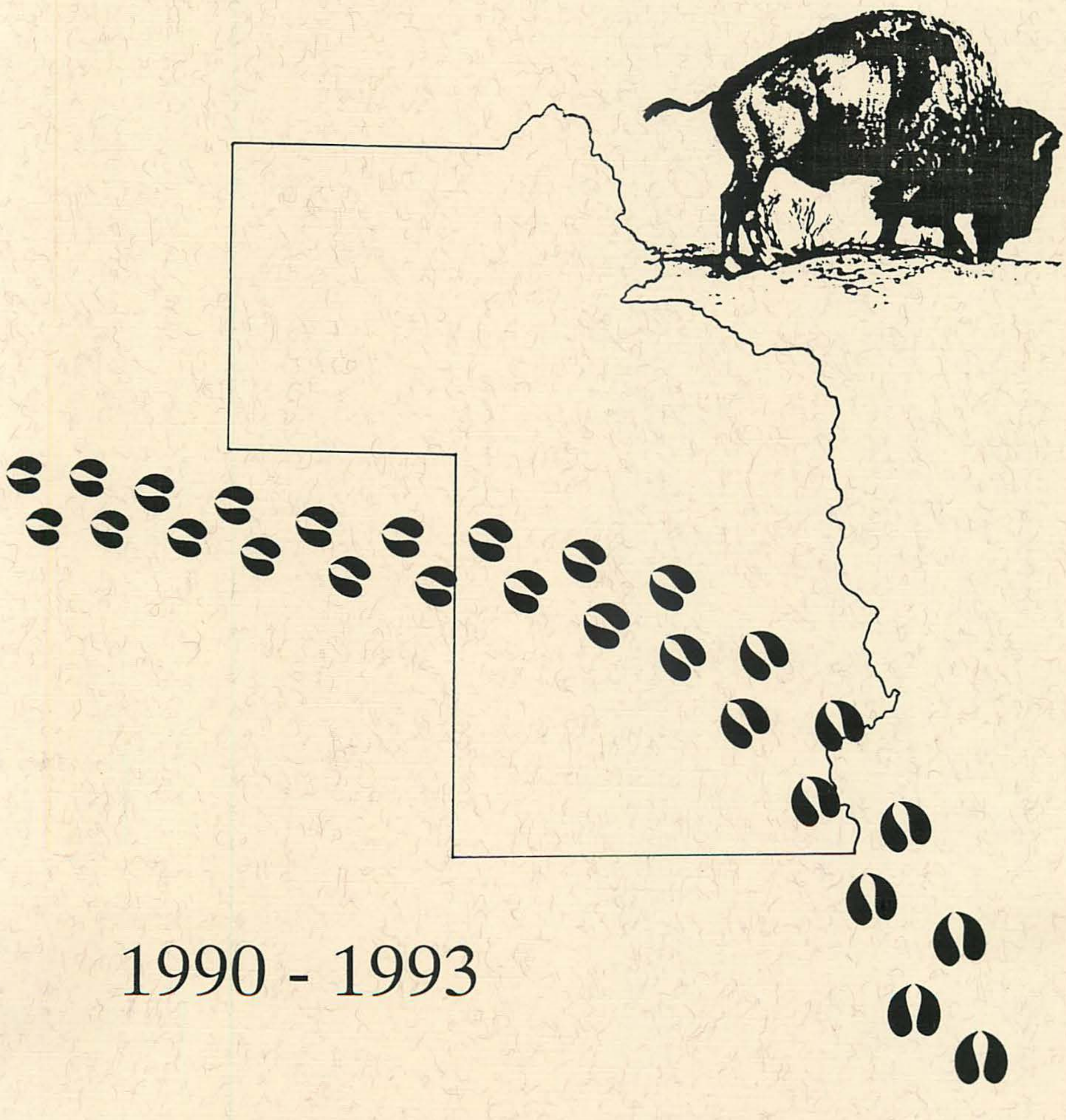
Wood Buffalo National Park

Bison Movement & Distribution Study



1990 - 1993

BISON MOVEMENT AND DISTRIBUTION STUDY

FINAL REPORT

Wood Buffalo National Park
Box 750
Fort Smith, Northwest Territories
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Technical Report 94-08WB

June, 1995

Approval Page

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Acknowledgements

Preparation of this report was a collective effort as was the development and implementation of this study. Charlie Pacas, Wildlife Management Specialist in the former Prairie and Northern Regional Office helped with development of the Terms of Reference and acted as middleman between Wood Buffalo and Telonics. Dr. Eric Broughton from Agriculture Canada participated in three collaring exercises and oversaw the immobilization and handling of all bison. Dr. Curtis Strobeck from the University of Alberta coordinated DNA sampling and participated in the initial field program. Willie Courtoreille and Jackson Whiteknife from Fort Chipewyan, Tom Unka from Fort Resolution, and Simon Nanooch and Paul Tallcree from Garden River participated as the community representatives in the field program.

Murray Peterson and Janet Mercer formed the core group for the first field team while Earl Wilson and Steve Catto were added in the second round. All four also participated in various components of progress report preparation. Dave Milne coordinated data management and conducted all GIS analysis. Axel Moehrenschlager conducted statistical analyses. George Mercer coordinated the initial stages of this study including equipment purchase and set-up, with assistance from Nora Manners. Biweekly monitoring flights were carried out by a number of people including Doug Bergeson, Steve Catto, Janet Mercer, and Earl Wilson. Loon Air Limited and pilots Billy Bourque (d.), Bill Hardman, Terry Best and Klaus Petak provided superb flying.

A number of people participated in the preparation of the final report including Earl Wilson as primary author and Dave Milne as graphics person. Janet Mercer, Jim Morgan and George Mercer prepared the final draft. David Henry, Boreal Ecologist at Prairie Regional Office and Cormack Gates, Bison Ecologist with the Government of the Northwest Territories provided a thorough review and editing.

Abstract

A bison movement and distribution study was carried out in Wood Buffalo National Park from September, 1990 to September, 1993. The primary objective of the study was to document bison movement patterns, specifically bison movement in and around park boundaries. Knowledge of these movements would provide a better understanding of northern bison ecology and assist in determining level of risk of disease transmission to cattle and other bison herds. Secondary objectives included: determination of mortality rates and associated factors, collecting habitat data, and conducting measurements for phenotypic analysis. Blood samples were also taken for DNA analysis and brucellosis testing.

A total of 111 bison were immobilized, 89 of which were fitted with radio collars. Relocation data was collected from 68 bison. Nineteen mortalities were recorded during the study, nine of which may have resulted from problems with the initial reversal agent, naloxone. Other mortalities were attributed to predation, hunting and anthrax.

Fifty-nine bison had relocation data collected for a period of approximately one year or greater (≥23 relocations). Minimum convex polygon (MCP) and harmonic mean (HM) home ranges and core areas were computed for these bison using Program Home Range®. Mean 100% MCP home range size was calculated as 2702.2 km^2 for female bison and 1096.1 km^2 for males. The 95% HM estimated home range sizes for female bison was 3609.1 km^2 and 1727.6 km^2 for males.

As expected, transboundary movements by bison in the Little Buffalo area did occur. Only three other incidents of transboundary movement occurred, these being in the Pine Lake and Garden River areas. There were no long distance forays outside the park by radio collared bison. No transboundary movement was documented in the Needle Lake and Sweetgrass areas.

Significant overlap of home ranges occurred among bison in the Sweetgrass, Pine Lake, and Garden River areas. It is concluded that the bison in the Park should be viewed as a single population for management purposes, although range or area designations assist with focussing management efforts.

Keywords: bison, home ranges.

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1.0 INTRODUCTION

Free-roaming bison are a key component of the greater Wood Buffalo National Park (WBNP) ecosystem, and currently number around 2500 animals (Bergeson 1994). These bison have been the focus of much debate since the introduction of plains bison from southern Alberta in the 1920's. The originating herd of plains bison were known to have been infected with tuberculosis. The diagnosis of brucellosis in the Park bison, in 1956, brought speculation that the introduced plains bison may have been infected with brucellosis as well.

The disease issue was most recently addressed by the Northern Diseased Bison Environmental Assessment and Review Panel in 1990. The Panel concluded that movement between bison in the greater WBNP ecosystem and adjacent cattle and bison herds posed a risk of disease transmission (Canada 1990). In response to these concerns, a three year bison movement and distribution study was initiated by Parks Canada (Peterson 1990).

The primary objective of the study was to document bison movement patterns, specifically bison movement in and around the Park boundaries. Knowledge of these movements, including periods of greatest mobility, would provide a better understanding of northern bison ecology and assist in determining level of risk of disease transmission. Secondary objectives for the study included determination of mortality rates and associated factors and identification of habitat use and preferred summer and winter home ranges (Peterson 1990). Genetic and phenotypic characteristics were also examined as part of a complementary study to evaluate the hybrid status of the park bison. To undertake the study a bison immobilization protocol was developed (Peterson and Mercer 1991).

The study focussed on five known bison concentration areas in and around the Park. This included the Little Buffalo area which incorporates a portion of the Park as well as some of the Slave River Lowlands in the Northwest Territories. Bison populations are known to occur in areas near but outside the Park (Firebag River and Mikkwa/Wabasca Rivers), however these were not included.

2.0 STUDY AREA

Wood Buffalo National Park encompasses 44 807 square kilometres of northeastern Alberta and southwestern Northwest Territories (Figure 1). The Park is representative of the Northern Boreal Plains natural region with small areas of the Southern Boreal Plains and the Northwestern Boreal Uplands. The predominant feature of the northern Park area is a poorly drained plain, vegetated with forests, muskegs, sedge and grass meadows interspersed with meandering streams, rivers and shallow lakes. The eastern boundary of the park has some granitic hills, outliers of the Canadian Shield. The Peace and Athabasca rivers enter the Park from the south and form the large (4 500 km^2) inland Peace-Athabasca Delta to the west of Lake Athabasca. The delta drains north to the Slave River and hence to Great Slave Lake (Parks Canada 1979).

Wood Buffalo has a typical boreal plains climate consisting of short cool summers, cold winters and light precipitation. The temperatures range from a mean of 16.4^0 Celsius in July to -24.6^0 Celsius in January. Average yearly precipitation is 265 mm of rain and 148 cm of snow. Freeze up occurs in October or early November with breakup in May.

The climate is generated by a mix of Arctic and Pacific air masses. These air masses in conjunction with summer convective currents produce an estimated 40 to 60 thunderstorm systems annually and form the primary ignition source of forest fires in the park. Wildlife species include 47 mammals, one reptile, 4 amphibians, 227 birds, 21 fish and an unknown number of insect species. Species composition is compatible with the northern boreal plains region (Ibid).

Coniferous forests are dominated by black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), and tamarack (*Larix laricina*). White spruce and balsam poplar (*Populus balsamifera*) dominate on alluvial flats. Upland sites are characterized by jack pine and trembling aspen (*Populus tremuloides*), while black spruce is prevalent in poorly drained areas. A variety of willows occur throughout the park. South of the Peace River, vegetation is dominated by the extensive sedge (*Carex* spp.) meadows of the Peace-Athabasca Delta.

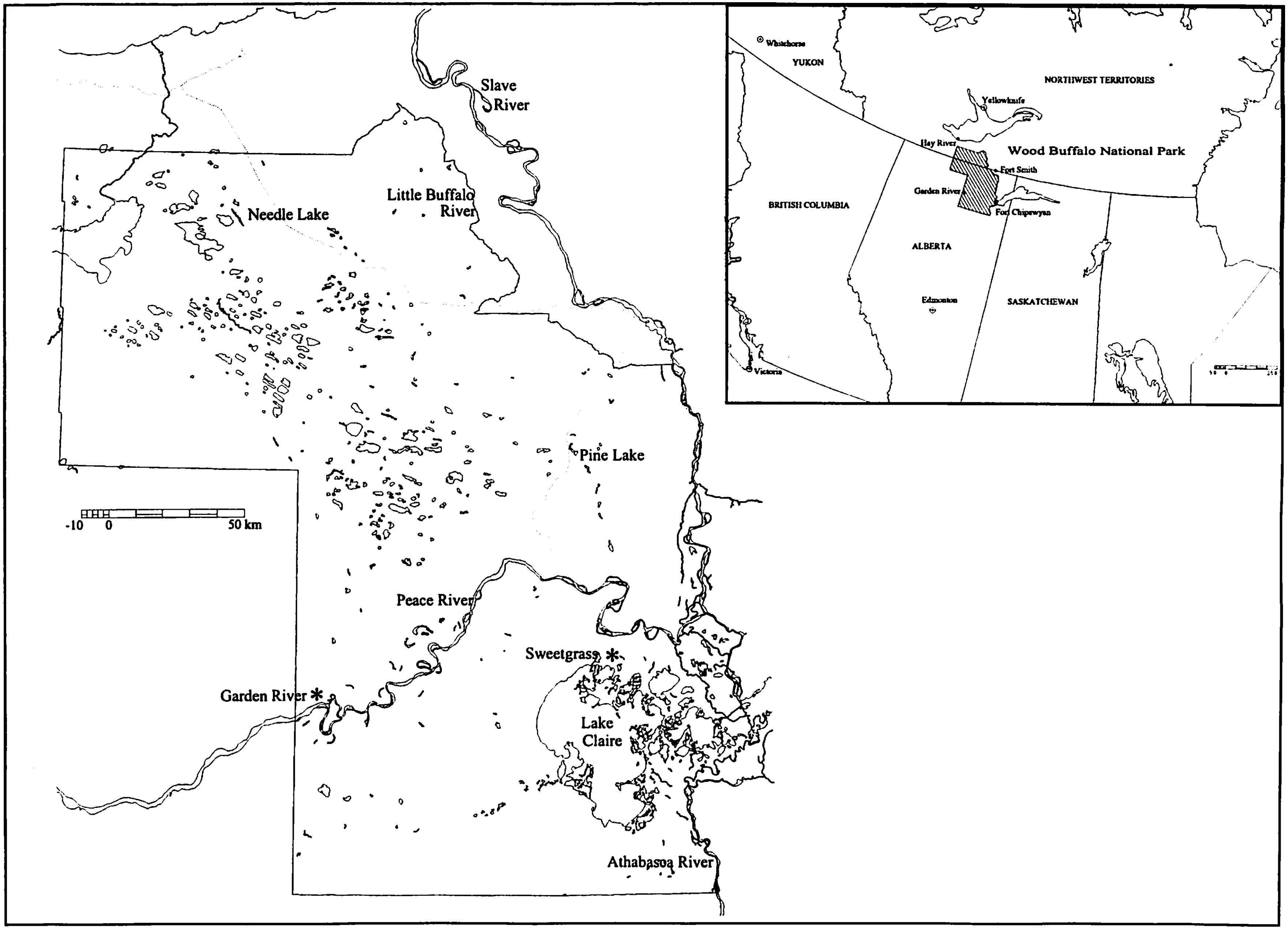

Figure 1: Wood Buffalo National Park

3.0 METHODS

The study was conducted from August 7, 1990 to September 23, 1993. Adult bison were immobilized and radio collared within five general regions of WBNP and adjoining lands in the Slave River Lowlands area of the Northwest Territories. These five areas were selected for having known concentrations of bison, based on the results of annual population surveys. Throughout the report, these areas are also referred to as generalized groups or ranges of bison. It is not inferred that these groups are in strict isolation of other groups. Each area was named after a dominant feature within them: Sweetgrass, Pine Lake, Needle Lake, Little Buffalo River and Garden River. The Terms of Reference (Peterson 1990) for the study proposed that 50 bison (25♀, 25♂), divided equally among the five ranges, be radio collared. Ten per area was chosen as the division in order that bison would be sampled from all the main concentration areas, thus providing data spatially representative of the majority of the park area. This allowed evaluation of the amount of movement among and between the bison groups. Radio collared bison were identified by the letters of the range where they were collared in chronological order, eg. PL12 would be the 12th bison radio collared in the Pine Lake area.

3.1 Field Handling and Immobilization

For immobilization purposes A-Star helicopters were utilized to locate bison herds. Once a suitable animal or herd was sighted, a four-person crew would land a safe distance downwind of the bison, minimizing disturbance. The shooter and one assistant would approach the bison and attempt a clear shot. Darting success increased if the bison were not excited and unaware of the team's presence. On occasion, the helicopter was used to herd the bison toward the shooter when the location provided a clear view of the herd's escape route. In such instances, if the attempt failed the animal or herd was left to calm down and another group of bison were targeted.

Large muscle masses (rump, thigh or shoulder) were targeted for darting. Once darted every attempt was made to keep the bison under continuous observation until the animal went down. Hit location, time of dart impact and the time it took the bison to lie down (induction time) were recorded by the shooter.

Bison were immobilized and sedated using a combination of 4.3 to 6.0 mg of Wildnil® (carfentanil citrate, 3.0 mg/ml) and 100 mg. Rompun® (xylazine hydrochloride, 100 mg/ml). Wildnil® proportions varied over the life of the study based on observations of bison response, beginning with 6.0 mg and eventually decreasing to 4.3 mg. During each immobilization period, all adult bison received an identical drug combination. These standards were used because this allowed preloading of darts, thereby increasing safety for the immobilization team by eliminating the necessity for field preparation of darts based on target bison sex or size. Drugs were administered intramuscularly with a 3.0 ml Pneudart® (3.6 cm barbed needle) delivered from a Pneu-Dart model 171C dart rifle (Pneu-Dart Inc., Williamsport, Penn.), fitted with a four power scope. Darts were propelled with a Remington® .22 calibre explosive blank (number 2-brown power level).

Immobilized bison were placed in a sternal recumbent position and stabilized with mounds of dirt placed along the animal's sides. The eyes were covered with a shroud. On hot sunny days a tarp would be positioned over the animal to provide shade. Withdrawal of blood samples, monitoring and recording of body temperature and respirations, and determination of general condition of each animal was completed by a veterinarian (Dr. E. Broughton DVM, Ottawa, Ontario). Approximately 50 ml of blood was drawn from the tail vein and stored in three purple topped (EDTA) 16 mm vacutainers for DNA analysis and two red topped (no preservative) 16mm vacutainers for brucellosis testing. Blood samples were kept cool in the field with the use of a small cooler and ice packs. Results of the DNA analysis are found in Strobeck (1992), while the brucellosis test results will be analyzed in a subsequent report.

Measurements were made of the girth, neck circumference, total length, horn circumference and length, ear length and left leg length from ankle to hoof tip. For identification purposes numbered metal Kurl-lock® ear tags were placed in both ears of each immobilized bison.

Immobilized bison were examined for general body condition and the presence of injuries. Each bison received an injection of 40 mg of Penlong XL® penicillin to help combat any introduced bacteria associated with the immobilization process. Lesions or open wounds found on the animals were treated with an antibacterial salve. Bison immobilized following an outbreak of anthrax in the Park in 1991 were also injected with an anthrax vaccine.

In 1990, five phenotypic characteristics of woods and plains bison as identified by Van Zyll de Jong (1986), were scored for each bison sampled. In 1991, the Taxonomy Subcommittee of the Wood Bison Recovery Team developed a new methodology. Bison immobilized in 1991 and 1992 were scored consistently by one field member using this later method. Results of the phenotyping are discussed in Strobeck (1993).

Bison were approximately aged based on a horn growth and wear system adapted from Fuller (1959). Males were classed as B1 (juvenile, 0-4 years), B2 (subadult, 4-7 years), B3 (adult, 7-8 years) and B4 (prime, 8+ years). Females were classed as C1 (juvenile, 0-3 years), C2 (prime cow, 3-12 years), C3 (old cow, 12-20 years), and C4 (very old cow, 20+ years). Pursuant to the development of a reference guide to identify age from dental wear patterns (Gates, pers. comm. 1992), tooth impressions of the upper right molars were taken using Presidents Dental® putty.

Radio collared bison were fitted with a Telonics® Model 600 collar (150 to 151 MHZ) equipped with a transmitter, lithium battery and mortality sensor. Total weight of the collar was approximately 490 gms. Each collar was adjusted to the size of the bison's neck and then bolted together. During the 1990 and 1991 field seasons the radio collars were attached with a medium weight collar material. This proved insufficient as loss due to torn collars, particularly on bulls, occurred regularly. In 1992, a heavier material, referred to as "elephant" collar material by Telonics, was utilized. These later radio collars were ordered with no predrilled holes in the material so as to maximize material integrity. A portable electric drill was used in the field to custom fit the collars to each bison. This change in collar material did not make any appreciable difference in collar retention by bulls.

Naloxone (50 mg/ml) was initially used as a reversal agent for carfentanil at a range of 83 to 300 mg/mg of carfentanil. After problems, possibly associated with renarcotization, were encountered, this drug was replaced with naltrexone (50 mg/ml) at an average rate of 128 mg/mg of carfentanil. M50-50 and/or yohimbine was used as a reversal for the Rompun®. The reversal agents were injected in equal parts intramuscularly in the rump and subcutaneously in the back. The time from injection of the reversal agents to the time the bison was standing was recorded as reversal time. Once a bison was ambulatory it was followed on foot until out of sight or until it appeared to have recovered from the effects of the carfentanil.

3.2 Relocations

Radio collared bison were relocated using aerial telemetry with a Telonics® Model TR 2 receiver. The receiver was connected to two RA-2A H-Type Yagi antennae mounted on the wing struts of a Cessna 185 fixed wing aircraft. A switch box controlled signal input from either antennae.

Bison telemetry relocation flights were scheduled to be flown biweekly. The location of each radio collared bison, accompanying herd size and habitat type was recorded. Remarks regarding unusual behaviour such as wolf presence or bison mortalities in the area were also recorded. Beginning in the winter of 1991, a Trimble® global positioning system (GPS) was used for assistance in determining bison locations. From field tests, the accuracy of relocations was estimated at ±250 m.

3.3 Data Management and Analysis

Relocation data were entered into a DBASE IV database program (Ashton-Tate Corp., Torrance, CA). A 15 day acclimation period, during which movement data was not analyzed, was used to compensate for the effects of immobilization. Movement patterns for all bison relocated at least twice were examined. Home range analysis was conducted using the program HOME RANGE (Ackerman et al. 1990). Home range estimates were determined using harmonic mean (HM) activity areas (Dixon and Chapman 1980) and minimum convex polygon (MCP) (Mohr 1947), for bison relocated at least 23 times (approximately 1 year). The minimum one year time frame was employed as a complete annual cycle of seasonal movements was required to adequately provide home range size estimates.

The minimum convex polygon and harmonic mean estimators were used as they are the most commonly applied in similar studies (White et al. 1990). The minimum convex polygon method is a simple and intuitive technique which is widely used. The harmonic mean method is more robust to changing use patterns and allows for determination of centres of concentrated use (Ackerman et al. 1990). The 100% MCP was generated to utilize all relocation points to examine forays and transboundary movements. The 95% HM and 95% MCP estimators were calculated to exclude outliers of the normal use areas. The 95% harmonic mean estimates were used to test for differences ($P< 0.05$) between sexes (t-test) and groups (ANOVA). HOME RANGE was also used to determine core areas of concentrated use which represent areas where use exceeded that expected from a uniform distribution (Ackerman et al. 1990).

The 95% harmonic mean home range estimates and core areas of individual bison were overlaid on a digitized park base map using Intera Tydac® Spans geographic information system (GIS) for geographic referencing. All core areas were overlaid to determine the extent of area ranges. The internal boundaries of these core areas were deleted to produce a composite core area for each group (ie. Sweetgrass, Pine Lake, Garden River, Needle Lake and Little Buffalo).

The survival rate of radio collared bison was estimated using the Kaplan-Meier procedure, extended to allow for the staggered entry and censoring (failed or dropped collars) of animals (Pollock et al. 1989). Park bison population estimates were obtained from the 1991 (Peterson) and 1992 (Wilson) Total Counts. Bison mortalities thought to have been associated with the immobilization process or that occurred prior to completion of the 15 day acclimation period were not included in the analysis.

Testing for the presence of brucellosis (*Brucella abortus*) antibodies in the bison blood samples was conducted by the Animal Health Division of Agriculture Canada, Ottawa, Ontario. The blood samples were subjected to the buffered plate test (BPAT), the standard tube agglutination test (TAT), the complement fixation test (CFT), the indirect enzyme linked immosorbent assay test (iELISA), and the competitive enzyme linked immosorbent assay test (cELISA). Parallel interpretation of the samples was conducted. Parallel interpretation is a procedure whereby a sample is declared positive for brucellosis antibodies if it is positive or suspected positive on any of the confirmatory tests. Results of these tests will be analyzed in a subsequent report.

4.0 RESULTS

4.1 Bison Characteristics and Handling

One hundred and eleven bison were immobilized during four time periods (August, 1990; n=59), (November, 1990; n=3), (July-August, 1991; n=29) (July-August, 1992; n=20). Eighty nine bison (38♀, 51♂) were radio collared. Twenty two additional bison (2♀, 20♂) were immobilized to obtain blood samples for DNA analysis and brucellosis testing. Immobilized females consisted of 2 C1's, 13 C2's, 24 C3's and 1 C4. Males consisted of 1 B2, 51 B3's and 19 B4's. The two C1 bison were accidental captures. Both C1's radio collars were fitted to allow for growth.

Of the physical measurements taken from the 111 bison, adult male bison (B3, B4) had significantly greater (t-test, $P<0.05$, n=70) chest girths, total lengths, neck circumferences and horn lengths than adult females (C2, C3 and C4, n=38). B4 males (n=19) were significantly different (t-test, $P<0.05$) than B3 males (n=51) only in that they had longer horns. Adult females (t-test, C2 and C3, n=37) were not significantly different in any measurements. Due to low sample sizes the C1 (n=2), B2 (n=1) and C4 (n=1) animals were omitted from statistical comparisons and from the calculation of summary statistics (Table 1). There was no significant difference (ANOVA, $P=0.05$) in any of the measurements between ranges.

Table 1. Physical characteristics of male and female bison immobilized during study. Measurements in cm.

Physical Characteristic	Male (n=70)		Female (n=37)	
	Mean	Stan. Dev.	Mean	Stan. Dev.
Girth	264.1	20.7	218.9	19.5
Neck Circumference	153.5	37.1	93.4	6.3
Right Horn Circumference	41.4	4.7	23.0	3.4
Right Horn Length	42.1	5.0	34.7	8.2
Left Horn Circumference	41.7	4.9	23.9	4.8
Left Horn Length	43.0	4.2	36.4	6.4
Left Leg Length	65.3	8.6	63.5	3.4
Total Length	335.6	37.1	278.2	19.7

The mean chest girth was 264.1 cm for males and 218.9 cm for females. Kelsall et al. (1978) developed a formula to estimate body weight from chest girth for male plains bison ($wt=.00185 * girth^{2.325}$) and for female plains bison ($wt=.00168 * girth^{2.325}$). Based on this, the estimated mean weight of bison in this study would be 789 kg for males and 463 kg for females.

During August and November, 1990, immobilization darts were initially preloaded with 6.0 mg of carfentanil and 100 mg of Rompun®. The carfentanil was later decreased to 5.0 mg. In 1991 and 1992 the dosage was further reduced to 4.3 mg carfentanil and 100 mg of Rompun®. Of the bison which required only one dose there was no significant difference (Kruskal-Wallis test, P=0.89) in the time from injection to recumbency with 6.0 mg (n=33), 5.0 mg (n=16) or 4.3 mg (n=43) of carfentanil. The median time to recumbency for all three doses was the same at 7.0 minutes. Similarly, there was no significant difference (Kruskall-Wallis test, P=0.93) between the three doses in the time it took a bison to become ambulatory following administration of the reversal agent (median=8.0 min for 6.0 and 5.0 mg; median=6.8 min. for 4.3 mg). Bison were recumbent for an average of 38 minutes (SD=2.8).

In the 1990 field season bison were initially reversed with naloxone (n=59), a short-acting antagonist. During this period, nine (3♀, 6♂) bison fatalities occurred, possibly resulting from problems associated with renarcotization (Peterson 1990). These bison were found dead or their radio collars were emitting a mortality signal on the first relocation efforts. Although each bison was located and examined in the field within 30 days, the cause of mortality could not be ascertained. The initial response to this was to increase the dosage and placement of the naloxone administered, from 83 mg/mg of carfentanil (n=20) to 125 mg/mg of carfentanil (n=39), and administration of a portion of the dosage subcutaneously. Some of the bison still appeared to be sluggish after the reversal was administered, so naloxone was replaced with naltrexone, a longer acting antagonist, for all subsequent immobilizations (n=52). Following this switch in reversal agents there were no unexplained mortalities associated with the immobilization process. This supported the theory that the original nine deaths were associated with the naloxone and possible renarcotization rather than other causes.

Additionally, physiological indicators examined during handling did not provide any evidence that the nine bison mortalities could have been predicted. The mean rate of respiration, while immobilized, for the nine bison was 12.6±2 inhalations/minute, while for all immobilized bison it was 12.5±2.8 (n=111) inhalations/minute. The mean body temperature of the nine bison was 38.9°C ±0.55 and for all immobilized bison it was 38.5°C± 0.84 (n=111). Neither difference would seem to indicate potential mortality factors.

Bison exhibited no significant difference in response (time from injection to standing) to either reversal agent (Mann-Whitney U test=0.77: naloxone, n=59 median=7 min.; naltrexone, n=52, median=6.3 min.).

4.2. Bison Movements and Home Range

4.2.1. Sample Size

From July 1990 to August 1992, 89 bison were radio collared. Relocation data of 6 or more relocations was collected from 68 bison. Appendix 1 contains summary data, while Appendix 2 provides individual home range maps for each bison. Data were not collected from 21 bison because of mortalities (6♀, 9♂) or lost radio collars (6♂) prior to completion of the 15 day acclimatization period. Of the 68 bison from which relocation data were acquired, the final outcome was as follows: 10 bison (6♀, 4♂) died, 2 (2♂) radio collar transmitters failed, 31 (7♀, 24♂) radio collars fell off due to material failure and 25 (22♀, 3♂) were still active at the end of the study period.

From September 1, 1990 to September 25, 1993, 75 sets of relocation flights were flown at a mean interval of 15 days (14.8±3.8 days). During this time 2478 individual relocations of radio collared bison were recorded. The mean number of bison radio collared throughout the park during the study was 33 (Table 2). Based on results of the 1992 total count survey in which 2940 bison were observed, the 33 bison represent 1.1 % of the total observed population. Over the duration of the study an average of 674 bison (23% of total Park population) were associated with the radio collared bison (Table 3).

Table 2. Mean number of radio collared bison during seasons for duration of the study.

Area	Winter 90/91		Summer 91		Winter 91/92		Summer 92		Winter 92/93		Summer 93		Study Mean	1992 obs. pop.	% of total pop. radio collared
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	ALL		
Sweetgrass	1.8	3.1	2.2	2.6	4.9	0	5.3	1.3	5.8	3.9	5.4	0.8	6.4	1444	0.44
Garden River	1.8	4.3	3.2	3.9	6	5	6.2	4.5	7	2	5.3	0.7	8.5	462	1.8
Pine Lake	2.8	5	3.1	4.7	5.8	1	5.5	1.7	4.3	4.8	4.4	2	7.2	385	1.9
Needle Lake	0	1.5	.5	3.1	2	4.9	3.2	4.5	7	2.4	6.7	1.3	6.5	236	2.8
Little Buffalo	2	3	2	2.7	2	1	2.5	1.3	3.8	2.1	4.4	1.1	4.8	415	1.2
Park	8.5	16.7	11	16.7	20.7	11.9	22.4	13.3	28	12.3	26	8.4	33	2940	1.1

* Means calculated by summing relocations during seasons and dividing by number of flights, hence not necessarily whole numbers.

Table 3. Mean number of bison associated with radio collared bison during the duration of the study.

Area	Mean # of bison seen		% of total population in the area
	x	SD	
Sweetgrass	318	138	22
Garden River	94	56	20
Pine Lake	93	47	24
Needle Lake	84	52	36
Little Buffalo	107	53	26
Park	674	290	23

4.2.2. Home Range

Fifty nine bison were relocated for approximately one year (>22 relocations) or more. The 95% harmonic mean estimates for these 59 bison were distributed normally (K-S test, P=0.924). Female home ranges (n=30, mean=3609.1km^2, s.d.=1247.2) (Table 4) were significantly (P<0.0001) larger than males (n=29, mean=1727.6, s.d.=1048.3) (Table 5).

Table 4. 95% harmonic mean home range size estimates (km^2) for female bison in the five ranges.

Range	N	Minimum	Maximum	Mean	Median	S.D.
Sweetgrass	7	2147.0	5818.9	3533.4	3232.0	1299.0
Garden River	9	1948.8	5731.7	2629.9	2402.3	1260.6
Pine Lake	3	3594.8	6536.2	5376.2	5997.7	1566.1
Needle Lake	7	3375.15	4396.2	3754.0	3728.7	356.3
Little Buffalo	4	1643.5	4596.5	3041.0	2962.1	1209.0
Overall	30	1643.5	6536.2	3609.1	3413.4	1247.2

Table 5. 95% harmonic mean home range size estimates (km^2) for male bison in the five ranges.

Range	N	Minimum	Maximum	Mean	Median	S.D.
Sweetgrass	3	290.3	565.6	384.1	296.5	157.2
Garden River	8	938.1	3747.7	1923.4	1847.3	909.4
Pine Lake	9	379.6	3206.8	1717.6	1990.5	1007.6
Needle Lake	5	1188.4	3954.2	2541.2	2448.5	1145.1
Little Buffalo	4	469.3	2412.8	1348.8	1256.6	808.3
Overall	29	290.3	3945.2	1727.6	1708.2	1048.3

Testing for significant difference in 95% HM home range estimates between the two male classes (B3, n=21; B4, n=8) did not demonstrate a significant difference (t-test, P>0.05). With female bison, small sample sizes necessitated combining of age classes (C1+C2, n=13; C3+C4, n=17). There was no significant difference found between the 95% HM home range estimates for the female bison age class groupings (t-test, P>0.05).

Tests for significant differences in the home range sizes between ranges were also conducted, however again due to the small sample sizes in some ranges the test results should be interpreted with caution. There was no significant difference (Tukey's HSD test, P>0.05) in female home range sizes between ranges. There was a significant difference (Tukey's HSD test, P<0.05) in male home range sizes between the Sweetgrass range and the Needle Lake range.

4.2.3. Composite Core Areas and Movement Patterns

Of the 59 bison which were radio collared for one year or more, a 95% core area could not be computed for five of them due to wide ranging and/or irregular movement patterns. For the remaining 54 bison, core areas were calculated. Figure 2 displays all the five composite core areas, and demonstrates areas of overlap. Figures 3-7 demonstrate core areas clustered to define a *composite* core area for each range and regions of overlap between ranges.

For each of the five ranges, 2 examples of 95% harmonic mean home range and core areas are provided (Figures 8 - 17). These examples illustrate the type and detail of information provided in Appendix 2.

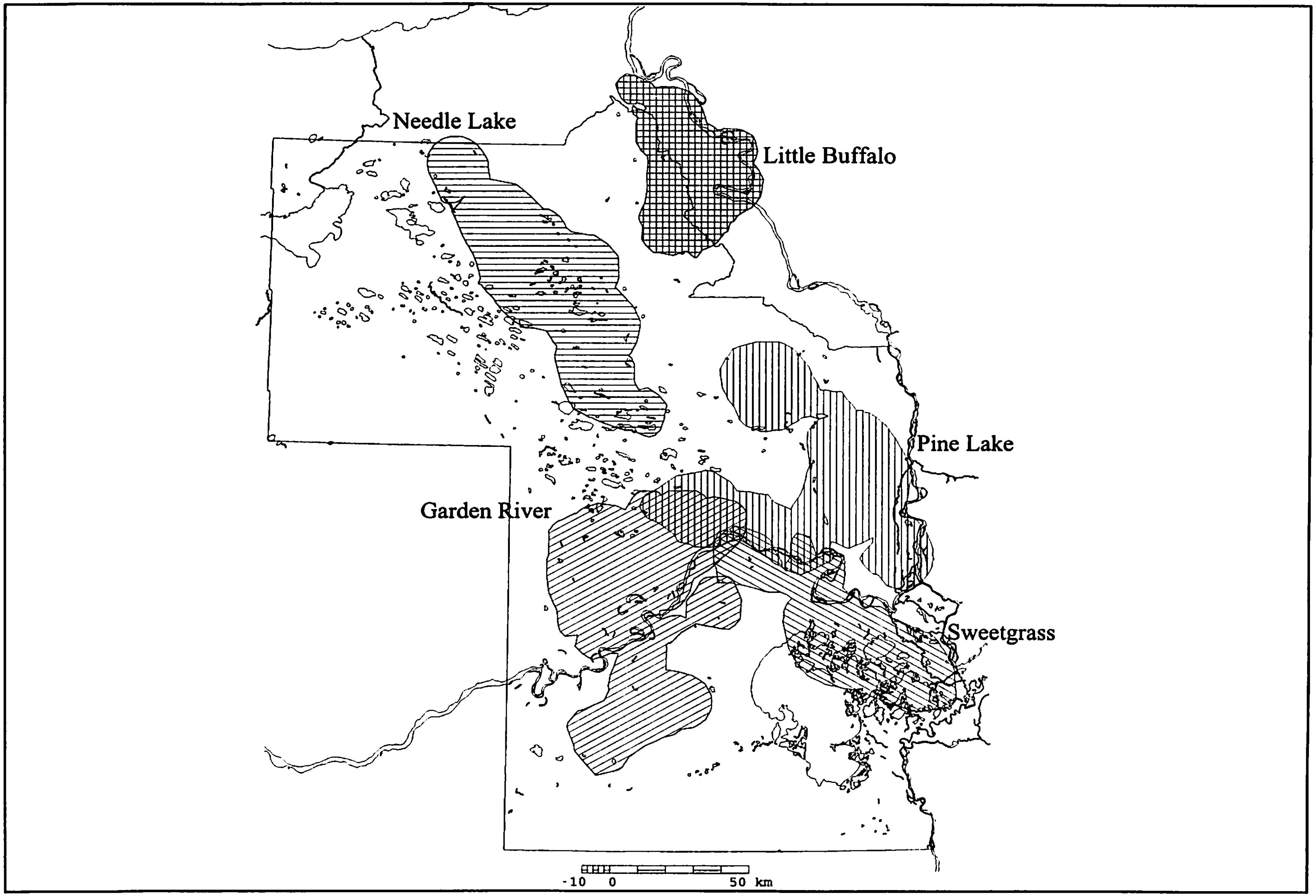

Figure 2: Composite core areas of five bison ranges in Wood Buffalo National Park.

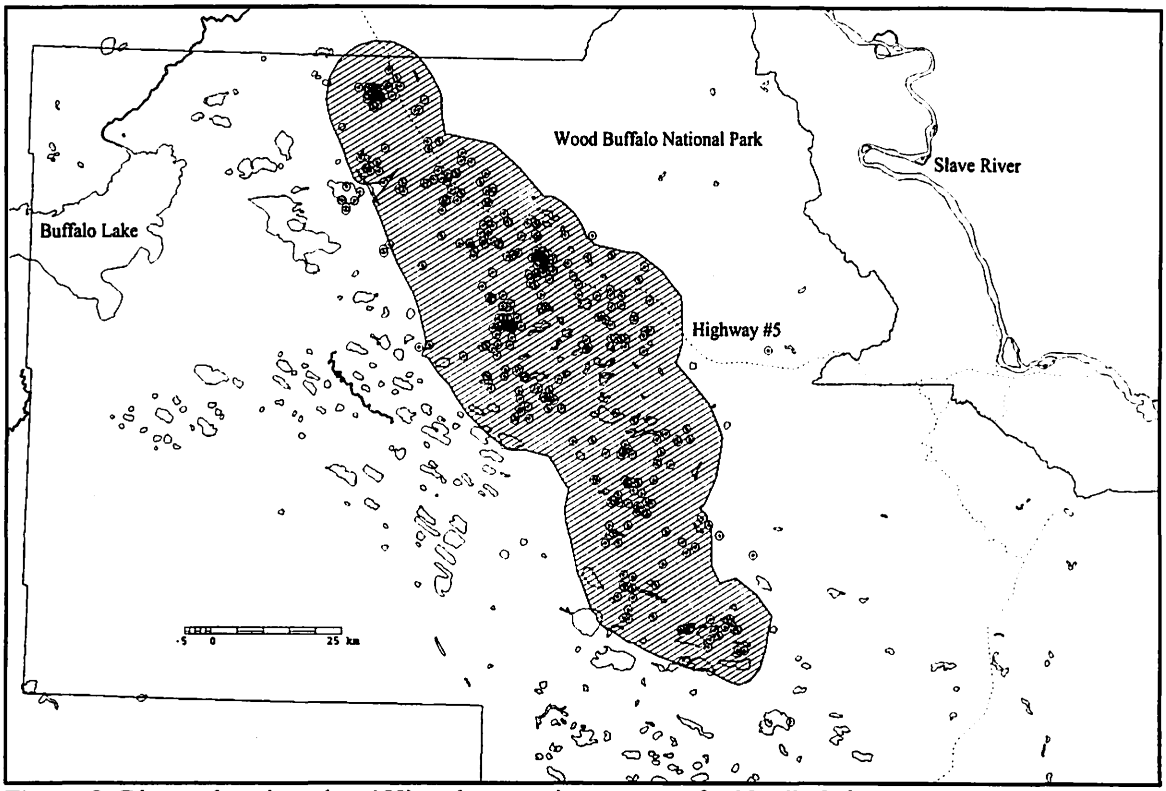

Figure 3: Bison relocations (n= 458) and composite core area for Needle Lake range.

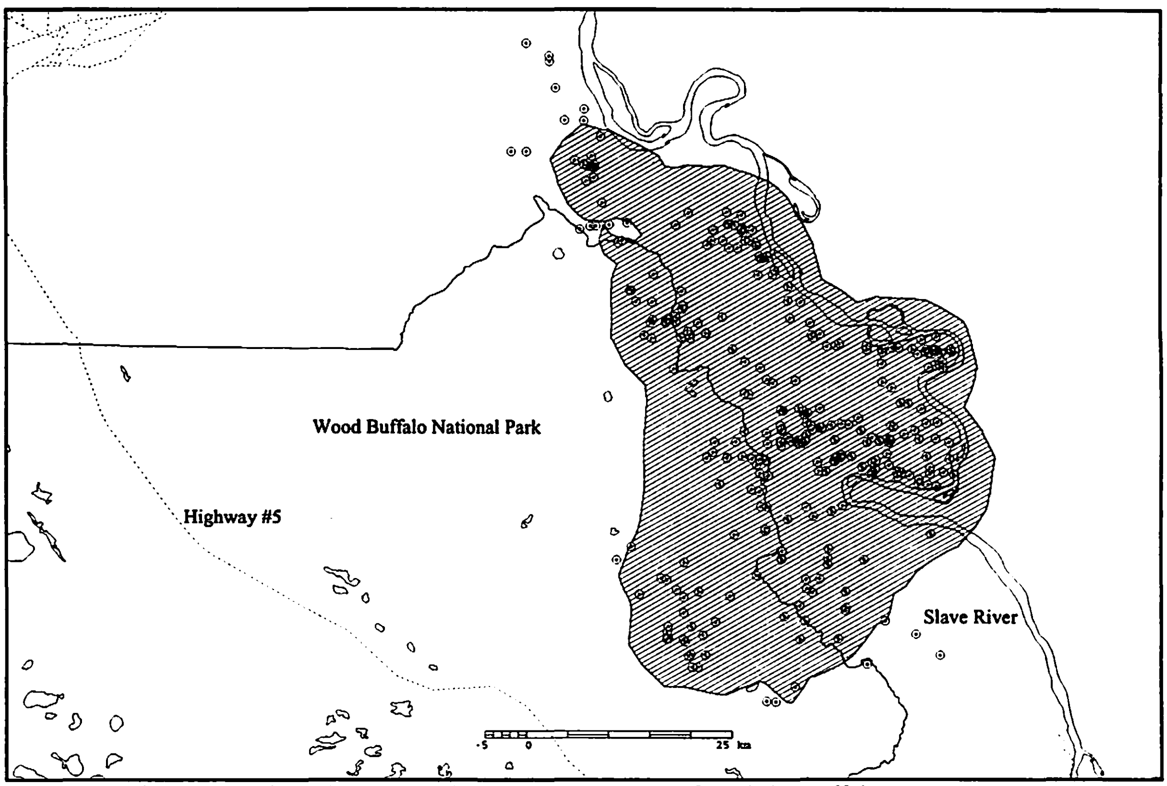

Figure 4: Bison relocations (n=322) and composite core area for Little Buffalo range.

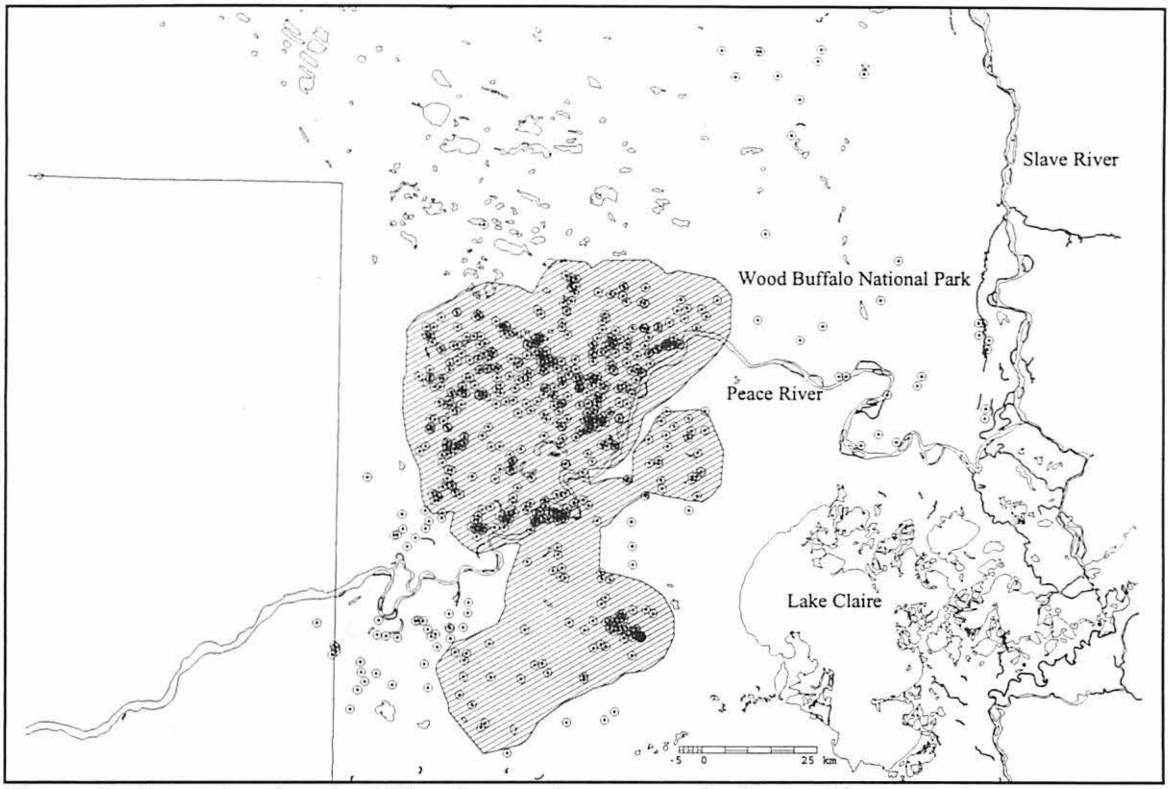

Figure 5: Bison relocations (n=702) and composite core area for Garden River range.

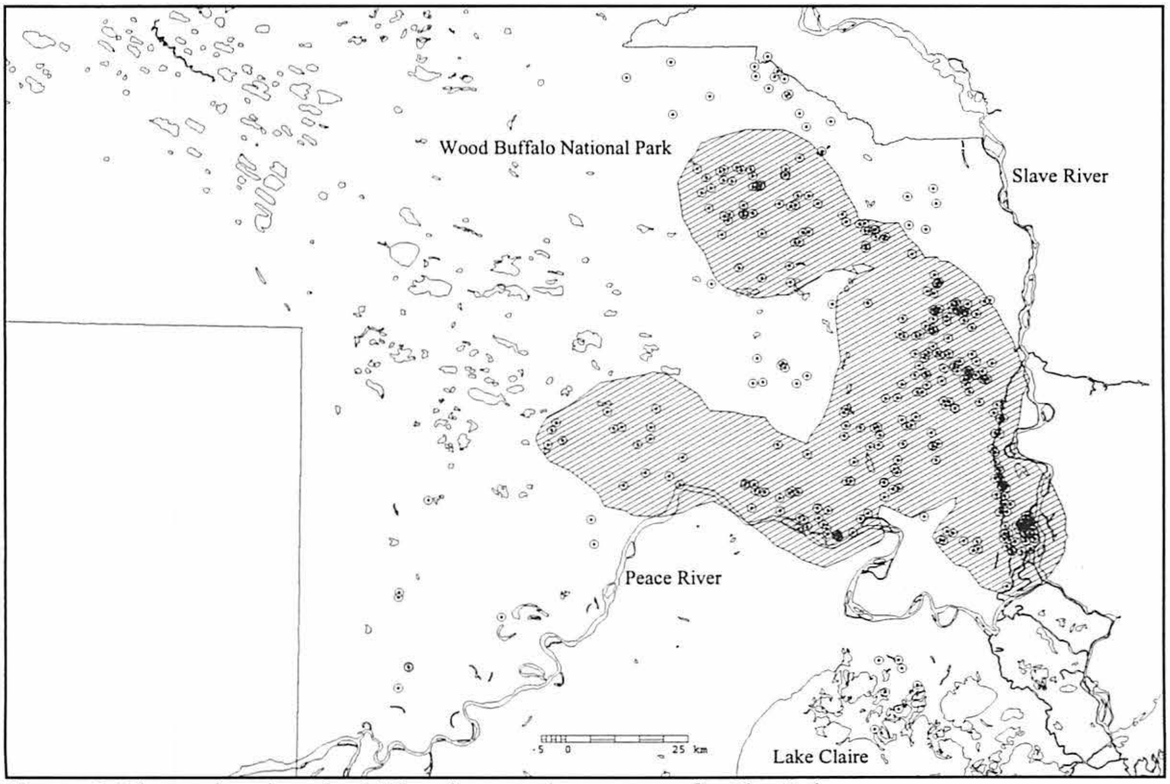

Figure 6: Bison relocations (n=347) and composite core area for Pine Lake range.

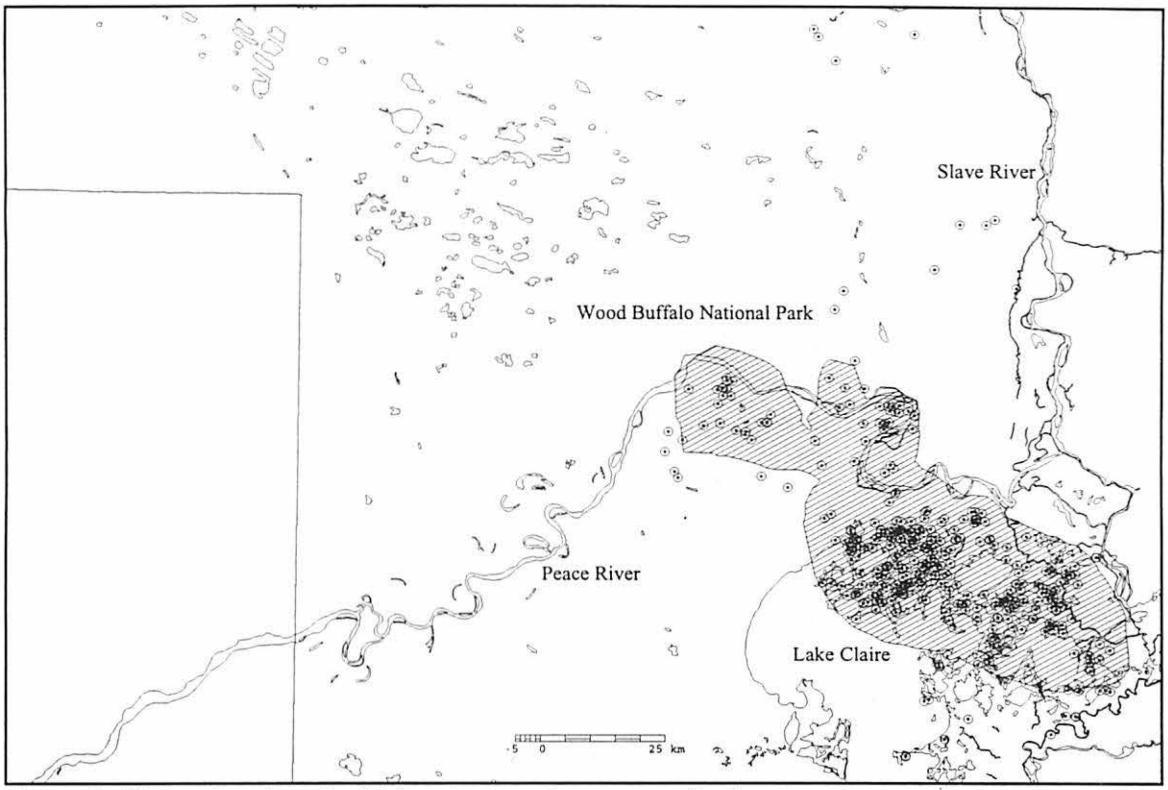

Figure 7: Bison relocations (n=347) and composite core area for Sweetgrass range.

Needle Lake (NL)

Fourteen bison (7♀, 7♂) were radio collared in the Needle Lake area, thirteen of which (7♀, 6♂) had movement patterns defined (Appendix 2). Cows typically summer in the northwestern portion of the range and winter in the southeastern area. A female, NL 82 (Figure 8), travelled a linear distance in excess of 80 km between typical summer and winter ranges. In contrast, Needle Lake bulls did not display extensive seasonal travel patterns (Figure 9). Their activity is generally centred between Sass and Needle Lake with occasional movements to the northwest or southeast. The composite core area for the Needle Lake bison, Figure 3, represents an overlaying of the core areas of the individual bison, not a statistical analysis of the range relocation data as a whole.

A large continuous stand of pine (approximately 225 km^2) to the east of Needle Lake has been a site of convergence for almost all the radio collared bison in June during each of the three years. This period is typically a time of post calving aggregations. During the rut in late July and early August, considerable bison activity was observed in the vicinity of Highway 5 and the Nyarling River.

Of the fourteen radio collared bison from this area none have moved outside this range and no collared bison from other ranges have been located in the area. There have been no observations of Needle Lake animals travelling outside the park.

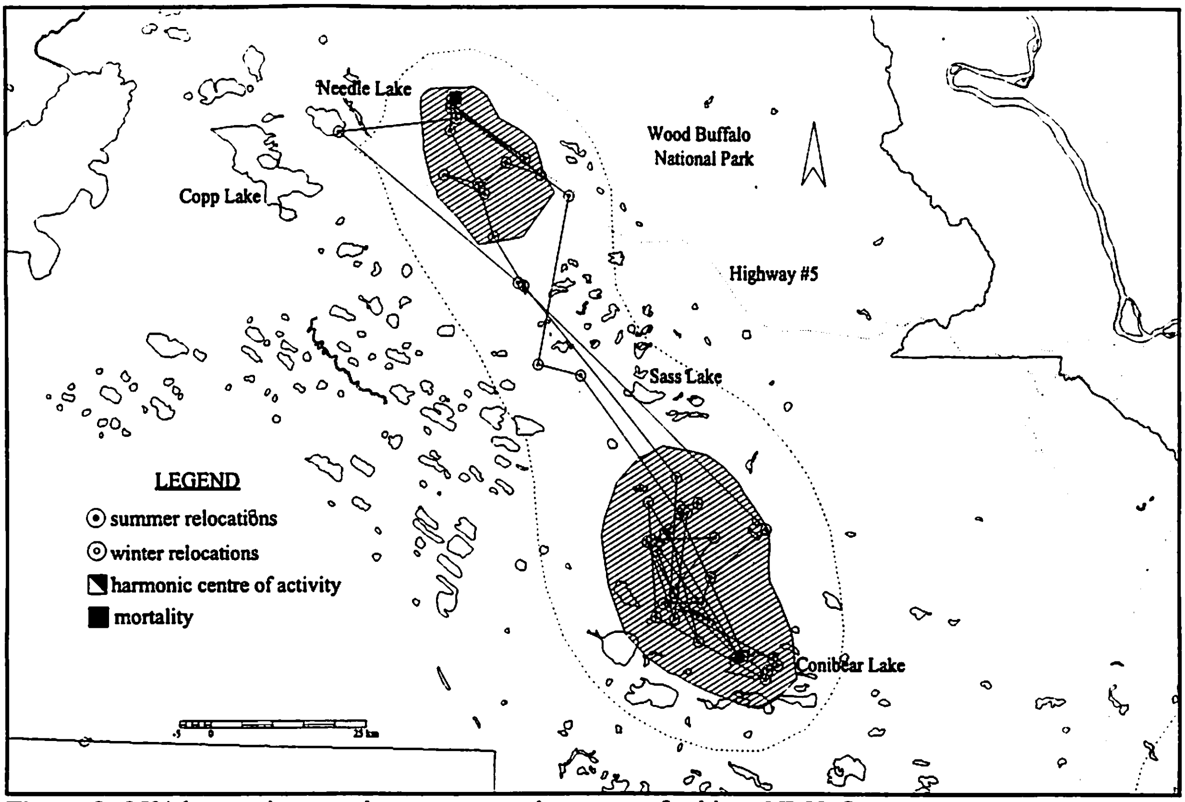

Figure 8: 95% harmonic mean home range and core area for bison NL82 ♀.

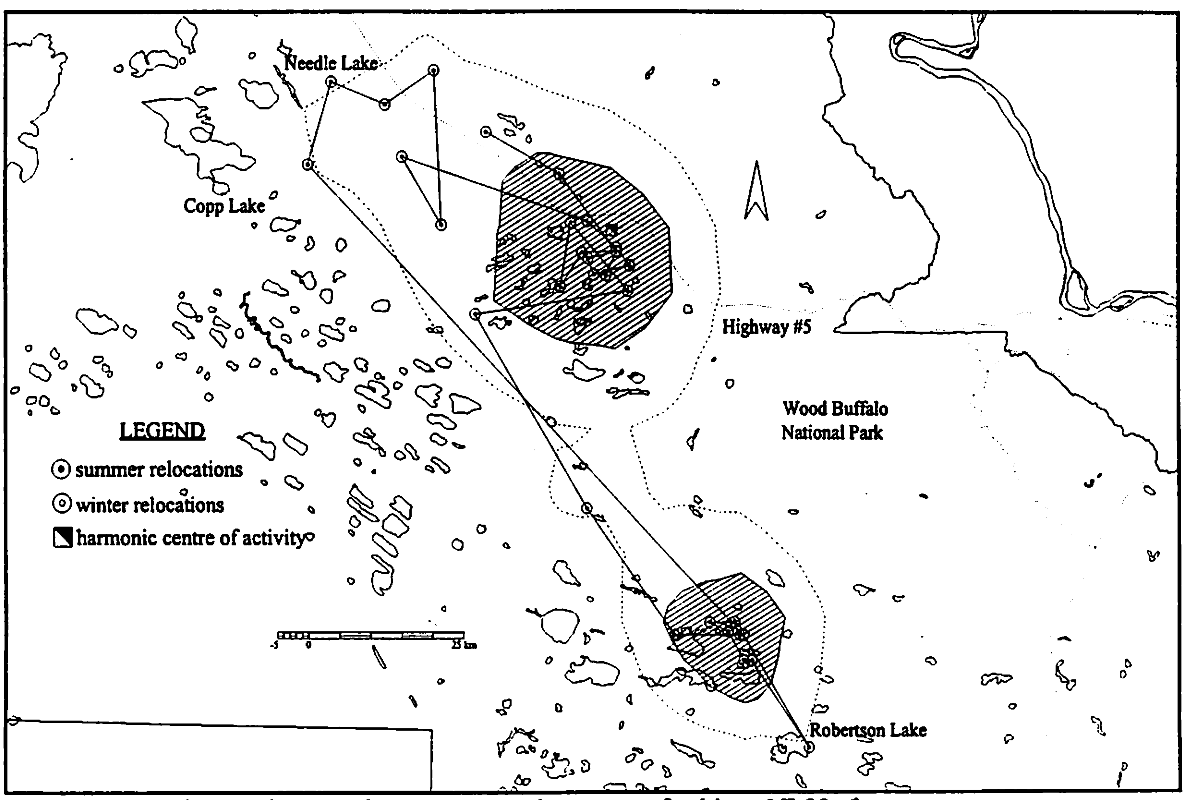

Figure 9: 95% harmonic mean home range and core area for bison NL89 ♂.

Little Buffalo (LB)

Twelve bison (4♀, 8♂) were radio collared in the Little Buffalo area, nine of which (4♀, 5♂) had movement patterns defined. The home range of the cow LB 40 (Figure 10), is typical of female bison in this range, in that they were frequently observed east of the Park, in the Grand Detour area, during the winter. In summer cows tend to travel along the Little Buffalo River and into the southwest corner of their range. Little Buffalo bulls, similar to LB 38 (Figure 11) spent a much greater time outside of the park. Bulls tended to utilize the northern and central portion of this range. Composite core area for bison in this range is shown in Figure 4. Relocation data for all the bison which had movement patterns defined is located in Appendix 2.

No distinct post-calving aggregation areas have been defined for this range, however some activity in relationship to this was noted in the south-western corner of the range. It occurred in an old 1950 burn bounded by muskeg to the north, south and west and currently vegetated with successional willow and aspen. Aggregations for the rut spread from this southwest corner into the Grand Detour area.

During the three year study no movement of radio collared bison out of this specific study area was observed. No collared bison from other ranges were located in this range. There was no observed movement by any bison in this area crossing the Slave River.

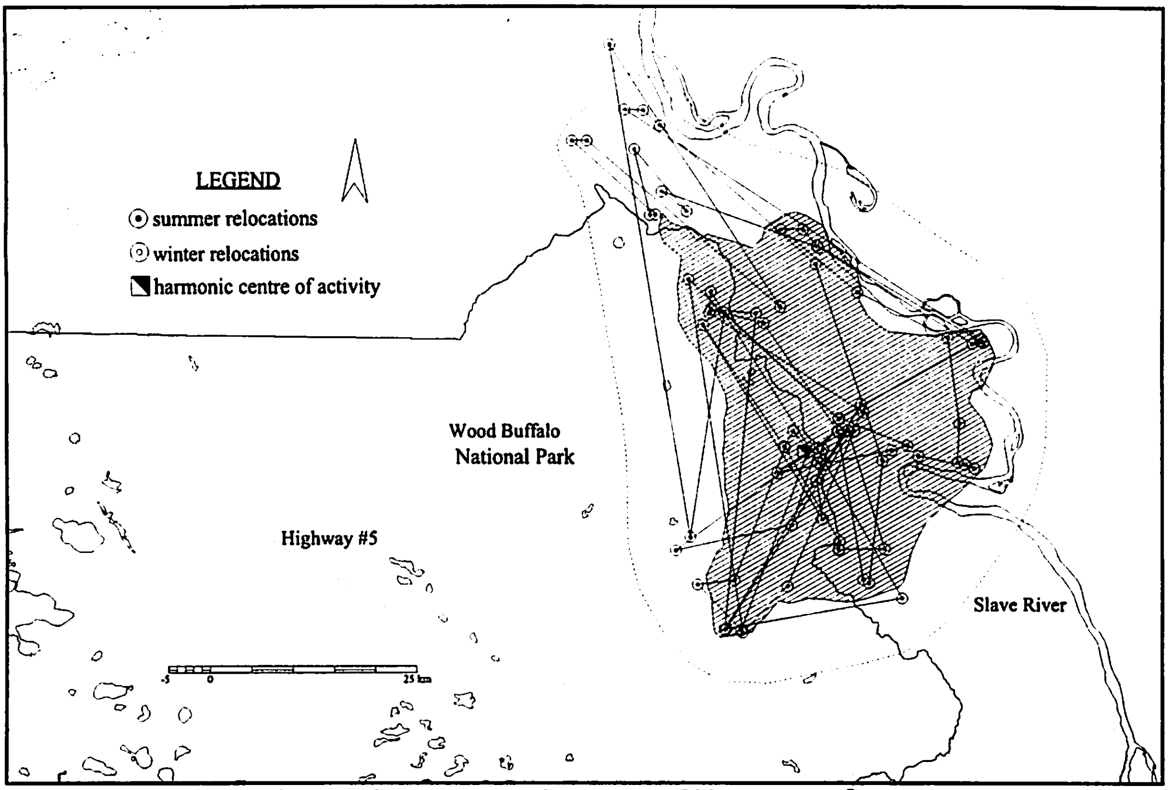

Figure 10: 95% harmonic mean home range and core area of bison LB40 ♀.

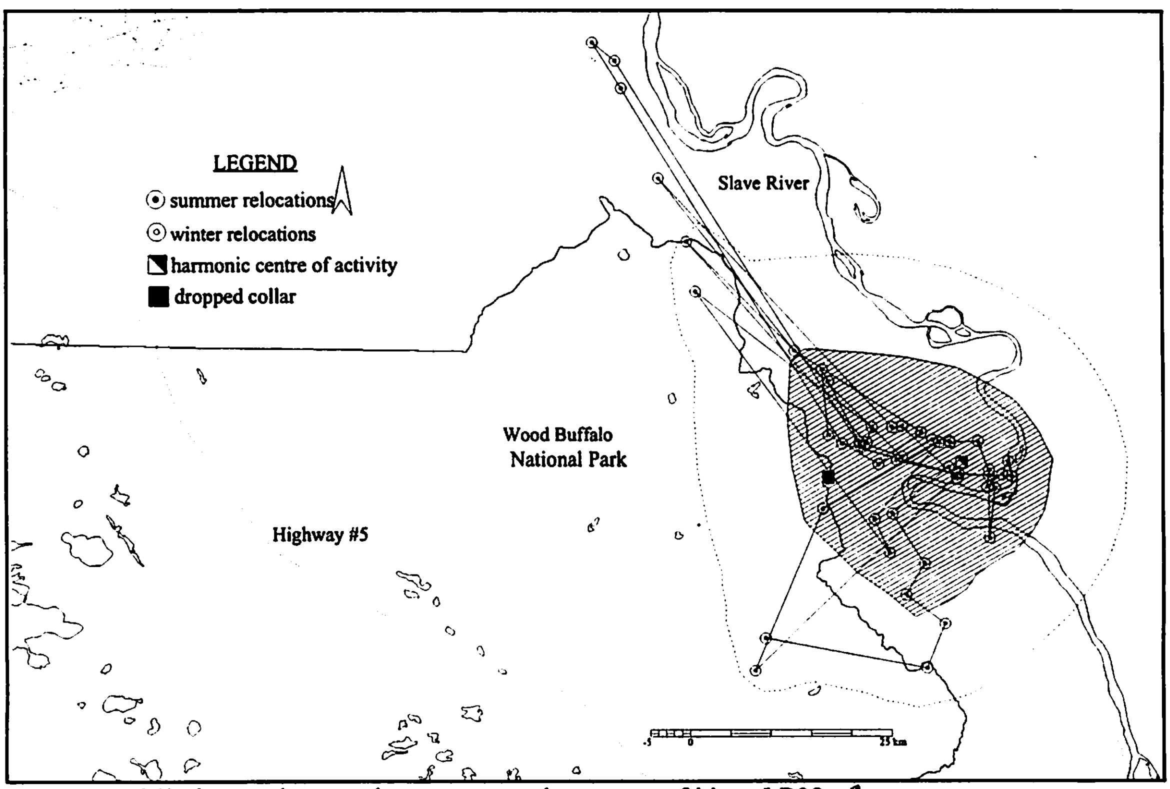

Figure 11: 95% harmonic mean home range and core area of bison LB38 ♂.

Garden River (GR)

Sixteen bison (7♀, 9♂) were radio collared in the Garden River area, fifteen (7♀, 8♂) of which had movement patterns defined. Their composite core area is shown in Figure 5. During the course of the study the one female and three males radio collared south of the Peace River were not observed north of it, nor were any of the 11 bison radio collared north of the river observed to the south (Appendix 2). Due to the limited number of bison radio collared south of the Peace River, distinct seasonal movement patterns have not been identified. The Brousseau Creek area, however, was noted as a site of activity during the rut for both bulls GR62 and GR78. Seasonal bison movements north of the river tended to be in an east-west pattern, with the concentration of animals in the eastern half of the range during summer moving westward with the onset of winter (Figures 12, 13).

During the three year study the Patenaude Lake hills were the site of some post-calving activity. These sand hills encompassing approximately 40 km^2 are anomalous to the core area due to their relief of 60+ meters above the surrounding landscape. Vegetation in the area is composed of grassy side hills and mature mixed and deciduous forests. While there was no clear region in which the rut took place the majority of relocations during July and August occurred between Patenaude and Davidson Lakes, commonly along the Jackfish and Beaver Indian Rivers.

Movement between the northern Garden River range bison and the Pine Lake bison was observed. One bull, GR22, was radio collared in August, 1990 in Garden River range; in September of 1990 it travelled to and wintered (1990/91) in the Hornaday River area of the Pine Lake range. Between May 12-28, 1991, it travelled 125 km back to the Garden River area. This movement was the longest observed movement within a 15 day relocation period. Two cows, PL46 and PL70, and two bulls, PL47 and PL68, originally radio collared in the Pine Lake area were located only once in that range (Appendix 2). All subsequent relocations occurred in the Garden River area.

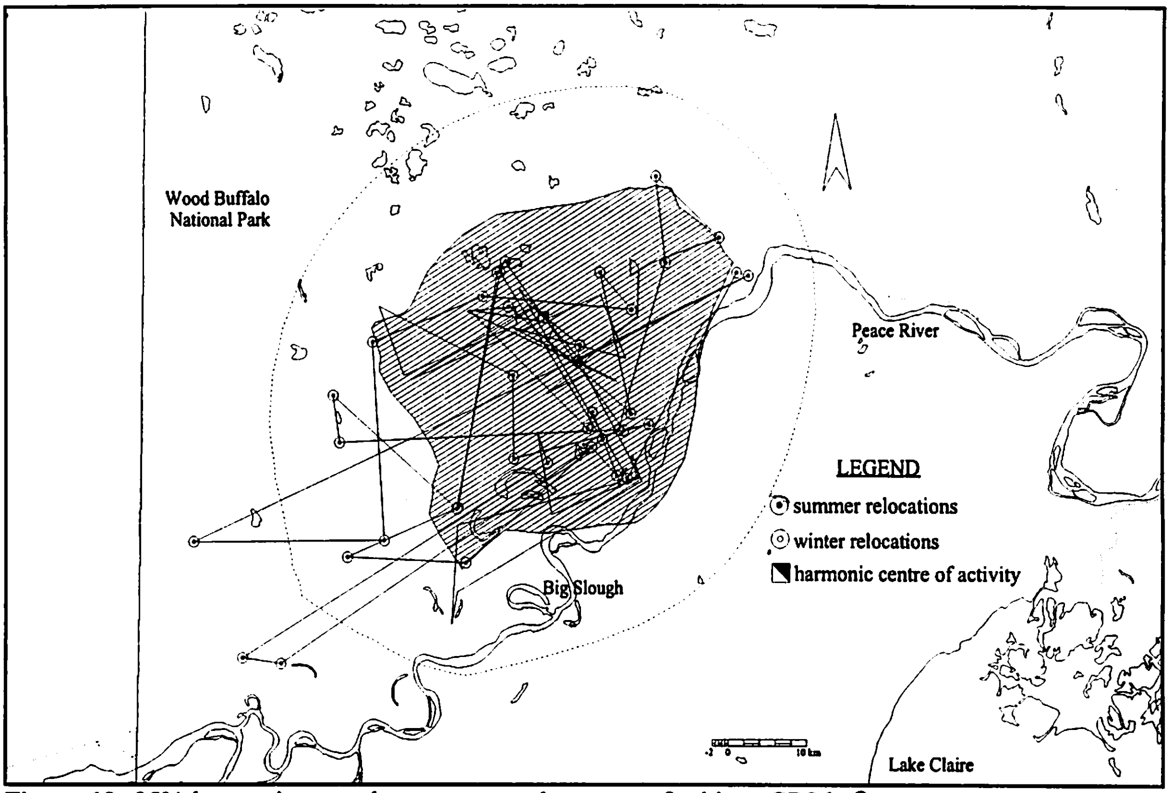

Figure 12: 95% harmonic mean home range and core area for bison GR26 ♀.

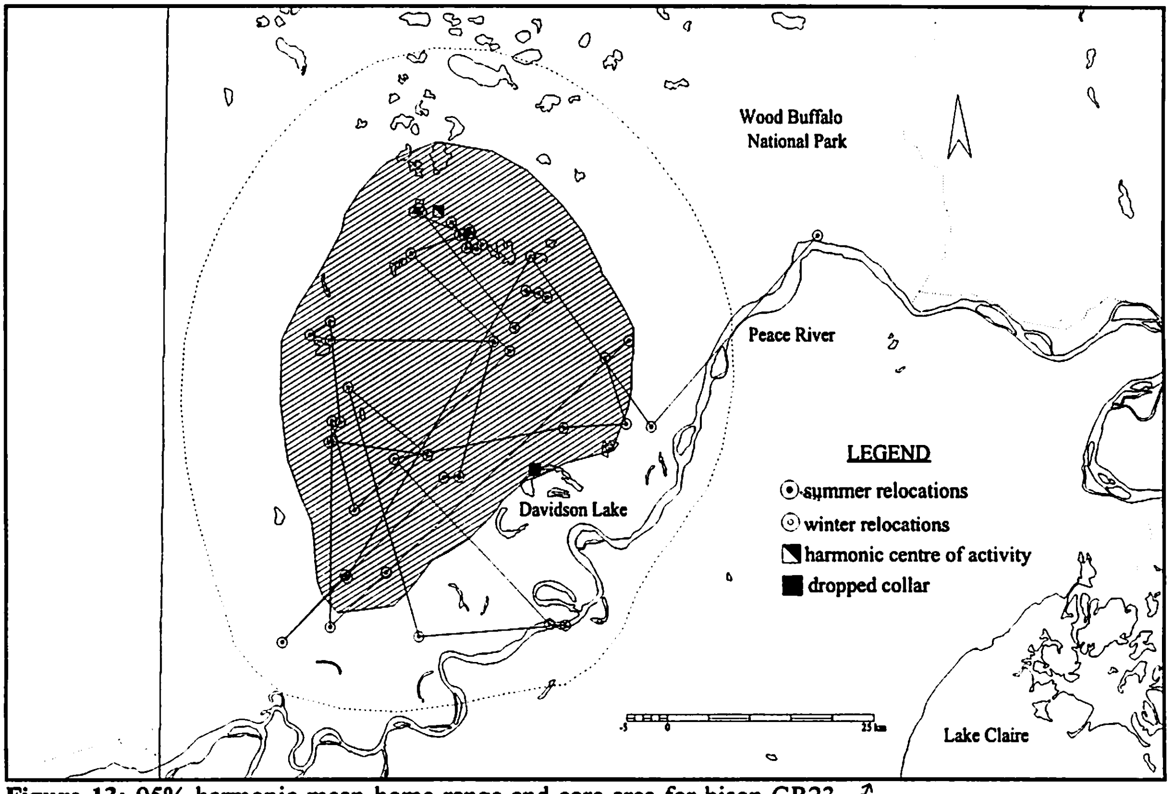

Figure 13: 95% harmonic mean home range and core area for bison GR23 ♂.

Pine Lake (PL)

Twenty-one bison (10♀, 11♂) were radio collared in the Pine Lake area. Eighteen (8♀, 10♂) had movement patterns defined, and a composite core area map was produced (Figure 6). In this region both cow and bull bison seasonal movements follow a north-south trend (summer-winter). Individual home ranges are located in Appendix 2. PL86 displays a common movement pattern for cows, occupying the Salt Plains/Parson Pine during the summer and wintering in the Point Providence area (Figure 14). PL31 is an example of male bison in this area; summering in the Pine and Raup Lake area, wintering to the southeast near Murdoch Creek (Figure 15).

The Parson Pine area of this range was noted as a distinct site for post-calving aggregations. This pine stand, approximately 600 km^2, is sparsely interspersed with small sedge meadows. From this pine collared bison were also observed entering the Salt Plains in herds up to 80 animals. The Parson Pine area (and to a lesser extent the Pine Lake road region) is also a site of the rut.

Movement of bison from the Pine Lake area into both Garden River and Sweetgrass ranges occurred. Movement into the Sweetgrass range was made by one female, PL 57. In August, 1990 PL57 was collared in the Parson Pines. Between September 8, 1990 and January 4, 1991 this bison travelled a minimum distance of 258 kilometres, eventually moving into the Sweetgrass range. On December 15, 1990 PL57 was observed with a herd of 80 bison in the Pine Lake area and with a similar sized herd on January 4, 1991 in the Sweetgrass range. This bison remained in the Sweetgrass area until September, 1992 when it again moved north across the Peace River. The home range for PL57 (95% HM, 5818.9 km^2) was the largest recorded during this study.

Similar movements occurred between bulls as well. Two males, SW92 and SW94, originally radio collared near Sweetgrass in August, 1992 separately moved north to winter in the Murdoch Creek area. During the summer of 1993, SW92 returned to the Sweetgrass area for the rut, while SW94 moved north to the Parson Pine. SW94 appeared to be heading south to the Murdoch Creek area when this study was concluded in late September.

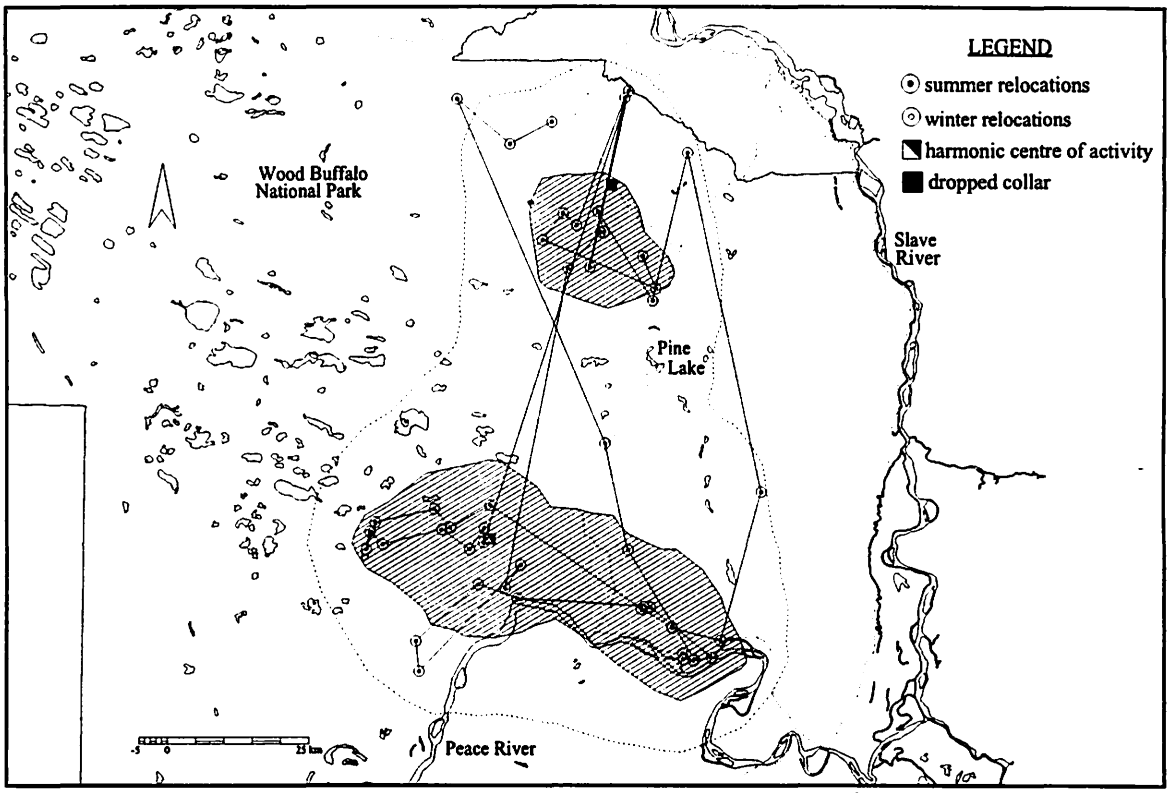

Figure 14: 95% harmonic mean home range and core area for bison PL86 ♀.

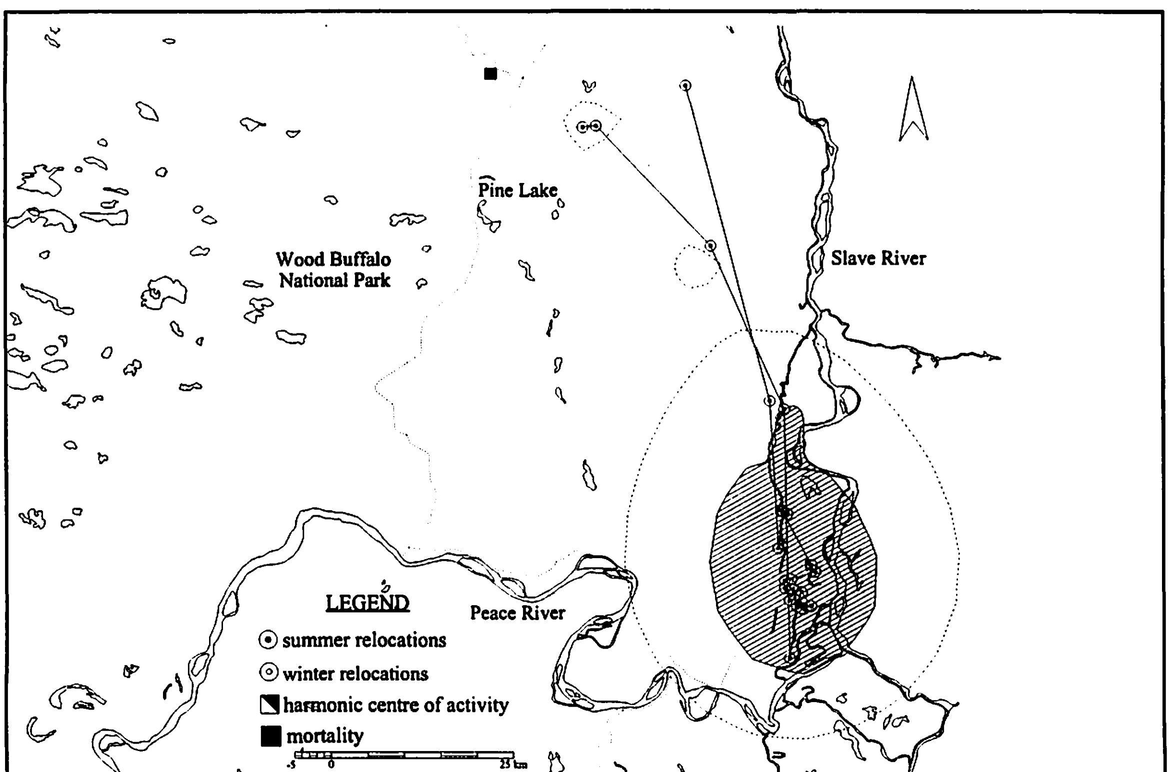

Figure 15: 95% harmonic mean home range and core area of bison PL31 ♂.

Sweetgrass (SW)

Twenty-six bison (10♀, 16♂) were radio collared in the Sweetgrass area, fifteen (8♀, 7♂) of which had movement patterns defined (Appendix 2). The composite core areas are presented in Figure 7. Cows typically spent the bulk of the summer in the Lousy Creek area and winters east of Baril Lake (Figure 16). Summer forays to the Lake One area occurred as well as winter movements south of Lake Mamawi. Male bison movements, with the exception of the transient behaviour of SW92 and SW94, were much more localized in the Lousy Creek and Baril Lake areas (Figure 17). Four bulls all spent close to a full year in the area. Their home range sizes varied from 290 to 566 km^2 representing the four smallest home ranges delineated over a one year period for this study.

The Lousy Creek area of this range is a distinctive post calving aggregation area. From annual segregation counts conducted in the area, 90% or more of the adult females inhabiting the Sweetgrass area are located within 250 km^2 of Lousy Creek. The rut also occurs primarily in this region.

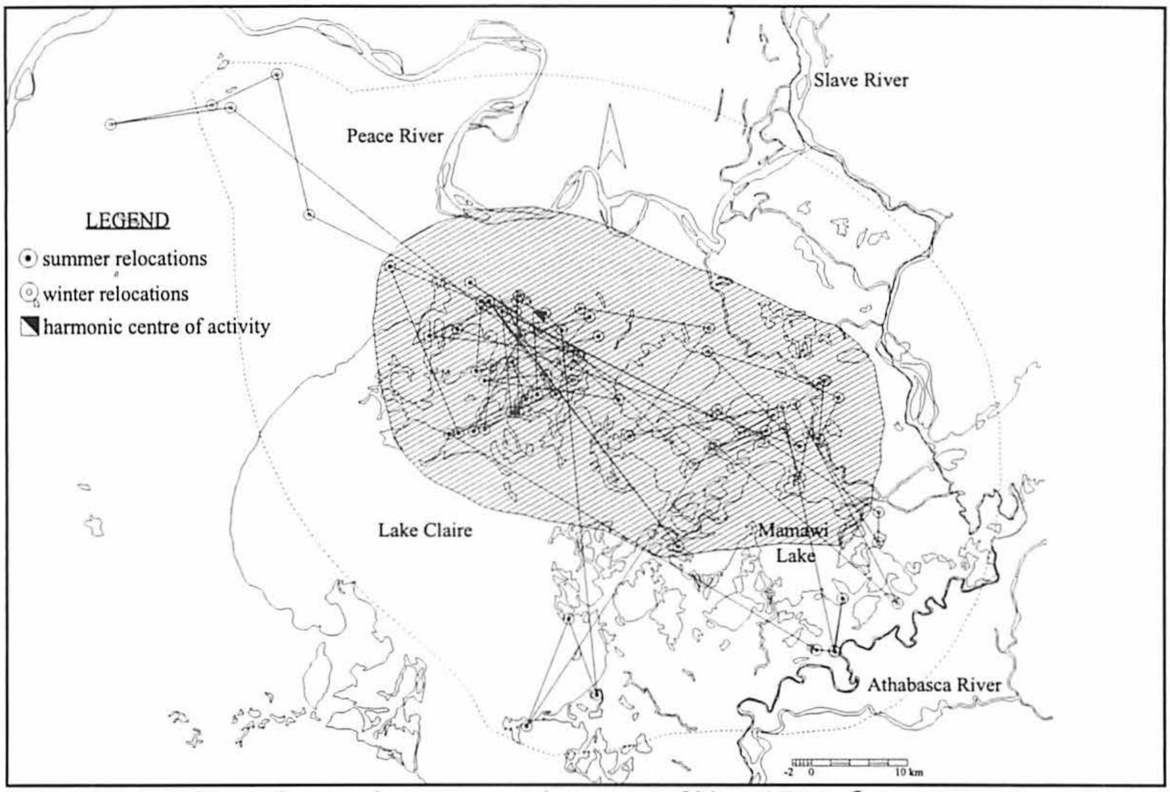

Figure 16: 95% harmonic mean home range and core area of bison SW09 ♀.

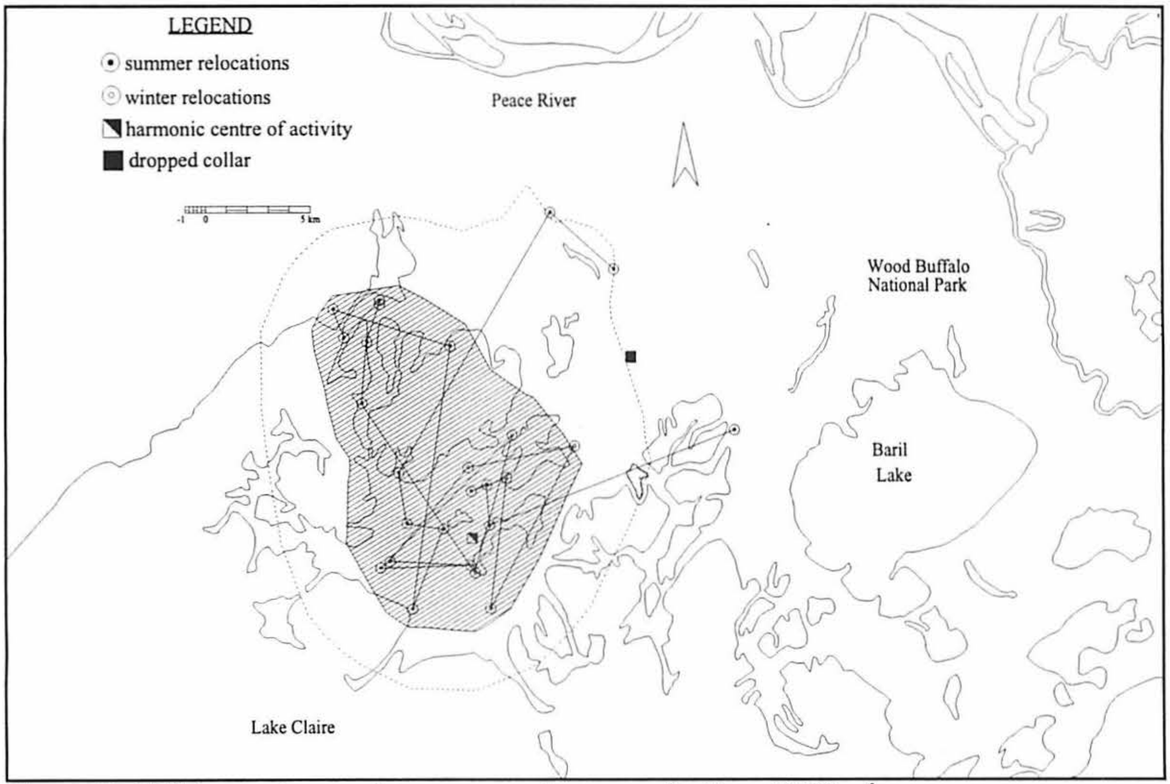

Figure 17: 95% harmonic mean home range and core area for bison SW93 ♂.

4.2.4 Transboundary Movements

Transboundary movements by park bison were observed in the Garden River, Pine Lake and Little Buffalo areas. The single transboundary movement in the Garden River range occurred when a bull, GR62, moved outside the southwestern park boundary sometime between December 16, 1990 and January 3, 1991. GR62 was relocated twice before moving back across the Park boundary on or before January 28, 1991. In August, 1992 GR62 could not be relocated, and radio failure was suspected (Figure 18).

Transboundary movements in the Pine Lake range involved two cows, PL29 and PL33. Both these cows were collared in the late summer/early fall of 1990, with only 6 and 7 respective relocations occurring before mortality. Both cows were shot by hunters in the winter of 1990 in the Mission Farms area adjacent to the Park. Mission Farms is the site of an old homestead which borders the Park along the Salt River and is vegetated with grass meadows. It is a common area of transboundary movement and a popular hunting area. Prior to the hunting mortality, one relocation of PL29 occurred outside the Park, while none of the PL33 relocations were outside the Park.

Transboundary movements in the Little Buffalo range occurred along the Little Buffalo River. These movements had previously been identified through numerous bison surveys conducted by both Park and GNWT staff, and were not unexpected (Canada 1990).

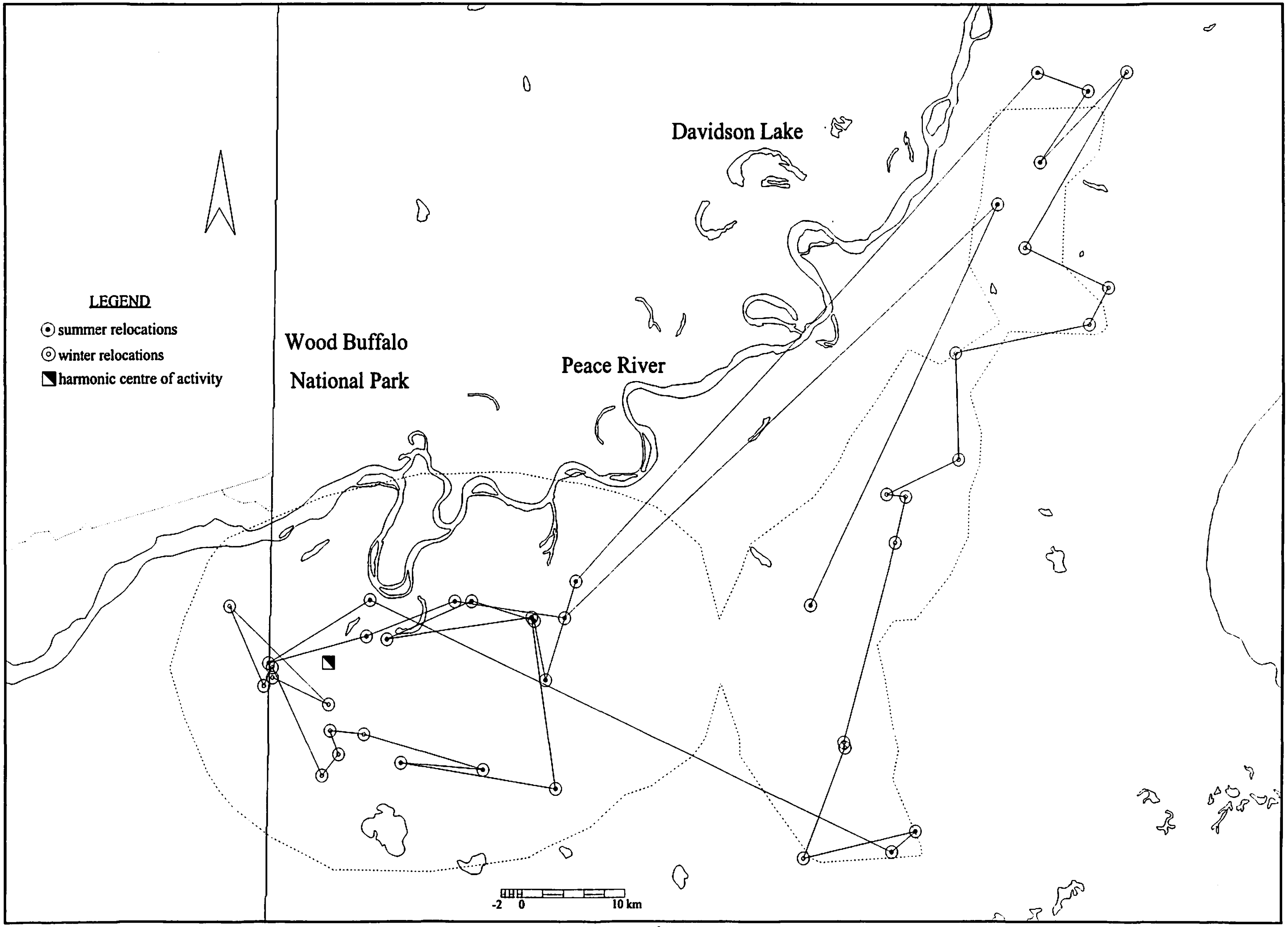

Figure 18: 95% harmonic mean home range and relocations for bison GR62 ♂.

4.2.5 Home Range Stability

Twenty-five (19♀, 6♂) bison were radio collared for at least two years and six (4♀, 2♂) bison for three years. The mean increase in the 100% MCP between the first and second years data was 21% for cows and 29% for bulls. Home range expansion from the second to the third year was 52% for the four females and 3.5% for the two males (Table 6).

Table 6. Annual increases in 100% MCP for all bison radio collared for 2 and 3 years.

Bison ID.	Fall, 1991			Fall, 1992		% Inc.	Fall, 1993		% Inc.
	Reloc	Area		Reloc	Area		Reloc	Area	
SW09 F	27	956		54	2239	132%	77	2889	29%
SW63 F	Active Summer 1991			31	1921		50	2255	17%
SW64 F	Active Summer 1991			31	1479		53	1706	15%
SW84 F	Active Summer 1991			31	2704		48	3199	18%
SW85 F	Active Summer 1991			30	1534		51	1640	7%
GR23 M	26	942		49	2053	62%	50	2053	0%
GR25 F	27	1140		54	1576	27%	65	3879	146%
GR26 F	25	1449		52	1711	6%	74	1921	12%
GR62 M	21	1702		42	3184	52%	Inactive Aug.,1992		
GR72 F	Active Summer 1991			31	1383		46	2086	51%
GR74 M	Active Summer 1991			31	820		50	843	3%
GR76 F	Active Summer 1991			31	1476		54	1674	13%
GR77 F	Active Summer 1991			31	1633		54	1644	1%

Bison ID.	Fall, 1991			Fall, 1992		% Inc.	Fall, 1993		% Inc.
	Reloc	Area		Reloc	Area		Reloc	Area	
GR79 F	Active Summer 1991			29	1640		50	1820	11%
PL57 F	28	5429		54	6277	9%	Inactive Jan. 1993		
PL70 F	Active Summer 1991			31	6113		53	7416	21%
PL71 F	Active Summer 1991			31	2017		52	2616	30%
PL83 F	Active Summer 1991			29	2761		52	3323	20%
PL86 F	Active Summer 1991			28	4732		51	5358	13%
NL67 M	Active Summer 1991			31	507		54	614	21%
NL82 F	Active Summer 1991			31	2049		47	2112	3%
NL90 F	Active Summer 1991			30	2492		53	2530	2%
LB37 F	27	1587		54	1738	5%	77	2108	21%
LB38 M	27	1071		48	1727	28%	Inactive Nov. 1992		
LB40 M	27	1767		54	1952	5%	76	2086	7%

Small increases in home range size typically occur with the addition of new data points outside, but in close proximity, to the previous year's contours such as with GR26 (Figure 19) and LB37 (Figure 20). Larger increases in home range size can result from a single long distance foray as occurred with PL71 (Figure 21). In this example, the majority of the 599 km^2 increase from one year to the next was the result of a single documented movement. PL70 (Figure 22) made long ranging movements in the first year it was radio collared thereby minimizing its home range increase the following year even though it completely shifted from one range to another. SW09 (Figure 23) also took a long foray, but remained in the new area for four subsequent relocations, thereby increasing it's home range by 1283 km^2, or 132% between years.

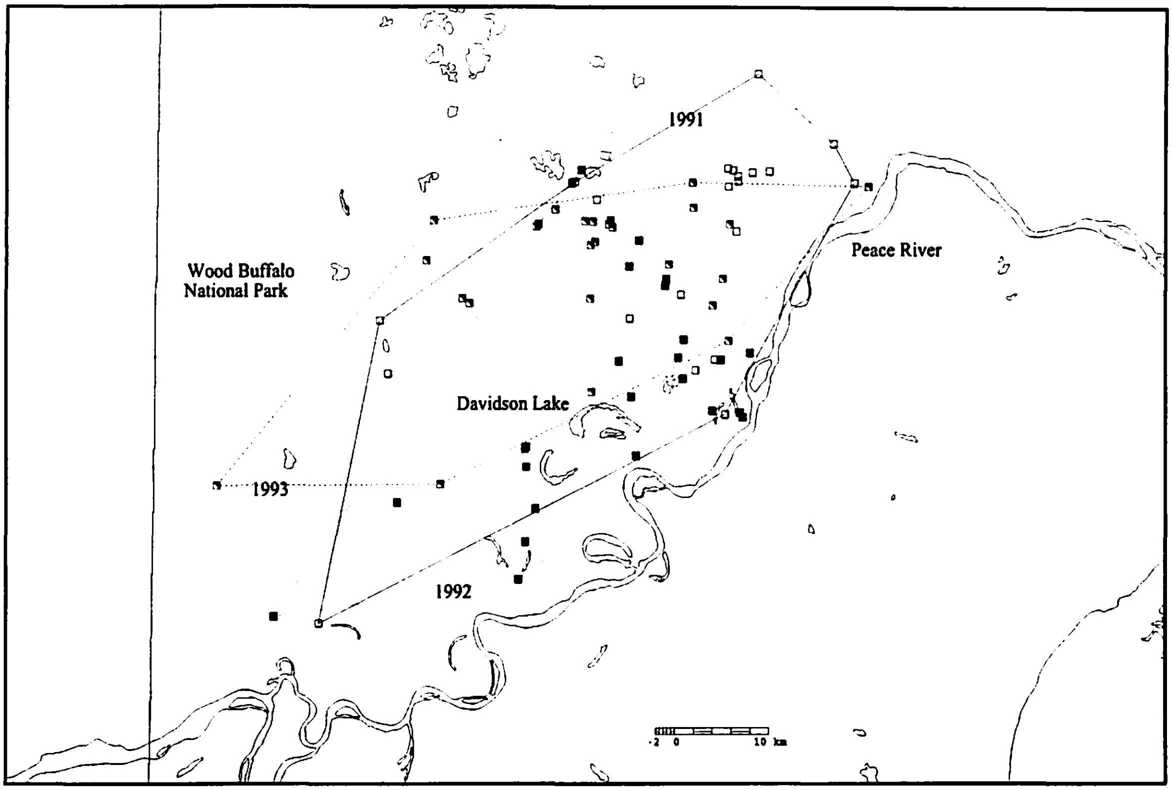

Figure 19: 100% MCP home ranges of bison GR26 (1991 to1993) ♀.

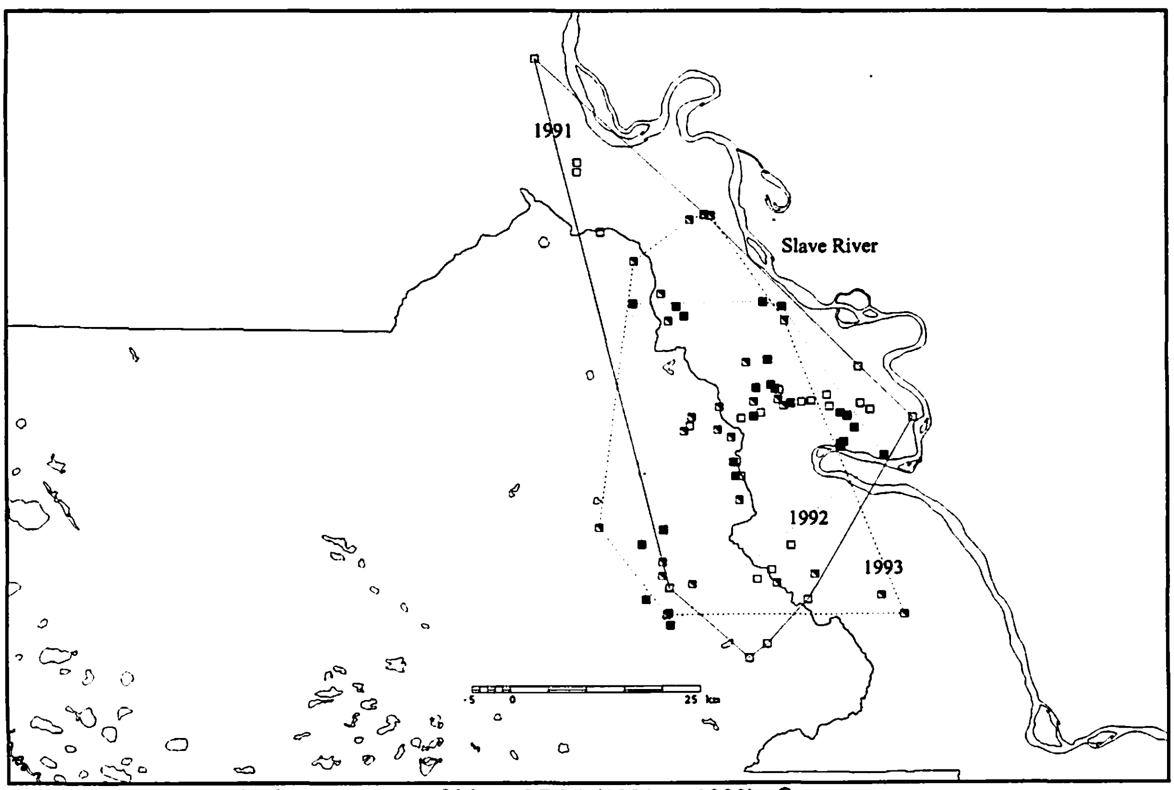

Figure 20: 100% MCP home ranges of bison LB37 (1991 to 1993) ♀.

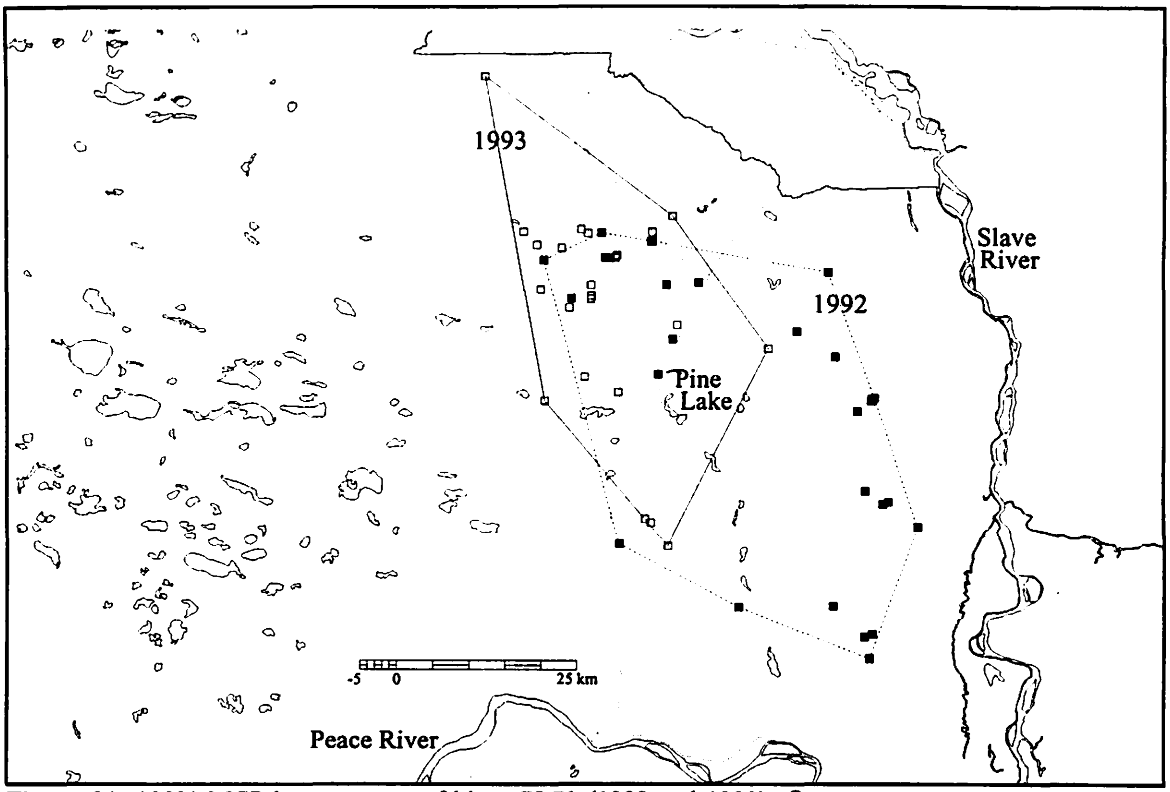

Figure 21: 100% MCP home ranges of bison PL71 (1992 and 1993) ♀.

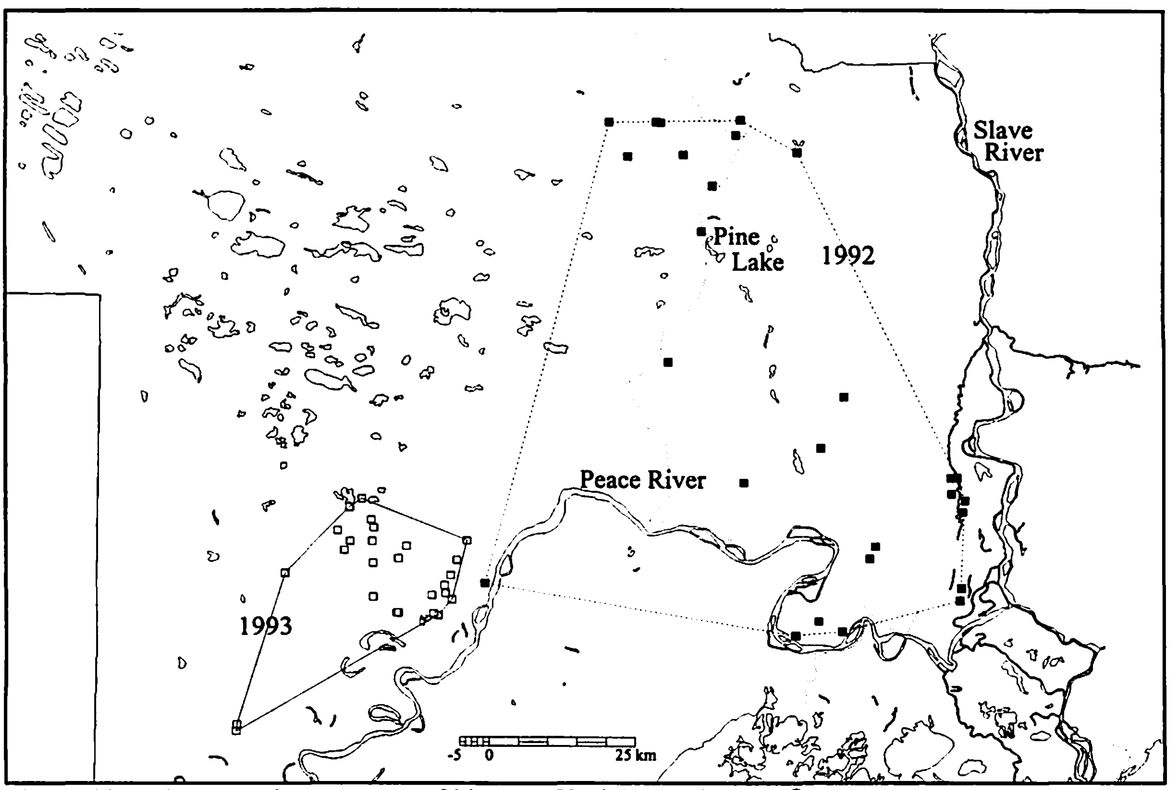

Figure 22: 100% MCP home ranges of bison PL70 (1992 and 1993) ♀.

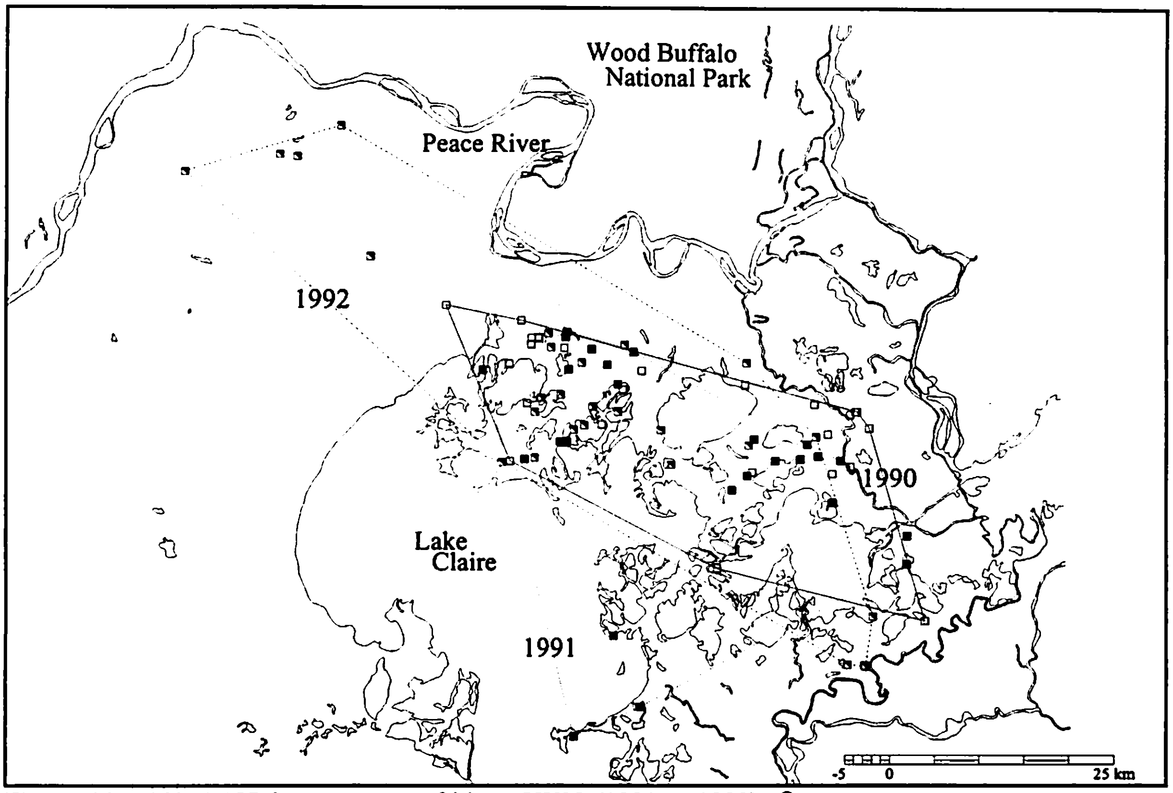

Figure 23: 100% MCP home ranges of bison SW09 (1991 to 1993) ♀.

In total three cows (PL46 to GR; PL57 to SW; PL70 to GR) and five bulls (GR22 to PL; PL47 to GR; PL68 to GR; SW92 to PL; SW94 to PL; and PL105 to GR) moved from one range to another.

Observed movements or forays outside the 95% harmonic mean core areas occurred more frequently for both sexes during the summer. Cows made 228 forays, 37% during winter and 63% in summer. There were 176 forays recorded for bulls, 16% in winter and 84% in summer.

4.3 Herd Sizes

During the three years of the study 1881 herds in association with collared bison (♀ 1074, ♂ 807) were counted. To satisfy requirements for data independence, a herd with more than one radio collared bison in it was counted only once. Sample sizes when analyzed monthly are small and should be interpreted with that proviso. Annual sample sizes are adequate. The mean monthly herd size for both females and males was largest in July and smallest in April. While the mean monthly herd sizes between areas varied, each area had similar trends in herd size fluctuations for sexes. On an annual basis the mean female herd size in Sweetgrass (x=86) was the largest, Garden River the smallest (x=20). Mean annual male herd sizes were largest in the Little Buffalo area (x=14) and smallest in Needle Lake (x=8) (Table 7).

Table 7. Mean annual herd sizes in the five ranges in WBNP.

RANGE	FEMALES			MALES		
	Number of Measurements	MEAN	SD	Number of Measurements	MEAN	SD
Sweetgrass	234	86	81.1	96	11	29.5
Garden River	264	20	16.5	188	9	13.4
Pine Lake	237	33	34.7	218	10	21.9
Little Buffalo	173	39	34.6	127	14	22.9
Needle Lake	159	24	21.4	183	8	17.5

Radio collared bison were observed in association with at least one other radio collared animal on 275 occasions (2 together=196; 3=53; 4=20; 5=2; 6=2; 7=2). The longest any two radio collared bison were observed together was for four consecutive relocations (approximately two months). Three radio collared bison maintained the longest association for two consecutive relocations. There were no consecutive relocations of four or more of the same radio collared bison in the same herd.

4.4 Mortality Factors

Ten radio collared bison (4♂, 6♀) mortalities were recorded during the study (Table 8). These deaths are in addition to the previously mentioned 9 deaths associated with the collaring exercise. Suspected causes of death were: 4 predated by wolves, 3 of anthrax, 2 were killed by hunters and one had an unknown cause of death, possibly the result of a vehicle collision. This is suspected as it was found dead just inside the forest along Highway 5 with some fragments of broken glass nearby. While these are the suspected causes of death, little or no information was available regarding other contributing factors such as nutritional status, injuries, parasites, or other diseases. The overall survival rate estimate for radio collared bison during the period from September 1, 1990 to September 25, 1993 was calculated to be 0.66 (0.51 - .80 CI).

Table 8. Suspected causes and locations of radio collared bison mortalities from September 1, 1990 to September 25, 1993.

Bison ID No.	Date of Death	Sex	Cause	Area Location	Brucellosis
GR 21	Sept. 14, 1990	Male	Wolf pred.	Garden River	negative
PL 29	Dec. 6, 1990	Female	Hunt	Fox Holes	positive
PL 33	Dec. 15, 1990	Female	Hunt	Mission Farms	positive
SW 07	Feb. 10, 1991	Female	Wolf pred.	Sweetgrass	positive
PL 31	July 21, 1991	Male	Anthrax	Parsons Road	negative
PL 45	July 21, 1991	Male	Anthrax	Parsons Road	positive
PL 50	July 21, 1991	Male	Anthrax	Parsons Road	negative
PL 46	Mar. 15, 1992	Female	Wolf pred.	Peace Point	positive
NL 82	July 16, 1993	Female	Unknown	Needle Lake	negative
NL 102	Sept. 25, 1993	Female	Wolf pred.	Needle Lake	positive

Only two incidents of predatory activity towards bison were observed during this study. The first incident occurred in the Garden River area on March 3, 1993 when ten wolves were observed, from the air, pursuing a herd of 60 bison. Two radio collared cow bison (GR25 and GR76) were located in the herd. The interaction was observed for 10 minutes in which time the bison, running together in single file travelled approximately 2 to 3 km through snow (approximately 50 cm deep). The wolves were spread out on the bison trail approximately 0.25 km behind the bison. While under observation three different wolves took up the forward position in the pack. Due to fuel constraints observations were interrupted for 20 minutes. When observations were reinstated the wolves were approximately 1.5 km behind the bison and appeared to be giving up the chase. The bison were still running but at a reduced rate of speed. The total distance travelled was 8 km north of their original position.

The second aggressive interaction was observed from the air along the western edge of Baril Lake in the Sweetgrass area on August 12, 1993. Two wolves were observed circling a female bison which had it's head down and appeared to be attempting to repel them. The wolves and bison were near the middle of a herd containing 280 bison, two of which were radio collared females. After approximately 5 minutes of observation the wolves moved away from the cow and laid down. The herd moved off to the north.

5.0 DISCUSSION

5.1 Bison Characteristics and Handling

The suspected problem with renarcotization of the bison originally receiving naloxone as an antagonist was satisfactorily overcome. Naloxone was originally chosen as the reversal agent as the only known published material (Kock and Berger 1987) on free-ranging bison immobilization reported good success using the combination of xylazine, carfentanil and naloxone. The initial dosage of carfentanil (2.4 ± 0.7/kg of bison) in that study was substantially lower than the amount used in our study. Our initial dosages of carfentanil were higher so as to immobilize the bison rapidly and prevent their escape into the forest. This may have succeeded as for all the bison immobilized, only 10% required a second injection. Kock and Berger (1987) had to administer a second dosage 20% (5 of 25 immobilizations) of the time. To compensate for our high dosage of carfentanil, the amount of naloxone administered (498 mg/bison) was also substantially higher than that used by Kock and Berger (1987) (mean = 174 mg/bison). This compensation did not appear to overcome the relatively short active life of naloxone. Once the switch was made to naltrexone, a longer acting antagonist, there were no unexplained mortalities associated with the immobilization process.

On several occasions, male bison were seen to apparently guard a sedated animal. This occurred in two ways. The first involved the darting of an apparent lone bull. Once the bull was down, a second bull sometimes appeared and was observed attempting to lift the sedated animal with it's head. This behaviour was presumed to be an attempt to get the sedated animal back on it's feet.

With herds, bulls tended to stand in close proximity to a sedated cow in an apparent guarding posture. This actually assisted in locating downed animals in the field. The apparent guarding behaviour was limited to standing in close proximity, as no attempts at lifting were observed. In all cases, members of the immobilizing team were able to chase the bull away, although in some instances the opportunity was used to immobilize the bull.

5.2 Bison Movements and Home Range

5.2.1 Home Range

Home range estimates of female bison in Wood Buffalo National Park are three times as large as those of female bison in the Mackenzie Bison Sanctuary while home range estimates of males are at least twice as large. Minimum convex polygons were used for comparative purposes with other studies of bison home range size as this is the only consistent estimator between studies. From data collected in the Mackenzie Bison Sanctuary, the mean 100% MCP female home range is 851 km^2 and the mean male home range is 432 sq. km^2 (Larter 1988). In Wood Buffalo National Park, average home range size was calculated at 2702 km^2 for females and 1096 km^2 for males.

5.2.2 Composite Core Areas and Movement Patterns

This study has demonstrated that some overlap and mixing of bison from the various areas occurs (Figure 2). This is further shown by bison initially radio collared in one area which subsequently moved and remained in another. If the home ranges of these bison were portrayed as if they were still members of the original area, the amount of overlap would be greatly increased. Although no radio collared Needle Lake bison were observed to enter any of the other ranges or vice versa, relocations of Needle Lake bison and animals collared in the other areas were in relatively close proximity. Spatially, although not temporally, a Needle Lake relocation was within 15 km of a Garden River relocation, 17 km from a Little Buffalo relocation and 20 km from a Pine Lake relocation.

A bison survey map prepared by J.D. Soper in 1932 (Soper 1934) clearly shows continuity of bison presence between Pine Lake and Conibear Lake. Similarly, a survey conducted by W. Fuller in 1949 (Fuller 1950) also reveals a near continuous presence of bison between these two locations. Bison total counts in Wood Buffalo National Park between 1975 and 1989 have also identified bison herds in the areas between Conibear Lake and the Garden River and Pine Lake ranges. The relatively large home ranges of Wood Buffalo National Park bison further supports the theory that considerable intermixing occurs among the groups.

Based on the results provided from this study, observed calving and rutting behaviour, and other researcher's findings (Carbyn et al. 1992; Larter 1988) bison behaviour and movement patterns can be categorized into fairly distinct time periods. Those time periods being: late winter (Jan. 1 - March 31), calving (April 1 to June 15), pre-rut/post calving (June 15 to Aug. 1), rut (Aug 1 to Aug. 31), post-rut (Sept. 1 to Sept. 15) and early winter (Oct. 1 to December 31). When bison movements determined by this study are examined, some patterns emerge. Mobility is lowest during the late winter, and increases to the highest point for both males and females during the calving period. Pre-rut/post-calving also has high mobility, and especially for males the rut has high mobility. During post-rut mobility remains high, and falls off during early winter. Further study is warranted to determine the reasons for these mobility patterns.

5.2.3 Transboundary Movements

Movement by radio collared bison across the Park boundary occurred in three instances (excluding the Little Buffalo range). None of the instances involved long distance forays or lengthy absences from the Park, however since the 2 Pine Lake animals were shot it is not possible to determine what movement patterns they would have followed. The Garden River bison re-entered the Park within 6 weeks of leaving.

The location of the Needle Lake group in relation to the Mackenzie Bison Sanctuary has been identified as a concern to the well-being of the sanctuary herd (Canada 1990). The fact that no transboundary movements by radio collared bison were observed in that area during the study suggests that there is very little if any movement by bison from within the Park towards the sanctuary. The study was not designed to address the possibility of bison from the sanctuary moving into the Park, and then returning to the sanctuary. Further study is required in this area.

5.3 Herd Sizes

As mentioned in Section 4.0, sample sizes for herd size analysis are too small for statistical analysis purposes. When considered in the context of the time periods identified in 5.2.2, some patterns appear to develop. Herd sizes are greatest during the post calving period, and are smallest during the winter. This is consistent with general findings of other researchers (Carbyn et al. 1993; Larter 1988).

5.4 Mortality Factors

With all forms of mortality considered, a bison radio collared in September, 1990 had a 34% (± 14%) chance of dying by September, 1993. Without anthrax and hunting mortalities that chance decreased to 17% (± 14%), or 5.7% per year. The estimated annual adult mortality in the MBS is 5% (Gates, pers. comm. 1992).

During this study there were 67 (mean = 22/year) confirmed hunting mortalities in the Mission Farms area of the Pine Lake range. During the study period the mean population (1990, 1991 and 1992 total count results) in the Pine Lake range was 664 bison. The mean annual hunting mortality was therefore 3.3%. The Pine Lake range was also the sight of an anthrax outbreak in July and August of 1991, with 32 confirmed deaths. The outbreak occurred between Raup Lake and the Salt Plains, an identified post-calving and rutting area for the range.

The effects of these anthrax and hunting mortalities in the Pine Lake range was partially reflected in a population decline of 486 bison between 1990 (n = 871) and 1992 (n = 385). The effects of emigration and immigration is not known. However, there was a decrease of 266 bison (1710 to 1444) in the Sweetgrass range and an increase of 144 (316 to 460) in the Garden River range during the same time period.

6.0 CONCLUSION

Several conclusions are reached based on the results of this study. Firstly, it is concluded that while bison in the Park can be found in groupings that have persisted temporally and spatially, these groupings are not so isolated as to be considered sub-populations. Sufficient mixing of the groups has been demonstrated that for management purposes bison within the Park should be managed as a whole. Identification of groupings assists in focussing management efforts, but groupings are clearly transitory.

Secondly, home range sizes for Park bison are significantly larger than those determined for the Mackenzie Bison Sanctuary. Further study is required to explore reasons for and implications of this difference.

Thirdly, the study did not demonstrate a high degree of transboundary (out of park) movement by bison. This has to be interpreted with caution. Since bison were primarily collared within the Park, this study is only able to provide supporting evidence to a theory that Park bison do not range large distances beyond the Park boundary.

7.0 REFERENCES

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8.0 APPENDICES

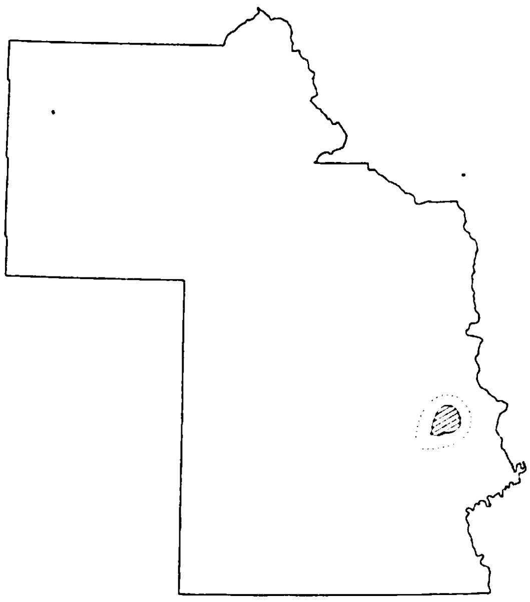
Appendix 1 - Relocation data summary sheets.

Bison	Sex	Number of Locations as of 25SEP93			Start Date	End Date	Mean Location Interval (days)	Fate	95% Harmonic Mean Home Range			Harmonic Mean Core Area			95% MCP Home Range (km2)	Mean Distance Between Consecutive Locations (km)
		ALL	Spr Sum	Fall Wint					Size (km2)	% in Park	% out of Park	Size (km2)	% in Park	% out of Park		
PL70	F	53	28	25	08AUG91	24SEP93	14.9		5731.7	99.4	0.6	884.1	100.0	0.0	6356.5	15.0
PL71	F	52	30	22	08AUG91	24SEP93	15.2		3594.8	100.0	0.0	1161.0	100.0	0.0	2202.9	13.4
GR72	F	45	20	25	14AUG91	12MAY93	14.5	DROP	2629.9	100.0	0.0	1153.5	100.0	0.0	1739.4	11.3
GR73	M	40	17	23	14AUG91	03MAR93	14.5	DROP	1472.1	100.0	0.0	n/a	100.0	0.0	826.8	11.1
GR74	M	49	24	25	14AUG91	15JUL93	14.6	DROP	1708.2	100.0	0.0	421.1	100.0	0.0	647.7	7.4
GR76	F	54	29	25	14AUG91	24SEP93	14.5		1948.7	100.0	0.0	878.1	100.0	0.0	1509.6	14.9
GR77	F	54	29	25	14AUG91	24SEP93	14.5		2305.0	100.0	0.0	773.8	100.0	0.0	908.6	10.5
GR78	M	25	13	12	14AUG91	20AUG93	14.9	WOLF	944.5	100.0	0.0	323.2	100.0	0.0	1141.6	8.1
GR79	F	50	25	25	20AUG91	24SEP93	15.6		2402.3	100.0	0.0	821.2	100.0	0.0	1580.6	12.7
NL80	M	43	18	25	09AUG91	15APR93	14.6	DROP	3954.2	100.0	0.0	1412.0	100.0	0.0	1316.7	11.0
NL82	F	46	21	25	08AUG91	15JUN93	15.0	ROAD?	3728.7	100.0	0.0	1176.2	100.0	0.0	1571.0	13.9
PL83	F	52	27	25	21AUG91	24SEP93	15.0		5997.6	91.0	9.0	2264.3	99.6	0.4	2872.4	16.0
SW84	F	47	22	25	08AUG91	24SEP93	14.7	DROP	3232.0	100.0	0.0	1315.8	100.0	0.0	2233.3	11.8
SW85	F	50	26	24	08AUG91	25SEP93	15.8		2147.2	100.0	0.0	921.1	100.0	0.0	1482.9	10.9
PL86	F	49	24	25	21AUG92	27AUG93	15.3	DROP	6536.2	91.0	9.0	1898.6	100.0	0.0	4751.6	15.1
NL89	M	33	16	27	22AUG92	25SEP93	14.6		3396.8	100.0	0.0	878.6	100.0	0.0	2178.0	13.3
NL90	F	53	28	25	22AUG92	25SEP93	14.7		3375.1	100.0	0.0	1260.8	100.0	0.0	2164.4	17.1
NL91	M	26	14	12	22AUG92	27AUG92	14.8	DROP	1188.4	100.0	0.0	276.8	100.0	0.0	695.8	8.6
SW92	M	25	12	13	12AUG92	12AUG93	15.1	DROP	969.6	84.4	15.6	315.9	95.7	4.3	616.1	10.6
SW93	M	26	13	13	12AUG92	12AUG93	14.5	DROP	296.5	100.0	0.0	120.3	100.0	0.0	126.8	4.8
SW94	M	27	14	13	12AUG92	24SEP93	15.7		1247.4	68.6	31.4	287.2	75.7	24.3	1698.5	11.8
SW95	F	28	16	12	12AUG92	24SEP93	15.1		3353.8	99.9	0.1	1139.0	100.0	0.0	1580.0	17.8
SW96	M	7	4	3	12AUG92	22OCT92	13.8	DROP	n/a			n/a			197.8	5.5
LB98	M	19	6	13	13AUG92	30APR93	14.4	DROP	881.6	0.0	100.0	236.2	0.0	100.0	441.3	9.5
LB99	F	29	16	13	13AUG92	25SEP93	14.5		1643.5	41.1	58.9	n/a			1439.8	16.1
LB100	M	25	12	13	13AUG92	13AUG93	14.6	DROP	1393.7	12.4	87.6	443.0	0.2	99.8	362.9	7.3
LB101	F	29	16	13	13AUG92	25SEP93	14.5		2956.7	79.6	50.4	1147.3	53.5	46.5	1022.5	18.7
NL102	F	28	15	13	13AUG92	09SEP93	14.5	WOLF	3890.6	100.0	0.0	1254.7	100.0	0.0	1696.5	20.8
NL103	F	29	16	13	13AUG92	25SEP93	14.5		3933.2	100.0	0.0	1388.6	100.0	0.0	1159.8	18.6
PL104	M	23	11	12	12AUG92	15JUL93	15.3	DROP	2376.4	100.0	0.0	549.0	100.0	0.0	746.2	11.1
PL105	M	23	11	12	12AUG92	26AUG93	15.9	DROP	1986.4	100.0	0.0	491.7	100.0	0.0	1231.7	20.6
PL107	M	27	14	13	12AUG92	24SEP93	15.7		3206.8	97.8	2.2	n/a			2190.7	16.9

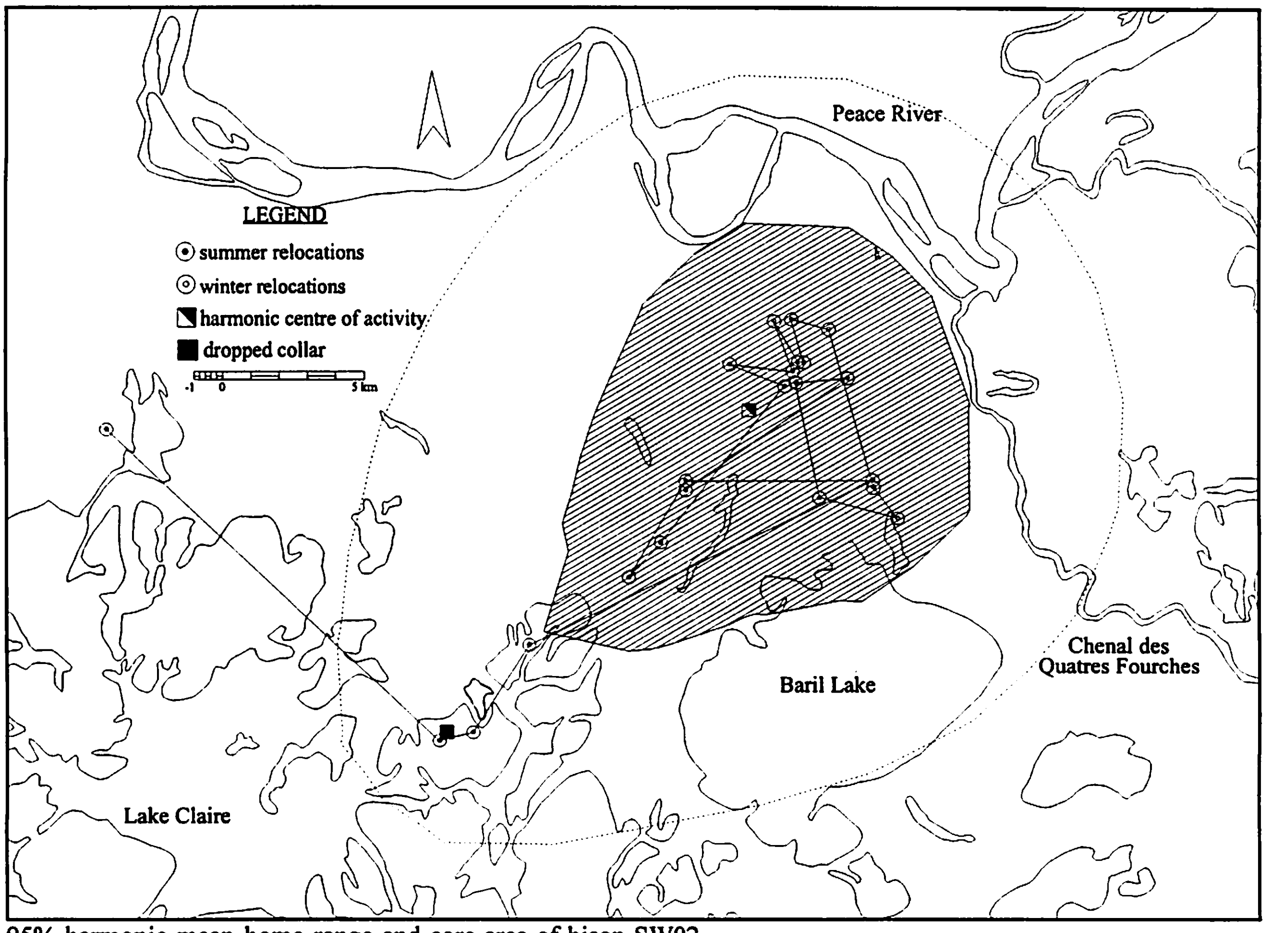
Bison	Sex	Number of Locations as of 25SEP93			Start Date	End Date	Mean Location Interval (days)	Fate	95% Harmonic Mean Home Range			Harmonic Mean Core Area			95% MCP Home Range (km2)	Mean Distance Between Consecutive Locations (km)
		ALL	Spr Sum	Fall Wint					Size (km2)	% in Park	% out of Park	Size (km2)	% in Park	% out of Park		
SW02	M	22	10	12	06SEP90	09JUL91	14.5	DROP	565.6	100.0	0.0	161.0	100.0	0.0	77.9	4.1
SW04	M	23	12	11	06SEP90	21JUL91	14.4	DROP	290.3	100.0	0.0	n/a			221.5	6.1
SW07	F	11	2	9	06SEP90	10FEB91	15.6	WOLF	305.8	96.5	3.5	n/a			334.4	7.4
SW09	F	77	40	37	06SEP90	24SEP93	14.6		4754.6	74.4	25.6	1525.8	100.0	0.0	1954.1	13.3
GR21	M	6	2	4	14SEP90	16DEC90	15.3	WOLF	n/a			n/a			61.0	2.6
GR22	M	24	12	12	14SEP90	20AUG91	14.7	DROP	2728.5	100.0	0.0	592.1	100.0	0.0	1624.3	17.1
GR23	M	49	25	24	14SEP90	27AUG92	14.8	DROP	3747.7	100.0	0.0	1460.9	100.0	0.0	1374.1	10.5
GR24	M	17	5	12	14SEP90	02MAY91	14.3	DROP	761.1	100.0	0.0	168.9	100.0	0.0	324.5	4.9
GR25	F	64	28	36	14SEP90	18MAR93	14.7	DROP	2310.0	100.0	0.0	1001.3	100.0	0.0	1378.2	12.6
GR26	F	74	39	35	14SEP90	24SEP93	15.1		3323.5	100.0	0.0	1221.1	100.0	0.0	1417.4	13.7
PL29	F	6	2	4	08SEP90	06DEC90	17.8	HUNT	n/a			n/a			934.7	32.3
PL31	M	23	11	12	08SEP90	21JUL91	14.3	ANTHX	1990.5	70.1	29.9	542.1	80.1	19.9	593.8	8.7
PL33	F	7	2	5	08SEP90	15DEC90	16.2	HUNT	n/a			n/a			16.4	6.7
LB34	M	26	14	12	01SEP90	04SEP91	14.6	DROP	1119.5	11.5	88.5	329.7	0.0	100.0	534.8	11.4
LB37	F	77	40	37	01SEP90	25SEP93	14.7		4596.5	42.9	57.1	1707.0	39.5	60.5	1664.5	16.7
LB38	M	47	24	24	01SEP90	13AUG92	14.8	DROP	2412.7	29.7	70.3	748.3	7.2	92.8	1356.8	12.7
LB39	M	21	10	12	01SEP90	10JUL90	14.8	DROP	469.3	0.0	100.0	148.1	0.0	100.0	220.1	6.7
LB40	F	76	40	36	01SEP90	25SEP93	14.9		2967.4	39.6	60.4	1242.7	36.8	63.2	1735.8	14.2
PL42	M	26	14	12	08SEP90	02SEP91	14.3	DROP	2119.8	99.8	0.2	506.1	100.0	0.0	1238.5	12.9
PL45	M	22	10	12	08SEP90	08SEP91	15.0	ANTHX	434.4	79.7	20.3	82.7	78.9	21.1	0.0	7.5
PL46	F	31	12	19	29SEP90	15MAR92	17.6	WOLF	4568.7	100.0	0.0	1948.6	100.0	0.0	2571.6	12.0
PL47	M	23	11	12	08SEP90	21JUL91	14.3	DROP	2312.4	100.0	0.0	586.2	100.0	0.0	1174.7	10.8
PL50	M	23	11	12	08SEP90	21JUL91	14.3	ANTHX	379.6	100.0	0.0	88.1	100.0	0.0	269.3	5.4
PL57	F	58	28	30	14SEP90	21JUL91	14.6	DROP	5818.9	100.0	0.0	2101.7	100.0	0.0	4459.7	16.4
SW59	M	20	9	11	05NOV90	21JUL91	13.5	DROP	404.6	100.0	0.0	109.9	100.0	0.0	142.9	5.3
NL60	M	41	21	20	04DEC90	31JUL92	15.1	FAIL	2448.5	100.0	0.0	683.2	100.0	0.0	843.4	8.5
NL61	M	20	11	9	04DEC90	22AUG91	13.7	DROP	2140.2	100.0	0.0	598.5	100.0	100.0	479.1	10.3
GR62	M	42	21	21	14DEC90	20AUG91	15.4	FAIL	2278.1	92.2	7.8	n/a			2776.3	12.8
SW63	F	49	25	24	08AUG91	01AUG93	15.0	DROP	2815.8	99.9	0.1	802.3	100.0	0.0	1341.0	12.1
SW64	F	53	28	25	08AUG91	24SEP93	14.9		2611.6	95.5	0.5	912.5	100.0	0.0	949.8	12.7
NL67	M	54	29	25	08AUG91	25SEP93	14.7		1717.9	79.6	20.4	440.3	100.0	0.0	415.3	7.3
PL68	M	25	13	12	08AUG91	29JUL92	14.8	DROP	938.1	100.0	0.0	255.0	100.0	0.0	689.7	6.2

Bison	Sex	Number of Locations as of 25SEP93			Start Date	End Date	Mean Location Interval (days)	Fate	95% Harmonic Mean Home Range			Harmonic Mean Core Area			95% MCP Home Range (km2)	Mean Distance Between Consecutive Locations (km)
		ALL	Spr Sum	Fall Wint					Size (km2)	% in Park	% out of Park	Size (km2)	% in Park	% out of Park		
GR108	F	26	13	13	12AUG92	24SEP93	16.3		3799.4	100.0	0.0	1418.9	100.0	0.0	1608.0	20.8
NL109	F	29	15	13	13AUG92	25SEP93	14.5		3451.7	100.0	0.0	1191.0	100.0	0.0	1916.9	17.9
NL110	F	27	14	13	13AUG92	25SEP93	15.7		3502.7	100.0	0.0	1273.7	100.0	0.0	1282.5	17.8
NL111	F	28	15	13	13AUG92	25SEP93	15.1		4396.2	100.0	0.0	1812.1	100.0	0.0	1572.9	17.3

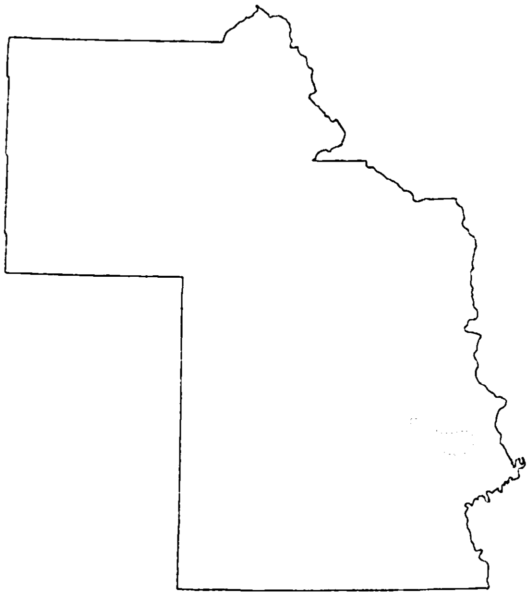
Appendix 2 - Individual home range maps for relocated bison.



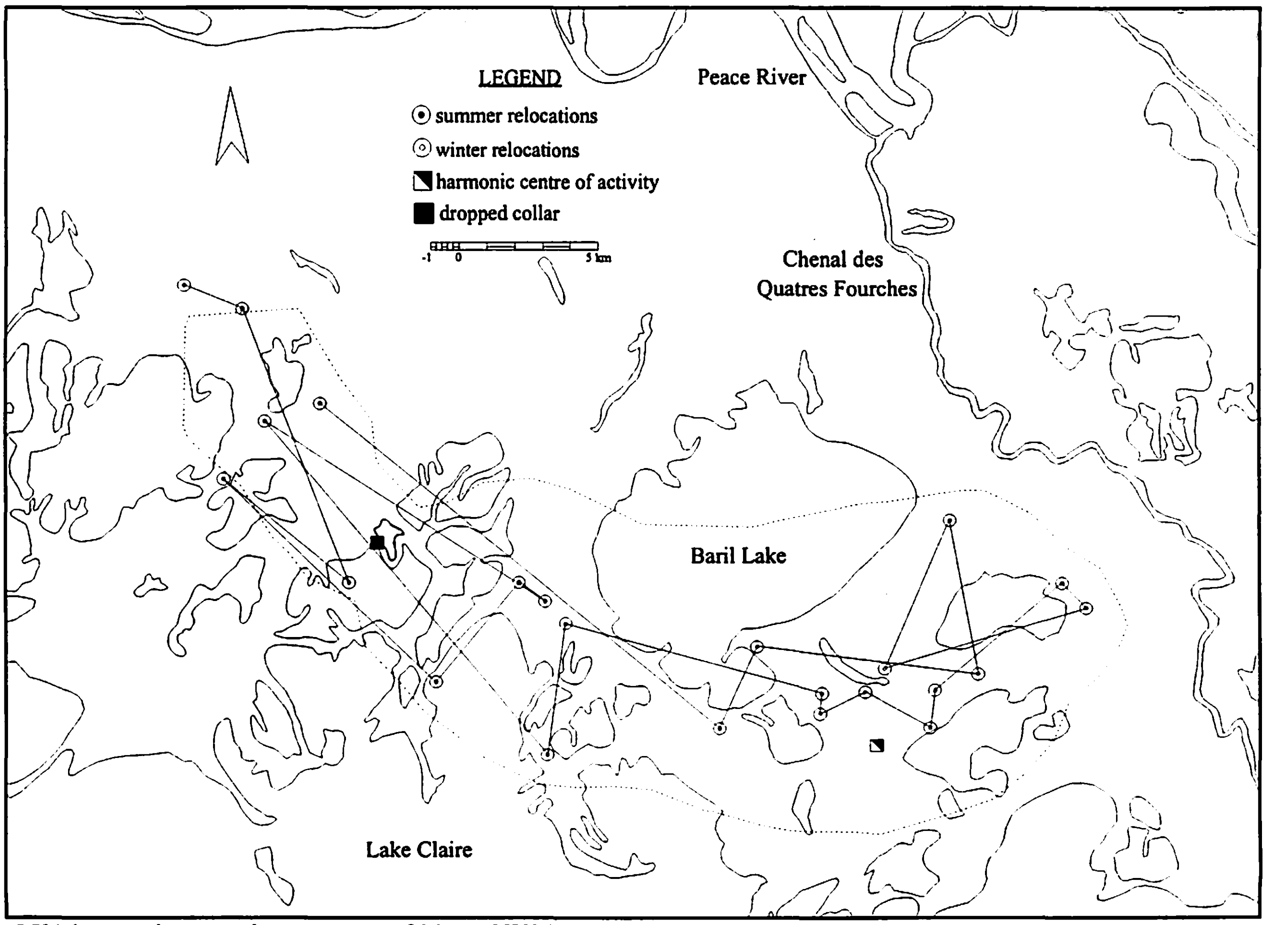
BISON: SW02
SEX: Male
RELOCATIONS: 22
95% HAR. HOME RANGE: 565.6 km^2
CORE AREA: 161.0 km^2
START: 06SEP90
END: 09JUL91
FATE: Dropped Collar



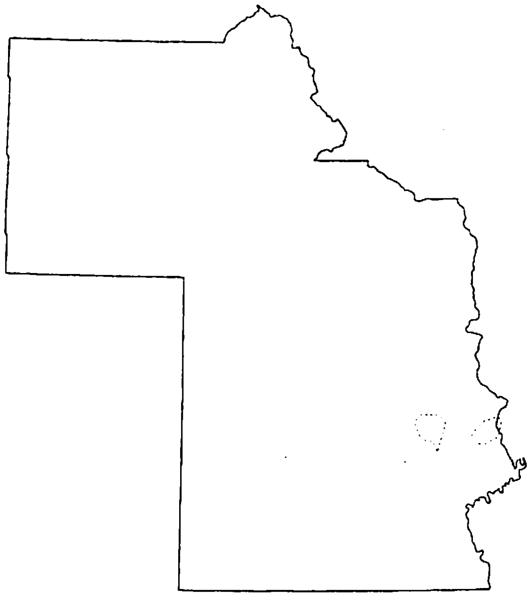
95% harmonic mean home range and core area of bison SW02.



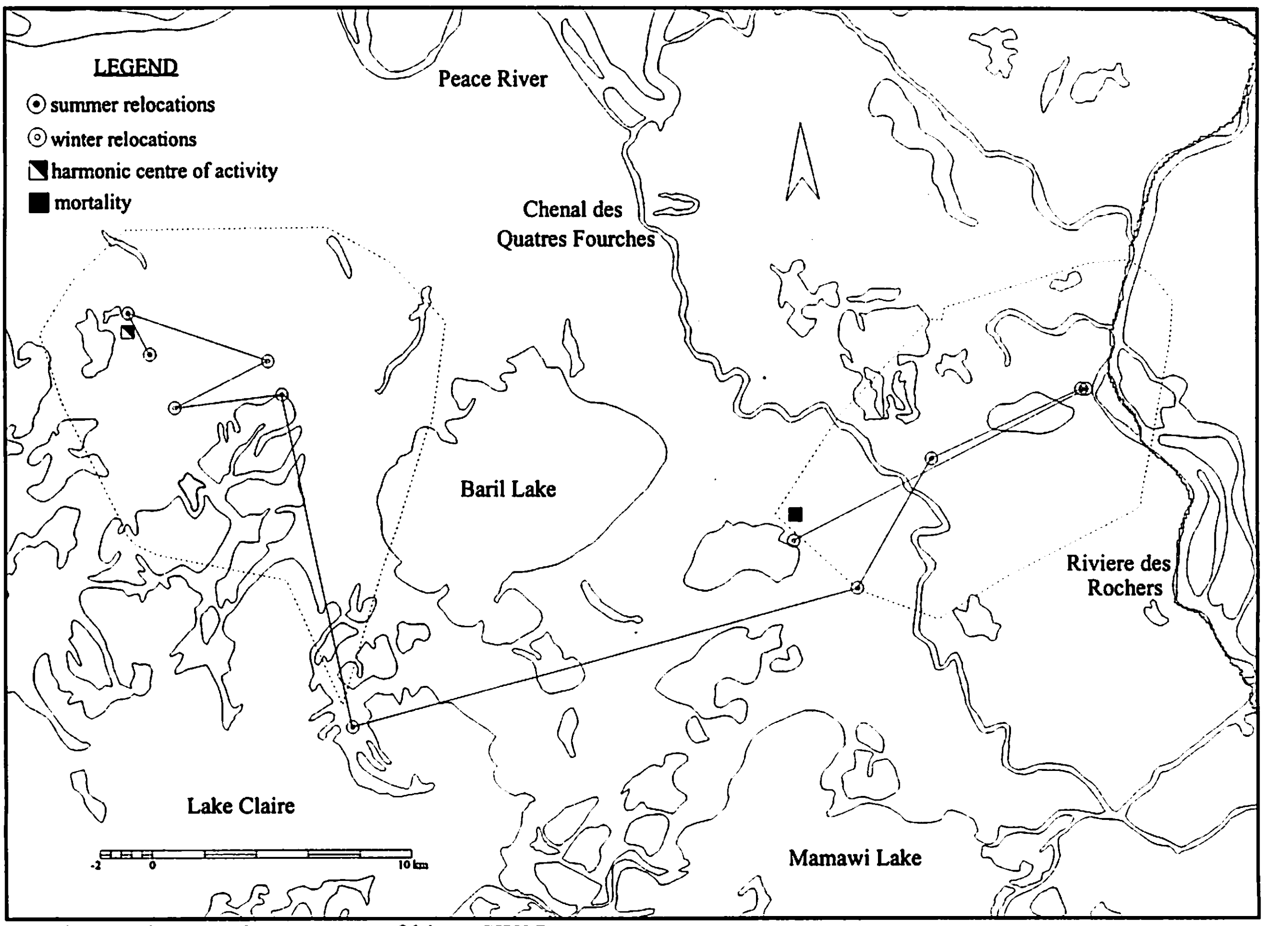
BISON: SW04
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 290.3 km²
CORE AREA: none
START: 06SEP90
END: 21JUL91
FATE: Dropped collar



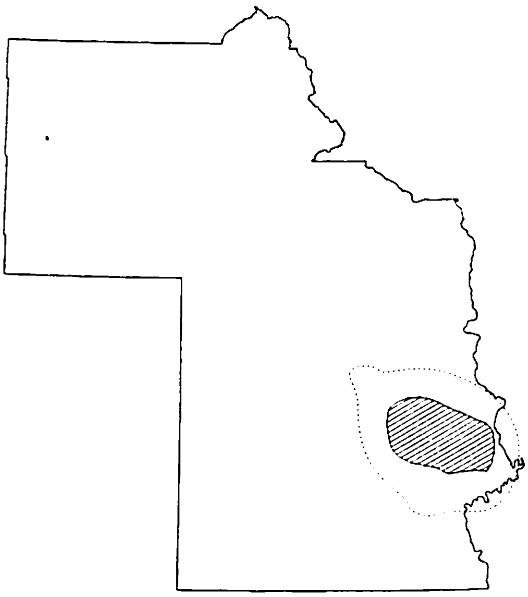
95% harmonic mean home range of bison SW04.



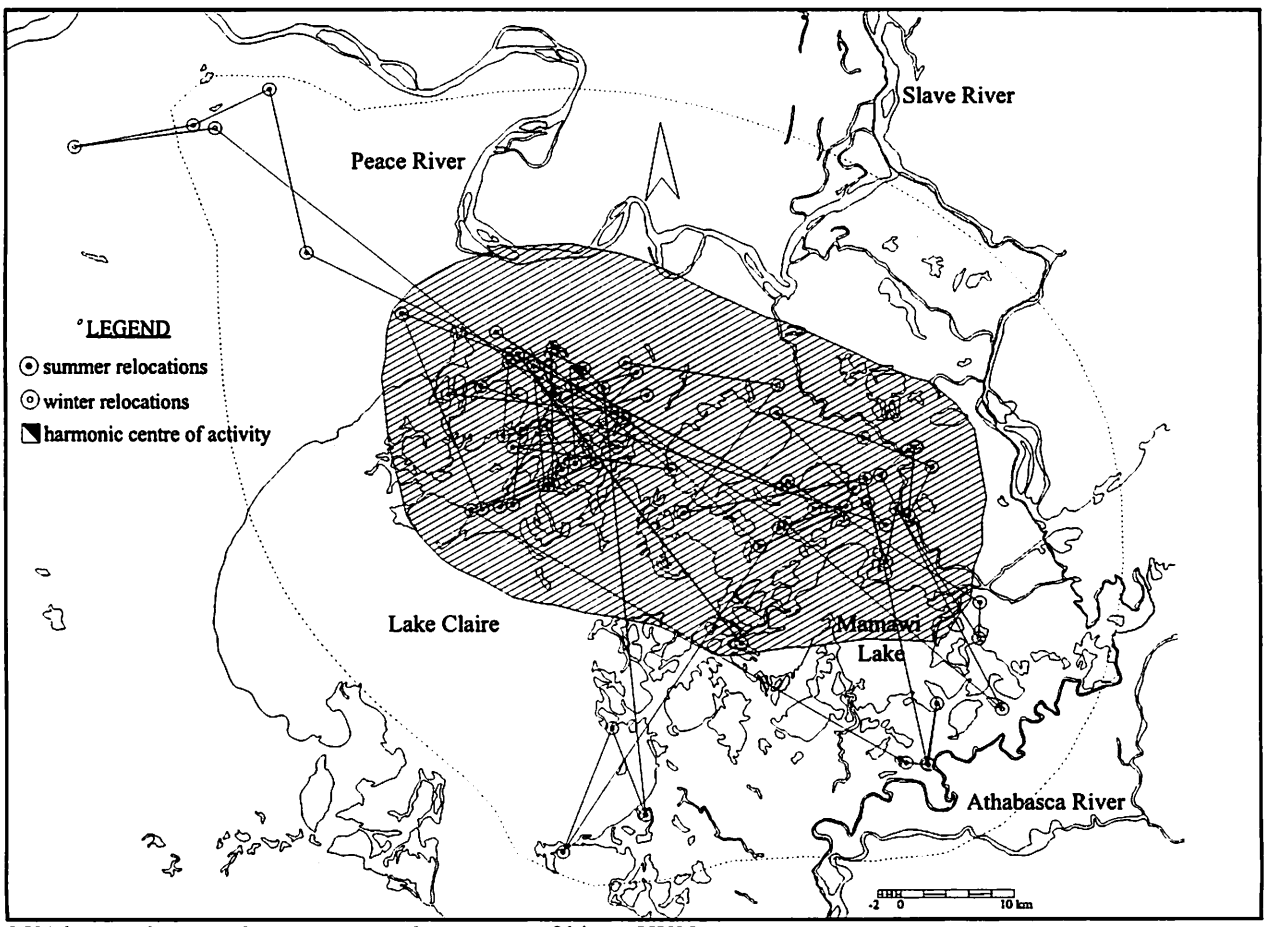
BISON: SW07
SEX: Female
RELOCATIONS: 11
95% HAR. HOME RANGE: 305.9 km^2
CORE AREA: none
START: 06SEP90
END: 10FEB91
FATE: Wolf Predation



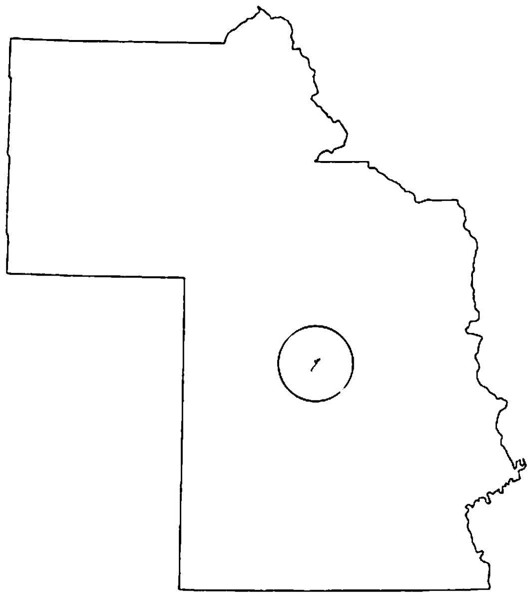
95% harmonic mean home range of bison SW07.



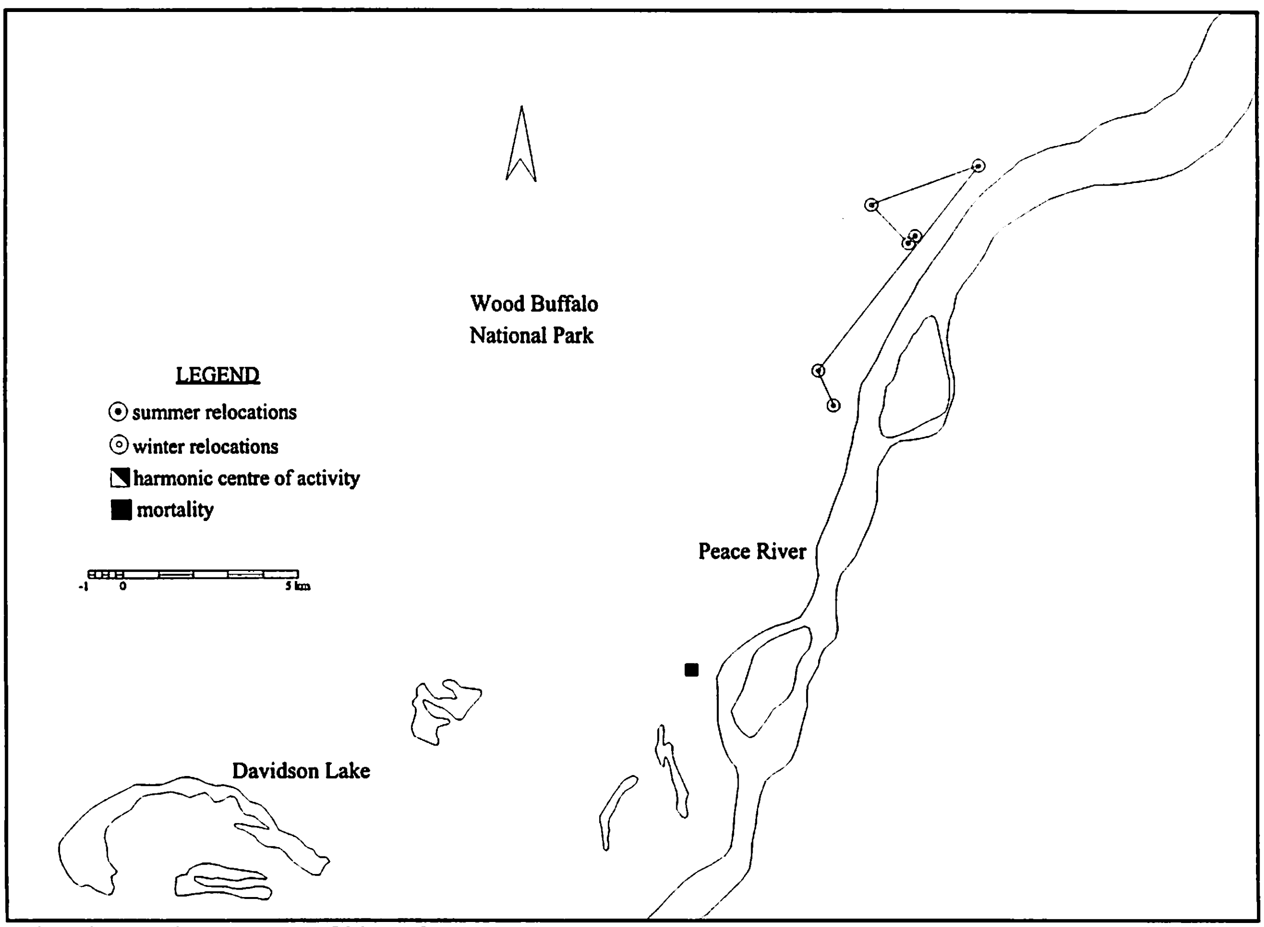
BISON: SW09
SEX: Female
RELOCATIONS: 77
95% HAR. HOME RANGE: 4754.6 km²
CORE AREA: 1525.8 km²
START: 06SEP90
END: 24SEP93
FATE: Active



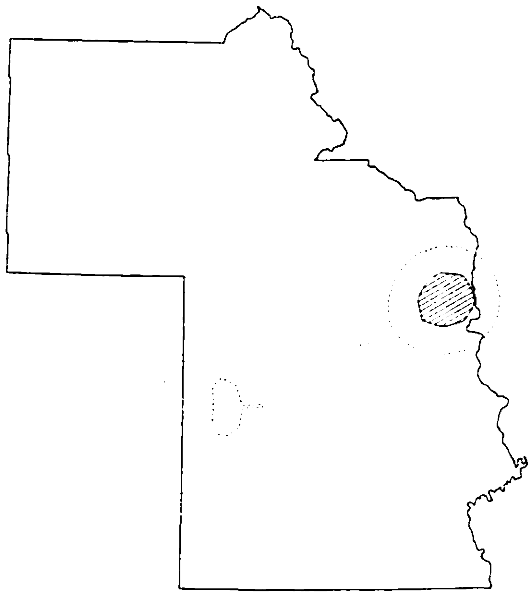
95% harmonic mean home range and core area of bison SW09.



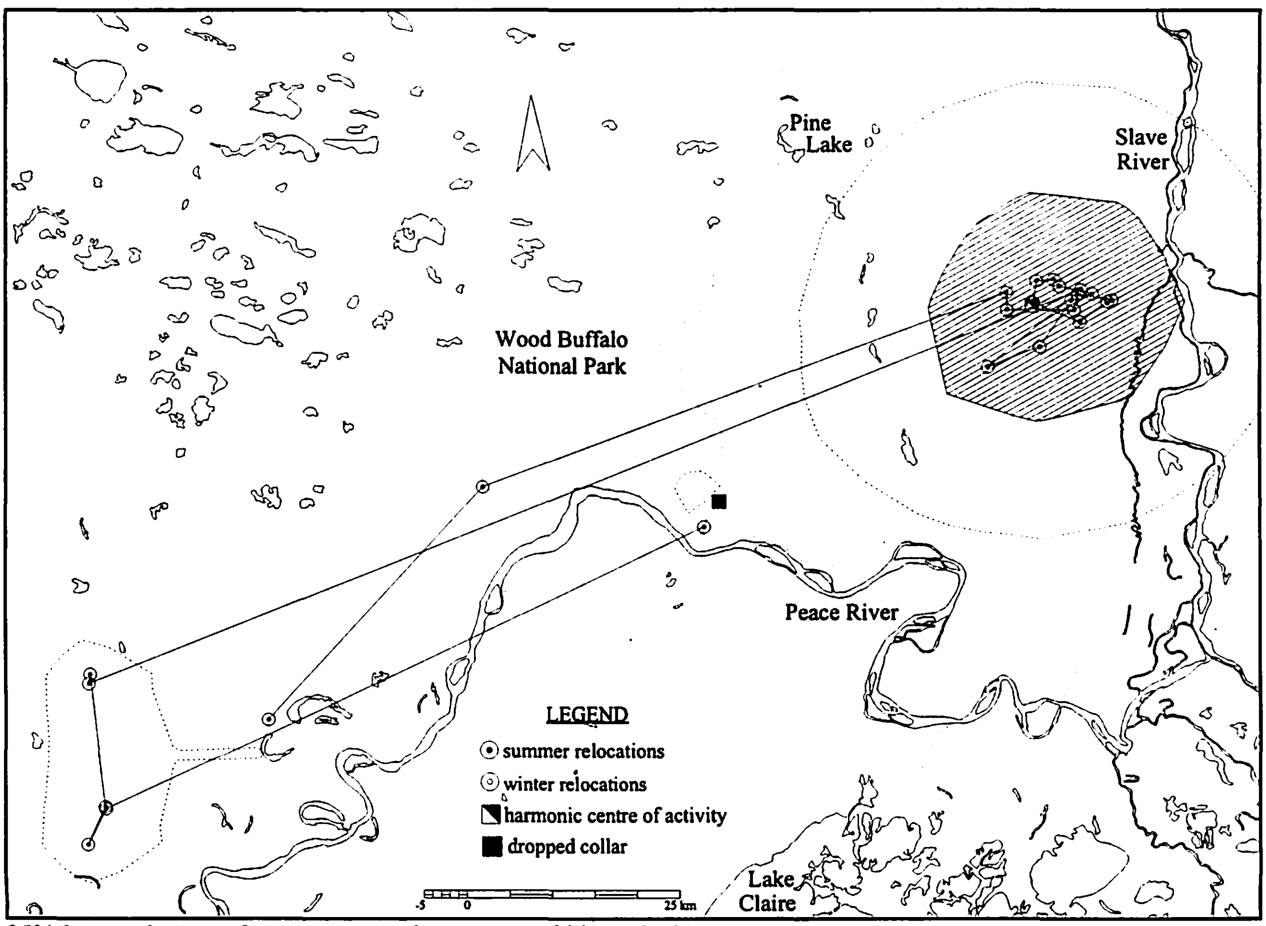
BISON: GR21
SEX: Male
RELOCATIONS: 6
95% HAR. HOME RANGE: none
CORE AREA: none
START: 14SEP90
END: 16DEC90
FATE: Predation



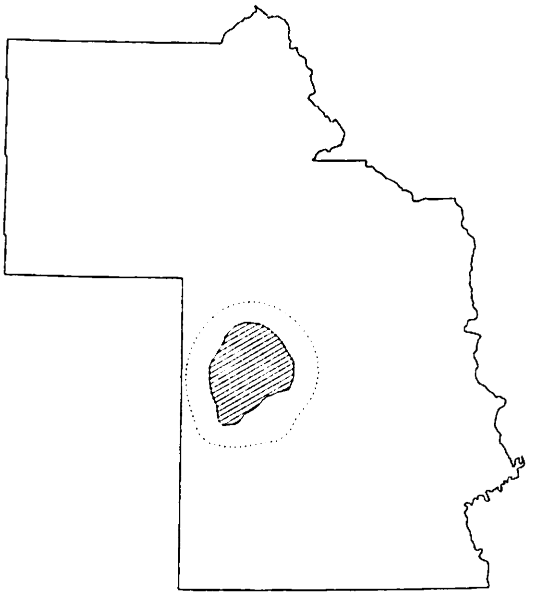
Relocations and movement of bison GR21.



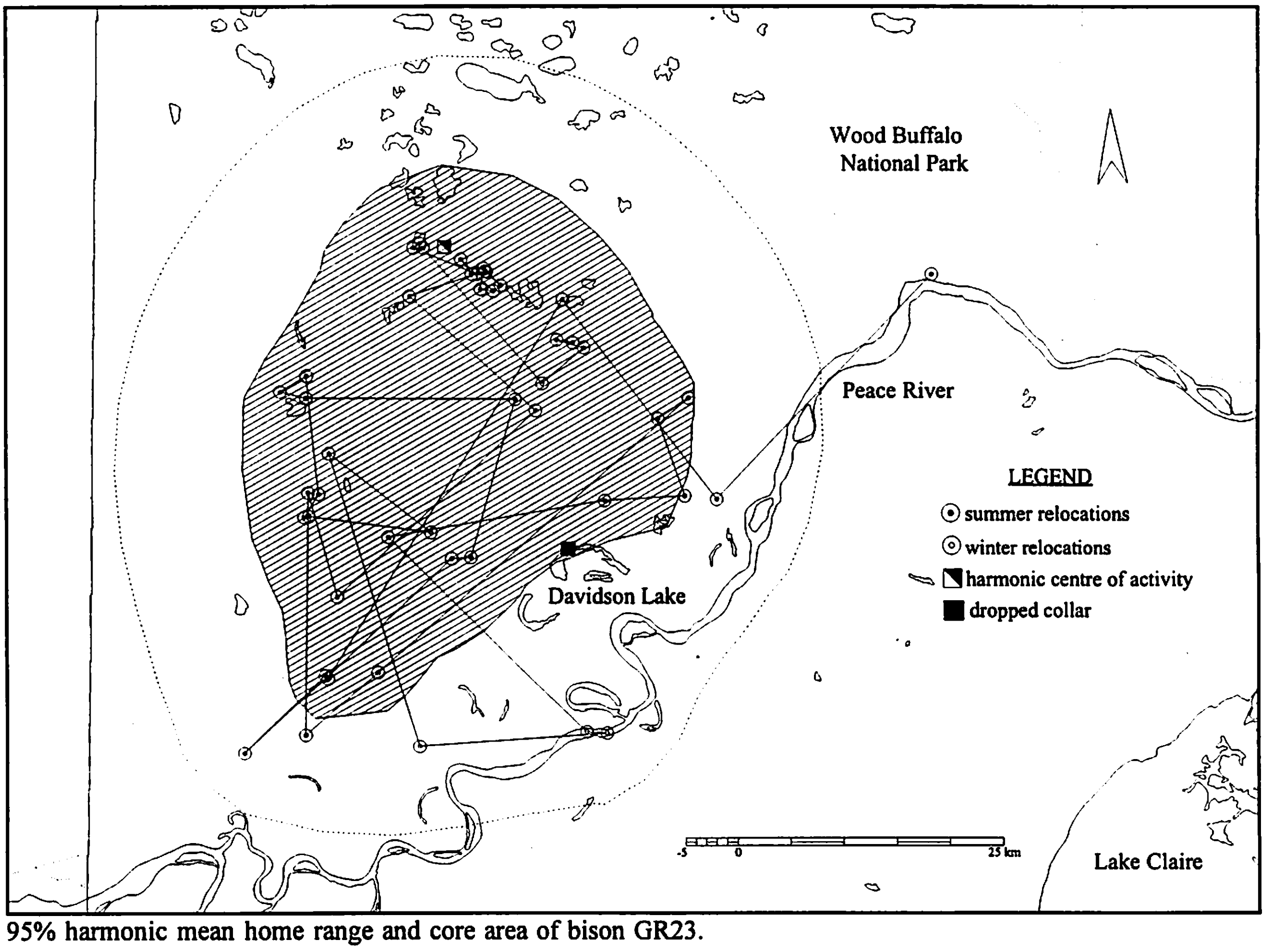
BISON: GR22
SEX: Male
RELOCATIONS: 24
95% HAR. HOME RANGE: 2728.5 km^2
CORE AREA: 592.1 km^2
START: 14SEP90
END: 20AUG91
FATE: Dropped Collar



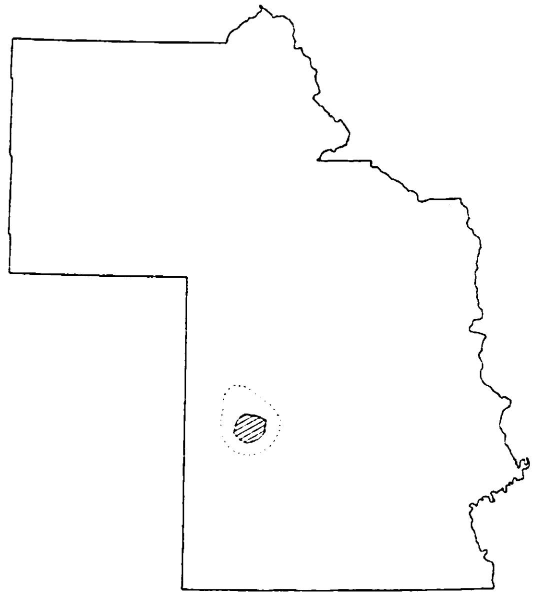
95% harmonic mean home range and core area of bison GR22.



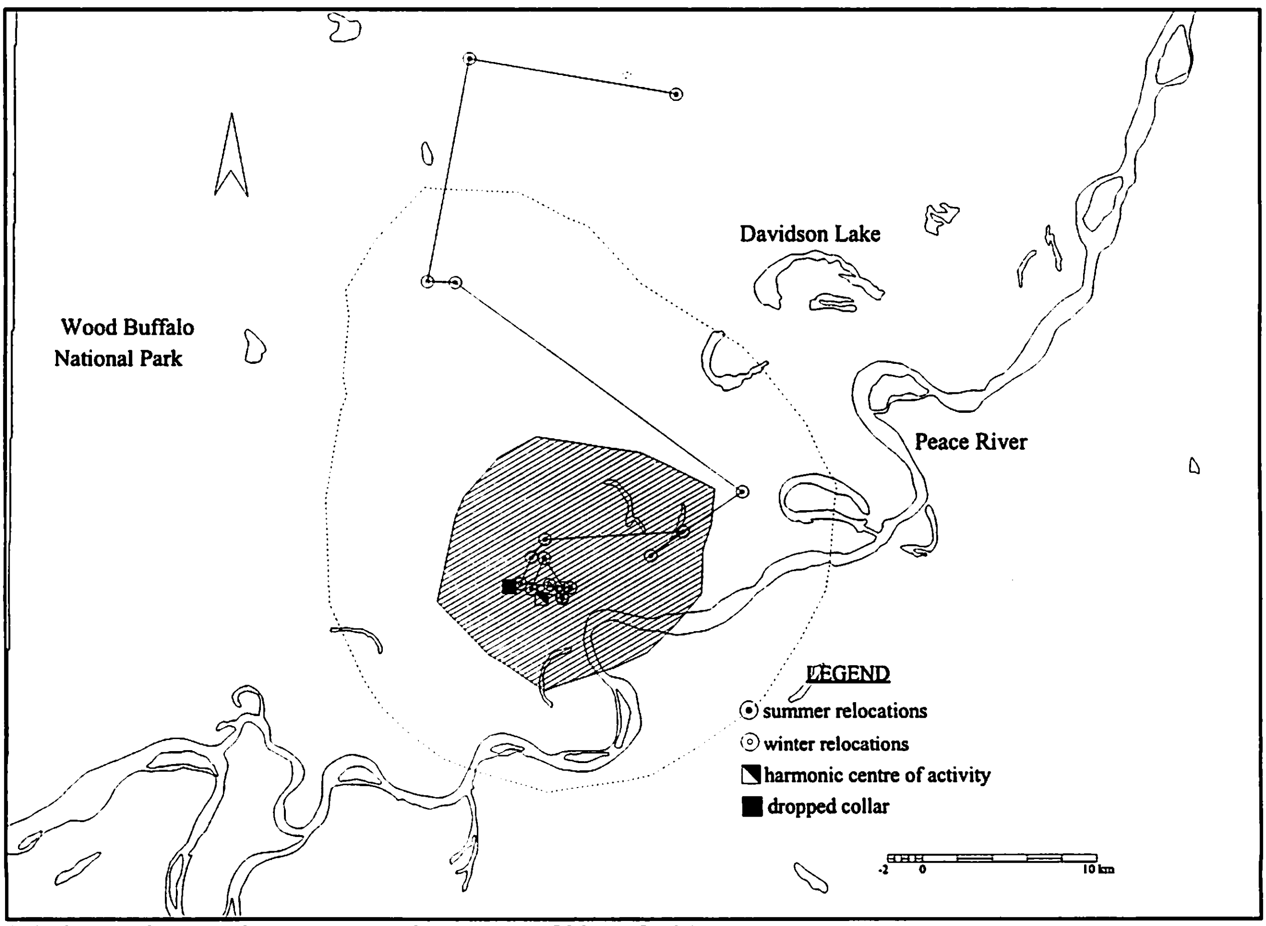
BISON: GR23
SEX: Male
RELOCATIONS: 49
95% HAR. HOME RANGE: 3743.7 km²
CORE AREA: 1460.9 km²
START: 14SEP90
END: 27AUG92
FATE: Dropped Collar



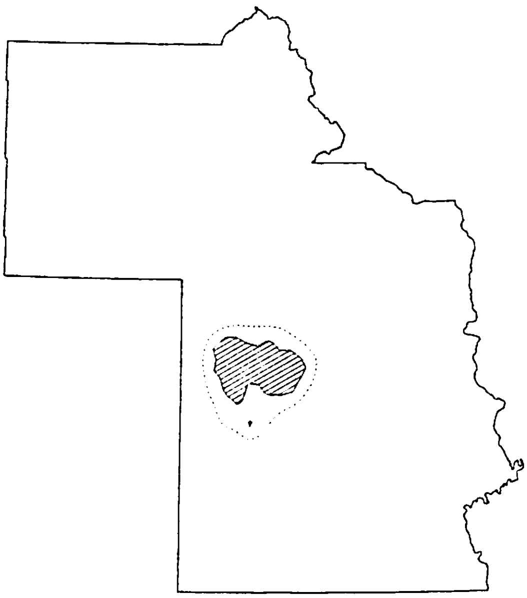
95% harmonic mean home range and core area of bison GR23.



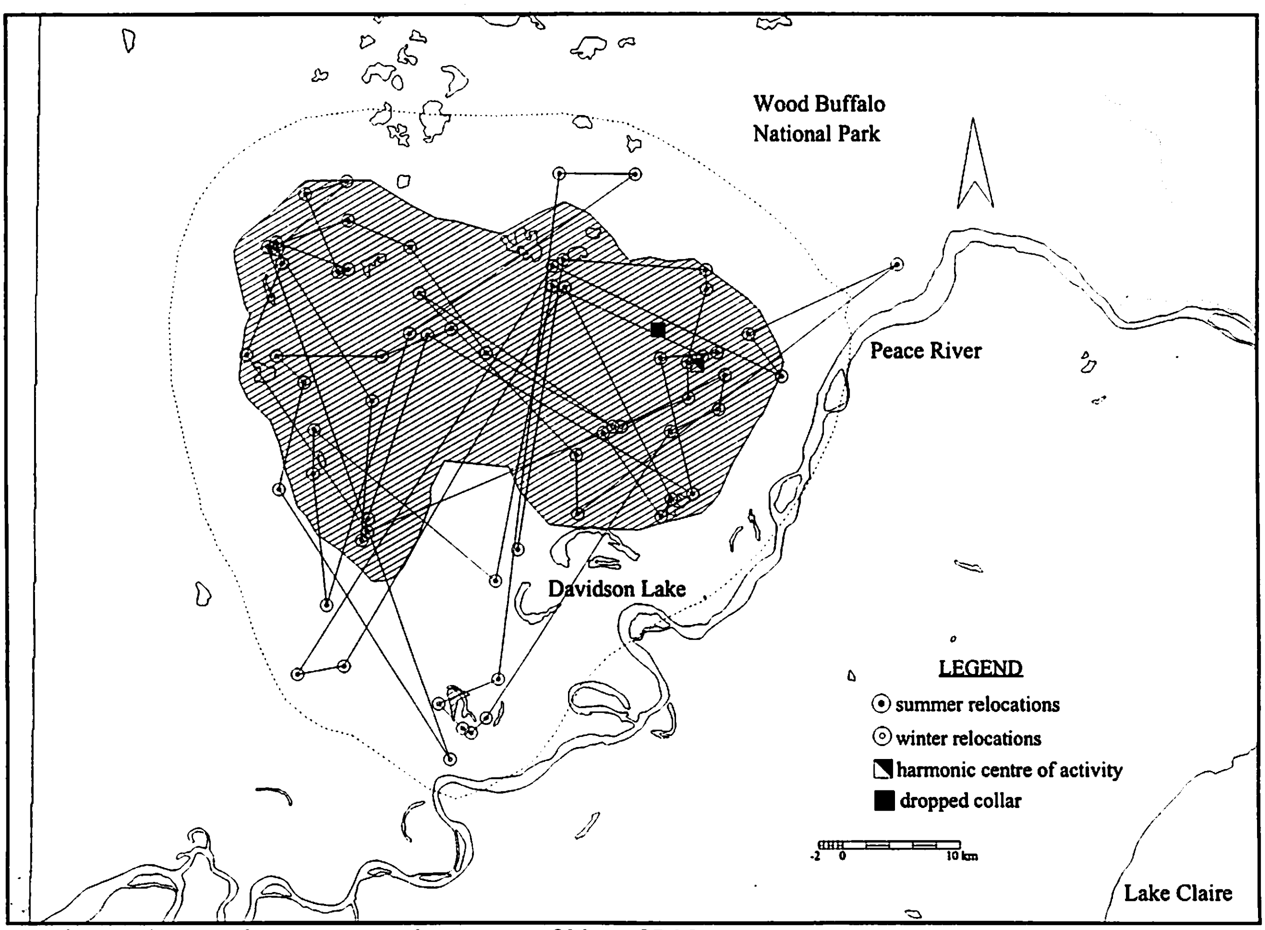
BISON: GR24
SEX: Male
RELOCATIONS: 17
95% HAR. HOME RANGE: 761.1 km²
CORE AREA: 168.1 km²
START: 14SEP90
END: 02MAY91
FATE: Dropped Collar



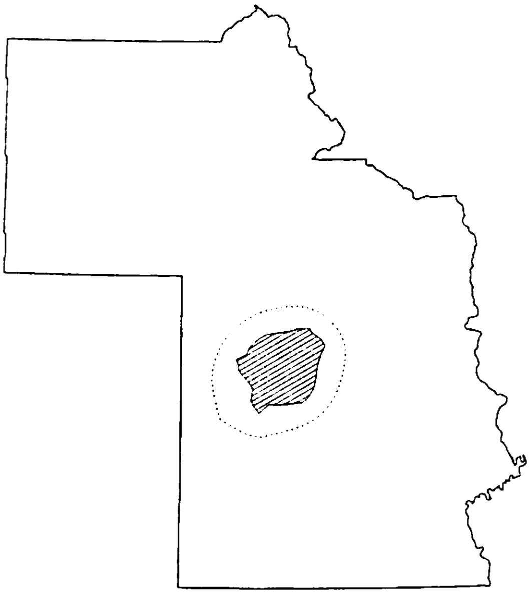
95% harmonic mean home range and core area of bison GR24.



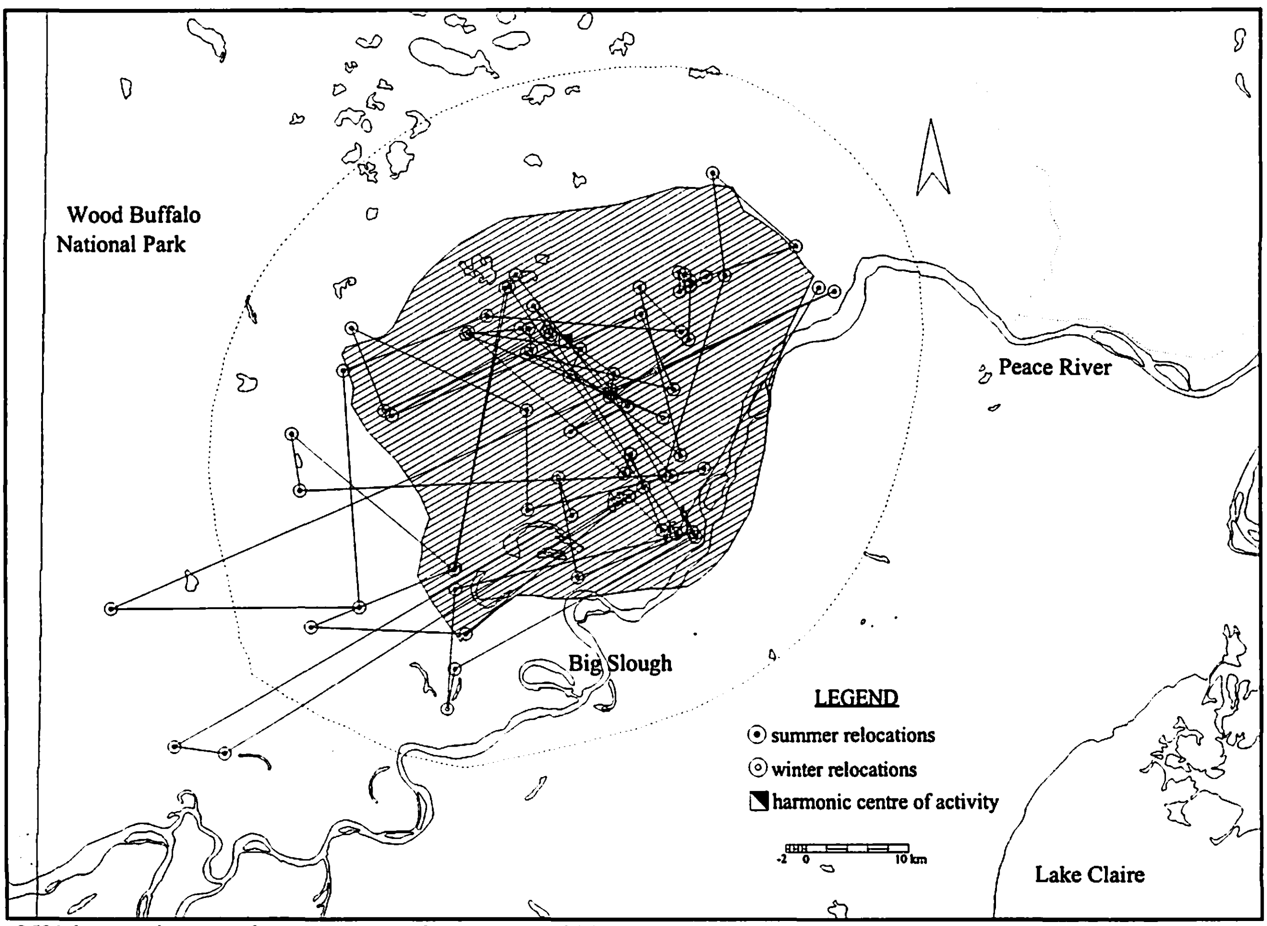
BISON: GR25
SEX: Female
RELOCATIONS: 64
95% HAR. HOME RANGE: 2310.0 km^2
CORE AREA: 1001.3 km^2
START: 14SEP90
END: 18MAR93
FATE: Dropped collar



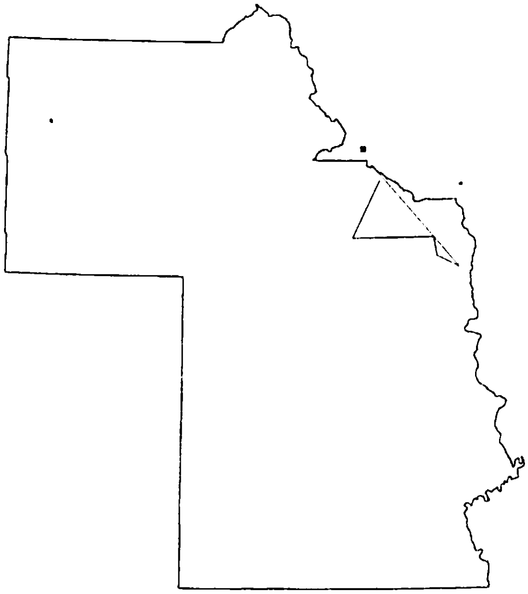
95% harmonic mean home range and core area of bison GR25.



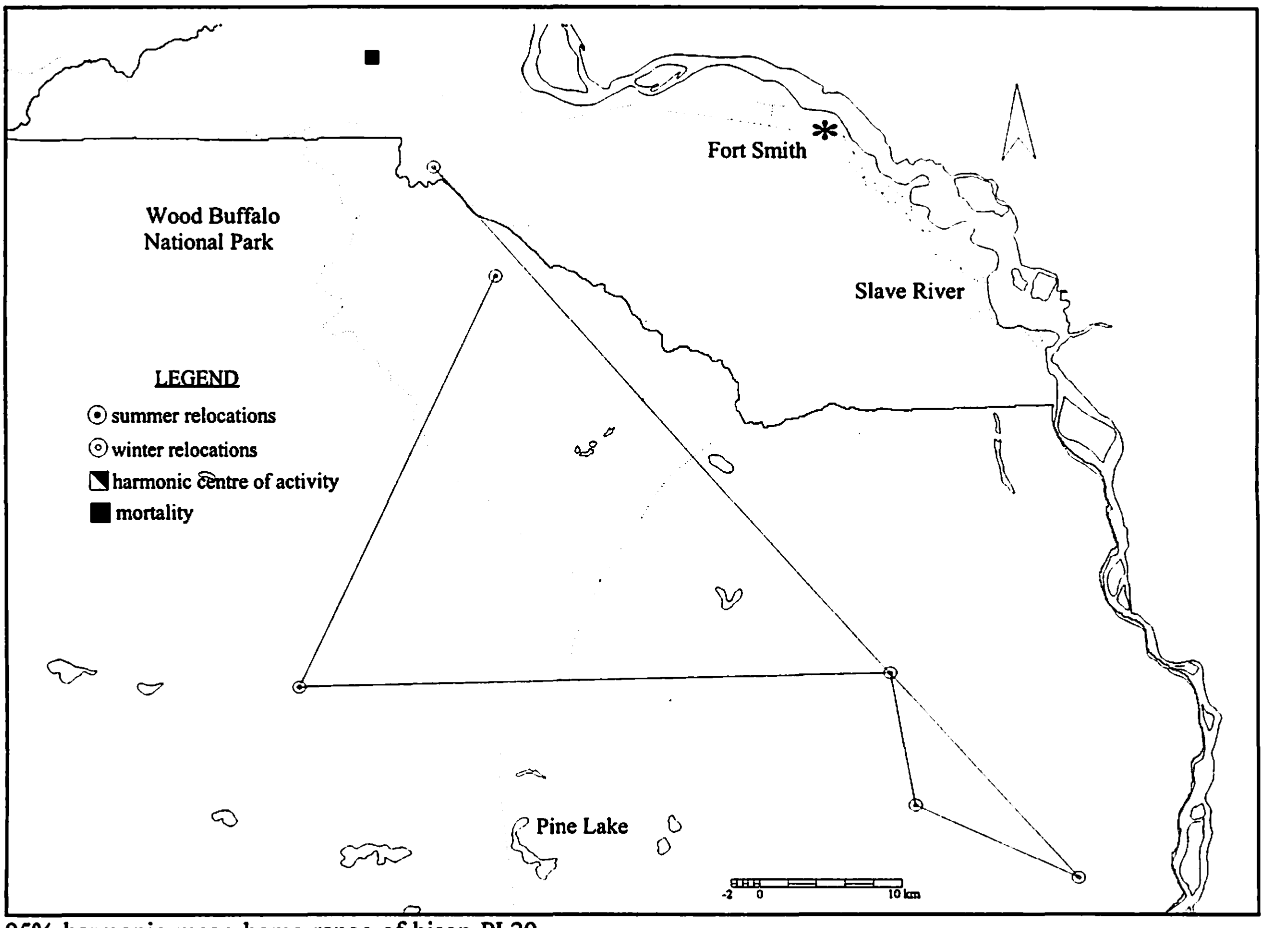
BISON: GR26
SEX: Female
RELOCATIONS: 74
95% HAR. HOME RANGE: 3323.5 km²
CORE AREA: 1221.1 km²
START: 14SEP90
END: 24SEP93
FATE: Active



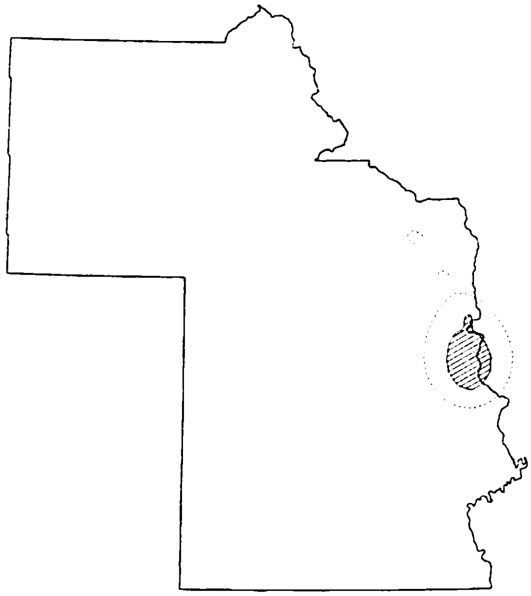
95% harmonic mean home range and core area of bison GR26.



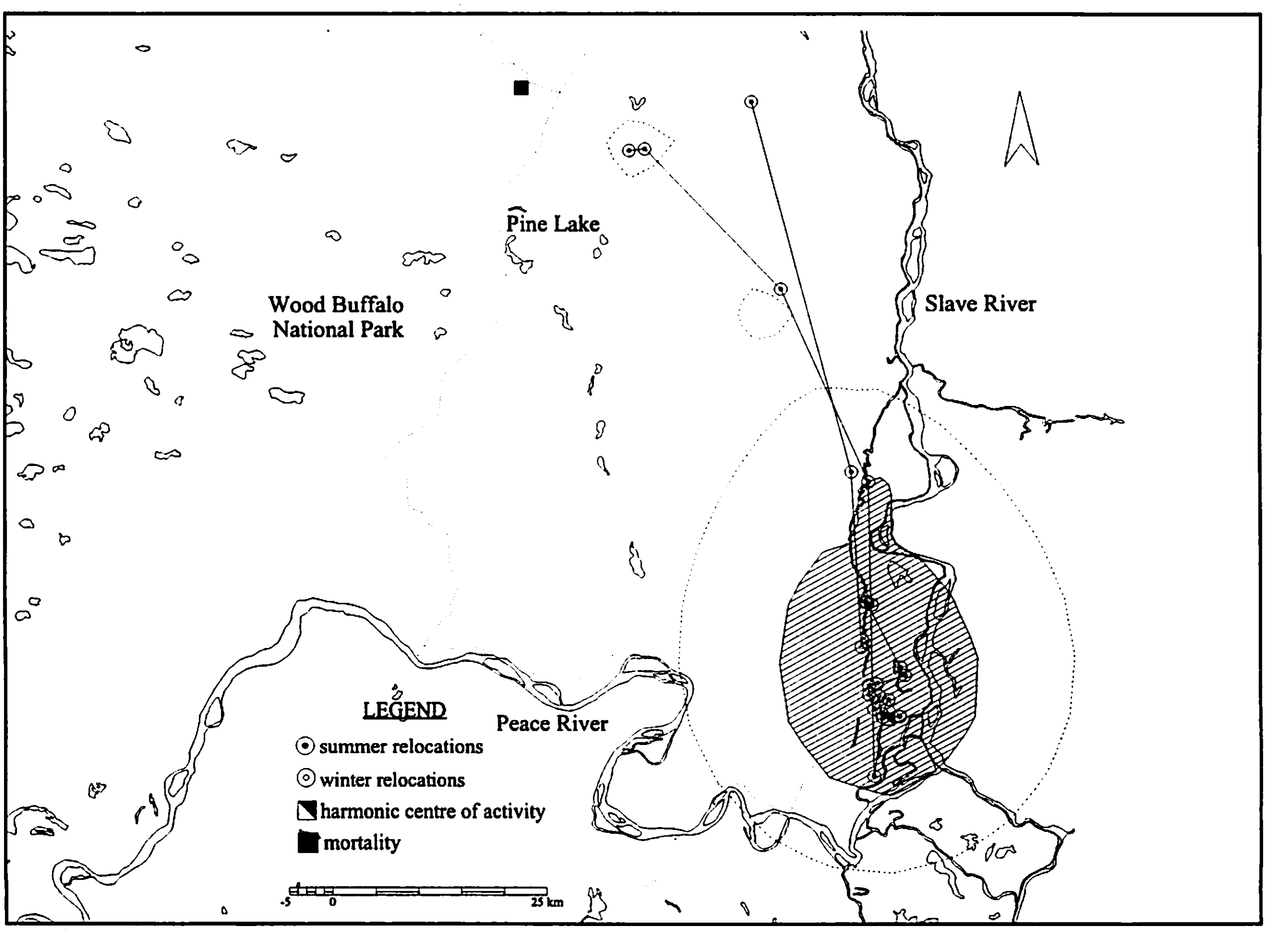
BISON: PL29
SEX: Female
RELOCATIONS: 6
95% HAR. HOME RANGE: none
CORE AREA: none
START: 08AUG90
END: 06DEC90
FATE: Hunted



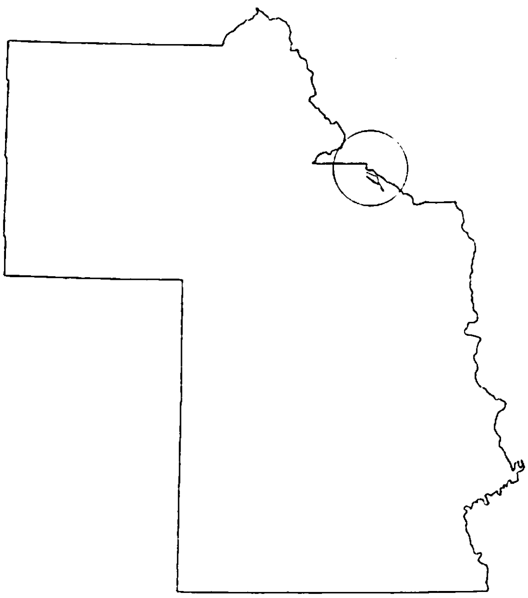
95% harmonic mean home range of bison PL29.



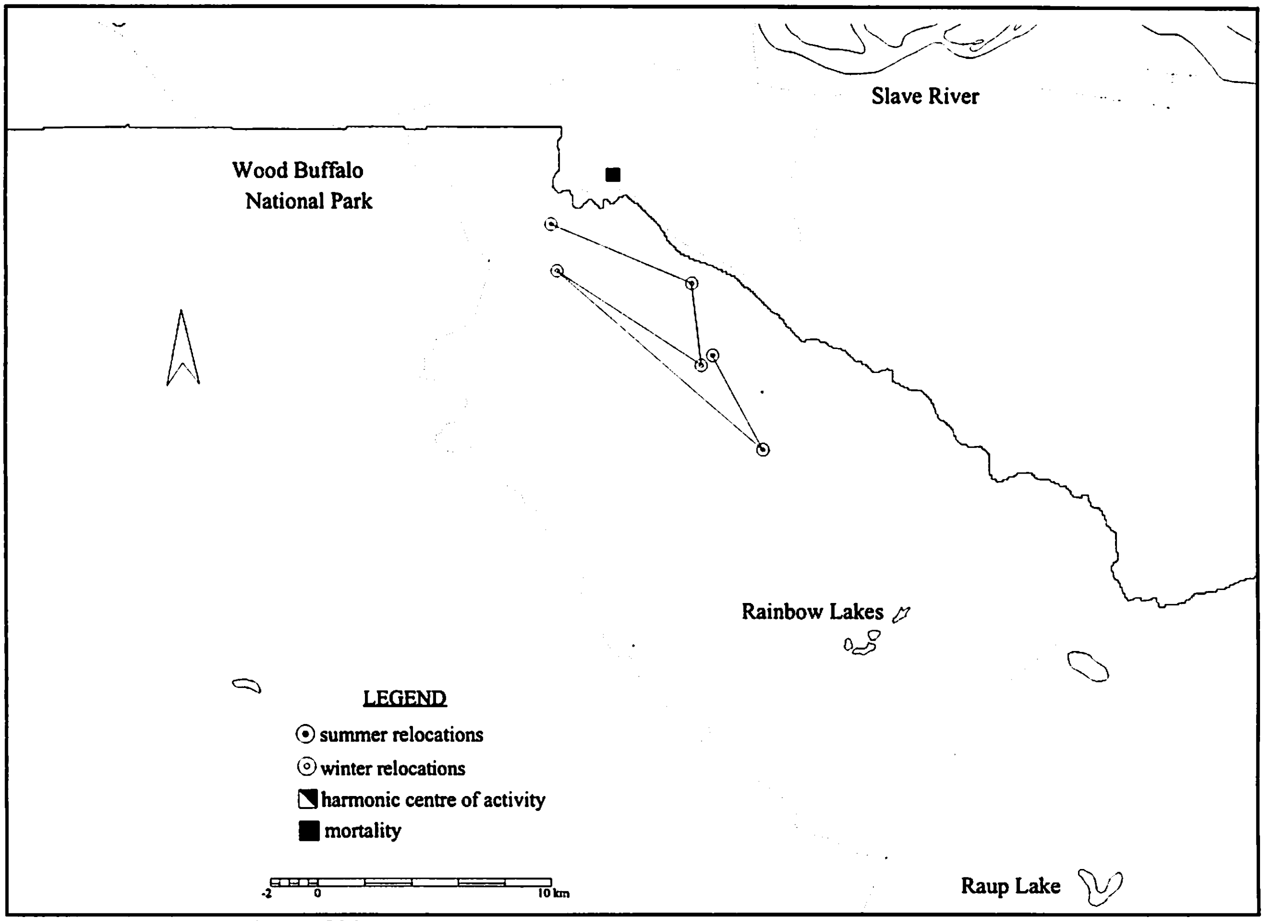
BISON: PL31
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 1990.5 km²
CORE AREA: 542.1 km²
START: 08AUG90
END: 21JUL91
FATE: Anthrax



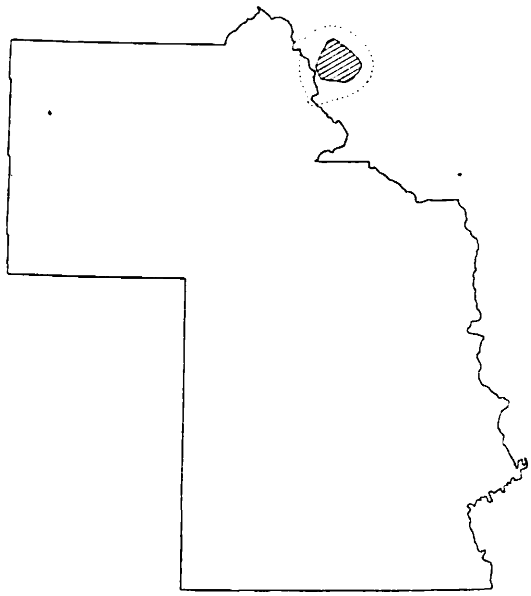
95% harmonic mean home range and core area of bison PL31.



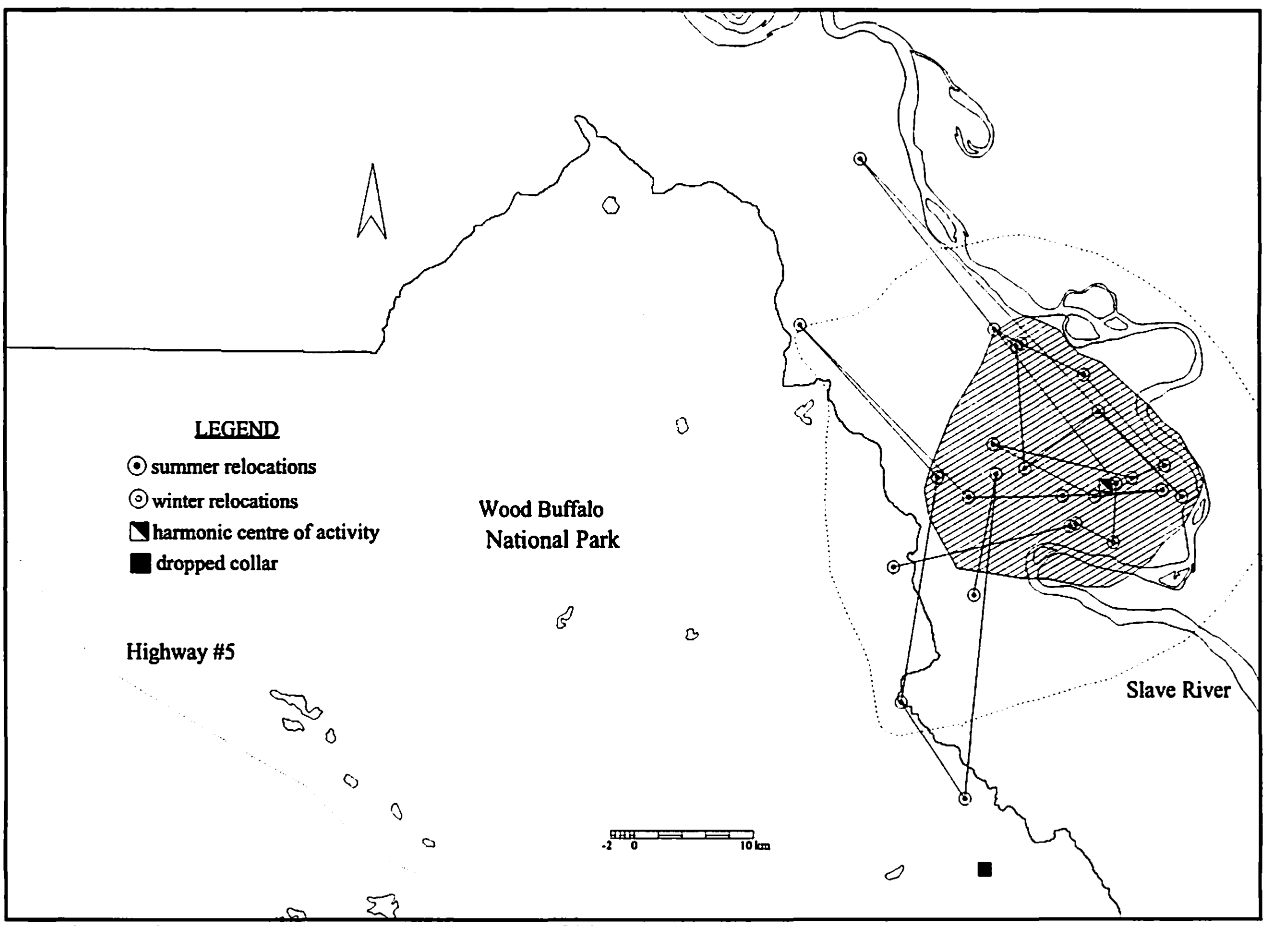
BISON: PL33
SEX: Female
RELOCATIONS: 7
95% HAR. HOME RANGE: none
CORE AREA: none
START: 08SEP90
END: 15DEC90
FATE: Hunted



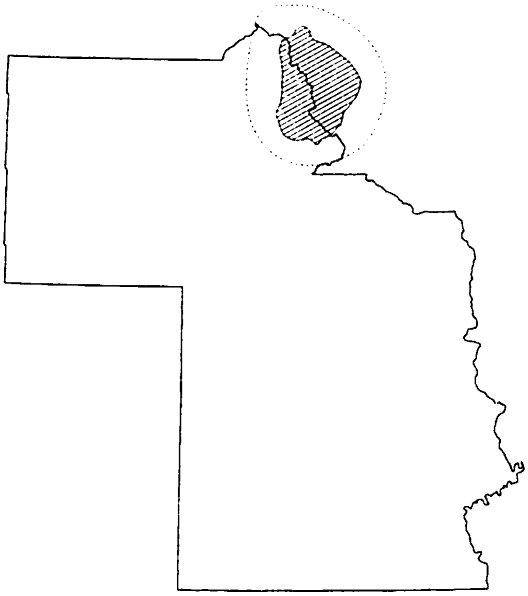
Movement and relocations of bison PL33.



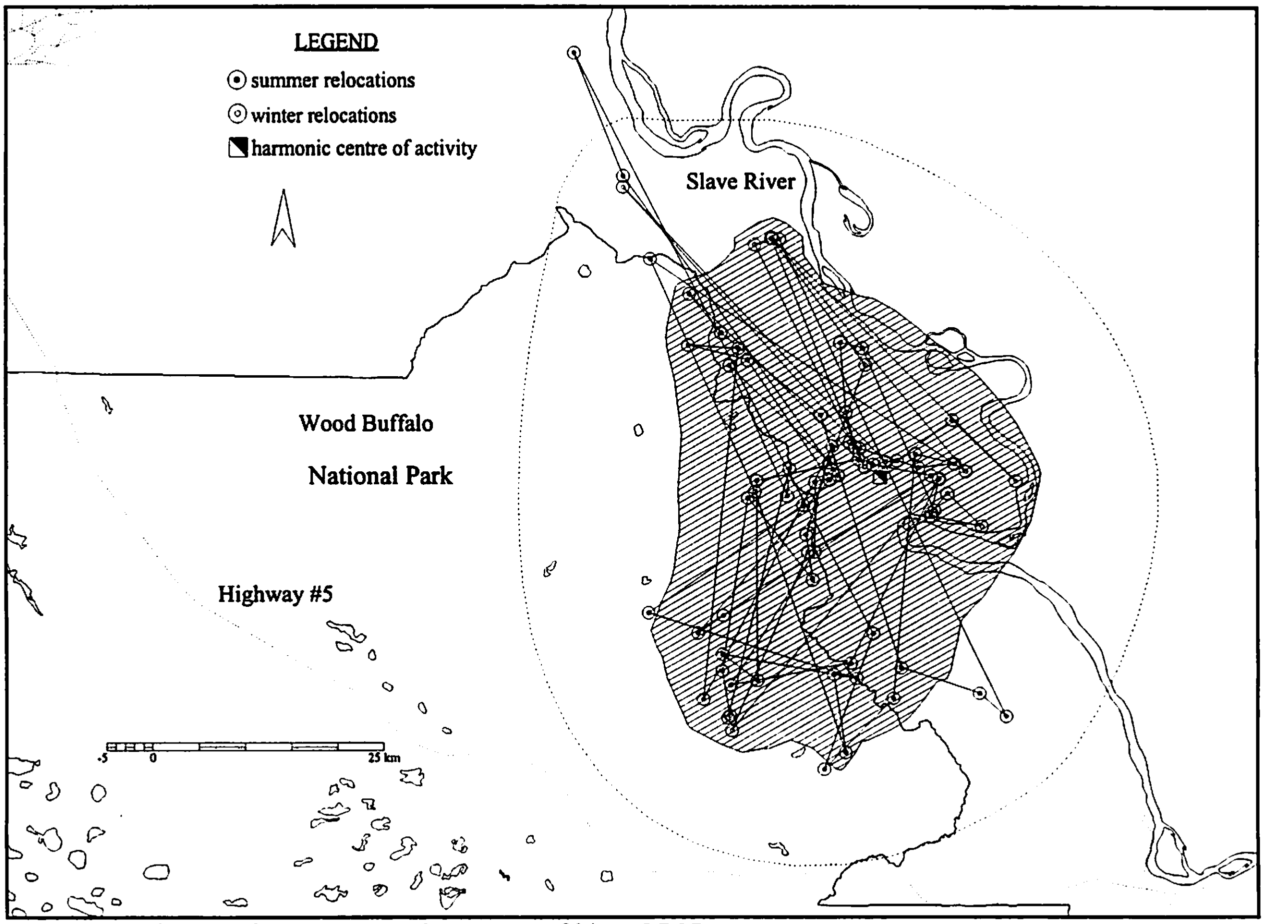
BISON: LB34
SEX: Male
RELOCATIONS: 26
95% HAR. HOME RANGE: 1119.5 km^2
CORE AREA: 329.7 km^2
START: 01SEP90
END: 04SEP91
FATE: Dropped Collar



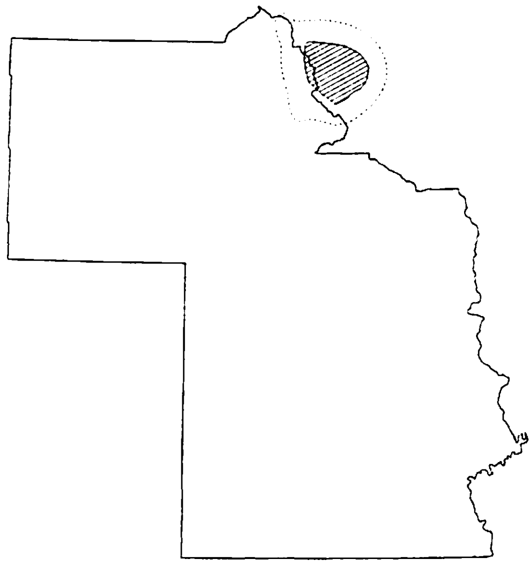
95% harmonic mean home range and core area of bison LB34.



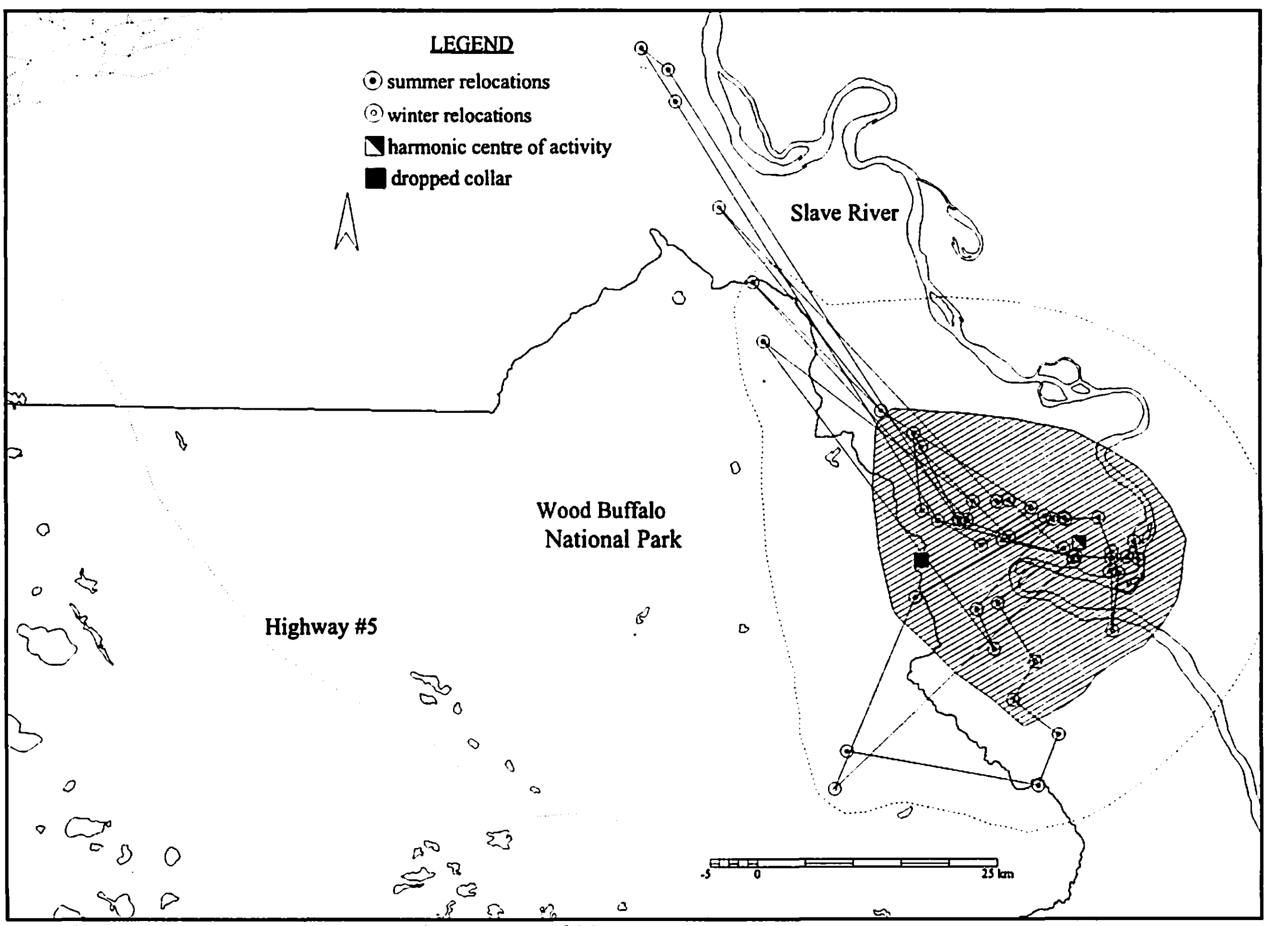
BISON: LB37
SEX: Female
RELOCATIONS: 77
95% HAR. HOME RANGE: 4596.5 km^2
CORE AREA: 1707.0 km^2
START: 21SEP90
END: 25SEP93
FATE: Active



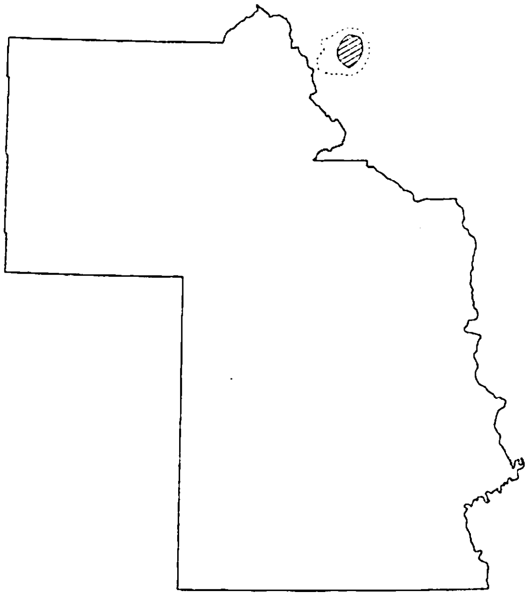
95% harmonic mean home range and core area of bison LB37.



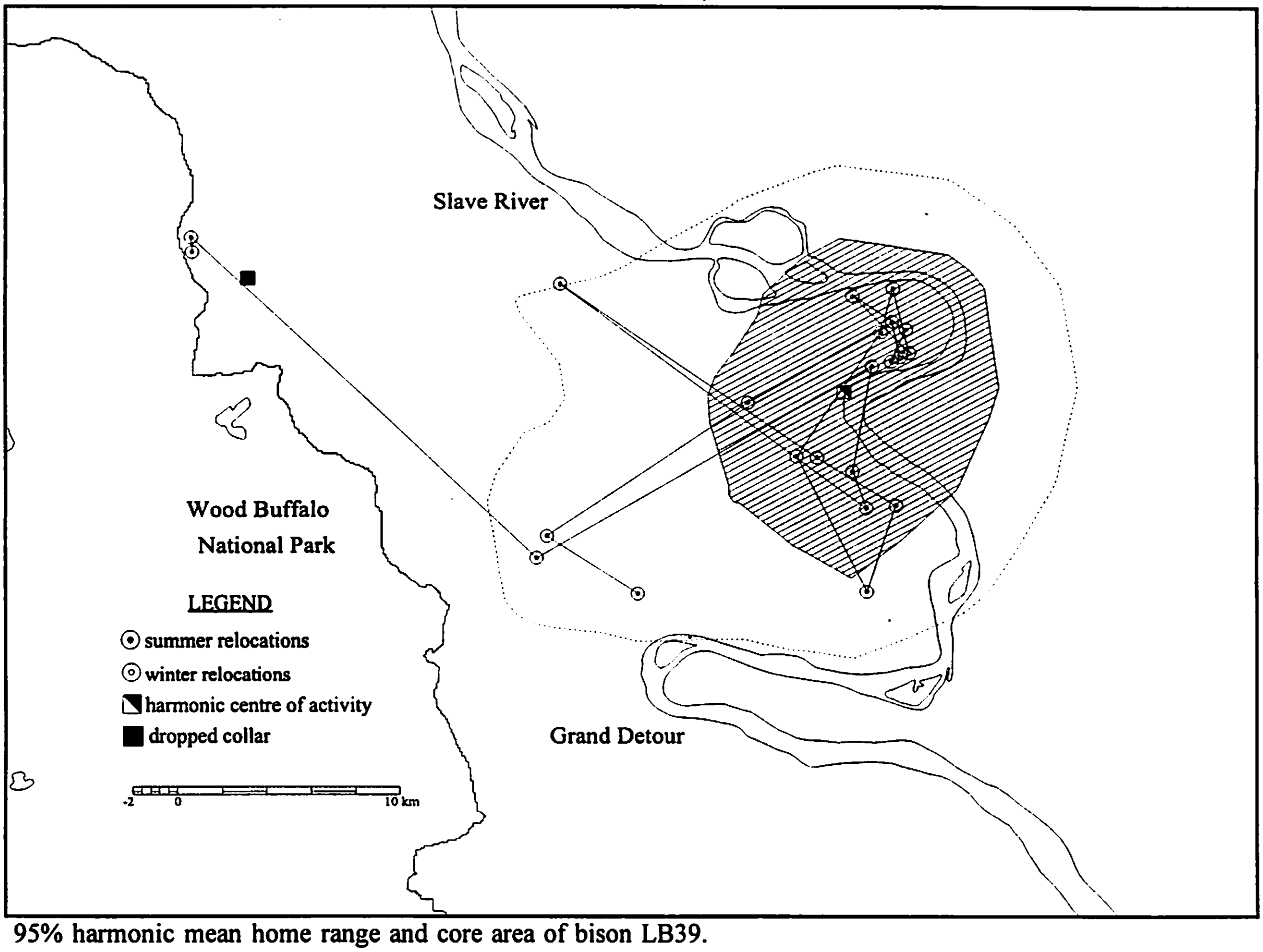
BISON: LB38
SEX: Male
RELOCATIONS: 48
95% HAR. HOME RANGE: 2412.7 km^2
CORE AREA: 748.3 km^2
START: 01SEP90
END: 13AUG92
FATE: Dropped Collar



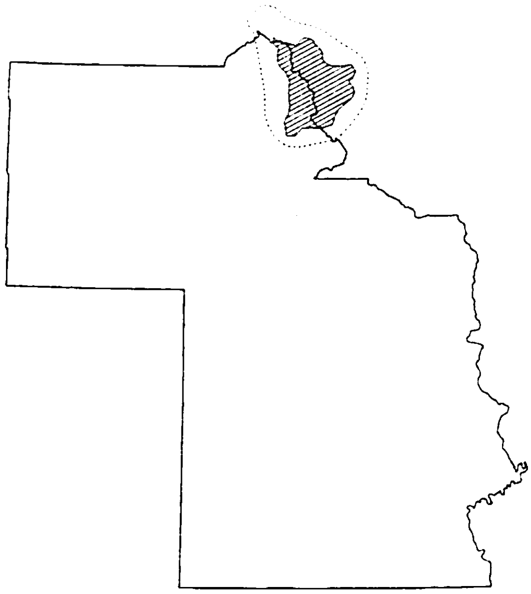
95% harmonic mean home range and core area of bison LB38.



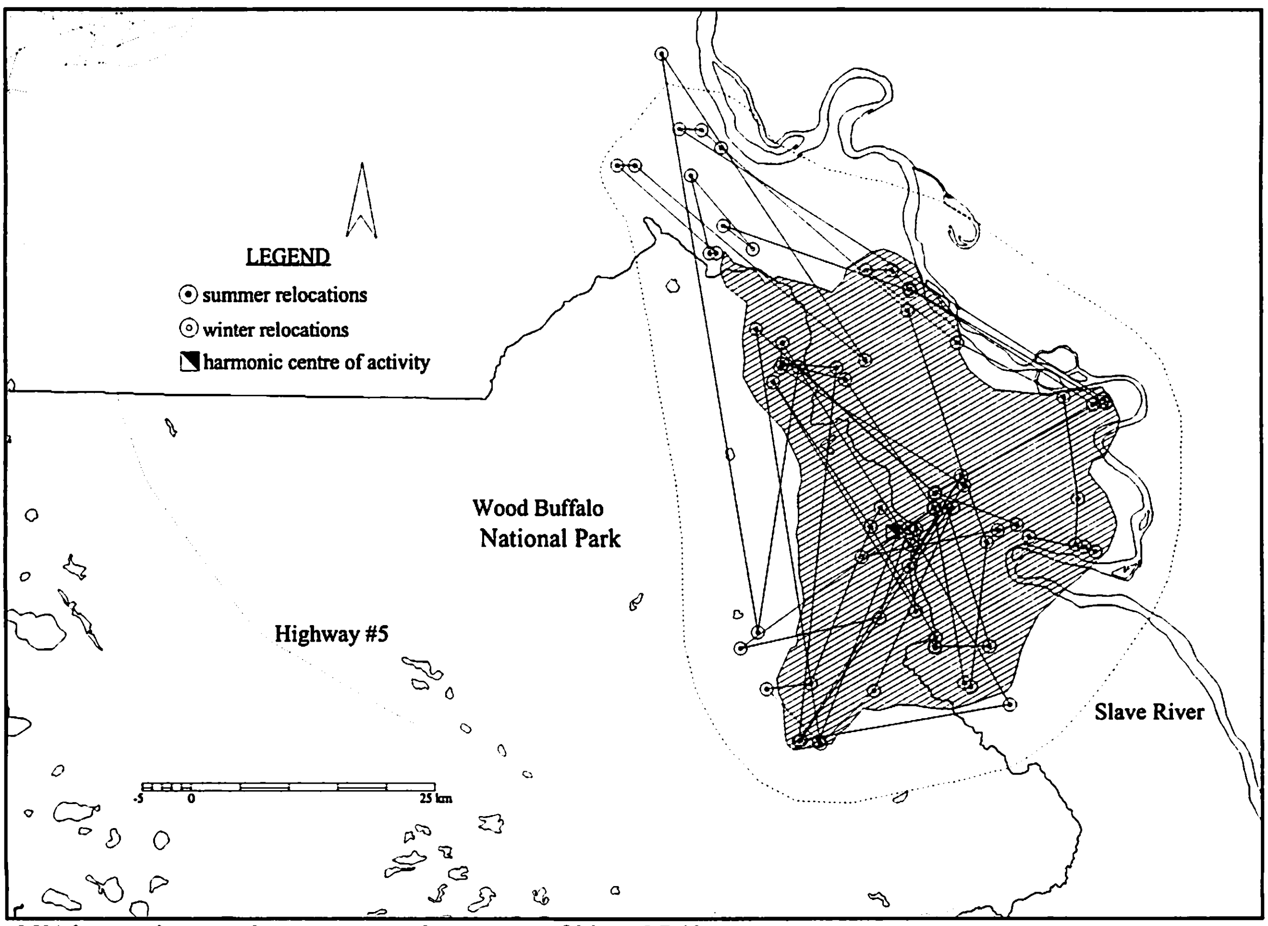
BISON: LB39
SEX: Male
RELOCATIONS: 22
95% HAR. HOME RANGE: 469.3 km²
CORE AREA: 148.1 km²
START: 01SEP90
END: 10JUL91
FATE: Dropped Collar



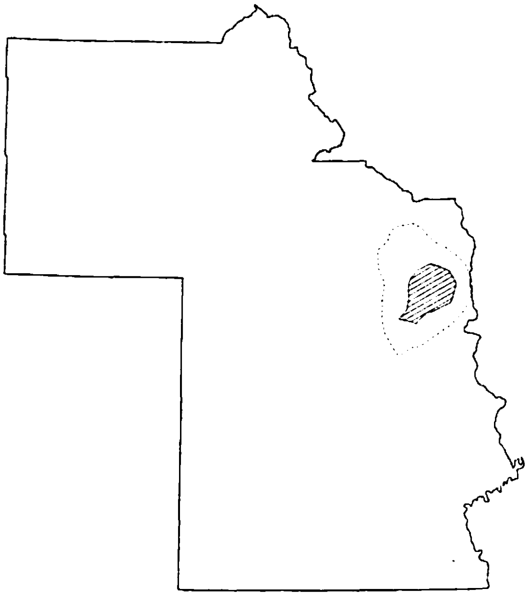
95% harmonic mean home range and core area of bison LB39.



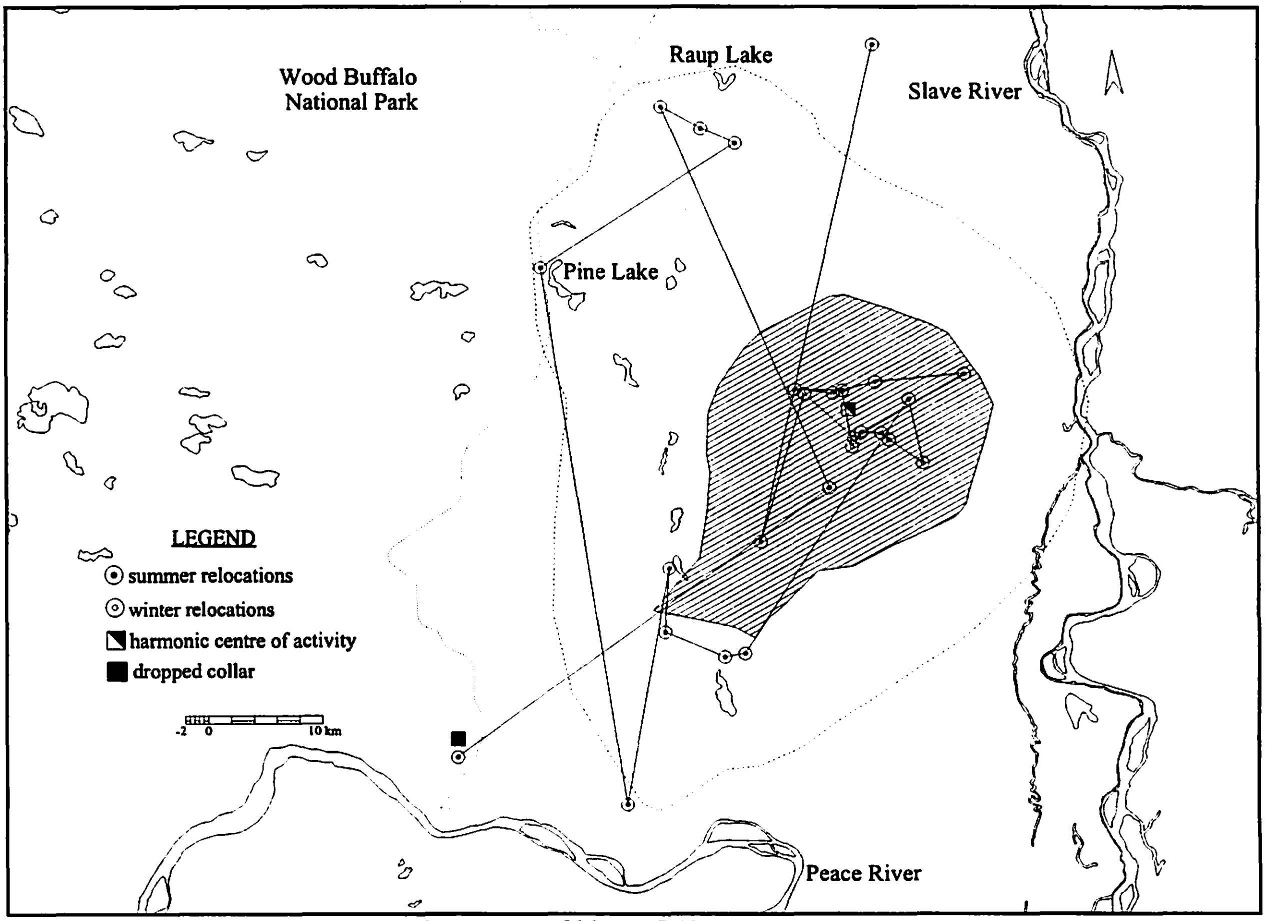
BISON: LB40
SEX: Female
RELOCATIONS: 76
95% HAR. HOME RANGE: 2967.4 km²
CORE AREA: 1242.7 km²
START: 01SEP90
END: 25SEP93
FATE: Active



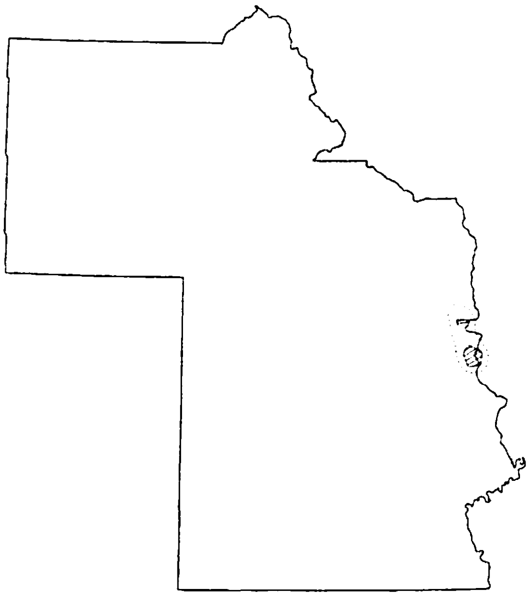
95% harmonic mean home range and core area of bison LB40.



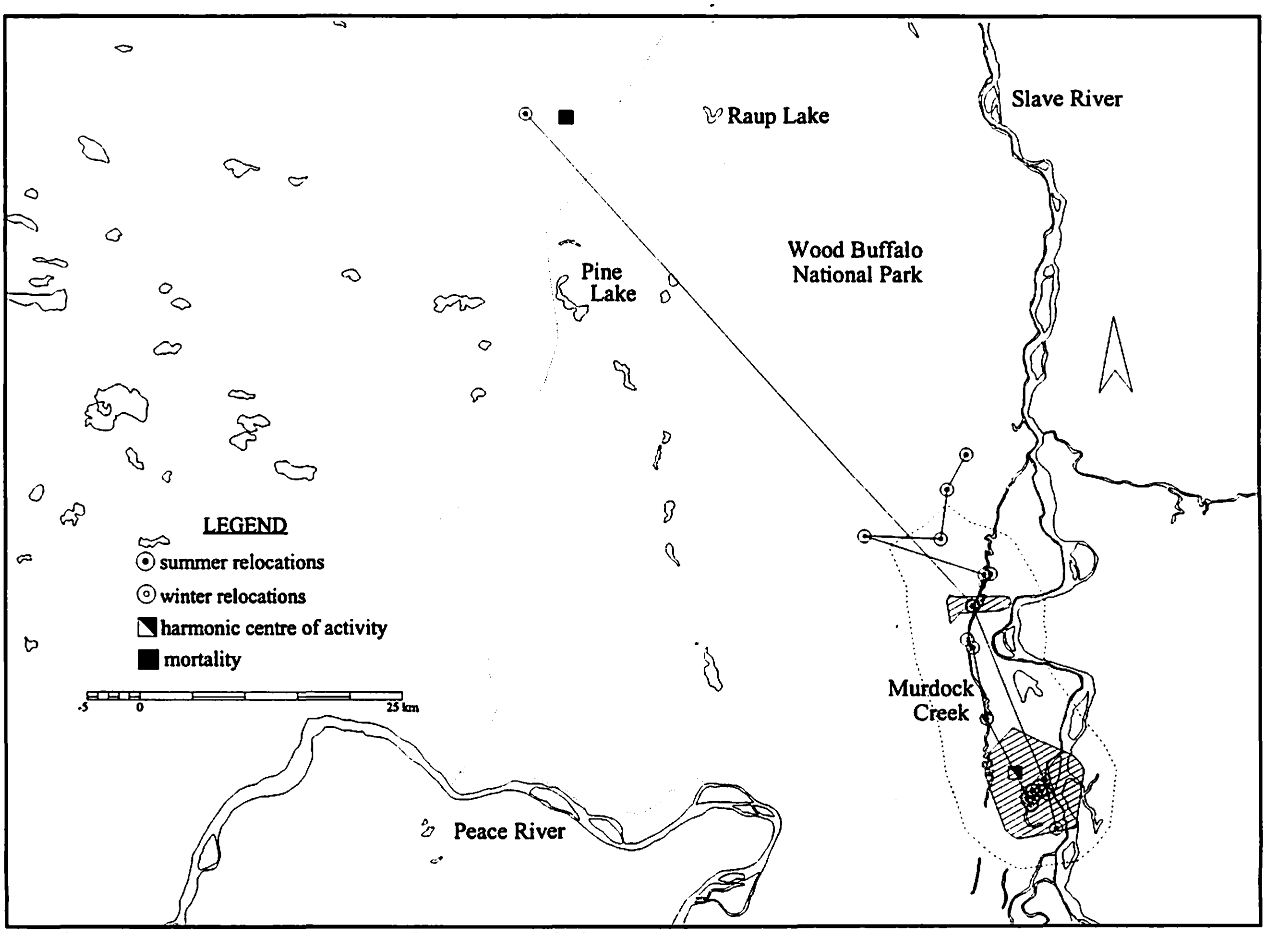
BISON: PL42
SEX: Male
RELOCATIONS: 26
95% HAR. HOME RANGE: 2119.8 km²
CORE AREA: 506.1 km²
START: 08SEP90
END: 02SEP91
FATE: Dropped collar



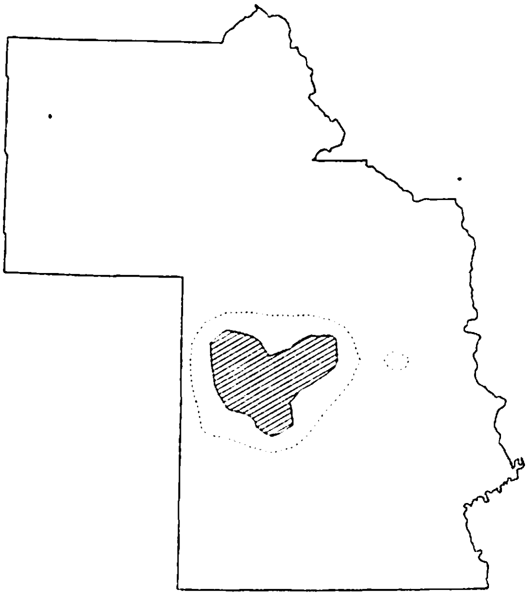
95% harmonic mean home range and core area of bison PL42.



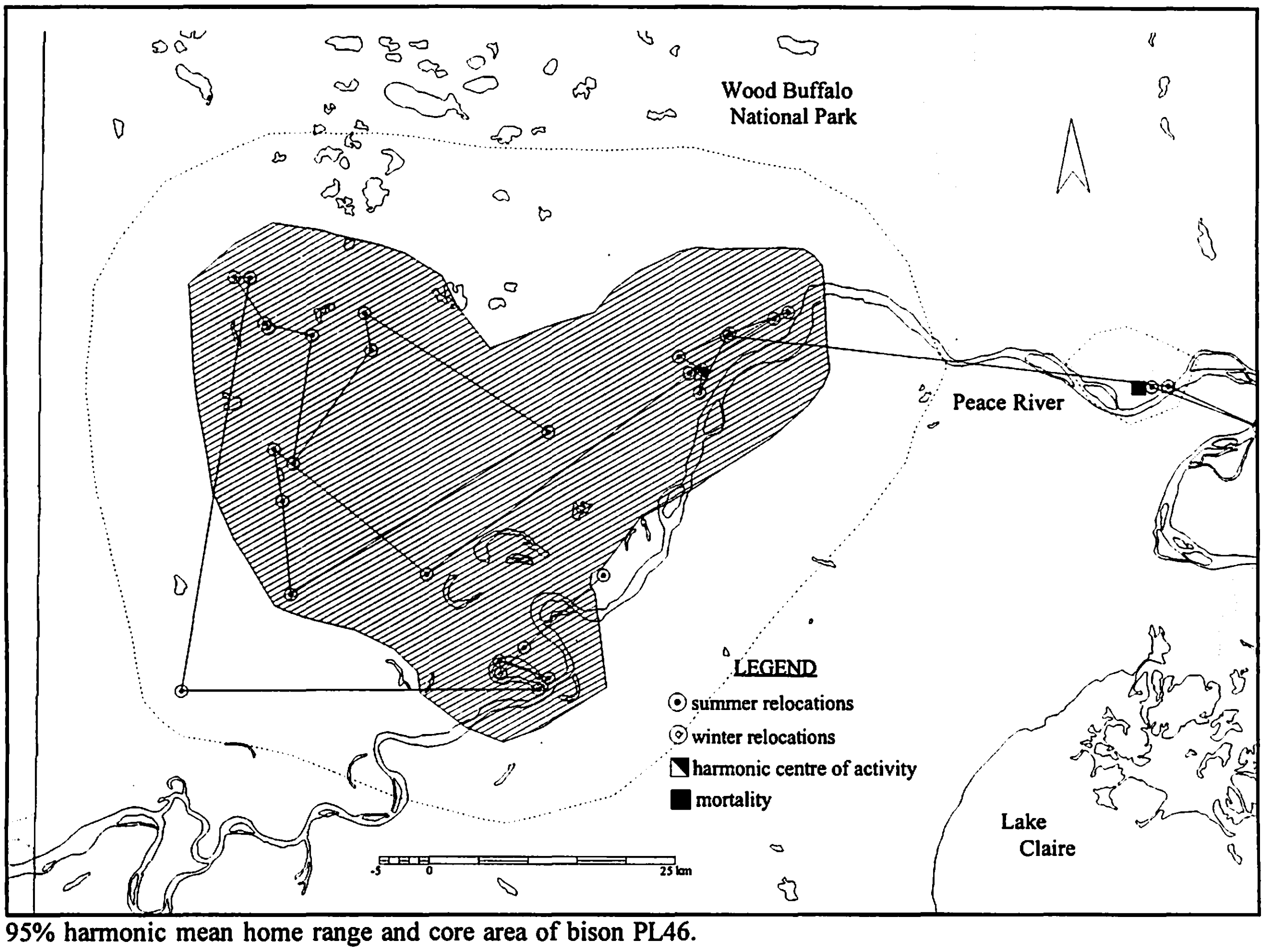
BISON: PL45
SEX: Male
RELOCATIONS: 22
95% HAR. HOME RANGE: 434.4 km^2
CORE AREA: 82.7 km^2
START: 08SEP90
END: 21JUL91
FATE: Anthrax



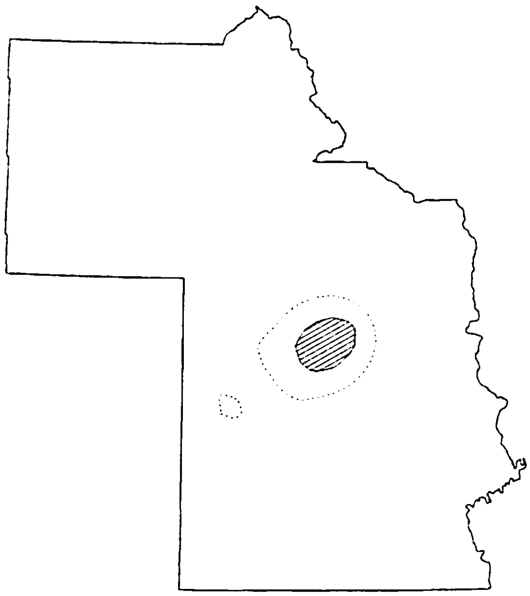
95% harmonic mean home range and core area of bison PL45.



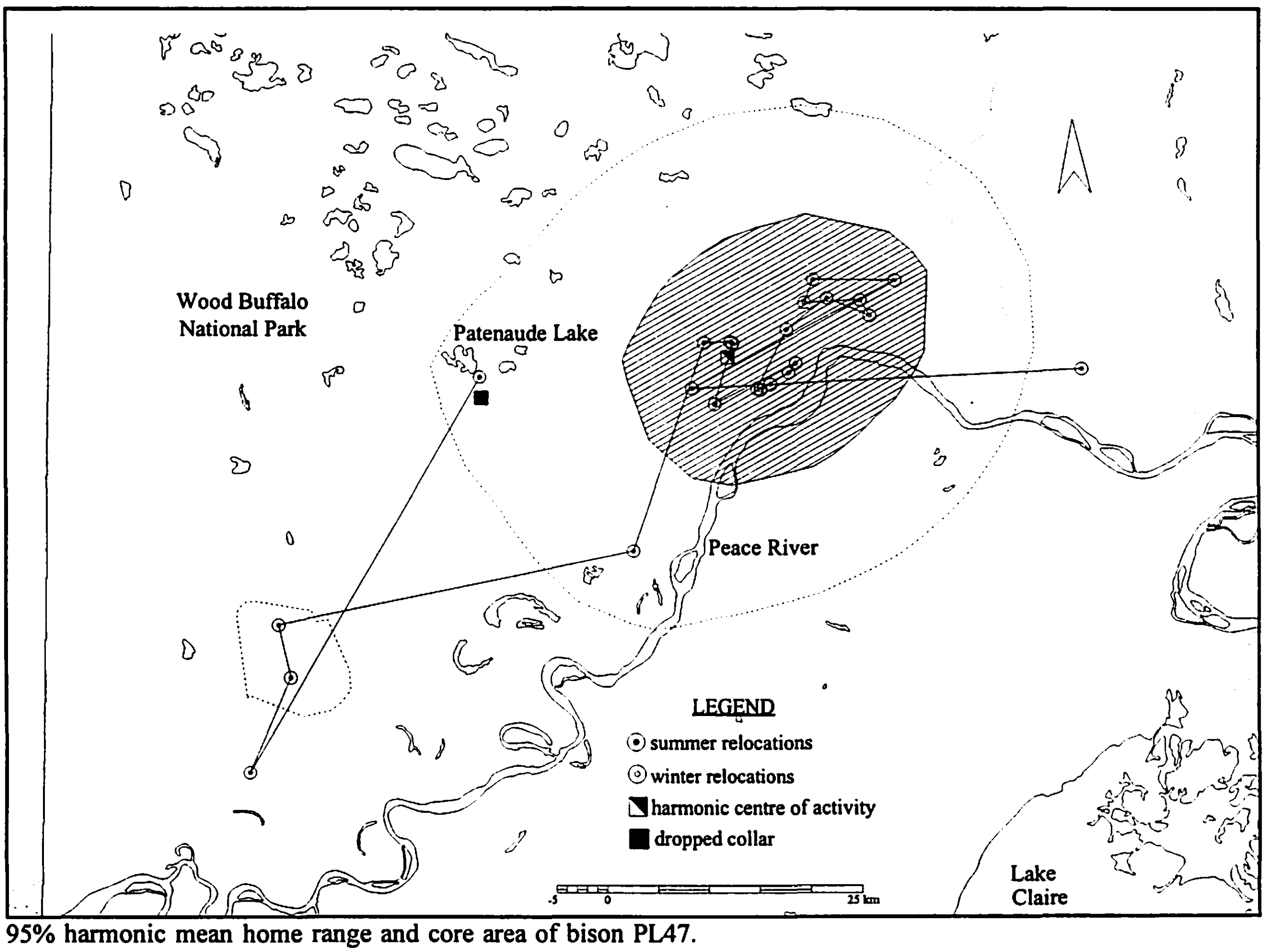
BISON: PL46
SEX: Female
RELOCATIONS: 31
95% HAR. HOME RANGE: 4568.7 km²
CORE AREA: 1984.6 km²
START: 29SEP90
END: 15MAR92
FATE: Wolf Predation



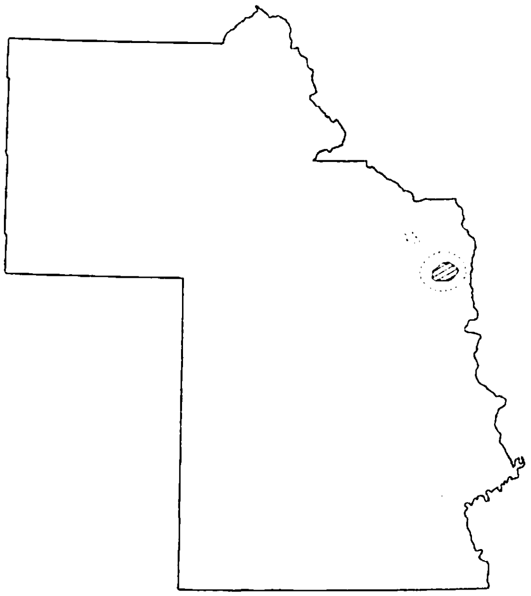
95% harmonic mean home range and core area of bison PL46.



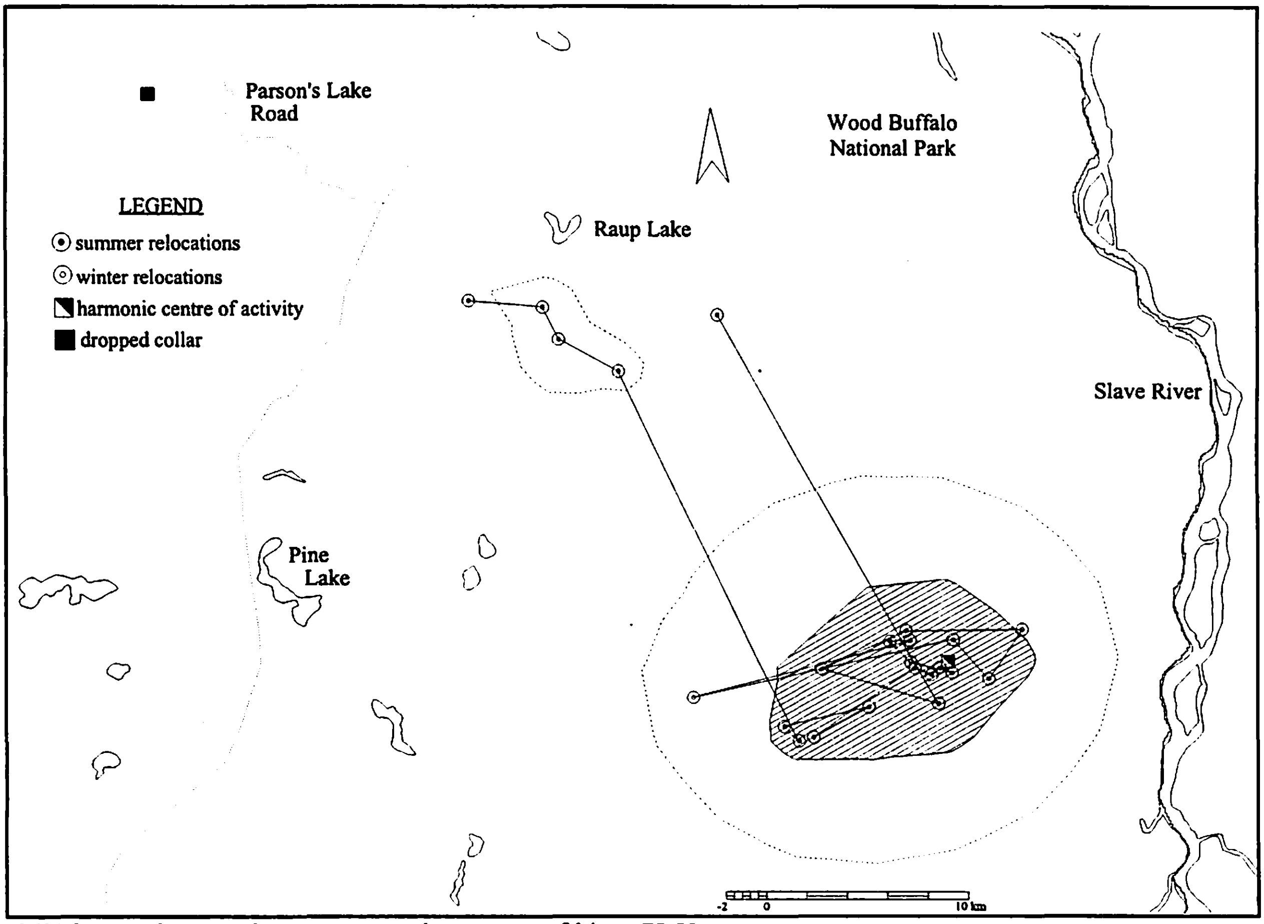
BISON: PL47
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 2312.4 km²
CORE AREA: 586.2 km²
START: 08SEP90
END: 21JUL91
FATE: Dropped Collar



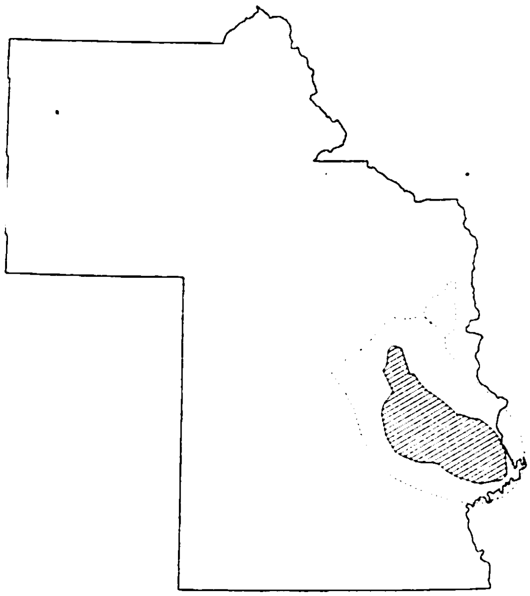
95% harmonic mean home range and core area of bison PL47.



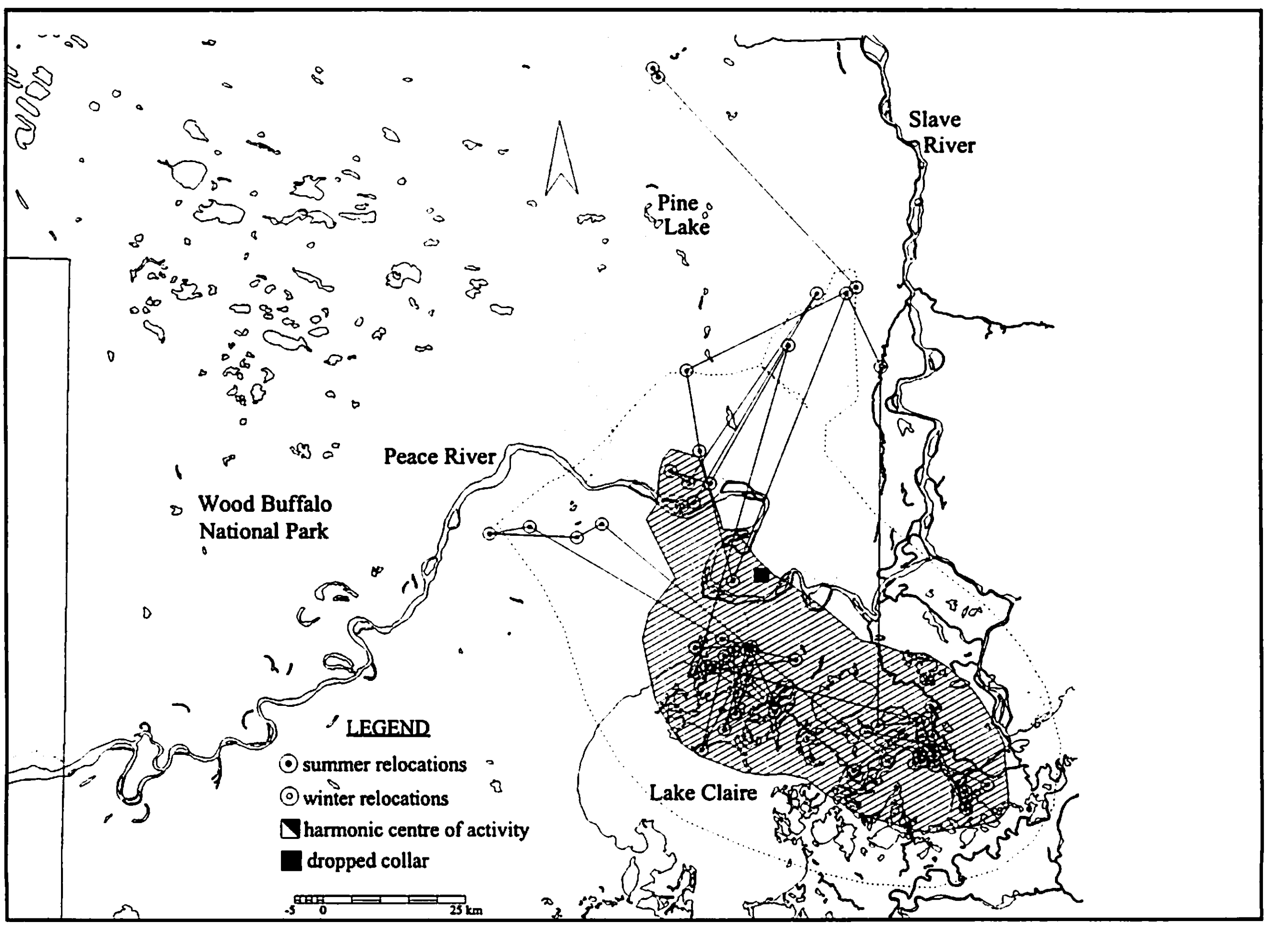
BISON: PL50
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 379.6 km^2
CORE AREA: 88.1 km^2
START: 08SEP90
END: 21JUL91
FATE: Dropped collar



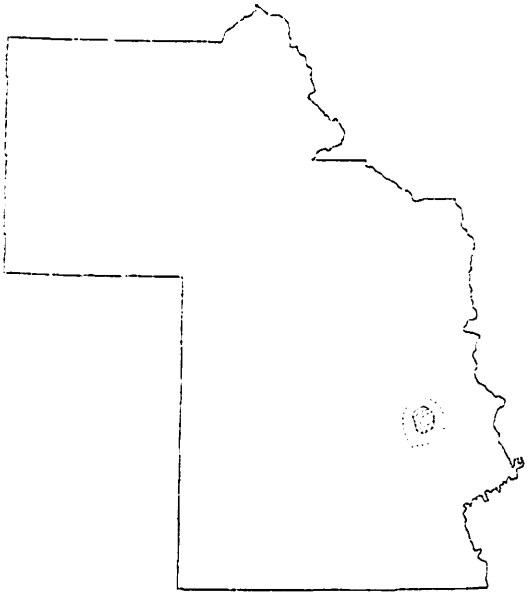
95% harmonic mean home range and core area of bison PL50.



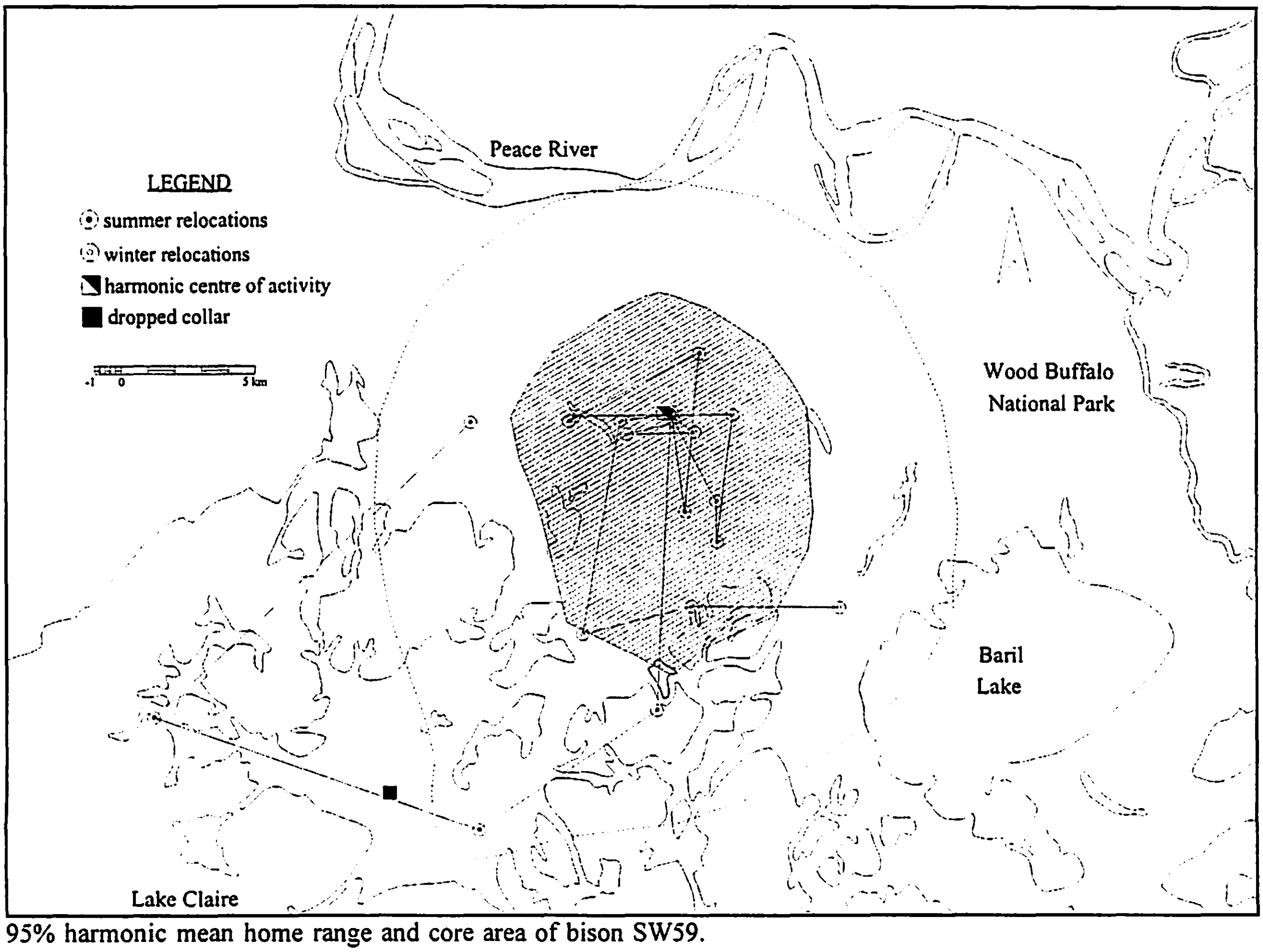
BISON: PL57
SEX: Female
RELOCATIONS: 58
95% HAR. HOME RANGE: 5818.9 km^2
CORE AREA: 2101.7 km^2
START: 01SEP90
END: 21JUL91
FATE: Dropped Collar



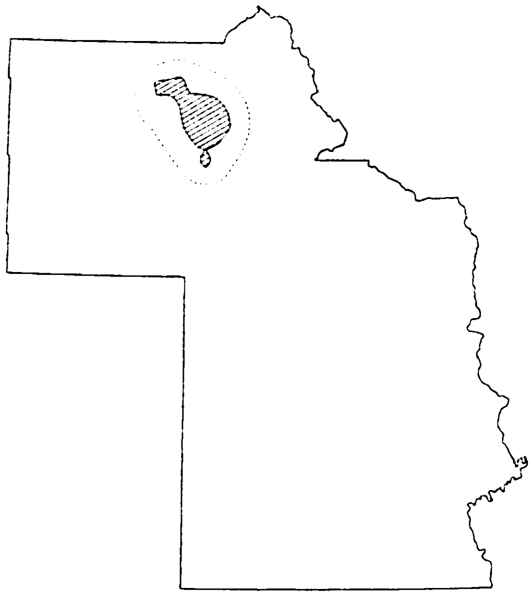
95% harmonic mean home range and core area of bison PL57.



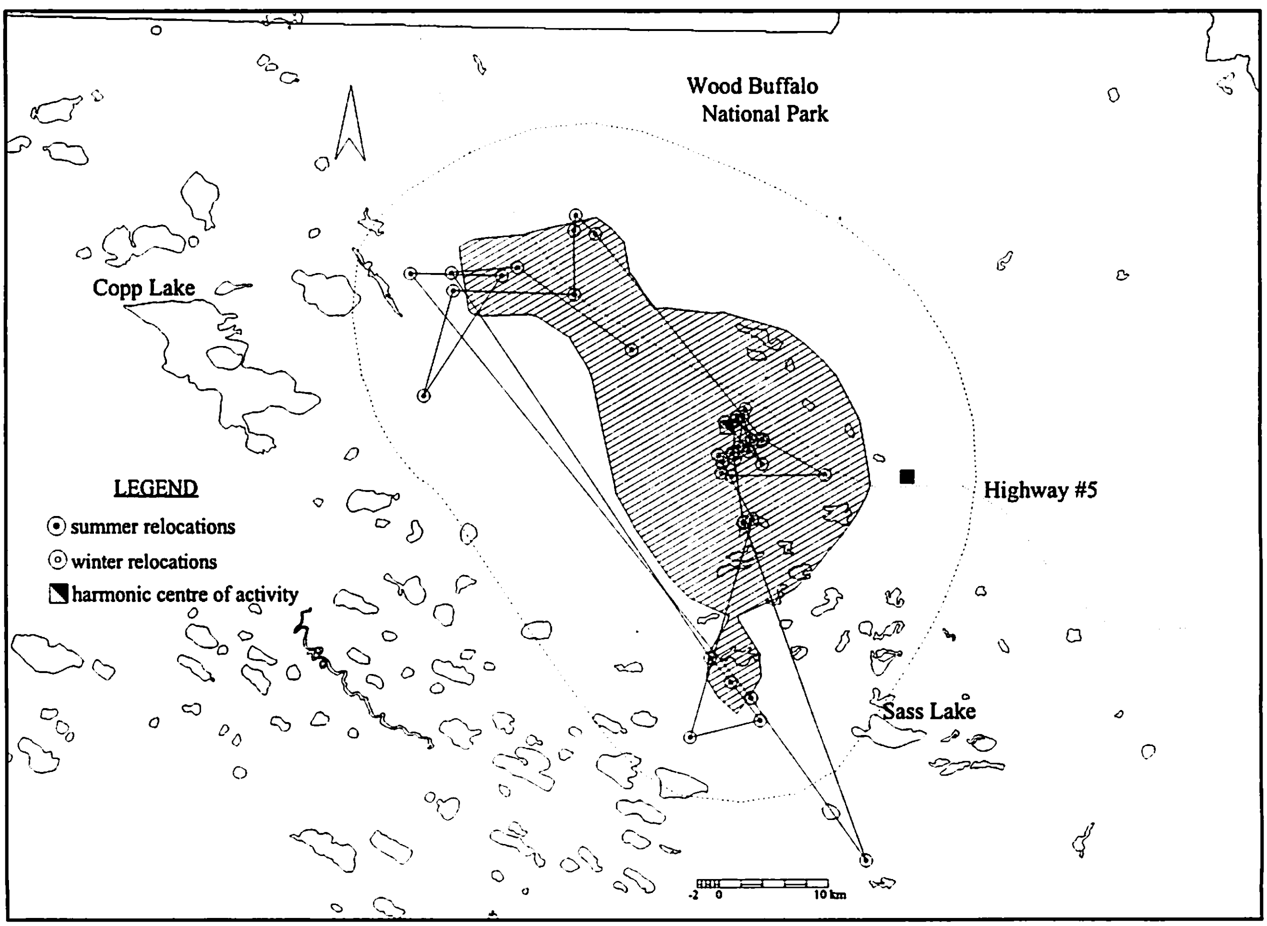
BISON: SW59
SEX: Male
RELOCATIONS: 20
95% HAR. HOME RANGE: 404.6 km^2
CORE AREA: 109.9 km^2
START: 05NOV90
END: 21JUL91
FATE: Dropped Collar



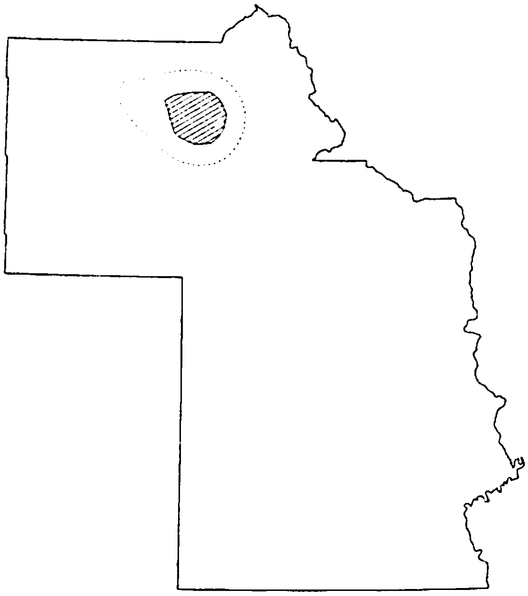
95% harmonic mean home range and core area of bison SW59.



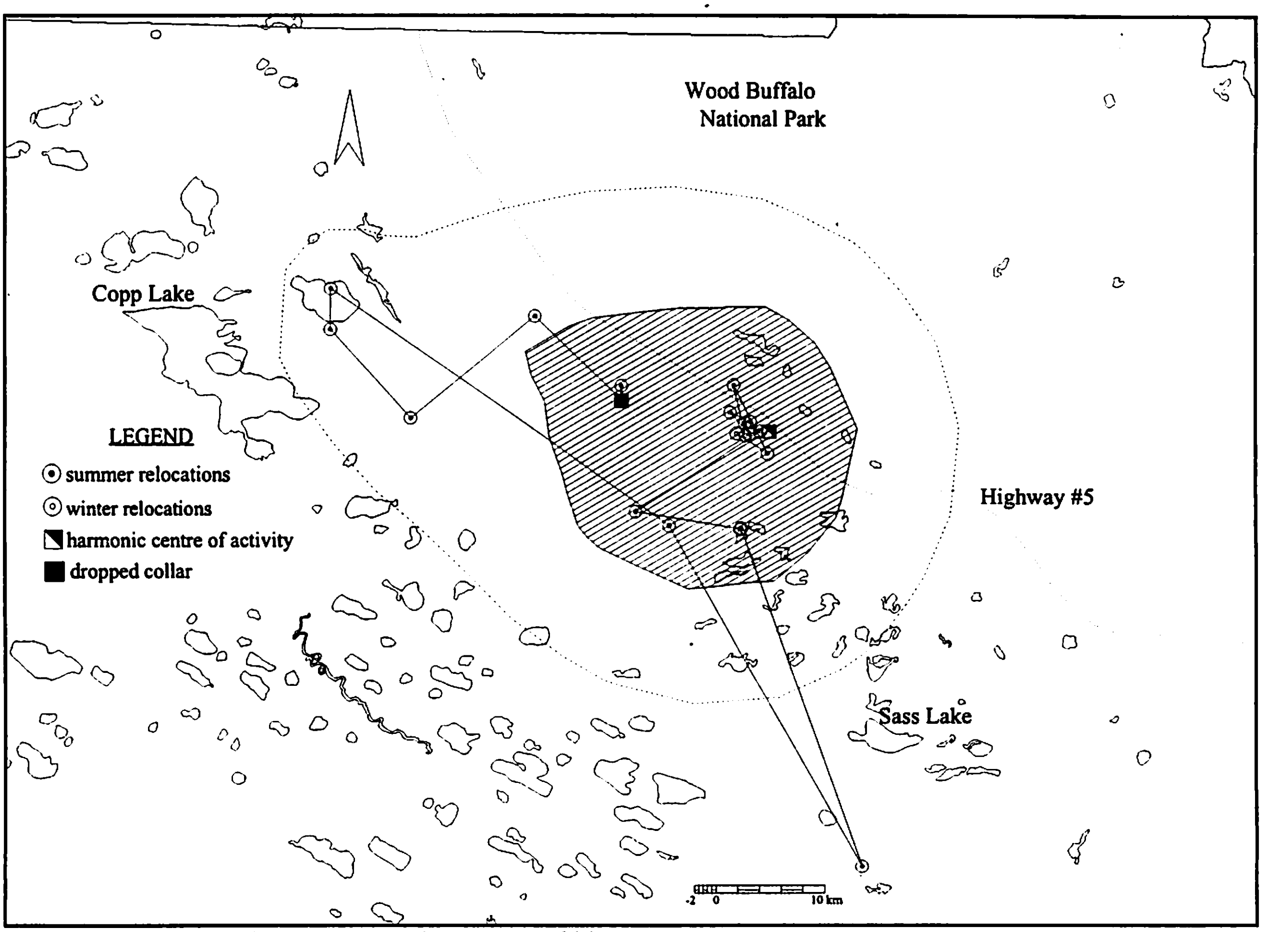
BISON: NL60
SEX: Male
RELOCATIONS: 41
95% HAR. HOME RANGE: 2448.5 km²
CORE AREA: 683.2 km²
START: 04DEC90
END: 31JUL92
FATE: Collar Failure



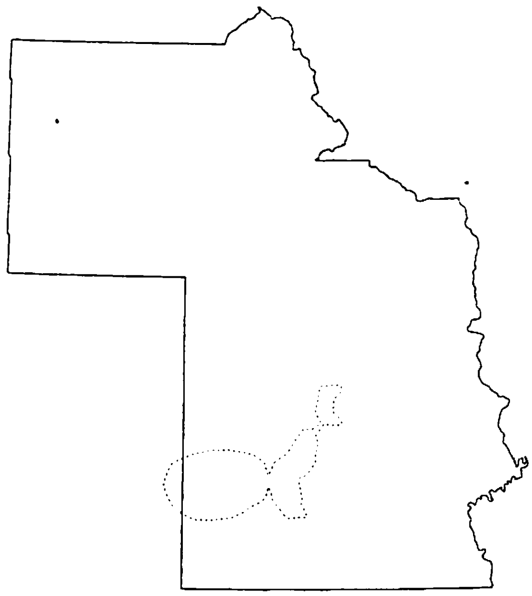
95% harmonic mean home range and core area of bison NL60.



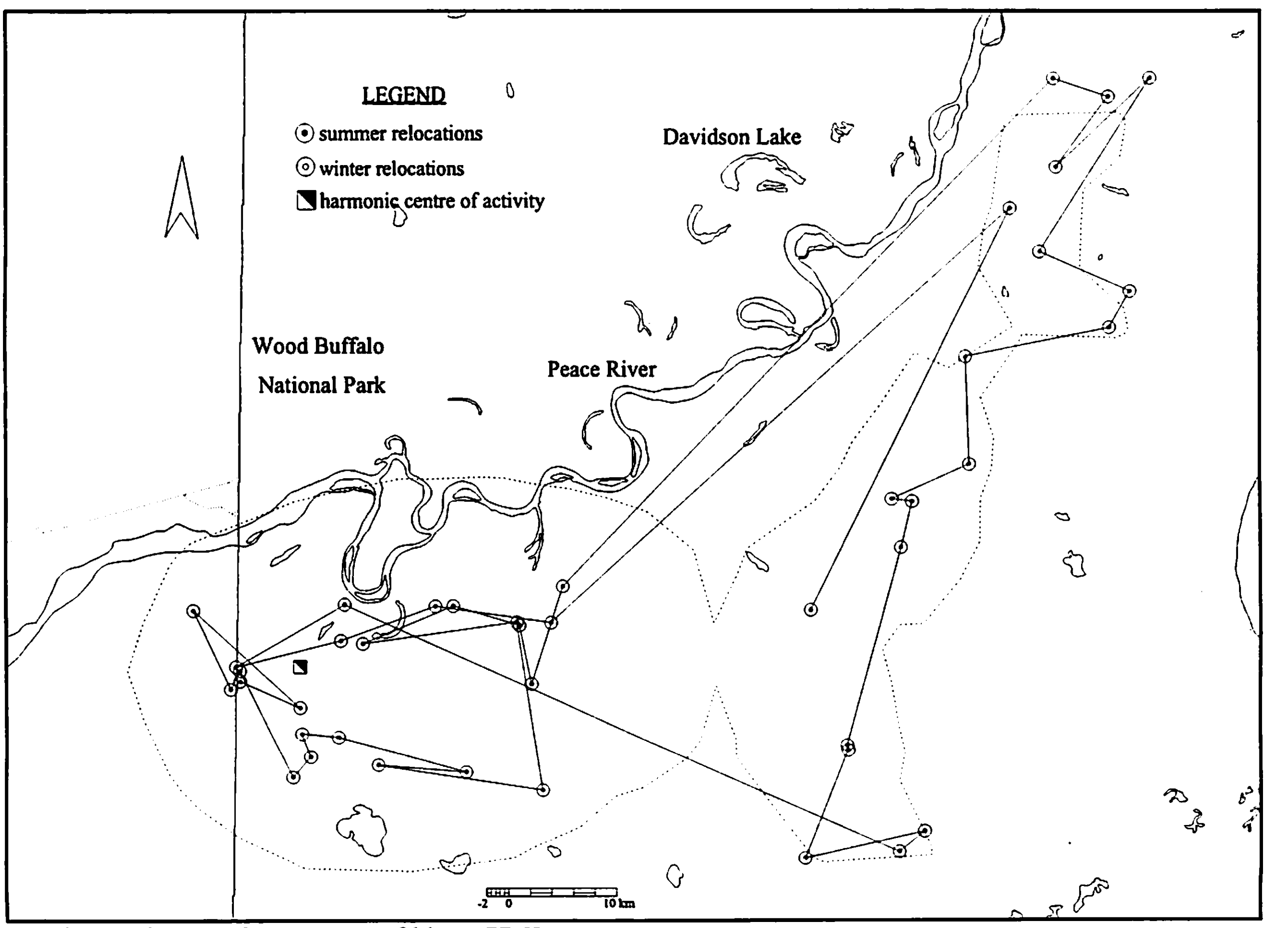
BISON: NL61
SEX: Male
RELOCATIONS: 20
95% HAR. HOME RANGE: 2140.2 km^2
CORE AREA: 598.5 km^2
START: 04DEC90
END: 22AUG91
FATE: Dropped Collar



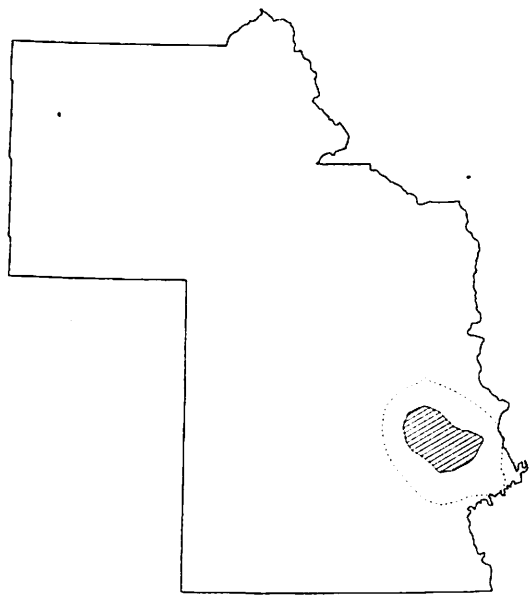
95% harmonic mean home range and core area of bison NL61.



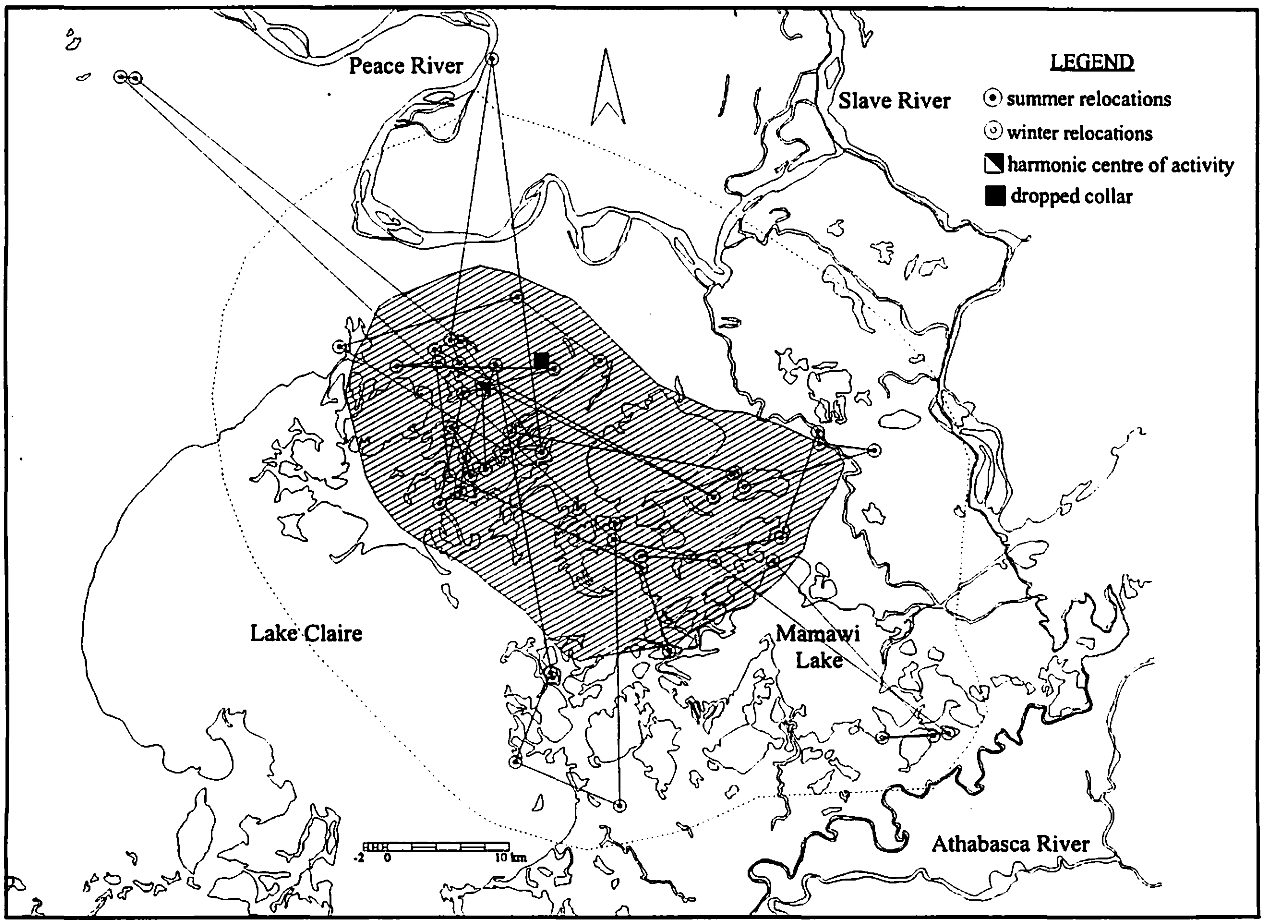
BISON: GR62
SEX: Male
RELOCATIONS: 42
95% HAR. HOME RANGE: 2278.1 km²
CORE AREA: none
START: 14SEP90
END: 20AUG91
FATE: Collar Failure



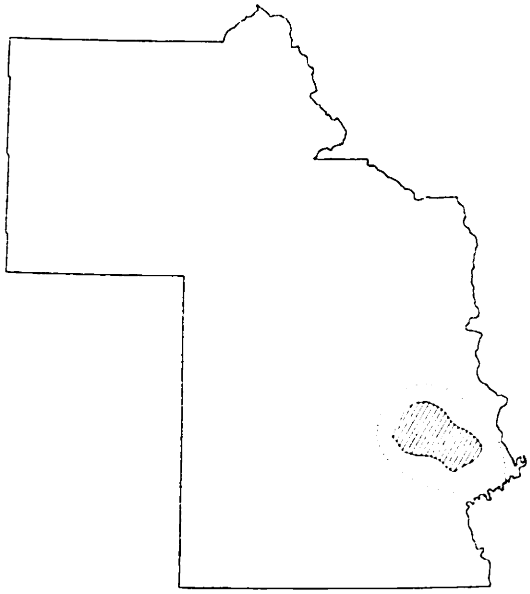
95% harmonic mean home range of bison GR62.



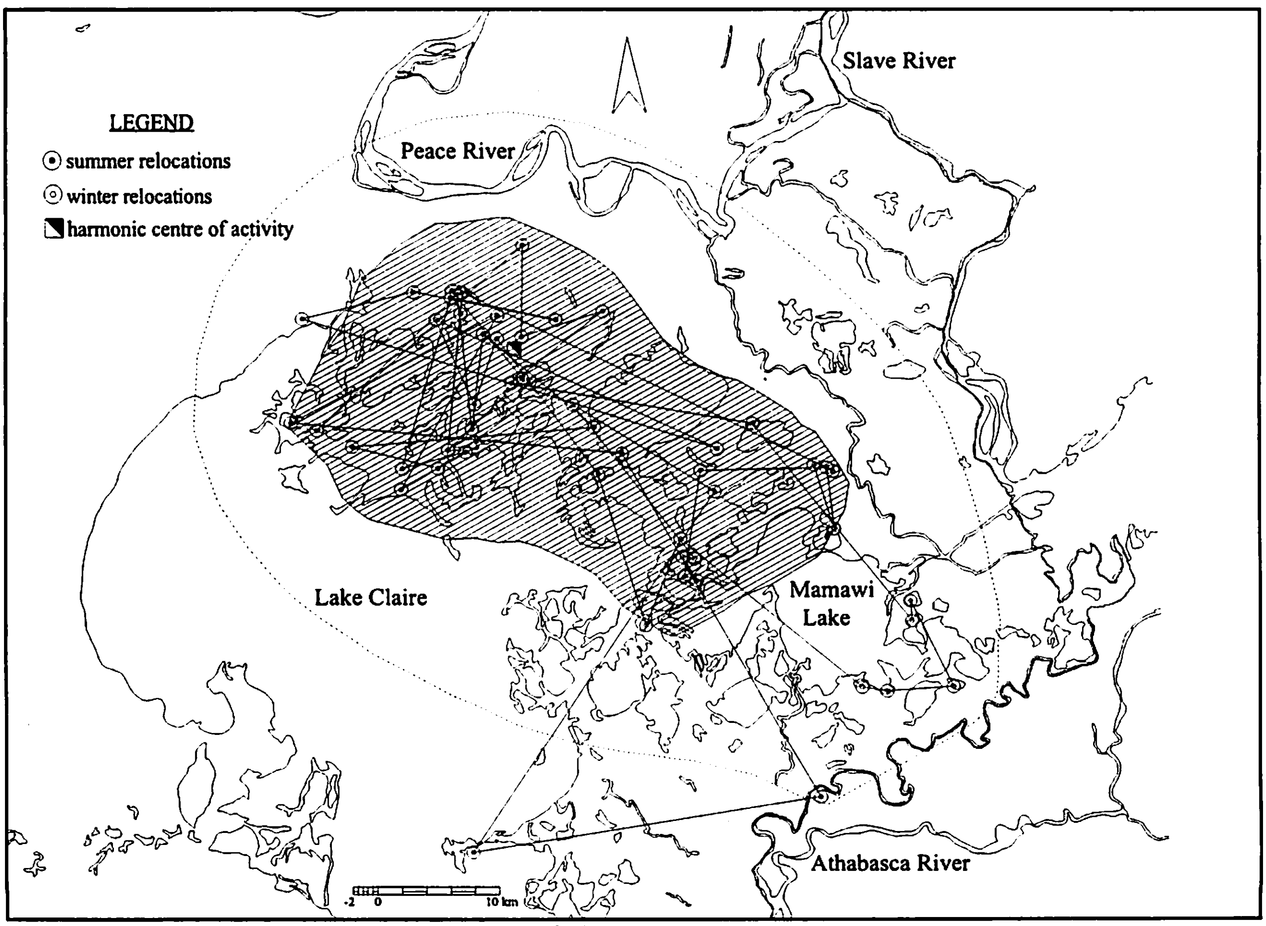
BISON: SW63
SEX: Female
RELOCATIONS: 23
95% HAR. HOME RANGE: 2815.8 km²
CORE AREA: 802.3 km²
START: 08AUG91
END: 01AUG93
FATE: Dropped collar



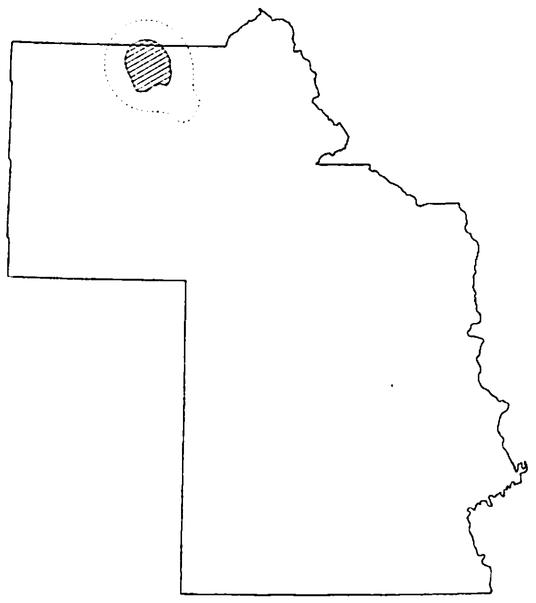
95% harmonic mean home range and core area of bison SW63.



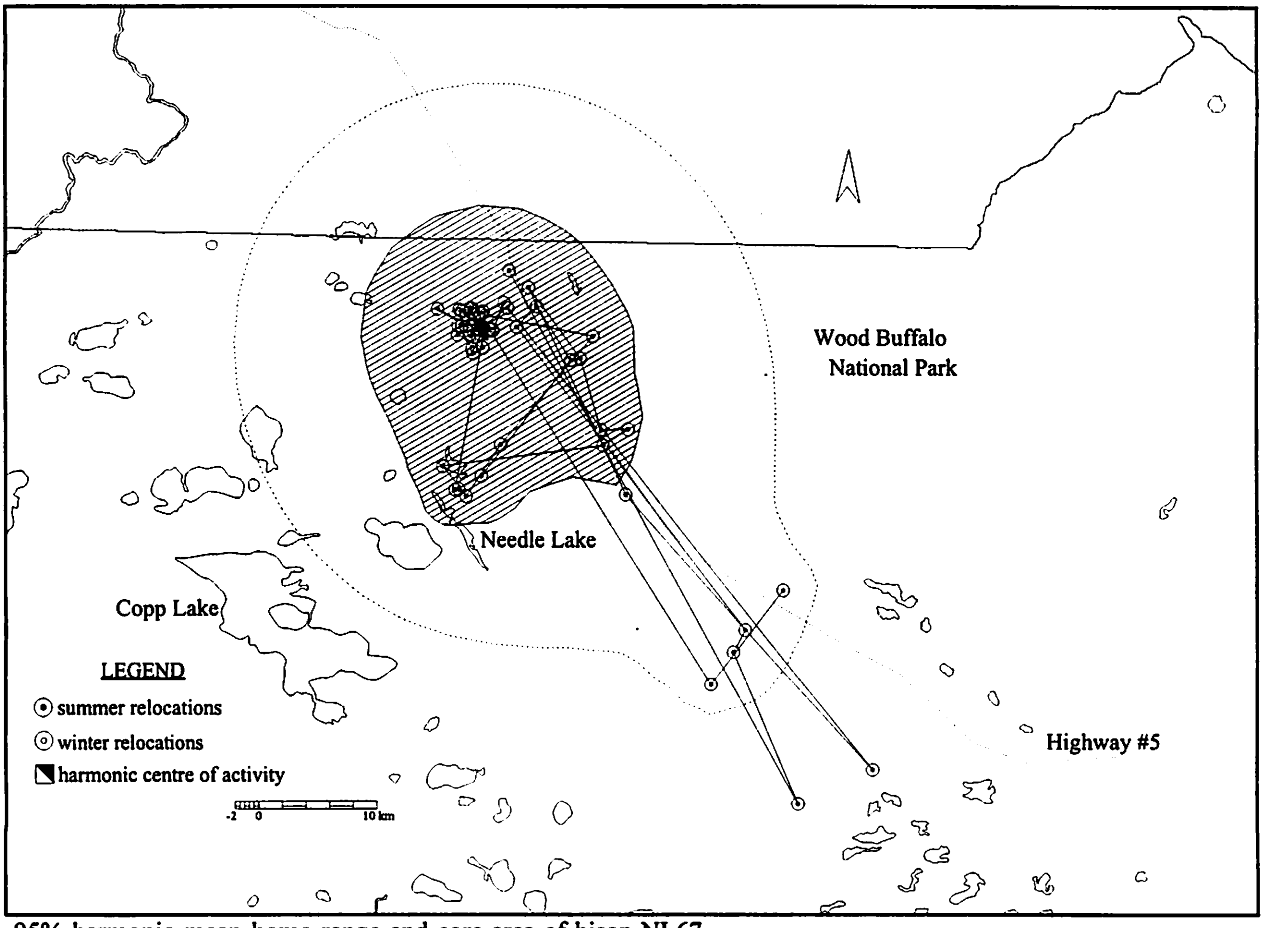
BISON: SW64
SEX: Female
RELOCATIONS: 53
95% HAR. HOME RANGE: 2611.6 km^2
CORE AREA: 912.5 km^2
START: 08AUG91
END: 24SEP93
FATE: Active



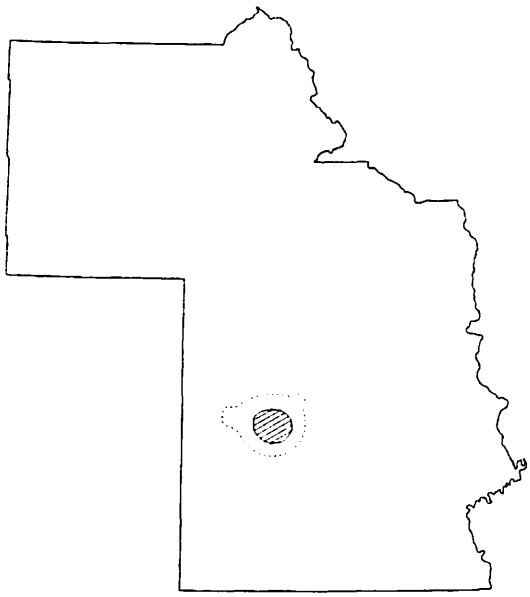
95% harmonic mean home range and core area of bison SW64.



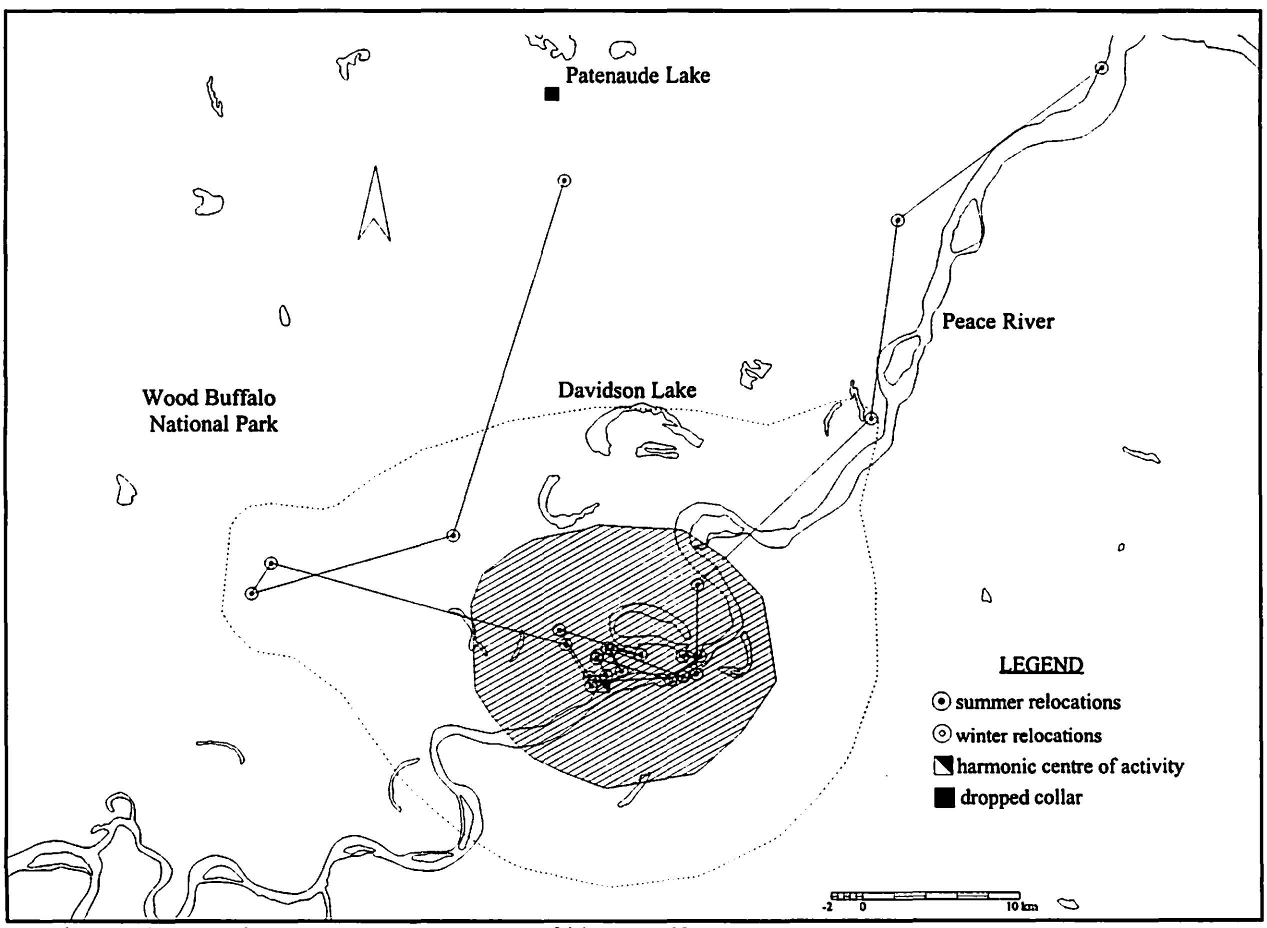
BISON: NL67
SEX: Male
RELOCATIONS: 54
95% HAR. HOME RANGE: 1717.9 km^2
CORE AREA: 440.3 km^2
START: 08AUG91
END: 25SEP93
FATE: Active



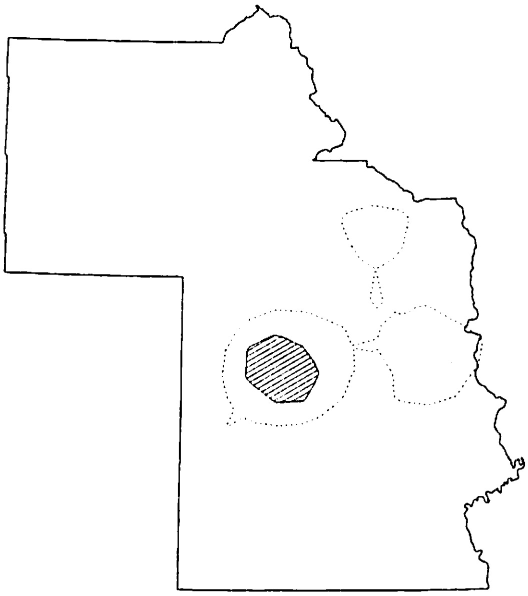
95% harmonic mean home range and core area of bison NL67.



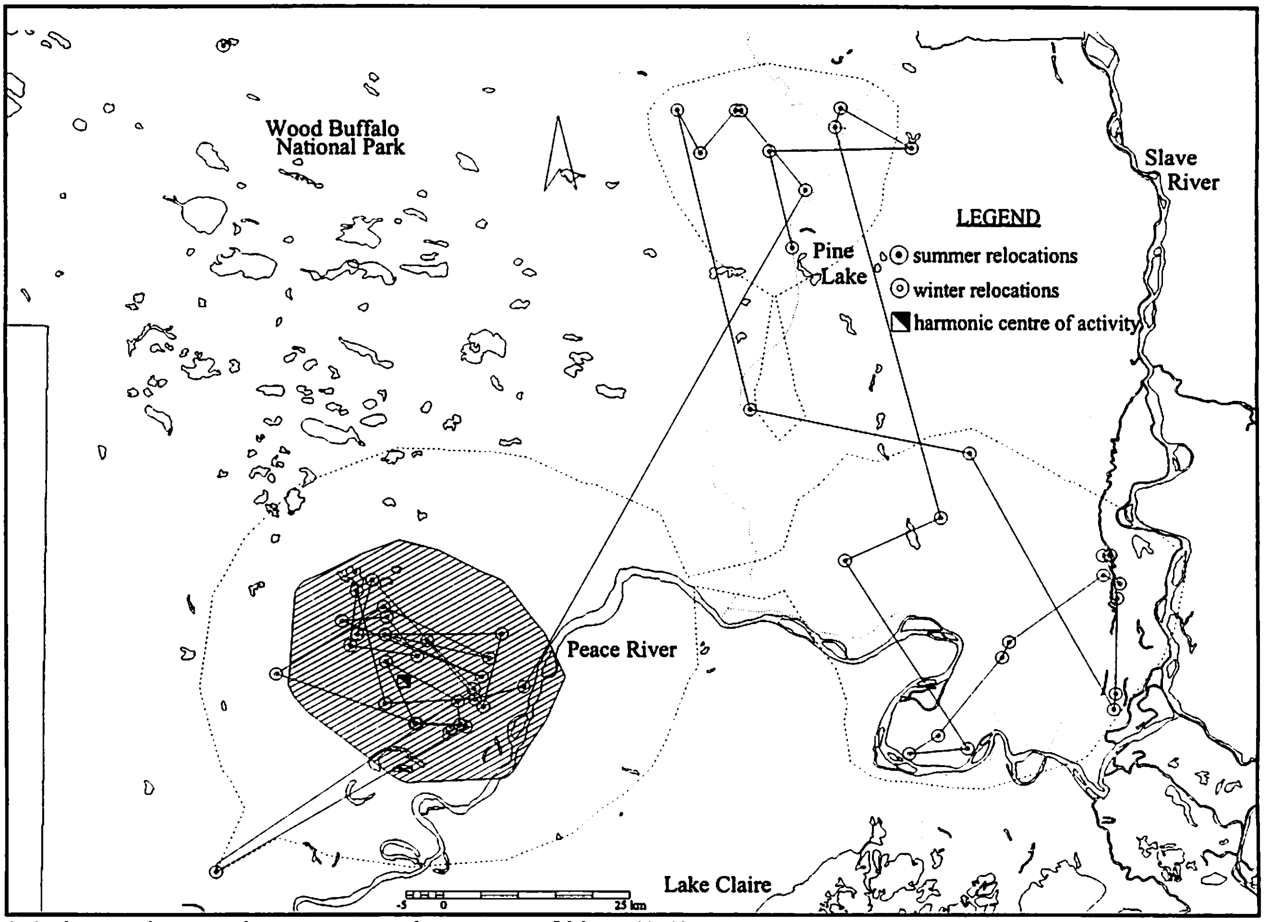
BISON: PL68
SEX: Male
RELOCATIONS: 25
95% HAR. HOME RANGE: 938.1 km²
CORE AREA: 255.0 km²
START: 08AUG91
END: 29JUL92
FATE: Dropped Collar



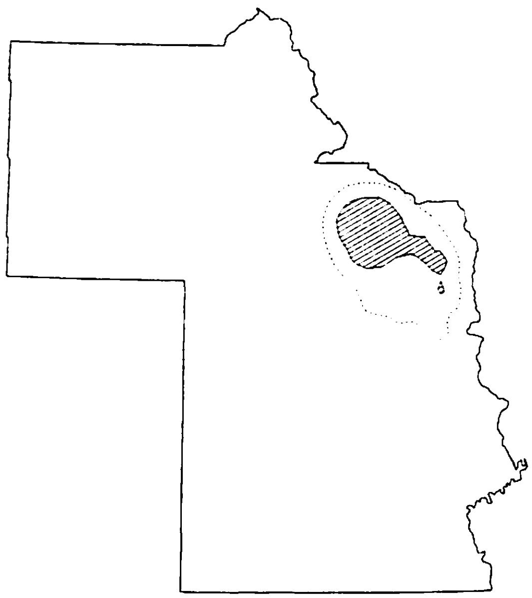
95% harmonic mean home range and core area of bison PL68.



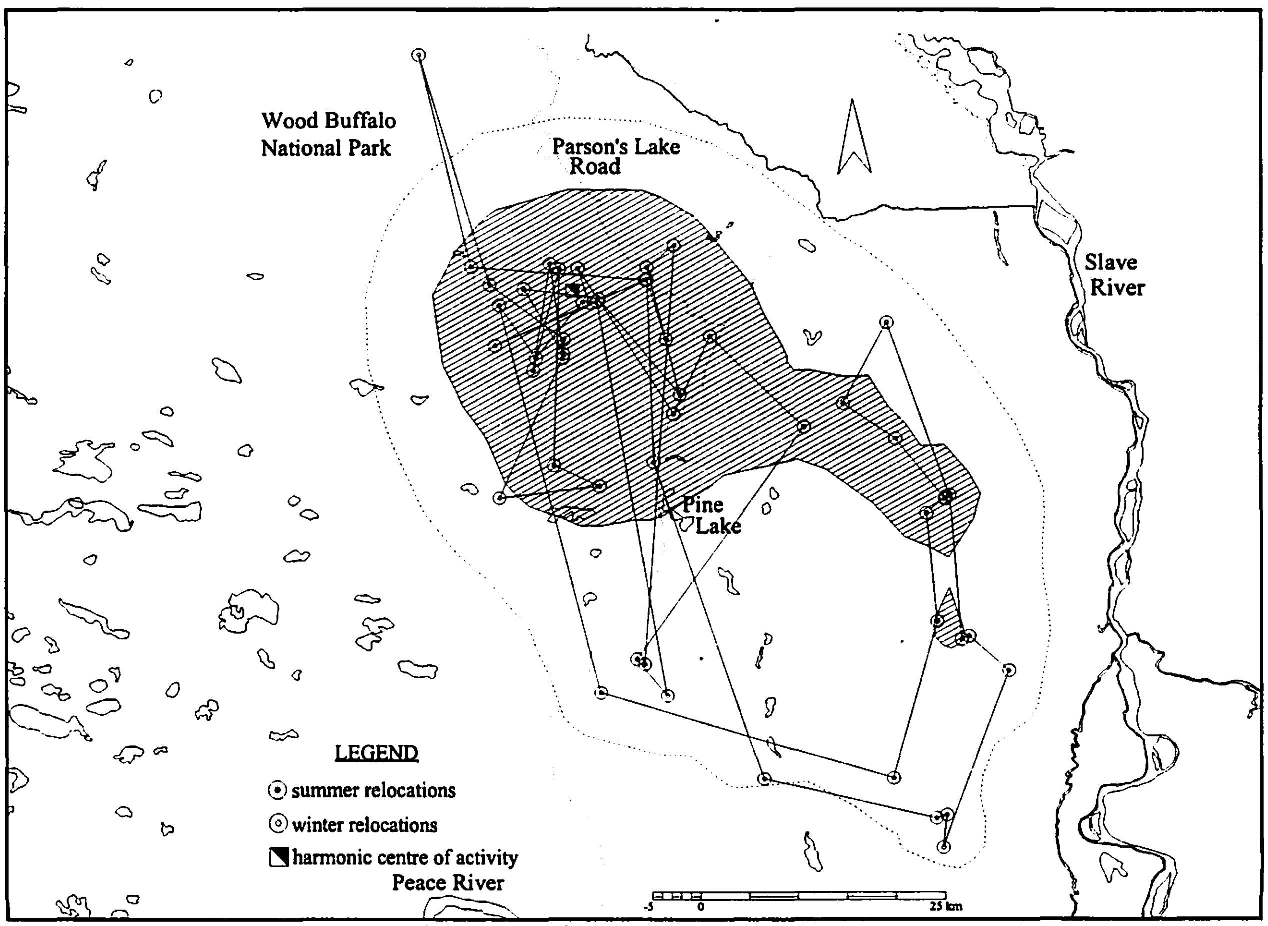
BISON: PL70
SEX: Female
RELOCATIONS: 53
95% HAR. HOME RANGE: 5731.7 km²
CORE AREA: 884.1 km²
START: 08AUG91
END: 24SEP93
FATE: Active



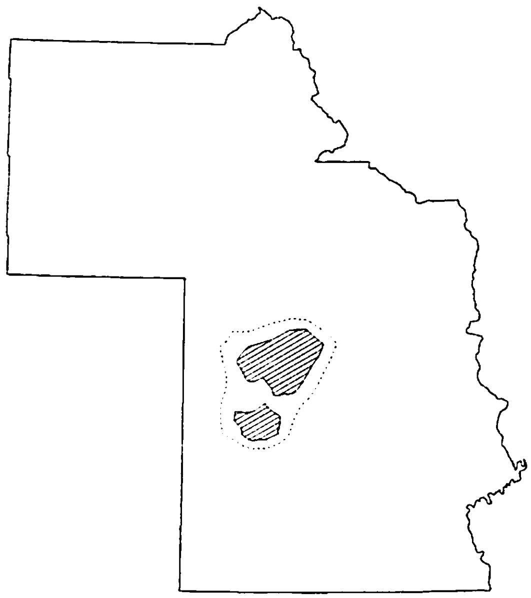
95% harmonic mean home range and core area of bison PL70.



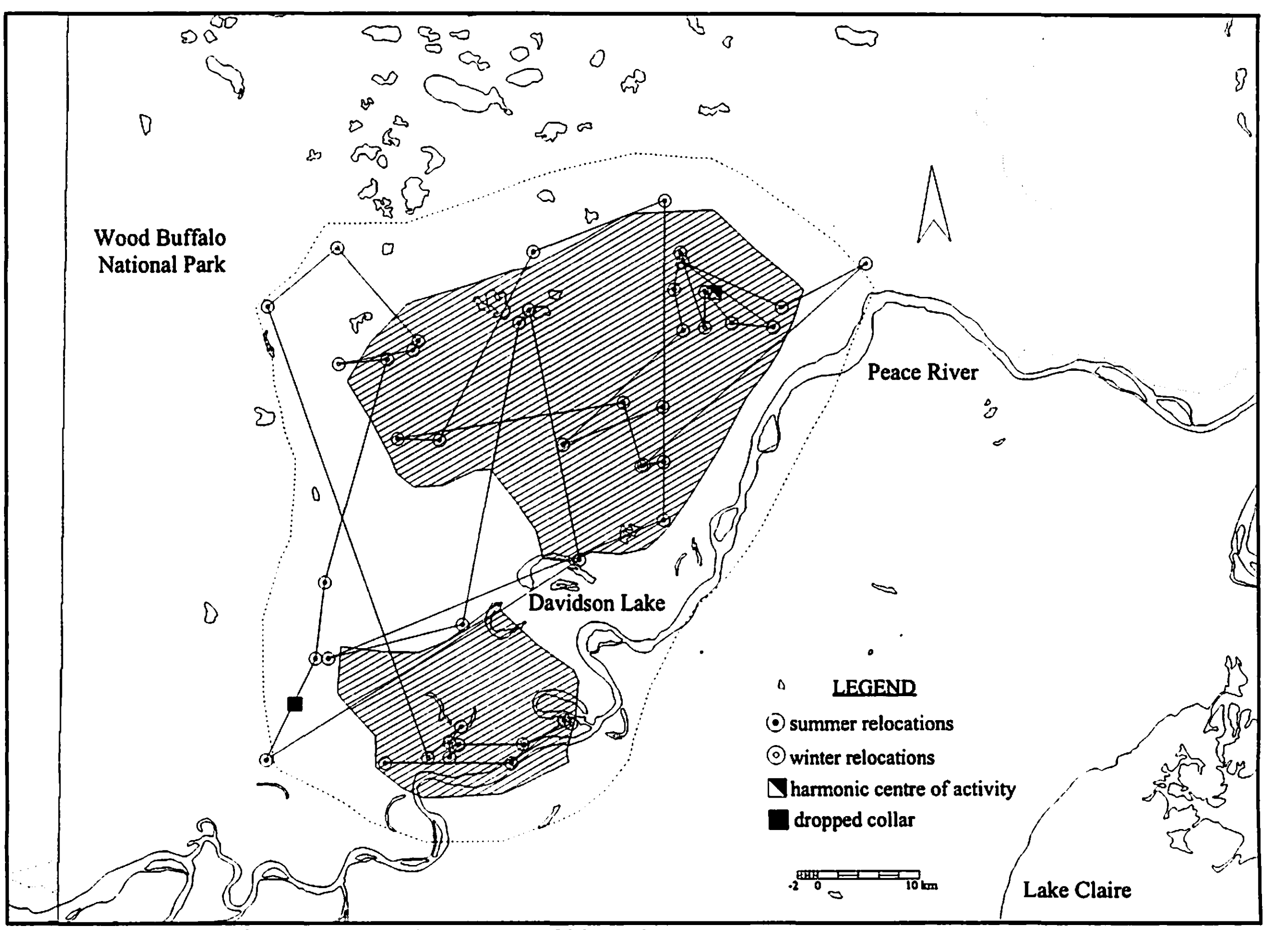
BISON: PL71
SEX: Female
RELOCATIONS: 52
95% HAR. HOME RANGE: 3594.8 km²
CORE AREA: 1161.0 km²
START: 08AUG91
END: 24SEP93
FATE: Active



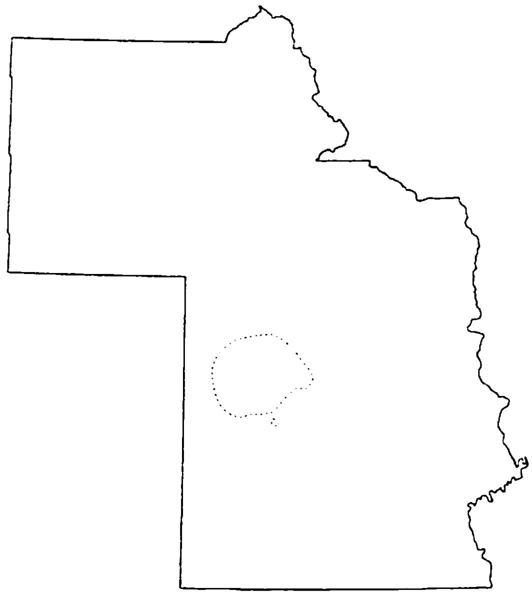
95% harmonic mean home range and core area of bison PL71.



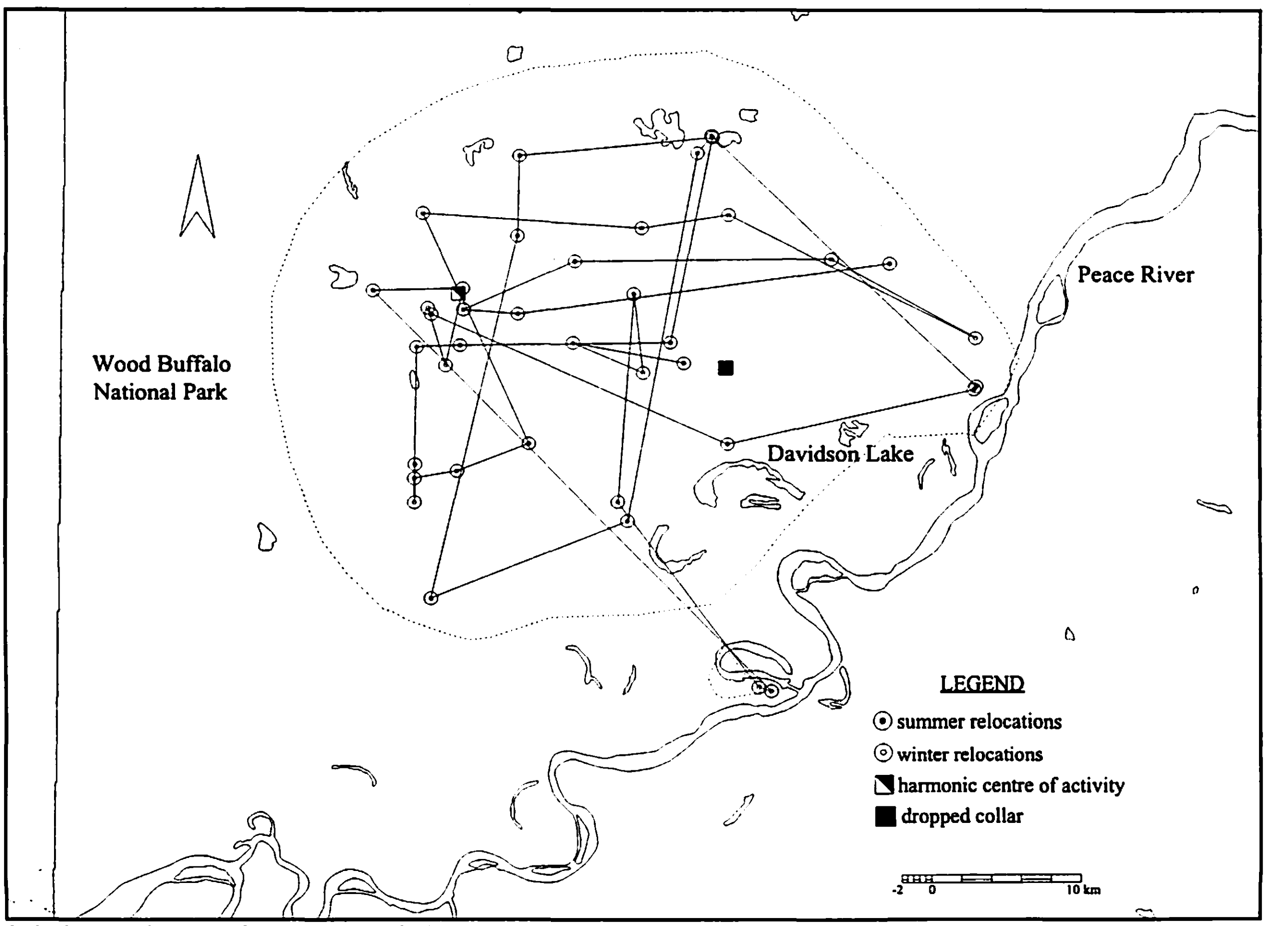
BISON: GR72
SEX: Female
RELOCATIONS: 45
95% HAR. HOME RANGE: 2629.8 km^2
CORE AREA: 1153.5 km^2
START: 14AUG91
END: 12MAY93
FATE: Dropped Collar



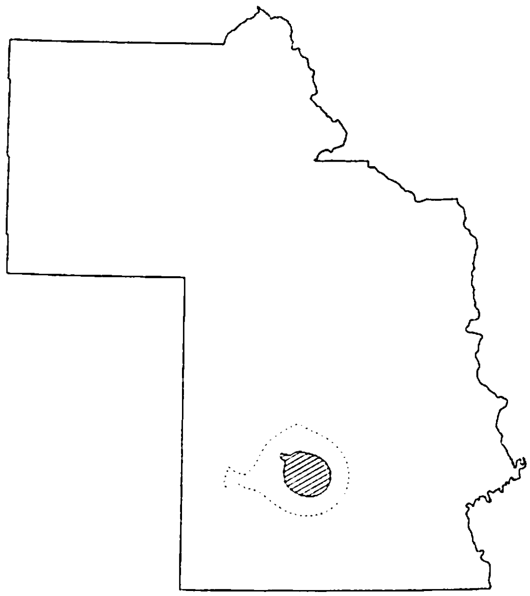
95% harmonic mean home range and core area of bison GR72.



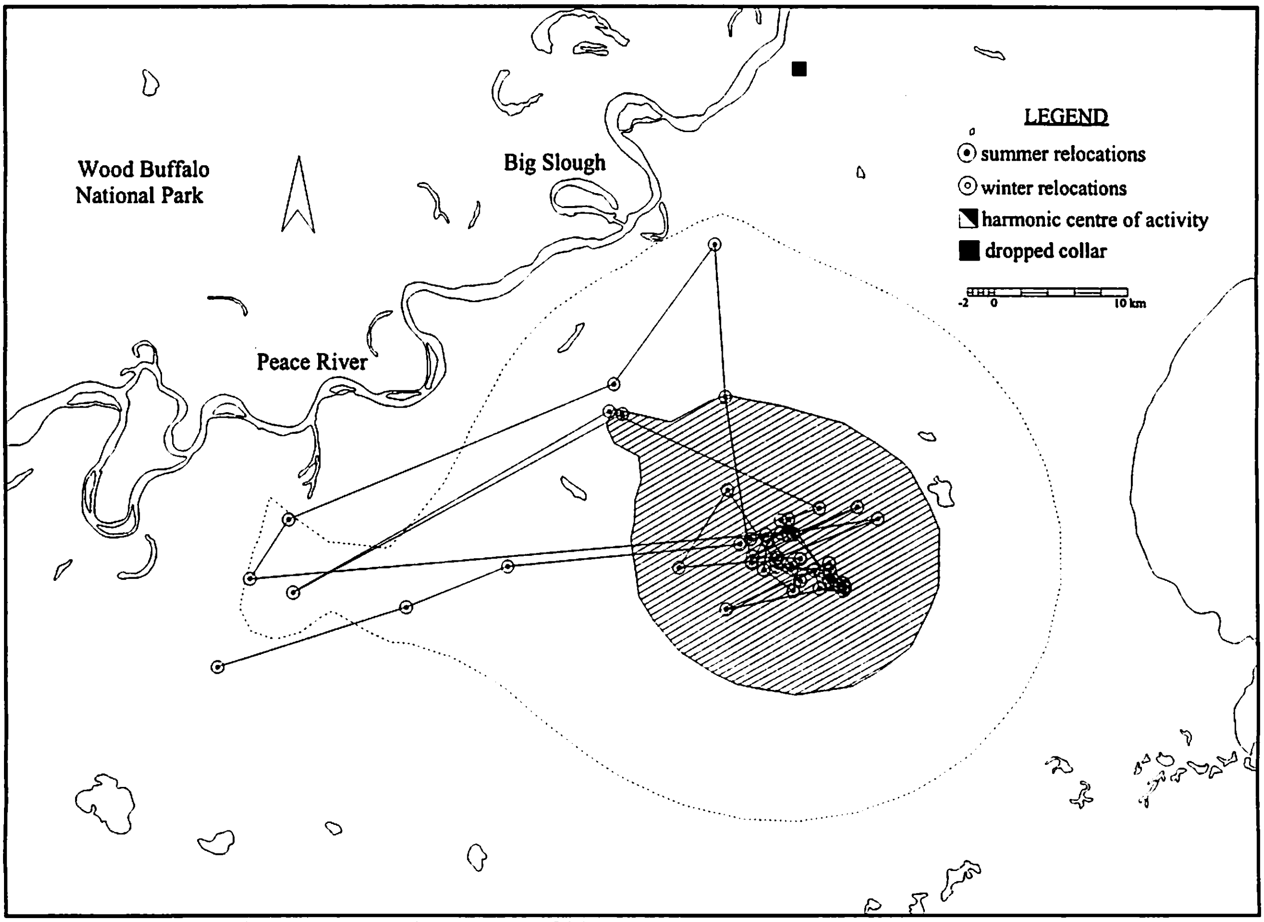
BISON: GR73
SEX: Male
RELOCATIONS: 40
95% HAR. HOME RANGE: 1472.1 km^2
CORE AREA: none
START: 14AUG91
END: 03MAR93
FATE: Dropped collar



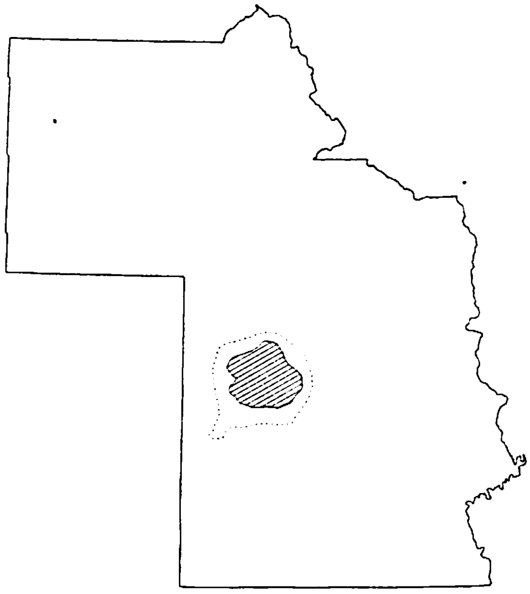
95% harmonic mean home range of bison GR73.



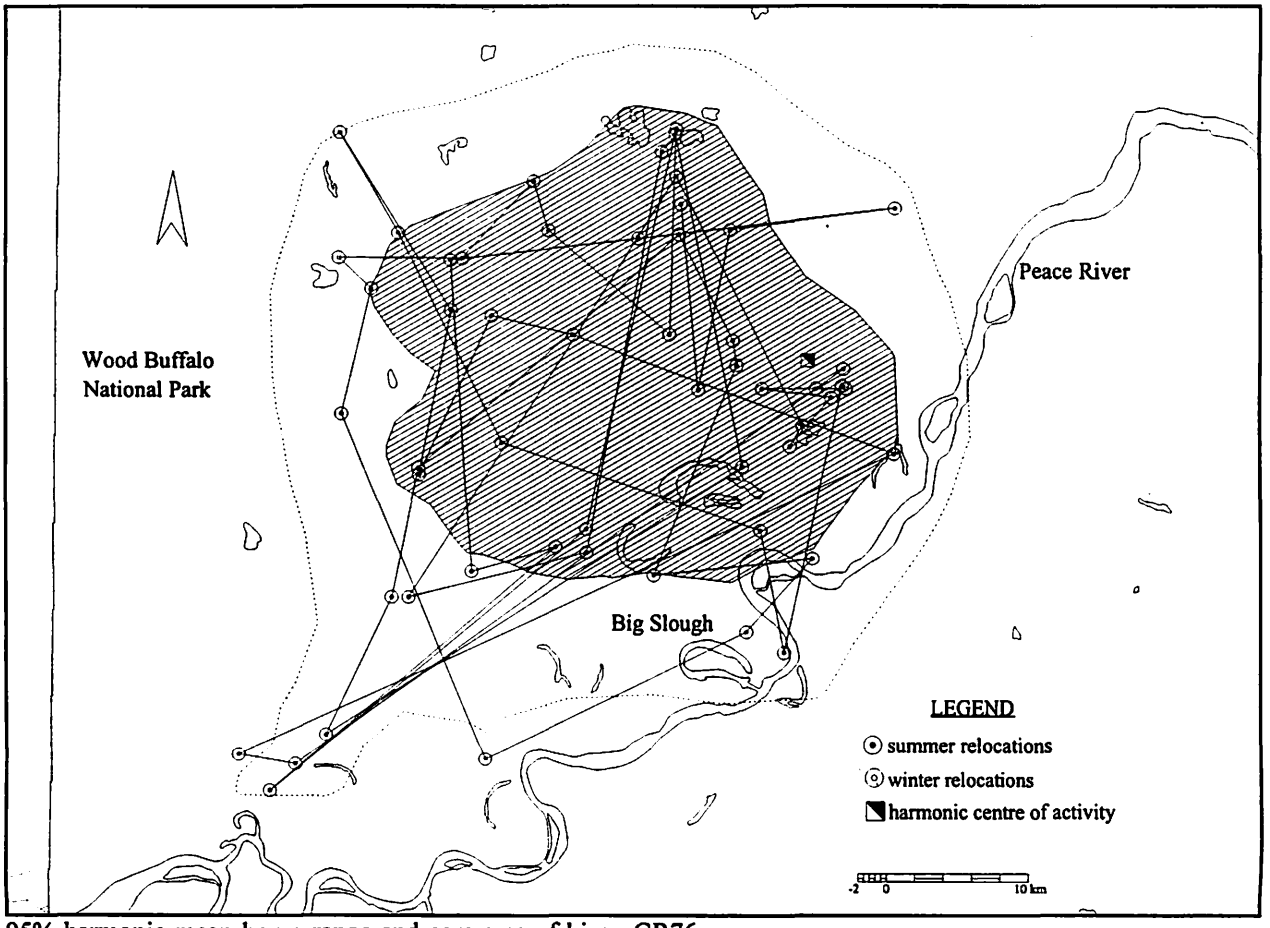
BISON: GR74
SEX: Male
RELOCATIONS: 49
95% HAR. HOME RANGE: 1708.2 km²
CORE AREA: 421.1 km²
START: 14AUG91
END: 15JUL93
FATE: Dropped Collar



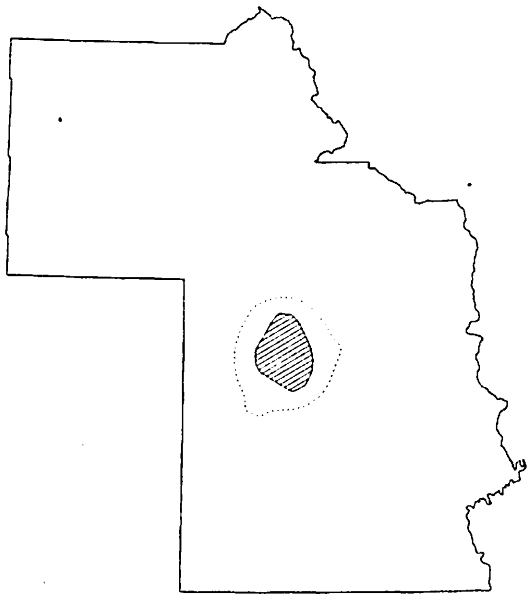
95% harmonic mean home range and core area of bison GR74.



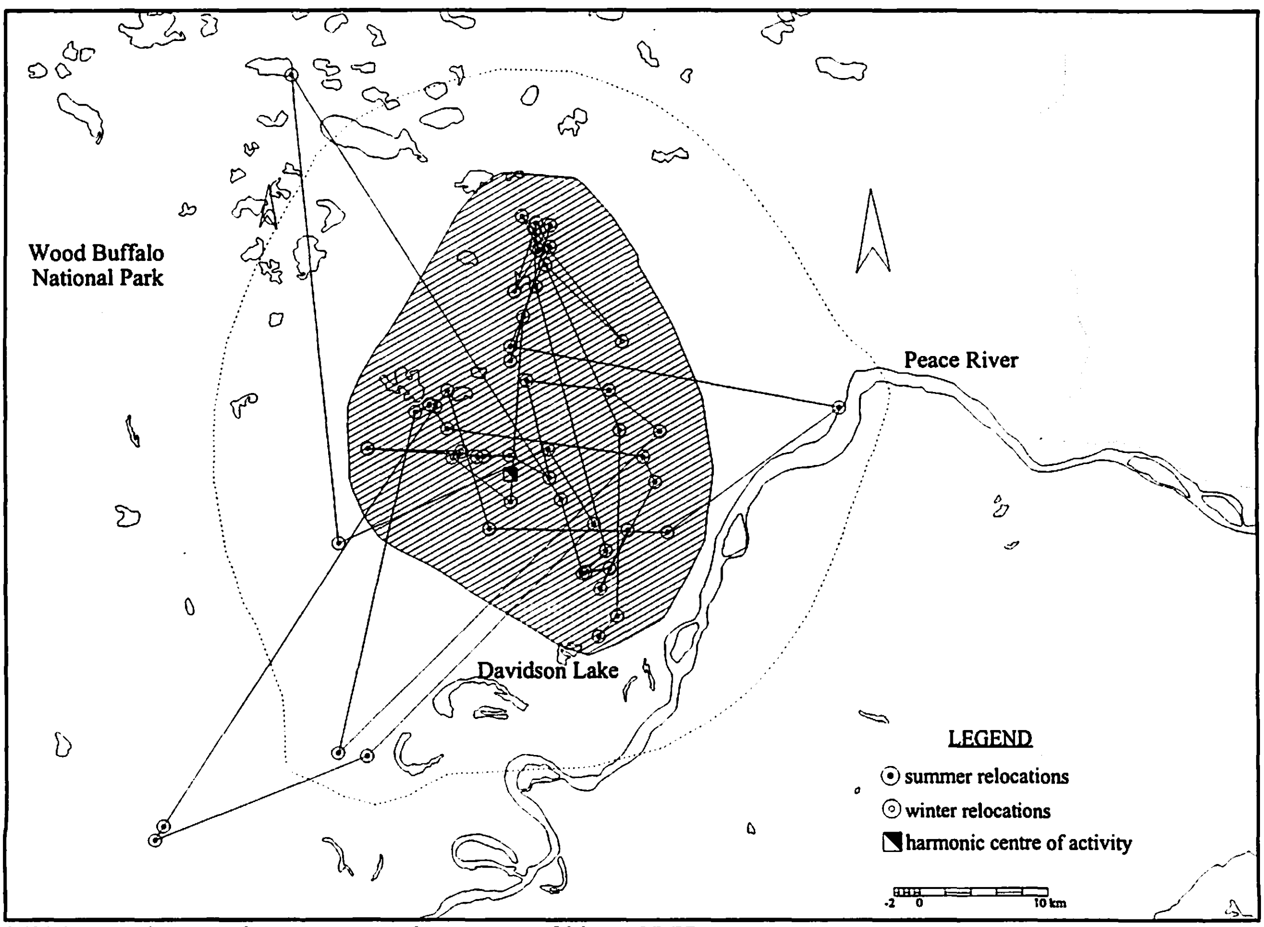
BISON: GR76
SEX: Female
RELOCATIONS: 54
95% HAR. HOME RANGE: 1948.7 km^2
CORE AREA: 878.1 km^2
START: 14AUG91
END: 24SEP93
FATE: Active



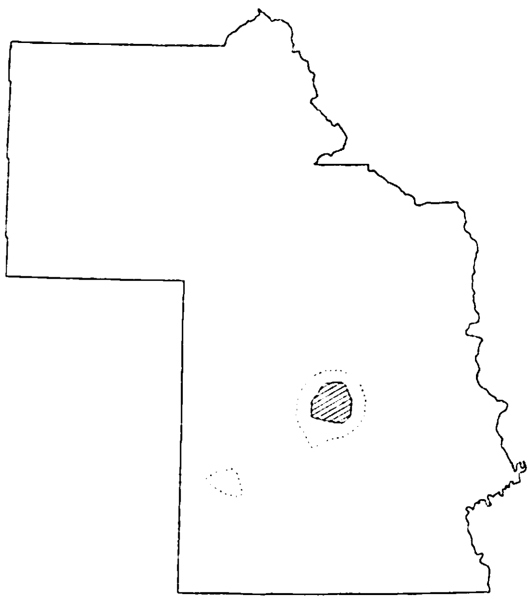
95% harmonic mean home range and core area of bison GR76.



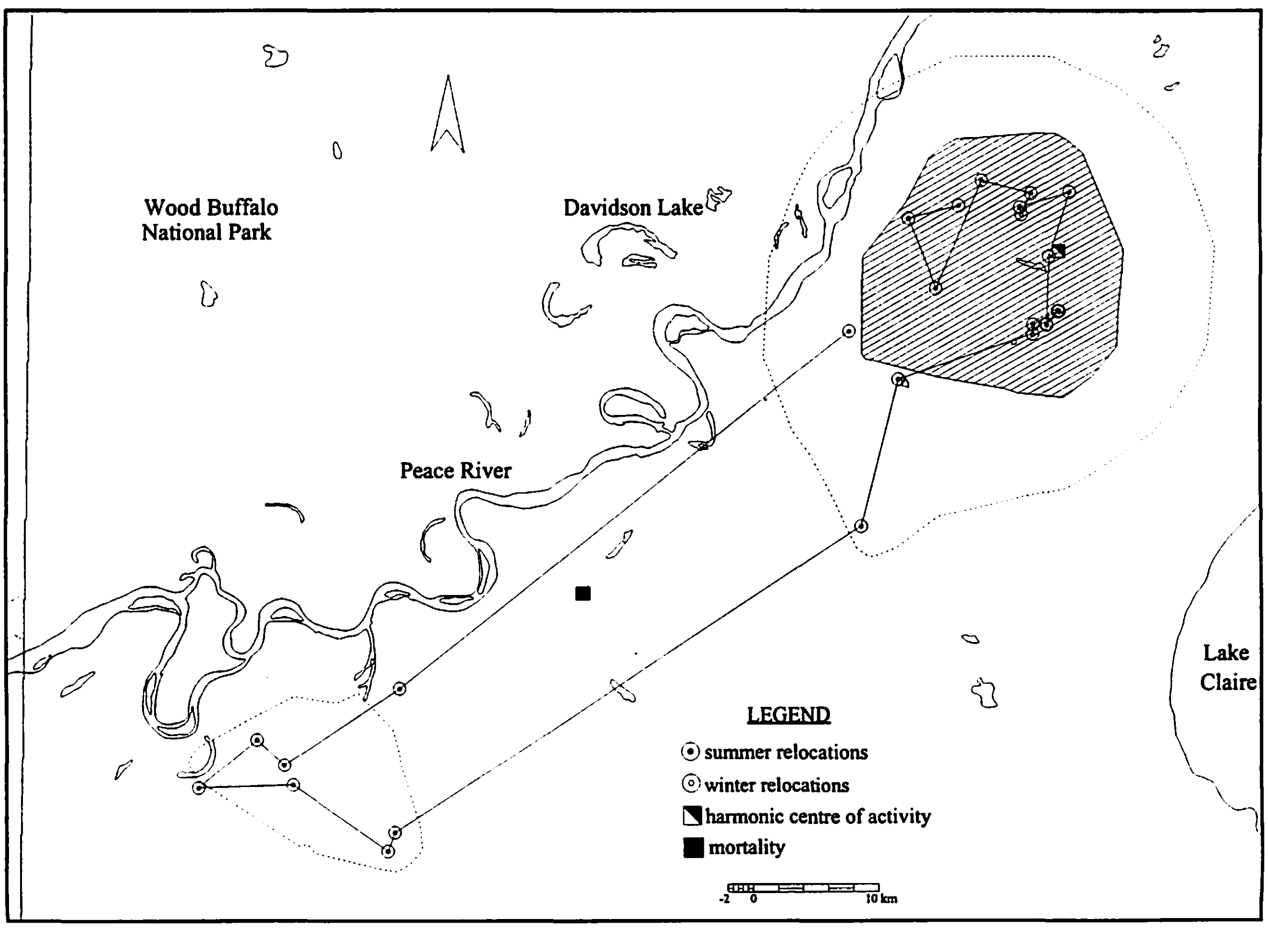
BISON: GR77
SEX: Female
RELOCATIONS: 54
95% HAR. HOME RANGE: 2305.0 km^2
CORE AREA: 773.8 km^2
START: 14AUG91
END: 24SEP93
FATE: Active



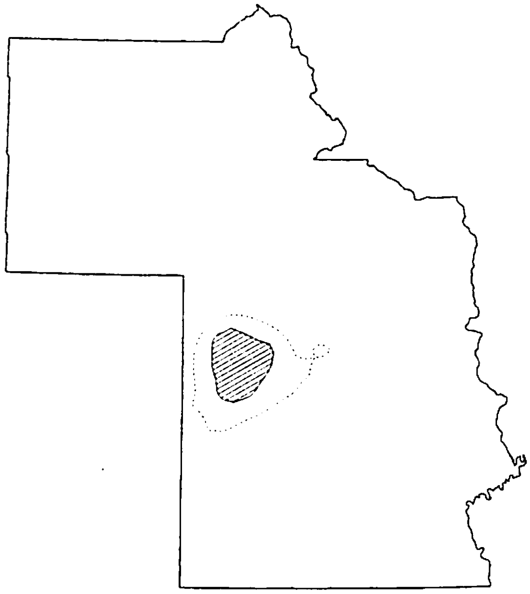
95% harmonic mean home range and core area of bison GR77.



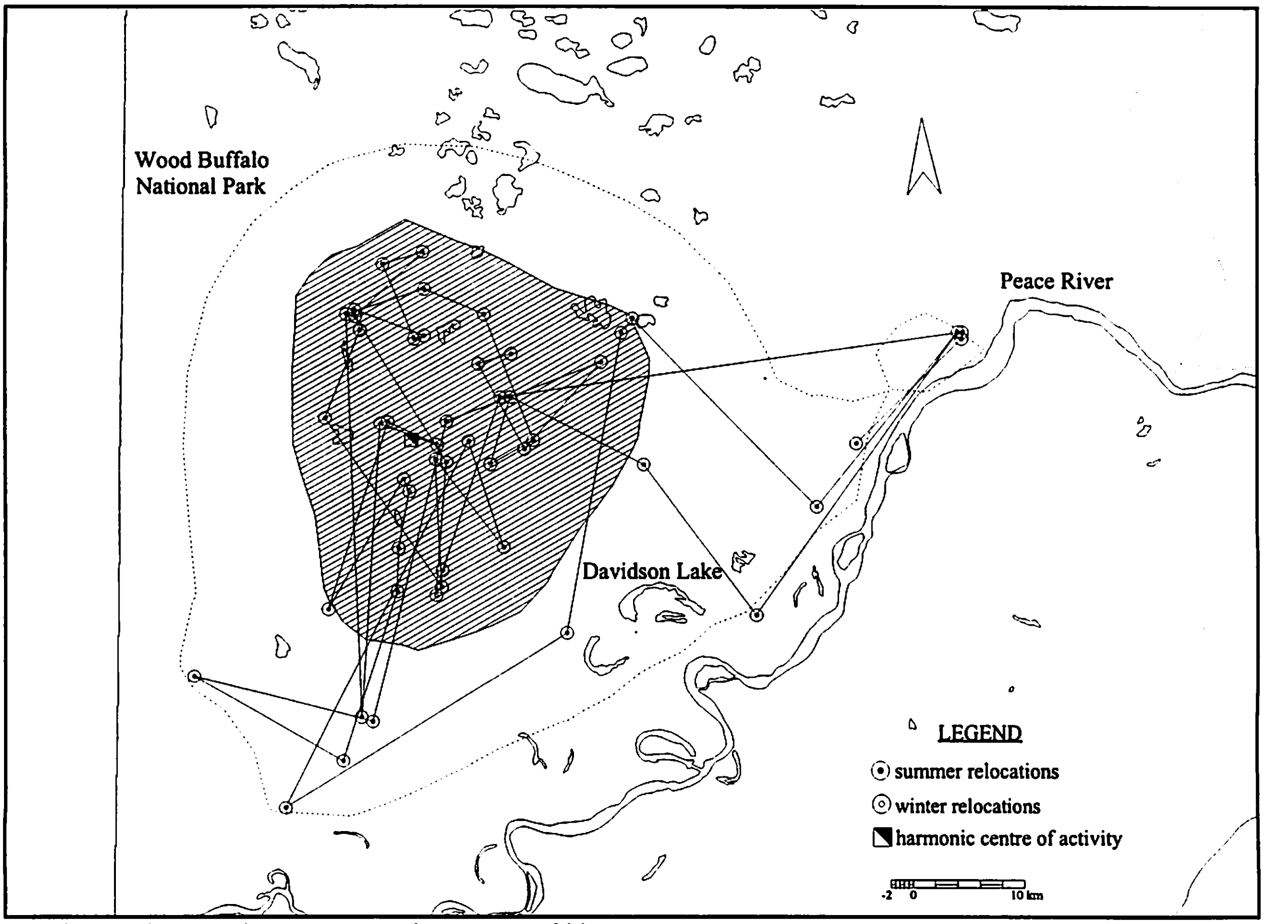
BISON: GR78
SEX: Male
RELOCATIONS: 25
95% HAR. HOME RANGE: 944.5 km^2
CORE AREA: 323.2 km^2
START: 14AUG91
END: 20AUG93
FATE: Wolf Predation



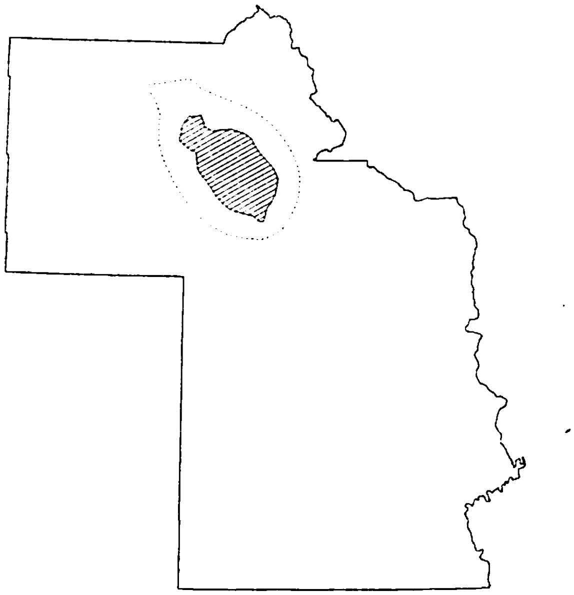
95% harmonic mean home range and core area of bison GR78.



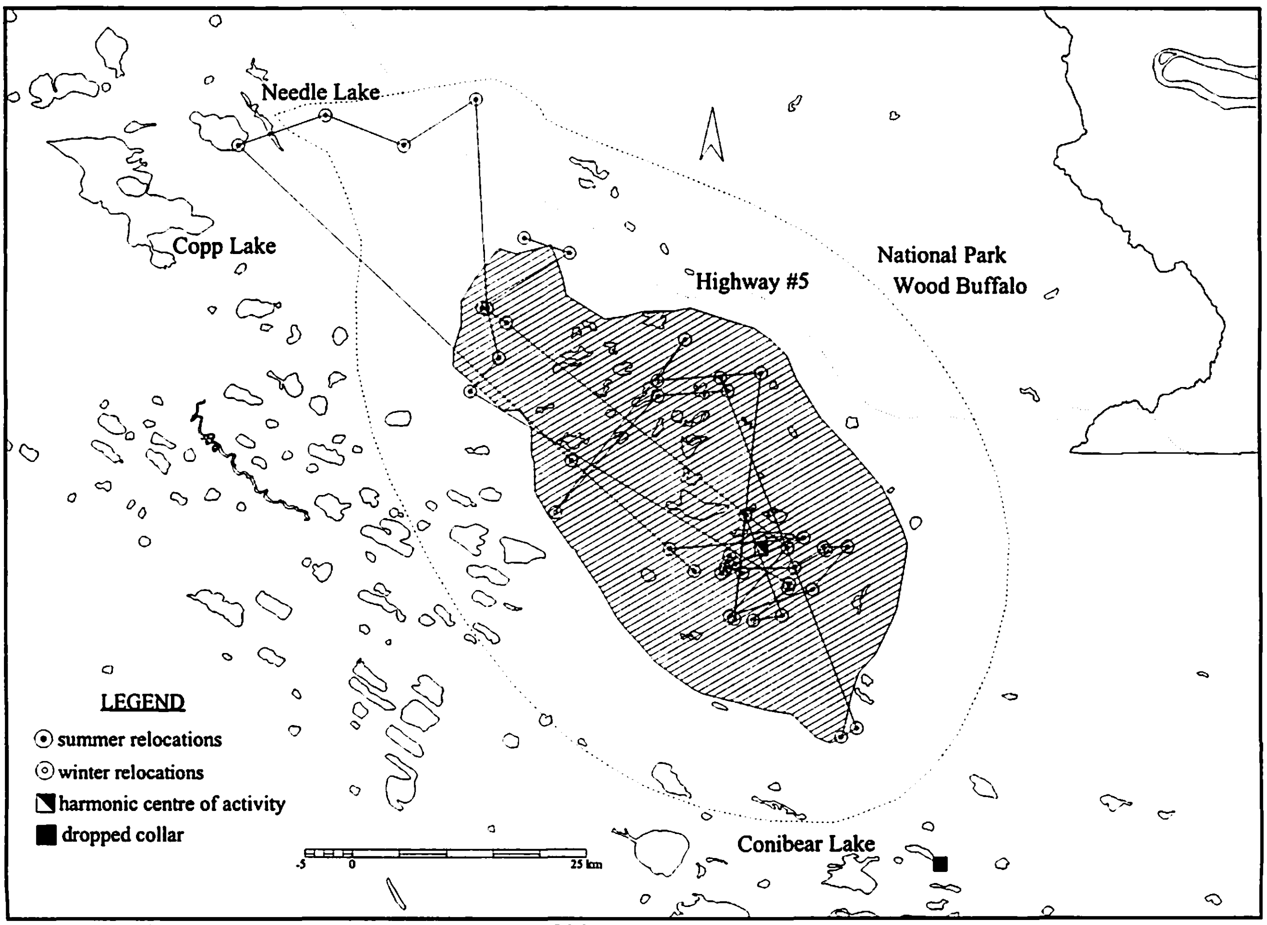
BISON: GR79
SEX: Female
RELOCATIONS: 50
95% HAR. HOME RANGE: 2402.3 km^2
CORE AREA: 821.2 km^2
START: 20AUG91
END: 24SEP93
FATE: Active



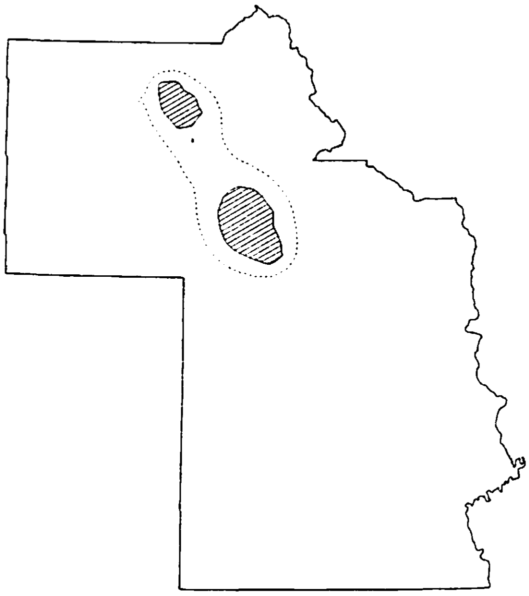
95% harmonic mean home range and core area of bison GR79.



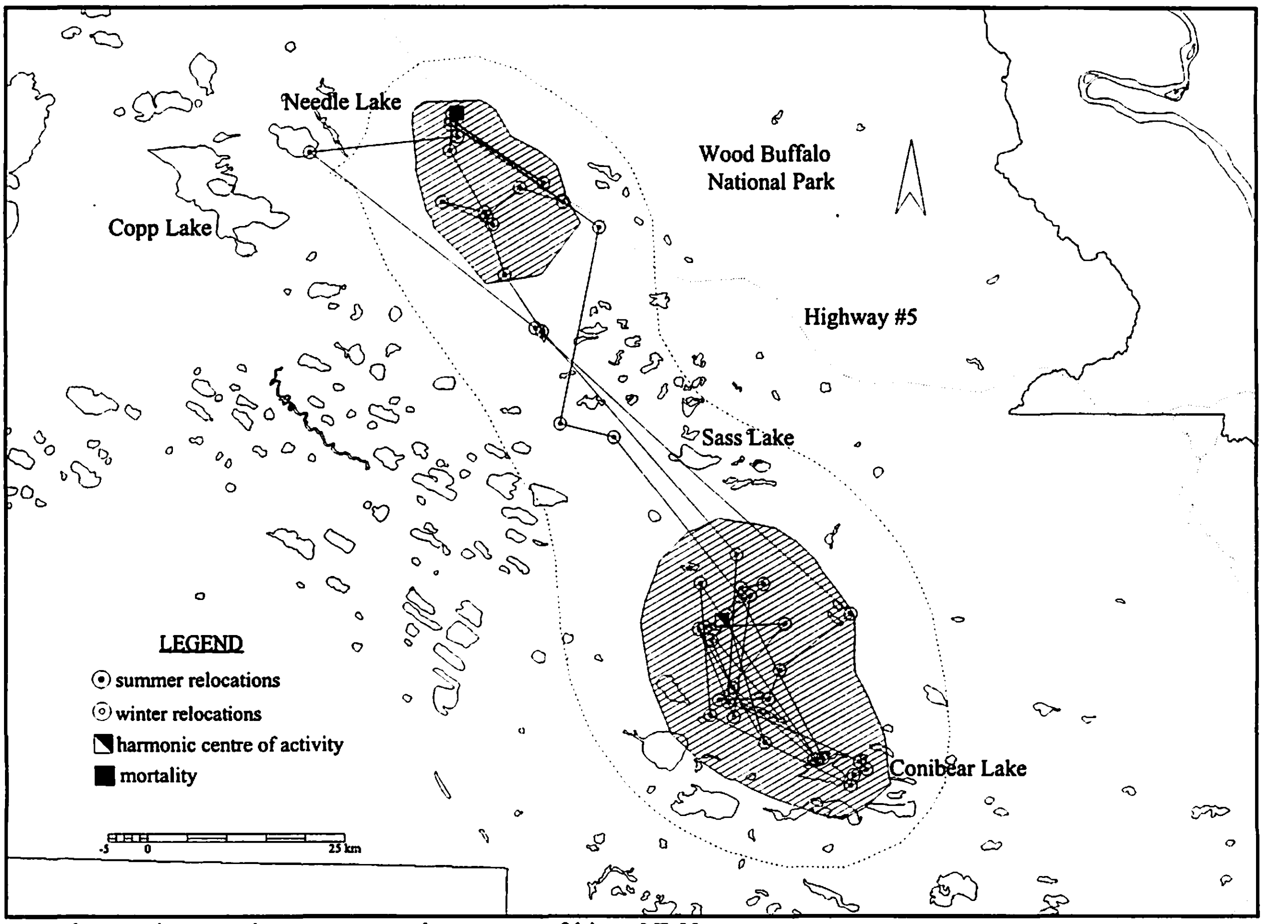
BISON: NL80
SEX: Male
RELOCATIONS: 43
95% HAR. HOME RANGE: 3954.2 km^2
CORE AREA: 1412.0 km^2
START: 09AUG91
END: 15APR93
FATE: Dropped Collar



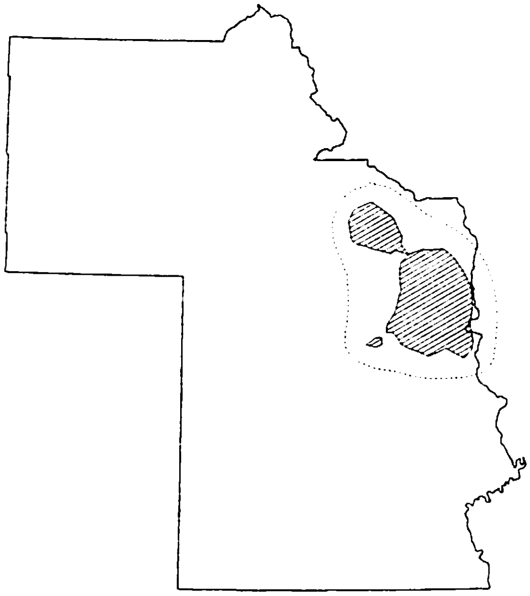
95% harmonic mean home range and core area of bison NL80.



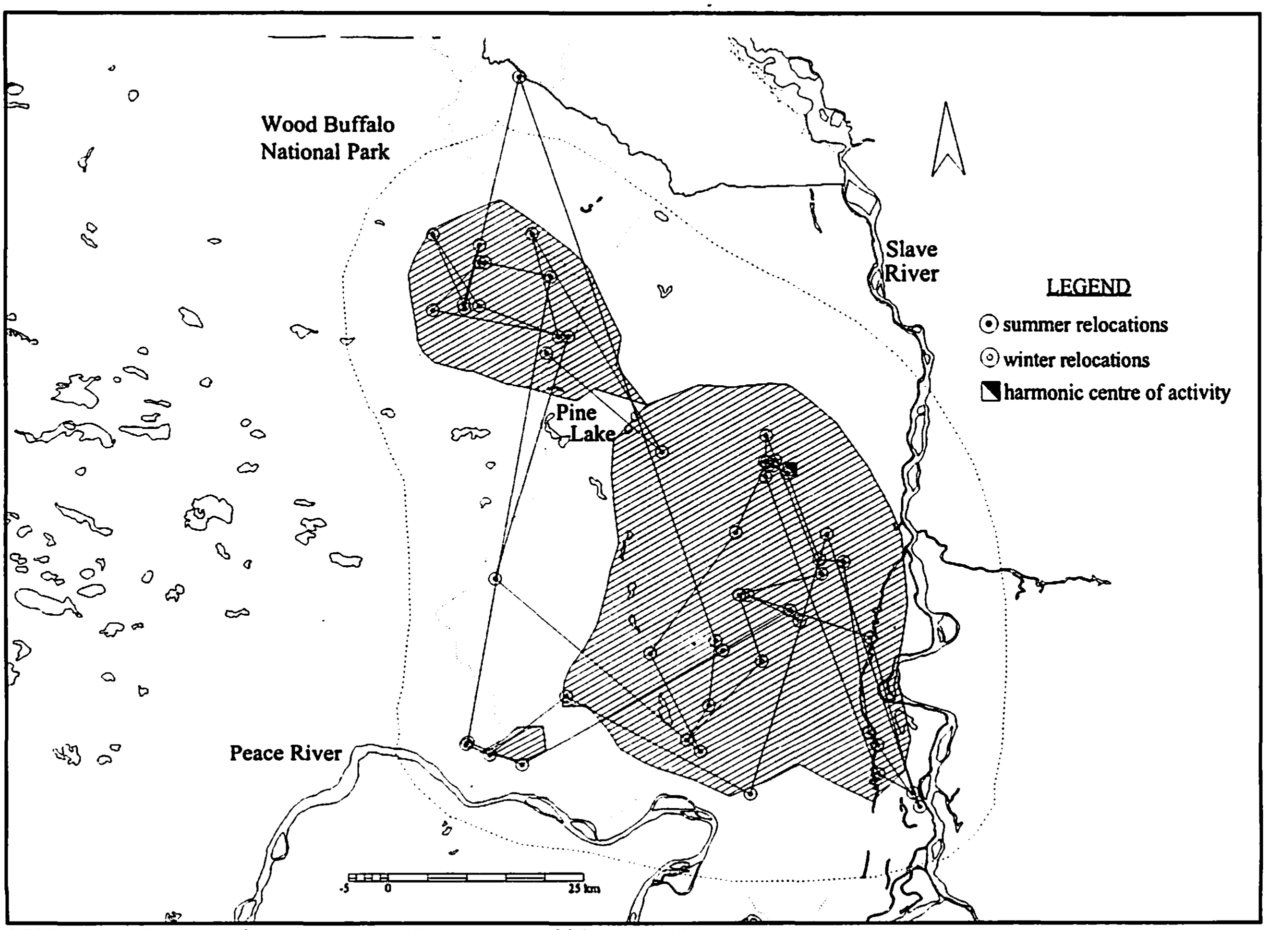
BISON: NL82
SEX: Female
RELOCATIONS: 46
95% HAR. HOME RANGE: 3728.7 km²
CORE AREA: 1176.2 km²
START: 08AUG91
END: 15JUN93
FATE: Mortality



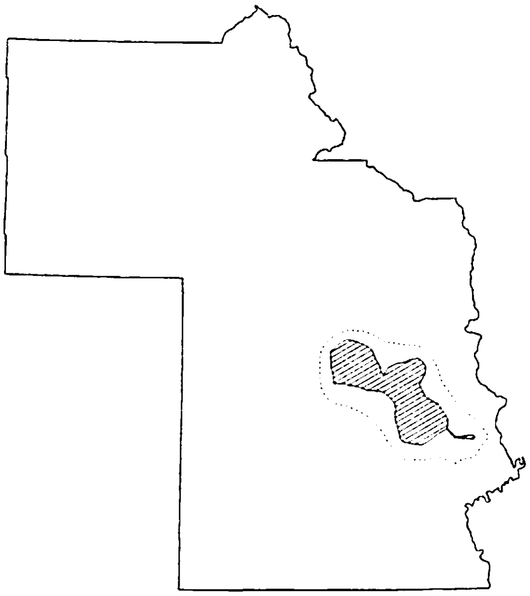
95% harmonic mean home range and core area of bison NL82.



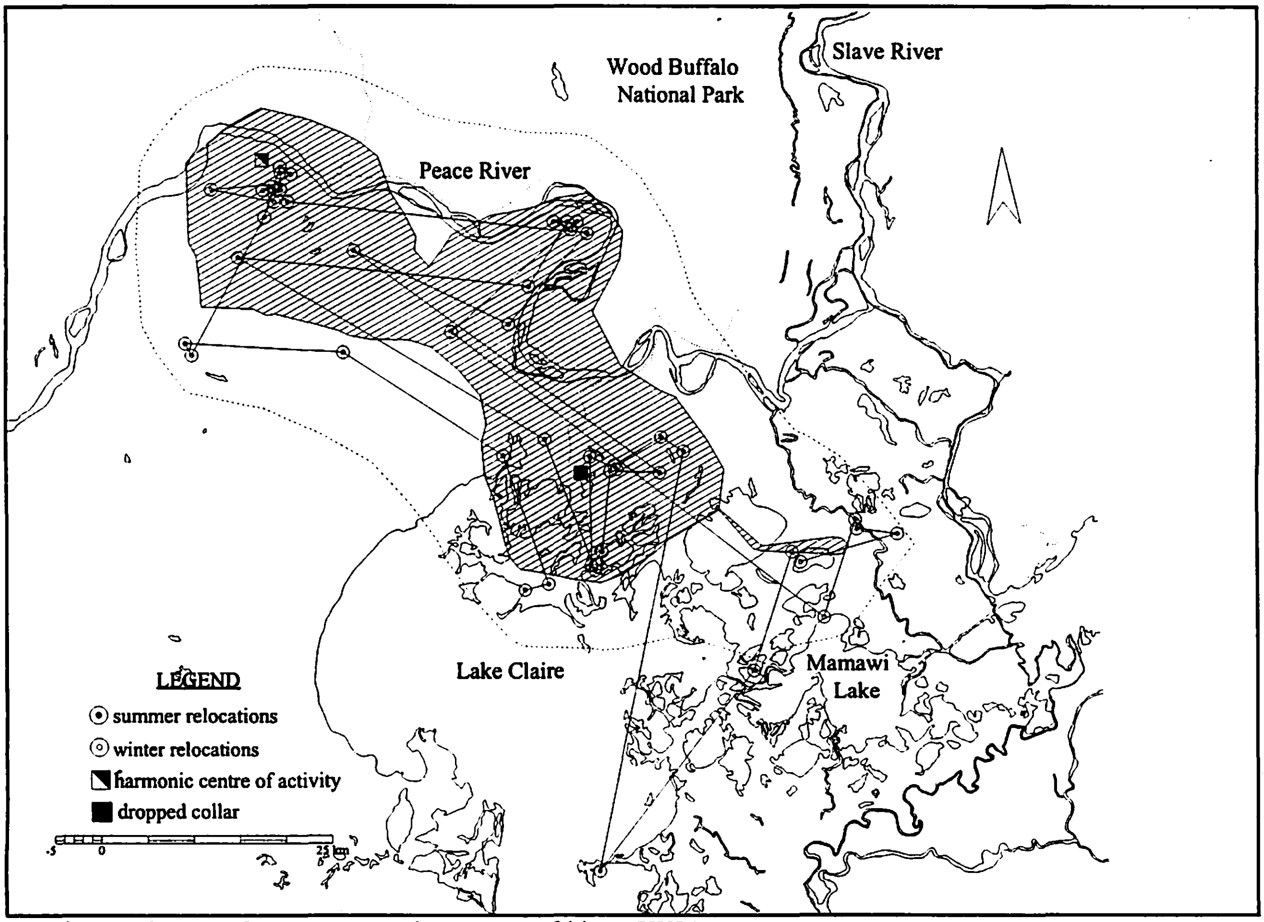
BISON: PL83
SEX: Female
RELOCATIONS: 52
95% HAR. HOME RANGE: 5997.6 km²
CORE AREA: 2264.3 km²
START: 21AUG91
END: 24SEP94
FATE: Active



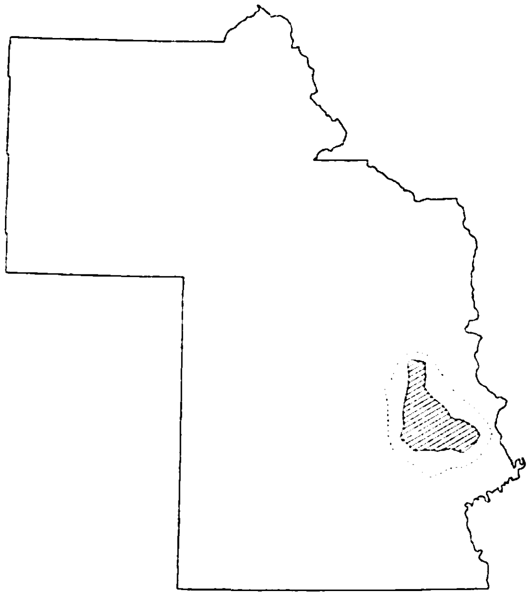
95% harmonic mean home range and core area of bison PL83.



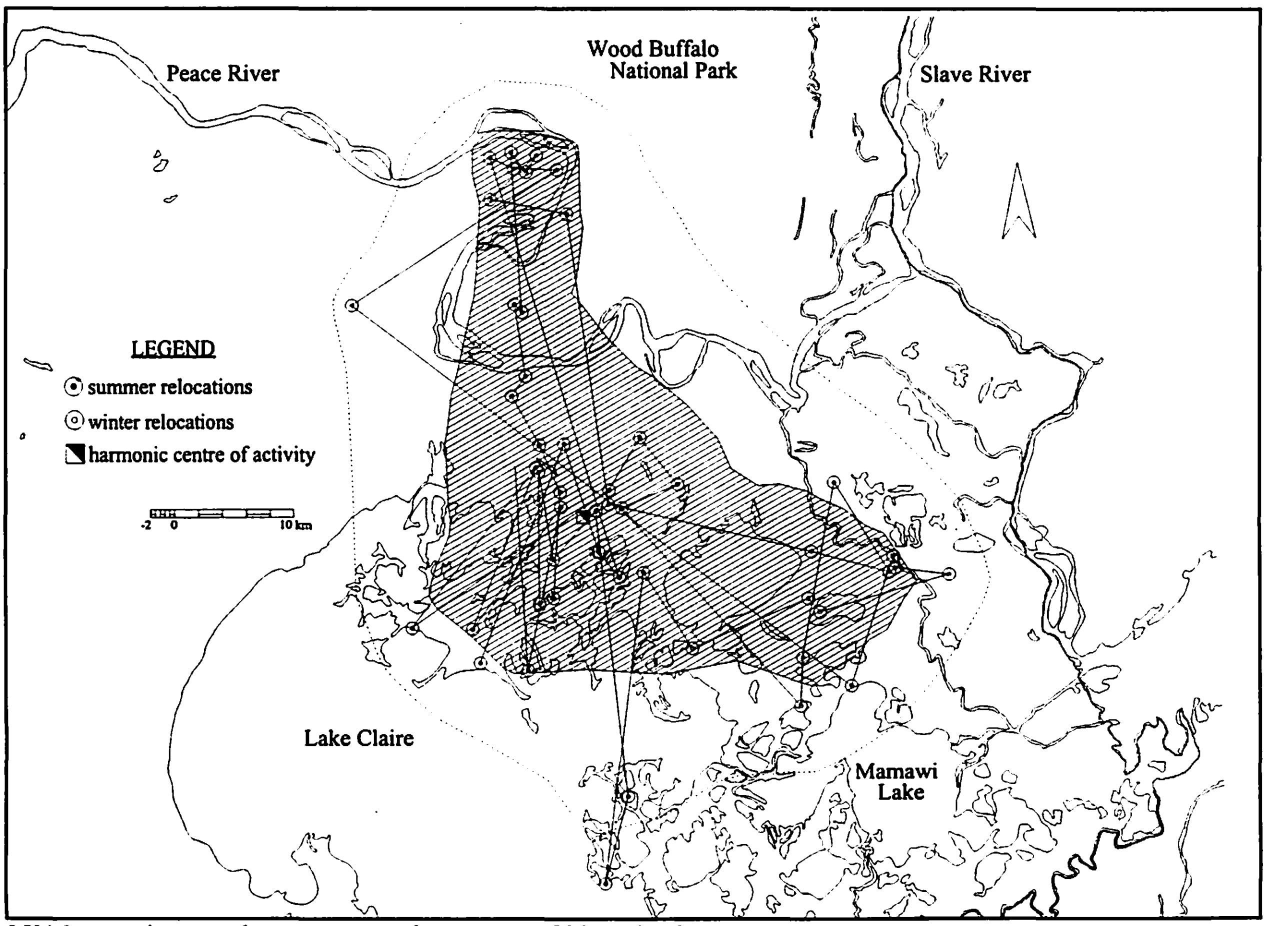
BISON: SW84
SEX: Female
RELOCATIONS: 47
95% HAR. HOME RANGE: 3232.0 km^2
CORE AREA: 1351.8 km^2
START: 08AUG91
END: 17JUN93
FATE: Dropped Collar



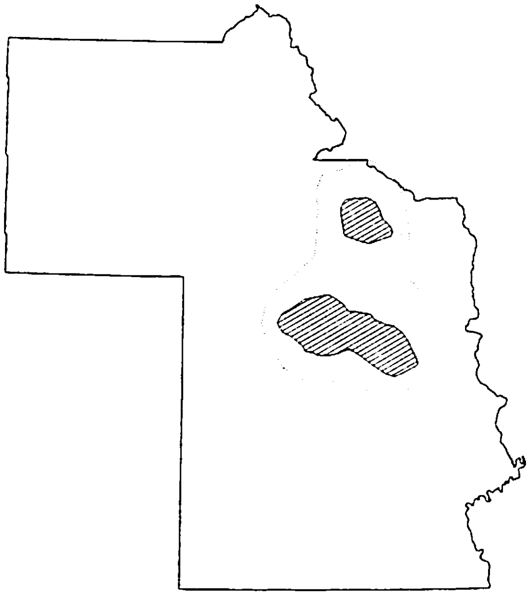
95% harmonic mean home range and core area of bison SW84.



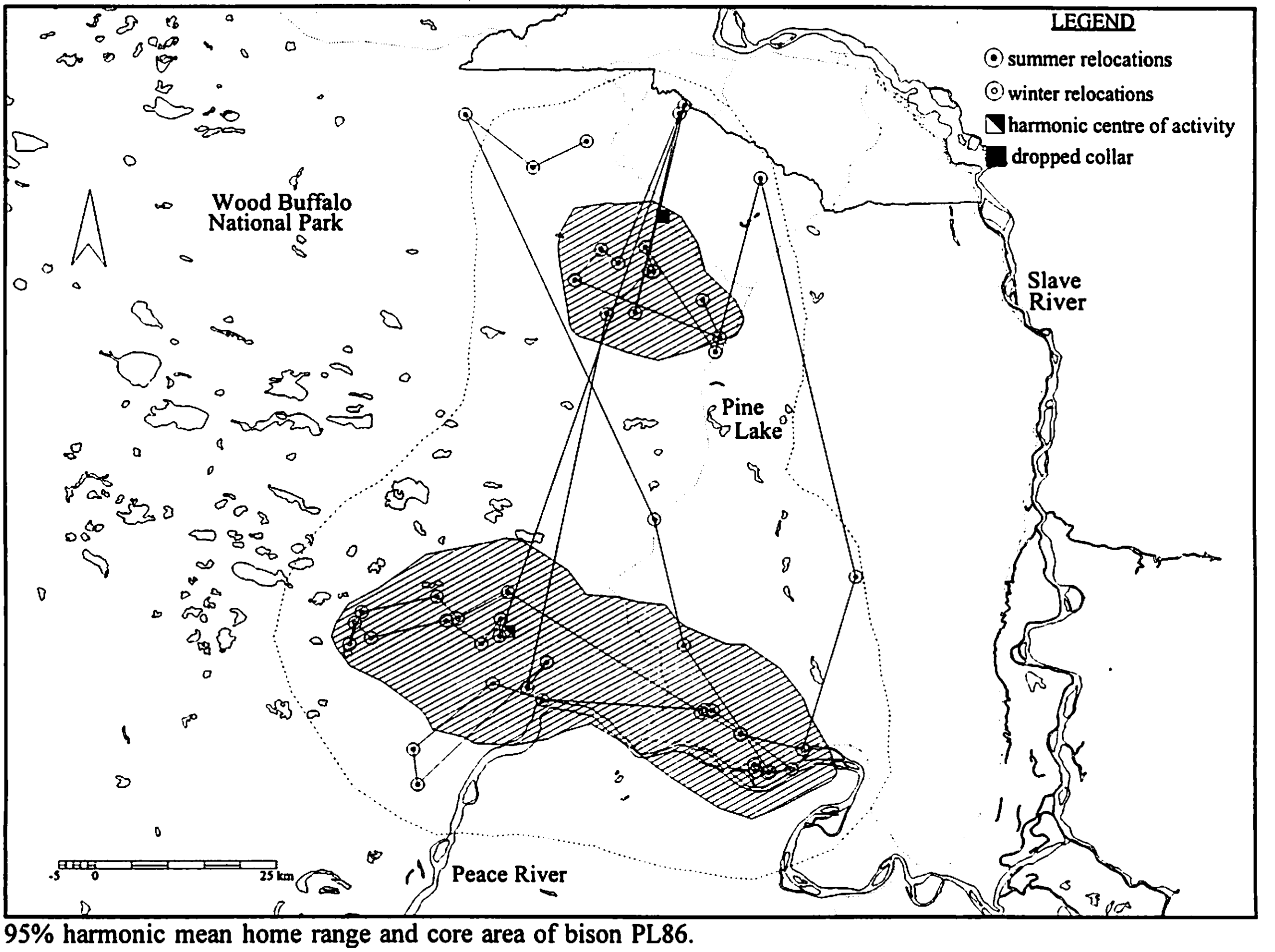
BISON: SW85
SEX: Female
RELOCATIONS: 50
95% HAR. HOME RANGE: 2147.2 km²
CORE AREA: 921.1 km²
START: 08AUG91
END: 24SEP93
FATE: Active



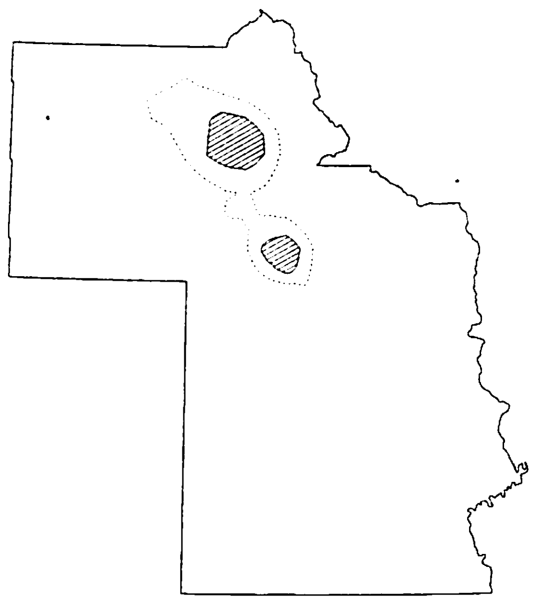
95% harmonic mean home range and core area of bison SW85.



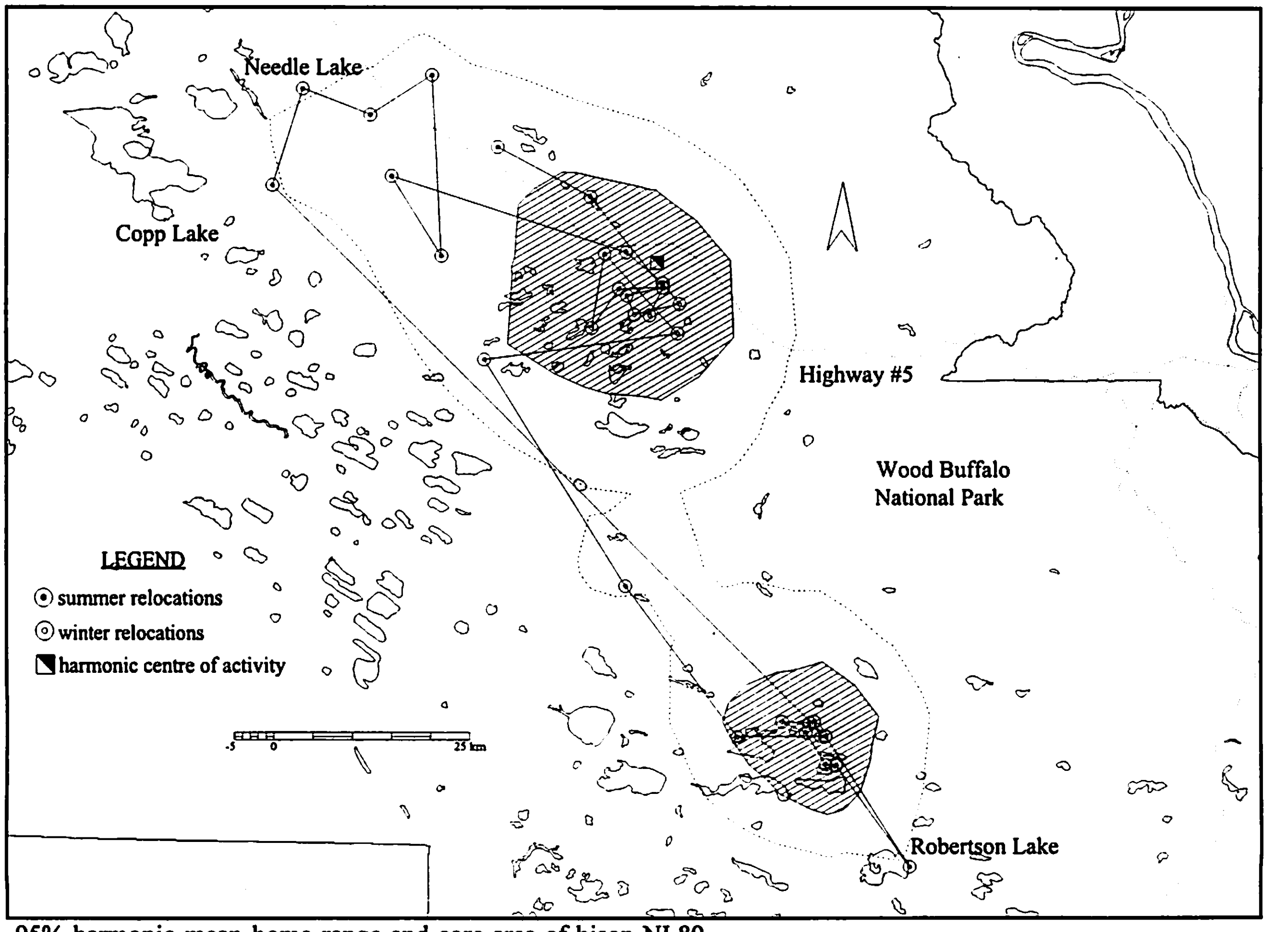
BISON: PL86
SEX: Female
RELOCATIONS: 49
95% HAR. HOME RANGE: 6536.2 km^2
CORE AREA: 1898.6 km^2
START: 08AUG91
END: 27AUG93
FATE: Dropped Collar



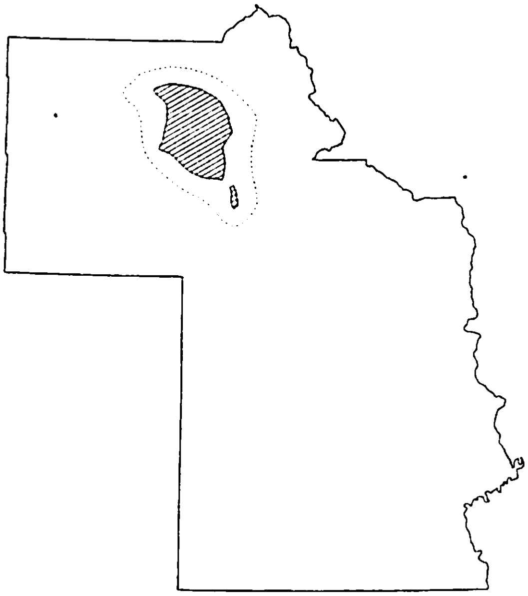
95% harmonic mean home range and core area of bison PL86.



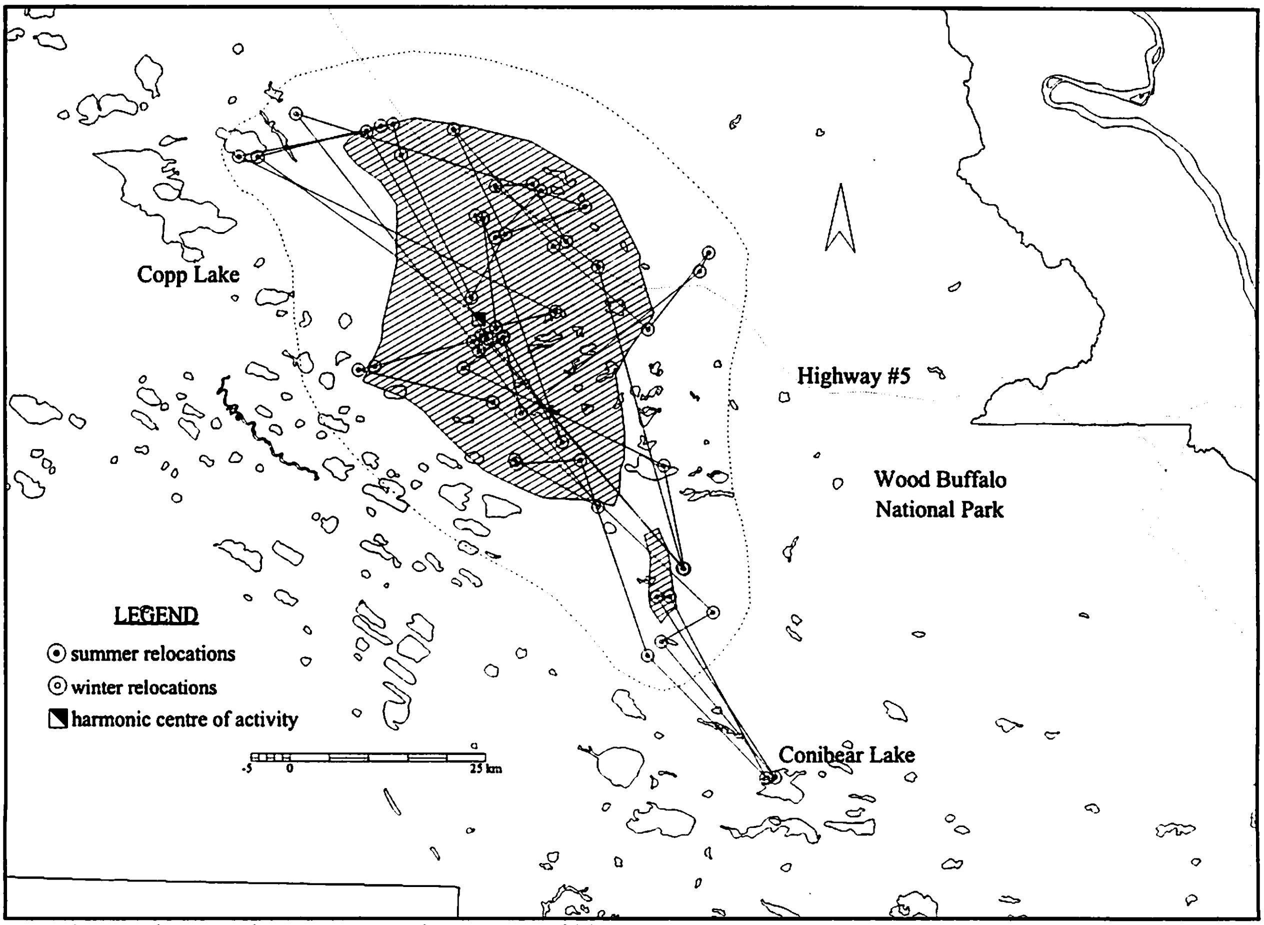
BISON: NL89
SEX: Male
RELOCATIONS: 33
95% HAR. HOME RANGE: 3396.8 km²
CORE AREA: 878.6 km²
START: 22AUG91
END: 25SEP93
FATE: Active



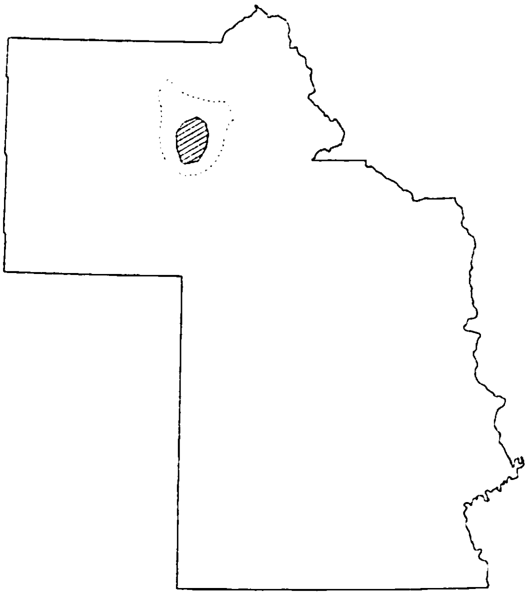
95% harmonic mean home range and core area of bison NL89.



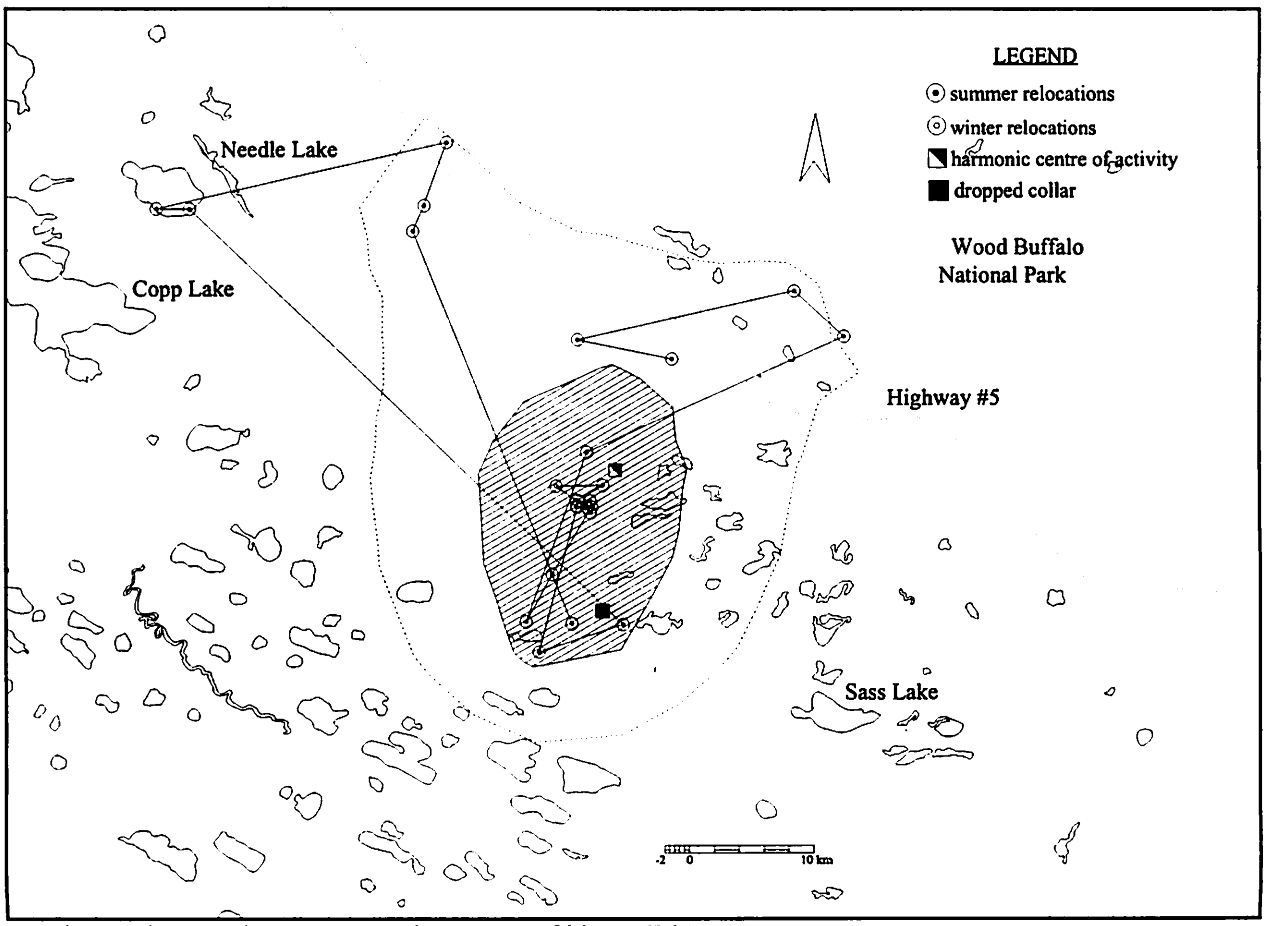
BISON: NL90
SEX: Female
RELOCATIONS: 53
95% HAR. HOME RANGE: 3375.1 km^2
CORE AREA: 1260.8 km^2
START: 22AUG91
END: 25SEP93
FATE: Active



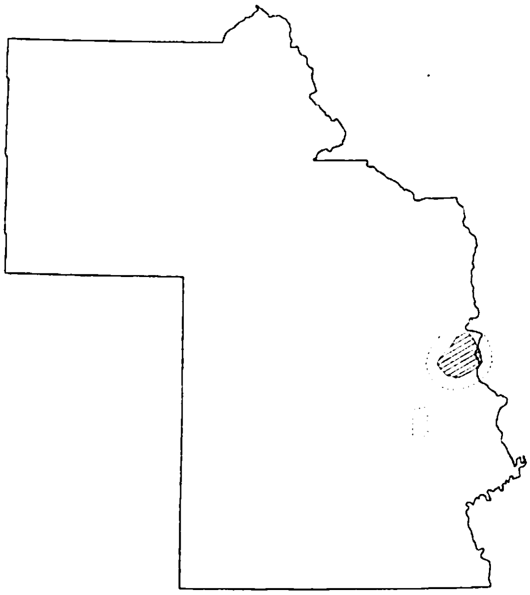
95% harmonic mean home range and core area of bison NL90.



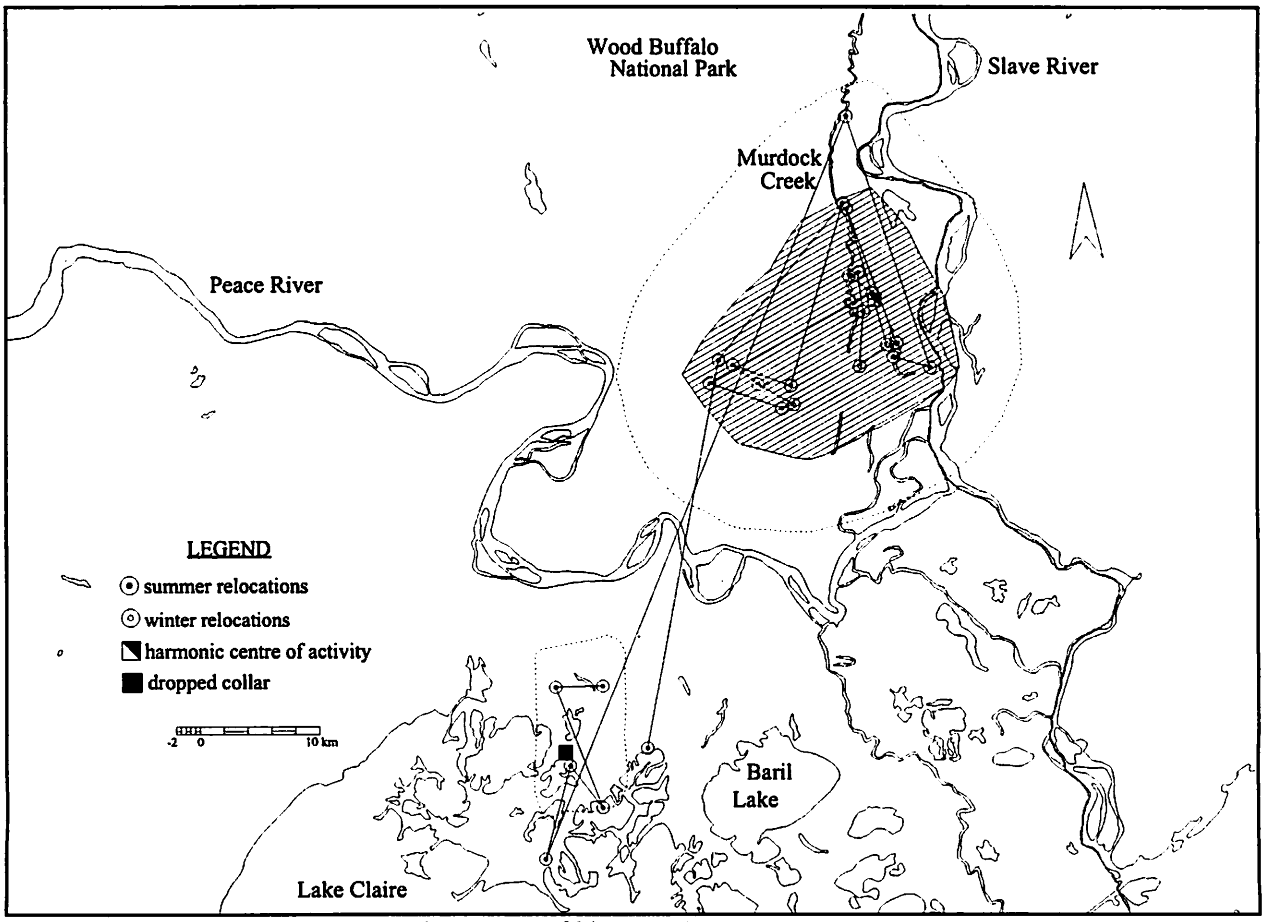
BISON: NL91
SEX: Male
RELOCATIONS: 26
95% HAR. HOME RANGE: 1188.4 km^2
CORE AREA: 276.8 km^2
START: 22AUG91
END: 27AUG92
FATE: Dropped Collar



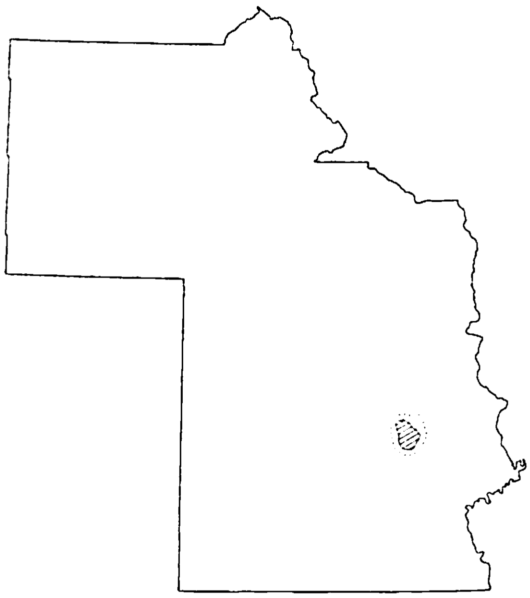
95% harmonic mean home range and core area of bison NL91.



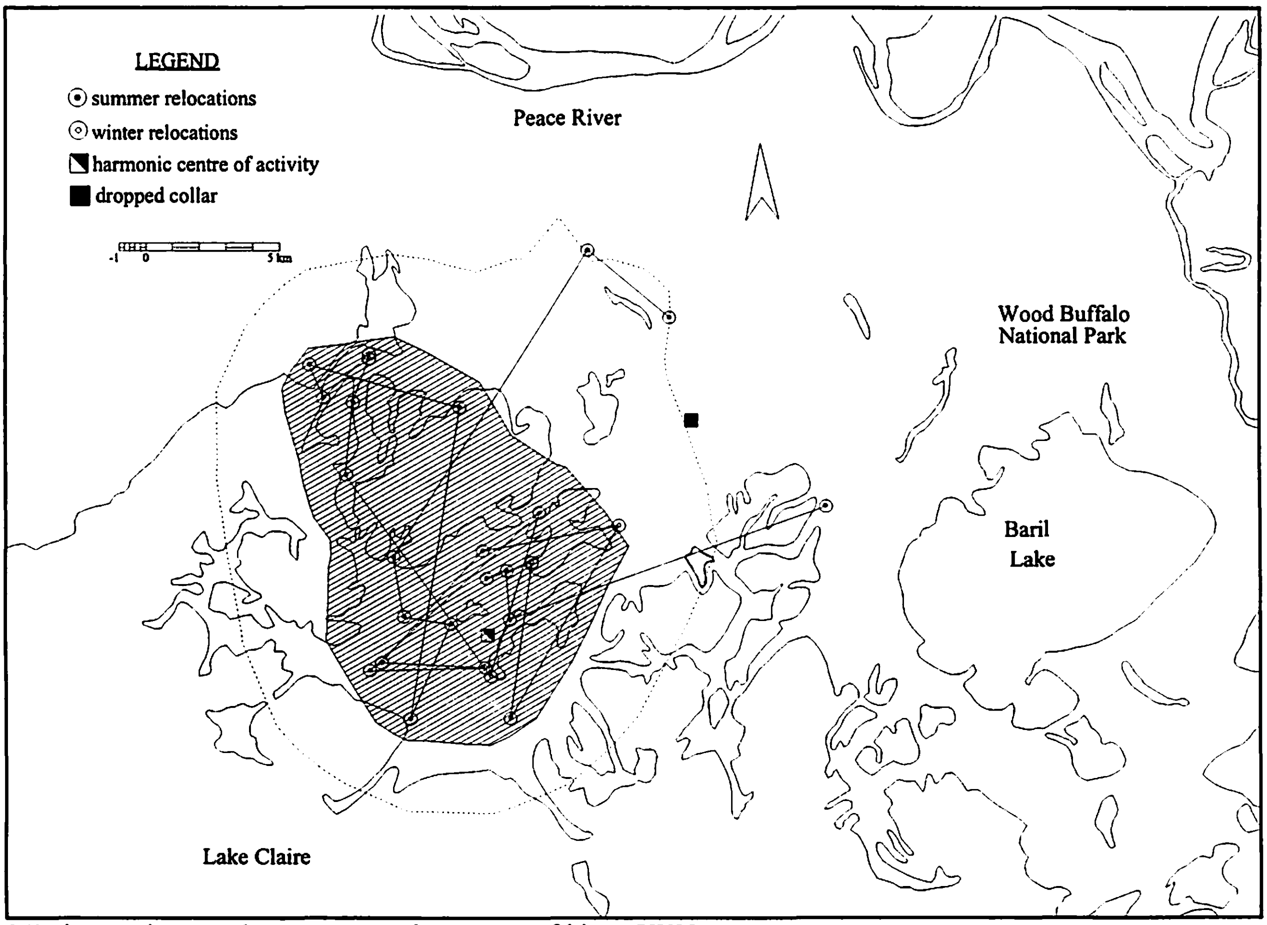
BISON: SW92
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 969.6 km^2
CORE AREA: 315.9 km^2
START: 12AUG92
END: 12AUG93
FATE: Dropped collar



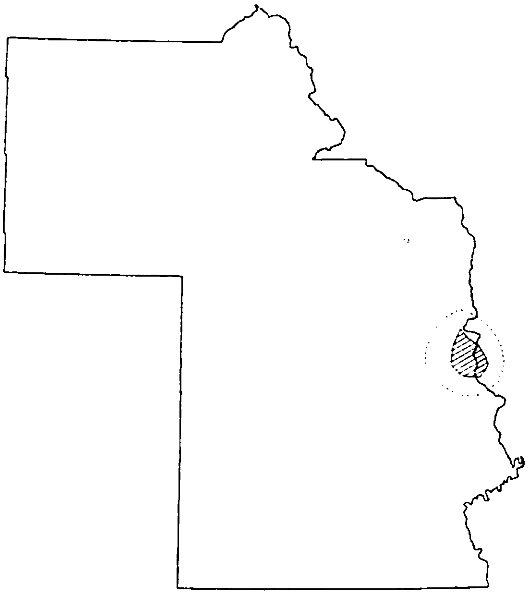
95% harmonic mean home range and core area of bison SW92.



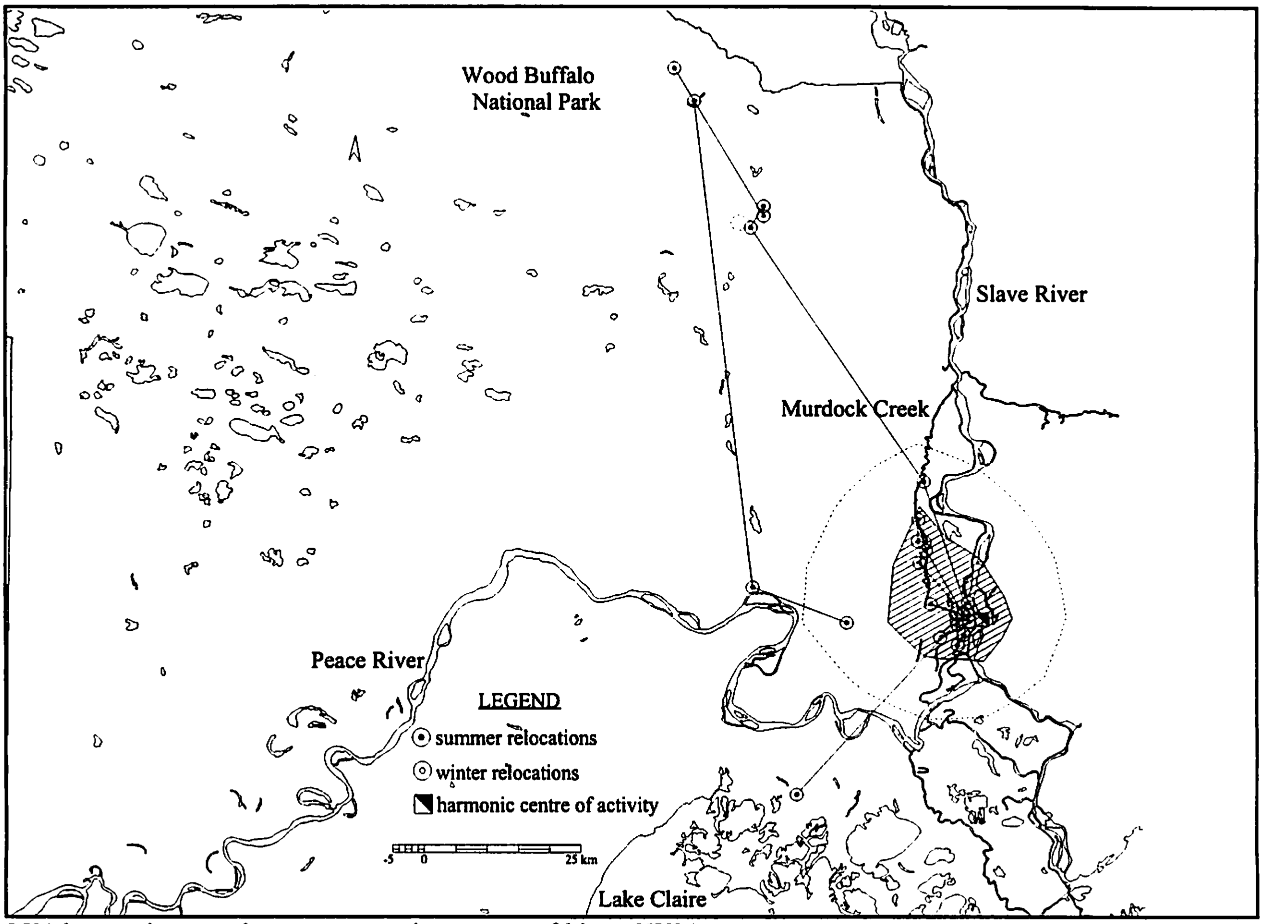
BISON: SW93
SEX: Male
RELOCATIONS: 26
95% HAR. HOME RANGE: 296.5 km^2
CORE AREA: 120.3 km^2
START: 12AUG92
END: 12AUG93
FATE: Dropped Collar



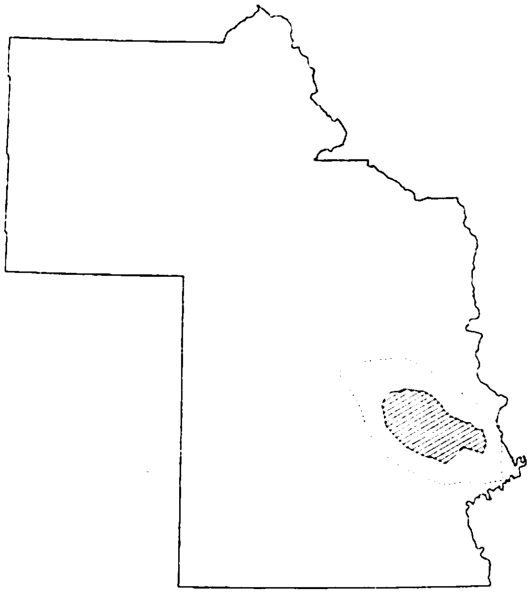
95% harmonic mean home range and core area of bison SW93.



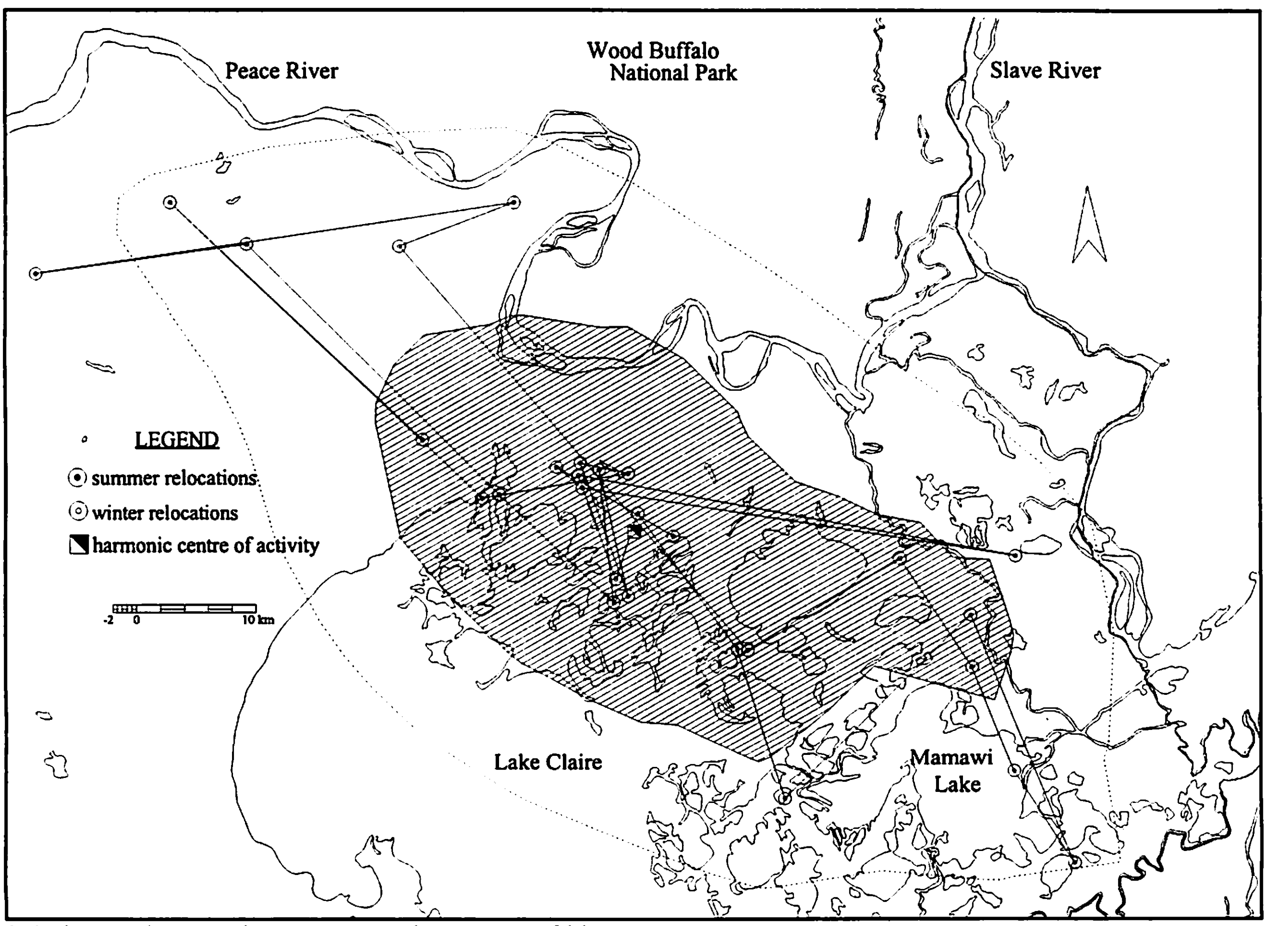
BISON: SW94
SEX: Male
RELOCATIONS: 27
95% HAR. HOME RANGE: 1247.4 km^2
CORE AREA: 287.2 km^2
START: 12AUG92
END: 24SEP93
FATE: Active



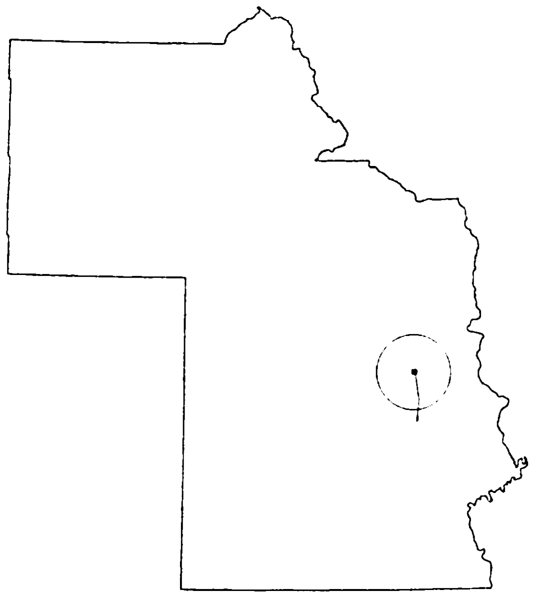
95% harmonic mean home range and core area of bison SW94.



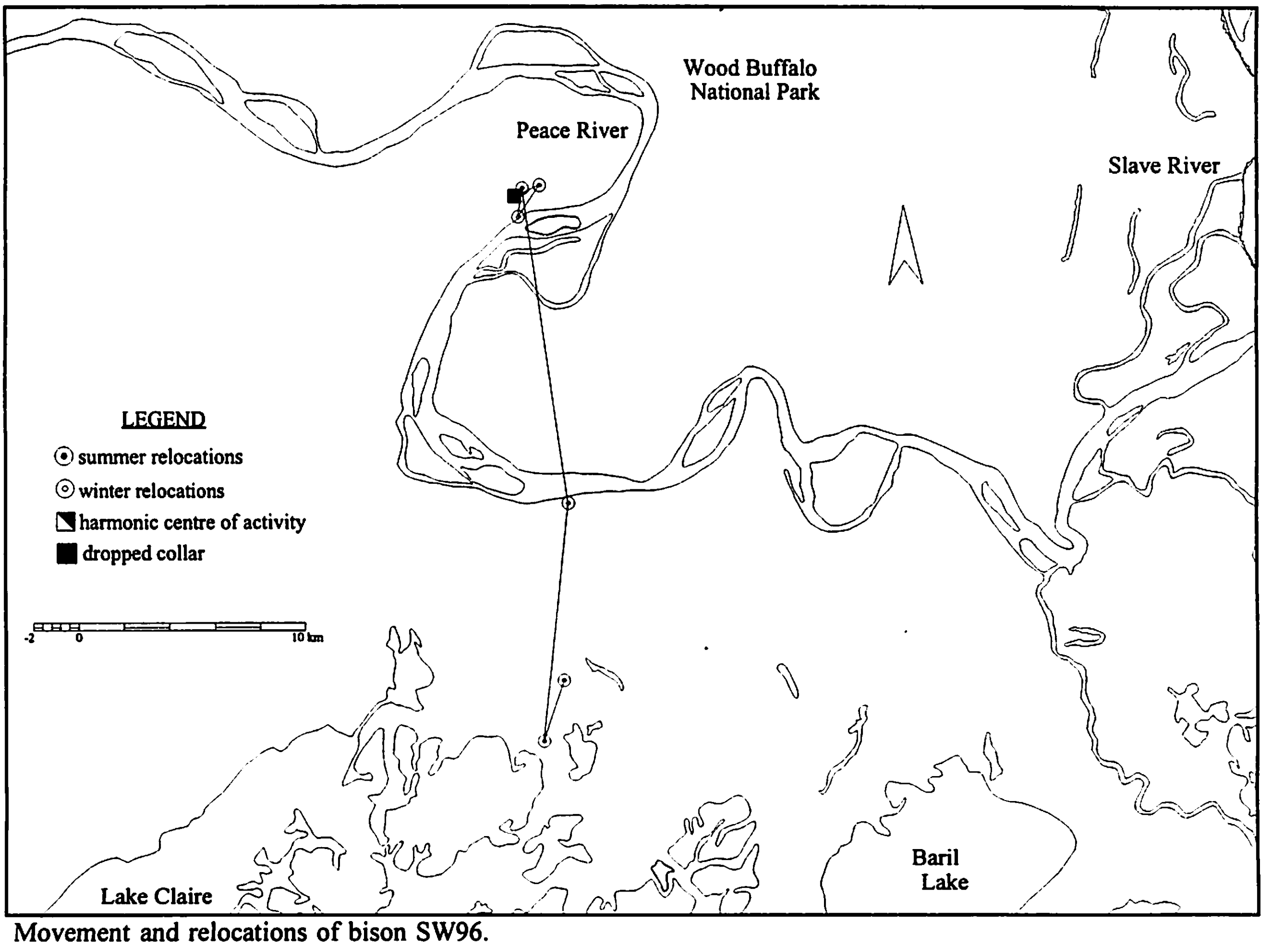
BISON: SW95
SEX: Female
RELOCATIONS: 28
95% HAR. HOME RANGE: 3353.8 km²
CORE AREA: 1139.0 km²
START: 12AUG92
END: 24SEP93
FATE: Active



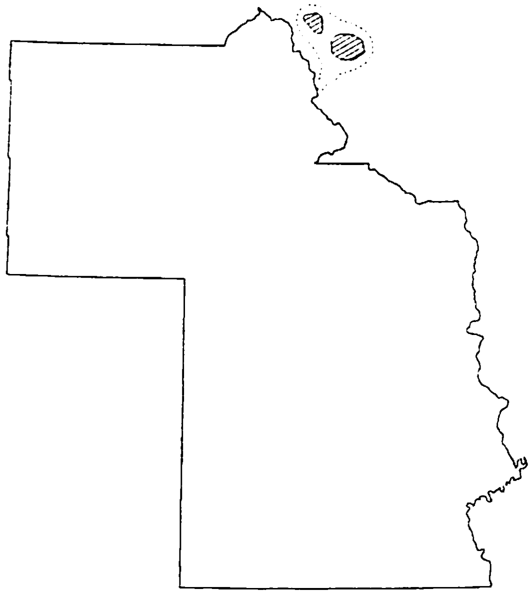
95% harmonic mean home range and core area of bison SW95.



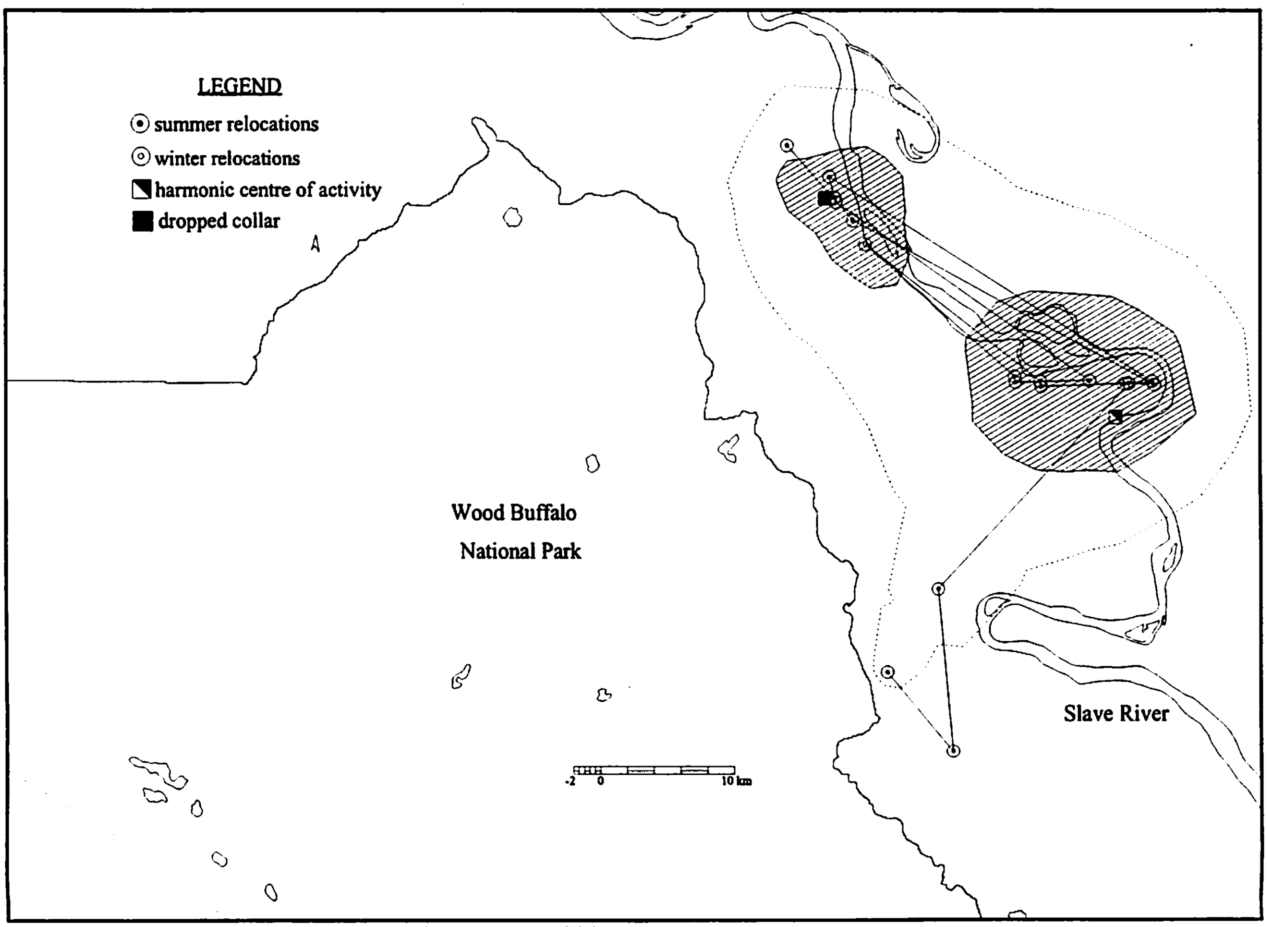
BISON: SW96
SEX: Male
RELOCATIONS: 7
95% HAR. HOME RANGE: none
CORE AREA: none
START: 12AUG92
END: 22OCT92
FATE: Dropped collar



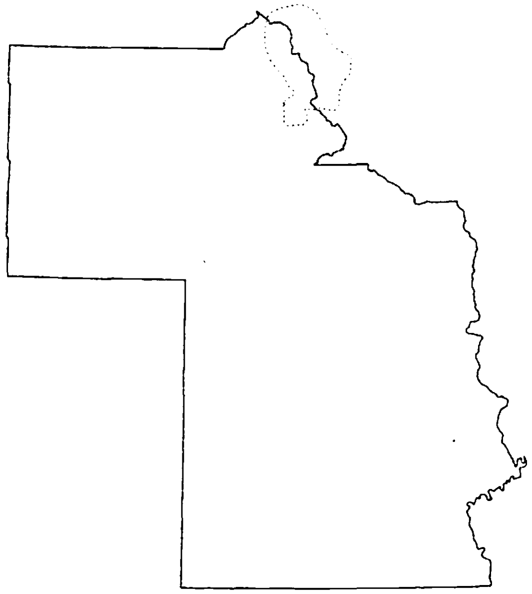
Movement and relocations of bison SW96.



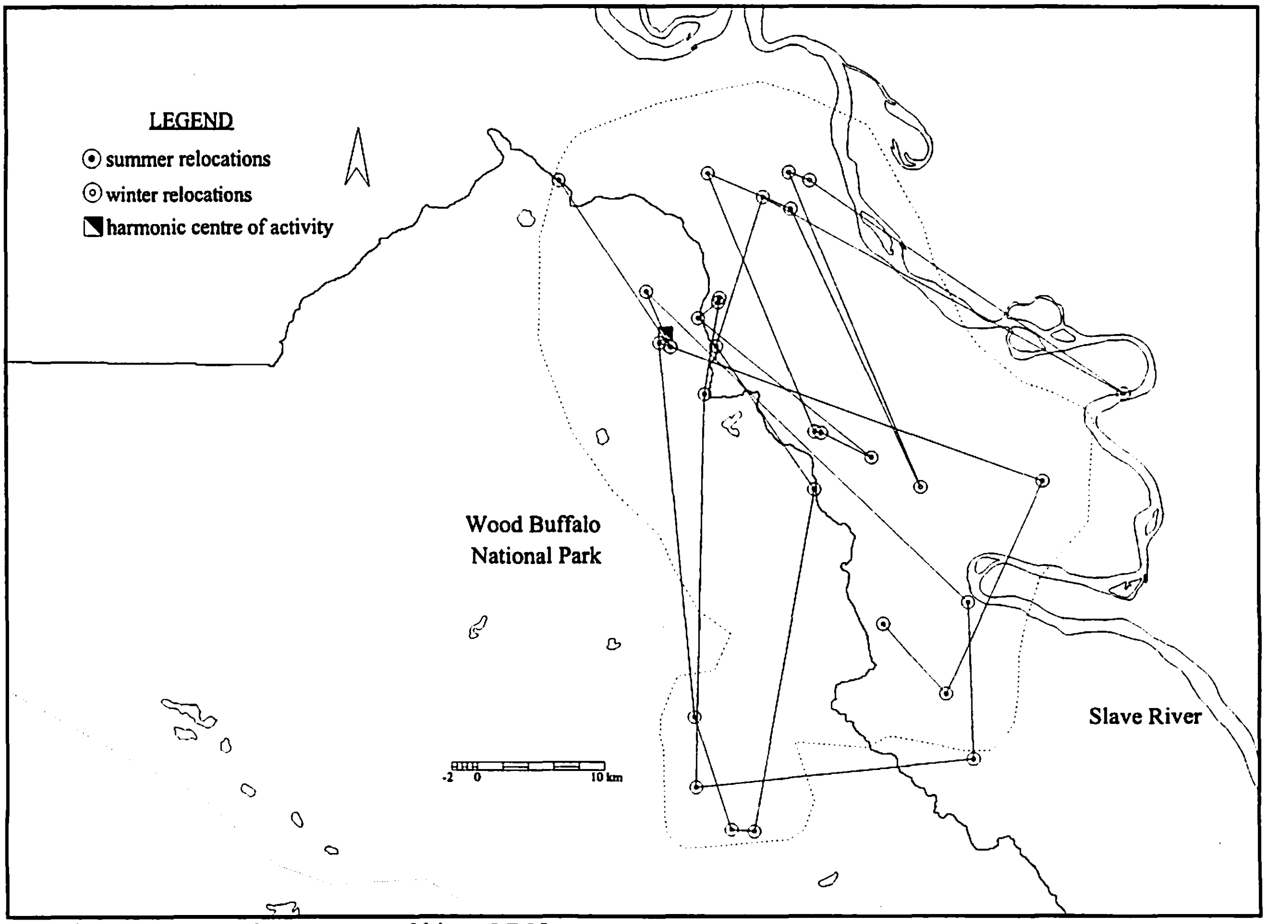
BISON: LB98
SEX: Male
RELOCATIONS: 19
95% HAR. HOME RANGE: 881.6 km^2
CORE AREA: 236.2 km^2
START: 13AUG92
END: 30APR93
FATE: Dropped Collar



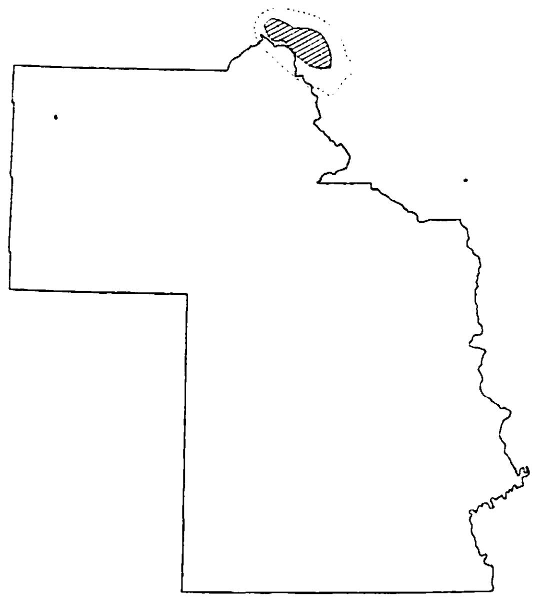
95% harmonic mean home range and core area of bison LB98.



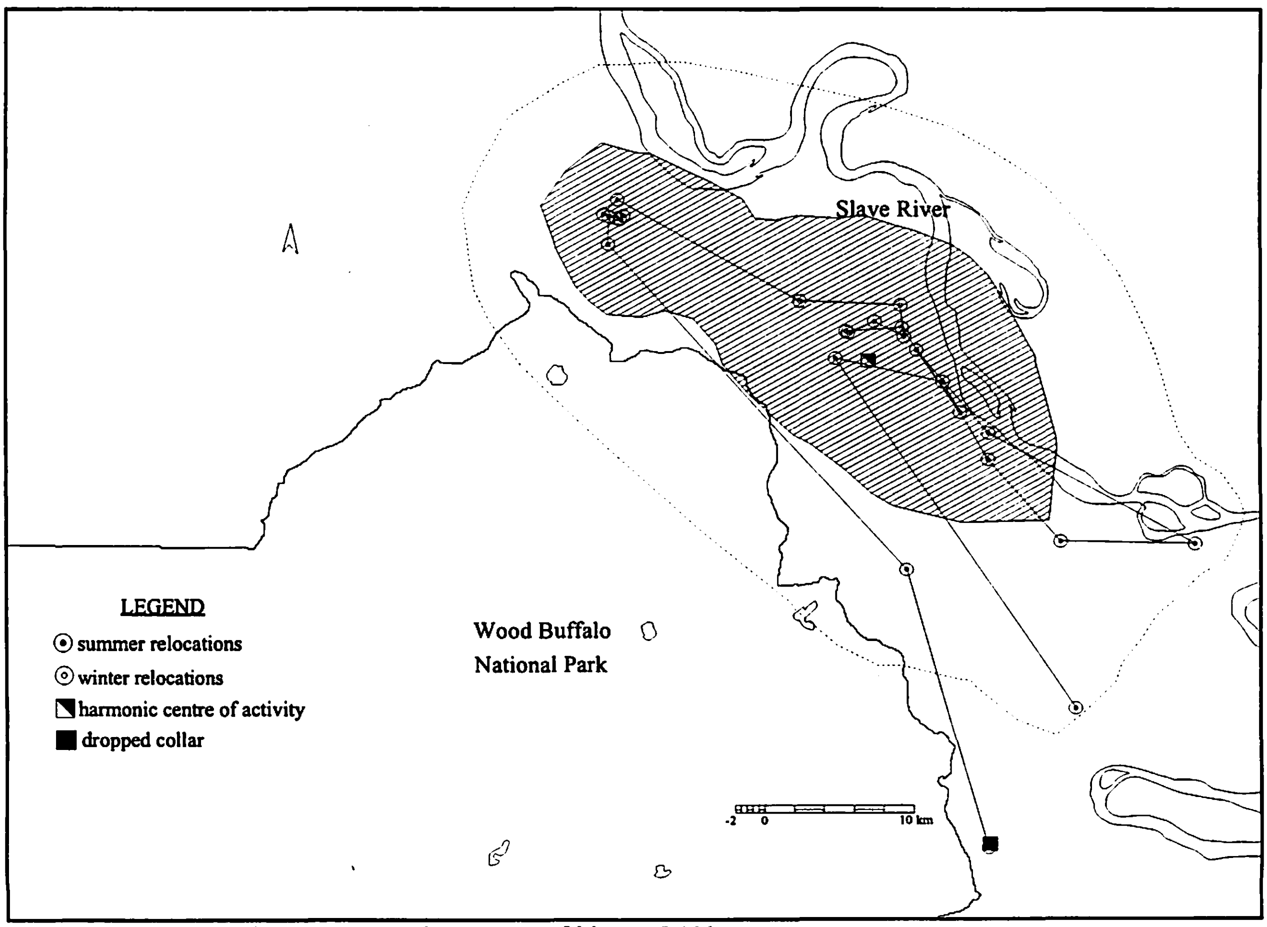
BISON: LB99
SEX: Female
RELOCATIONS: 29
95% HAR. HOME RANGE: 1643.5 km^2
CORE AREA: none
START: 13AUG92
END: 25SEP93
FATE: Active



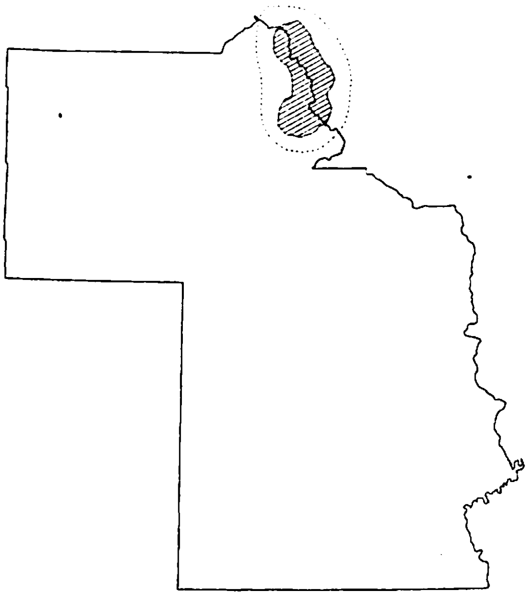
95% harmonic mean home range of bison LB99.



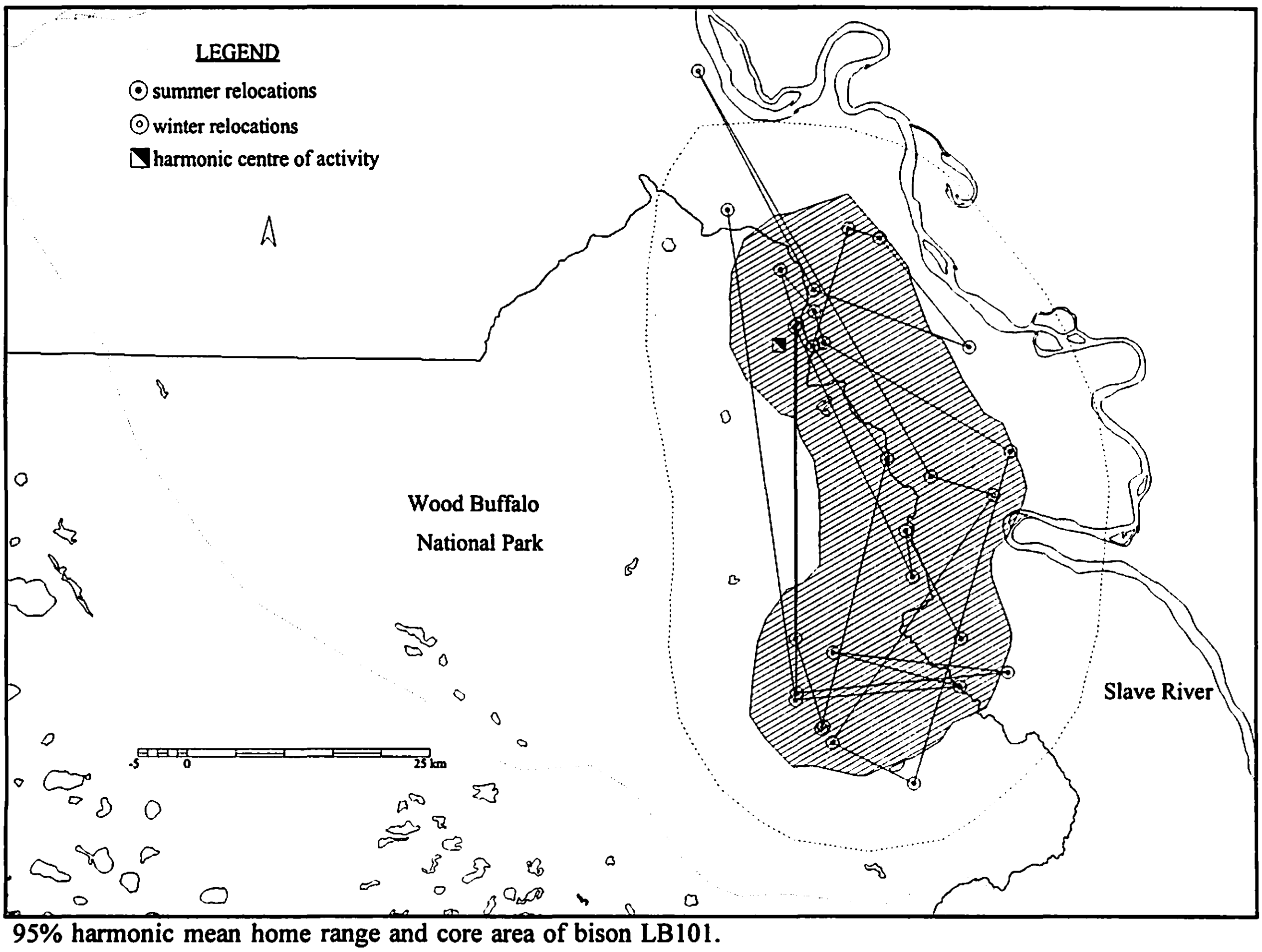
BISON: LB100
SEX: Male
RELOCATIONS: 25
95% HAR. HOME RANGE: 1393.7 km^2
CORE AREA: 443.0 km^2
START: 13AUG92
END: 13AUG93
FATE: Dropped Collar



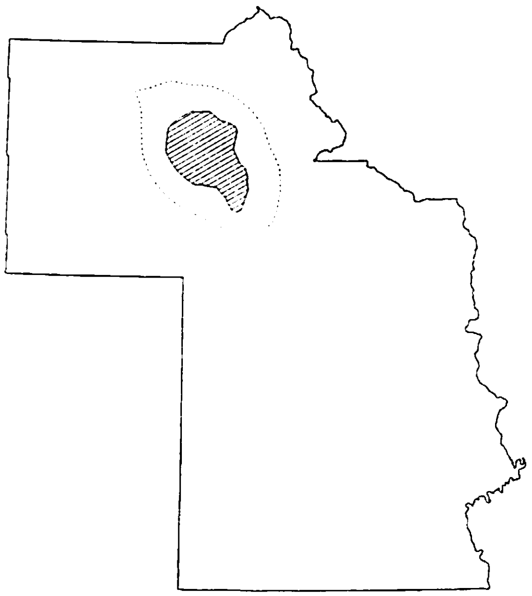
95% harmonic mean home range and core area of bison LB100.



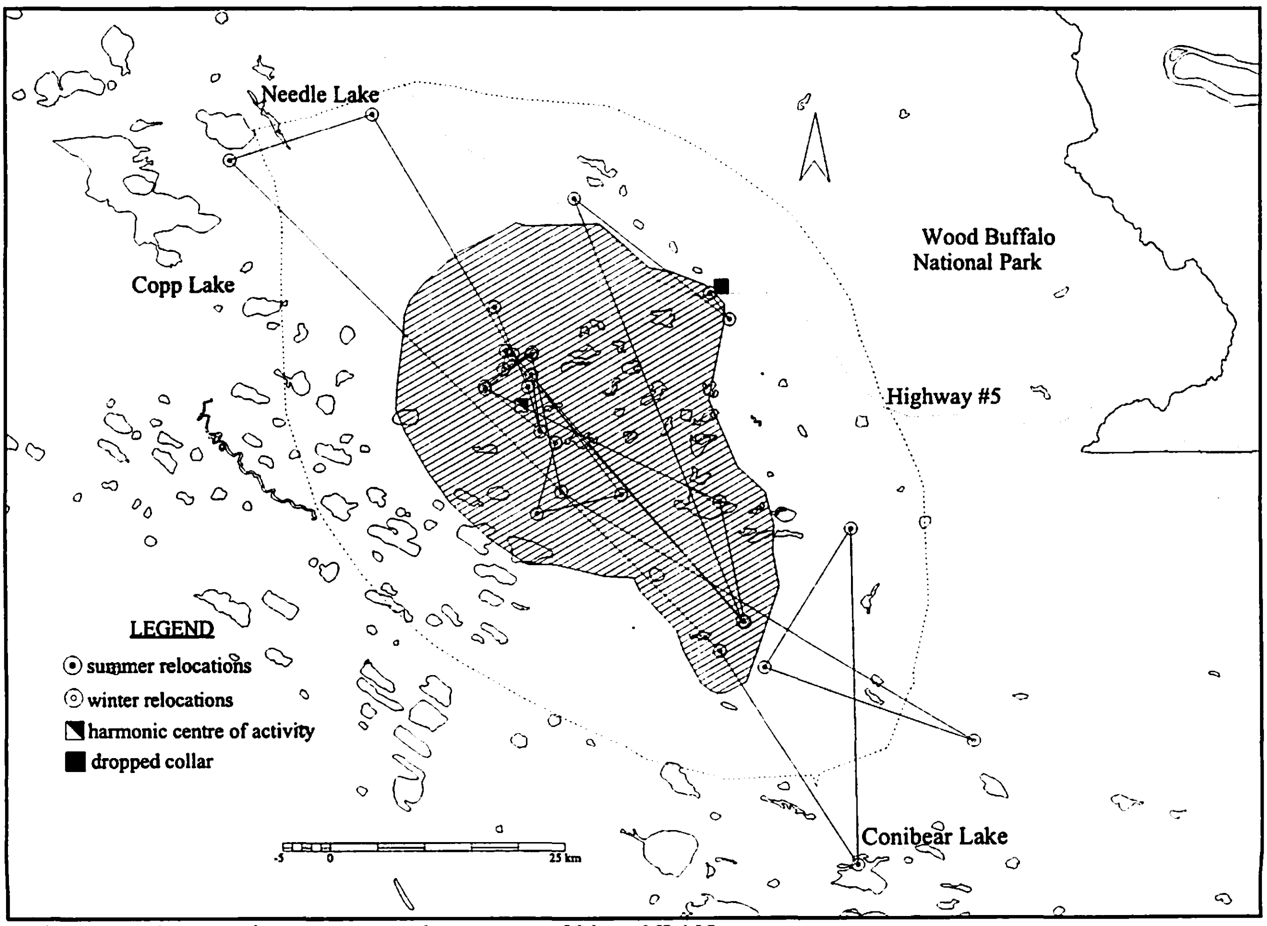
BISON: LB101
SEX: Female
RELOCATIONS: 29
95% HAR. HOME RANGE: 2956.7 km²
CORE AREA: 1147.3 km²
START: 13AUG92
END: 25SEP93
FATE: Active



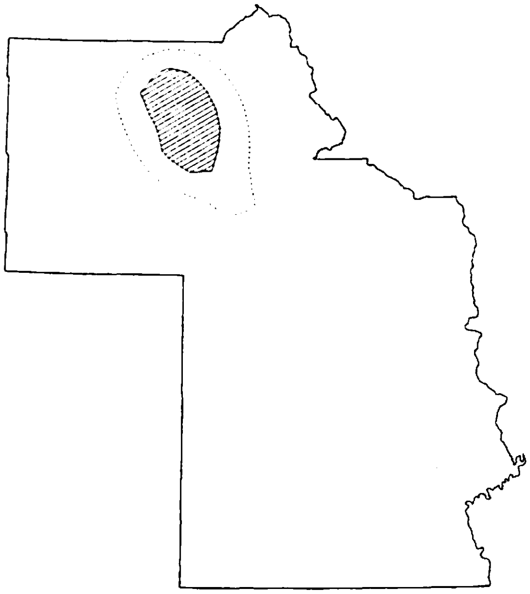
95% harmonic mean home range and core area of bison LB101.



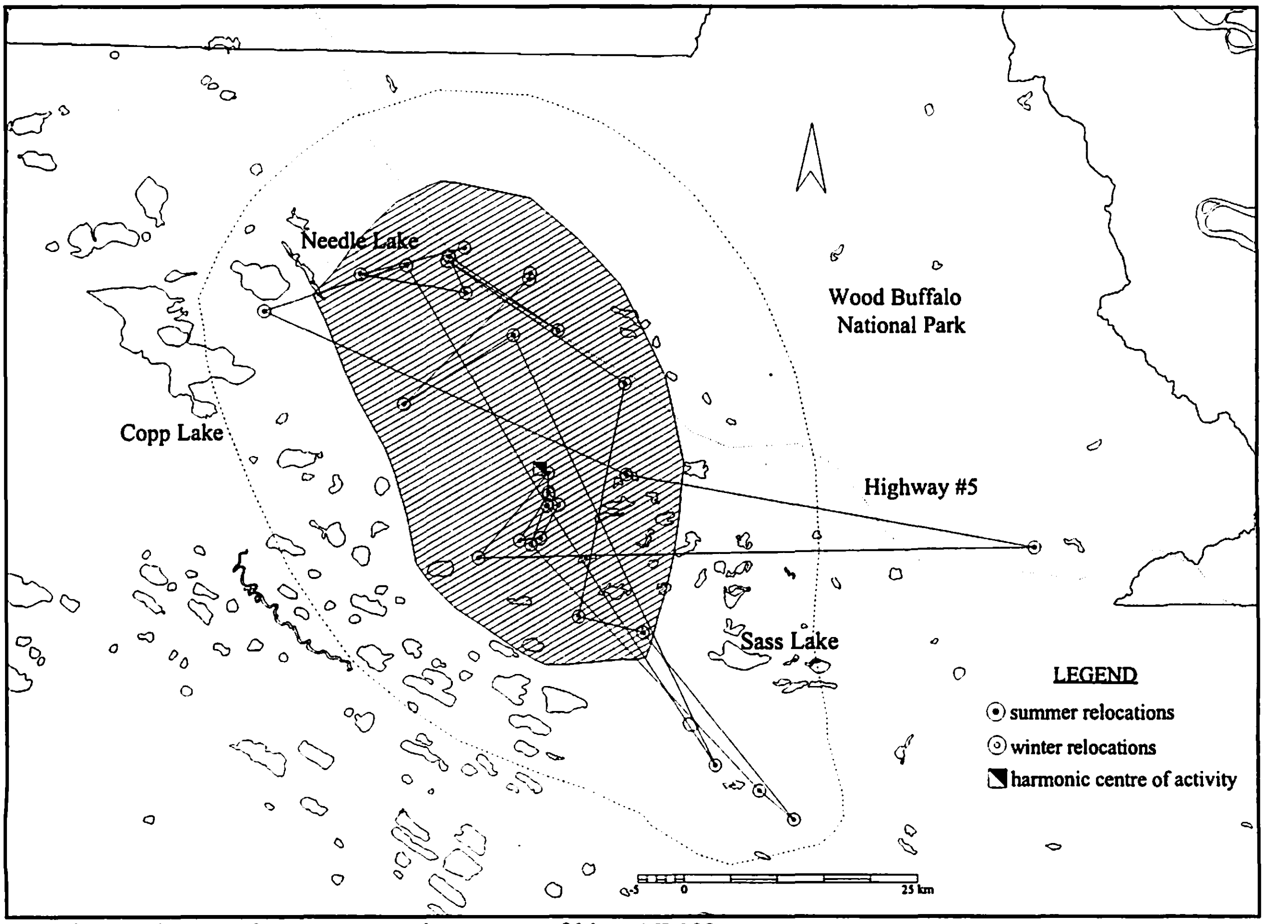
BISON: NL102
SEX: Female
RELOCATIONS: 28
95% HAR. HOME RANGE: 3890.6 km^2
CORE AREA: 1254.7 km^2
START: 13AUG92
END: 09SEP93
FATE: Dropped Collar



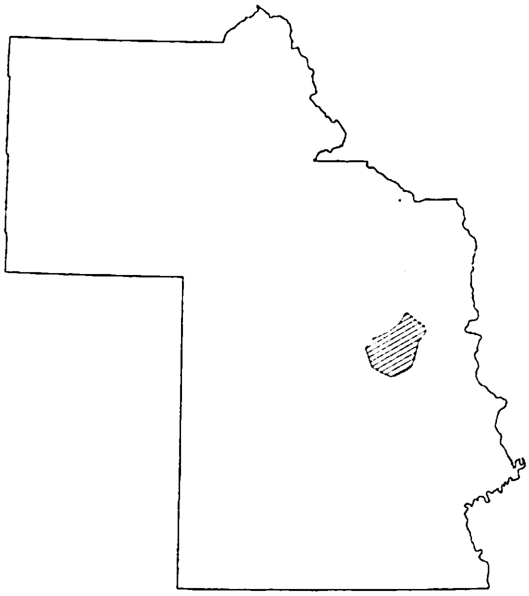
95% harmonic mean home range and core area of bison NL102.



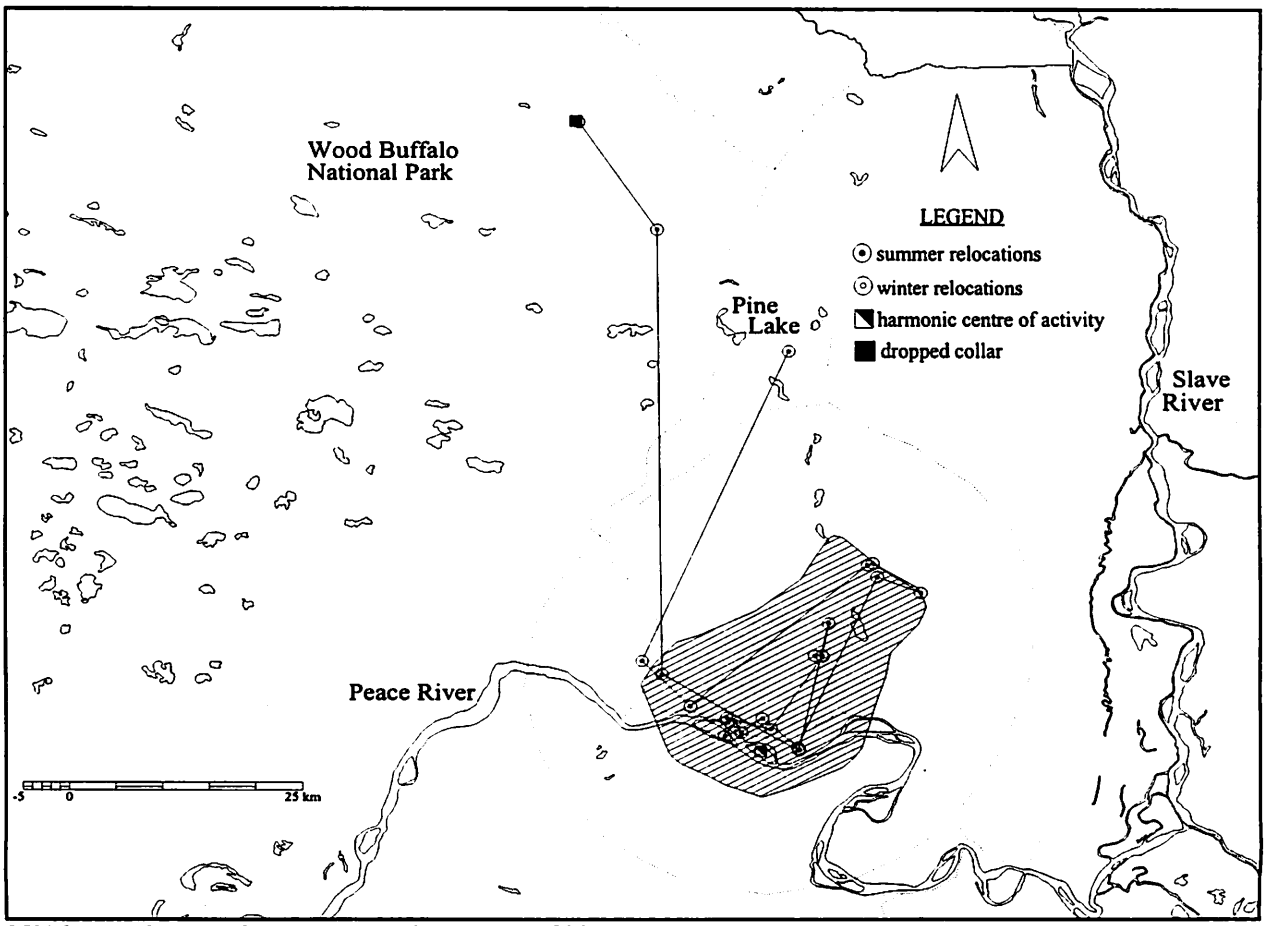
BISON: NL103
SEX: Female
RELOCATIONS: 29
95% HAR. HOME RANGE: 3393.2 km²
CORE AREA: 1388.6 km²
START: 13AUG92
END: 25SEP93
FATE: Active



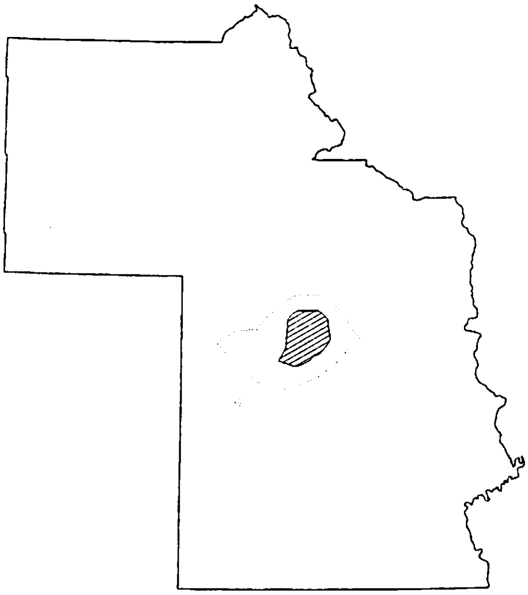
95% harmonic mean home range and core area of bison NL103.



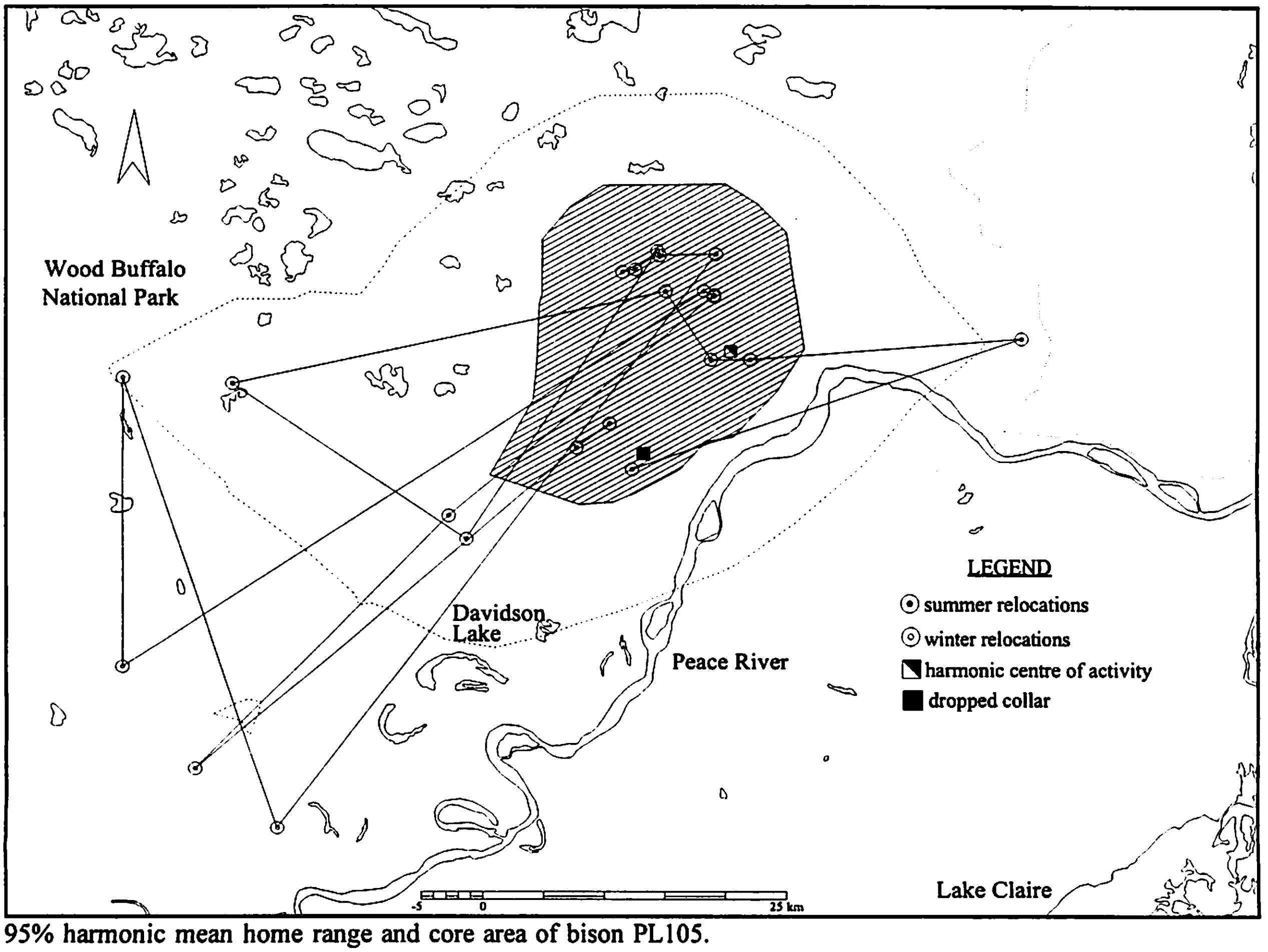
BISON: PL104
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 2376.4 km²
CORE AREA: 549.0 km²
START: 12AUG92
END: 15JUL93
FATE: Dropped Collar



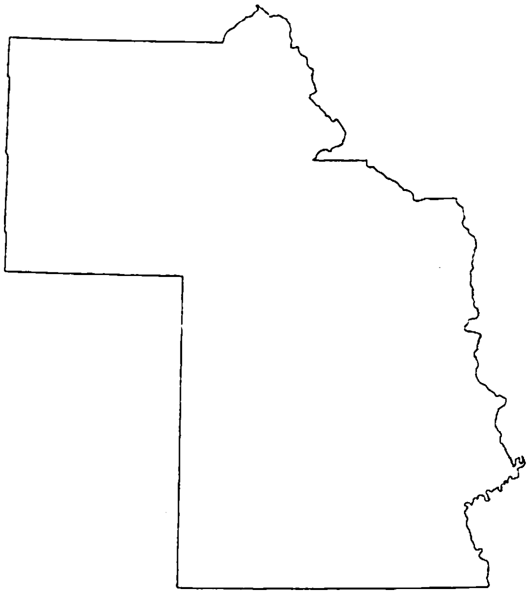
95% harmonic mean home range and core area of bison PL104.



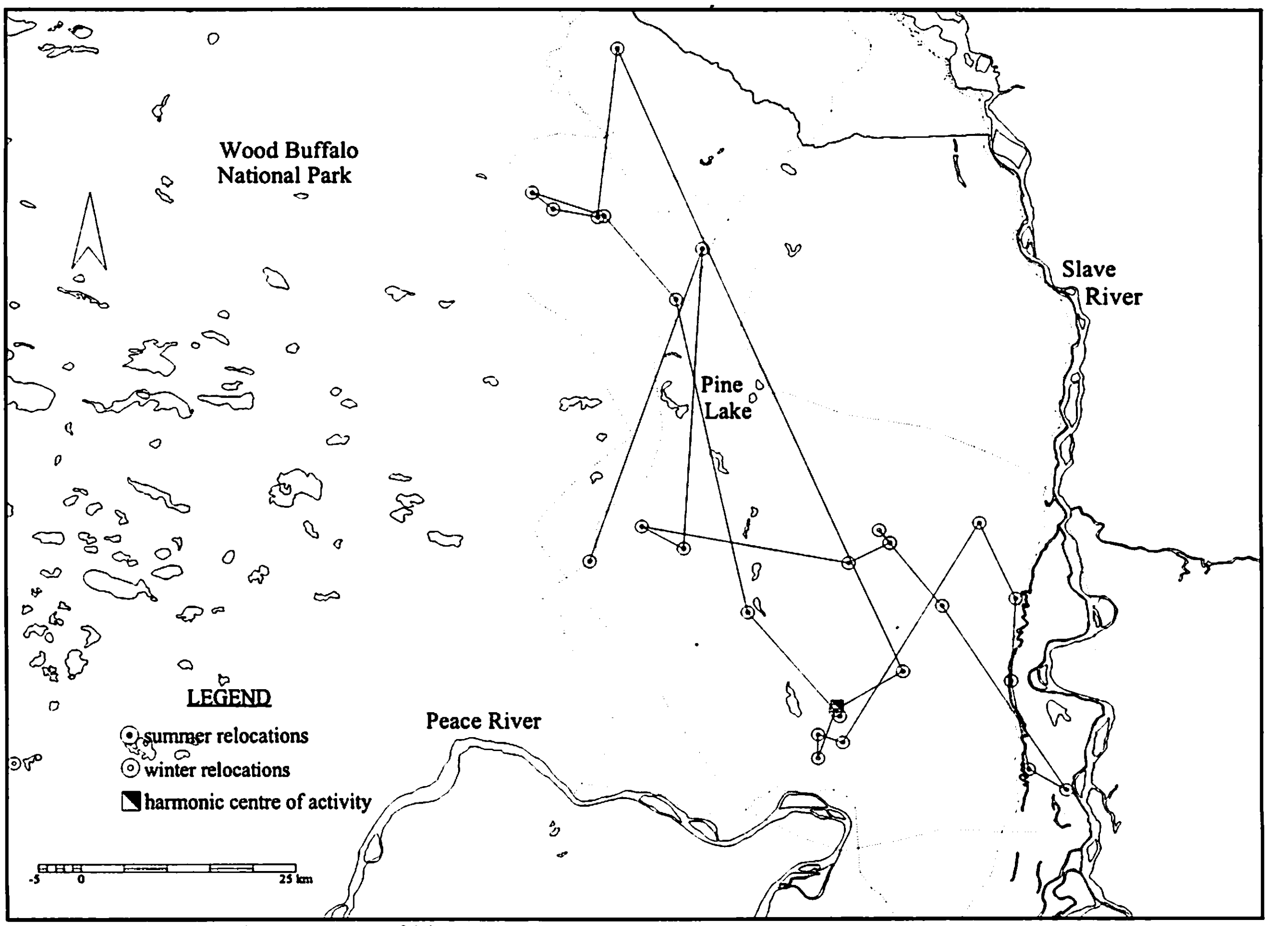
BISON: PL105
SEX: Male
RELOCATIONS: 23
95% HAR. HOME RANGE: 1986.4 km2
CORE AREA: 491.7 km^2
START: 12AUG92
END: 26AUG93
FATE: Dropped Collar



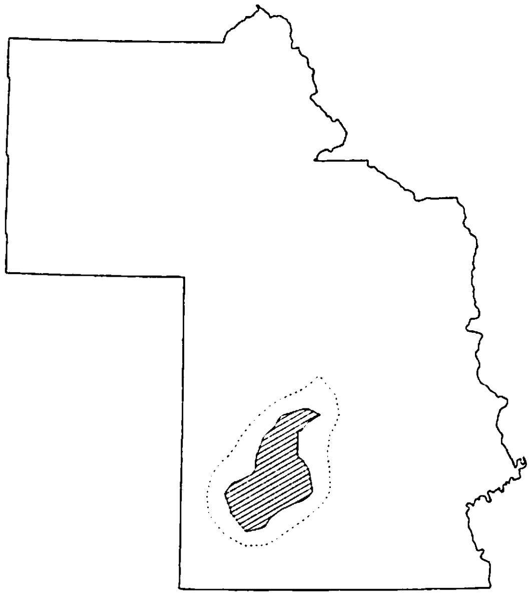
95% harmonic mean home range and core area of bison PL105.



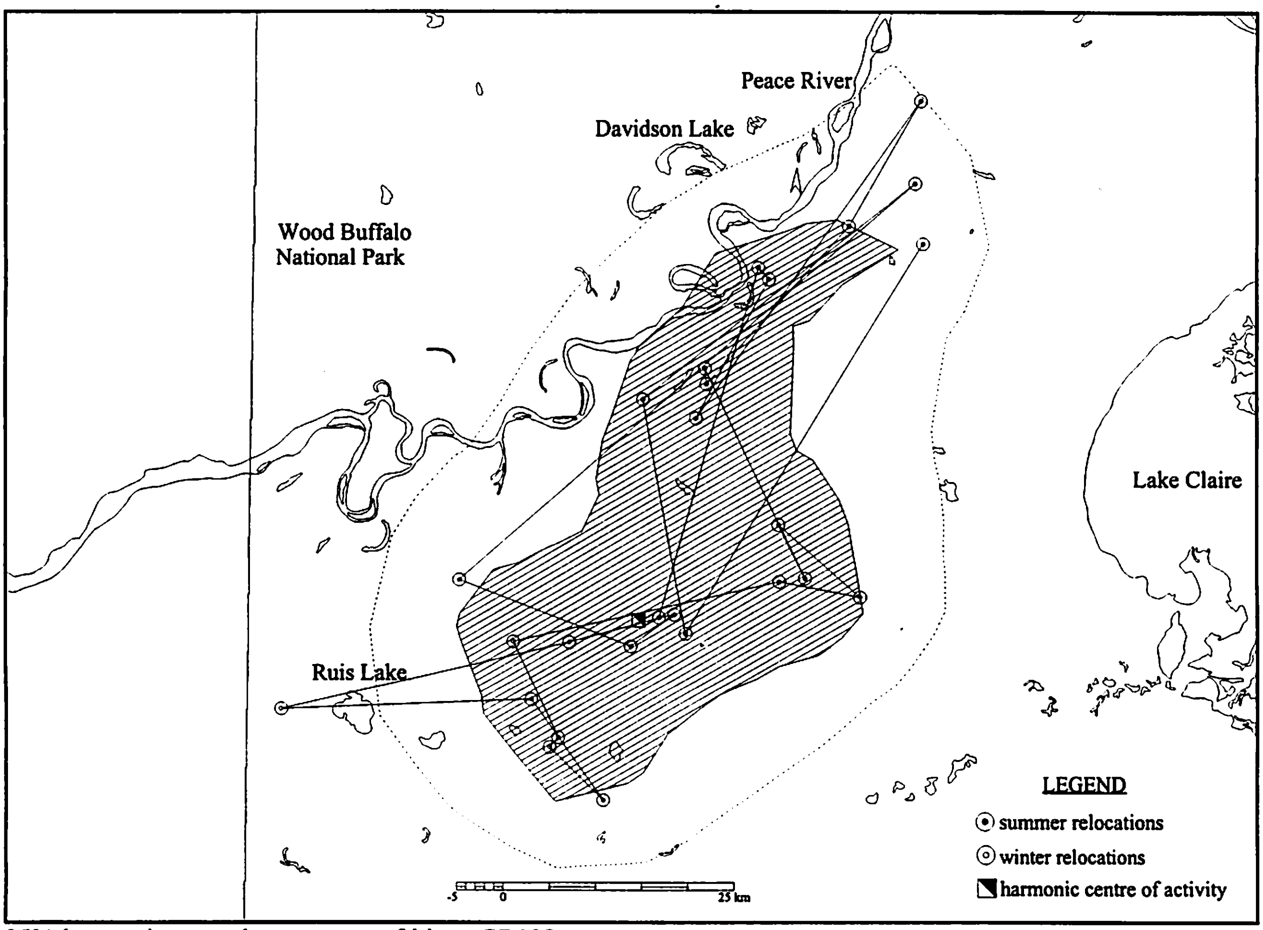
BISON: PL107
SEX: Male
RELOCATIONS: 27
95% HAR. HOME RANGE: 3206.8 km^2
CORE AREA: none
START: 12AUG92
END: 24SEP93
FATE: Active



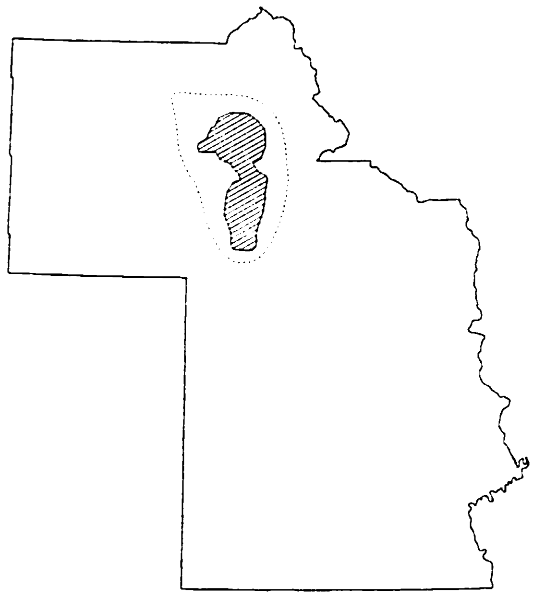
95% harmonic mean home range of bison PL107.



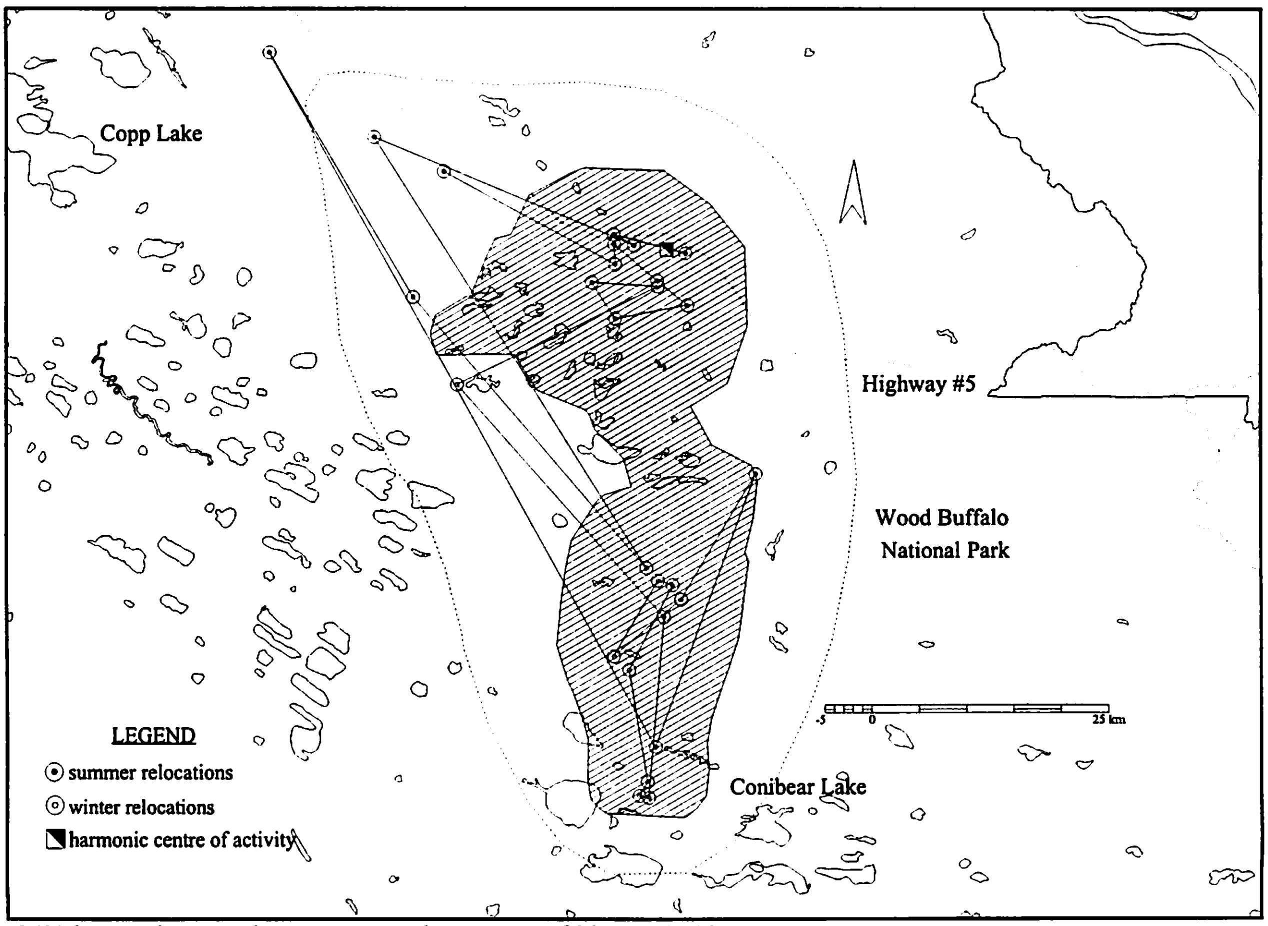
BISON: GR108
SEX: Female
RELOCATIONS: 26
95% HAR. HOME RANGE: 3799.4 km²
CORE AREA: 1418.9 km²
START: 12AUG92
END: 24SEP93
FATE: Active



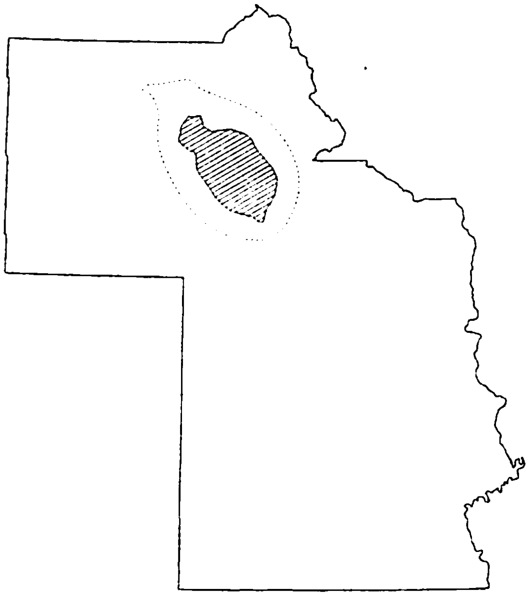
95% harmonic mean home range of bison GR108.



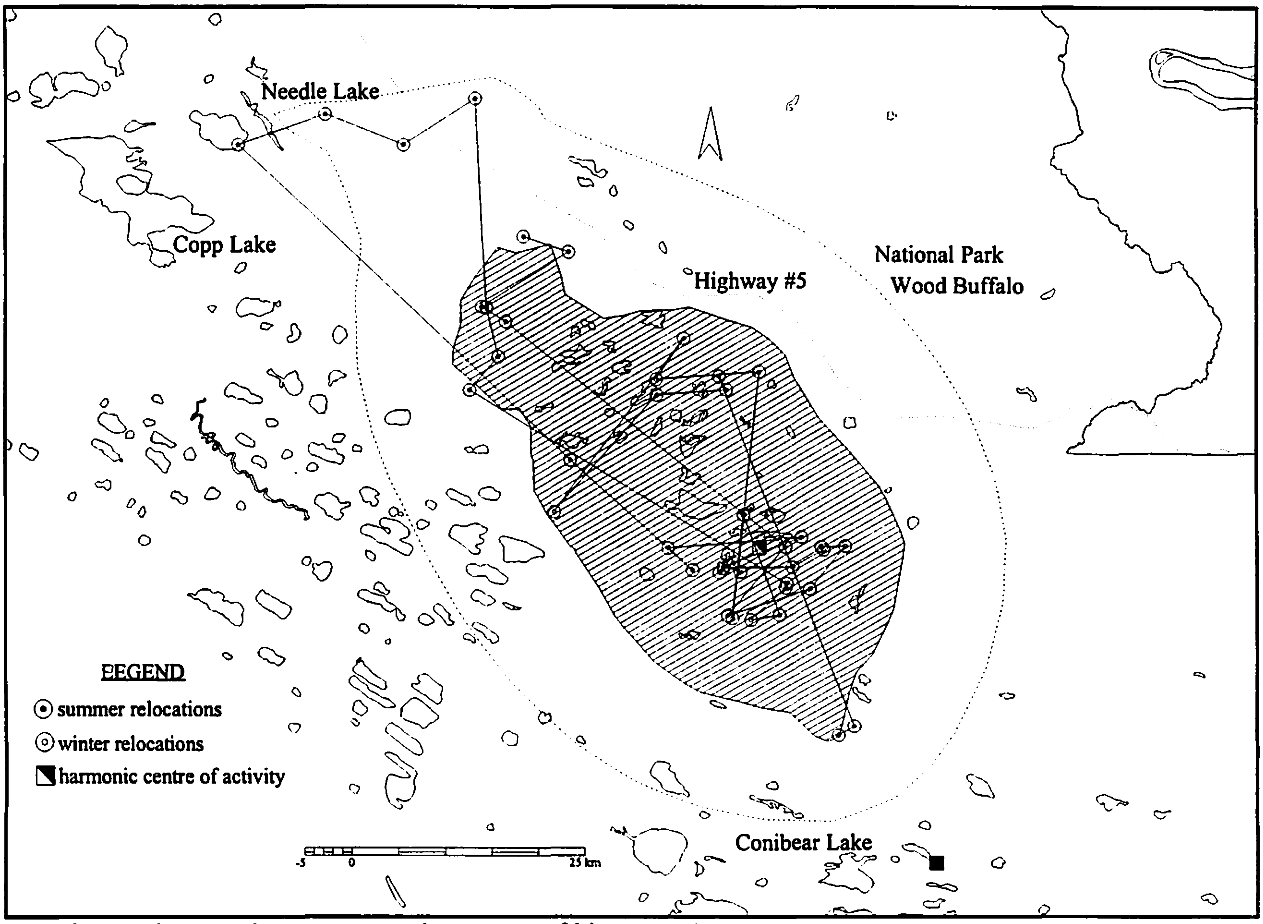
BISON: NL110
SEX: Female
RELOCATIONS: 27
95% HAR. HOME RANGE: 3502.7 km²
CORE AREA: 1273.7 km²
START: 13AUG92
END: 25SEP93
FATE: Active



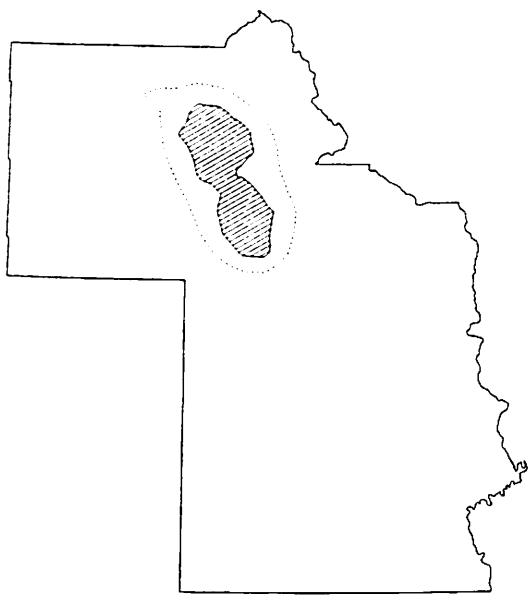
95% harmonic mean home range and core area of bison NL110.



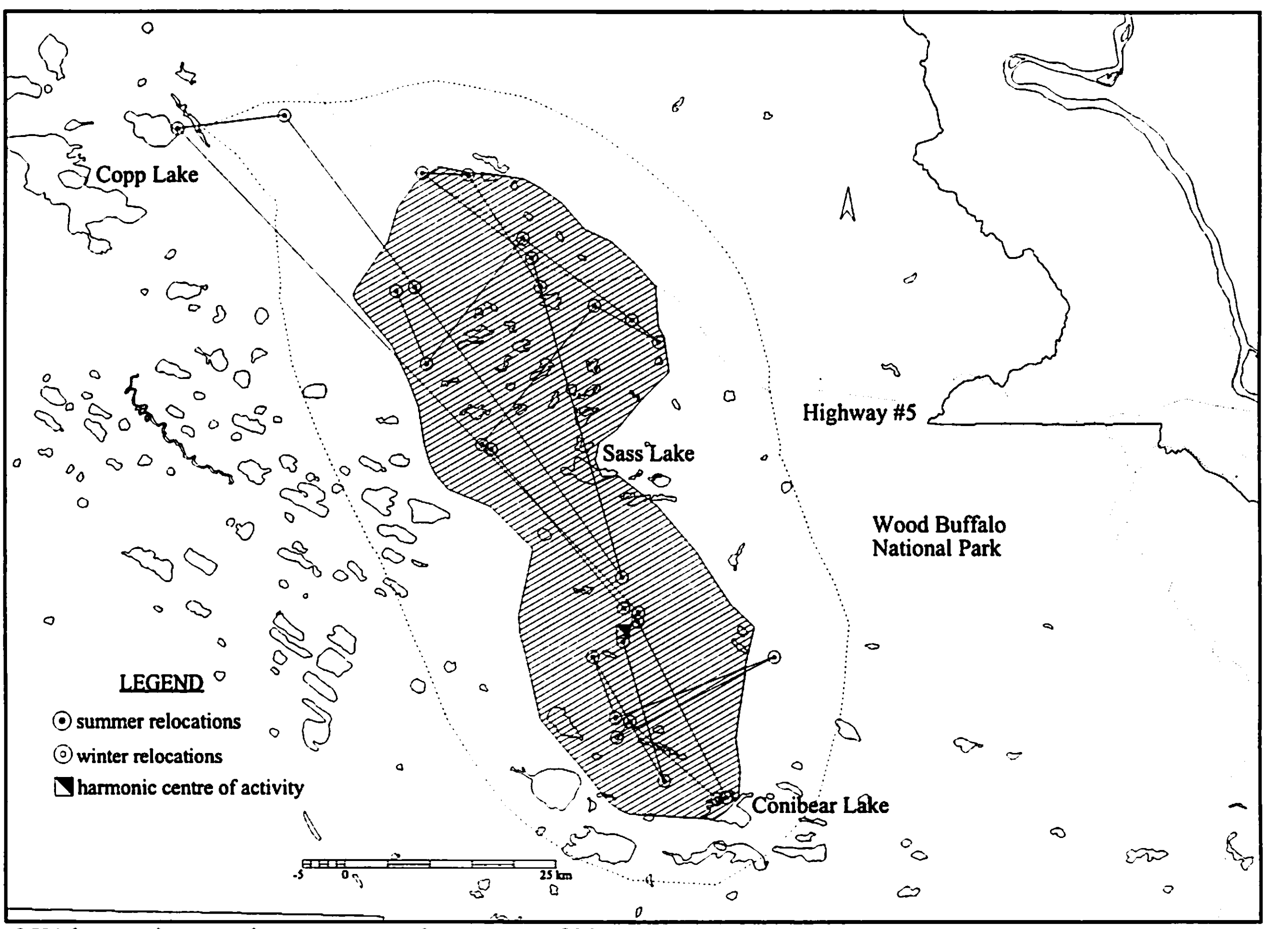
BISON: NL109
SEX: Female
RELOCATIONS: 29
95% HAR. HOME RANGE: 3451.7 km²
CORE AREA: 1191.0 km²
START: 13AUG92
END: 25SEP93
FATE: Active



95% harmonic mean home range and core area of bison NL109.



BISON: NL111
SEX: Female
RELOCATIONS: 28
95% HAR. HOME RANGE: 4396.2 km^2
CORE AREA: 1812.1 km^2
START: 13AUG92
END: 25SEP93
FATE: Active



95% harmonic mean home range and core area of bison NL111.