Aerial Beaver Survey
2004
Riding Mountain National Park

Parks Canada
Resource Conservation
Riding Mountain National Park
Wasagaming, Manitoba

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1.0 Introduction

Beaver (*Castor canadensis*) have been identified in numerous park management documents (*Ecosystem Conservation Plan* (1997), *Ecological Integrity Statement* (2002)), both as a key component of the greater Riding Mountain ecosystem and as cause for concern among people inside and outside the park who are impacted by the landscapes beavers create. Beavers were thought to be abundant in the area prior to European settlement, but through trapping and poaching their numbers declined to an estimated low of 5 or 6 families by 1936 (Green, 1936). In 1947, 28 beaver from Prince Albert National Park were released around Elk Lake, the upper reaches of Ochre River and Teepee Creek (Trottier, 1974). Twenty additional animals were released in 1958 to address run-off concerns along the escarpment and adjacent agricultural land. (Snyder, 1962). Over the past three decades the population appears to have increased and stabilized at around 3000 colonies (caches), which roughly equates to 17000 beaver at the Canadian average colony size of 5.7 (Banfield, 1981).

The Canadian Wildlife Service initiated systematic aerial surveys of caches in 1973 in order to obtain population trends within Riding Mountain National Park (RMNP). The data provides a trend for colonies distributed across the park within watersheds and ecological land districts. The data is also subjected to standardized statistical analysis to determine 95% confidence limits, which qualify the estimates and allow managers to gain a sense of how prevalent beaver are in the ecosystem.

2.0 Methodology

The 2004 aerial beaver survey was the 15th survey to be completed, conducted between 20 October 2004 and 1 November 2004. The survey techniques were consistent with past beaver surveys described in *Aerial Beaver Survey, RMNP, Guidelines & Methodologies*. (Andrews, Pylypuik, Toews, 1982), except that navigation and data collection were completed with a laptop computer linked to a GPS rather than hardcopy 1:10,000 scale air photo mosaics (1985) that were used in the previous three surveys. Navigation was conducted by the pilot with the aid of a Garmin 3+ GPS unit and verified by the recorder who had real-time mapping capabilities on a laptop computer.

Due to a shortage of observers available during the survey, the role of right observer and recorder were combined for much of the survey, but given the density of caches on this survey and the ease of recording on the laptop, the consensus among the recorders was that the dual role did not significantly compromise their ability to detect caches.

Dauphin Air Services provided a Cessna 206 for the first two days and a Cutlass aircraft for the remainder of the survey. Robert Simpson, an experienced survey pilot who has flown the survey several times before, piloted the aircraft. He noted that the laptop recording and navigation system diminished much of the navigational and recording confusion that was commonplace in previous surveys.

2.1 Survey Crew

Robert Simpson – Pilot – Dauphin Air Services
Glenn Schmidt – Recorder (20,25,26,31 Oct), Right Observer (25,26,31 Oct) – RMNP
John Ledoux – Right Observer (20 Oct), Left Observer (25,26,27 Oct) – Manitoba Conservation
Tim Sallows – Left Observer (20 Oct, 1 Nov) – RMNP
Robert Watson – Recorder & Right Observer (1 Nov), Left Observer (31 Oct) – RMNP
Sean Frey – Recorder & Right Observer (27 Oct) – RMNP

2.2 Survey Costs

There are two main realized costs: aircraft time (see Table 1) and survey crew meals ($306.78), which totalled $ 8924.78 for this survey.

Table 1 – Aircraft Costs – Dauphin Air Service Ltd.

Date	Item Description	Rate	Hours	Cost (-GST)
2004-10-20	C-206 GEXT Aircraft	$390.00	4.3	$ 1,677.00
2004-10-25	C-206 GEXT Aircraft	$390.00	5.9	$ 2,301.00
2004-10-26	C-172 RG GIQH Aircraft	$290.00	3.6	$ 1,044.00
2004-10-27	C-172 RG GIQH Aircraft	$290.00	2.6	$ 754.00
2004-10-31	C-172 RG GIQH Aircraft	$290.00	4.7	$ 1,363.00
2004-11-01	C-172 RG GIQH Aircraft	$290.00	5.1	$ 1,479.00
Total			26.2	$ 8,618.00

There is also the indirect cost of salary, which is somewhat difficult to track due to mixed travel and waiting times on the ground due to poor weather. An estimate of hours spent on the survey is tabulated in Table 2 and categorized in Table 3.

Table 2 - Survey Crew Hours

Date	Item	Type	Hours	Notes
2004-09-15	Digitally delineate survey blocks and transects in GIS	Preparation	2	This will not need to be done in subsequent surveys
2004-09-15	Generate waypoints and routes for transects for GPS and Fugawi upload	Preparation	4	
2004-09-17	Electronically integrate transects and orthoimages (1994), transfer to Fugawi	Preparation	6	May want to use 2004 orthos next survey
2004-09-18	Load block maps and routes into laptop	Preparation	0.5	
2004-10-15	Laptop / Fugawi training refresher	Preparation	4	Important
2004-10-20	Travel - Tim (2), Glenn (.5), John (.5)	Travel	3	

Date	Item	Type	Hours	Notes
2004-10-20	Conduct Survey	Flying	12.9	
2004-10-20	Backup data, send for processing, merged	Data	0.5	
2004-10-25	Travel - Glenn (.5), John (.5)	Travel	1	
2004-10-25	Conduct Survey	Flying	11.8	
2004-10-25	Backup data, send for processing, merged	Data	0.5	
2004-10-26	Travel - Glenn (.5), John (.5)	Travel	1	
2004-10-26	Conduct Survey	Flying	7.2	
2004-10-26	Backup data, send for processing, merged	Data	0.5	
2004-10-27	Travel - Sean (2), John (.5)	Travel	2.5	
2004-10-27	Conduct Survey	Flying	5.2	
2004-10-27	Backup data, send for processing, merged	Data	0.5	
2004-10-31	Travel - Glenn (.5), Rob (.5)	Travel	1	
2004-10-31	Conduct Survey	Flying	9.4	
2004-10-31	Backup data, send for processing, merged	Data	0.5	
2004-11-01	Travel - Tim (2), Rob (.5)	Travel	2.5	
2004-11-01	Conduct Survey	Flying	10.2	
2004-11-01	Backup data, send for processing, merged	Data	0.5	
2004-11-02	Process data, begin report	Report	5	
2004-11-05	Build report	Report	5	
2004-11-08	Complete report	Report	15	
Total			112.2	

Table 3 - Categorized Survey Crew Hours

Category	**Total**
Data	3
Flying	56.7
Preparation	16.5
Report	25
Travel	11
Grand Total	112.2

Note that only two crew were used for the majority of the survey rather than the three recommended so the hours spent are lower than would be expected for this survey.

2.3 Survey Area

The same 30 survey blocks as surveyed in past years were flown in 2004. They are primarily township quadrats, which translate to a total of 725 square km or 23.4 % of the area of Riding Mountain National Park. Figure 1 shows where the blocks are situated across the park.

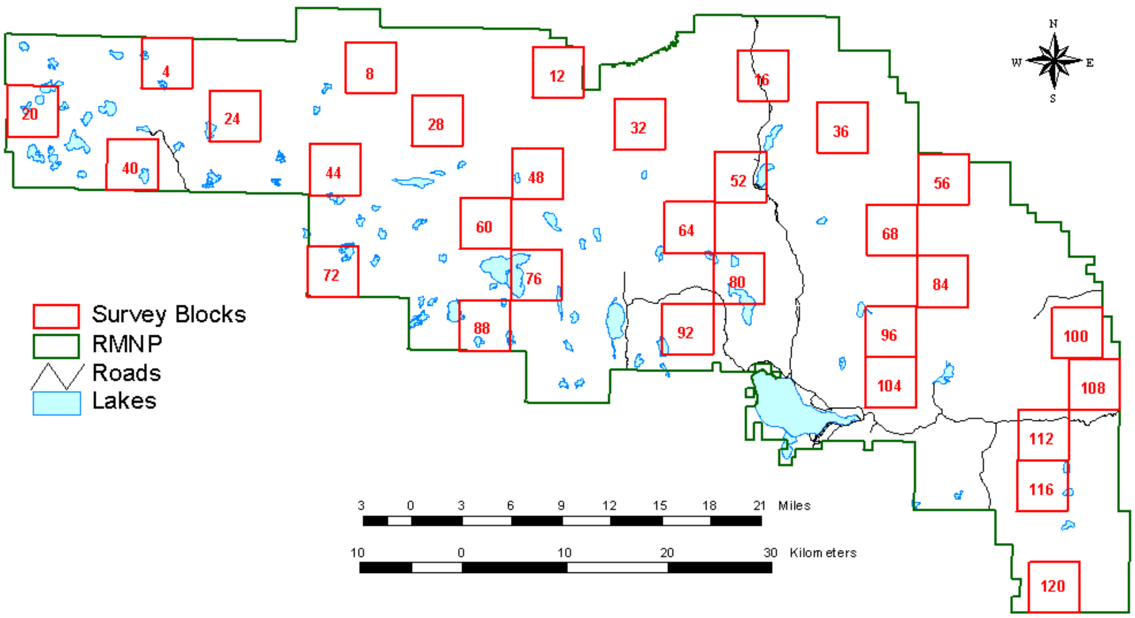

Figure 1 - Aerial Beaver Cache Survey Blocks

Each block is bisected north south by 12 transects 408 m apart (see Figure 2) numbered from west to east, but flown in reverse order. Waypoints on either end of the transects begin sequentially at the NE corner of the block and finish at the NW to minimize ferry time from the airport to the first transect and to ensure the teardrop turns are generally made into the prevailing winds, which lowers the risk involved in the low altitude turns.

With 30 blocks and 24 waypoints per block, the survey involves navigating a total of 720 waypoints on 1772 km of transect. The survey guidelines (Andrews, Pylypuik, Toews, 1982) indicate that due to observer fatigue flights should remain less than 2.5 hours, which is generally enough time to complete 3 blocks. Thus under ideal weather conditions flying mornings and afternoons, the survey takes 25 hours or five days of solid flying.

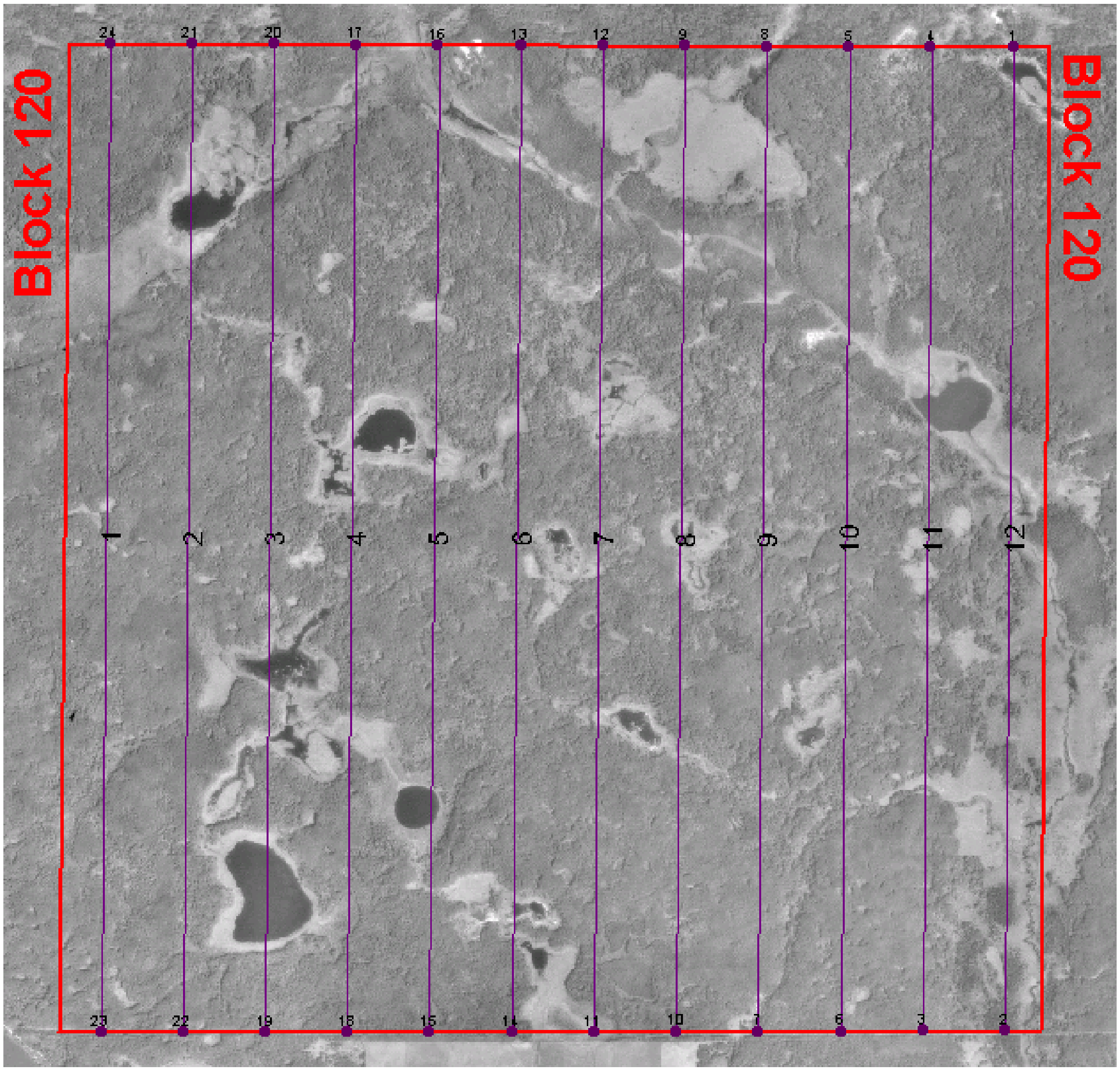

Figure 2 - An example survey block (120) with transects and waypoints over the 1994 digital orthophoto.

2.4 Preparation

This is the first beaver survey to move completely to digital navigation and data collection systems. GPS was first used in 1992 to aid navigation, but data collection for the past three surveys consisted of 1:10,000 air photo mosaics and markers. Given that the blocks at that scale are 24-inch square sheets (60 cm square) the challenge of using this system in an aircraft where the pilot and navigator/recorder are shoulder to shoulder is readily apparent (see Figure 3).

For this survey the blocks, transects and waypoints were constructed using ESRI ArcView 3.3 and then overlaid on 1994 digital orthophotos. The resulting maps were then digitally exported to image bitmaps at 1:10,000 scale that were then imported to a moving map software package called Fugawi 2.19. The waypoints were transferred from ArcView to Fugawi using a GPS unit and then block transect routes were constructed in Fugawi. Fugawi was utilized in the aircraft for navigation and data collection (see Figure 3). In future ESRI ArcPad software would be a better fit for this application as it would avoid the need for layer translation and would allow for interactive zooming which could be very useful when making the long teardrop turns. Fugawi was used in this survey because it was familiar to the data recorders from use in ungulate surveys, and there wasn't enough time to train them on a new software package.

Figure 3 - Robert Watson using navigation and recording laptop inside Cutlass aircraft (photo: Tim Sallows).

The pilot was able to navigate independently using the GPS III+ unit that was mounted (Velcro) on the dash of the aircraft, and connected to the laptop via a serial cable. Position data was downloaded to the laptop using NMEA protocol. In this fashion, the recorder/navigator can see in real time where the aircraft is relative to transects and any potential cache locations. A track log was also active so the plane's flight path and speed was recorded, helping reduce confusion between pilot and/or navigator about which lines had been completed, or if cross winds were creating significant crabbing of the aircraft. Data is captured in Fugawi using the waypoint creation function and data is then saved to hard disk and emailed to Wasagaming.

3.0 Results

All the observers noted during the course of the survey that many lodges where observed without caches, suggesting that beavers might be at lower levels than they have been in the past. The total feed cache numbers appear to support the observation, as only 417 caches were observed in the 30 blocks in 2004 compared to 823 in 1995 - representing a 49% drop in observed beaver colonies.

Through the consistent statistical process used in previous surveys (see Appendix A) an estimate of 1773 caches was calculated with ± 517 caches being the range represented by 95% confidence limits on the estimate, or between 1256 – 2290 caches. In 1995 the estimate was 3499. Figure 4 graphs the colony estimate for the park from the beginning of the survey.

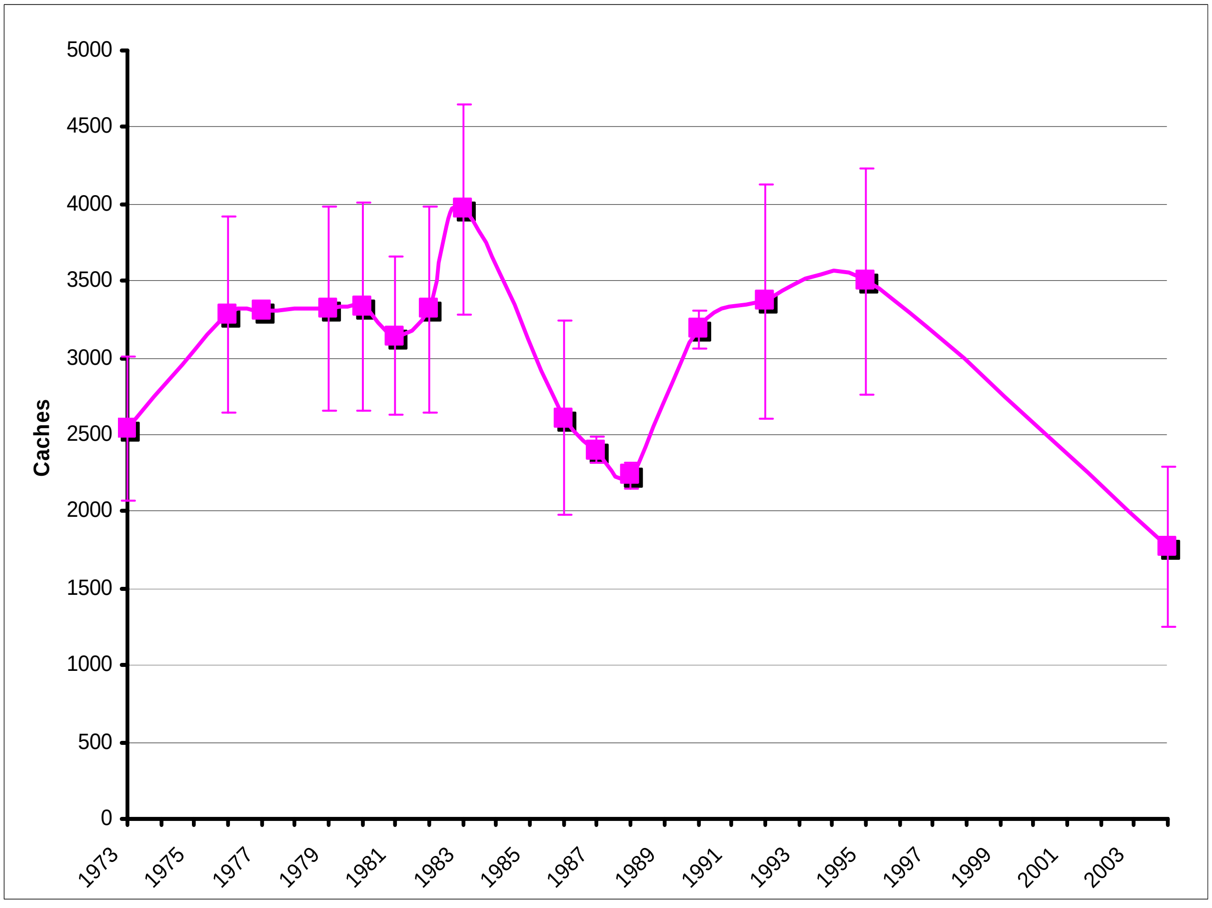

Figure 4 - Riding Mountain National Park cache estimates from 1973 to 2004 with 95% confidence limits.

It is apparent in Figure 4 that the estimate for 2004 is lower than has ever been recorded in the past 30 years in 15 surveys, and outside the range of statistical variation.

3.1 Weather

Wind, overcast conditions, light rain, snow and particularly fog interrupted the survey a couple times for periods of up to four days over the course of the survey. Snow was light and only present on the ground for the first few days of the survey and was not present in amounts that appeared to have an effect on the visibility of the caches. The first two days of the survey also saw many of the ponds with light ice cover, but again it did not appear to be an impediment to cache observations. A warm air mass moved in towards the middle of the survey causing all of the snow and ice to melt. Ground conditions during the flights are given in Table 4 and although they do not provide an accurate correlation with conditions aloft they nevertheless give a sense of the conditions. One day the air temperature at 400 ft above ground was 10°C warmer than the ground and while there was only a light breeze on the ground there were high winds over the escarpment. Weather conditions changed quickly between blocks even in a single morning, but care was taken to avoid conditions that would affect the results of the survey or impact safety.

Table 4 - Ground weather conditions at Dauphin Airport during flight times

Date	From	To	Elapsed	Temp °C	Wind km/h	Direction °	Visibility km	Blocks
2004-10-20	10:40	12:30	1:50	1.2	13	260	15	12, 28
2004-10-20	13:40	16:10	2:30	2.0	11	90	15	32,48,60
2004-10-25	9:00	12:00	3:00	4.0	9	270	15	8,44,72
2004-10-25	13:20	16:15	2:55	8.5	11	280	15	120,116,112
2004-10-26	12:42	16:20	3:38	9.0	17	120	15	108,100,104,96
2004-10-27	9:35	12:10	2:35	6.0	15	180	15	52,16,64
2004-10-31	9:25	11:45	2:20	4.0	15	240	15	80,92,36
2004-10-31	12:55	15:15	2:20	8.0	24	270	15	56,84
2004-11-01	9:00	12:20	3:20	2.0	20	260	15	20,4,40,24
2004-11-01	13:45	15:35	1:50	6.0	24	260	15	76,88

3.2 Block counts

2004 block counts were consistently lower than 1995 block counts except in Block 16 – representing an average 49% decrease in numbers (See Table 5). 2004 counts were also below the average counts in all but 5 blocks (Blocks 16, 20, 56, 72, 100) with an average percent difference of -41%. A full table of counts from 1973 to 2004 is included in Table 5 and illustrated in Figure 5 with a graphing map that shows the counts by block and their arrangement across the park.

Table 5 - Block counts from 1973 to 2004

	YEAR																2004 % Change	
BLOCK#	1973	1976	1977	1979	1980	1981	1982	1983	1986	1987	1988	1990	1992	1995	2004	Mean	1995	Mean
4	13	12	6	11	14	14	12	18	12	8	6	15	13	14	5	12	-64%	-57%
8	39	50	37	49	51	37	48	58	33	24	20	43	52	57	15	41	-74%	-63%
12	8	5	7	14	12	11	15	23	9	13	18	12	17	20	11	13	-45%	-15%
16	3	7	8	2	5	12	8	11	9	19	12	13	11	16	18	10	13%	75%
20	12	25	29	29	48	29	33	41	45	48	26	51	45	60	39	37	-35%	4%
24	15	19	15	13	24	20	18	26	21	13	13	13	14	19	14	17	-26%	-18%
28	35	51	27	34	34	26	39	44	24	19	13	22	36	30	8	29	-73%	-73%
32	27	26	23	25	25	19	24	22	18	22	14	20	12	28	9	21	-68%	-57%
36	15	28	25	23	18	23	25	33	19	15	18	19	10	14	11	20	-21%	-44%
40	15	37	31	51	80	61	70	61	77	51	67	66	78	79	58	59	-27%	-1%
44	34	37	34	45	46	32	43	58	29	26	21	26	32	39	12	34	-69%	-65%
48	18	23	26	26	20	27	21	27	11	10	11	16	21	18	6	19	-67%	-68%
52	10	9	15	14	10	15	11	14	10	17	13	13	17	12	3	12	-75%	-75%
56	11	8	10	13	11	10	9	12	11	10	4	8	16	17	12	11	-29%	11%
60	14	31	19	17	15	16	12	20	14	10	11	12	14	23	2	15	-91%	-87%
64	15	16	16	11	29	27	31	22	14	21	10	14	25	23	9	19	-61%	-52%
68	13	7	6	13	9	16	17	17	9	8	14	15	14	19	5	12	-74%	-59%
72	23	34	23	34	35	32	34	42	30	25	21	29	25	44	39	31	-11%	24%
76	16	26	22	25	21	21	21	27	13	12	10	17	15	24	3	18	-88%	-84%
80	13	13	17	14	12	13	21	10	8	8	12	14	13	10	3	12	-70%	-75%
84	17	22	20	24	19	14	23	32	19	17	10	20	11	11	10	18	-9%	-44%
88	21	50	49	71	60	46	57	71	43	42	42	55	50	55	17	49	-69%	-65%
92	26	55	53	61	47	43	40	42	26	17	24	23	43	41	26	38	-37%	-31%
96	38	34	28	31	31	36	20	37	12	9	14	29	12	12	9	23	-25%	-62%
100	8	12	17	15	12	17	19	2	5	21	13	12	18	17	14	13	-18%	4%
104	28	28	38	25	20	32	19	39	10	16	15	27	22	24	10	24	-58%	-58%
108	3	1	7	7	1	2	1	2	1	2	2	1	3	2	0	2	-100%	-100%
112	42	52	69	35	45	32	31	38	32	23	29	51	57	32	19	39	-41%	-51%
116	42	33	61	29	34	33	32	34	31	18	25	57	59	43	17	37	-60%	-53%
120	24	32	42	26	39	24	27	33	19	20	5	37	39	20	13	27	-35%	-51%
Mean	20	26	26	26	28	25	26	31	20	19	17	25	26	27	14	24	-49%	-41%

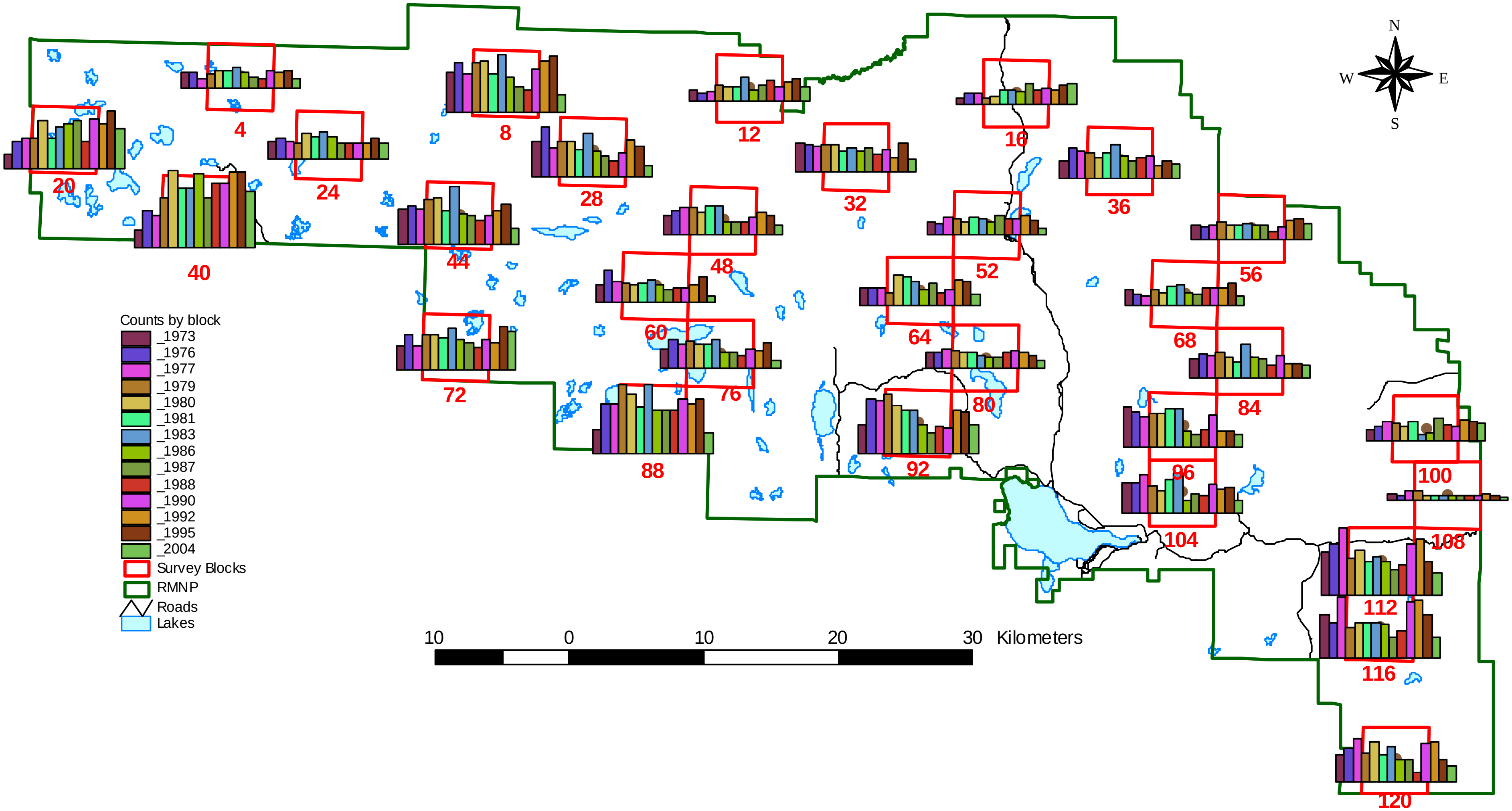

Figure 5 - Graphing map showing count per block for each year surveyed between 1973 and 2004.

Figure 6 illustrates the percent difference from the mean for each block indicating that the majority of blocks exhibited a decrease in the number of caches counted (greater than 50%) and the blocks with the greatest decrease are situated along the highland plateau land district of the park on the upper ends of the watershed. Note that although Block 108 shows the maximum decrease (100 %), past counts have been very low and during the last survey there were only two caches reported. Thus that decrease is less significant compared to Blocks 52, 60, 76 and 80 in the interior of park, which have contained moderate numbers of caches historically.

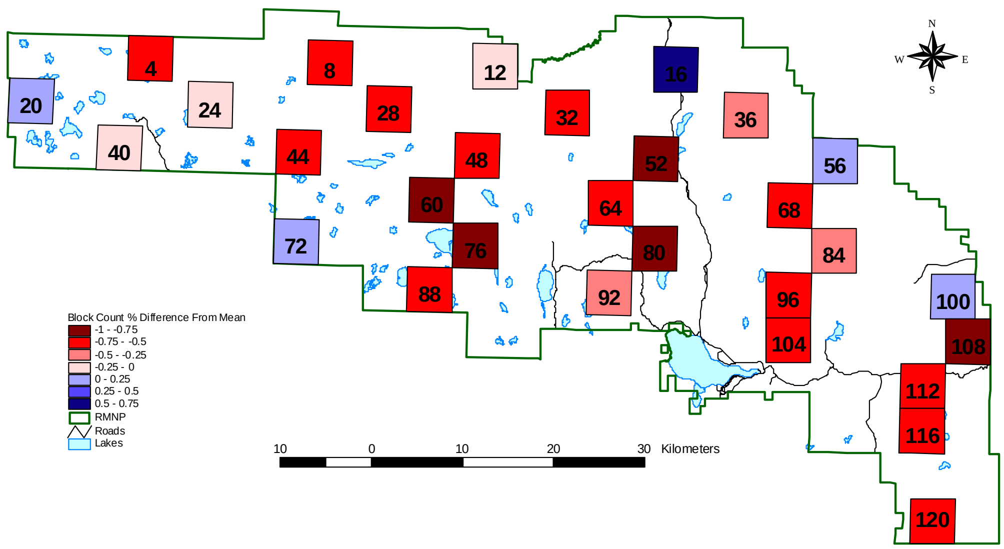

Figure 6 - Map depicting percent difference of 2004 count from the count mean by block

The blocks that have retained above average numbers of caches are all near or immediately adjacent to the park boundary. Only Block 16 had an increase in caches from the 1995 survey, and is situated along the north end of Highway 10. Block 16 had a concentration of colonies along the bottom edge of the escarpment (northern portion of the block) along a watercourse that may be heavily supplied by groundwater.

3.3 Density by Watershed

Figure 7 illustrates the cache density (caches / square km) within the three major watersheds of the park for each year the survey was completed. The cache count was divided into the three watersheds by conducting a GIS analysis of the area within the sample blocks and determining the proportion of the watersheds within the block and then multiplying that proportion against the total count within the block. This assumes that in blocks in which multiple watersheds are present the caches are normally distributed, which is not the case in the field. However, this year the actual point reference data for each cache was collected and was used to calculate the actual cache count by watershed to cross reference the proportional technique.

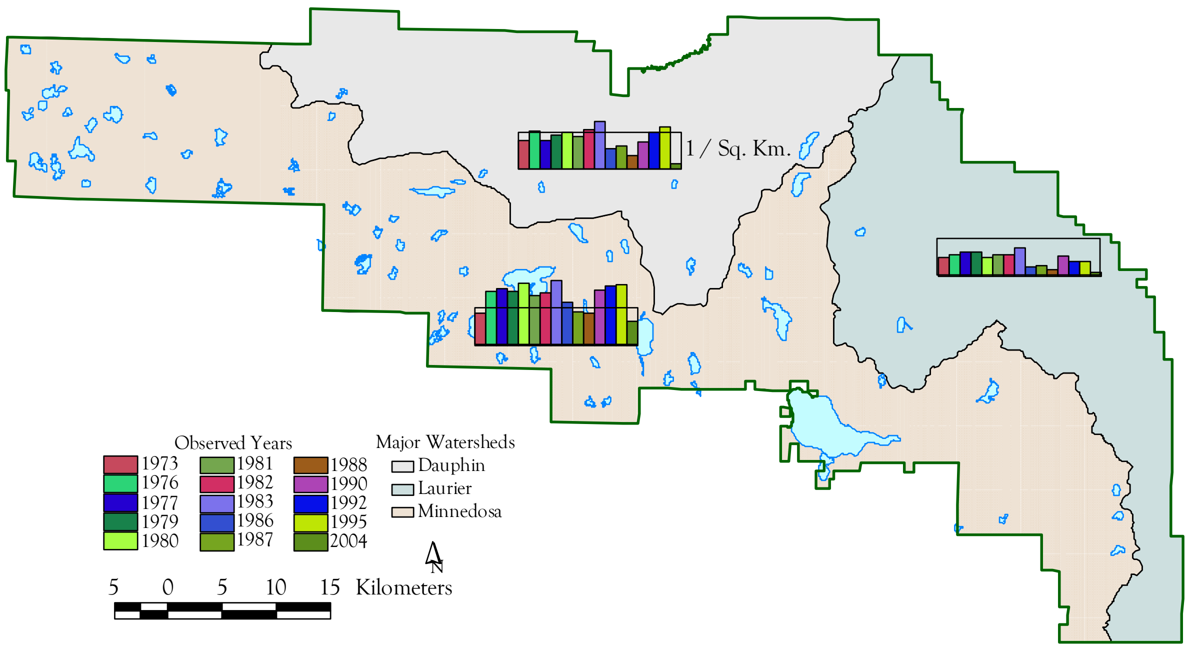

Figure 7 - Density of caches (sq km) by major watershed for each year the survey has been completed (1973 - 2004). The rectangular grid represents 1 cache/ sq km.

This approach also revealed that it was a reasonable way to get a comparative assessment within the watershed (see Tables 6, 7 and 8). It was also more accurate than techniques used in the past (without GIS analysis), which included totalling blocks that had more than 50% of their area within a particular watershed. The map clearly shows that the 2004 data represents a decrease in density across all three watersheds, but the largest decreases have occurred in the Dauphin and Laurier watersheds – both of which also have a lower density of lakes than the Minnedosa watershed.

Table 7 - 2004 cache counts within blocks by watershed using coordinate cache locations within the block.

Block Number	Dauphin Watershed	Laurier Watershed	Minnedosa Watershed	Grand Total
4			5	5
8	15			15
12	11			11
16	18			18
20			39	39
24			14	14
28	8			8
32	9			9
36		11		11
40			58	58
44	3		9	12
48	6			6
52	1		2	3
56		12		12
60	1		1	2
64	8		1	9
68		5		5
72			38	38
76			3	3
80			3	3
84		10		10
88			17	17
92			26	26
96		7	2	9
100		14		14
104		2	8	10
108		0		0
112		3	16	19
116			17	17
120		2	11	13
Total	80	66	270	416
Area	180.80	179.72	363.70	Sq km
Density	0.44	0.37	0.74	

Table 8 - Density and count of caches within watershed using proportional method.

Density	0.42	0.38	0.75
Count	76	68	273

Table 6 - Hectares of major watersheds within survey blocks.

Block	Name	Hectares
4	Minnedosa	2410
8	Dauphin	2385
12	Dauphin	2402
16	Dauphin	2410
20	Minnedosa	2409
24	Minnedosa	2430
28	Minnedosa	19
28	Dauphin	2405
32	Dauphin	2410
36	Minnedosa	1
36	Dauphin	21
36	Laurier	2380
40	Minnedosa	2408
44	Minnedosa	2201
44	Dauphin	228
48	Dauphin	2416
52	Minnedosa	1234
52	Dauphin	1184
56	Laurier	2410
60	Minnedosa	2028
60	Dauphin	387
64	Minnedosa	581
64	Dauphin	1832
68	Laurier	2421
72	Minnedosa	2397
76	Minnedosa	2425
80	Minnedosa	2409
84	Minnedosa	3
84	Laurier	2422
88	Minnedosa	2403
92	Minnedosa	2420
96	Minnedosa	345
96	Laurier	2092
100	Laurier	2408
104	Minnedosa	2191
104	Laurier	252
108	Laurier	2401
112	Minnedosa	2135
112	Laurier	282
116	Minnedosa	2418
120	Minnedosa	1501
120	Laurier	904

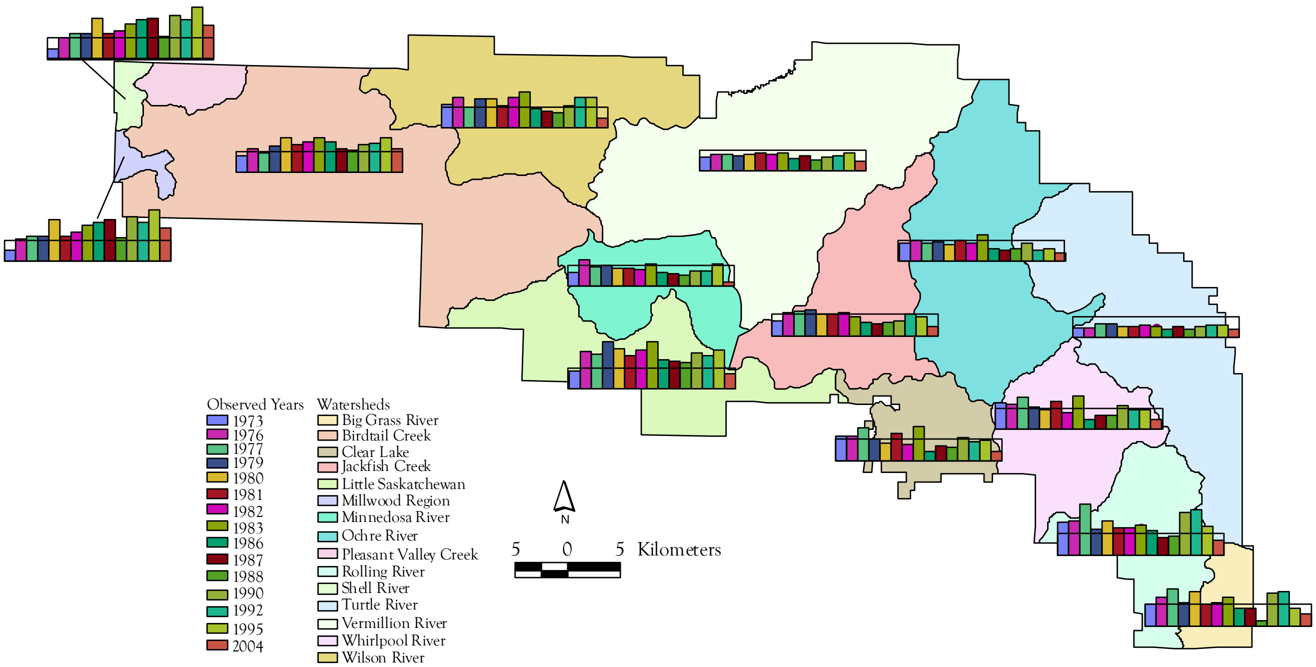

Figure 8 - Map showing density by basin for each year surveyed.

The watershed can be further divided into smaller watershed basins and a map illustrating the densities for each year of the survey is shown in Figure 8. It highlights in better detail how the smaller basins at the head of the major watersheds have suffered the greatest decline in caches compared to those further downstream.

3.4 Density by Land District

Four major ecological land districts are identified for Riding Mountain including lowlands, escarpment, upland plateau and upland hummocky. The density of caches within the various districts is illustrated in Figure 9, highlighting the logical link between the landscapes that promote standing water, such as upland hummocky, and the higher densities of caches. Conversely, rapidly drained sites along the escarpment and lowlands district have had lower numbers of caches historically and also have declined in the most recent survey. Note that the upland plateau region of the park, which generally has moderate densities of caches, has exhibited the largest decline in the 2004 survey.

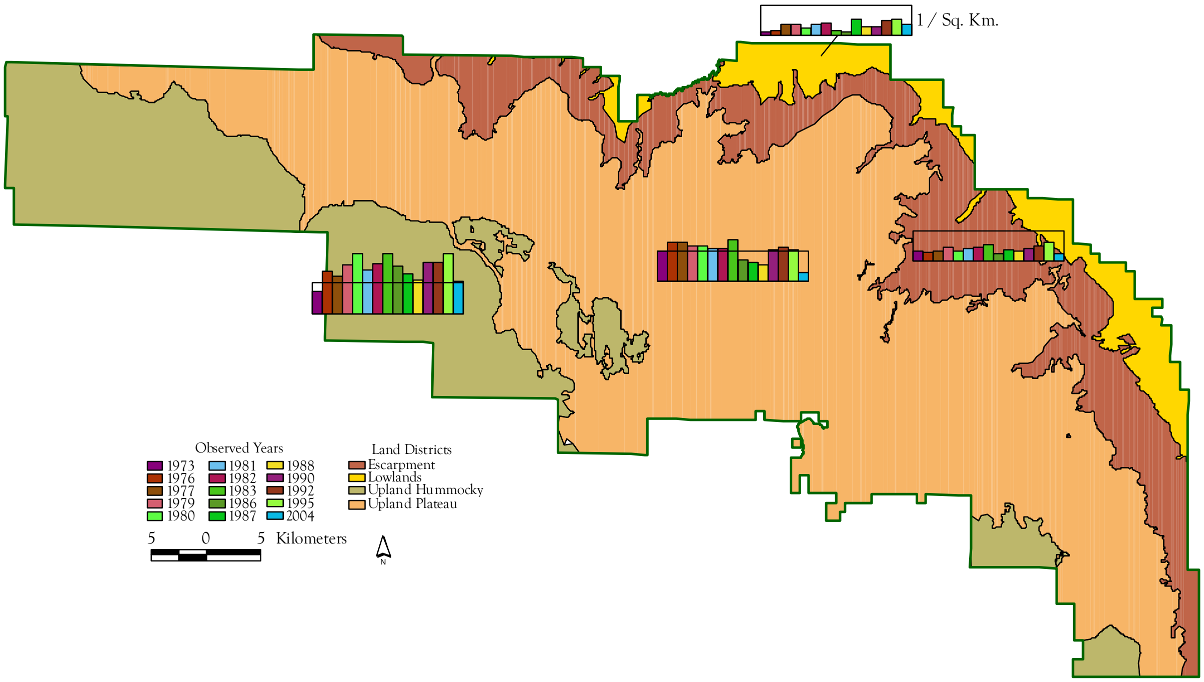

Figure 9 - Map showing cache density by ecological land district.

3.5 Comparison with Precipitation

Figure 10 shows the recorded annual precipitation at three weather stations in the Riding Mountain area for the last 30 years. The cache estimates for the beaver survey are superimposed on a secondary axis to look at the relationship. Visually it appears that the cache counts do not respond to short-term variation in precipitation. However, a persistent condition of reduced precipitation for a period of three or more years does appear to impact the cache count to some degree. It is important to note that the weather stations are in lower areas, some distance from the ridge of the escarpment that collects the majority of precipitation in the area through orthographic effect. It may be interesting to correlate hydrographic records on stream flow within the major basins to the historical cache count, but that data wasn't readily available for the purposes of this report.

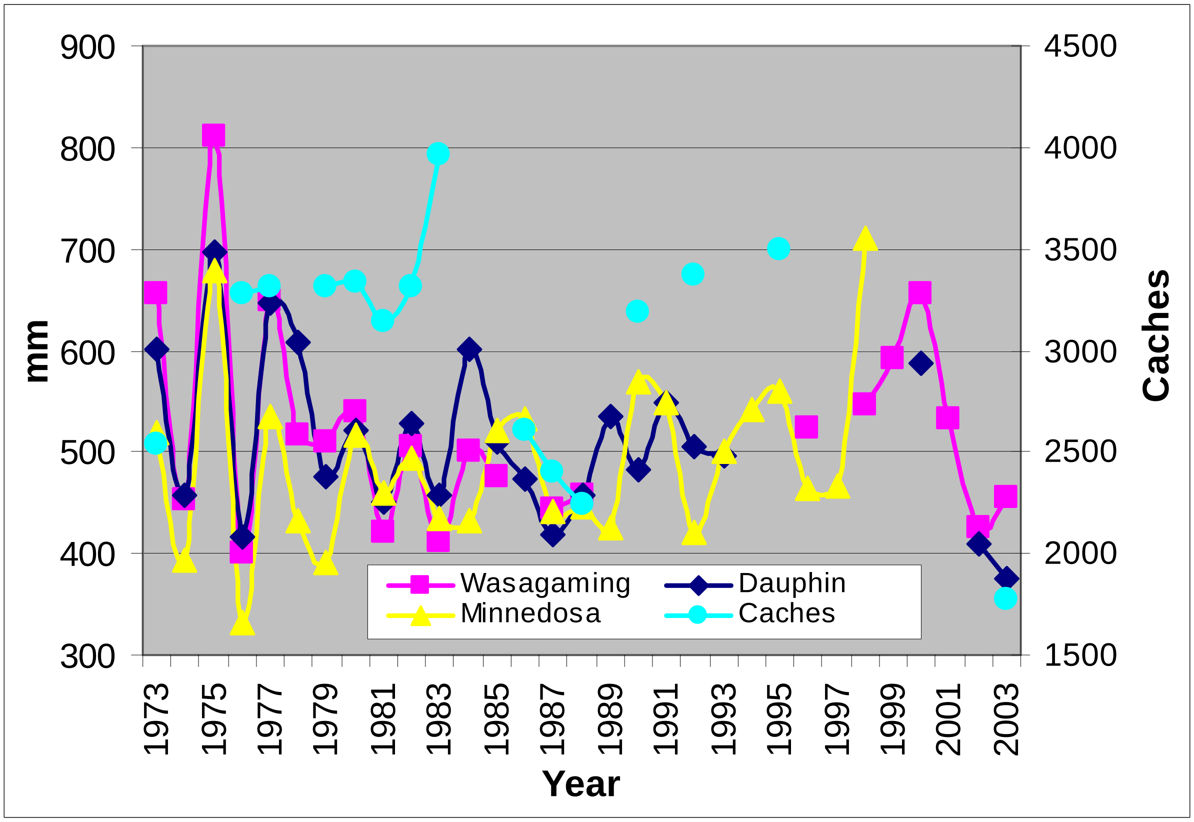

Figure 10 - Graph of annual precipitation from weather stations around Riding Mountain compared with historic cache counts from 1973 – 2003.

3.6 Wolves

Wolves are known to be a predator on beaver through recent diet studies which show that around 30% of spring and summer wolf scat contain beaver (Sallows, 2002). A comparison of the park wolf population estimates and the beaver cache estimates over the past 30 years is illustrated in Figure 11. While they may not independently explain the decline of the caches in 2004 the recovery of wolves in recent years may be a factor.

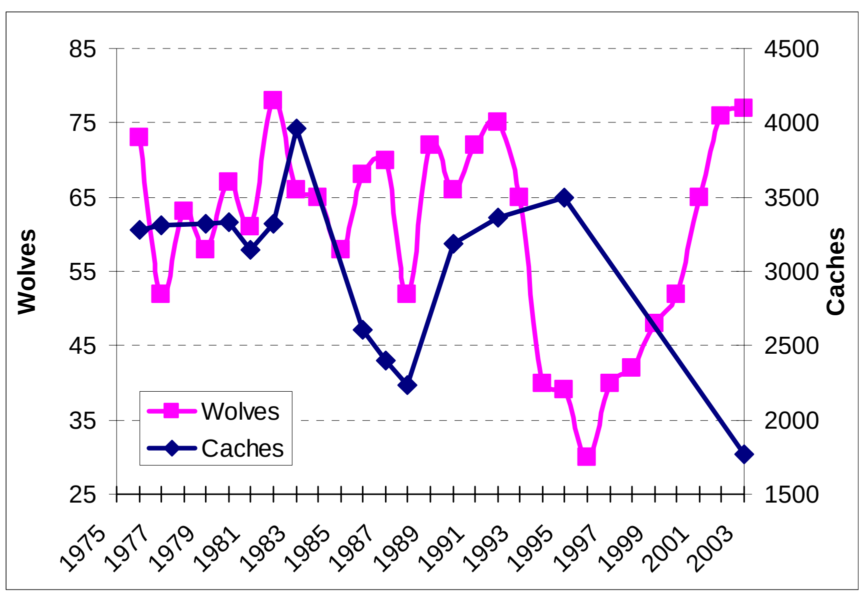

Figure 11 - Wolf versus beaver cache estimates from 1975-2003

4.0 Discussion

It is clearly evident that the beaver population in Riding Mountain has decreased in the period from the 1995 survey and is below the historic range of variation in the cache estimates from the past 15 surveys since 1973. Whether the decrease is from a series of dry, warm years with reduced precipitation; increased predation; vegetation and habitat change; or disease is unknown. Spatially it appears that the greatest decreases in population occurred in the highest reaches of the watersheds in the highland plateau district, which is also the most susceptible to drought, therefore it would be reasonable to assume that the lack of water is a factor in the decline. It is also clear that nine years between surveys is inadequate temporal resolution to be able to monitor trends in the beaver population or to make conclusions.

4.1 Recommendations

1. Conduct a power analysis to validate experimental design and determine optimal temporal resolution for monitoring. Barring that, 3 to 5 years between sampling for years where the estimate is within historical variation seems reasonable, and annually where the estimate is outside of the historical range. Thus the fall of 2005 would be the next recommended survey.

2. Adopt the adapted methodologies of this survey for future surveys. Now that the survey has been moved into an electronic format, setup time is reduced from a week or two down to a half day. The need for hardcopy photos is eliminated. The time to generate data analysis and a report are also significantly reduced. The use of more recent digital orthophotography as it becomes available will help pinpoint potential cache locations and place observations to avoid double counts.

3. Use the smaller aircraft if at all possible. The $100/hour difference is a significant cost savings and with the new data collection system it is logistically feasible.

4. Use crews from the Dauphin area as first choice to reduce travel and waiting times during bad weather. Schedule one crew for the whole duration of the survey if at all possible to maintain consistency across the park. Locate good flyers at offices around the north end of the park closer to the airport whenever feasible.

Appendix A

STATISTICAL TREATMENT OF 2004 DATA

Total number of sample units in the population (total blocks in the park)	N =	127.555
Number of sample units in Aerial Survey (number of sample blocks)	n =	30
Number of colonies sampled per block.		

Problem: Calculate the estimated number of beaver caches (Y) in Riding Mountain National Park based on 2004 Aerial Beaver Survey data.

Y = Average caches per block x total blocks in the park.

$$\frac{Y^1 + Y^2 \ \ldots \ Y^{30} \times N}{n}$$

$$= \frac{\text{total caches counted on survey} \times 127.555}{30}$$

$$\frac{417 \times 127.555}{30} = 1773.015$$

Therefore, the estimated park cache number is: 1773

Problem: Calculate the 95% confidence limits of the cache estimate (Y) for 2004.

The following statistical treatment is carried out to establish confidence limits of the cache estimate (Y). Please remember that the cache estimate is not the absolute true number in the park, but the true number will very likely lie within the 95% confidence limits. Also note that each cache may represent anywhere from 4 to 11 beaver.

Total number of sample units	N =	127.555	blocks
Number of units in the sample	n =	30	blocks
Number of caches counted/block	y =		
Sample estimate (cache estimate)	Y =	1773	

Step 1: Calculate sample variance Sy^2

Sum of small y Σy = 417

Sum of small y squared $(\Sigma y)^2$ = 173889

Sum of small y squared Σy^2 = 10285

Sample variance $Sy^2 = \frac{1}{n-1} \left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)$

Sample variance Sy^2 = 155

Step 2: Calculate the population variance Var (Y)

$$\text{Var}(Y) = \frac{N(N-n)}{n} \times Sy^2$$

Var (Y) = 64292.08

Step 3: Calculate population standard error SE (Y)

$$SE(Y) = \sqrt{\text{Var}(Y)} = 253.56$$

$\frac{n(N-N)}{n}$ = A correction factor which expresses the intensity of sampling, being a form of weighting: the higher the sampling intensity, the smaller this term becomes, so that if all blocks in the park were surveyed, this function would become 0.

Step 4: Calculate the 95% confidence limits.

95% confidence limits of y

= $\pm$ 2.04* SE (y)

= $\pm$ 2.04 x 253.56 = 517.26

Therefore, the cache estimate with 95% confidence limits is:

Minimum 1256 Likely 1773 Maximum 2290

Note: This calculation was set up within the Excel workbook (2004BeaverSurveyData) for the survey data under the sheet tab labelled ‘Estimate’.

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