FISH AND WILDLIFE COMPENSATION PROGRAM

PEACE REGION

BEHAVIOUR OF GRIZZLY BEARS (*Ursus arctos*) IN RELATION TO CLOSURE OF THE MCLEOD LAKE LANDFILL IN NORTH-CENTRAL BRITISH COLUMBIA

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EXECUTIVE SUMMARY

Each year in British Columbia, an average of 47 grizzly bears (*Ursus arctos*) and 784 black bears (*U. americanus*) are killed as the result of conflict with humans (Mike Badry, Ministry of Environment, pers. comm.). In many parts of the province, negative human-bear interactions occur because bears become conditioned to human foods ("garbage-conditioned") and subsequently more tolerant of human presence (human-habituated"). Public acceptance of open-pit landfills has decreased in recent years, and as landfills are closed and their food source is removed, garbage-conditioned bears may be displaced from these sites and seek out human foods in surrounding communities.

To assess the likelihood that different sex and age classes of bears that use landfills would display problem behaviour following landfill closure, we conducted the *McLeod Lake Landfill Grizzly Bear Behaviour Project* over a 3-year period: 2000 (pre-landfill closure), 2001 and 2002 (post-landfill closure). Our study was designed to identify attributes or behaviours that may be used to predict which bears are more likely to seek out alternate human-food sources after a landfill closes, thus becoming problem bears and posing a threat to humans. If we are able to predict whether certain classes of bears are more likely to become problems than others, this knowledge could be applied during subsequent landfill closures where those bears with an increased likelihood of posing a threat to human safety would be destroyed, while the remaining bears would be allowed to live.

We captured and radio-collared 12 grizzly bears that used the McLeod Lake landfill prior to closure: 5 adults (1 male, 4 females), 2 subadult males, and 5 subadult females. Between 2000 – 2002, we monitored the frequency, timing and duration of visits by radio-tagged bears to the landfill with a fixed-telemetry station positioned at the landfill. We recorded 522 visits to the landfill at night by 12 bears wearing 24-hour transmitters in 2000, and 42 night visits by 7 bears in 2001. Some bears wore transmitters that only functioned during daytime, for some periods of the study. We recorded an additional 74 records in close proximity to the landfill in daytime (<400 m; "Landfill Area") from 4 of those bears in 2000, and 25 records in the Landfill Area from 5 bears in 2001.

Use of the landfill by most radio-tagged bears prior to closure was lowest during summer (when natural food sources are typically more abundant) and peaked during fall (when natural foods are generally least abundant). The lone adult male was the only bear to use the landfill more in summer. Most bears fitted with 24-hour transmitters visited the landfill only at night both pre- and post-closure, and avoided the landfill during daylight hours. One subadult female was responsible for the majority of daytime use of the landfill, including spending entire days in the landfill. The same individual exhibited the longest duration spent in the Landfill Area, 8.8

days, in the fall prior to closure. Surprisingly, bears continued to visit the landfill following closure (albeit at substantially lower levels), with increased visits to the landfill in fall. Visit durations decreased post-closure, with increased incidences of short "walk-throughs"; the amount of time spent in the Landfill Area also decreased.

We used the percentage of nights each bear spent in the landfill in fall as determined by a fixed-telemetry station to classify bears into 3 broad categories of degree of landfill use: Light: ≤33% of available time spent at landfill; Moderate: 34 – 66%; and Heavy: 67 – 100%. We classified 9 radio-tagged bears as heavy landfill-users and 3 as light landfill-users; no bears fell into the moderate-use category.

We expected that bears would expand their home ranges after closure to access more natural foods. Pre- and post-landfill closure annual home ranges sizes were compared for 2 female bears for which sufficient aerial-locations were obtained, and both were found to increase their annual home range sizes post-closure. Although the subadult female was a newly independent 2-year old which may have contributed to her increased range size, the adult female was accompanied by cubs-of-the-year post-closure which would typically result in a smaller home range. Female bears were also found to move significantly greater distances from the landfill post-closure than pre-closure. This may be the result of bears having to search more widely for natural food sources after closure. Bears used significantly lower elevations pre-landfill closure than after closure, likely related to their closer proximity to the landfill pre-closure.

As of fall 2010, 6 of the 12 radio-tagged bears had died, all post-landfill closure, and all killed by people. Three of the 9 heavy landfill-users were killed as problem bears:

- 9 heavy landfill users:
    - 2 were killed during the first post-closure year (2001) as problem bears; 1 in a transfer station at the McLeod Lake landfill by a Conservation Officer, and 1 in the community of McLeod Lake by a local resident,
    - 1 was killed 10 years post-closure (2010) as a problem bear in the town of Mackenzie by a Conservation Officer, and
    - 1 was killed illegally (shot and left in a clearcut).
- 3 light-landfill users:
    - 2 died in causes unrelated to problem-bear behaviour (1 killed in self-defence while hunting, and 1 died during re-capture).

The fates of the remaining 6 bears are unknown due to transmitters that either dropped or failed between 2001 – 2003, but they were not reported as problem bears or human-caused mortalities to the COS as of fall 2010.

We suggest that a high level of landfill dependence prior to landfill closure (in combination with at least one of the 3 additional attributes listed below), increases the likelihood of a bear becoming a problem after closure. Measures of landfill dependency prior to closure should include:

a. The degree of landfill use as measured by the number of nightly visits to the landfill in fall (bears that visit more often are more dependent),

b. The season(s) of landfill use (bears that use the landfill in summer when natural foods are typically most abundant are more dependent),

c. The diurnal timing of landfill use (bears that enter the landfill during daylight hours, and/or remain in the landfill during daytime are more dependent),

d. The size and spatial location of home ranges (bears with smaller home ranges centered around the landfill are more dependent).

Additional attributes include:

1. Age and gender: Subadult females were more likely to develop problem behaviour following landfill closure. In natural systems, subadult bears are forced to disperse from their natal range and fend for themselves. In the subsequent establishment of their home range, males are expected to disperse widely while females tend to occupy a portion of their mother's home range (i.e., philopatry). If that range included the landfill then it appears that these females have an increased potential to become consistent landfill users or, if the landfill closes, potential future problem bears.
2. Previous injuries: Bears with injuries that limited mobility were more likely to be reliant on the landfill and less likely to seek food elsewhere and thus have an increased probability of future problem behaviour.
3. Human habituation: Bears that demonstrated a higher tolerance of human presence as determined by daytime use of the landfill, tolerance of public landfill-users, and multiple re-captures within the landfill, were more likely to develop problem behaviour.

Our results show that not all bears that fed at the landfill automatically turned to other human food sources after closure. Because of this, the removal of all bears using a landfill scheduled for closure is unwarranted. Based on our findings, we suggest 2 options be considered prior to closure: 1) Removing only those bears determined prior to landfill closure to be heavy-landfill users, and that are also subadults, have significant injuries, or have exhibited a lack of fear of or tolerance to humans, or, 2) Radio-tagging all bears that meet these criteria prior to landfill closure, and closely monitoring the bears movements, range use, and proximity to human food sources after closure, particularly in seasons or years of low natural food availability.

ACKNOWLEDGEMENTS

The McLeod Lake Grizzly Bear Behaviour Project was funded by the Fish and Wildlife Compensation Program – Peace Region (FWCP-P), a co-operative venture of BC Hydro (BCH), the BC Ministry of Environment (MoE), Fisheries and Oceans Canada (DFO), First Nations and public stakeholders. The FWCP-P was established in 1989 to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

Trapping, tranquilizing, and handling of grizzly bears was conducted by M. Wood and S. Myers with additional assistance from J. Paczkowski (spring 2000), R. Damstrom (fall 2000, 2001), P. Hengeveld and R. Piccini (spring 2002). We wish to thank the MoE Conservation Officer Service for providing safety backup during all captures, and assisting with the trapping and handling of bears. Conservation Officer (CO) S. Dowling assisted with the majority of captures throughout the 3 year period, while CO's T. Boschmann, L. Brown, B. Smith, B. Coyle, C. deBoon, J. Hanratty, M. Smith, and D. Velkjar provided many additional hours of invaluable support. Many volunteers also provided helpful assistance setting snares and traps, and recording data on captured bears. Thanks to M. McCulloch, C. Crossland, and R. Shymanski for donating beaver and moose carcasses for bait. R. Damstrom also obtained excellent video footage of the trapping and handling of grizzly bears. We also extend many thanks to Terry and Andrea Hall at Whiskers Bay Resort for making us feel a part of their family, for good food and good conversation, and for our nightly "dump pie". P. Hengeveld monitored radio-tagged bears with pilots L. Frey and E. Stier (Vanderhoof Flying Services), and K. Connors, L. Scott, and L. Frey (Northern Thunderbird Air) who conducted fixed-wing tracking flights in a safe and efficient manner. P. Hengeveld conducted site investigations in 2000 with assistance from K. Murphy, F. Corbould, D. Wellwood, and M. Wood. L. Ciarniello and E. Jones with the adjacent Parsnip Grizzly Bear Project (PGBP) provided additional aerial telemetry and site investigation data on a few bears monitored in common between the projects. Den site investigations were conducted by M. Wood in 2001 assisted by R. Damstrom, S. Dowling, and P. Hengeveld. Pilots G. Altoft (Altoft Helicopters) and G. Luck (Interior Helicopters) provided helicopter access to remote den and snare sites in 2001.

The objectives and design of the McLeod Lake Grizzly Bear Behaviour Project were initially developed by D. Heard, MoE. B. Arthur and S. Barry (MoE) assisted with GIS analysis, and R. McCann (Wildlife Infometrics) with fixed-telemetry station analyses. K. Annis, M. Badry, and T. Manley provided comments on an earlier draft. Our sincerest appreciation goes to H. Davis and D. Heard for providing detailed reviews and valuable advice and expertise, which greatly improved this manuscript.

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1.0 INTRODUCTION

Both grizzly bears (*Ursus arctos*) and black bears (*U. americanus*) maximize their fitness by acquiring calorie-rich foods (Graf et al. 1992, Herrero 1989). Landfills, and other human food sources, are highly concentrated sources of these calories that require little energy expenditure to acquire, and bears exploit these resources if possible. Bears that use landfills have increased body size, reproductive output (Stringham 1989), and social status. The distribution of natural foods that bears exploit explains the attraction that bears have to non-natural foods. Natural bear foods, such as berries and forbs, vary widely in their abundance, quality, and distribution. However, because the supply of food at landfills is consistent (both spatially and temporally), bears do not have to use energy to search for new food sources once they have encountered a landfill in their travels.

However, bears are exposed to considerable risk when using landfills. Physical injuries can result from sharp edges of glass and cans that are encountered while searching for food items. Furthermore, a diet of refuse can result in negative health consequences resulting from tooth decay, consumption of plastics and petroleum products, and other toxic items (Smith and Lindsey 1989). Additionally, increased interactions with other bears can result in physical confrontations that may result in injury or death.

Grizzly bears that are conditioned to human food in landfills (i.e., garbage-conditioned) have been reported to threaten human safety (Smith and Lindsey 1989) and injure people after landfill closure (e.g., Yellowstone National Park landfill closures; Craighead et al. 1995). This is because bears that use landfills have an increased potential to become habituated to humans (i.e., do not flee from, and essentially lose their fear of, humans). These human-habituated bears are more often reported in conflicts with humans than non-habituated bears (Herrero 1985, Meagher and Fowler 1989, Matthews et al. 2006).

Past landfill closures have lacked prior planning and management of bears has been largely reactive, usually involving the translocation or destruction of problem bears (Ministry of Environment, Lands and Parks 1996). Unfortunately, translocations of garbage-conditioned bears are often ineffective (Miller and Ballard 1982, Brannon 1987, Kansas et al. 1989, MacKay 1996) because they either seek out human foods and become a problem in their new release area, or travel long distances to return to their capture site and original food source. In addition, competition with established resident bears in the release area can result in death or displacement of the translocated bear (Robbins et al. 2004).

In the late 1990s through mid-2000s, open-pit landfills in smaller communities throughout British Columbia were being either enclosed by an electric and/or chain link fence, or replaced by more efficient and sanitary transfer-station systems. This change was also being undertaken in an effort to restrict the access of unnatural attractants to wildlife, particularly bears and wolves (*Canis lupus*), thereby reducing problems that can develop when wildlife becomes garbage-conditioned. Improved management of garbage is one of the primary goals of the BC Bear Smart program which aims to prevent and reduce conflict between people and bears in BC's communities through education and management of non-natural attractants (Davis et al. 2002).

Closures of landfills used by grizzly bears can have large effects on the local bear population. In April 1995, the town of Mackenzie (46 km north of McLeod Lake) installed an electric fence around its landfill (MacKay 1996). Sixty-seven bears were killed or translocated between 1992 and 1995, 63 of which were confirmed dead by the end of 1996. Removing this high number of bears can have several negative effects on the sustainability of the local population and can also reduce legal hunting opportunities. Furthermore, this type of management approach is extremely costly to implement and unpopular with the general public.

Very little is known about the behaviour of bears that use landfills, and how their behaviour might relate to their likelihood of exhibiting future problem-bear behaviour. Closures of landfills have been linked to reduced body weight (Robbins et al. 2004) and decreased survival (Craighead et al. 1995) of bears. Subadults, particularly males, have been more commonly found to become problem bears in a variety of situations (Mace et al. 1987, McLellan et al. 1999, Dyck 2006, Homstol et al. 2007, Towns et al. 2009), though none of these studies focused on landfill-using bears. However, it is possible that not all bears that use landfills will become human-habituated to the point that they will become a threat to human safety following closure. In January 2001, the open-pit landfill servicing the community of McLeod Lake in north-central BC was scheduled for closure and replacement with a bear-resistant transfer station. This provided an opportunity for us to monitor bears that used the landfill to determine if aspects of behaviour and landfill use that were exhibited pre-closure, could be used to identify individuals that were at-risk of becoming problem bears following closure.

In 2000, prior to the landfill closure, we radio-tagged and monitored grizzly bears that used the McLeod Lake landfill site to assess the response by bears to closure of the landfill over the winter of 2000/01. We expected that bears that fed at the landfill would:

1) move to find other garbage sources, have increased negative interactions with humans, and ultimately higher mortality, or,

2) revert to natural bear behaviour, determined by such measures as:
    a. expanding or shifting their home range away from the landfill after closure (presumably to obtain natural foods),
    b. avoiding humans and towns and thus negative human-bear conflicts, and
    c. selecting "safer" sites further away from roads or towns, or conversely "riskier" sites necessary in order to obtain adequate natural forage.

In this report we investigate whether we are able to accurately predict which bears would display future problem-bear behaviour by monitoring the use and behaviour of individual radio-tagged grizzly bears at the McLeod Lake landfill before and after closure. We also investigate whether alternate options to removing bears are feasible at landfill sites proposed for closure throughout the province.

2.0 STUDY AREA

The study area was centred on the McLeod Lake landfill approximately 110 km north of Prince George in north-central BC (Figures 1, 2). The landfill was located at 695 m elevation, approximately 350 m east of McLeod Lake and 270 m east of Highway 97, a major 2-lane paved highway extending northwards from Prince George (Figure 3). The landfill serviced the small community of McLeod Lake (population ~125) located approximately 3.6 km north of the landfill; the nearest residences were 900 m from the landfill.

The study area was located within the Prince George and Mackenzie Forest Districts, primarily within the Fraser Basin eco-region, and the Nechako Lowland and McGregor Plateau eco-sections (Demarchi 1995). The majority of the study area was characterized by a gently rolling plateau landscape, with elevations ranging between 675 and 1,200 m. The extreme eastern portion of the study area was within the mountainous Hart Ranges of the Rocky Mountains (approximately 25 km east of McLeod Lake). The study area covered portions of 6 biogeoclimatic subzones. The moist-cool subzone of the Sub-Boreal Spruce zone (SBSmk1; DeLong et al. 1993) occurred at elevations below 1,100 m to the west of McLeod Lake, whereas the wet-cool subzone (SBSwk1; DeLong et al. 1996) occurred in these low-elevation areas to the east of McLeod Lake. Higher elevations on the plateau (1,100-1,200m) were within the moist-very cold Engelmann Spruce Subalpine Fir zone (ESSFmv3; McKinnon et al. 1990). The wet-cool and wet-cold subzones of the ESSF (ESSFwk2, ESSFwc3; DeLong et al. 1994) occurred at higher elevations between 1,200 and 1,500 m in the Hart Ranges. Alpine Tundra (AT) occurred above 1,500 m (DeLong et al. 1994). Predominant tree species on the plateau landscape included hybrid white spruce (*Picea glauca x engelmannii*), lodgepole pine (*Pinus contorta*), and subalpine fir (*Abies lasiocarpa*). The plateau had a typical sub-boreal climate, with long snowy winters, and moist cool summers (DeLong et al. 1993).

Other wildlife species in the study area included moose (*Alces americanus*), black bears, wolves, and coyotes (*Canis latrans*), and, to a lesser extent, mule deer (*Odocoileus hemionus hemionus*), white-tailed deer (*O. virginianus*), elk (*Cervus canadensis*), woodland caribou (*Rangifer tarandus caribou*), and wolverine (*Gulo gulo*).

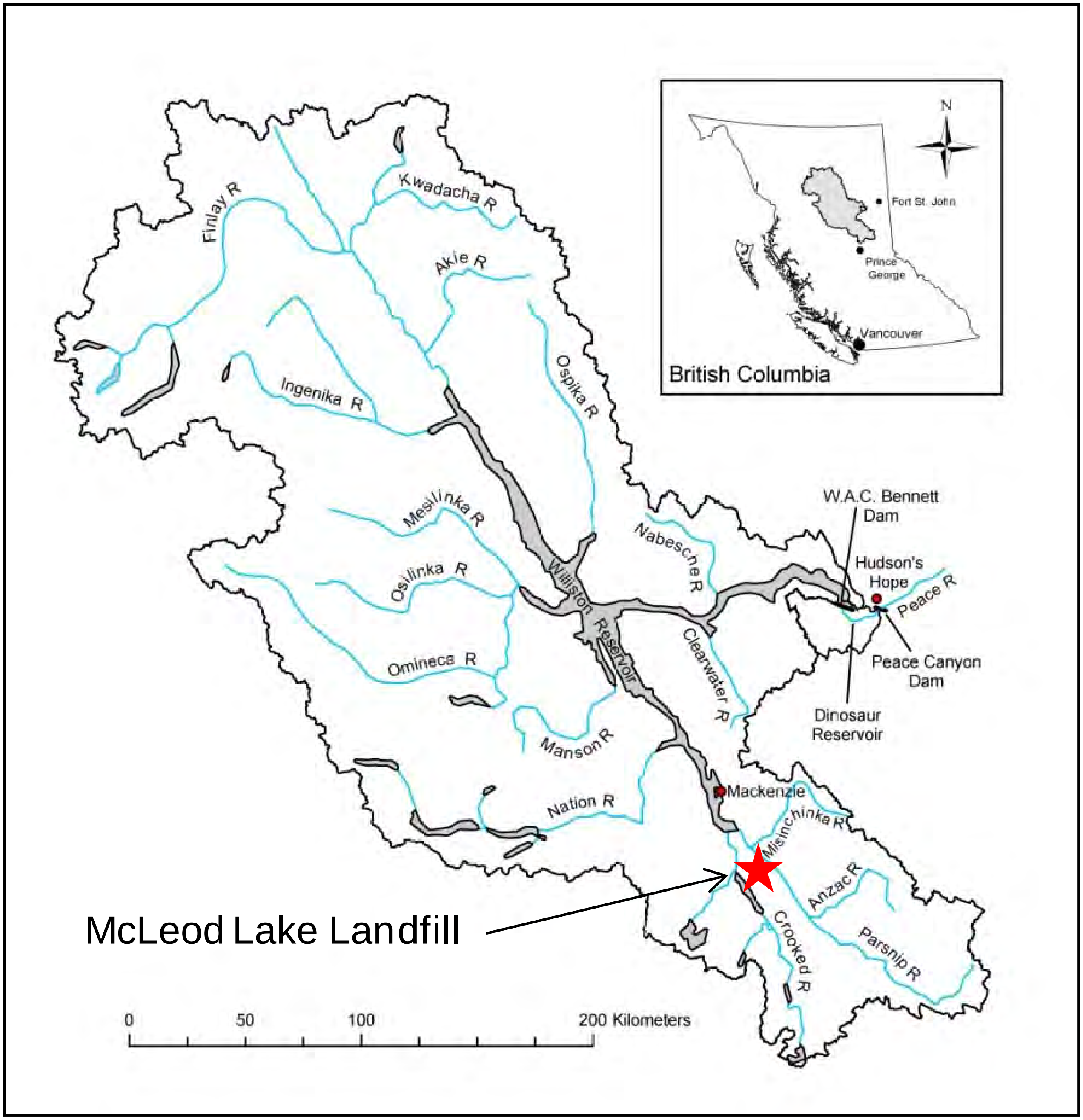

Figure 1. Location of McLeod Lake Landfill and study area for the McLeod Lake Grizzly Bear Behaviour Project in the Parsnip River drainage of the Williston Reservoir watershed, north-central British Columbia.

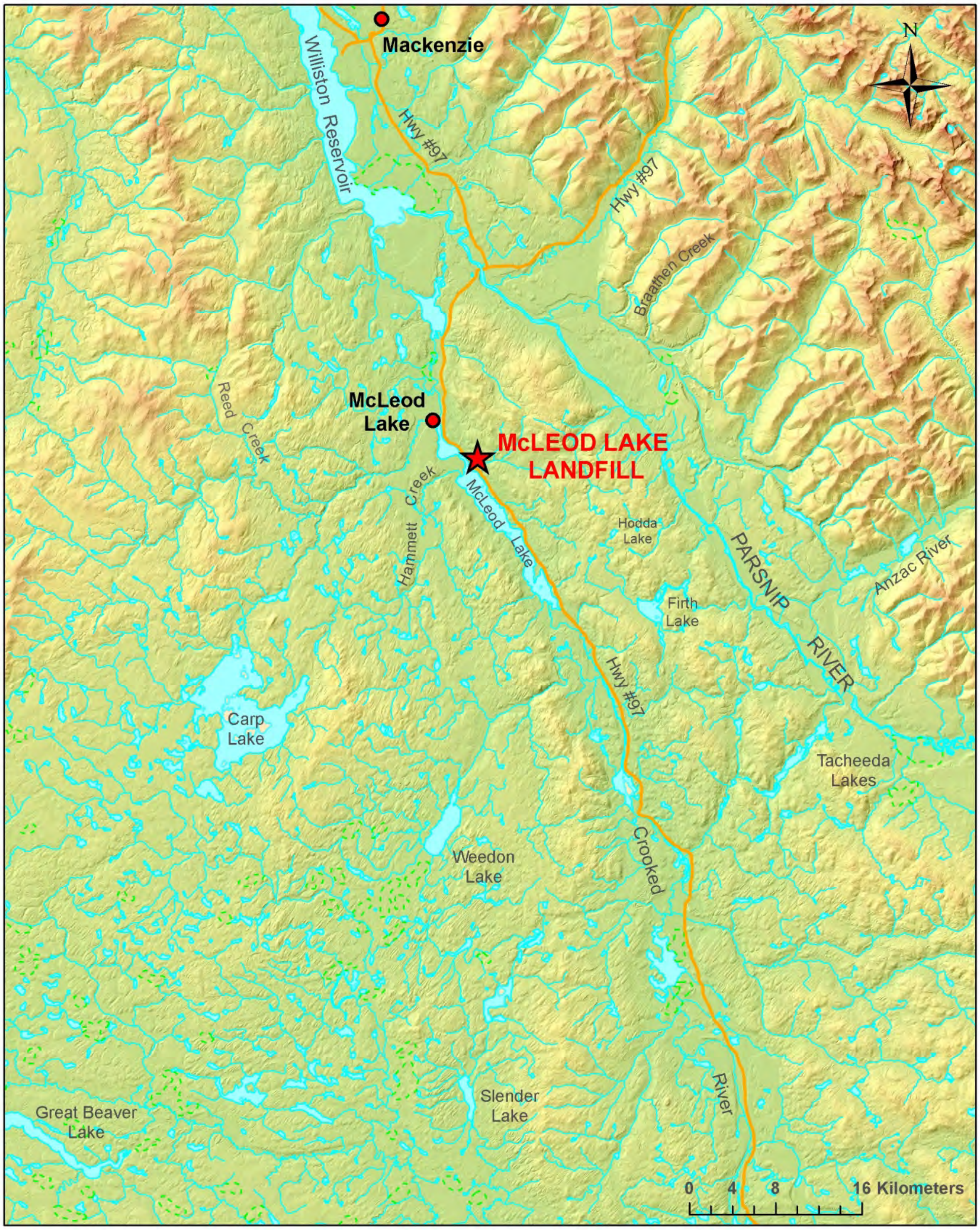

Figure 2. Location of the McLeod Lake Landfill and study area on the sub-boreal plateau in north-central BC.

Figure 3. Aerial view of the McLeod Lake Landfill, looking southwest.

3.0 METHODS

3.1 Capture and Handling

3.1.1 Trapping

Capture permits were acquired from the BC Ministry of Environment, Lands and Parks (MELP; C083650, D009538) and all captures followed guidelines and protocols developed by the Canadian Council on Animal Care, Ottawa, ON (CCAC 2003) and the Resources Inventory Committee, MELP, Victoria, BC (RIC 1998).

We captured bears in snare sets in baited cubbies and non-baited trail sets using Aldrich snares with ¼" anchor and throw cables (Margo Supplies, Calgary, AB), and in baited 1.37 m diameter metal culvert traps. To avoid catching cubs-of-the-year (COY) and wolves, multiple layers of electrician's tape were placed near the end of the throw cable to prevent the cable from cinching tight. Culvert traps and cubby sets were baited with beaver (*Castor canadensis*) in spring and moose and non-game fish in fall. We set traps and snares within the landfill and on the natural gas pipeline right-of-way 450 m east of the landfill. Cubby-set snares were also set in remote locations up to 10 km away from the landfill in 2001 in order to re-capture bears whose radio-tags had been lost or were failing. We attached the cables of trail sets within the landfill to large trees specifically cut and hauled into place; we made use of existing large diameter live trees for cubby sets.

In 2000 and 2001, traps were active between 18:00 and 6:00 in spring (April/May), and 18:00 to 7:00 in fall (September/October), during which time the landfill was closed to the public. Signage was placed at the entrance to the landfill advising the public of closures due to trapping. A pick-up truck was used to block the road entrance during closure periods to prevent public access. We remained in the landfill every evening to observe grizzly bears using the landfill and to process bears captured before dark. After dark, we observed bears (but could not identify individuals) using third generation Scout Eagle monocular night vision equipment (Westinghouse, Toronto, Ontario). A trap-night was defined as 1 trap set for 1 night, and capture success is presented as the number of captures per 100 trap-nights.

3.1.2 Immobilization, Sampling, and Tagging

We immobilized grizzly bears using Telazol® (tiletamine hydrochloride and zolazepam hydrochloride) at 8 mg/kg based on body weight estimated prior to immobilization. We darted bears in snare sets using a Palmer Cap-Chur CO_2 pistol primarily from a pick-up truck and occasionally from the ground. A jabstick was used to deliver Telazol® to bears captured in culvert traps, and to administer second dosages to partially sedated animals in snare sets. Ketaset® (ketamine hydrochloride) at a dosage of 2 mg/kg, or Telazol® at varying dosages, were used as top-up drugs when necessary, and were either hand-injected intramuscularly or delivered by jabstick. Most bears were processed at their capture sites although some were transported by pick-up truck to the gas pipeline for processing for safety (if other bears were in the landfill or the public required landfill access). As a precautionary measure, we attached a snare cable to 1 foot of the bear for the immobilization period (for snared bears, the cable was removed from the snared foot and attached to an alternate foot). All bears were blindfolded, and we monitored pulse, body temperature, and respiration regularly throughout the immobilization period. We took standard body measurements and weighed all bears. We estimated body condition as Poor, Fair, Good, or Excellent according to LeCount 1986 *in*: Jonkel 1992.

We obtained tissue and hair samples for future genetic and stable isotope analysis. We extracted a premolar (PM1, usually upper) during immobilization using a dental elevator and an extractor. Cementum aging of teeth was conducted by Matson's Laboratory, Milltown, Montana. We collected additional samples (blood, scat) from tranquilized bears for possible use by other researchers. We administered 3.0 – 20.0 ml of a long-acting broad-spectrum antibiotic

(Bio-mycin 200®, Boehringer Ingelheim Canada Ltd., Burlington, Ontario) subcutaneously to most bears.

All adult and male subadult grizzly bears were fitted with VHF radio-collars with internal antennas and mortality option (LMRT-4, Lotek Engineering, Newmarket, Ontario). Webbing was inserted between brackets to allow for the collar to drop off after the webbing deteriorated. Each bear was also fitted with colour-coded and numbered ear-tags for identification. Subadult female bears not large enough to wear a conventional VHF collar were fitted with 22 g ear-tag transmitters with mortality option (Advanced Telemetry Systems, Isanti, Minnesota). Male bears were also fitted with ear-tag transmitters as a back-up system in the event of a collar failure or loss. Ear-tag transmitters were programmed using 4 primary types of schedules (with the exception of 1 transmitter attached to a yearling in 2002 which accidentally operated 16 hours/day turning off for 8 hours each night between 23:45 and 07:45). Two of the schedules allowed for immediate transmission (Programs 1 and 3) while the other 2 delayed transmission until the subsequent year to extend the monitoring period. The restricted duration of daily transmission for Programs 1, 2 and 4 (8 hours/day, 5 days/week) was also designed to extend battery life and thus the bear monitoring period.

Program 1: "9-5, Mon-Fri":

Deployment:	Spring 2000.
Program:	Transmit 8 hours/day, 5 days/week for a 259 day period, turn off for 106 days (during the approximate winter denning period), and then repeat this program (active 259 days at the 8hrs/5day schedule, off 106 days) the following year.
Activated:	9:00 on 3 April 2000 (initiating transmission 9:00 – 17:00, Monday to Friday).
Battery Life:	Estimated to remain active until approximately December 2001.

Program 2: "Delayed #1":

Deployment:	Spring 2000.
Program:	Transmit for 1 full day (3 April 2000), turn off for 364 days, then transmit on the same schedule as Program #1.
Activated:	9:00 on 3 April 2000.
Battery Life:	Estimated to remain active until approximately December 2002.

Program 3: "24 Hours":

Deployment:	Fall 2000
Program:	Transmit 24 hours/day for 112 days (until approximate winter denning period), turn off for 105 days, then transmit on the same schedule as Program #1.
Activated:	9:00 on 28 August 2000.
Battery Life:	Estimated to remain active until approximately December 2001.

Program 4: "Delayed #2":

Deployment:	Fall 2000.
Program:	Transmit for 1 day (28 August 200), turn off for 216 days, then transmit on the same schedule as Program #1.
Activated:	9:00 on 28 August 2000.
Battery Life:	Estimated to remain active until approximately December 2002.

3.1.3 Family Relationships

In 2001, Wildlife Genetics International (D. Paetkau, Nelson, BC) examined 14 loci in tissue samples from bears captured in 2000 and 2001 to determine genotypes of each individual bear and identify parent-offspring relationships. In 2002, the adjacent Parsnip Grizzly Bear Project (PGBP) hired Greg Wilson, PhD (University of Alberta, Department of Medical Genetics) to conduct genetic analyses on DNA samples obtained from bears captured by the PGBP, bears captured at the McLeod landfill, and bears "captured" in DNA-based mark-recapture grids in the Parsnip drainage (Mowat et al. 2002). Analyses on the 189 individual grizzly bear samples were conducted using CERVUS and 15-locus genotypes to examine family relationships between bears and assign the 10 nearest potential mothers and fathers.

In 2009, Wildlife Genetics International provided 15-locus genotypes for 2 additional bears captured in 2002 (F14 and M15, yearling offspring of F10) to determine the genetic relatedness and paternity between samples of our known individuals (McLeod Lake and Parsnip bears). Using the program Parente, the known mothers genetic contribution was subtracted to generate the potential genotypes of fathers to the matriarchal females' sets of cubs. We also submitted samples to confirm identities of dead bears that were no longer marked (had lost their transmitters and/or coloured ear-tags), and live un-marked bears captured by the COS at the landfill site in 2007, after conclusion of the study. We used cementum ages and visual observations to confirm or deny DNA parent-offspring relationships and relatedness of study bears.

3.2 Use of the Landfill and Landfill Area by Bears

3.2.1 Fixed-Telemetry Monitoring

To determine use of the McLeod Lake Landfill and the area immediately around the landfill we used an SRX_400 datalogging radio-telemetry receiver (Lotek Engineering Inc., Newmarket, ON) between 30 May and 29 November 2000, 26 April and 16 November 2001, and 17 April and 15 November 2002. We erected the fixed-telemetry station in May 2000 on the highest point of land available (20 m above the landfill site) 250 m east of the landfill. The fixed-telemetry station was powered by a 12V battery in turn powered by 2 solar panels, and was used in combination with Lotek's W21 Event_Log software, an automatic signal detection and analysis software package. W21 Event_Log was programmed to scan all radio-frequencies of tagged bears every 10 minutes searching for signals. When a signal was detected, the program temporarily suspended scanning, and measured the signal strength on each of 3 directional antennas. One antenna pointed directly west towards the landfill; the other 2 were aimed away from the landfill (SE and NE). In 2000, we programmed test transmitter frequencies into the station and positioned transmitters at various locations around the landfill to identify the configuration of signal strengths received on the antennas. This enabled us to better interpret data collected on tagged grizzly bears, including identifying when bears were within the general vicinity versus within the landfill pit itself. Bear radio-tag frequencies were generally programmed into the datalogger within 1 day of capture. We downloaded data from the SRX_400 into a Toshiba Pentium laptop computer monthly, and converted into MS Excel format for analysis. All data were gathered and reported in Pacific Daylight Time (PDT).

3.2.2 Closure of the Landfill

The entire landfill site, including borrow pits, was approximately 5 acres in size, with the open pit approximately 15 m x 20 m. Initial closure activities occurred in the first half of November 2000 with approximately 30 cm of intermediate cover being applied to unused areas of the landfill. The site was officially closed to the public on 31 December 2000 and replaced by a bear-resistant transfer station located 200 m west of the pit. An additional 30 cm of intermediate soil cover was applied in January 2001 to the used areas of the landfill. Final closure activities, including filling of the pit and site clean-up, occurred between 20 and 26 June 2001. The 8,000 m^3 of cover used to complete the closure was excavated from on-site. The resulting depth of fill over the pit area itself was approximately 1.0 to 1.5 m deep.

3.2.3 Determining Bear Use of the Landfill and Landfill Area

Bear use of the landfill and surrounding area was provided by the data-logging radio-telemetry receiver daily in hours:minutes:seconds. We partitioned the data into 2 categories depending upon the strength and direction of the signals received from the 3 triangulating antennas:

(1) Landfill: bear using the landfill pit, pad and immediately surrounding bush.

(2) Landfill Area: bear using the area surrounding the landfill (including the landfill pit by default). The maximum range of datalogger detection was approximately 1.4 km which was determined by comparing datalogger signals with known bear locations obtained during aerial telemetry flights that occurred at the same date and time. Detection distances around the landfill varied due to the surrounding topography, with the furthest detections to the north and closest to the south.

We calculated the time each bear entered and exited the landfill based on strong readings from the direction when the bear first entered and before leaving the area. We found that signals from the datalogger varied in their strength, particularly through the night as bears moved in and out of the landfill pit to the adjacent bush. On several occasions during these time periods, we also visually observed individual bears entering the pit area and dragging a bag of garbage away into the bush presumably to move away from the other bears, then returning to the pit some time later. We assigned these readings as in "landfill" because we were confident in our ability to differentiate between the datalogger signal patterns exhibited when bears were in close proximity to, and coming and going from, the landfill pit, compared to the consistently weaker signals of longer duration when bears used the surrounding "Landfill Area". If the bears' signals disappeared from the datalogger altogether, then the bear was considered to have left the "Landfill Area".

For bears wearing 24-hour transmitters, we focused our analyses on the time in hours spent in the landfill itself, and the number of visits to the landfill. We believe that the amount of time spent in the Landfill Area could be less accurately determined, since individual transmitter signal strengths varied (particularly the further a bear was from the landfill itself), and the location of the bear within the Landfill Area due to varying topography which also influenced signal transmission. We found that use of the landfill occurred almost entirely at night, therefore we describe use of the landfill by the number of "dark" hours (sunset to sunrise) spent in the landfill, and by the number of nights the landfill was visited. Sunrise and sunset times for each day of the study period were obtained for Mackenzie, BC from the National Research Council Canada (www.nrc-cnrc.gc.ca). All times were converted to PDT.

We could not record visits to the landfill by bears wearing daytime/weekday ear-tag transmitters that transmitted between 9:00 – 17:00, Monday to Fridays, since virtually all use of the landfill occurred at night. We therefore determined both the number of hours spent in the Landfill Area during the daytime for these bears, and the number of records in the Landfill Area that occurred within at least 1 hour of 9:00 or at least 1 hour prior to 17:00, as indicators of potential nightly landfill use.

3.2.4 Determining "Availability" of the Landfill and Landfill Area

We calculated "availability" of the landfill and Landfill Areas individually for each bear according to its transmitter program. For bears wearing radio-collars or ear-tags transmitting 24 hours/day, we calculated "availability" based on the number of hours that the datalogger was operational and the bear's transmitter was functioning between sunset and sunrise each day. Availability of the landfill and Landfill Area therefore changed throughout the year, with more "available" hours in fall (1 Sep – den arrival) when nights were longer than in spring (den emergence – 30 Jun) and summer (1 Jul – 31 Aug) seasons. We also calculated "availability" based on the number of nights that the datalogger was operational and the bear's transmitter was functioning.

The landfill itself was not considered to be "available" for bears wearing daytime/weekday ear-tag transmitters that transmitted between 9:00 – 17:00, Monday to Fridays, since virtually all use of the landfill by bears wearing 24-hour transmitters was found to occur at night. Instead, we calculated "availability" of the Landfill Area only for these bears, based on the number of hours that the datalogger was operational and bear's transmitter was functioning between 9:00 – 17:00, Monday to Fridays.

Occasionally the datalogger received continuous signals from a bear when it was on the west side of McLeod Lake (≥ 680 m west of the landfill) which occurred more for some bears than others depending on the placement of their home range. We found these signals difficult to interpret in cases without aerial telemetry to confirm the bears' locations; we assigned these as in the "Landfill Area" for instances where we were unable to verify the exact location of the bear in order to remain consistent between bears.

The start date for "availability" was the first day the datalogger was operational in spring of that year and the bears' transmitter was working; the end date for working transmitters was the last day the datalogger was operational in November of that year. For transmitters that either stopped working, went onto mortality mode (bear died or transmitter was dropped), or went missing (bear left study area), we calculated the end date for "availability" as the mid-point between the date the last active signal was received (by datalogger or aerial telemetry), and the first aerial telemetry date where the transmitter was found emitting a mortality signal or was not transmitting.

3.2.5 Adjusting Use and Availability for Capture Effect

Capture times for radio-tagged bears recaptured at the landfill were determined by actual observation of a bear getting caught, or estimated from either (1) a change in datalogger signals to consistent readings throughout the remainder of the night (showing the radio-tagged bear remained in the same location all night, i.e., in a trap), or (2) the time the radio-tagged bear entered the landfill. For the latter, we estimated capture time to be 1 hour after the bears' landfill entry time. We based this on 22 captures where both the landfill entry time and capture times were known: 11 of the captures occurred within 1 hour of landfill entry, and the other 11 after 1 hour at the landfill. If both the landfill entry and capture times were unknown (as was the case for most bears with "9-5, Mon-Fri" transmitters), we estimated the capture time at 22:30, given that half of the 22 known captures occurred before this time, and half after. The landfill entry time was then consequently estimated to be 1 hour earlier at 21:30. If the capture time was known due to actual observation, then the landfill entry time was not, it was estimated to be 1 hour earlier. Therefore, for purposes of calculating "use" and "availability", each captured bear received a minimum of 1 hour "use" and 1 hour "availability" for the hour immediately preceding it's re-capture.

Once captured, we omitted a bears' "use" and "availability" times for an independently determined period after capture ("capture effect"). If the bear was not immobilized, we omitted all data from the exact or estimated time of capture to 1 hour after the bears' release from the culvert trap. If the bear was immobilized, we omitted all data from the time of capture to 24 hours after the last tranquilizer dose was administered. We chose 24 hours because most tranquilized bears missed at least 1 night before returning to the landfill, whereas bears that were not tranquilized usually returned to the landfill that subsequent night. If a dependent family member was captured (offspring <2 years old, or mother of <2 year-old offspring) data for all remaining family members were omitted for the same time period because their use of the landfill was likely influenced by the captured family member.

3.2.6 Analysing Bear Use of the Landfill

We examined the time of day that bears wearing 24-hour transmitters visited the landfill, and compared entry and exit times with sunset and sunrise hours. We determined the percentage of entry and exit times that occurred in daylight hours (before sunset and after sunrise respectively, including a 10-minute "grace period" on each end to allow for the 10 minute scan cycle of the datalogger), excluding landfill "exit" times that occurred on nights when the bear was captured or the datalogger ceased working. We calculated the percentage of hours and visits by bear that occurred entirely within dark hours excluding capture nights, and calculated mean durations of monthly landfill visits. We tested whether mean durations were shorter after the landfill closed (2001) than before closure (2000) using a one-tailed *t*-test.

We examined the number and timing of visits to the landfill by a family group (female with dependent offspring) and 2 orphaned yearlings in 2000 to determine if family members were acting dependently or independently during landfill visits. Dependent bears were excluded from all analyses of use of the landfill, but visit data are graphed in results for illustrative purposes.

We used the time in hours each bear wearing a 24-hour transmitter spent in the landfill at night ("use") as a percentage of the time the datalogger was recording and the bears' radio-tag was transmitting ("availability"), to determine the percentage of hours spent in the landfill at night by bear by season. We also determined the percentage of nights each bear wearing a 24-hr transmitter spent in the landfill. We examined the percentage of days (determined as any datalogger readings between 9:00 – 17:00) spent in the Landfill Area for each bear wearing a transmitter (both "9-5, Mon-Fri", and 24-hour transmitters).

We also evaluated and compared bear use of the landfill for 3 shorter subsets of time within fall:

(1) 1 October – last landfill visit for each individual bear ("core" landfill use period)
(2) 1 October – last date landfill was used by any radio-tagged bear (14 November 2000)
(3) 1 October – den arrival

We based the degree of landfill use by bears on the percentage of nights each bear spent in the landfill, and classified bears into 1 of 3 broad categories:

(1) Light: ≤33% of available time spent at landfill
(2) Moderate: 34 – 66% of available time spent at landfill
(3) Heavy: 67 – 100% of available time spent at the landfill

We caution the reader that we cannot accurately rank bears within those categories because subtle differences in the rankings may be attributed to an additional capture night for an animal, resulting in a subsequent missed visit to the landfill due to tranquilization, and/or a night when the bear did not visit the landfill. We further used the degree of landfill use to assign a level of potential threat to humans; bears that were heavy landfill-users were felt to have an increased probability of displaying threatening behaviour towards humans post-closure, whereas bears that exhibited a light degree of use of the landfill were not felt to be a threat to humans anymore than their "wild" counterparts.

3.3 Home Range and Habitat Use

3.3.1 Aerial-Telemetry Monitoring

We conducted radio-telemetry monitoring flights during daylight hours from a Cessna 182 fixed-wing aircraft, using a pilot experienced with aerial telemetry and a biologist as observer. The monitoring period extended from den emergence through to den arrival. Bears also monitored by the PGBP received a den flight in early to mid-February of each year to confirm the den site location. Flights were conducted weekly to bi-weekly, weather permitting. Telemetry equipment included a Telonics TR2 scanning receiver, switchbox, and dual H-antennas (Telonics Ltd., Mesa, Arizona) mounted on the wing struts of the plane.

An attempt was made to locate all radio-tagged animals on each flight. We recorded the location in UTM coordinates obtained from an on-board GPS unit as well as a hand-held GPS unit. Habitat data was collected for each radio-location including dominant tree species, canopy cover, snow cover, slope, and aspect. We recorded group size and activity when bears were visually observed.

Location coordinates were manually plotted on topographic and forest cover maps (Ministry of Forests 1990) to discern site elevations and forest cover designations. Elevations were provided to the nearest 50 m from contour levels on 1:50,000 scale topographic maps. Field notes made in-flight aided in plotting each location and discerning the appropriate forest cover polygon. In 2000, a photograph was taken of each bear location to identify site access for future micro-site investigations and also to assist in assigning the correct forest cover polygon. The PGBP also conducted aerial telemetry on some radio-tagged McLeod Lake grizzly bears using similar data collection methods; these data were included in our analyses.

3.3.2 Dependent Samples

We determined the number of dependent bear locations by calculating the straight-line distance between UTM coordinates between each radio-tagged bear in a family group (e.g., mother-offspring 1, mother-offspring 2, offspring 1-offspring 2). We considered locations to be dependent if the bears were located within 500 m from any one of their family members. In analysis of habitat use where independence is important to the statistical outcome, only 1 location for the dependent bears was used. We chose 500 m because we believe that the chance of a bear encountering a different habitat type is probable beyond those distances, and any influence of the mother on the offspring would be unlikely beyond that distance. If bears were greater than 500 m but in the same habitat types, we assumed this to reflect individual choice rather than dependence on their mother or sibling. We also examined the percentage of locations that offspring were found within 100 m, 101-500 m, or greater than 500 m from their mother to support our use of distances greater than 500 m for independence.

For comparison of annual home range sizes, we excluded home ranges of offspring if greater than 50% of their locations were in the presence of (within 500 m of) a family member ("dependent offspring"). Conversely, if greater than 50% of their locations were independent of their mother or sibling ("independent offspring"), we included them in the pre- and post-home range size comparisons.

Incidental sightings of an unmarked offspring of a radio-tagged female that was later captured and radio-tagged were included in some analyses.

3.3.3 Home Range Use and Movements

We calculated 100% Minimum Convex Polygon (MCP) seasonal, annual, and multi-year home ranges for radio-tagged grizzly bears using capture locations, aerial-telemetry locations (including previous and subsequent winter den site locations), as well as 1 landfill location for each season that the bear visited the landfill (spring = den emergence – 30 Jun; summer = 1 Jul – 31 Aug; fall = 1 Sep – den arrival). For purposes of calculating seasonal home ranges for bears wearing daytime/weekday transmitters operating from 9:00 – 17:00, Monday to Friday for which no night visits to the landfill could be obtained, we included 1 landfill location for each season that the bear was detected in the Landfill Area by the fixed-telemetry datalogger during the daytime because a review of bears wearing 24-hour transmitters revealed that the majority of times a bear was recorded in the Landfill Area during the daytime it also subsequently visited the landfill at night. We did not use other methods of home range calculation (e.g., kernel; Seaman and Powell 1996) or report seasonal ranges due to low sample sizes.

MCP home ranges were calculated using the program HawthTools (Beyer 2004) as an extension in ArcMap™ 9.2 (ESRI® Environmental Systems Research Institute, Redlands, CA). Home range images were generated in ArcMap™ 9.2 using 120-metre resolution orthophotos underlay obtained from BC Imagery WMS layer (bc_bc_xb1m_bcalb_1995-2003). These years most closely resemble the forest conditions when the study was conducted.

Statistical differences between females were calculated using Mann-Whitney U-tests with the Type I error rate at $\alpha \leq 0.05$. Statistical tests were performed using Statistica Version 5.0 (StatSoft, Tulsa, OK). We also examined the average distance of aerial-telemetry locations to the landfill by female and male bears in each of the spring, summer, fall, and denning periods, to determine whether we could detect population-level movement patterns by bears that used the landfill and, if so, whether these movement patterns changed pre- to post-landfill closure.

3.3.4 Habitat Use

All aerial radio-telemetry bear locations were overlaid on Vegetation Resource Inventory (VRI; BC Ministry of Forests) map images and Digital Elevation Maps (DEM) using ArcMap™ 9.2 Geographic Information System (ESRI® Environmental Systems Research Institute, Redlands, California, USA). VRI images were queried to obtain the predominant forest stand type(s), species composition of the stand, crown closure (%), forestry harvest date, and biogeoclimatic zone. We also examined the crown closure of the stand based on the amount of ground area covered by the tree crowns (i.e., vertical projection) as determined through VRI. Forest cover maps (FCM, BC Ministry of Forests) were used to obtain land-cover type and projected stand age. The DEM was built from terrain resources inventory maps (TRIM2; BC Ministry of Water, Land, and Air Protection, Victoria, Canada) and were used to obtain elevation above sea level in metres. All raster layers (DEM, slope, aspect, hillshade, distance to roads, forest age) had a resolution (pixel size) of 25 m. We categorized stand age into early seral (0-45 years), young forest (46–99 years), and old forest (≥100 years). The VRI images queried were 2009 layers and we were unable to locate images that dated back to the study years; therefore, we examined the reference year of the VRI layer to ascertain if the data received from the VRI related to the years when the data was gathered. Only locations in which we were confident of the position of the animal (determined in-flight by the biologist) were used in analyses.

Logged areas were determined using the "harvest date" in the VRI database. We classified the location as "cutblock" if it had been harvested after 1979, which is 21 years before the start of the study; blocks harvested earlier than 1979 were classified using the same methods we used to classify the dominant land-cover type.

We classified the dominant land-cover type beginning with the leading tree species percentage, followed by examining non-productive and non-forested descriptors, and finally the broad "land_cover" class found in the VRI database. After plotting on forest cover maps, aerial telemetry locations were grouped into 1 of 5 broad habitat types based on primary tree types:

Coniferous	Stands with >60% conifer tree as leading species.
Mixedwood	Stands with approximately similar composition of conifer and deciduous trees.
Deciduous	Stands with >60% deciduous trees as leading species.
Cutblock	Previously forested sites that were logged in or after 1979. Includes replanted sites with immature stands <10.5 m tall.
Non-commercial	Non-productive brush, not satisfactorily restocked (NSR) lands, meadows, and riparian shrub.

Aerial-telemetry locations from radio-tagged grizzly bears were grouped for examination of seasonal and annual habitat use patterns. Statistical differences were calculated using Mann-Whitney U-tests with the Type I error rate at $\alpha \leq 0.05$. Capture and recapture locations, fixed-telemetry landfill locations, and den site locations were excluded from seasonal habitat use analyses. To avoid pseudo-replication of dependent samples (i.e., family groups travelling together), when more than 1 radio-tagged bear from a family unit were located together, the location was used only once in the habitat data analyses. If members of a family unit were located separately (e.g., greater than 500 m apart) then each separate location was included (see Section 3.3.2).

3.4 Mortalities

In cases where the cause of death was not known or reported, we investigated sites by vehicle or helicopter within 2 weeks of detection of 2 consecutive mortality signals from a radio-transmitter during telemetry flights. Cause of death was ascertained by evidence found at the mortality site, including body condition, degree and type of remains, habitat, and/or prey remains. The identities of the remains of 2 bears belonging to a family unit were determined through the matching of DNA fingerprints (Wildlife Genetics International, Nelson, BC).

All causes of death were placed into 1 of 4 categories:

(1) Threat to humans as a result of the bear feeding on garbage, which included those bears dispatched by the Conservation Officer Service or shot by a private citizen in defence of life and property,

(2) Threat to humans but not related to garbage, which included bears that were incidentally encountered by people while hunting other species,

(3) Unknown threat to humans but not likely garbage-related, which included those bears that were poached, or shot and left possibly through species misidentification, or

(4) Not a threat to humans, which included trapping mortality.

4.0 RESULTS

4.1 Capture and Trapping

4.1.1 Capture

We captured and radio-tagged 12 grizzly bears (9 females and 3 males) using the McLeod Lake landfill in 2000, 6 in spring and 6 in fall (Table 1, Appendix A). A cub-of-the-year was also captured (M13) but marked only with a coloured ear-tag. Two offspring born to F10 during the winter that the landfill was closed (2000/01) were captured as yearlings in spring 2002 and fitted with ear-tag transmitters. A sibling to M13 was observed in 2000 but not captured, and 3 cubs-of-the-year born to F02 in winter 2000/01 were observed in 2001 but never captured. Details on captures, non-capture injuries, and seasonal weight gain by bears in 2000 are described in Wood and Hengeveld (2001).

All adult bears and subadult males were fitted with VHF radio-collars; all males were also fitted with ear-tag transmitters. Four subadult females, and 2 yearlings were fitted with 1 or 2 ear-tag transmitters. See Appendix B for a detailed evaluation of the efficacy of ATS ear-tag transmitters used for monitoring grizzly bears.

Two bears captured in fall 2000 (M08 and F09) had been previously captured and radio-collared by the PGBP on 24 and 25 May 2000 respectively at Firth Lake, 20 km south of the McLeod Landfill. No black bears were observed or captured at the landfill in 2000; exclusion of black bears by grizzly bears from landfills has been observed in previous studies (Smith and Lindsey 1989, MacKay 1996). Three wolves were captured in snare sets in 2000 and 1 was radio-collared (Appendix A).

Table 1. Sex, age, capture dates and number of re-captures of grizzly bears captured at the McLeod Lake Landfill and vicinity 2000 – 2002.

Bear ID no.	Sex	Age at 1st capture[a]	Date of 1st capture[b]	No. of times caught in Landfill in 2000	Date of capture after landfill closure	Total # captures
Adult female with 2 COY dependents 2000[c]						
F12	F	5	27-Sep-00	1		1
M13	M	COY	01-Oct-00	1		1
Adult female with 2 3-year-old dependents 2000 (all independent 2001)						
F09	F	10	25-May-00	4	25-May-01	6
M08	M	3	25-May-00	2		3
F07	F	3	31-Aug-00	6		6
Orphaned dependent yearling siblings 2000 (independent 2-year-olds 2001)						
F01	F	1	29-Apr-00	4		4
F06	F	1	27-May-00	4	06-May-01	5
Adult female no dependents 2000 (3 dependent COY 2001)						
F02	F	8	30-Apr-00	9	19-Sep-01	10
Young adult female no dependents 2000 (2 dependent yearlings 2002)						
F10	F	4	01-Sep-00	2	16-May-02	3
F14	F	1	13-May-02	0		1
M15	M	1	15-May-02	0		1
Subadult females 2000, 2001[d]						
F04	F	2	09-May-00	7		7
F11	F	2	18-Sep-00	2		2
Subadult male[d]						
M03	M	2	09-May-00	1		1
Adult male						
M05	M	17	23-May-00	2	08-May-01	3

[a] Age based on birth date estimated at February 1st
[b] All bears were initially captured at the landfill except M08 and F09 (20 km south) and F14 and M15 (1 km south)
[c] COY M13 captured and color-marked only, 2nd COY observed but not captured
[d] F04, F11, and M03 all independent siblings, and offspring of F02

We believe we captured all adult bears using the landfill in 2000 by the end of trapping in fall (5 October 2000) because we did not observe any new individuals during our night or daytime observations, and we recaptured 10 of the 12 radio-tagged bears during fall trapping, some of them multiple times. However, DNA analyses (see section 4.3) revealed unidentified fathers of some of the bears we captured at the landfill, suggesting that some additional adult males may have used the landfill but were not captured or that the females were bred elsewhere in their home ranges.

F02 was captured more often than any other bear in 2000; she was first captured in spring, and subsequently recaptured 8 times in fall. This 8-year old female was observed to exhibit less aggressive behaviour with each successive capture so we attempted to dissuade her from being recaptured by spraying capsicum bear spray immediately prior to her being released on each of her last 3 captures (21, 26, and 29 September). Trapping ceased 5 days later so it is unknown if the aversive conditioning would have eventually become effective. F02 was recaptured again in a culvert trap in the landfill in fall 2001 (after landfill closure), she was the only bear caught that fall.

Trapping in 2001 and 2002 after the landfill was closed was primarily aimed at re-capturing bears to replace transmitters, but also to ensure all independent individuals using the landfill during the study period had been radio-tagged. Four grizzly bears were recaptured in 2001 (Table 1): 3 were trapped at the landfill, and 1 (F09) was darted from the air by the PGBP in spring in order to replace her VHF collar with a GPS collar. Bear F06 that previously wore only ear-tag transmitters was fitted with a VHF radio-collar. No new grizzly bears were captured. One black bear was captured in a baited cubby set approximately 500 m from the landfill in spring 2001 and released without collaring.

In 2002, F10 was recaptured along with her 2 unmarked yearling cubs. F10 had dropped her VHF collar in October 2001 and her ear-tag transmitter ceased working in April 2002. Traps were set when she was incidentally observed on the gasline approximately 1 km south of the landfill in May. The family unit was captured over 2 consecutive nights using a culvert trap: F10 was fitted with a GPS collar for the PGBP, and her 2 yearling cubs (F14 and M15) were fitted with ear-tag transmitters.

Aside from capture, we did not apply negative stimulus (such as rubber bullets or emetic chemicals) to bears in an attempt to reverse potential negative behaviours after landfill closure, nor were any bears killed or translocated prior to landfill closure. Bears were only radio-tagged and monitored by remote datalogger, aerial telemetry, and visual observations.

4.1.2 Trapping Success

We trapped for 26 nights in the McLeod Lake Landfill Area in spring 2000 (25 April – 30 May) resulting in 238 trap-nights, and 30 nights in fall 2000 (29 August – 5 October) resulting in 310 trap-nights. Capture success in 2000 was 3 times higher in fall (11.6 captures/100 trap-nights) than in spring (3.8 captures/100 trap-nights). We captured bears 9 times in spring (6 individual grizzly bears) and 36 times in fall (12 individuals) suggesting that more bears used the landfill in fall than in spring, and individual bears visited the landfill more often (resulting in multiple recaptures) in fall than in spring. The success of capturing bears in different trap types is discussed in Appendix C.

In 2001, after closure of the landfill, we trapped in the Landfill Area for 8 nights in spring (6 – 13 May) resulting in 47 trap-nights, and 15 nights in fall (11 September – 31 October) for 28 trap-nights. Two bears were recaptured in spring (F06, M05) and 1 in fall (F02). Capture success was similar between spring 2000 and spring 2001 (3.8 versus 4.3 captures/100 trap-nights respectively), but success was substantially lower in fall 2001 (3.6 captures/100 trap-nights) after landfill closure than in fall 2000 (11.6 captures/100 trap-nights). One culvert trap was operational at the landfill in spring 2002 for 26 nights, but no bears were captured.

4.1.3 Family Relationships

We examined the family relationships of bears using the landfill to determine if bears that were raised at the landfill were more likely to utilize the landfill than bears that were not (i.e., the landfill was drawing unrelated bears from a larger area).

Mother/offspring relationships were established for 12 of the 15 bears captured including 4 family groups and 1 sibling pair (Table 2, Appendix D). Two adult females were accompanied by offspring during their landfill visits: 10-year-old F09 with 3-year-old offspring F07 and M08, and 5-year-old F12 with 2 cubs-of-the-year (M13 and an unmarked cub). Another adult female captured at the landfill in 2000 (4-year-old F10) was alone, but produced 2 cubs-of-the-year over the 2000/01 winter that were subsequently captured and radio-tagged as yearlings in spring 2002 (F14, M15).

We were able to determine much about the familial relationships of an 8-year-old adult female (F02). Based on genetic analysis, F02 appeared to be the mother of three 2-year-old bears (M03, F04 and F11), all 3 of which were captured at the landfill in 2000. All 3 offspring shared an allele in common with F02 at every locus analysed, which is strong evidence for a parent-offspring relationship (J. Weldon, Wildlife Genetics International, pers. comm.). These offspring appeared to have dispersed in spring 2000; they were not located with F02 during subsequent radio-telemetry flights. F02 was observed with 3 cubs-of-the-year in 2001, meaning she was bred in spring 2000. Interestingly, all 3 independent offspring (M03, F04, F11) denned within 2 km of their mother over the winter of 2000/01, during which time she gave birth to a new set of cubs.

We further examined potential fathers of bears using the landfill through genetic analysis assignment programs because we believed we had trapped all animals using the landfill and therefore assumed the large male, M05, would be the father of many of the landfill offspring. However, M05 did not father any of the aforementioned cubs as indicated by genetic analysis, suggesting that either we did not catch all the bears using the landfill, or that the landfill-captured females bred elsewhere (Appendix D). Instead, 4 different males emerged as candidate fathers for offspring of landfill bears, 3 from existing DNA samples and 1 that did not match any known samples. M05 did appear to be either the father or full sibling of F09. Please refer to Appendix D for further details on offspring relationships based on the genetic analyses.

Table 2. Mother-offspring relationships, and years where offspring were dependent or independent of their mothers, as determined by observational and genetic data for grizzly bears captured at McLeod Lake Landfill, 2000 - 2002.

Bear ID # and gender	Relation	Birth year	Capture year	Method of determination	Offspring dependency[a] 2000	2001	2002
F12	Mother	1995	2000				
M13	Sibling	2000	2000	Visual	Dependent	Dependent	unknown
unknown	Sibling	2000	n/a	Visual	Dependent	Dependent	unknown
F09	Mother	1990	2000				
M08	Sibling	1997	2000	Visual	Dependent	Independent	
F07	Sibling	1997	2000	Visual	Dependent	Independent	
unknown[b]	Mother		n/a				
F01	Sibling	1999	2000	Visual, Orphaned	Dependent	Independent	
F06	Sibling	1999	2000	Visual, Orphaned	Dependent	Independent	
F02	Mother	1992	2000				
M03	Sibling	1998	2000	DNA and Age[c]	Independent		
F04	Sibling	1998	2000	DNA and Age[c]	Independent		
F11	Sibling	1998	2000	DNA and Age[c]	Independent		
unknown	3 COY	2001	n/a	Visual		Dependent	Dependent
F10	Mother	1996	2000				
M15	Sibling	2001	2002	Visual		Dependent	Dependent
F14	Sibling	2001	2002	Visual		Dependent	Dependent

[a] Offspring were considered dependent if they were cubs-of-the-year, or still in the presence of their mother (or sibling) >50% of aerial telemetry locations

[b] Unknown adult female = mother of orphaned yearlings F01 and F06 that was shot in 1999 prior to study

[c] Offspring inferred from genetic analysis and cementum aging (all 2 years old); not observed with mother F02

4.2 Bear Use of the Landfill and Landfill Area

4.2.1 Fixed-Telemetry Monitoring

Use of the McLeod Lake Landfill by radio-tagged bears was determined by the fixed-telemetry datalogger station positioned at the landfill. The datalogger was operational from 30 May - 29 November 2000 (pre-landfill closure), 26 April - 16 November 2001 (immediately post-closure), and 17 April - 15 November 2002. The datalogger logged 34,963 *cumulative bear hours* (i.e., dependent upon the number of bears transmitting) in 2000, 26,102 cumulative bear hours in 2001, and 8,264 cumulative bear hours in 2002 (Appendix E). Signals were better received in some surrounding areas of the landfill than others (e.g., if the bear was to the north of the landfill we often obtained continuous readings, however, if they moved to the south of the landfill the signals often faded and then returned just before a landfill visit). The range of the signals received from the datalogger appeared to be dependent upon the terrain between the bear and datalogger, speed that the bear entered the Landfill Area, and transmitter variability; because of the influence of these factors on readings received, we believe the "in Landfill Area" and "in landfill" results presented are minimums. By examining aerial-telemetry data that occurred at similar times as datalogger readings, transmitter signals could be detected by the datalogger up to 1.4 km from the landfill although most readings were less than 1 km.

4.2.2 Closure of Landfill

Closure of the landfill over the winter of 2000/01 and subsequent spring was successful in that bears were no longer able to access garbage. Although some digging by bears was observed in the first spring after closure, it was minimal and resulted in little, if any, food reward. Only 30 cm of soil cover covered the pit at that time. No further diggings were observed after the final fill (1.0 to 1.5 m deep) was applied to the pit area in June 2001. Aerial-telemetry confirmed that no radio-tagged bears were in the vicinity of the landfill prior to commencement of these activities, thus no displacement of bears was apparent. Repeated visits by bears to the landfill in 2001 and 2002 were likely because bears were attracted to the landfill by our baited trap sites. However, occasional food rewards were also obtained around the newly established transfer stations from spilled garbage in the parking area. On 2 occasions, radio-tagged bears climbed into the transfer bin itself after a public user left the lid open and were unable to get out. One bear was shot (F01, October 2001) and the other was tranquilized and moved to her denning area (F02, October 2007).

4.2.3 Number of Landfill Visits by Bears

We recorded 522 visits to the landfill by 12 bears wearing 24-hour transmitters in 2000, and 42 visits by 7 bears wearing 24-hour transmitters in 2001 (Table 3). The majority of visits were recorded in fall (1 Sep – den arrival; n = 460 in 2000, and n = 23 in 2001), however in 2000 this is partially a reflection of the increased number of bears radio-tagged with 24-hour transmitters by late September.

These numbers represent a minimum number of landfill visits in both years since visits occurred at night (see section *4.2.2*) and were therefore not recorded by the datalogger for bears wearing daytime/weekday transmitters. Bears wearing 24-hour transmitters subsequently visited the landfill after being recorded within the Landfill Area during the day on 97% of occasions (n = 339 records of 8 independent bears). (Eight of the 10 records where bears were in close

Table 3. Number of night-time visits (including initial landfill capture) to the McLeod Lake Landfill by bears wearing 24-hour transmitters in 2000 (pre-closure) and 2001 (post-closure) in spring (datalogger start date – 30 Jun), summer (1 Jul – 31 Aug), and fall (separated into 1 – 30 Sep, and 1 Oct – datalogger end date). Blank cells denote bear was not captured or transmitter dropped. Numbers in brackets are the number of times bears wearing daytime/weekday transmitters (9:00 – 17:00, Monday to Friday) were recorded in the Landfill Area (and include initial captures); these numbers suggest possible landfill visits but are for illustrative purposes only and are not included in the total number of actual visits. (Datalogger start dates: 30 May 2000, 26 April 2001; datalogger end dates: 29 November 2000, 26 November 2001.)

Bear	Number of landfill visits									
	2000					2001				
ID no.	Spring	Summer	Sep	Oct/Nov	Total	Spring	Summer	Sep	Oct/Nov	Total
Adult female with 2 COY dependents 2000 (dependent yearlings 2001, 2-year-olds 2002)										
F12			1	12	13	0	0	0	2	2
Adult female with 2 radio-tagged 3-year-old dependents 2000 (all independent 2001)										
F09	0	9	21	35	65	1				1
M08	0	10	21	35	66	1	0			1
F07		1	18	35	54	0	0	(1)	0	
Orphaned dependent yearling siblings 2000 (independent 2-year-olds 2001)										
F01	(14)	(23)	15	44	60	(2)	(4)	(3)	(11)	
F06	(12)	(16)	(3), 5	42	48	(2), 2	2	1	4	9
Adult female no dependents 2000 (3 dependent COY 2001, yearlings 2002)										
F02	1	5	20	20	46	0	1	8	8	17
Young adult female no dependents 2000 (2 dependent COY 2001, radio-tagged yearlings 2002)										
F10			18	13	31	1	2	0	(2)	4
Subadult females no dependents 2000, 2001										
F04	(1)	(8)	15	31	48					
F11			9	44	53	0	0	0		
Subadult male										
M03	1	0	0	0	1					
Adult male										
M05	4	27	6	0	37	8				8
Total	9	53	149	311	522	13	5	9	14	42

proximity but did not subsequently visit the landfill were attributed to M05 who remained in the Landfill Area in June but visited it only twice.) This suggests a high likelihood that bears wearing daytime/weekday transmitters recorded in the Landfill Area during the daytime probably visited the landfill either the previous or subsequent nights. We documented 74 records within the Landfill Area in the daytime for 4 bears wearing daytime/weekday transmitters in some seasons in 2000, and 25 records in the Landfill Area from 5 bears in some seasons in 2001

(Table 3). These records denote time periods when signals were received for at least an hour after 9:00 (suggesting a possible previous night visit to the landfill), or at least an hour prior to 17:00 (suggesting a night visit to the landfill).

Only 4 bears wore 24-hour transmitters for portions of 2002. No landfill visits were recorded for F06 (died 23 May), F02 or F12 (dropped radio-collars on 30 May and 30 June respectively). F10 did not have a functioning transmitter in spring 2002 until her 16 May re-capture approximately 1 km south of the landfill. She visited the landfill twice in summer, dropped her collar on 23 September, and visited only once in fall on 24 September as determined through her offspring's transmitter (F14). However, F14's transmitter was not operational for 8 hours every night between 23:45 and 7:45 so some additional night-time landfill visits by this family unit may have been missed.

Although we conducted baited trapping throughout fall 2000, we think it had little influence as an attractant to bears given the abundant garbage supply on site. However, the administration of immobilization drugs during fall captures did influence an individuals' use of the landfill and subsequent visits. In 13 of 16 cases, bears captured overnight and tranquilized in the morning missed at least 1 nightly visit before returning to the landfill. Conversely, 16 of 17 captured bears released in the morning without immobilization (i.e., from culvert traps), visited the landfill the subsequent night. Conversely, in fall 2001 when garbage was no longer available in the landfill, baited trapping would have provided potential food rewards and may have resulted in more visits by bears than if trapping hadn't occurred.

4.2.4 Daily Timing of Landfill Visits

Grizzly bears fitted with 24-hour radio-transmitters visited the landfill at night both pre- and post-landfill closure (Figures 4, 5, 6, 7). Bears avoided the landfill during the day in both years, but often remained in the Landfill Area in the day, particularly in fall 2000.

Bears entered the landfill later during the lighter summer months and earlier during the darker fall months (Figures 4, 5). Only 12% of all landfill entry times occurred before sunset in 2000 (n =322), and 13% before sunset in 2001 (n =39). One subadult female (F04) was responsible for the majority of earlier entry times in both years (53% of all early entry times in 2000, and 80% in 2001).

Bears primarily exited the landfill in the latter part of the night with most bears leaving by sunrise (Figures 6, 7). Only 12% of exit times occurred after sunrise in 2000 (n =293), and 22% after sunrise in 2001 (n =36).

Of the 287 visits by 8 bears or family groups in 2000 for which we determined both entry and exit times, 72.5% of them occurred entirely in the dark. The percentage of an individual bears

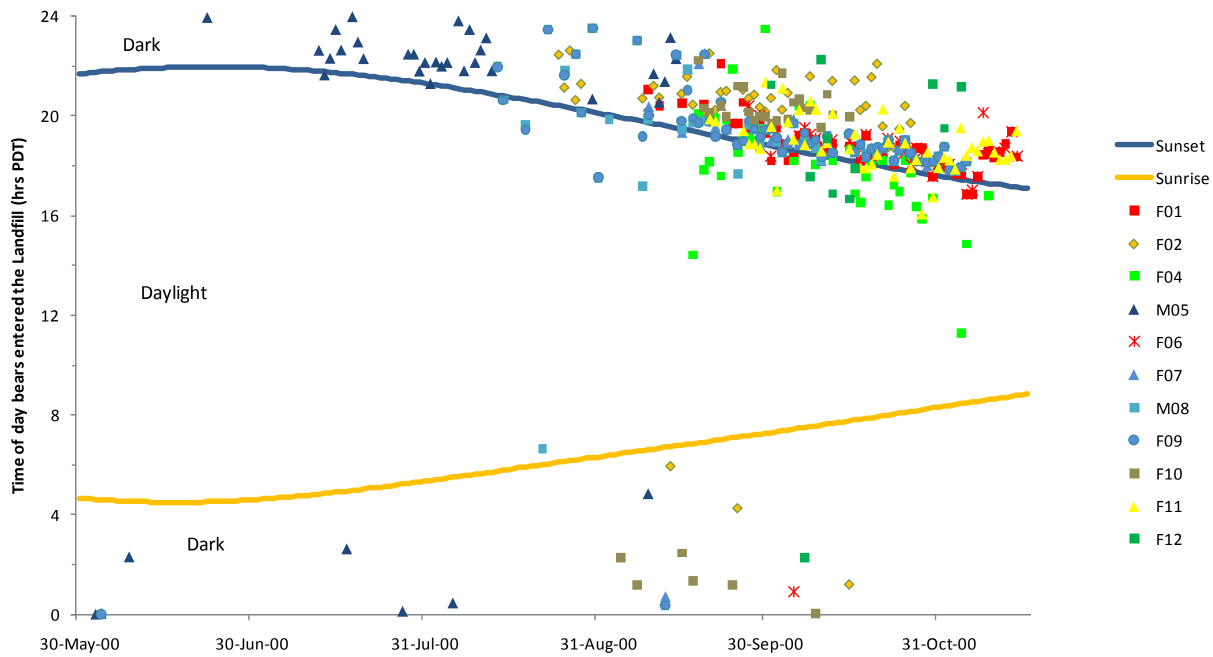

Figure 4. Time of day that grizzly bears wearing 24-hour transmitters entered the McLeod Lake Landfill in 2000 (pre-closure).

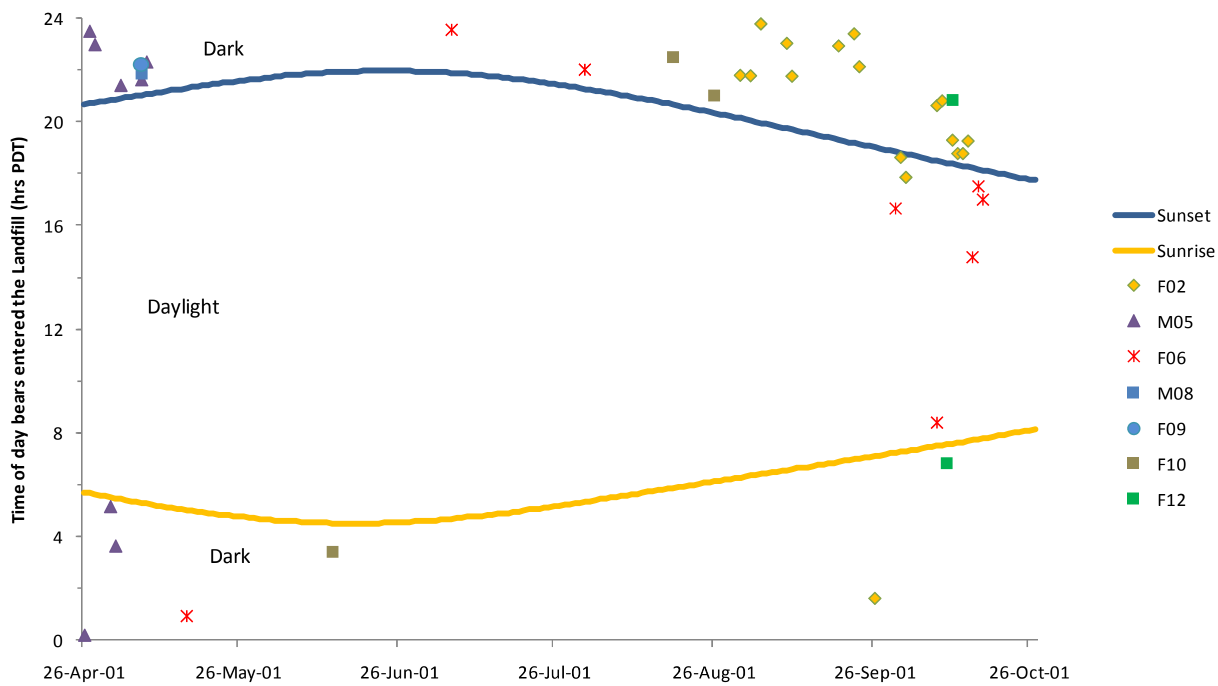

Figure 5. Time of day that grizzly bears wearing 24-hour transmitters entered the McLeod Lake Landfill in 2001 (post-closure).

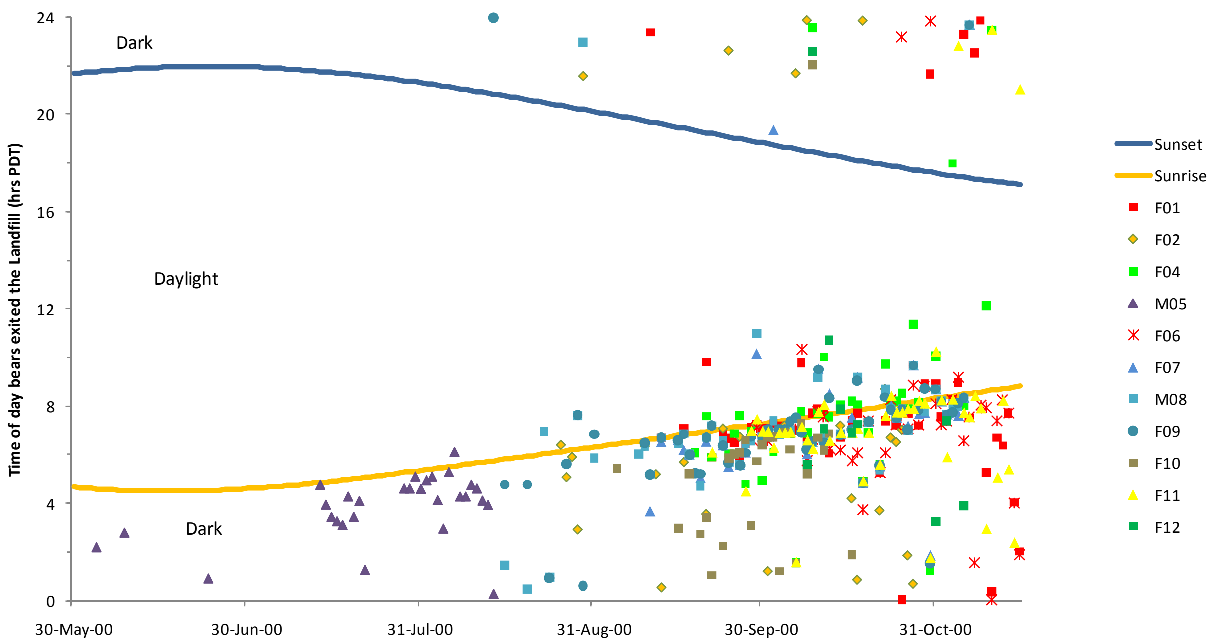

Figure 6. Time of day that grizzly bears wearing 24-hour transmitters exited the McLeod Lake Landfill in 2000 (pre-closure).

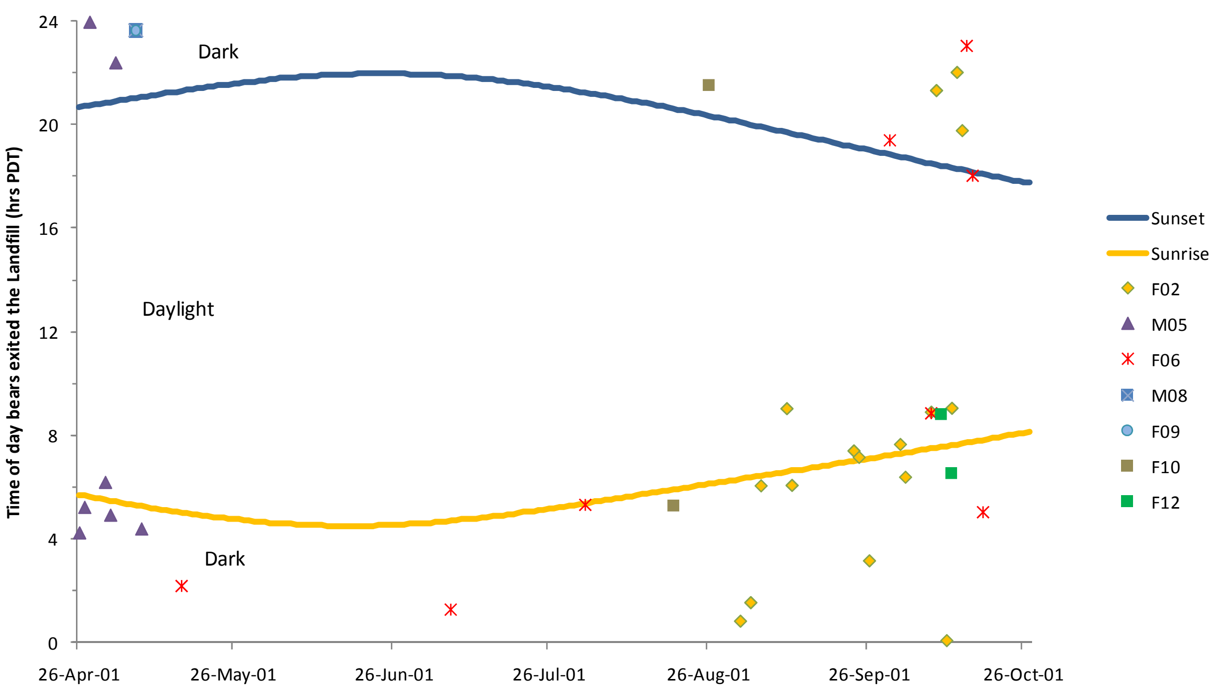

Figure 7. Time of day that grizzly bears wearing 24-hour transmitters exited the McLeod Lake Landfill in 2001 (post-closure).

visits that occurred entirely in the dark ranged from 34.2 – 100%. The mean percentage of visit hours per bear that occurred in darkness was 96.3% (SE = 2.1, *n* = 8 bears. F04 was the only bear to use the landfill during daylight hours (e.g., not just entering the landfill for a short time in the day preceding a night visit but spending entire days in the landfill); 2 of her landfill visits in October and 1 in November 2000 spanned 1.4, 3.0, and 3.9 full days respectively. In 2001, 61% of all visits to the landfill (*n* =36 visits) occurred in complete darkness. The mean percentage of visit hours per bear that occurred in darkness was 92.7% (SE = 3.5, *n* = 6 bears); only 2 bears spent 100% of their visits entirely in the dark.

Given that all bears' transmitters (both "24-hour" and "9-5, Mon-Fri") were operational in daytime hours for at least 5 days/week throughout the course of the study, this general lack of daytime use of the landfill by most bears demonstrates that bears prefer to use the landfill primarily during dark (sunset to sunrise) hours.

4.2.5 Seasonal Timing of Landfill Visits

In spring 2000, we first observed grizzly bears (orphaned yearlings F01 and F06) using the McLeod Lake Landfill on 9 April; no bears or fresh sign were observed on 5 April. Local reports confirmed the yearlings continued to frequent the landfill throughout the month. We trapped in the landfill between 25 April and 30 May and captured 6 grizzly bears including both orphaned yearlings. Overall use of the landfill in spring 2000 (as determined by both nightly observation and capture success rate) was deemed to be relatively low. After 30 May, use of the landfill by radio-tagged grizzly bears was monitored using the fixed-telemetry datalogger station. The single adult male M05 was the only bear with a 24-hour transmitter recorded to visit the landfill in spring after the datalogger was operational (Appendix F). However, F01 and F06, fitted only with daytime/weekday transmitters operating from 9:00 – 17:00 Monday to Fridays, were frequently recorded within the Landfill Area in the daytime in spring (Figure 8), suggesting they likely visited the landfill at night (see rationale in section *4.2.3*).

A similar pattern of spring visits by bears to the landfill was noted for the post-closure year 2001 (Figure 9). We expected similar dates of initial visits to the landfill because bears would not be aware the landfill had been closed and covered during winter hibernation. A site visit on 12 April revealed fresh grizzly tracks near the transfer station. The datalogger began operating on 26 April, and a few spring visits by radio-tagged bears were recorded in late April and early May (Appendix F). Two bears were captured during trapping between 6 and 13 May (F06 – 6 May; M05 – 8 May). M05 frequented the landfill in spring, visiting 8 nights between the datalogger start on 26 April and when he died on 8 May. Two of the 3 bears wearing transmitters during both pre- and post-closure spring seasons (orphaned yearlings F01 and F06) substantially decreased their daytime use of the Landfill Area in 2001 (Figure 8), while F02

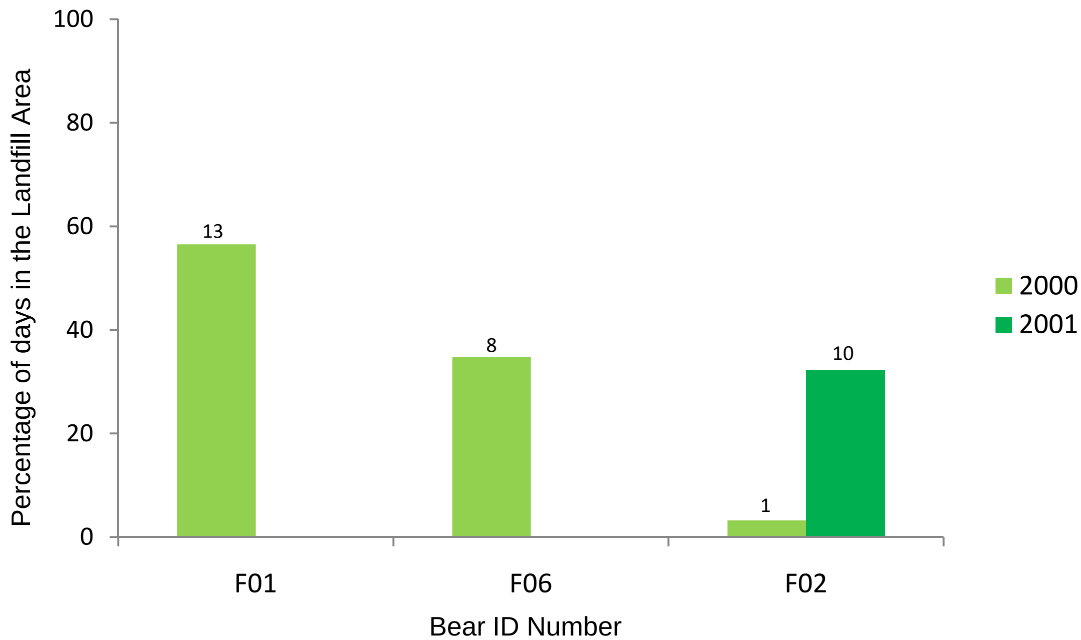

Figure 8. Percentage of days spent in the McLeod Lake Landfill Area between 30 May (datalogger start date in 2000) and 30 June for all bears with operational transmitters both pre- and post-closure. Number of days (*n*) listed above bars.

actually increased the amount of time she spent in the Landfill Area in the daytime. She did not visit the landfill at night however.

In the second year post-closure (2002), 3 of the 4 bears wearing 24-hour transmitters were not recorded in the Landfill Area in spring between the datalogger start date (17 April) and the dates they either dropped their collars (F02 – 31 May; F12 – 10 Jul) or died (F06 – 23 May). The fourth bear (F10) dropped her collar the previous fall and was re-collared on 15 May 2002; her first visit to the landfill after that point was 25 July. One culvert trap was baited periodically at the landfill throughout May, but no bears were captured and little sign was observed. Only 4 bears transmitted for portions of 2002 and none visited the landfill that spring.

Use of the landfill in summer was low overall both pre- and post-landfill closure, but slightly higher in 2000 primarily due to use by M05. M05 was the only bear wearing a 24-hour transmitter that made greater use of the landfill in summer than other seasons; he spent 27% of the dark hours in summer 2000 in the landfill (Appendix F). The orphaned yearlings F01 and F06 (wearing only "9-5, Mon-Fri" transmitters) spent 56% and 34% of their days respectively in the Landfill Area in summer 2000 (Figure 10) and likely visited the landfill at night. F02, and F09 with her dependent offspring M08 and F07, also periodically visited the landfill in late summer 2000. In 2001, summer use was minimal and exhibited by only 2 bears (Appendix F). Only 1 bear was wearing a 24-hour transmitter in summer both pre- and post-closure; F02 spent 5 nights in the landfill in 2000 and 1 in 2001.

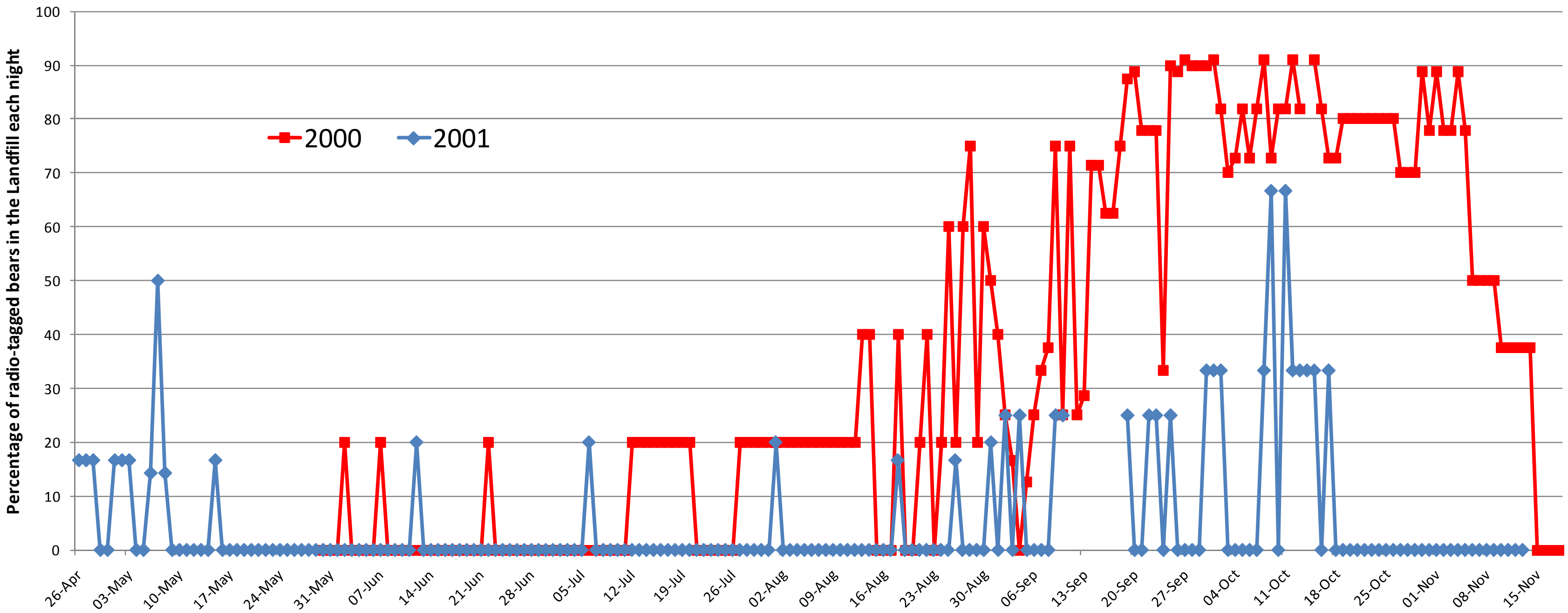

Figure 9. Percentage of grizzly bears with 24-hour transmitters in the McLeod Lake Landfill each night that the datalogger was working in 2000 (pre-closure) and 2001 (post-closure). Datalogger operational from 30 May – 29 November 2000 (except 14 October), and 26 April – 16 November 2001 (except 11 – 18 September). The number of bears (*n*) transmitting varied daily and seasonally. In 2000: spring and summer (5), 4 – 19 Sep (7 to 8), 20 – 27 Sep (8 increasing to 11), 28 Sep – 26 Oct (11 decreasing to 8), 27 Oct – 16 Nov (8 decreasing to 3), 17 – 18 Nov (2). In 2001: 26 April (6), 25 May (5), 2 August (6), 28 August (5), 1 September (4), 29 September (3), 3 November (2).

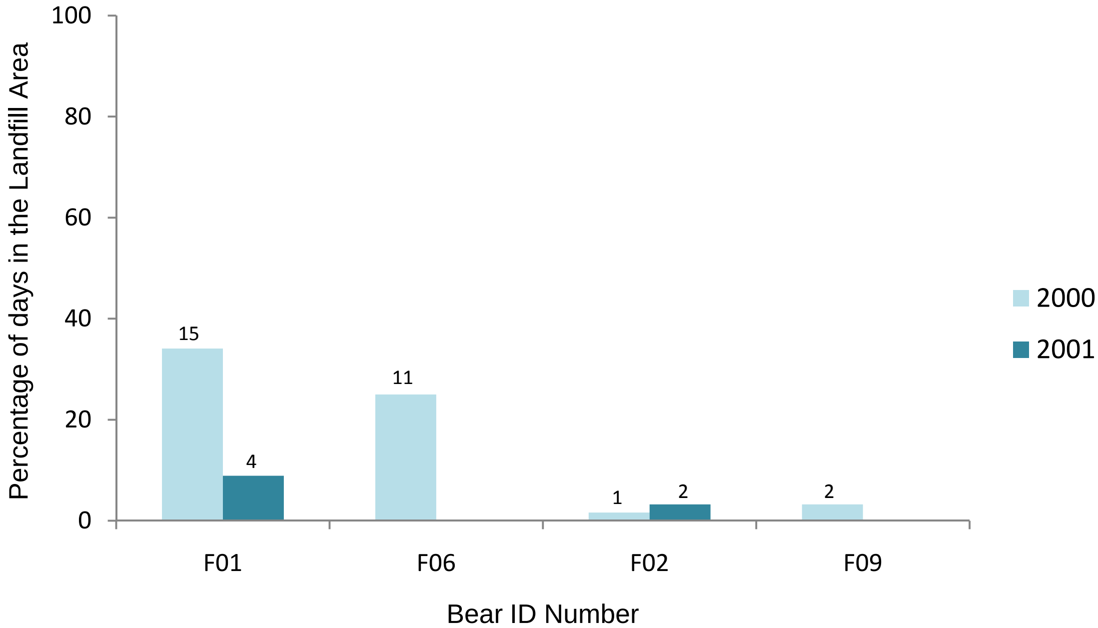

Figure 10. Percentage of days spent in the McLeod Lake Landfill Area in summer (1 Jul – 31 Aug) for all bears wearing operational transmitters both pre- and post-closure. Number of days (*n*) listed above bars.

Similar to spring, 2 of the 3 bears wearing transmitters during summer both pre- and post-closure (orphaned yearlings F01 and F06) substantially decreased their daytime use of the Landfill Area in 2001 (Figure 10), while F02 slightly increased the amount of time she spent in the Landfill Area in the daytime.

Use of the landfill by radio-tagged grizzly bears peaked during the fall hyperphagia period both pre- and post-closure (Figure 9). However, use was much higher in fall 2000 than 2001. In 2000, the number of radio-tagged bears in the landfill each night increased in fall with 70 – 91% of the radio-tagged bears visiting the landfill each night between 25 September - 5 November. Use of the landfill declined from late October to November in both years as bears moved to den sites. The 3 bears wearing 24-hour transmitters during both pre- and post-closure fall seasons substantially decreased their use of the landfill in 2001 (Figure 11), and left the landfill earlier in the season in fall 2001 than they did when the landfill was open in 2000 (Appendix L1).

Four of the 5 bears wearing transmitters in fall both pre- and post-closure decreased their daytime use of the Landfill Area in 2001 (Figure 12). F01 was the only bear to increase her daytime use of the Landfill Area suggesting she spent significant time visiting the landfill at night. She subsequently died October 13 after climbing into an open transfer station.

The 2 independent males (M03 and M05) made little if any use of the landfill in fall 2000. M05 frequented the landfill in early September, but did not return to the landfill after being re-

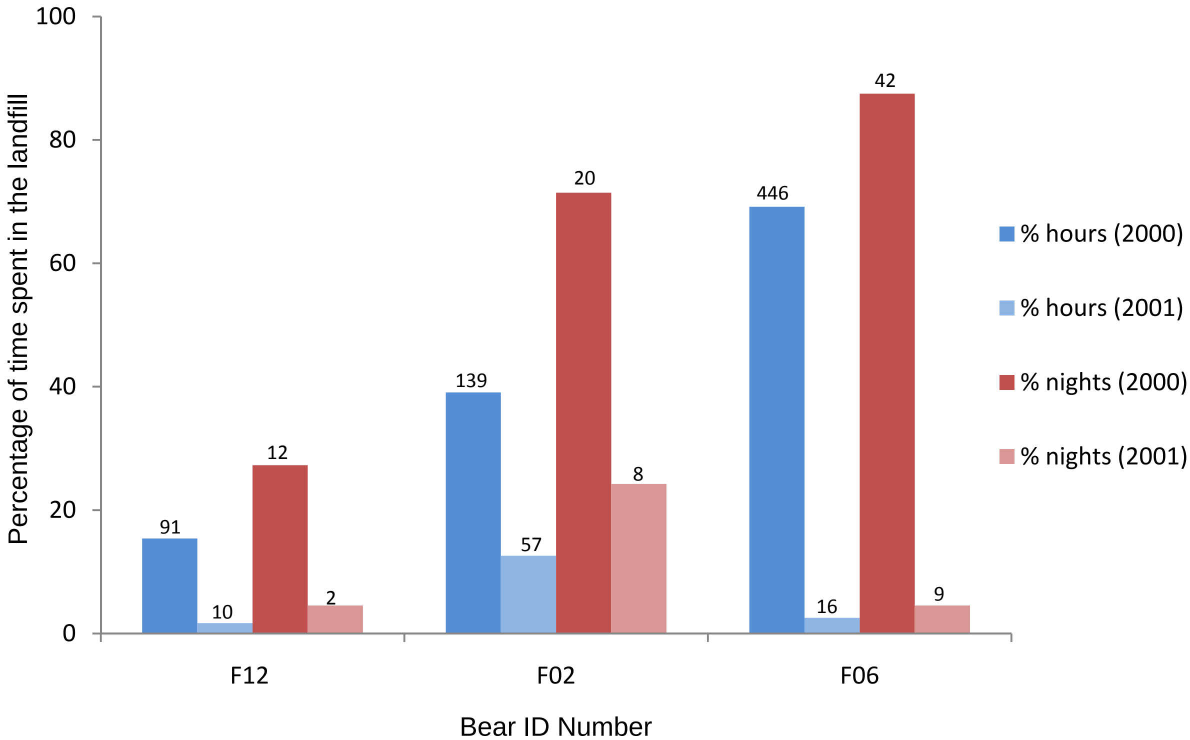

Figure 11. Percentage of hours and percentage of nights spent in the McLeod Lake Landfill between 1 October – den arrival for 3 bears wearing 24-hour transmitters operating in fall 2000 (pre-closure) and fall 2001 (post-closure). Number of hours listed above blue bars, and number of nights listed above red bars.

captured on 15 September. Subadult M03 was never recorded at the landfill after his initial capture in early May 2000, however, he dropped his 24-hour radio-collar on 30 August and was thereafter monitored only through his "9-5, Mon-Fri" transmitter. He was recorded by the datalogger in the Landfill Area on 4 occasions after 15 September, and denned only 11.7 km from the landfill.

4.2.6 Duration of Landfill and Landfill Area Visits

The average duration of landfill visits by bears fitted with 24-hour transmitters varied seasonally with longer visits in fall than in spring (Table 4). During fall, the mean duration of nightly visits before closure ($\bar{x}$ = 11.2 hours, SE = 0.5, n = 244) was significantly longer than after closure ($\bar{x}$ = 6.4 hours, SE = 1.0, n = 21; P = 0.003, t = 2.83). There was no significant difference in the mean duration of visits during summer between pre- ($\bar{x}$ = 5.4, SE = 0.4, n = 35) and post-closure ($\bar{x}$ = 3.9, SE = 1.3, n = 5; P = 0.092, t = 1.35).

In 2000, some bears remained within the Landfill Area for up to 9 consecutive days visiting the landfill during night/dark hours; most of these multi-day visits occurred in fall (Table 5). Five additional multi-day visits occurred in summer: F02 spent a 28.5 hour period in the Landfill Area with 2 nightly landfill visits, and M05 spent all 4 of his multi-day periods in the Landfill

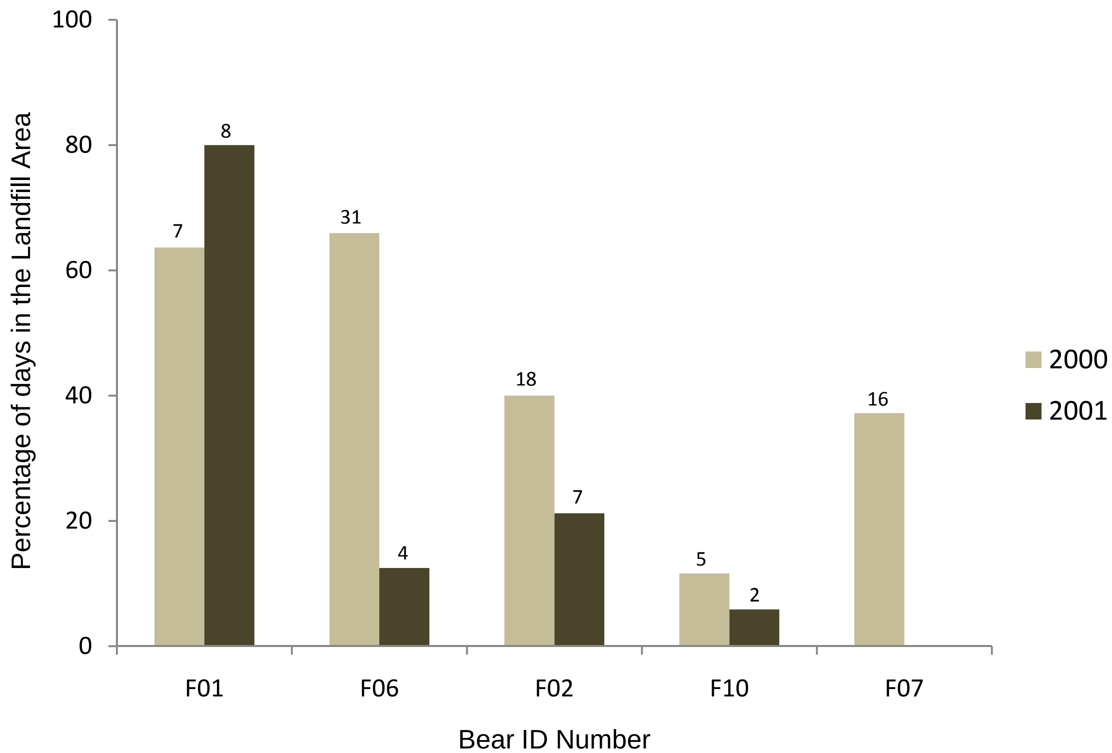

Figure 12. Percentage of days spent in the McLeod Lake Landfill Area between 1 October – den arrival for all bears wearing operational transmitters both pre- and post-closure. End date used for F01 was October 13 (for comparison between both years) which was her date of death in 2001. Number of days (*n*) listed above bars.

Table 4. Mean duration (hours) of nightly visits to the McLeod Lake Landfill each month by all grizzly bears fitted with 24-hour transmitters in 2000 and 2001.

	2000				2001			
	$\bar{x}$	SE	*n* (visits)	*n* (bears)	$\bar{x}$	SE	*n* (visits)	*n* (bears)
Apr					3.6	1.38	3	1
May					2.1	0.88	6	3
Jun	1.2	0.49	3	1	0.8	0.00	1	1
Jul	5.0	0.43	14	1	1.8	0.00	1	1
Aug	5.7	0.48	26	3	4.4	1.60	4	3
Sep	8.9	0.37	70	7	5.9	1.24	7	2
Oct	11.2	0.30	134	7	6.7	1.47	14	3
Nov	11.2	0.64	37	5				

Table 5. Number and duration of multi-day periods bears wearing 24-hour transmitters spent in the Landfill Area in fall (1 Sep – den arrival), and the number of nightly visits made to the landfill during these multi-day periods, 2000.

Bear	No. of multi-day periods				Duration (hours)			No. of landfill visits		
ID no.	Sep[a]	Oct	Nov	Total	$\bar{x}$	SE	range	$\bar{x}$	SE	range
Adult female with 2 COY dependents 2000 (dependent yearlings 2001, 2-year-olds 2002)										
F12	0	3	0	3	38.6	9.04	22.2 - 53.3	3	0.58	2 - 4
Adult female with 2 radio-tagged 3-year-old dependents 2000 (all independent 2001)										
F09	0	3	1	4	43.1	6.90	33.2 - 63.5	2.3	0.25	2 - 3
Orphaned dependent yearling siblings 2000 (independent 2-year-olds 2001)										
F01	3	8	4	15	62.4	9.70	35.6 - 170.7	2.9	0.38	2 - 7
F06	0	6	4	10	59.1	13.40	34.1 - 169.8	2.8	0.51	2 - 7
Adult female no dependents 2000 (3 dependent COY 2001, yearlings 2002)										
F02	1	5	0	6	47.5	8.63	34.7 - 89.0	2.3	0.33	2 - 4
Young adult female no dependents 2000 (2 dependent COY 2001, radio-tagged yearlings 2002)										
F10	3	1	0	4	42.4	10.91	28.9 - 74.9	2.5	0.50	2 - 4
Subadult females no dependents 2000, 2001										
F04	1	4	1	6	75.3	27.69	37.5 - 212.1	3.3	0.95	2 - 8
F11	0	1	3	4	39.1	3.50	29.5 - 45.5	2	0	n/a

[a] Bears were transmitting with 24-hour transmitters by the following dates in September: F04, F09, F10 (1 Sep), F01 and F02 (6 Sep), F11 (19 Sep), F06 (25 Sep), and F12 (27 Sep). The differing start dates are due to initial capture dates, or date of replacing "9-5, Mon-Fri" transmitters with 24-hour transmitters.

Area in summer ($\bar{x}$ = 39.8 hours, SE = 6.1, range = 30.7 – 57.7 hours) with 2 to 3 nightly visits each time ($\bar{x}$ = 2.3 visits, SE = 0.5). The longest duration a bear remained in the Landfill Area was 8.8 days by F04 in October 2000; she visited the landfill on all 8 nights and even remained in the landfill during the day on 2 occasions within this time period. F01 remained in the Landfill Area for multiple days on 15 different occasions throughout fall 2000, visiting the landfill 7 nights within her longest multiple-day period of 7.1 days.

Post-landfill closure (2001 and 2002), the number and duration of visits by bears to the landfill and Landfill Area decreased overall with most bears spending less time in the landfill itself. Bears increased their incidences of "walking-through" the landfill, and decreased the amount of time spent within the Landfill Area. In 2001, we recorded only 2 bears that remained in the Landfill Area for multiple days: M05 on 1 occasion in April for 39.7 hours during which he visited the landfill on 2 nights, and F02 on 3 occasions in October (26.3, 46.0, and 47.0 hours respectively), with 2 nightly visits each time.

4.2.7 Degree of Use of the Landfill

We based degree of use of the landfill on the percentage of nights that a bear visited the landfill between 1 October – den arrival in 2000 when the landfill pit was open and receiving garbage. We chose 1 October as the start date for 2 reasons: 1) bear use of the landfill occurred at night and several bears previously fitted with daytime/weekday ("9-5, Mon-Fri") transmitters were all re-fitted with 24-hour transmitters by 1 October (with the exception of 1 bear that dropped his radio-collar in August), and 2) use of the landfill increased from non-daily use by bears in September to daily use in October.

We examined the time period between when bears were last detected at the landfill and when they were first detected at their dens in order to choose a behavioural period that best reflected bear choice related to landfill use. For most bears, there was only a small difference between the percentage of landfill use from 1 October – their last landfill visit and 1 October – den arrival, which illustrates that bears moved almost immediately to den sites after last leaving the landfill, rather than to other natural foraging areas. F09 and her 3-year-old dependent offspring exhibited the greatest difference between these 2 time periods, and had the furthest den site location from the landfill of any of the bears (41.7 km from the landfill). Therefore, we chose den arrival as the end date because we think this most accurately reflected the individual choice of bears. We excluded the time period "1 October - last landfill visit" because we believe that the time spent between last visiting the landfill and first arriving at its den site reflects individual bear choice. We excluded the "1 October – last date landfill was used by any radio-tagged bear" because this assumes the landfill was equally available to all bears until that date, and does not take into account individual variability in den arrival dates relating to reproductive status of bears.

We based degree of use of the landfill on percentage of nights and not hours, because we believe the number of nightly visits better represents dependency on the landfill. The duration of nightly visits by an individual bear may be more reflective of its reproductive status, with lone adults able to forage more efficiently (thus staying for shorter time periods) than subadults or females with offspring that may spend more time avoiding conflicts with other bears. Three bears (lone adult females F02 and F10, and F12 with 2 cubs-of-the-year) spent almost twice as high a percentage of available nights in the landfill than they did available hours, that is, they visited the landfill on many nights, but for short durations of time, compared with the remaining bears (Figure 13).

Based on the percentage of nights that a bear visited the landfill between 1 October – den arrival in 2000, we classified 9 bears as heavy landfill-users (F09 and her two 3-year-old dependent offspring F07 and M08, orphaned female yearlings F01 and F06, lone adult females F02 and F10, and independent subadult female siblings F04 and F11), and 2 bears as light landfill-users (adult male M05, and adult female F12 accompanied by 2 cubs-of-the-year; Figure

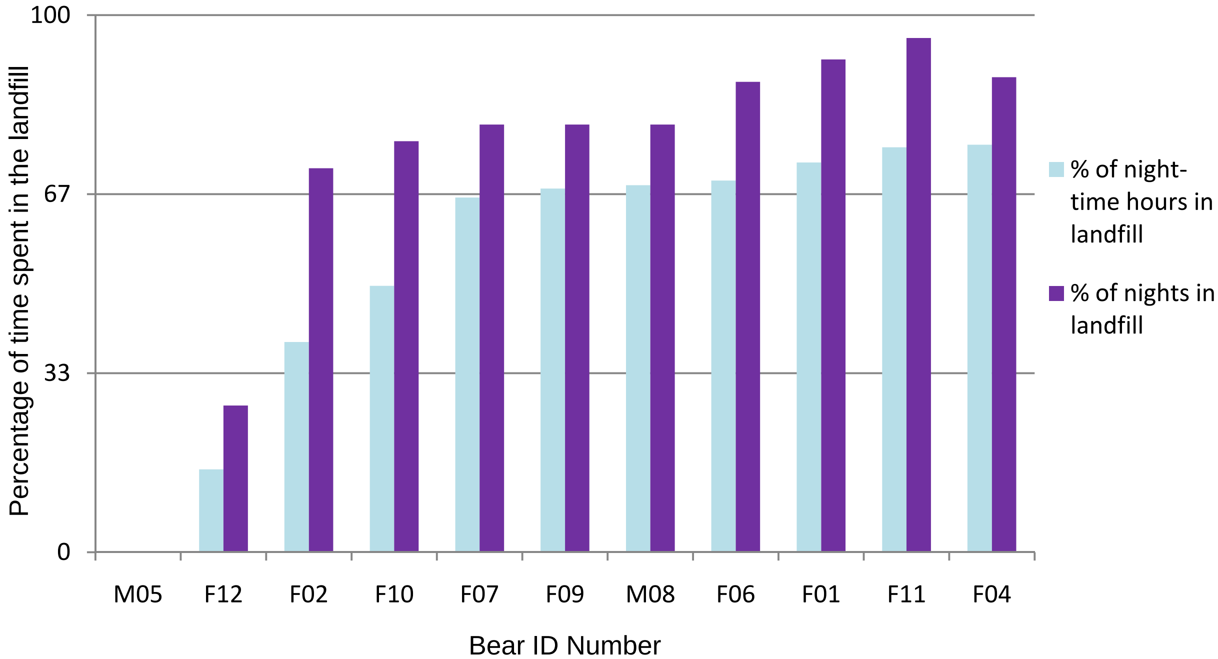

Figure 13. Percentage of nights and percentage of hours spent in the McLeod Lake Landfill by grizzly bears wearing 24-hour transmitters between 1 October – den arrival, pre-landfill closure 2000. Degree of use of the landfill was based on the percentage of nights (purple bars): ≤33% was considered Light use, 34 – 66% Moderate use, and 67 – 100% Heavy use. M03 was the only bear not fitted with a 24-hour transmitter by Fall 2000 (he wore a 9-5, Mon-Fri transmitter) so was omitted from this graph.

13, Table 6). We also classified subadult male M03 as a light landfill-user. Although M03 was fitted with only a "9-5, Mon-Fri" transmitter (and therefore we could not detect night visits to the landfill), he was never detected by the fixed-telemetry datalogger in the Landfill Area in the daytime in fall, or located near the landfill during any aerial-telemetry flights.

4.3 Aerial-Telemetry Locations

During 2000 - 2002, we gathered 733 aerial-telemetry locations on 12 radio-tagged bears (9 females and 3 males) captured prior to landfill closure: 641 seasonal locations, 17 den site locations and 75 repeat den-site locations (Appendix G). We gathered an additional 65 seasonal locations on 2 dependent offspring born after closure of the landfill (F14 and M15), and 13 locations on 1 radio-collared male wolf (W3). A summary of W3's movements and landfill use is presented in Appendix H.

The majority of bears were consistently located throughout their monitoring period (i.e., from initial capture to den-up, mortality or dropped transmitter) with the exception of subadult males M03 and M08 (Appendix G). M03 went missing from mid-to-late May, again in late June and the first 3 weeks of August 2001, during which time he separated and then reunited with his family group (F09, F07).

Table 6. Percentage of nights spent in the landfill between 1 October – den arrival 2000 by radio-tagged bears, and resulting category of degree of landfill use.

Bear ID no.	Age	% nights in landfill	Level of Landfill use[a]	Last known status of bear[b]
Adult female with 2 COY dependents 2000 (dependent yearlings 2001, 2-year-olds 2002)				
F12	5	27.3	Light	Last alive – July 2002
Adult female with 2 radio-tagged 3-year-old dependents 2000 (all independent 2001)				
F09	10	79.6	Heavy	Last alive – August 2001
M08	3	79.6	Heavy	Last alive – June 2003
F07	3	79.6	Heavy	Last alive – April 2002
Orphaned dependent yearling siblings 2000 (independent 2-year-olds 2001)				
F01	1	91.7	Heavy	Dead – Garbage related
F06	1	87.5	Heavy	Dead – Not garbage-related (illegal kill)
Adult female no dependents 2000 (3 dependent COY 2001, yearlings 2002)				
F02	8	71.4	Heavy	Last alive – October 2007
Young adult female no dependents 2000 (2 dependent COY 2001, radio-tagged yearlings 2002)				
F10	4	76.5	Heavy	Last alive – November 2002
Subadult females no dependents 2000, 2001				
F04	2	88.4	Heavy	Dead – Garbage related
F11	2	95.7	Heavy	Last alive – August 2003
Subadult male				
M03	2	0	Light	Dead – Not garbage-related (self-defense)
Adult male				
M05	17	0	Light	Dead – Died during recapture

[a] Categories of Landfill Use: Light: ≤33%; Moderate: 34 – 66%; Heavy: 67 – 100%.
[b] For further information on causes of mortalities and bear fates see section 4.6

Three family groups monitored over the course of the study contained greater than 1 radio-tagged individual (Table 7): orphaned siblings F01 and F06, female F09 with cubs F07 and M08 (3-year-old dependents in 2000), and female F10 with cubs F14 and M15. Locations of F14 and M15 were excluded from all analyses since they were not born until after the landfill closed, with the exception of 3 locations from M15's transmitter in fall 2002 through which we monitored F10 who had dropped her transmitter earlier that fall. All dependent locations were omitted from habitat, den site, and home range analyses. Please refer to Appendix G for the number of dependent locations by family group and information on the dispersal of 4-year-old siblings F07 and M08 from their mother F09.

We based calculations of annual and seasonal home ranges on 739 locations including 641 aerial-locations, 32 den site locations (maximum 1 for each of the previous and subsequent

Table 7. Number of capture and re-capture (maximum 1 per season), aerial radio-telemetry, and fixed-telemetry landfill locations (maximum 1 per season) for 12 radio-tagged grizzly bears captured prior to landfill closure, in spring (den emergence – 30 Jun), summer (1 Jul – 31 Aug), fall (1 Sep – den arrival), and denning, 2000 - 2002. Parentheses indicate the number of shared locations between family members (see Appendix G).

Bear	Number of locations by season and year															
	2000					2001					2002					
ID no.	Spring	Summer	Fall	Den	Total	Spring	Summer	Fall	Den	Total	Spring	Summer	Fall	Den	Total	Total
Adult female with 2 COY dependents 2000 (dependent yearlings 2001, 2-year-olds 2002)																
F12			7	1	8	7	8	10	2	27	12	2		1	15	50
Adult female with 2 radio-tagged 3-year-old dependents 2000 (all independent 2001)																
F09	8 (7)	19 (12)	24 (21)	1 (1)	52	24 (9)	16		1	41						93
M08	8 (7)	17 (12)	24 (21)	1 (1)	50	15 (8)	11	1	1	28						78
F07	2 (2)	3 (2)	24 (19)	1 (1)	30	17 (5)	16	22	2	57						87
Orphaned dependent yearling siblings 2000 (independent 2-year-olds 2001)																
F01	8 (3)	10 (9)	13 (5)	1 (1)	32	11 (4)	10	7	1	29						61
F06	7 (3)	10 (9)	12 (5)	1 (1)	30	12 (4)	10	10	2	34	3			1	4	68
Adult female no dependents 2000 (3 dependent COY 2001, yearlings 2002)																
F02	9	14	19	1	43	18	19	19	2	58	7			1	8	109
Young adult female no dependents 2000 (2 dependent COY 2001, radio-tagged yearlings 2002)																
F10[a]			9	1	10	9	10	10	2	31	11	11	14	1	37	78
Subadult females no dependents 2000, 2001																
F04	8	11	9	1	29	2			1	3						32
F11			8	1	9	10	8	1	1	20						29
Subadult male																
M03	4	12	2	1	19											19
Adult male																
M05	7	10	10	1	28	6			1	7						35
Total	61	106	161	12	340	131	108	80	16	335	55	35	38	6	64	739

[a] After dropping her own transmitter in September 2002, F10 was monitored through 3 locations from her offspring's transmitters (F14 and M15) until November 2002.

winters den sites if known), 27 capture/recapture locations (maximum 1 per season per bear), and 39 landfill locations as determined by the fixed-telemetry datalogger station (maximum 1 per season per bear) (Table 7, Appendix G).

We obtained 340 locations on 12 radio-tagged bears in 2000, 335 locations on 11 bears in 2001, and 64 locations on 4 bears in 2002 (Table 7). Of the 739 locations gathered during the study, 607 were for female grizzly bears (n = 9 bears, $\bar{x}$ = 67/bear, SE = 9.1, range 29 – 109) and 132 locations for male bears (n = 3 bears, $\bar{x}$ = 44/bear, SE = 17.6, range 19 - 78). We gathered 247 locations in spring, 249 in summer, 279 in fall, and 34 in denning.

4.4 Home Range Use, Movements, and Habitat Use

4.4.1 Annual and Seasonal Home Range Sizes

We examined annual and seasonal home range sizes and location on the landscape pre (2000) and post (2001 and 2002) landfill closure to determine whether home range sizes increased after closure of the landfill, and whether bears would shift their home ranges away from the landfill (Figure 14, Appendix I). In order to compare MCP size between years the bear must be monitored throughout both pre- and post-closure years and a sufficient number of samples (n > 30) must be obtained to adequately calculate MCP size. Sufficient data was collected on only 2 females both pre- and post-closure (F02 and F06) (Table 7). In both cases, the size of the area that they used increased (F02, pre-closure: 288 km^2, post-closure: 367 km^2; F06, pre-closure: 32 km^2, post-closure: 182 km^2). We provide analyses of seasonal and annual home ranges for all bears, regardless of sample size, in Appendix I. A summary of each bears' general movements, range use, and landfill use is presented in Appendix J.

4.4.2 Seasonal Distances to Landfill

We hypothesized that bears would be required to travel greater distances from the landfill to obtain foods post-landfill closure than pre-closure (when foods were concentrated within the landfill). Therefore, we examined the distance from each aerial-telemetry location to the landfill by year. We found that female bears moved significantly greater distances from the landfill during post-closure than pre-closure ($U_{213,310}$ = 21905.5, P < 0.0001). Only 2 females (F10 & F12) remained radio-tagged post-closure; they moved farther from the landfill from spring to summer, which was opposite to pre-closure.

Seasonally, female bears tended to move closer to the landfill as the seasons progressed from spring (den emergence – 30 Jun) through summer (1 Jul – 31 Aug) to fall (1 Sep – den arrival), then further away again for denning in the year prior to landfill closure (Figure 15, Appendix K). The only 2 females that had similar average distances to the landfill in both spring and summer 2000 were the orphaned yearlings, F01 and F06. Generally, females exhibited a similar seasonal

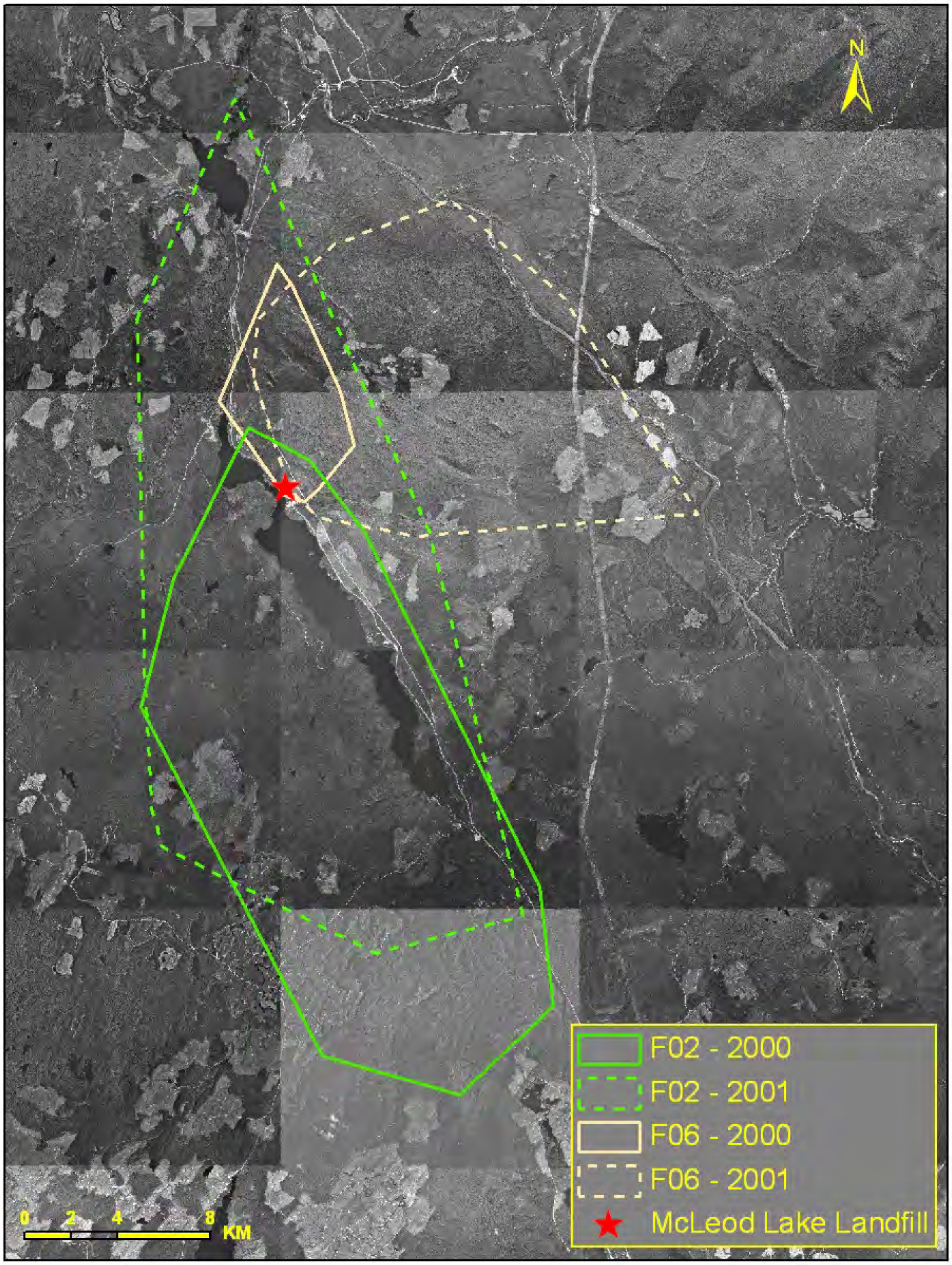

Figure 14. 100% MCP seasonal home ranges for 2 radio-tagged female grizzly bears pre- and post-closure of the McLeod Lake Landfill.

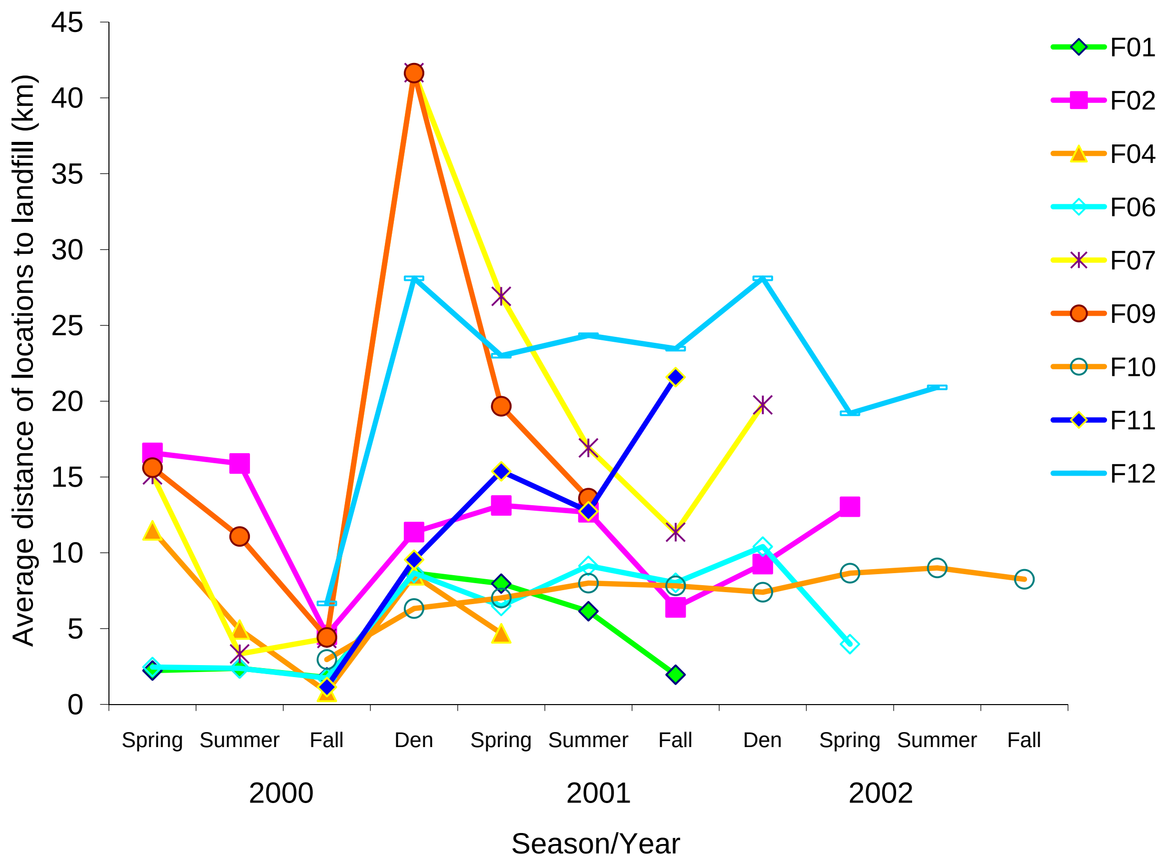

Figure 15. Average distance (km) of aerial-telemetry locations to the landfill for female grizzly bears by spring, summer, fall, and den site seasons pre (2000) and post (2001 & 2002) landfill closure.

pattern in 2001 after the landfill had closed, with the majority of females averaging closer distances to the landfill as the seasons progressed from spring to fall. However, 3 of the 8 females (F6, F10, and F12) slightly increased their average distance to the landfill from spring to summer in 2001. All females moved farther away for denning, except F10 who remained about the same average distance as in the fall (Figure 15, Appendix K).

Sample sizes pre- versus post-closure were too small to test for differences among the 3 male bears (n[2000] = 52, n[2001] = 6).

4.4.3 Seasonal Habitat Use

We conducted GIS-based habitat analysis of 544 of the 641 aerial-telemetry locations, omitting 97 locations of dependent bears (i.e., family or sibling groups). We found that female bears used different land-cover types pre-closure than post-closure of the landfill (χ_4^2=30.29, $P <$ 0.001).

In all seasons, both pre- and post-landfill closure, female bears were primarily located in forests dominated by coniferous trees (Figure 16). The only season for which this trend changed was in fall 2002, but sample sizes were very low. Cutblocks were the second most used land-cover type by female grizzly bears, both pre- and post-closure. Use of the deciduous land-cover type by female grizzly bears was relatively similar through 2000 and 2001 but it was used less in the summer of 2002 and more in the fall of 2002. Female grizzly bears did not use the mixedwood land-cover type a great deal in any year. Use of the non-commercial land-cover type appeared to decrease in the first year post-landfill closure and increase the second year post-closure.

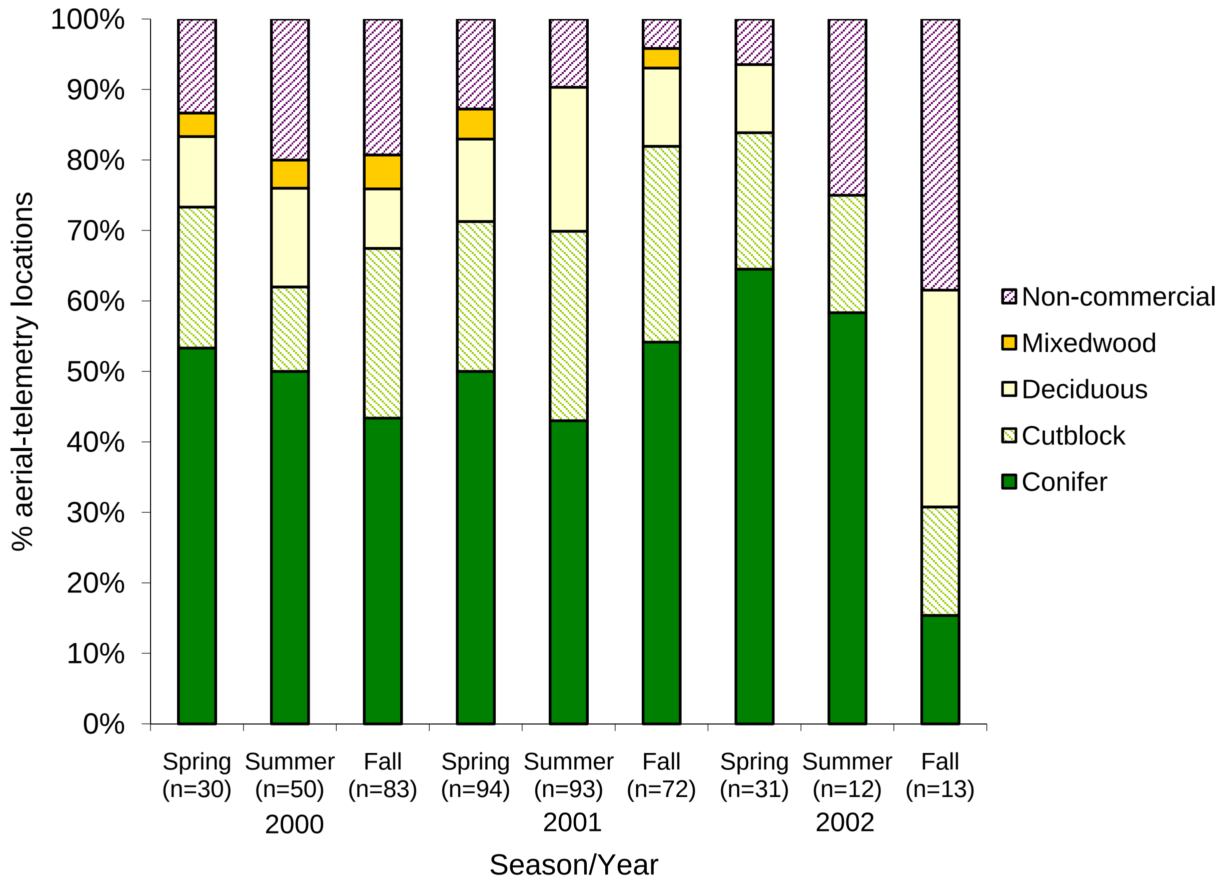

Figure 16. Dominant land-cover type used seasonally by female grizzly bears (*n* = 478 locations; *n* = 9 bears), pre (2000) and post (2001 and 2002) closure of the McLeod Lake Landfill.

Female grizzly bears were primarily located in open stands (0 – 10 % canopy closure; Figure 17) as well as treed stands with gaps (31 – 50 %). There did not appear to be any differences in use by canopy closure pre- and post-closure by female bears (Figure 17). Bears were never (pre- or post-closure) located in stands with greater than 80% canopy closure.

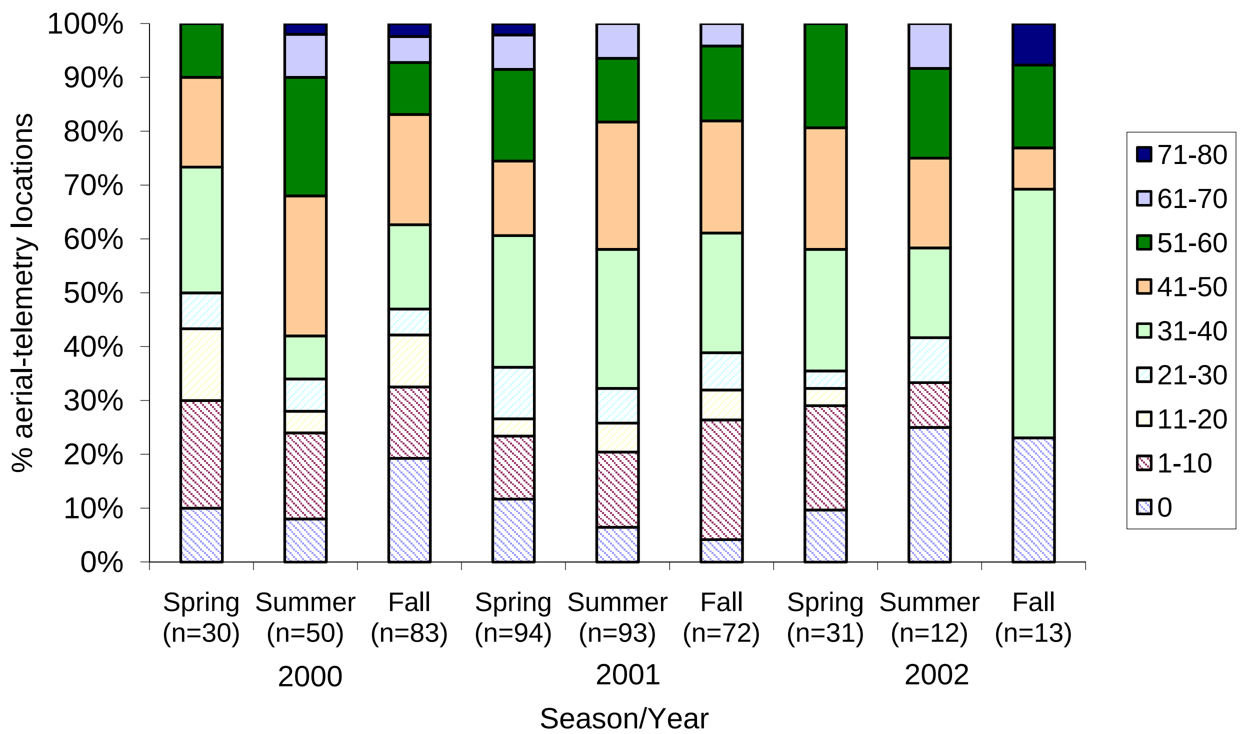

Figure 17. Seasonal use of canopy cover classes by radio-tagged female grizzly bears (*n* = 478 locations; *n* = 9 bears) pre (2000) and post (2001 and 2002) closure of the McLeod Lake Landfill. (Canopy cover values are represented in a 10% canopy range; note that combining 0 and 1-10% categories is required to make the remaining classes comparable in their percentage increments.)

Bears were most often located in the SBSmk1 biogeoclimatic (BEC) zone with the exception of spring 2000 and 2002 where they were most often located in SBSwk1 (Figure 18). These 2 BEC zones accounted for the majority of bear locations pre- and post-closure; however, they also covered the majority of the study area. Occasionally bears made use of the higher ESSF biogeoclimatic zones, which occurred only in small pockets on the western plateau and also in the mountains to the East.

During the non-denning/active season, bears used slightly higher elevations in summer than in spring and fall, which was consistent both pre- and post-closure (Figure 19). Comparison between pre- and post-closure years revealed that bears used lower elevations pre-closure 2000, than post-closure 2001 ($U_{207,281}$ = 17449, $P \leq 0.001$) or 2002 ($U_{207,56}$ = 3549.5, $P \leq 0.001$). We could not detect a difference in bear use of elevations between the two post-closure years (2001 and 2002; $U_{281,56}$ = 7459.5, P = 0.5).

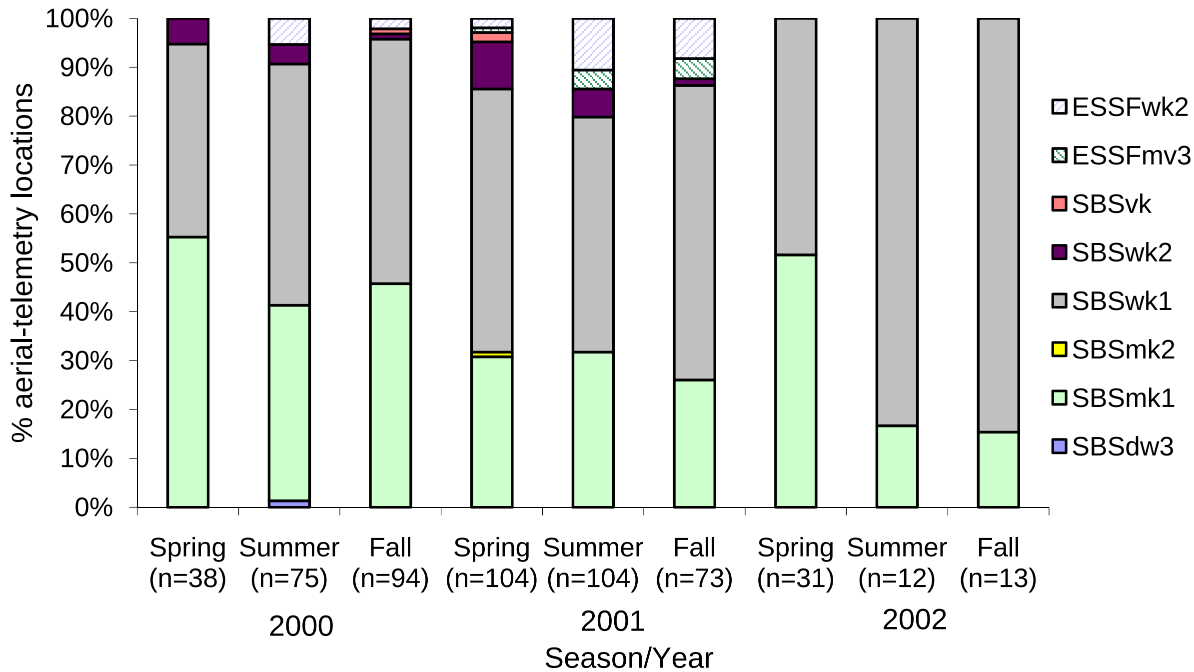

Figure 18. Seasonal use of biogeoclimatic zones for radio-tagged grizzly bears (females and males combined; *n* = 544 locations, *n* = 12 bears) pre (2000) and post (2001 and 2002) closure of the McLeod Lake Landfill.

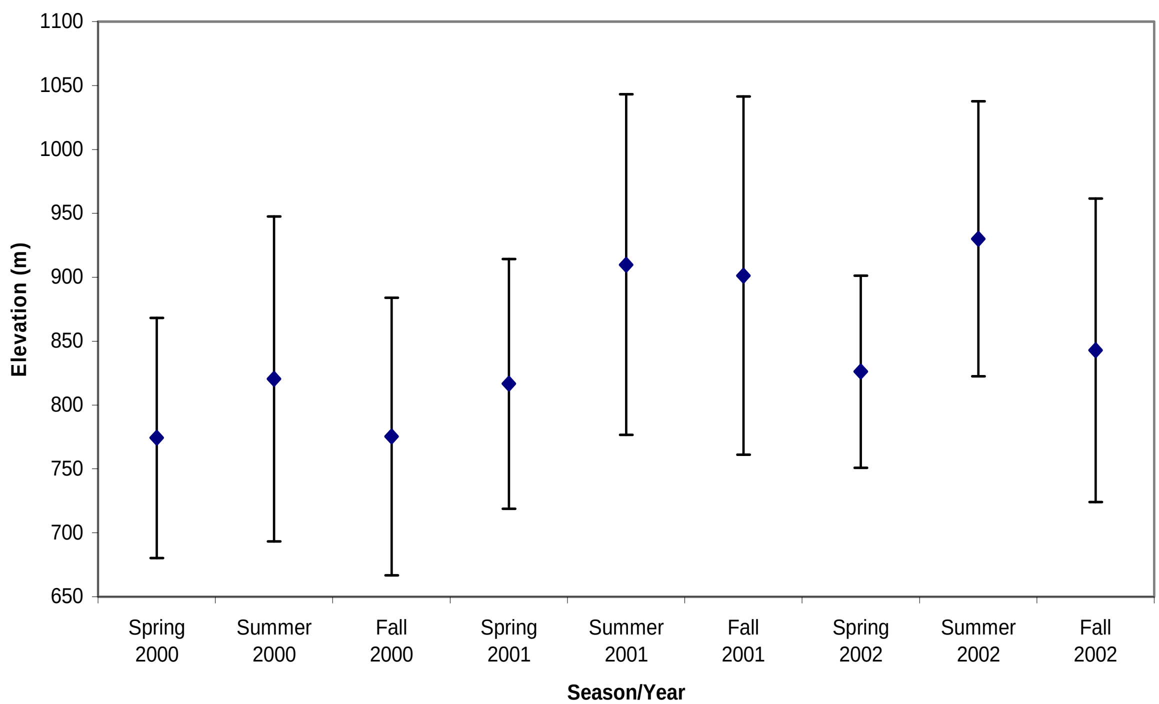

Figure 19. Seasonal use ($\bar{x}$ ± SD) of elevations by radio-tagged grizzly bears (females and males combined; *n* = 544 locations, *n* = 12 bears) during pre (2000) and post (2001 and 2002) closure of the McLeod Lake Landfill.

4.4.4. Den Site Use

We did not detect any significant differences in den site attributes between pre (2000) and post (2001) landfill closure ($U_{9,5}$ = 20, *P*[elevation] = 0.7; $U_{9,5}$ = 14, *P*[canopy] = 0.25; $U_{9,5}$ = 17, *P*[slope] = 0.07) (Appendix L). The mean elevation of pre-closure den sites was 956 m (SD = 150.5, *n* = 9) and post-closure den sites was 980 m (SD = 150 m, *n* = 5; *P* = 0.46). Typically, den sites were located at higher elevations than other sites used throughout the year (all den sites $\bar{x}$ = 965 m, SD = 145 m, *n* = 14. Seven of the 14 den sites (4 of 9 in 2000/01, and 3 of 5 in 2001/02) were located in the SBSwk1 while 2 (2000/01) and 1 (2001/02) were located in the higher elevation ESSF zone). One of these den sites was in the mountains while the remaining 2 were on the higher elevation ridges of the plateau west of the landfill, and were occupied by the same bear (F12) pre- and post-closure. Detailed den site characteristics and timing of movements to den sites can be found in Appendix L.

All of the den sites located in 2000/01 (*n* =9) and 3 of the 5 den sites in 2001/02 were located in coniferous forests stands; the remaining 2 dens were in mixed-wood stands. The den sites were primarily located in stands with spruce as the leading tree species (*n* = 7 in 2000/01; *n* =3 in 2001/02) although we also located den sites in Douglas-fir, true fir and lodgepole pine dominated stands. These stands were primarily old-growth age classes ($\geq$100 year; *n* = 10 of 14 den sites); only 1 den site occupied by 1 of the lone subadult females (F07) was located in a young, regenerating cutblock logged in 1972 (~29-year-old stand at the time of denning).

4.5 Mortalities and Last Known Fates of Landfill Bears Post-Landfill Closure

Six of the 12 radio-tagged bears captured at the McLeod Lake Landfill in 2000 prior to landfill closure, died after the landfill was closed: 5 within the study period in 2001 and 2002, and 1 in 2010 (Table 8). Three deaths were classified as a threat to humans as a result of being garbage-conditioned (heavy landfill-users F01, F04, and F02) and 3 deaths were classified as not garbage-related (heavy landfill-user F06, and light landfill-users M03 and M05). All bear deaths were non-natural, in that humans or human activities were implicated as the direct cause.

Two of the 3 garbage-related mortalities occurred in the first fall after the landfill was closed (F01 and F04; 2001), and 1 (F02) occurred 10 years after the landfill closed, in fall 2010. F01 and F04 were subadult females (2 and 3 years old respectively) and heavy users of the landfill as a food source pre-closure. F01 climbed into the “bear-resistant” transfer station bin at the McLeod Lake Landfill after the lid was left open by a public user. She displayed threatening behaviour towards humans from within the bin and prevented people from disposing of their garbage. The COS deemed her to be a threat to humans, and she was shot and killed. F04 was shot and killed by a resident of McLeod Lake while she was on their porch. The residents had a moose carcass hanging in their garage and F04 had been repeatedly visiting the property. F02 was shot and killed by the COS in the town of Mackenzie in September 2010, 10 years after closure of the McLeod Lake Landfill. F02 was classified as a moderate landfill-user and did not exhibit any problem-bear behaviour in the first 7 years post-landfill closure. In mid-October 2007, F02 and her yearling cub climbed into one of the "bear-resistant" transfer station bins at the McLeod Landfill after the lid was left open by a public user. Since she had not posed a serious threat to people in the 7 years since the landfill closure, the COS agreed to tranquilize and relocate the bears. F02 and her yearling cub were released west of McLeod Lake in the general vicinity of her previously known den sites. In mid-September 2010, F10 was sighted with 3 new yearlings feeding on garbage in the town of Mackenzie, BC. Several attempts were made to drive the bears out of town using vehicles, sirens, and rubber bullets, but the bears continued to frequent the town site. F10 was trapped in a culvert trap by the COS, and she and her 3 yearling cubs were subsequently shot and killed.

Three other radio-tagged bears died after landfill closure, but from non-garbage related causes. M05 was an older male that died during recapture at the landfill in spring 2001 from asphyxiation on his existing radio-collar during immobilization. M03 was shot and killed 121 km from the landfill by a guide-outfitter in fall 2001, after he charged out of the bush at the outfitter who had sent his dog to retrieve a grouse. F06 appeared to have been illegally killed in spring 2002, possibly mistaken for a black bear during the spring hunting season. The site investigation revealed that she had been shot approximately 2 weeks earlier in a clearcut and left intact; her carcass had not been disturbed (not killed or scavenged by predators).

Three of the 7 remaining bears that had been captured at the landfill prior to closure (6 radio-tagged, 1 color-marked) were confirmed to be alive subsequent to the end of this study (Table 9). Between June and August 2003, a 7,031 km^2 DNA based mark-recapture grid was established in the Nations River area north-west of the landfill (Mowat and Fear 2004), and the DNA of M08, F11 and M13 (marked offspring of F12) was identified. The fates of the other 4 bears remain unknown, however, it is unlikely they died in garbage-related situations since there have been no problem bear reports or compulsory inspections submitted. It is possible these bears remain alive, although they could have died in unreported situations.

Two additional bears (F14 and M15, offspring of F10), not born until after the landfill had closed, also died. The bears were first radio-tagged as yearlings in spring 2002. The family unit was located in November 2002 through M15's ear-tag which was transmitting from near a hunter's moose kill site. A larger bear, believed to be F10, was seen from the air. The site investigation revealed a hunter-killed cow and calf moose; the calf was found buried in a manner typical of grizzly bears. The site was re-visited in spring 2003 and a bear skull and bones were collected which were confirmed through DNA to be siblings F14 and M15. We believe the yearlings were likely shot by the hunters while attempting to defend their moose carcasses.

Table 8. Timing and causes of death for 6 radio-tagged grizzly bears captured at the McLeod Lake Landfill in 2000, prior to landfill closure.

Bear ID no.	Age at mortality	Category of death	Level of Landfill use[a]	Mortality date	Description of mortality
F04	3	Threat – Garbage-Related	Heavy	10-Oct-01	Shot by private resident while on porch of McLeod Lake residence
F01	2	Threat – Garbage-Related	Heavy	15-Oct-01	Shot by COS after climbed into McLeod Lake Landfill transfer station
F02	18	Threat – Garbage-Related	Heavy	21-Sep-10	Shot by COS after frequenting townsite of Mackenzie
M03	3	Threat – Not Garbage Related	Light	04-Oct-01	Shot by hunter in self-defense after charging hunter
F06	3	Unknown Threat – Not Garbage-Related	Heavy	20-May-02[b]	Found dead in clearcut; presumed shot by black bear hunter
M05	18	No Threat	Light	09-May-01	Died during re-capture of probable asphyxiation from radio-collar

[a] The level of landfill use was determined in section 4.2.5 which represents the bear"s dependency on the landfill as a food source.
[b] Mortality date was the median date between the last location the bear was confirmed alive and the first location on mortality mode.

Table 9. Last known status of 7 grizzly bears (6 radio-tagged and 1 ear-marked only) captured at the McLeod Lake Landfill in 2000, excluding known mortalities (see Table 8).

Bear ID	Level of	Last confirmed alive		
no.	Landfill use[a]	Date	Age	Details
F09	Heavy	Aug 2001	11	Transmitter failed
F07	Heavy	Apr 2002	5	Transmitter failed
F11	Heavy	Aug 2003	5	DNA found in Nations Grid[b]
M08	Heavy	Jun 2003	6	DNA found in Nations Grid[b]
F10	Heavy	Nov 2002	6	Transmitter failed[c]
F12	Light	Jul 2002	7	Transmitter failed
M13	Light[d]	Jul 2003	3	DNA found in Nations Grid[b]

[a] The level of landfill use determined in section 4.2.5 which represents the bear's dependency on the landfill as a food source.
[b] DNA-based mark-recapture study in Nations River area north-west of landfill (Mowat and Fear 2004).
[c] F10 had failed transmitter and was monitored through offspring F14 and M15 until their death in Nov 2002.
[d] Dependent COY M13 was assigned a level of landfill-use based on his mother's (F12) assessment.

5.0 DISCUSSION

5.1 Capture

We believe that we captured all adult and older subadult bears using the McLeod Lake landfill prior to its closure, since we did not identify any unmarked bears during visual observations at the landfill, and due to the high number of recaptures that we observed. Use of the landfill was dominated by 4 matriarchal adult females, and there appeared to be a high degree of relatedness among our study bears.

We captured 3 male and 9 female grizzly bears; a sex ratio opposite to that at a landfill in Alaska (63% males and 37% females; Peirce and Van Daele 2006). However, in the nearby community of Mackenzie, the sex ratio of garbage-conditioned bears at or near their landfill was almost equal (18 males and 14 females; MacKay 1996). Perhaps the high number of bears that were killed at or near the Mackenzie landfill in the mid-90s may have affected the composition of the bears that were captured at the McLeod Lake Landfill, however our sex ratio may simply be linked to low sample size.

Marked bears in our study were of various stages of social development and reproductive status, which confounded the interpretation of results in this study. For example, F01 and F06 (orphaned yearlings) were monitored as a sibling pair prior to landfill-closure, and as individuals after closure, and we believe that increased movements from the landfill by F06 post-closure were in part or fully a result of their separation rather than landfill closure. Further, F01 and subadult female F07 were injured which may have increased their use of the landfill as a supplemental food source. We also monitored the dispersal of older subadults including males M03 and M08 that travelled widely in establishment of their own home ranges. Reproductive status of adult females also varied. Three females produced cubs-of-the-year during the study, 1 prior to closure (F12) and 2 after the landfill closed (F02 and F10), and it is possible that their use (or non-use) of the landfill was influenced by their small offspring. Females with dependent offspring have been found to be infrequent users of landfills (Peirce and Van Daele 2006) and therefore reproductive status may have had an influence on our rankings. However, the sample of bears in Alaska (Peirce and Van Daele 2006) was predominately adult males while our sample was predominantly adult females and it is likely that females with dependent offspring avoid adult males more than lone adult females.

5.2 Bear Use of the Landfill and Landfill Area

The methods used to close the landfill were successful at stopping bears from accessing garbage. Most specifically, the landfill pit was capped with 1.0 to 1.5 m of fill, which has been recommended elsewhere as an adequate depth to discourage activity by bears (Davis et al. 2002).

Bears continued to visit the landfill post-closure (but much less than pre-closure), likely because our continued trapping efforts resulted in some food rewards (e.g., accessing bait from cubby sets and culverts) and because bears were occasionally able to access non-natural foods when people left garbage around the transfer station or failed to close the lids at the station.

Data collected with a remote radio-telemetry datalogging unit stationed at the landfill allowed us to document temporal use of the landfill pre- and post-closure. As expected, bears greatly decreased their number of visits to the landfill post-closure, likely because they were no longer receiving food rewards. During the day, bears that were less reliant on the landfill left the Landfill Area possibly to forage on natural foods, and returned to the landfill as night approached. Bears that appeared to be more reliant upon the garbage in the landfill tended to remain in the immediate Landfill Area during the daytime, particularly in fall. We also found that bears used the landfill primarily during dark hours (sunset to sunrise). Bears most often entered the landfill at dusk or under the cover of darkness. Most bears avoided using the landfill during the daytime except subadult female F04 who often entered the landfill during daylight hours, and also remained in the landfill during the day. Use of the landfill in daylight appeared to be indicative of bolder bears that may be more likely to become problem bears after landfill closure: F04 was shot as a problem bear in the community of McLeod Lake the first fall after landfill closure. Clark et al. (2002) found the "time of nuisance activity [of black bears] reflects the level of habituation and food-conditioning, with increasing daytime activity in developed areas indicating progressively bolder, habituated behavior."

Use of the McLeod Lake Landfill by subadults, lone adult females and family groups was highest during the fall hyperphagia period both pre- and post-closure, with much higher use observed pre-closure. This pattern is similar to that seen in the Great Yellowstone Ecosystem where the number of grizzly bear-human conflicts involving property damage/anthropogenic foods, human injuries, gardens/orchards, and beehives peaked during late hyperphagia (Gunther et al. 2004). Although we did not measure it, we attribute the increased use of the landfill by bears in fall to the diminishing productivity of natural forage items such as herbaceous green vegetation and berries, which may have resulted in the landfill acting as a supplemental food source. This observation is similar to other studies that have found conflicts or use of landfills increase when the availability or abundance of natural foods is low (Gunther et al. 2004, Peirce and Van Daele 2006). Seasonal use patterns that we observed were very different than those found at a landfill in Alaska (Peirce and Van Daele 2006), where use of the landfill peaked in early July. In spring, the timing and availability of foods at McLeod Lake are somewhat similar to Alaska, with moose calves being an important forage item (Ciarniello et al. 2007). However, starting in late July, abundant salmon become available in Alaska providing a high-quality natural food source (Peirce and Van Daele 2006) that is not present in the McLeod Lake area. At McLeod Lake, subadult bears tended to be the last bears to leave the landfill in fall and we suggest that this is because of decreased competition from more socially dominant bears, which had already left the site. Other studies have reported that subadult bears spend the least amount of time foraging at landfills because they are the least socially dominant bears and are displaced by the larger, more dominant bears (Peirce and Van Daele 2006).

Following landfill closure (i.e., in 2001 and 2002), the number and duration of visits by bears to the landfill and Landfill Area decreased, with most bears spending less time in the landfill itself. Bears "walked-through" the landfill more often following closure and decreased the amount of time spent within the Landfill Area. The average duration of landfill visits by bears were highest in the fall. We identified 2 distinct types of visits to the landfill by bears: 1) extended visits, and, 2) determined visits. Extended visits were those where bears loitered around the Landfill Area for extended periods of 3-4 days (up to 8 days) and were usually exhibited by subadult bears. During these extended visits, bears would visit the pit area primarily at night and move to the surrounding forested areas during the day, presumably to rest or feed on garbage carried into the forest. Determined visits were those where the bears appeared to arrive quickly at the landfill as the evening approached. These visits were characterized by the datalogger abruptly recording a strong signal from a bear that had not been previously detected in the area in the preceding period.

Bears changed some, but not all, behaviours pre- versus post-closure of the landfill. In fall, the duration of landfill visits was significantly longer pre-closure than post-closure because of the decrease in availability of foods; we expected that bears would not use the landfill site when anthropogenic foods were no longer available. The other primary change in behaviour was a reduction in extended visits in the area of the landfill as well as a reduction in repeated visits to the pit area, particularly in fall. Immediately post-closure, use of the landfill and area began to decline and the majority of visits were "walk throughs" the pit and area. Overall, bears spent less time in the pit itself and the number of repeat visits to the pit greatly reduced. Bears remained to investigate the area post-closure, and in 2001 some bears still spent time in the immediate area of the landfill overnight; however, we noted a general reduction in both extended and repeated visits with most bears moving along from the landfill fairly quickly. Bait associated with our continued trapping at the landfill may have had an influence on the visitation patterns of some bears by encouraging them to return to the area and possibly artificially inflated visits to the landfill during the post-closure years. Regardless, use of the landfill during the post-closure years was quite low compared with bear use of the open-pit in 2000.

Although we were unable to collect substantial data on patterns of use by most bears, we did collect sufficient information on an adult female bear to assess her trends in visitation. Following closure of the landfill, F02's visits to the landfill decreased during the fall of 2001 compared with fall 2000, when she was consistently located at the landfill. In fall 2001, she only visited the landfill 16 times compared to 40 times in 2000; however, her mean distance from the landfill increased by approximately 2 km. Although the open pit landfill was closed, F02's repeated visits in fall 2001 suggest that bait associated with our continued trapping influenced visitations although it is also possible she remained to repeatedly check the area for available non-natural attractants. F02 was relocated from the landfill site 7 years after its closure, indicating that she did indeed continue to check on the availability of this potential food source, particularly since her core non-landfill home range was on the west side of McLeod Lake and therefore to access the landfill she likely swam the lake. F02 was eventually killed by the COS in Mackenzie in fall 2010, along with her 3 yearling cubs (see mortality section 5.5).

5.3 Home Range and Movements

Habitat use, home range use and movements away from the landfill by grizzly bears were measured through aerial telemetry. We collected data on space use to assess changes in home range sizes of individuals as well as shifts in seasonal ranges pre- versus post-landfill closure. However, sufficient aerial-telemetry locations (i.e., n>30) were only collected for 2 female bears (F02 & F06) during each pre- and post-closure period and although they increased their home range sizes post-closure, the increase was not significant likely due to our small sample size. The increase in these home range sizes may have been partially the result of closure of the landfill and removal of a concentrated food source. F06's annual home range size increased almost 6-fold in 2001, but this could reflect increased independence from her sibling (F01) and her older status in combination with closure of the landfill. However, F02's range increase was was likely due to landfill closure. F02 did not have dependent offspring during the pre-closure period, but had 3 cubs-of-the-year post-closure. Because of this change in reproductive status, we expected her home range to decrease in size. However, her annual home range size increased following closure of the landfill (288 to 367 km^2). Females with cubs-of-the-year typically have smaller home ranges than those without cubs, or with older dependent offspring (Lindzey and Meslow 1977, Dahle and Swenson 2003), and it is possible that the increase in range size was due to a need to use a larger area to obtain food.

Closure of the landfill may have caused bears to search more widely for food. Our observation that most bears increased their average distance to the landfill from pre- to post-closure supports this hypothesis. Therefore, although the overall home range sizes remained similar, the increased average distance to the landfill may represent a return to "natural" foraging patterns by these bears.

5.4 Habitat Use

In general, the use of habitats by female grizzly bears did not change greatly pre- versus post-landfill closure. Seasonal use of different land-cover types, use of different canopy closure categories, elevations and biogeoclimatic zones were also similar pre- and post-closure. Given that, for some bears, a substantial food source was removed from their diet, we expected to observe substantial changes in habitat use as bears had to look for alternative foraging habitats. However, we were unable to discern any significant changes in use patterns, possibly because our sampling intensity was not sufficient.

We recognize however, that GIS layers are made for commercial forestry operations and based on polygons which are not likely at the scale required to detect attributes that are biologically relevant to grizzly bears (e.g. subtle shifts with specific forage items and /or movement that occurs within a GIS polygon). Further, since locations were collected during aerial-telemetry flights, we were unable to determine if the time spent within a patch, or movement between patches, increased from pre- to post-closure. We believe it is possible that these smaller-scale attributes (e.g., longer times spent within a patch, larger movements between patches) may have been affected by the landfill closure but at the level of our analysis given our data collected, we were unable to detect the change.

5.5 Degree of Landfill Use and Subsequent Mortalities

We observed several key differences in the behaviour and ecology between the 3 bears that were destroyed due to problem behaviour post-landfill closure (subadult females F01 and F04 in fall 2001, and adult female F02 in fall 2010) and their siblings, family units, and other bears.

The degree of landfill use was based on the percentage of nights spent in the landfill in fall. We expected bears classified as “heavy” landfill-users to display problem behaviour post-landfill closure more than the other classes; we also expected these bears would have the highest probability of displaying threatening behaviour towards humans. All 3 bears destroyed as problems bears post-closure were heavy landfill-users. Bears classified as “light” landfill-users were predicted to be the group that displayed the most tendencies to revert to wild bear behaviour measured by expansions or shifts in their home ranges away from the landfill during the post-closure years: no light landfill-users were killed as problem bears after closure. We expected that “moderate” landfill-users would be the more difficult group to predict, with some bears reverting to wild behaviour and others likely becoming problems, however, none of our study bears fell into this category.

We also examined the amount of time bears spent in the surrounding Landfill Area, and the diurnal timing of landfill visits. Subadult females F01 and F04 had the longest Landfill Area visit durations of all the bears prior to closure, and both were destroyed as problem bears post-closure. In fall 2000, they often remained in the Landfill Area for multiple days (F04: maximum 8.8 days; F01: maximum 7.1 days). F01 also exhibited the most multi-day visits to the Landfill Area (15) of all the bears.

Subadult female F04 was responsible for the majority of daylight and early evening entry times in 2000 and 2001; she was the only bear to use the landfill during the day, and generally remained in the Landfill Area during the day in fall. We observed F04 carrying bags of garbage into the adjacent forested stands, and believe she fed and rested in the adjacent forested areas in the daytime. F04 was the only bear observed foraging in the landfill while public users were dumping garbage; she was also relatively predictable in her behaviour as the first bear to enter the landfill in the early evening, walking past the observing research crew to enter the pit. This apparent tolerance of human presence by some bears was also observed during capture sessions. While capture of some individuals appeared to be a deterrent to subsequent landfill visits (e.g. adult male M05 captured in early September 2000 did not return to the landfill until the following spring), others were captured multiple times. Adult female F02 was captured 8 times in a 23-day period in September 2000, and subjected to aversive conditioning (sprayed with capsicum) immediately prior to release from her last 3 captures. F02 visited the landfill more times than any other bear in the first fall after closure, and was the only individual to be caught again that fall. Due to her bold behaviour and tolerance of humans, F02 was eventually destroyed as a problem bear in 2010, several years after the landfill closed.

Subadult bears, particularly females, consistently spent more time at the landfill and used it as a food source than adult bears. Subadult female bears were more likely to become problem-bears after landfill closure, which we attributed to their increased reliance on the landfill, smaller home ranges, and lower social status. The only bear to display threatening behaviour towards humans was a subadult female (F04) that was classified as a heavy landfill-user. Although the link between the level of garbage-conditioning and habituation of bears to humans is unclear, our results suggest that younger, more garbage-conditioned bears are more likely to act on their learned behaviour (i.e., conditioned to human food sources) and become habituated to humans. Young bears that use landfills may have a higher probability of searching for non-natural foods in surrounding towns, particularly those classified as heavy landfill-users. However, caution should be used in interpreting our results due to low sample sizes of subadults (5 females, 2 males); one study in Yellowstone National Park (not at a landfill) found that male and female subadults had to be killed in equal numbers (Meagher and Fowler 1989).

We also hypothesized that the high degree of relatedness among bears that used the McLeod Lake landfill was linked to the learning of foraging behaviours from their parents. It is possible that cubs learn to forage at the landfill site from their mothers, which has lead some researchers to believe that problem bears tend to create problem offspring (Meagher and Fowler 1989). However, Breck et al. (2008) examined the relatedness of garbage-conditioned versus “wild” black bears, and concluded that “maternal behavior was not an accurate predictor of offspring behavior.” Similarly, Mazur and Seher (2008) found that the location where cubs were raised had a greater influence on their future garbage-conditioned foraging and subsequent associated behaviours such as habituation to humans, than the fact that their mother fed on human foods. Although not all bears raised at the landfill became problem bears, we suggest that the probability of creating problem bears is higher for cubs raised at a landfill than in wild populations. This conclusion is based on our knowledge of wild bears monitored during the same period (2000 - 2002) on the adjacent Parsnip Grizzly Bear Project (none were destroyed for exhibiting garbage-related behaviour in that time span). However, not all offspring or adults that fed on garbage at the McLeod Lake Landfill became a problem when those attractants were removed; some offspring became problems after landfill closure but others did not and this variation in behaviour occurred even within a single family group.

Our results suggest that social status within the family group (e.g., bear-bear interactions, boldness) also influenced future behaviour. For example, independent subadult F04 had 2 siblings (M03, F11), neither of which exhibited problem bear behaviour after landfill closure. M03 did not return to the landfill after his initial capture and was not reported in any nearby towns or camps. He ranged widely, moving far south-west of the landfill, did not return to the landfill, and only returned to the McLeod Lake area for denning (close to his mother's den, F02). Although shot by a guide outfitter in self-defense the first year post-closure, he was not destroyed as a garbage-conditioned problem bear. F11 established her home range adjacent to her mother's and also was not reported to have caused problems in adjacent towns; she was known through genetic sampling to be alive 3-years post-landfill closure. Their sister, F04, however, was deemed a threat to human safety the first fall post-landfill closure, and was shot by a resident of McLeod Lake while on the resident's porch. We noted the following differences between these siblings: M03 was male and dispersed widely during his first independent year, likely establishing his own home range territory, and did not subsequently visit the landfill. The larger female sibling, F04, was the bear responsible for the majority of daylight entry and was the only bear observed in the landfill during the day. Although the smallest sibling F11 was also classified as a heavy landfill-user, her use patterns were not predictable and she exhibited skittish behaviours (e.g., timid around the other bears and was quite vocal, often bawling loudly) while at the landfill. F11 visited the landfill primarily at night and avoided it during the day. Also, unlike her sibling, she tended to exit the landfill before sunrise. F11 also was smaller and in poorer condition than her sister F04 (117 kg versus 148 kg both in mid-September). We suggest that the skittish and wary behaviour of F11 helped her avoid conflicts with humans post-closure. Contrary to the 2 female siblings, the male sibling M03 did not frequent the landfill during his first independent year (2000).

Orphaned and/or injured bears may also be more likely to rely upon landfills as a food source and be more likely to develop problem behaviours. F01 was both orphaned and injured, compared to her sibling F06 (orphaned only), and subadult female F07 (injured only). F01 and F06 were orphaned as cubs-of-the-year in the vicinity of the landfill when their mother and third sibling were illegally killed in fall 1999. The proximity of the family group to the landfill also suggests that their mother may have frequented the landfill prior to being killed and taught her offspring to use it as a food source. Both orphans relied heavily on the landfill as yearlings in 2000 and were classified as heavy landfill-users. However, F01 also spent a substantial amount of time in the Landfill Area throughout spring and summer (likely visiting the landfill at night), while F06 decreased her use of the Landfill Area in summer. Overall, F06's patterns showed her using the landfill less as she grew older, and she began to separate from her sibling which also coincided with the timing of landfill closure. Conversely, F01, who had sustained a broken hind leg from multiple buckshot wounds when her mother and sibling were killed in fall 1999, remained in close proximity to the landfill both pre- and post-closure and visited the landfill more often than F06 post-closure, possibly due to her leg injury and restricted mobility. Although F07 also sustained a serious injury to her front leg, it occurred in the fall of her 3rd year while still accompanying her mother F09 and sibling M08. Not only did she make a long trip with the family unit to den in the mountains approximately 40 km from the landfill after sustaining her injury, she would also have knowledge of the area surrounding the landfill including the location of alternate natural food sources.

6.0 MANAGEMENT OF LANDFILL CLOSURES

Our results show that bears that fed at the landfill did not automatically turn to other human food sources after closure. Because of this, the removal of all bears using a landfill scheduled for closure is unwarranted. Although we found that some offspring raised at the landfill were more likely to display problem behaviour once the landfill was closed, not all offspring that were reared by mothers that foraged at the landfill became future problem animals, even within the same family unit. Predicting the exact causes for the development of problem-bear behaviour post-closure was difficult to evaluate with our study because of low sample sizes. Additionally, marked bears varied in their stages of social development and reproductive status, which further confounded interpretation of results.

Although we did not compare landfill closure techniques in this study, we suggest that the manner in which landfills are closed influences the type and intensity of future problems at the landfill site, as well as in surrounding communities. We recommend closing landfills during the winter hibernation period rather than during periods when bears are active. Shortly after den emergence, bears search for early spring food sources. Closures may be more effective if bears are not able to access landfills upon emergence from dens, as opposed to closing the site once bears have gained access. If winter closures are not possible, closures should occur during the season with the least amount of use by bears, which is typically the peak in availability of natural food sources such as fish or berries (Gunther et al. 2004, Peirce and van Daele 2006).

Furthermore, landfills should not be closed in years with shortages of natural foods used by bears (Davis et al. 2002). Alternatively, other researchers have recommended that garbage pile size be reduced and kept small throughout seasons of use to minimize bear use because smaller pile sizes restricts the number of bears that feed on garbage (Peirce and van Daele 2006).

Several steps should be followed to minimize bear-human conflict resulting from the closure of open-pit landfills. Data specific to bears that use the landfill needs to be gathered prior to its closure. Individual animals need to be identified and monitored to determine the patterns of use of each bear. Marking can be conducted through such means as paint-marks, radio-tags, or ear tags; marking animals also aids in identification during night-time monitoring with infrared vision. Being able to identify animals allows biologists to more reliably identify potential problem animals. Monitoring of bears should begin during the pre-closure years, particularly to identify the site-specific season of peak use by bears, and as a baseline for post-closure comparisons. Night-time monitoring should also be used to identify animals that use the landfill at night. If fixed-telemetry dataloggers are used to evaluate use of the landfill by radio-tagged bears, the distance over which signals can be detected should be determined and refined to limit detection to the immediate “Landfill Area”. Monitoring should focus on the amount of time each bear spends in the landfill and surrounding Landfill Area, the daily timing of visits and the individual bears’ behaviour. This information can then be used to evaluate the likelihood of each bear that uses the landfill to exhibit problem-bear behaviour following closure.

We suggest that a high level of landfill dependence prior to closure (in combination with at least one of the additional attributes listed on the next page), increases the likelihood of a bear becoming a problem after closure of a landfill. Measures of landfill dependency prior to closure should include:

a. The degree of landfill use as measured by the number of nightly visits to the landfill in fall (bears that visit more often are more dependent),

b. The season(s) of landfill use (bears that use the landfill in summer when natural foods are typically most abundant are more dependent),

c. The diurnal timing of landfill use (bears that enter the landfill during daylight hours, and/or remain in the landfill during daytime are more dependent),

d. The size and spatial location of home ranges (bears with smaller home ranges centered around the landfill are more dependent).

Additional attributes include:

1. Age and gender: Subadult females were more likely to develop problem behaviour following landfill closure. In natural systems, subadult bears are forced to disperse from

their natal range and fend for themselves. In the subsequent establishment of their home range, males are expected to disperse widely while females tend to occupy a portion of their mother's home range (i.e., philopatry). If that range included the landfill then it appears that these females have an increased potential to become habitual landfill users or, if the landfill closes, potential future problem bears.

2. Previous injuries: Bears with injuries that limited mobility were more likely to be reliant on the landfill and less likely to seek food elsewhere and thus have an increased probability of future problem behaviour.
3. Human habituation: Bears that demonstrated a higher tolerance of human presence as determined by daytime use of the landfill, tolerance of public landfill-users, and multiple re-captures within the landfill, were more likely to develop problem behaviour.

Our results show that not all bears that fed at the landfill automatically turned to other human food sources after closure. Because of this, the removal of all bears using a landfill scheduled for closure is unwarranted. Based on our findings, we suggest 2 options be considered prior to closure: 1) Removing only those bears determined prior to landfill closure to be heavy-landfill users, and that are also subadults, have significant injuries, or have exhibited a lack of fear of or tolerance to humans, or, 2) Radio-tagging all bears that meet these criteria prior to landfill closure, and closely monitoring the bears movements, range use, and proximity to human food sources after closure, particularly in seasons or years of low natural food availability.

7.0 FUTURE RESEARCH NEEDS

Although our data provides information to help guide future closures of landfills, several key knowledge gaps still remain. Better information on home ranges and habitat use of bears that use the landfill could be collected by deploying GPS collars. Additionally, the nutritional aspect of the use of landfills by bears has been an under-researched aspect of the management of landfill closures (Robbins et al. 2004). We suggest that a study that examines the foraging patterns of bears that uses focal or scan sampling observations would be useful to better determine the degree of food reward or apparent digestible energy consumed by bears during foraging bouts in the landfill. This information would also aid in better determining the level of garbage-dependency of each bear. Assessing the phenology and productivity of natural bear foods in the area surrounding the landfill would provide useful baseline information on diet structure and food availability in the surrounding area. Determining whether bears 1) select less productive natural foraging sites before closure than after closure, 2) spend more time resting than feeding at these sites before closure than after closure, and, 3) consume less high quality bear foods before closure than after closure could also be assessed through a large sample of site investigations both pre- and post-landfill closure.

8.0 LITERATURE CITED

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS v3.27. Available at http://www.spatialecology.com/htools.

Brannon, R. D. 1987. Nuisance grizzly bear (*Ursus arctos)* translocations in the Greater Yellowstone area. Canadian Field Naturalist. 101: 569-575.

Breck, S. W., C. L. Williams, J. P. Beckmann, S. M. Matthews, C. W. Lackey, and J. J. Beecham . 2008. Using genetic relatedness to investigate the development of conflict behaviour in Black Bears. Journal of Mammalogy 89:428-434.

Chi, D. K., D. Chester, and B. K. Gilbert. 1998. Effects of capture procedures on black bear activity at an Alaskan salmon stream. Ursus 10:563–569.

Ciarniello, L. M. 1997. Reducing human-bear conflicts: Solutions through better management of non-natural foods. Unpublished report prepared for Bear-Human Conflict Committee, Ministry of Environment, Lands, and Parks, Victoria, BC.

Ciarniello, L. M., M. S. Boyce, D. C. Heard, and D. R. Seip. 2007. Components of grizzly bear habitat selection: density, habitats, roads, and mortality risk. Journal of Wildlife Management 71:1446-1457.

Clark, J. E., F. T. van Manen, and M. R. Pelton. 2002. Correlates of success for on-site releases of nuisance black bears in Great Smoky Mountains National Park. Wildlife Society Bulletin 30:104-111.

Craighead, J. J, Sumner, J. R., and Mitchell, J. A. 1995. The grizzly bears of Yellowstone: their ecology in the Yellowstone ecosystem, 1959–1992. Island Press, Washington, DC, USA.

Dahle, B., and J. E. Swenson. 2003. Seasonal range size in relation to reproductive strategies in brown bears. Journal of Animal Ecology 71:660-667.

Davis, H., D. Wellwood, and L. M. Ciarniello. 2002. "Bear Smart" Community Program: Background Report. BC Ministry of Water, Land and Air Protection, Victoria, British Columbia.

DeLong, C., D. Tanner, and M. J. Jull. 1993. A field guide for site identification and interpretation for the southwest portion of the Prince George Forest Region. Ministry of Forests Land Management Handbook Number 24. Ministry of Forests, Prince George, BC.

DeLong, C., D. Tanner, and M. J. Jull. 1994. A field guide for site identification and interpretation for the Northern Rockies portion of the Prince George Forest Region. Ministry of Forests Land Management Handbook Number 29. Ministry of Forests, Prince George, BC.

DeLong, C., D. Tanner, and M. J. Jull. 1996. Draft field guide insert for site identification and interpretation for the southeast portion of the Prince George Forest Region. Ministry of Forests, Prince George, BC.

Demarchi, D.A. 1995. Ecoregions of British Columbia. Fourth Edition. 1:2,000,000 Mapsheet. Ministry of Environment, Lands, and Parks.

Dyck, M. G. 2006. Characteristics of polar bears killed in defense of life and property in Nunavut, Canada, 1970–2000. Ursus 17:52-62.

Gibeau, M. 2005. Mortality of grizzly bears in the Bow River Watershed. Pages 61 – 62 *in*: S. Herrero, editor. Biology, demography, ecology, and management of grizzly bears in and around Banff National Park and Kananaskis Country: The final report of the Eastern Slopes Grizzly Bear Project. Faculty of Environmental Design, University of Calgary, Alberta, Canada.

Gunther, K. A., M. A. Haroldson, K. Frey, S. L. Cain, J. Copeland, and C. C. Schwartz. 2004. Grizzly bear–human conflicts in the Greater Yellowstone ecosystem, 1992–2000. Ursus 15:10-22.

Herrero, S. 1985. Bear attacks: their causes and avoidances. Lyons and Burford, New York, New York, USA.

Homstol, L., C. Cassady St. Clair, N. Brabyn, and A. Hamilton. 2007. Abstract. Applications of aversive conditioning on bears in conflicts with humans. Presented at the 18th International Conference for Bear Research and Management, Monterrey, Mexico, Nov 4-11, 2007.

Jonkel, J. J. 1992. A complete manual for handling black and grizzly bears (for managers and researchers). U.S. Fish and Wildlife Service, Missoula, Montana.

Kansas, J. L., R. M. Raine, and M. L. Gibeau. 1989. Ecological studies of the black bear in Banff National Park, Alberta, 1986-88. Final Report. Prepared for the Banff National Park Warden Service, Canadian Parks Service, Banff, Alberta.

Lindzey, E. G. and E. C. Meslow. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41:413-435.

Mace, R., K. Aune, W. Kasworm, R. Klaver and J. Claar. 1987. Incidence of human conflicts by research grizzly bears. Wildlife Society Bulletin 15:170-173.

MacKay, A. E. 1996. Landfill closure to garbage-habituated grizzly bears: The Mackenzie experience. Unpublished report. Ministry of Environment, Lands, and Parks, Mackenzie, BC.

Matthews, S. M., J. J. Beecham, H. B. Quigley, S.S. Greenleaf and H. M. Leithead. 2006. Activity patterns of American black bears in Yosemite National Park. Ursus 17:30-40.

Mazur, R., and V. Seher. 2008. Socially learned foraging behaviour in wild black bears, *Ursus americanus*. Animal Behaviour. 75:1503-1508.

McLellan, B. N., F. W. Hovey, and J. G. Woods. 1999. Rates and causes of grizzly bear mortality in the interior mountains of western North America. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk, Kamloops, BC, 15 – 19 February 1999. 2:673-677.

Meagher, M., and S. Fowler. 1989. The consequences of protecting problem grizzly bears. Pages 141-144 *in:* Bear-people conflicts: proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, 6-10 April 1987, Yellowknife, Northwest Territories, Canada.

Miller, S. D. and W. B. Ballard. 1982. Homing of transplanted Alaskan brown bears. Journal of Wildlife Management 46: 869-876.

Ministry of Environment, Lands, and Parks. 1996. Human-bear conflict in British Columbia: Draft discussion paper. Ministry of Environment, Lands, and Parks, Victoria, BC.

Mowat, G. and D. Fear. 2004. Grizzly bear density in the Nation River area of British Columbia. Final Report. Prepared for Slocan Forest Products, Mackenzie, BC and BC Ministry of Water, Land and Air Protection, Prince George, BC.

Mowat, G., K. G. Poole, D. R. Seip, D. C. Heard, R. Smith, and D. W. Paetkau. 2002. Grizzly and black bear densities in interior British Columbia. Prepared for Canadian Forest Products and the BC Ministry of Water, Land and Air Protection, Prince George, BC.

Peirce, K. N., and L. J. Van Daele. 2006. Use of a garbage dump by brown bears in Dillingham, Alaska. Ursus 17:165–177.

Robbins, C. T., C. C. Schwartz, and L. A. Felicetti. 2004. Nutritional ecology of ursids: a review of newer methods and management implications. Ursus 15:161–171.

Seaman, D. E. and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075-2085.

Smith, B. L., and D. G. Lindsey. 1989. Grizzly bear management concerns associated with a northern mining town garbage dump. Pages 99-104 *in:* Bear-people conflicts: proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, 6-10 April 1987, Yellowknife, Northwest Territories, Canada.

Stringham, S. F. 1989. Demographic consequences of bears eating garbage at dumps: an overview. Pages 35-42 Pages 35-42 *in:* Bear-people conflicts: proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, 6-10 April 1987, Yellowknife, Northwest Territories, Canada.

Towns, L., A. E. Derocher, I. Stirling, N. J. Lunn, and D. Hedman. 2009. Spatial and temporal patterns of problem polar bears in Churchill, Manitoba. Polar Biology 32:1529-1537.

Wood, M. D. and P. E. Hengeveld. 2001. Behaviour of grizzly bears (*Ursus arctos*) in relation to closure of the McLeod Lake landfill in North-Central BC. Year 1 (2000) Progress Report. Peace/Williston Fish and Wildlife Compensation Program Report No. 244.