# ANALYSIS OF BLACK BEAR HOME RANGE USING A GEOGRAPHIC INFORMATION SYSTEM

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*Abstract:* Habitat loss adjacent to Riding Mountain National Park (RMNP), as is common on nature reserves throughout North America, is creating insular pockets of wilderness and wildlife. Consequently, successful management of black bear (*Ursus americanus*) populations within the area of RMNP requires an understanding of trans-boundary movement, spatial distribution, and location specific areas of mortality. The Canadian Parks Service (CPS) is mandated to preserve black bears in a naturally regulated system, while the Manitoba Department of Natural Resources (MNR) is required to maintain a black bear population of sufficient size to support existing consumptive and nonconsumptive uses. Information derived from radio monitoring 47 black bears of mixed ages, sexes, and reproductive status over a 3-year period was analyzed using a Geographic Information System (GIS). Movements of individual bears, were analyzed relative to the availability and distribution of home ranges, den locations, and unnatural foods at landfill locations and hunter bait sites. Implications and applications of GIS are discussed.

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Continuous habitat modification is impinging on nature reserves throughout North America, creating insular pockets of wilderness and wildlife; RMNP is no exception. In recent years, bear hunting over bait has become increasingly popular, creating concern that baiting and the high hunter-related mortality of bears along the boundary of RMNP, combined with increased human activities and development within and adjacent to RMNP, could significantly influence the regulation and spatial distribution of the black bear population. In recognition of the need for interagency management of black bears in the Riding Mountains, the CPS and MNR initiated a cooperative field study to determine the influence of landfill locations and hunter bait sites on bear home ranges.

## STUDY AREA

Riding Mountain National Park is a 2,974 km² highland of mixed coniferous and deciduous forest, interspersed with lakes, grasslands, and bogs. It is located approximately 225 km northwest of Winnipeg (50'39°N, 99'58°W)(Fig.1).

Most of the provincial study area is cleared agricultural land, which is used as pasture or for cereal crops. Provincial Crown land in the study area is mostly uncleared and not leased for agricultural use. The percentage of cleared land on farms within the Provincial study zone varies from 90% to <5% (Barto and Vogel 1978) and increases with increasing distance from RMNP. Production of livestock and raising of forage and cereal crops are the most prevalent agricultural practices. Small towns and recreational housing developments are scattered throughout the study area.

Western and southcentral areas of RMNP contain slow moving streams and many small bogs and sloughs (Kooyman and Hutchinson 1979). On the eastern slopes and the northeastern escarpment, fast running water has deeply incised numerous valleys.

The study area occupies the forest transition zone between the Canadian prairie ecosystem to the south and boreal forest to the north. The southern portion of this zone lacks continuous forest cover, with only isolated pockets occurring in agricultural areas around RMNP. Flora is representative of 3 distinct vegetative zones, the Southern Boreal Forest, Eastern Hardwood Forest, and Prairie Grasslands (Love 1959). Dominant cover is poplar-forest (*Populus tremuloides, P. balsamifera*), interspersed with sedge (*Carex* spp.)-willow (*Salix* spp.) wetland, upland fescue (*Festuca* spp.) prairie, and mixed coniferous forest (*Abies balsmea, Picea mariana, P. glauca, Pinus banksiana, Larix laricina*). The lower slopes of the escarpment within RMNP are comprised of eastern deciduous forest (Canadian Parks Service 1987).

Climate is dry continental, characterized by long cold winters and short warm summers. There is a profusion of markedly different microclimates due to topography and RMNP's northern continental location. July is the warmest month with a mean daily temperature of about 16°C (range 13.8 to 18.4) and January the coldest with a mean daily temperature of -20.4°C (range -13.8 to -26.4)(Environment Canada, A.E.S. 1988, unpubl. data). Annual precipitation is moderate with an average rainfall of 15 cm and average snowfall of 150 cm.

## METHODS

Field investigations (Paquet 1991) were carried out in RMNP and surrounding provincial areas from May 1987 to February 1990. Sixty-seven black bears were captured during the study of which 53 were radiocollared and monitored. Instrumented bears were

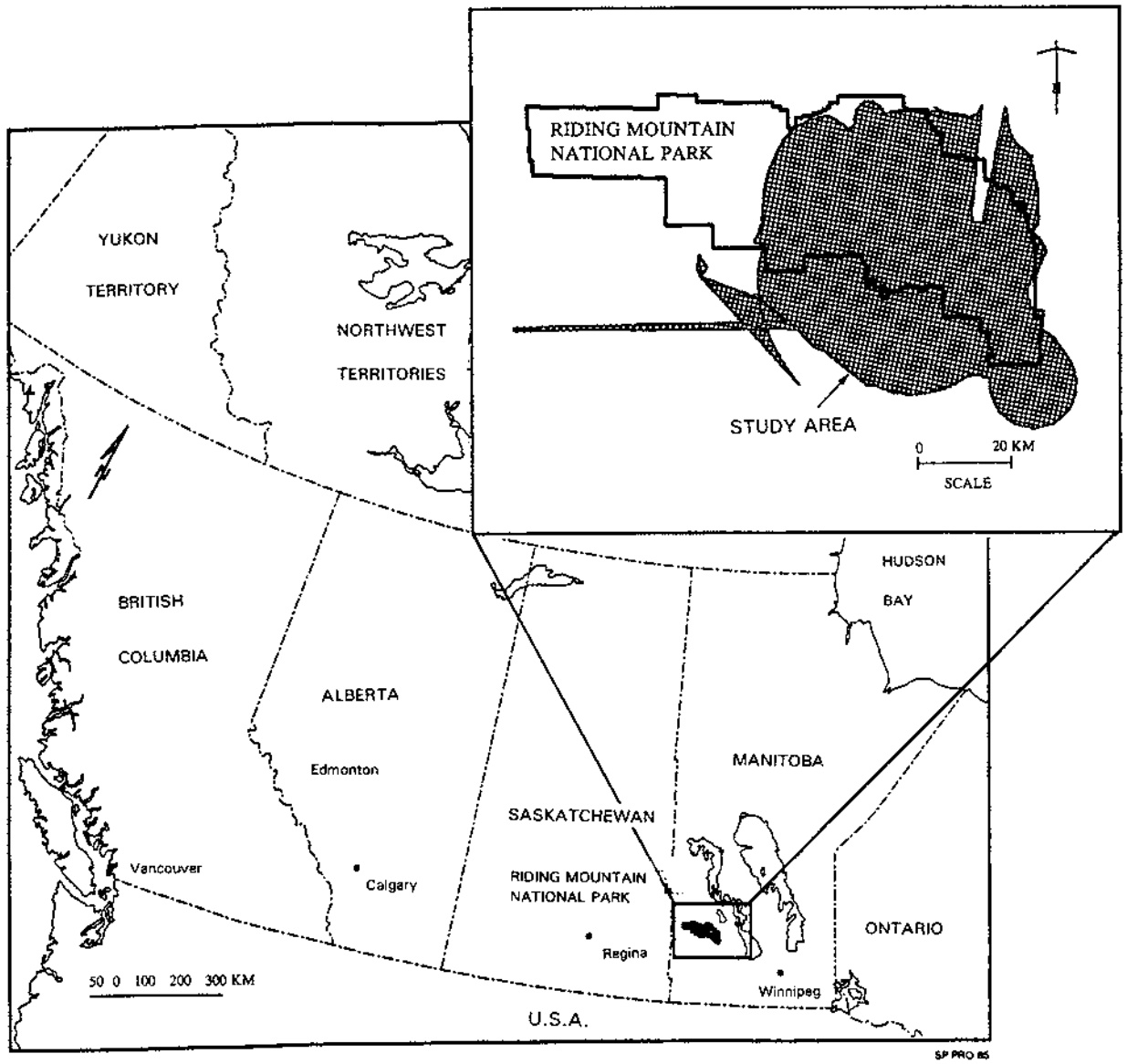


**Fig. 1. Location of study area and Riding Mountain National Park.**

relocated by aerial telemetry approximately every 4 days from den emergence to den entry. The total study area (3,351.0 km²) was defined by the movements of collared bears. Data were stored in the Reflex database program and exported as an ASCII file for analysis by Program Home Range (Ackerman et al. 1988).

Spatial point data (95% Harmonic mean home ranges, core areas, and activity centers) were imported into and analyzed using the Intera Tydac SPANS GIS.

## GIS Spatial Analysis

We calculated home ranges and core areas with the harmonic mean method (Dixon and Chapman 1980) as it was the least biased of indicators (Boulanger and White 1990). Core areas (Ackerman et al. 1988) are defined as the maximum area where the observed utilization distribution based on harmonic values exceeds a uniform utilization distribution. Obvious extraterritorial forays, dispersals (outliers), and serially correlated data points were excluded from analysis. Home ranges (95% harmonic mean) and core areas were classified as RMNP, Provincial or trans-boundary. Park bears maintained home ranges fully within RMNP, while provincial bears maintained home ranges within

the Province. We determined the amount of home-range and core-area overlap by age and sex class using matrix analysis. Home ranges were defined as the area encompassed by the 95% harmonic mean contour. Using matrix analysis and multiple overlays, home ranges of sex and age groups were reclassified and analyzed incorporating point data. Matrix analysis was also used to determine core-area and home-range overlap of adult classes and to ascertain unique areas that were used by only one age and sex class.

We determined the influence of landfill locations and hunter bait sites on individual home ranges by overlaying home ranges, landfill locations, bait site locations, activity centers, and trapsite locations. As trapsite locations function in a similar manner to landfill and hunter bait site locations, we used GIS to ascertain distance from trapsite locations to activity centers for each bear, and determine the mean for each age and sex class.

We pooled capture distances for all bears to determine the "zone of influence" of hunter bait sites. The zone of influence can be defined as the calculated buffer placed around each known trapsite location or bait site location to determine the attraction capability of a particular location. Using the technique of buffer analysis with an overlay of activity centers we determined the zone of influence of hunter bait sites within home ranges. We overlaid activity centers of all study bears on various mean distance buffers from the RMNP boundary (calculated from the bait station analysis) to determine the number of bears influenced by hunter bait site locations.

## RESULTS

Radio-collared bears were located from the air 3,473 times. The number of radiolocations from which annual home ranges were estimated varied from 10 to 198 ($\bar{x}$ = 53, SD = 35, $n$ = 47 bears). The range in radiolocations was largely due to bear mortality.

Hunting accounted for 16 mortalities (10 M, 6 F). Four bears were killed in depredation control (3 M, 1 F), and the fates of 8 bears (5 M, 3 F) were unknown. One male lost a collar and 18 bears were alive (5 M, 13 F) at the end of the study.

The sex ratio of bears used for analysis was 24 F: 23 M. Bears <3 years old at the time of capture were classified as subadults. Ages of bears at capture ranged from 1.5 years to 28 years.

### Home Ranges

Home ranges were determined for 21 adult females, 14 adult males, 2 subadult females, and 10 subadult males (Table 1). Mean home-range sizes were 464.7 km², 294.8 km², and 185.8 km² for adult males, adult females, and subadult males, respectively. Differences were not significant ($P > 0.05$). A small sample size prevented comparison for subadult females.

Age, sex, and the number of relocations did not appear to be factors in determining home-range size (Table 1). For example, 2 adult females with 107 (BB22) and 63 (BB34) relocations during the study had respective home ranges of 52.2 km² and 889.4 km².

### Home-Range Overlap

There was extensive home-range overlap between and among all age and sex groups. Thirty-nine black bears (83%) had home ranges that overlapped RMNP boundaries. The use of home range differed between RMNP and the Province. Subadult males had a larger portion of their home range within the park than adult females and males (subadult M $\bar{x}$ = 81.3%, F $\bar{x}$ = 65.3%, M $\bar{x}$ = 64.4%). Differences were not significant ($P > 0.05$).

Females with trans-boundary home ranges had a 59% overlap in home-range area. Comparison of home-range sizes of a group of females that lived in the center of RMNP indicated a 39.4% home-range overlap which is significantly different ($P < 0.05$) (RMNP F, $\bar{x}$ = 95.5 km², SD = 56.3, $n$ = 7), (Transboundary F, $\bar{x}$ = 394.4 km², SD = 352.7, $n$ = 14).

Similar comparisons could not be made with adult males as all had trans-boundary home ranges. Two subadult males had their entire home range within the Province.

Home-range overlap by adult males was 59.5%. Home-range overlap in RMNP and the Province were 37.5% and 45.9% respectively. Home-range overlap by subadult males was 60.8% within RMNP and 68.1% in the Province.

### Core Areas

Core areas were determined for 32 adult (M = 12, F = 20) and 9 subadult bears (Table 1). Male adults ($\bar{x}$ = 156.6 km², SD = 109.8) had larger core areas in size than adult females ($\bar{x}$ = 85.9 km², SD = 85.1) and subadult males ($\bar{x}$ = 98.5 km², SD = 98.5). Differences were not significant ($P > 0.05$). Core area size within adult home ranges were similar (M = 31.5%, F = 30.3%).

Ten adults (7 F and 3 M), and 2 subadults (1 F and 1 M) had total core areas within RMNP. Two males, (1 adult, 1 subadult) had total core areas within the Province. Mean core area size differed ($P < 0.05$)

between park ($\bar{x}$ = 29.6 km², SD = 19.2, $n$ = 7) and trans-boundary females ($\bar{x}$ = 116.3 km², SD = 92.0, $n$ = 13). Female bears with core areas in the center of RMNP had smaller but more exclusive core areas (overlap by 1 bear), however core-area overlap was 76% versus 60.4% for adult females with trans-boundary core areas. An analysis of pooled core areas (RMNP and Province adults) indicated there was no significant difference in core-area size ($P > 0.05$). Core areas for adult males had 57.7% overlap. Seven females and 1 male had core areas that did not overlap other radio-collared bears.

Adult male black bears had larger home-range (158%) areas and core areas (182%) than adult female bears; however, the mean core area within adult bear home ranges was consistent between sex classes (M = 31.5%, F = 30.3%). Male adults had a greater portion of their home ranges within the Province than females (37.4% and 24.8% respectively).

We used matrix overlay of adult home-range maps to determine the amount of home-range and core-area overlap between adults as well as to define unique (no overlap) home range and core areas. Unique core areas comprised 7.0% ( F = 3.7%, M = 3.4%) of the study area. Unique male and female home ranges comprised 20.5% and 16.9% of the study area. Home-range and core-area overlap occurred in 26.7% of the study area, while male and female home ranges and core areas overlapped in 28.9% (home range = 14.2%, core area = 14.7%) of the study area.

## Activity Centers

Activity centers based on the harmonic mean of an areal distribution (Dixon and Chapman 1980) were calculated by Program Home Range for all bears and later analyzed through GIS. Sixteen of 46 bears (34.8%) had activity centers within 0.5 km of the RMNP boundary. Fifty-four percent of black bears had activity centers within 2.5 km of the RMNP boundary or totally within the Province.

## Hunter Bait Sites

A minimum of sixty-four hunter bait sites were located within the study area. A number of sites however had multiple baits. Except for 3 adults (1 M, 2 F) and 1 subadult male, all bears with trans-boundary home ranges had hunter bait sites located within their home range (Table 1).

The number of bait stations within trans-boundary core areas of individual bears ranged from 0 to 18. The mean number of bait stations were 7.5 (SD = 6.7), 2.3 (SD = 3.9), and 4.4 (SD = 3.6) for adult females, adult males and subadult males, respectively, but differences were not detected ($P > 0.05$).

Bait station locations within home ranges ranged from 1 to 30. Eleven subadults had hunter bait sites within their home ranges and 7 subadults had greater than 10 bait station locations within their home range. One subadult male (BB08A) had 25 bait station locations within a home range of 46.9 km² (density of 1 bait location/1.8 km²). Thirteen adult males and 12 adult females had hunter bait sites (range: M = 1-30, F = 1-20) within their home range.

The effectiveness of baits in attracting bears is well illustrated by a single 4-hr observation period during which 16 different bears visited a bait location (Paquet 1991). Among the visitors were 3 radio-collared adult females. Thirteen study bears were caught in trapsites bordering bait stations.

Distances from each bear's capture location to activity center were calculated using the GIS (Table 1). Mean distance for subadults ($\bar{x}$ = 12.0 km, SD = 11.3, $n$ = 12) were greater than those for adult males ($\bar{x}$ = 10.1 km, SD = 9.4, $n$ = 14) and adult females ($\bar{x}$ = 6.7 km, SD = 8.4, $n$ = 21). The differences, however, were not significant ($P > 0.05$). Pooled distances for all bears were $\bar{x}$ = 9.7 km, SD = 10.0, $n$ = 47.

## Zone of Influence

Seven bears (4 F, 2 M, 1 subadult M) with activity centers near the geographic center of RMNP were not influenced by bait locations. Twenty-one bears had activity centers within 6.7 km of the RMNP boundary, 7 bears within 9.7 km (adult mean), and 1 bear had an activity center within 10.0 km. Eleven bears had activity centers outside RMNP, of which 7 bears had activity centers within 9.1 km (6 $\leq$ 6.7 km).

## Use of Wasagaming Landfill

The activity centers of 17 bears were centered (we used the mean values calculated in the zone of influence to define centered) in or around the Wasagaming landfill site. The core areas of 7 (M = 5, F = 2) bears and home ranges of 18 (M = 8, F = 10) study bears overlapped the landfill location. Direct observations (Paquet 1991) of bears at the landfill site indicated large males were primary users. The presence of adult males appeared to discourage use of the landfill by females with cubs and subadults. In the absence of large males the maximum number of bears observed at the landfill simultaneously was 9.

**Table 1. Home-range and core-area analysis of 47 radio-collared bears, Riding Mountain National Park, 1987-89.**

| | | | | | | # Baits[e] | | Home-range size (km²) | | Core-area size (km²) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bear Id[a] | Sex | Age | # of Rel[b] | Fate[c] | Dist[d] (m) | Core | HR | Total | RMNP | Total | RMNP |
| BB13A | M | SA | 40 | U | 1,484 | | 1 | 3.48 | | | |
| BB11 | M | SA | 10 | D | 8,271 | | 1 | 4.96 | 2.03 | | |
| BB32 | F | A | 56 | A | 3,084 | 0 | 2 | 15.04 | 11.63 | 4.59 | 3.49 |
| BB20 | M | SA | 43 | H | 942 | 3 | 3 | 15.33 | 8.50 | 5.10 | 3.18 |
| BB19 | M | SA | 11 | H | 4,096 | 1 | 3 | 15.88 | 1.12 | 3.75 | |
| BB24A | M | SA | 27 | H | 5,161 | 6 | 8 | 22.89 | 9.18 | 5.62 | 2.07 |
| BB26A[2] | M | SA | 38 | D | 2,522 | | | 24.52 | 8.58 | | |
| BB06[1] | F | A | 90 | U | 2,794 | | | 29.35 | 29.35 | 12.80 | 12.80 |
| BB18A | M | A | 19 | H | 2,640 | 1 | 0 | 31.35 | 18.71 | 4.79 | 4.21 |
| BB25A | F | A | 20 | A | 25,456 | | 1 | 33.53 | 33.29 | | |
| BB08[2] | F | A | 12 | D | 442 | | | 34.34 | 11.86 | 7.12 | 2.54 |
| BB22[1] | F | A | 107 | A | 987 | | | 52.22 | 52.22 | 15.71 | 15.71 |
| BB09[1] | F | A | 95 | A | 570 | | | 52.61 | 52.61 | 16.92 | 16.92 |
| BB36 | F | A | 58 | A | 30,310 | 3 | 1 | 59.49 | 47.43 | 23.38 | 20.48 |
| BB12A[1] | F | A | 93 | A | 1,800 | | | 73.34 | 73.34 | 29.40 | 29.40 |
| BBR01 | F | A | 18 | A | 2,085 | 1 | 3 | 138.53 | 66.49 | 37.87 | 16.50 |
| BB02A[1] | F | A | 20 | A | 508 | | | 141.47 | 141.47 | 29.43 | 29.43 |
| BB30[1] | F | A | 30 | H | 14,179 | | | 153.19 | 153.19 | 62.77 | 62.77 |
| BB23[1] | F | A | 67 | A | 3,773 | | | 166.33 | 166.33 | 40.26 | 40.26 |
| BB10A | M | A | 18 | U | 2,662 | | 17 | 177.07 | 64.67 | | |
| BB08A | M | SA | 28 | U | 21,449 | 11 | 14 | 207.25 | 160.33 | 96.04 | 96.04 |
| BB11A | M | A | 35 | U | 11,653 | 0 | 1 | 285.44 | 5.00 | 85.52 | 11.36 |
| BB15 | F | A | 31 | H | 2,856 | 4 | 11 | 286.88 | 210.60 | 89.32 | 69.36 |
| BB03 | M | A | 83 | U | 2,250 | | 3 | 290.53 | 279.60 | 100.54 | 100.54 |
| BB33[2] | F | A | 20 | A | 3,168 | | | 299.53 | 61.16 | 69.58 | 1.56 |
| BB31[2] | M | A | 56 | H | 17,535 | | | 300.05 | 42.14 | 96.12 | |
| BB15A | F | A | 58 | U | 11,343 | 10 | 5 | 301.52 | 222.72 | 103.22 | 73.80 |
| BB27 | M | A | 64 | H | 24,613 | | 1 | 333.24 | 333.09 | 108.16 | 108.16 |
| BB25 | M | A | 30 | L | 956 | 1 | 7 | 351.15 | 283.69 | 69.89 | 66.19 |
| BB38 | M | SA | 38 | A | 9,219 | 5 | 11 | 357.88 | 264.16 | 154.28 | 130.05 |
| BB21 | F | A | 90 | A | 8,190 | 12 | 4 | 363.33 | 305.66 | 143.69 | 123.88 |
| BB13 | M | A | 37 | H | 4,645 | 12 | 18 | 366.55 | 182.61 | 122.93 | 58.61 |
| BB0130 | M | A | 71 | A | 1,283 | 0 | 2 | 386.73 | 373.58 | 152.36 | 152.36 |
| BB01A | M | SA | 53 | D | 6,236 | 5 | 7 | 427.62 | 336.78 | 174.71 | 139.79 |
| BB16 | M | A | 75 | H | 4,086 | 0 | 10 | 630.98 | 591.37 | 254.40 | 254.35 |
| BBR03 | F | A | 25 | A | 6,046 | 8 | 12 | 644.18 | 450.43 | 190.64 | 154.20 |

| Bear Id[a] | Sex | Age | # of Rel[b] | Fate[c] | Dist[d] (m) | # Baits[e] | | Home-range size (km²) | | Core-area size (km²) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Core | HR | Total | RMNP | Total | RMNP |
| BB1807 | F | A | 198 | H | 462 | 18 | 2 | 647.89 | 264.67 | 158.23 | 33.92 |
| BB14 | M | A | 34 | H | 18,509 | 0 | 6 | 659.66 | 316.50 | 182.66 | 20.07 |
| BB04 | F | A | 83 | H | 728 | 16 | 3 | 664.03 | 351.86 | 139.66 | 42.15 |
| BB35 | M | A | 39 | A | 19,601 | 0 | 21 | 718.03 | 489.26 | | |
| BB28 | M | SA | 86 | A | 30,678 | 0 | 16 | 778.08 | 719.75 | 250.09 | 250.09 |
| BB02 | M | A | 63 | H | 4,036 | 5 | 1 | 824.46 | 732.98 | 348.07 | 327.01 |
| BB29 | F | SA | 60 | H | 30,492 | 0 | 10 | 860.10 | 769.95 | 230.43 | 230.43 |
| BB34 | F | A | 63 | A | 6,078 | 16 | 2 | 889.39 | 325.40 | 238.62 | 28.22 |
| BB17 | F | SA | 85 | H | 23,455 | 6 | 20 | 1,080.42 | 798.08 | 334.68 | 283.17 |
| BB05 | F | A | 69 | U | 16,776 | 2 | 9 | 1,143.61 | 1,009.39 | 305.50 | 303.11 |
| BB37 | M | A | 47 | A | 26,821 | 4 | 14 | 1,150.79 | 482.55 | 355.10 | 92.86 |

[a] = [1] Bears with home ranges totally within RMNP, [2] transboundary bears with no baits in their home range.

[b] = Number of relocations.

[c] = A=alive, D=depredation, H=hunter kill, L=lost collar, U=unknown.

[d] = Distance measured from activity center to trapsite location.

[e] = Total number of baits within a bear's home range (Total core + home range [HR]) indicated large males were primary users. The presence of adult males appeared to discourage use of the landfill by females with cubs and subadults. In the absence of large males the maximum number of bears observed at the landfill simultaneously was 9.

## DISCUSSION AND CONCLUSION

The capability of displaying point data and analyzing home ranges within a GIS has valuable applications in wildlife management. In this study, we integrated home-range data with analytical capabilities of GIS to facilitate interpretation of large amounts of home-range and point data. The capability to quickly display and analyze the information in digital mode has numerous advantages over traditional methods. Databases can be quickly updated, errors corrected, and interpretation of data can be carried out easily. We believe that GIS is a valuable tool that has many advantages over traditional methods but has been underutilized to date. Part of the process of GIS applications use was development.

We used the harmonic mean method in describing home range; however, the capability to view and analyze home ranges methods such as convex polygons, bivariate normal ellipses, or fourier transform methods was also possible. Analyses from these methods are also straightforward.

The use of GIS allowed us to quickly overlay point data such as trapsite, activity center, and den locations with individual home ranges. This enabled us to comprehend the areal and spatial movements of individual bears and cohorts.

Our analysis and results indicate that only a RMNP population of bears inhabited the study area. We used GIS to determine the magnitude of trans-boundary bear movements, the impact of hunter bait sites, and the influence of the Wasagaming landfill on the movements of study bears. Approximately 78% of study bears had trans-boundary home ranges. This may be a result of a "productive habitat" due to the placement of hunter bait sites on the periphery of RMNP. A "core" population of bears (7 adult F) resided entirely within RMNP boundaries. One subadult male had a home range within the Province. Except for a core population of females and 3 adults (1 M, 2 F) and 1 male subadult, all bears with trans-boundary home ranges had hunter bait sites within their home range or core areas. The attractiveness of bait locations is further supported by the fact that 18 bears had home ranges that overlapped the Wasagaming landfill. Activity centers of 54% of study bears were within 2.5 km of the RMNP boundary. Our analyses suggest that the need to maintain a similar spacing of home range is not required for bears that used bait locations. Adult female and male home-range overlap was much greater for bears using bait locations.

This study depicted the use of home range and hunter bait sites in a spatial sense. However, the temporal influence of hunter bait sites is not clearly understood. Many hunter bait sites were baited from den emergence until the end of hunting season; however we did not analyze information on bait locations that may have been used only during hunting season. While a large proportion of bears were killed at hunter bait sites, many study bears with bait station locations within their home-range habitat were not, we therefore hypothesize that bears may be selective in their use of habitat. A temporal analysis of black bear home range is required to coincide with changes in plant phenology, weather patterns, and seasonal baiting practices to determine the influence of baiting activities.

Our analysis and results indicate that only a RMNP population of bears inhabited the study area. This has serious park management implications in that RMNP cannot maintain black bears in a naturally regulated system, which it is mandated to do. The analysis and subsequent presentation of results should lead to better comanagement of black bears.

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