. P.** 1988. Survival rates of mountain lions in southern Utah. Journal of Wildlife Management 52: 664-667.

Lindzey, F. G., W. D. Van Sickle, B. B. Ackerman, D. Barnhurst, T. P. Hemker, and **S. P. Laing.** 1994. Cougar population dynamics in southern Utah. Journal of Wildlife Management 58: 619-624.

Logan, K. A., L. L. Irwin, and **R. Skinner.** 1986. Characteristics of a hunted mountain lion population in Wyoming. Journal of Wildlife Management 50: 648-654.

Meidinger, D. V., and **J. Pojar.** 1991. Ecosystems of British Columbia. Special Report Series 6, British Columbia Ministry of Forests, Victoria, British Columbia. 330 pages.

Pierce, B. M., V. C. Bleich, and **R. T. Bowyer.** 2000. Social organization of mountain lions: does a land-tenure system regulate population size? Ecology 81: 1533-1543.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and **P. D. Curtis.** 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7-15.

Ross, P. I., and **M. G. Jalkotzy.** 1992. Characteristics of a hunted population of cougars in southwestern Alberta. Journal of Wildlife Management 56: 417-426.

Shackleton, D. M. 1999. The Hoofed Mammals of British Columbia. Volume 3: The Mammals of British Columbia. Royal British Columbia Museum, Victoria, British Columbia. 268 pages.

Spreadbury, B. R., K. Musil, J. Musil, C. Kaisner, and **J. Kovak.** 1996. Cougar population characteristics in southeastern British Columbia. Journal of Wildlife Management 60: 962-969.

Statistica. 1995. Statistica users manual volume III. Statsoft Incorporated, Tulsa, Oklahoma. 782 pages.

Received 7 May 2001
Accepted 5 November 2004

Erratum *Canadian Field-Naturalist* 118(2):

Back cover contents omission:

Fifteenth census of seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence 1998-1999 JEAN-FRANÇOIS RAIL AND GILLES CHAPDELAINE 256

Replacement Figure 2, page 161 for
Morphology and population characteristics of Vancouver Island Cougars, *Puma concolor vancouverensis,*
STEVEN F. WILSON, APRYL HAHN, AARON GLADDERS, KAREN M. L. GOH, AND DAVID M. SHACKLETON

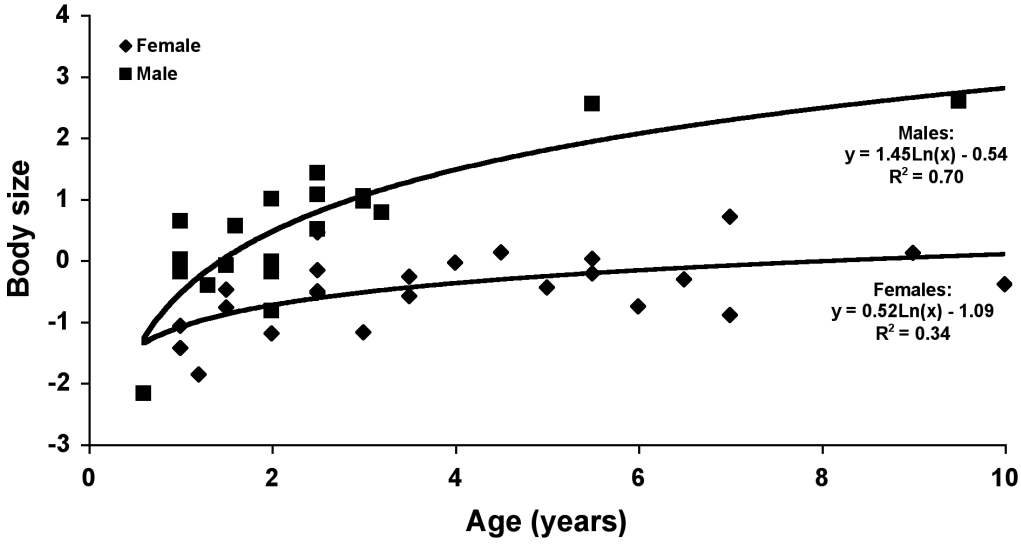

FIGURE 2. Relationship between body size (derived from the principal component analysis on morphological measurements, see text) and age for male and female Cougars in two Vancouver Island study areas. Logarithmic trend lines are presented for males (squares ■) and females (diamonds ◆) pooled by study area. The body size measurement was used because it was less condition-dependent than using total weight alone.