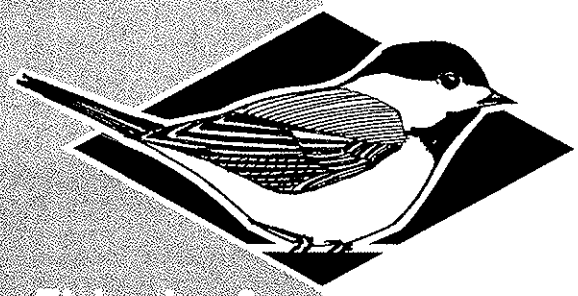


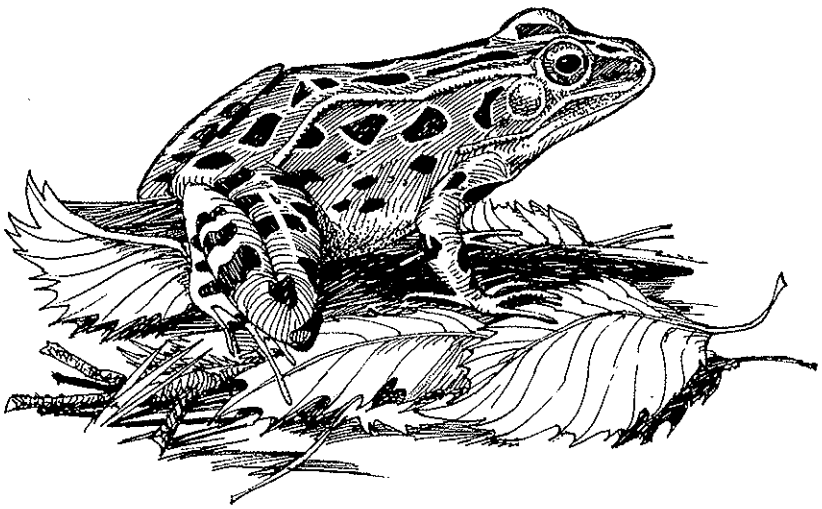
Fisheries & Wildlife Management Division

RESOURCE STATUS AND ASSESSMENT BRANCH

Translocation of Northern Leopard Frogs (*Rana pipiens*) in the Upper Red Deer River Drainage Basin

A comprehensive study on wintering habitat selection of translocated adult leopard frogs near Caroline, Alberta

Kris Kendell



December 2000

Alberta Conservation Association

Alberta ENVIRONMENTAL PROTECTION

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North American Waterfowl Management Plan
Plan nord-américain de gestion de la sauvagine
Plan de Manejo de Aves Acuáticas de Norteamérica

Alberta Conservation Association

Alberta Sport, Recreation Parks & Wildlife Foundation
Enhancing Alberta's Communities

Illustration: Brian Huffman

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Executive Summary

The Northern Leopard Frog (*Rana pipiens*) has exhibited population declines in the province of Alberta and is currently extirpated from much of its former range. Remnant populations of leopard frogs in Alberta have demonstrated limited recolonization potential, and are therefore vulnerable to disturbance, leading to potential further local extirpations. In the spring of 1998 a management project was proposed to repatriate the Northern Leopard Frog into currently vacant areas of its historic range. The primary objective of this project was to establish breeding populations of Northern Leopard Frogs in formerly occupied habitats in the headwaters of the Upper Red Deer and North Saskatchewan River drainage basins. In order to help ensure the success of the project, research on fall natural history and required overwintering conditions critical to hibernating leopard frogs was continued in the field.

In September 1999 a comprehensive study investigating winter physiology and ecological requirements of the Northern Leopard Frog took place in the area surrounding the Raven Brood Trout Station near Caroline, Alberta. The study involved the tracking of 16 translocated adult leopard frogs to potential overwintering locations along Beaver Creek and the Raven River, using radiotelemetry. Aquatic parameters relating to overwintering leopard frog requirements were measured and recorded throughout the study area in suitable overwintering habitats. Additional habitat characteristics (aquatic and terrestrial) along Beaver Creek and the Raven River were recorded at each radioed frog observation during the radio-tracking period. This included a physical habitat description of both the creek and upland, and water quality tests in the immediate area of the frog observations. Microhabitat selection and frog activity were also noted upon each observation during radio tracking, generating a wealth of ecological and natural history information relating to the fall activities of the translocated leopard frogs in this study.

Sixteen translocated leopard frogs were collected from southern Alberta and were released into Beaver Creek, near the Raven Brood Trout Station, near Caroline, Alberta. Initially, 8 of the translocated leopard frogs were released on 28 September 1999 into sections of Beaver Creek. Eight additional translocated leopard frogs were released into sections of Beaver Creek on 29 October 1999. Radiotelemetry of the leopard frogs began on 29 September 1999 and was concluded on 17 April 2000. The eight translocated leopard frogs, of the first release, travelled

combined total distance of 1165 meters during the tracking period. The remaining eight translocated leopard frogs, of the second release, travelled a combined total distance of 740 meters during the tracking period. With the exception of two separate individual frogs, all frogs remained within 1 m of the water's edge of Beaver Creek, with substantial movements occurring in a downstream direction. Three of the 16 leopard frogs released during the course of this study appeared to have successfully survived to, and initiated hibernation. Two of these three leopard frogs were subsequently found deceased (causes of death unknown) and one was determined to be in winter dormancy as on 22 December 1999. Extensive searches for the last surviving frog in a section of the Raven River between 17 April and 01 May 1999 produced no observations or specimen. Of the remaining 13 translocated frogs three shed their transmitter, four were depredated, two demonstrated indications of disease and subsequently died (actual cause of death unknown), one experienced a transmitter malfunction, two were discovered frozen (one in water and one on land), and one was discovered deceased (cause of death unknown). All deceased frogs collected were sent to the Canadian Co-operative Wildlife Health Center, Saskatoon, Saskatchewan for examination and necropsy.

Acknowledgements

The author would first like to thank Alberta Conservation Association, Alberta Environment – Fisheries and Wildlife Management Division, Alberta North American Waterfowl Management Plan and Alberta Sport, Recreation, Parks and Wildlife Foundation; if not for their funding and in kind support, this project would not have been possible.

A special thanks is owed to the Raven Brood Trout Station staff, Rod Burns, Katherine Kossmann, and Steve Cunningham for their much appreciated contribution of volunteered time, equipment, counsel, logistical information and technical expertise, that truly enhanced this project. I would like to extend a sincere thank-you to Abigail Knight for her countless volunteer hours of field assistance.

I would like to acknowledge the following individuals for their assistance, support and dedication to this project: Steve Brechtel (Alberta Environment), Lisa Takats (Alberta Conservation Association), Mike Norton (Alberta Conservation Association), Isabelle Michaud (Alberta Conservation Association), Lance Engley (Alberta Conservation Association), Jeff Adamyk (Alberta Conservation Association), Chris Fisher and Mark Wendlandt. Editorial comments from Isabelle Michaud (Alberta Conservation Association) and Lisa Takats (Alberta Conservation Association) were greatly appreciated. Thanks also to Geoff Holroyd (Canadian Wildlife Service) who kindly provided logistical information.

A final acknowledgement to Trent Bollinger (Canadian Cooperative Wildlife Health Center) and John Edwards (Holohil Systems Ltd.) who contributed valuable information and helpful suggestions within their areas of expertise. My sincere apologies to anyone I have neglected.

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1.0 INTRODUCTION

In the province of Alberta, the Northern Leopard Frog (*Rana pipiens*) is designated as a Threatened Species (Wildlife Act, Alberta Environmental Protection, 1996). As a result, the Northern Leopard Frog (Photo 8) merits special management consideration regarding existing populations as well as the habitats in which they occur. Once a common and widespread species throughout much of Canada, leopard frog populations vanished or declined from much of their historic western range.

In the spring of 1998 a management project was proposed to repatriate the Northern Leopard Frog (*Rana pipiens*) into currently vacant areas of its historic range. The primary objective of the project was to establish breeding populations of Northern Leopard Frogs in formally occupied habitats in the headwaters of the Upper Red Deer and North Saskatchewan River drainage basins. The area proximate to the Raven Brood Trout Station, near Caroline, Alberta was identified as the site for the pilot year of a reintroduction program for the leopard frog.

To improve the understanding of the key habitat elements and natural history, that are necessary to the survival and growth of leopard frog populations in Alberta, a study was initiated in the area surrounding the trout station near Caroline Alberta involving 16 translocated adult leopard frogs. The purpose of the study was to investigate late fall and winter habitat selection and aquatic parameters necessary for the overwinter survival of leopard frogs at the reintroduction site. This information would then be integrated with known data on breeding and summering habitat requirements to establish an 'ideal' habitat suitability prescription for the leopard frog to help identify future reintroduction sites.

The Northern Leopard Frog (*Rana pipiens*) is a member of the family Ranaidae or 'true frogs'. Many ranid anurans hibernate in aquatic habitats (Wright and Wright 1949, Porter 1972) to escape freezing temperatures. In Alberta, the Northern Leopard Frog and Colombia Spotted Frog (*Rana luteiventris*) are the only frog species that hibernate underwater. Some frog species that hibernate on land, such as the Boreal Chorus Frog (*Pseudacris maculata*) and Wood Frog (*Rana sylvatica*), are capable of producing a glucose "antifreeze" in their blood in response to cold temperatures. This "antifreeze" inhibits tissue damage caused by freezing, making the Boreal

Chorus Frog and Wood Frog (unlike the leopard frog and spotted frog) freeze tolerant. To ensure winter survival, hibernating leopard frogs require specific aquatic overwintering conditions. Most basic of these required aquatic conditions include, suitable dissolved oxygen levels, sufficiently low water temperatures and substrates that remain free of ice.

A variety of methods are available to field scientists studying movement patterns and other natural history aspects of amphibians. Radioactive tags (Madison and Shoop 1970, Semlitshc 1981, Kleeberger and Werner 1982, Ashton 1994) thread bobbins (Dole 1965, Heyer 1994), fluorescent yarn tags and luminescent capsules (Windmiller 1996), ingested radio transmitters (Oldham and Swan 1992) and external radio transmitters are such examples.

Each of the described tracking method offers both advantages and limitations. The small size of many amphibian species and difficulties in externally and internally attaching transmitters has historically been a hindrance when tracking amphibians via radiotelemetry (Werner 1991). For the purposes of this study radiotelemetry utilizing an external transmitter on a harness configuration was the identified as the premium device for radio tracking adult leopard frogs (Wendlandt 1999a). Radiotelemetry is a useful technique of obtaining information on behavioural patterns of cryptic and secretive species, such as the leopard frog.

Sixteen adult leopard frogs were collected and translocated from Circle E Ranch near Brooks, Alberta and fitted with tiny radio transmitters and released in potential overwintering habitat near Caroline, Alberta. The following report details the results of this radiotelemetry study in the upper Red Deer Drainage Basin near Caroline, Alberta.

2.0 STUDY SITE

The fall radiotelemetry study was conducted in the area proximate to the Raven Brood Trout Station which is located approximately 10 km southeast of the town of Caroline, Alberta and immediately west of Highway 22 (Figure 1). Owned and operated by Alberta Environment, the Raven Brood Trout Station is situated on a quarter-section of crown land (SW Section 5 - Township 36 - Range 5 - West of 5th Meridian).

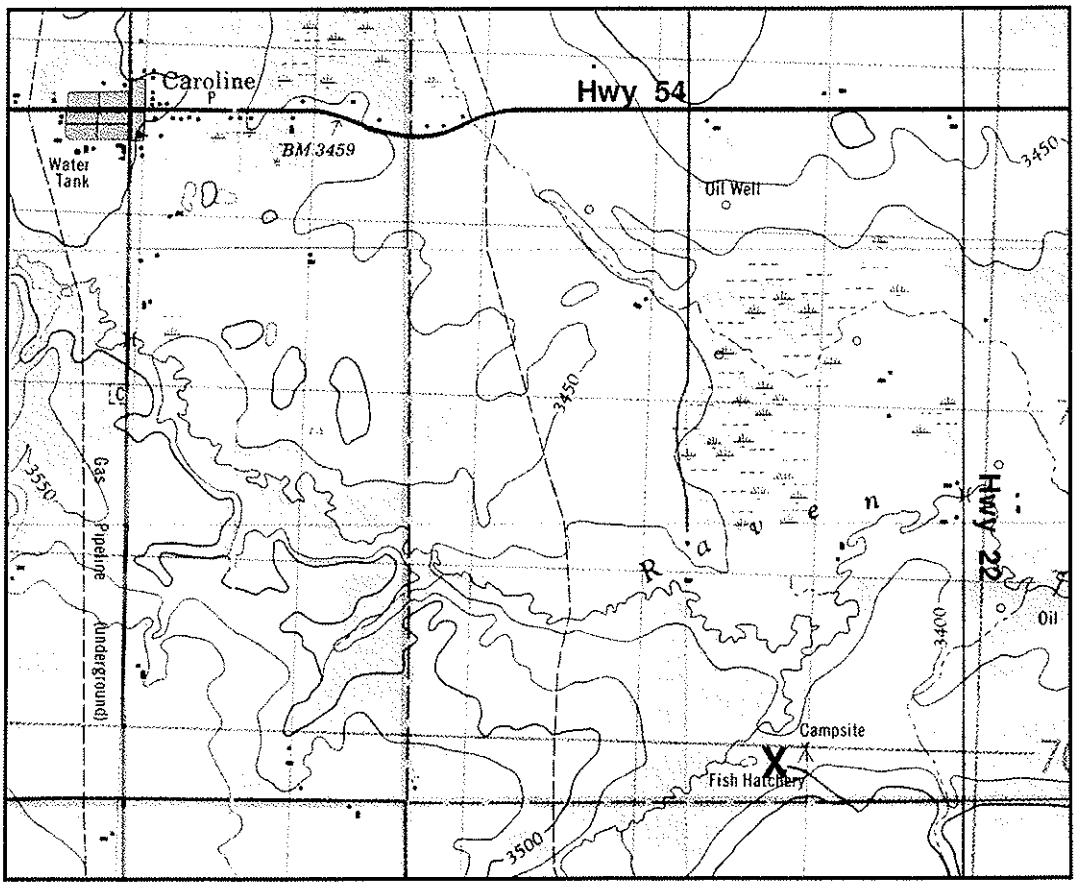


Figure 1 Topographical map showing location of Raven Brood Trout Station (Fish Hatchery) marked with an **X**, in relation to Caroline, Alberta.

2.1 Habitat

The quarter section on which the trout station occurs offers a variety of terrestrial and aquatic habitats that are supportive of leopard frog wintering and breeding natural history. The majority of the land base on the quarter section consists of upland mix wood forest (trembling aspen,

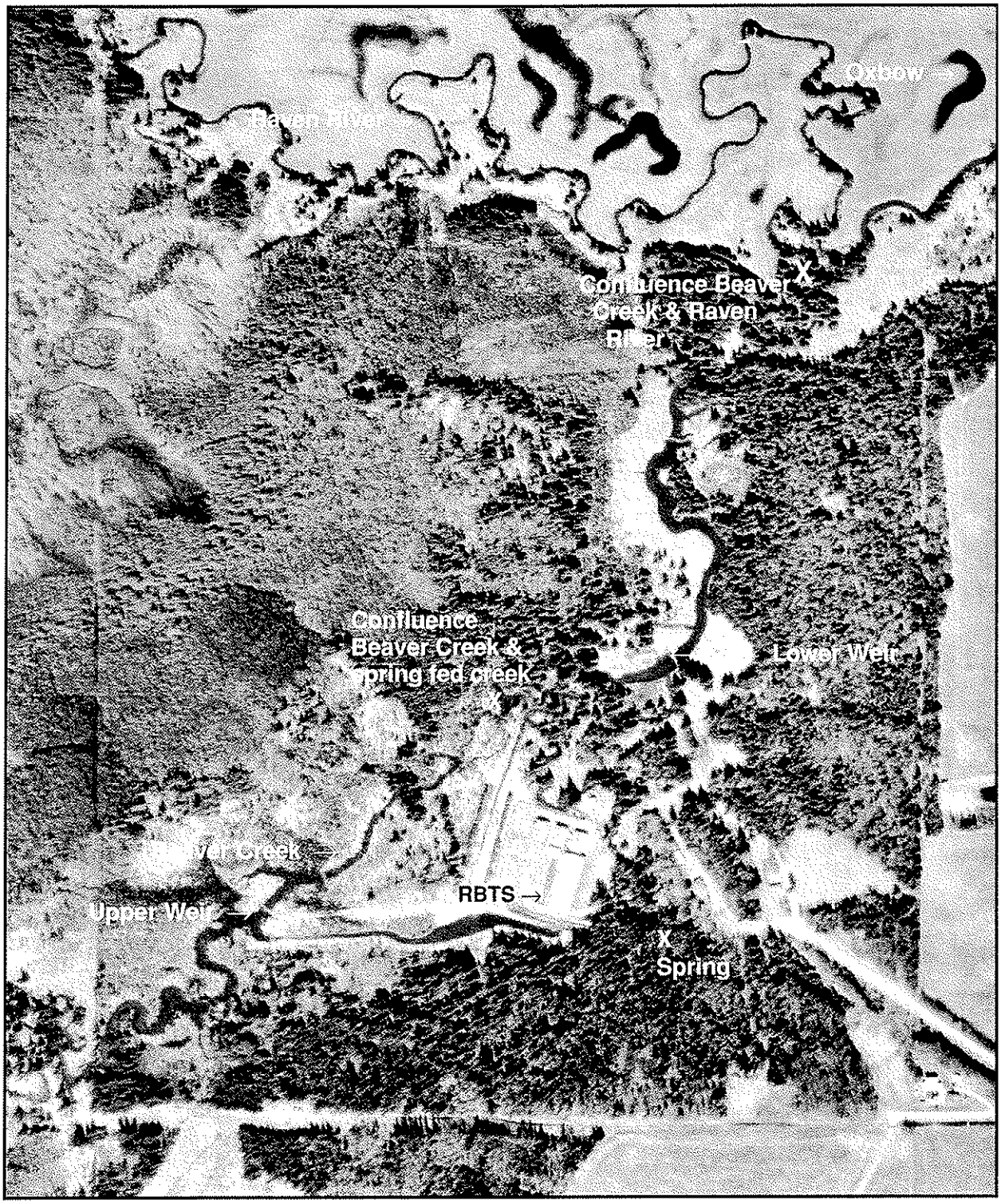


Photo 1 Aerial photograph of Raven Brood Trout Station (RBTS), Beaver Creek, Raven River and surrounding habitat types.

balsam popular, white spruce, lodgepole pine) and lowland forest (black spruce and tamarack) with varying degrees of understory. Open areas of grasses, sedges and shrubs (willow, alder) frequently occur along watercourses, riparian areas and areas influenced by either flooding or beaver activity. Beaver ponds, and areas of permanent and semi-permanent standing water (of various sizes and depths) as well as bogs/muskegs and small tributaries, are common on the quarter section.

2.2 Hydrology

Beaver Creek (Photo 2) and a spring fed creek that originates from a hillside near the trout station are the two primary flowing waterbodies on the quarter-section. A number of smaller springs and ground water seeps of unknown source locations may also influence the hydrology in the area. Beaver Creek enters the quarter-section in the southwestern corner and flows through the section in a roughly northeastern direction until it exits the quarter section in the northeastern corner (Photo 1). The spring fed creek meanders from the east and joins Beaver Creek at a large beaver pond just north of the trout station. Beaver Creek (amalgamated with spring water) then joins the Raven River (Photo 3) just outside the northwestern corner of the quarter section (see Photo 1). The Raven River occurs to the north of the quarter-section and flows in a general west to east direction. Several shallow semi-permanent to permanent oxbows occur just north and parallel to the meandering Raven

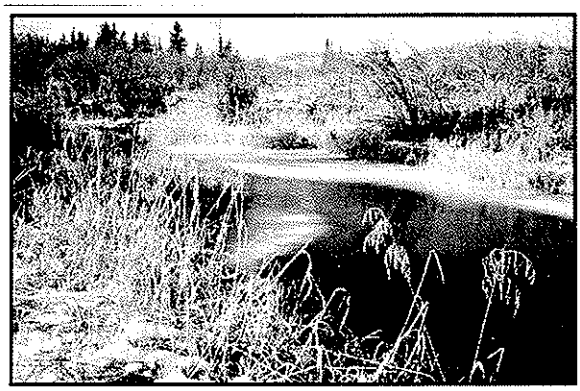


Photo 2 Representative section of Beaver Creek up stream of confluence of spring fed creek.

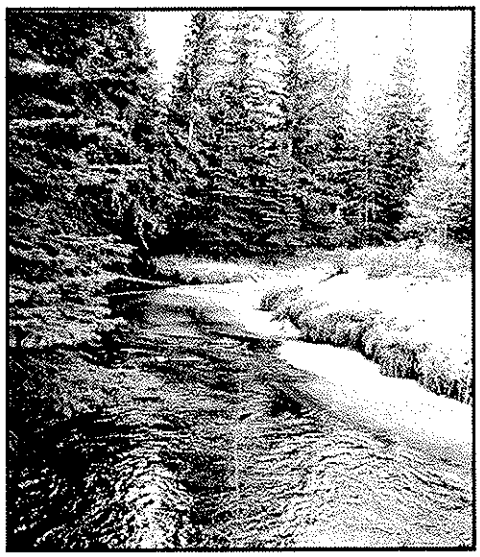


Photo 3 Raven River, at confluence of Beaver Creek amalgamated with spring water.

River (Photo 11). These oxbows were surveyed on 6 October 1999 and 18 May 2000 to determine moisture levels and synopsis of occurring vegetation. The results of this survey and an aerial photograph of the oxbows can be found in Appendix H and Appendix I, respectively.

3.0 METHODS

3.1 Harness Design

The harness design used during this study was identical to that of Wendlandt's (1999a) study. It comprised of a soft surgical grade, polyethylene tubing (Intramedic Clay Adams Brand non-radiopaque PE 50 tubing with an outside diameter of 0.965 mm) available from Fisher Scientific Ltd. (Bartelt 1994, Wendlandt 1999a). The polyethylene tubing was threaded through a tiny tube built into the transmitter housing with a comparable diameter, which produced a snug fit. Modified size nine flyline pins (manufactured by Mustad) and Krazy glue were used to connect the tubing which was cut to length according to the waist size of the frog. The entire assembly was passed over the legs and thighs of each frog to a final destination of around the frog's waist (Photo 4).

Photo 4 An adult male Northern Leopard Frog fitted with a temperature sensing radio-transmitter and harness.

Care was taken to ensure the smooth side of the transmitter was adjacent to the frog's back producing a flush fit. This harness design has proven to be light weight, inert to water, and complemented the transmitters used in this study. See Wendlandt (1999a) for further details on the construction and application of this harness design.

3.2 Transmitters and Receiver

Transmitter models BD-2G and BD-2GT (temperature sensing) manufactured by Holohil Systems Ltd. were the two transmitters used during this study. Both transmitters were a crystal controlled two stage design pulsed by a multivibrator. The life span and weight of each model is dependent on the battery size and transmitter configuration. As outlined by Holohil Systems Ltd., the model BD-2G transmitter has a battery life of about four months, while the model BD-2GT (temperature sensing) has a battery life up to about eight months. Pulse rate nominal for the BD-2G transmitters ranged between 0.62 (37 p/m) and 0.65 p/s (39 p/m) while the pulse rate nominal for the BD-2GT transmitters varied with temperature. With the sensing option, the BD-2GT transmitter experiences an increase or decrease in pulse rate that results from a corresponding increase or decrease in ambient temperatures. This decrease in pulse rate reduces the energy consumption on the battery thereby significantly prolonging the life of the battery. The BD-2G transmitter weighed 1.85 g whereas the BD-2GT (temperature sensing) transmitter weighed 1.95 g. The transmitters used in this study were encapsulated in an inert waterproof epoxy. The antenna length ranged between 17.5 cm and 20 cm and consisted of a stranded stainless steel wire covered with a nylon coating. Activation and deactivation was accomplished simply by removing and replacing (respectively) a magnet over the immediate vicinity of the battery. All transmitters operated within the frequency range of 150-151 MHz.

The receiver used during this study was manufactured by Telonics Canada and carried the model number TS-1 Scanner/Programmer. The Telonics TS-1 Scanner/Programmer is a companion accessory unit of the TR-2 Series Biomedical Telemetry Receiver. The TS-1 Receiver offers full programming and memory capabilities, with a resolution of 1 KHz and a frequency accuracy of 0.1 KHz.

3.3 Dissolved Oxygen Reader

A handheld dissolved oxygen and temperature system (YSI model 55) was used during field studies to measure and record dissolved oxygen and water temperature. The system displayed temperature in °C and dissolved oxygen in either mg/l or percent air saturation. The system is reliable to a temperature accuracy of +/- 0.2 °C with a resolution of 0.1 °C. Dissolved oxygen percent saturation accuracy and resolution (in percent) is identical to that of temperature, however dissolved oxygen mg/l accuracy and resolution is +/- 0.3 mg/l and 0.01 mg/l respectively.

3.4 Tracking

Prior to being fitted with transmitters, unique dorsal spot patterns on individual leopard frogs were sketched and photographed to provide a specific identity to each frog for future recognition in the field. Prior to being released, each leopard frog was also assigned an individual number or letter, weighed (using a pasola scale) and snout-vent-length (SVL) measured. General health and physical appearance of each frog was also assessed and noted. Harnesses were assembled and fitted with transmitters, then placed on the leopard frogs to be released. After being fitted with the transmitters the leopard frogs were held in captivity for five to nine days in order for them to adjust and become accustom to the harness and transmitter. Observing the frogs in captivity prior to release allowed the researcher to reattach any exuviated transmitters, loosen harnesses that appeared to be causing localized bruising or appeared to be too tight, and provided an opportunity to gather initial behavioural responses resulting from the attachment of the transmitters.

Upon release the translocated leopard frogs were tracked on an irregular schedule that frequently corresponded with environmental conditions and frog activity (Photo 5). During periods when frogs were actively moving effort was made to track and visually monitor the frogs daily. During cool weather or when frogs were inactive tracking occurred less frequently. Attempts were made to achieve visual observations on all frogs on any given tracking day. Locations of translocated frog observations were recorded in a field book and marked on a hand drawn map of the creek system in the study area. The distance between each individual frog observation was measured using a 30 m rope, marked in 2 m increments.

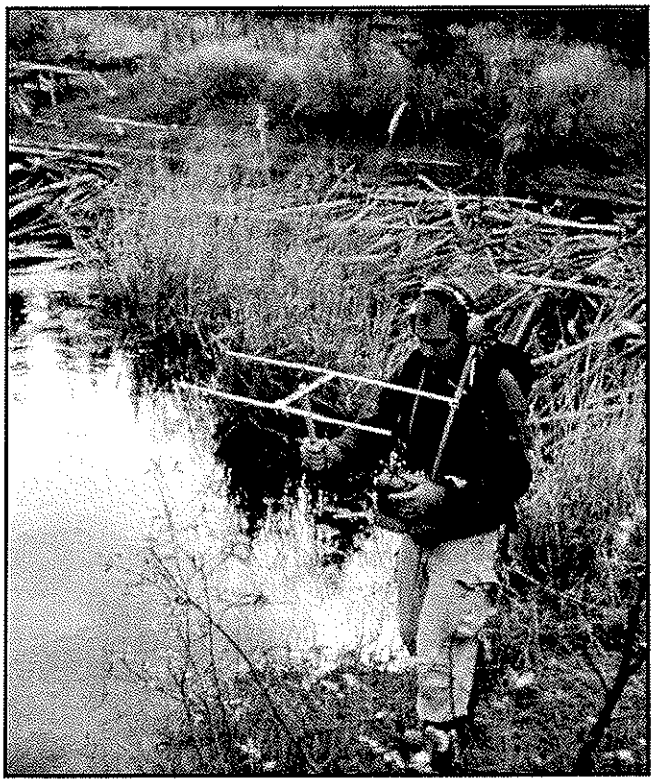


Photo 5 Biologist radio tracking a translocated adult leopard frog along Beaver Creek; downstream of confluence of the spring fed creek.

For each frog observation or location, numerical data (date, time, air temperature, water temperature, pH and dissolved oxygen), habitat characteristics (terrestrial and aquatic), and frog behaviour (activity and positioning) were recorded whenever possible. Air and water temperatures were measured at the vertical position of the frog using a basic scientific thermometer and a hand held dissolved oxygen reader, respectively. If a frog was away from water, data were collected from the nearest water source. To minimize stress on the translocated leopard frogs, they were disturbed and handled only occasionally for health inspections and to ensure the harness and transmitter was fitting correctly. At these times the frogs were also weighed and released in the exact location they were found.

Leopard frogs that survived to and initiated hibernation were retrieved and fitted with refurbished temperature sensing transmitters in order to be monitored until spring emergence. During the course of the study, all frogs found deceased were sent to the Canadian Co-operative Wildlife Health Centre in Saskatoon, Saskatchewan for necropsies and disease testing.

4.0 TRANSLOCATED LEOPARD FROGS

Wendlandt (1999b) and Fisher (1999) identified leopard frog breeding sites having large and stable breeding populations. Leopard frogs used during the 1999 radio telemetry study were collected from a predetermined source population recommended by Wendlandt (1999b) located on the Circle 'E' Ranch, in southeastern Alberta. The ranch is located on the south side of the

Bow River, south of Bow City. Twenty-two frogs were collected in total along Drainage 'K', an irrigation canal/creek in a grazing lease that is part of a Ducks Unlimited Irrigation/Wetlands project (Photo 6).

Photo 6 Drainage 'K' located on the Circle 'E' Ranch in south-eastern Alberta was the source of adult leopard frogs to be translocated to the Raven Brood Trout Station and fitted with transmitters.

The canal/creek drains from Lonesome Lake into the Bow River, and at two recharge wetland complexes along the drainage (Wendlandt 1999b). Adult leopard frogs were collected from Drainage 'K' on three occasions and were held in captivity on site at the Raven Brood Trout Station until they were fitted with transmitters and released into the wild. Six adult leopard frogs were collected from Drainage 'K' on 20 May 1999, eight on 4 September 1999, and an additional six on 20 October 1999.

4.1 Captivity

All leopard frogs collected in May and September were housed in a large aquarium tank and later an outdoor enclosure. The enclosure was constructed of silt fencing manipulated into an irregular oval shape, measuring approximately 2 m in width, 3 m in length and 0.30 to 0.60 m in height. The silt fence enclosure was situated on the east shore of the west rearing pond,

incorporating a roughly equal area of land and water. Benefits to the enclosure design included a large and natural terrestrial and aquatic habitat. However, the design was abandoned as it proved to be problematic in that it was not entirely escape or predator proof. In addition the high walls of the silt fencing heavily shaded the interior of the enclosure and may have acted as a physical barrier for potential prey items. By 9 September, four of the 14 leopard frogs (three from the May capture and one from the September capture) had disappeared from the enclosure and were never found. A leopard frog holding cage was built using half-inch hardware cloth and 2X4 lumber to address the problems of the previous enclosure. The pen measured 2.53 m in length, 0.92 m in width and 0.60 m in height (Photo 7). Two large doors located on the top of the cage allowed easy access to its interior.

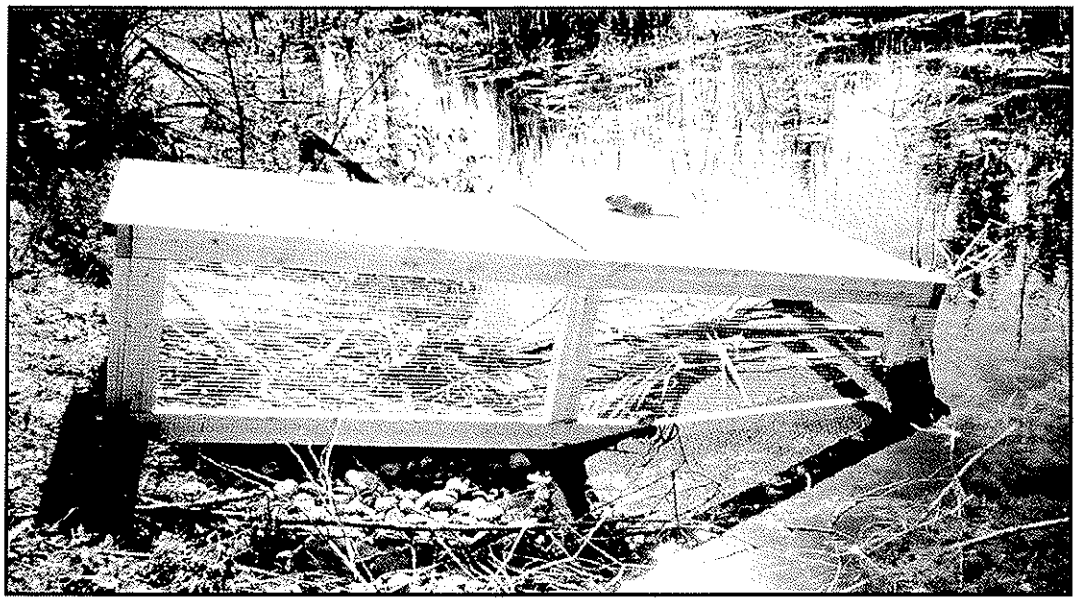


Photo 7 Large outdoor holding cage built to temporally house translocated leopard frogs for acclimatization, quarantine and observation.

The cage was situated along the east shore of the west rearing pond and positioned perpendicular to the shoreline, with a portion of the cage in the water. With the cage in this position the leopard frogs had roughly equal portions of water and land, with a maximum water depth of about 0.50 meters. Grasses, cattails, small branches and aquatic plants were place inside the cage to simulate natural conditions, and provide cover, shade and protection from light frost. For health reasons it was decided not to house the six leopard frogs captured in October in the rearing ponds in newly built cage. Instead, a cooler and aquarium was used in substitution.

4.2 Release Sites

Seven sites were chosen for release of the translocated adult leopard frogs. Each chosen release site demonstrated a variety of potential water quality parameters and conditions supportive of overwintering requirements of leopard frogs. In addition, each release site was selected with proximal potential breeding habitat. In September (first release), six of the eight frogs were released into sections of Beaver Creek amalgamated with spring water, downstream of the "lower weir" and upstream of the confluence of Beaver Creek and the Raven River. The two remaining frogs were released into Beaver Creek approximately 60 m upstream of the confluence of the spring fed creek and Beaver Creek. All eight frogs released in October (second release) were released into Beaver Creek a considerable distance up stream of the confluence of Beaver Creek and the spring fed creek. Of the eight frogs, two were released just up stream of the "upper weir" and six were released down stream of the same weir (see Photo 1 and Appendix I).

4.2.1 First Release

On 28 September 1999, eight out of ten leopard frogs collected from Drainage 'K' in May and September were fitted with radio transmitters and released in four locations along Beaver Creek near the Raven Brood Trout Station. These frogs were numbered from one to eight and were comprised of two males and six females (Table 1). Two emaciated male leopard frogs where held in captivity until 29 October 1999 for further observation and subjected to a short feeding campaign to improve energy reserves for overwintering.

Table 1 Summary of translocated frogs (individuals and sex) at each release site.

First Release (28 September)		Second Release (29 October)	
Release Site	**Frog (sex)**	**Release Site**	**Frog (sex)**
1	4 (female) 5 (male)	5	A (female) B (male) D (male)
2	1 (female) 8 (male)	6	C (female) F (male) 10 (male)
3	2 (female) 6 (female)	7	E (female) 9 (male)
4	3 (female) 7 (female)	-	-

4.2.2 Second Release

Due to the high mortality rate of the initial 8 translocated leopard frogs, on 29 October 1999 eight additional leopard frogs were fitted with radio transmitters and released into Beaver Creek near the Raven Brood Trout Station. Frogs captured from Drainage 'K' in October were

identified by the letters 'A' through 'F' while the two remaining leopard frogs collected in September and May from Drainage 'K' were numbered nine and ten, respectively. Frogs released in October comprised of five males and three females (Table 1). Individual characteristics of each translocated leopard frog such as sex, SVL, weight and length of transmitter harness are summarized in Table 2.

Table 2 Individual characteristics of translocated leopard frogs upon release; including the length of harness.

Frog	SVL (mm)	Weight (g)	Harness (mm)	Frog	SVL (mm)	Weight (g)	Harness (mm)
1	75	50	57	**9**	65	29	45
2	95	63	63	**10**	66	35	49
3	100	80	71	**A**	90	76	76
4	89	55	62	**B**	75	46	60
5	74	43	59	**C**	85	72	61
6	95	86	72	**D**	73	45	56
7	84	56	61	**E**	80	62	60
8	75	40	60	**F**	72	43	57

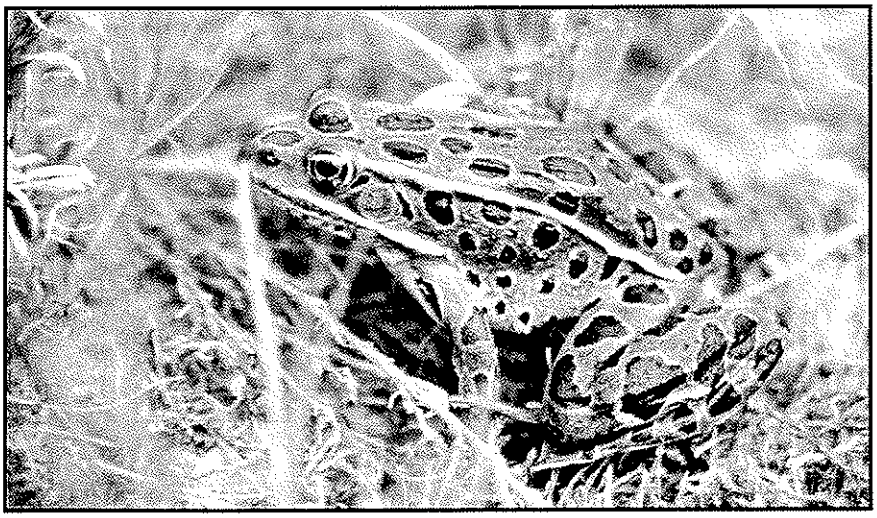
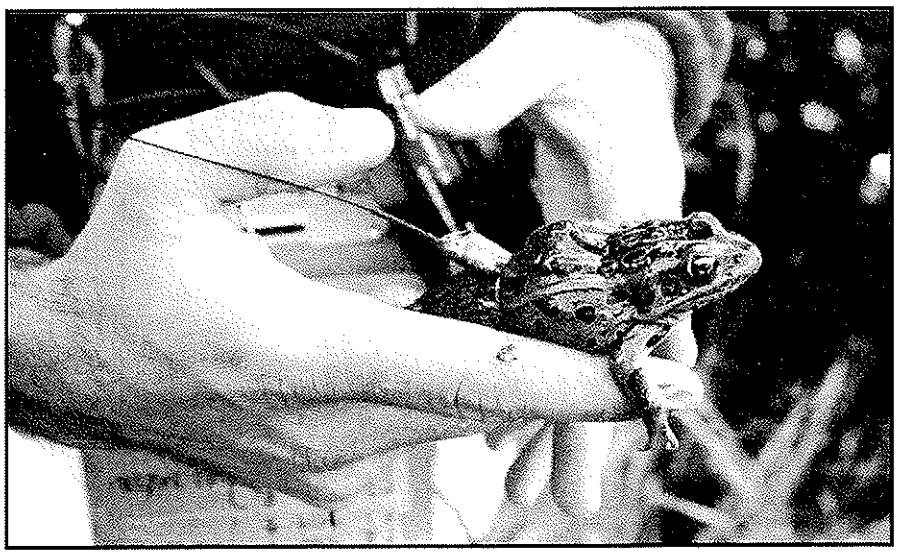


Photo 8 Northern Leopard Frog (*Rana pipiens*).

Photo 9 Translocated leopard frog fitted with a harness and transmitter.



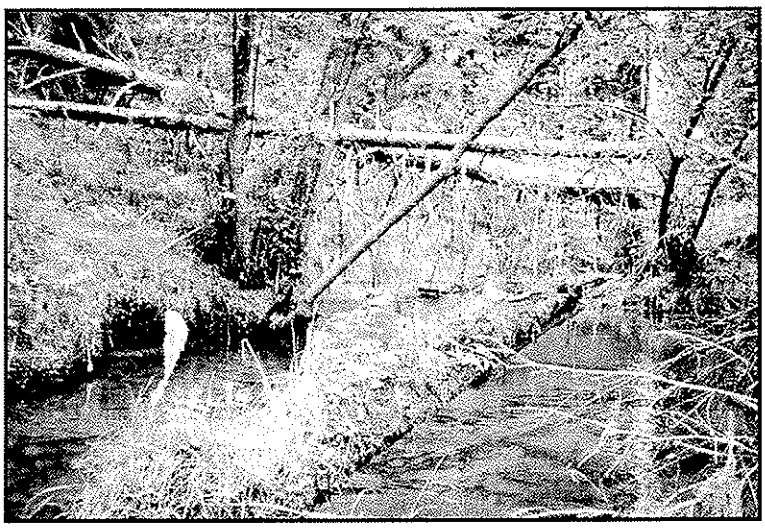


Photo 10 A section of Beaver Creek. Heavily influenced by a spring fed creek, much of Beaver Creek remains ice-free during the winter.

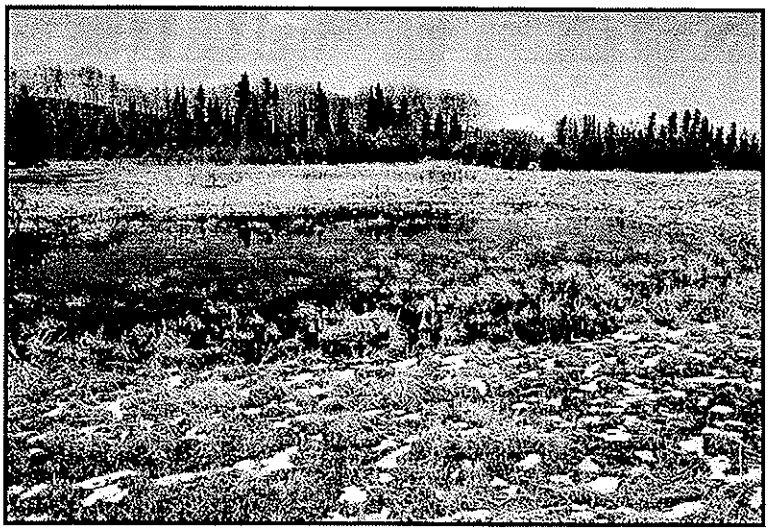


Photo 11 Shallow semi-permanent to permanent oxbow located parallel to the Raven River, just north of the Raven Brood Trout Station quarter section. Photo taken early spring.

Photo 12 Raven River north of the Raven Brood Trout Station quarter section. High dissolved oxygen levels that occur in the Raven River are supportive of overwintering leopard frogs, however the presence of large game fish and potential for flooding may have a negative impact on hibernating leopard frogs.

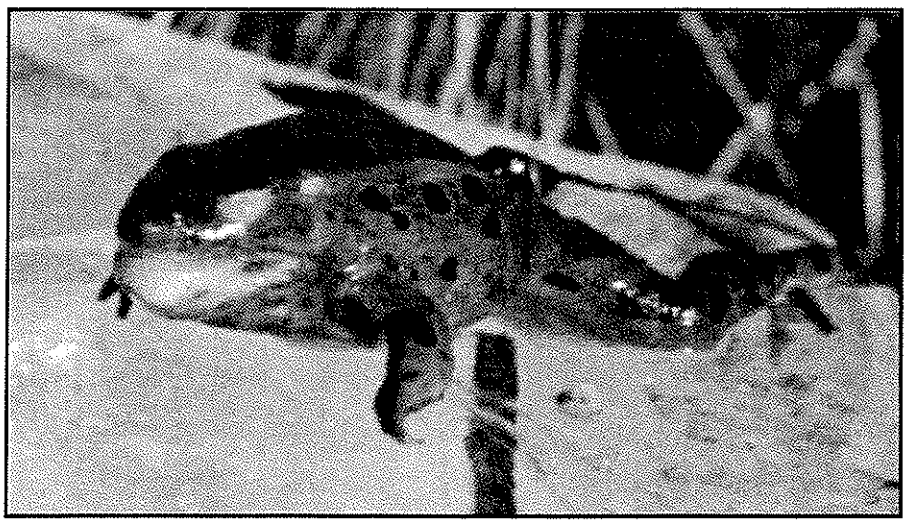


Photo 13 Frog E was retrieved from Beaver Creek on 18 January 1999 and confirmed deceased.

5.0 RESULTS

In total 16 translocated leopard frogs were released into Beaver Creek, and tracked over the period of 135 days from 29 September 1999 to 17 April 2000.

5.1 Movement Patterns

The eight translocated leopard frogs from the first release, travelled combined total distance of 1165 m during the tracking period. The remaining eight translocated leopard frogs from the second release travelled a combined total distance of 740 m during the tracking period (Appendix A). With the exception of two individual frogs (Frog 6 and Frog A), all substantial movements by the frogs occurred in a downstream direction. On numerous occasions frogs traversed from one side of the creek to the other or remained stationary in one location. Frog 6 travelled approximately 52 m up the spring fed creek from the confluence of that creek and Beaver Creek, then returned 5 days later to the confluence downstream. Frog A travelled approximately 40 m upstream from its initial release location at the "Upper Weir" to the downstream side of a beaver dam on Beaver Creek. All frogs with the exception Frog 4 and Frog F (and frogs preyed upon) remained within 2 m of the waters edge of Beaver Creek over the tracking period. Frog F was found frozen on land on 13 November 1999, 8 m from the edge of Beaver Creek. It is uncertain if Frog 5 was depredated, nevertheless its harness and transmitter was discovered 3 m from the edge of Beaver Creek on 4 October 1999.

Frog E travelled 22 m over a 24-hour period, representing the greatest distance travelled by an individual frog over the shortest recorded period of time. This movement occurred between 7 and 8 November 1999, and entirely underwater and ice, along Beaver Creek. Frog 8 demonstrated the maximum average distance travelled by a frog over a period of time. Frog 8 travelled a total distance of 139 m over 3-day period from 12 October to 14 October along Beaver Creek. However, it is not known what percentage of time Frog 8 may have spent travelling aquatically or terrestrially. Frog 6 and Frog E remained stationary for the greatest duration of time between periods of activity. Frog 6 and Frog E remained in one locality for 20 and 25 days, respectfully, prior to demonstrating a movement greater than 1 meter.

5.2 Habitat Selection

Habitats selected by the translocated leopard frogs were broken down into four broad categories: in water; out of water; underwater; or unknown position of frog with respect to water (Appendix B). Each of these broad categories was divided into six further habitat descriptors relating to vegetation and positioning of the frog (Appendix C). They are defined as follows:

• Dense vegetative cover	Tall or thick terrestrial or semi-aquatic vegetation or dense aquatic vegetation; frogs frequently concealed from view
• Sparse vegetative cover	Short or thin terrestrial or semi-aquatic vegetation or thin aquatic vegetation; frogs frequently partially concealed from view
• No cover	Barren substrate on land or bottom of creek with no vegetation or debris present; no possibility of concealment from view
• In or under creek bank	Spaces along creek bank created by water erosion, fallen trees, slumping, animals etc.; in or out of water
• In beaver dam	Interstitial spaces within the matrix of beaver dams or lodges; in, under or out of water
• Under an object	Object such as a rock, log, branch or other debris – alive or dead; in, under or out of water

Translocated frogs selected a variety of aquatic, semi-aquatic and terrestrial habitats (Figure 2).

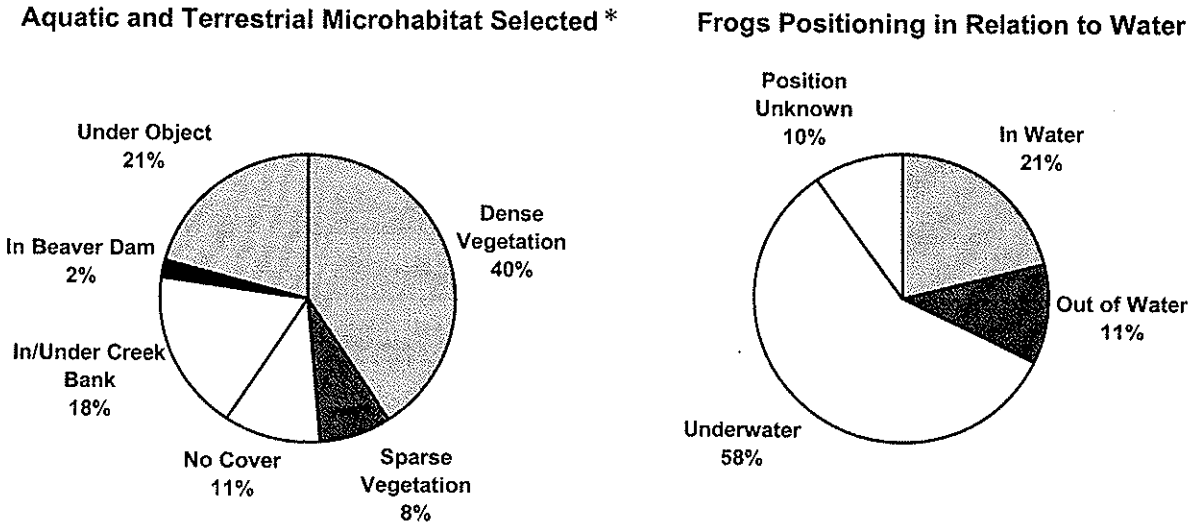


Figure 2 Microhabitat selected by all 16 translocated leopard frogs during a total of 198 field observations. (*) Differentiation between aquatic and terrestrial microhabitat selection by frogs is not specified in this graph.

5.3 Field Observations

Four of the 16 leopard frogs (Frog A, Frog E, Frog 6, Frog 10) released during the course of this study appeared to have successfully survived to and initiated hibernation. Of these four leopard frogs, three frogs (Frog 10, Frog E and Frog A) were confirmed deceased (cause of death unknown). Frog 6 was could not be relocated in a section of the Raven River despite a functioning transmitter; it was last observed in winter dormancy, on 18 January 1999 (health status undetermined). Of the remaining translocated frogs four were depredated, two were discovered frozen (one in water and one on land), two were discovered deceased, cause of death unknown, and three transmitters (with harnesses intact) where found (Table 3).

The transmitter that experienced a malfunction belonged to Frog C and was pulsing abnormally fast. Unfortunately the transmitter could not be retrieved before the battery expired. Sometime between 9 and 13 November the transmitter completely failed. The cause of the malfunction was most likely contributed by water leakage within the transmitter (per. comm. John Edwards, Holohil Systems Ltd.). Whether this leakage was influenced by a predator or occurred due to the failure of the transmitter's waterproof epoxy armour, is not known.

Table 3 Summary of field activities of all translocated leopard frogs.

Frog	Number of Days in the field	Number of Tracking Days†	Total Distance (m) Tracked	Status and Reason Tracking Ceased
1	20	10	83	Shed Transmitter
2	12	7	224**	Depredated
3	7	4	449**	Depredated
4	24	13	212	Deceased††
5	7	4	9	Shed Transmitter
6	113*	33*	334*	Hibernation*/Deceased/lost?
7	24	13	149	Deceased††
8	20	10	305	Depredated/Disease?
9	41	15	12	Depredated
10	41	15	38	Deceased††
A	81*	17*	72*	Hibernation*
B	39	14	286	Shed Transmitter
C	16	7	80	Transmitter Malfunction
D	29	13	15	Frozen (in water)
E	55	16	91	Deceased††
F	16	7	146	Frozen (on land)

(*) Data recorded as of 10 February 2000.
(**) Distance influenced by unknown predator.
(†) Number of tracking days, not including initial release day.
(††) Unknown cause of death.

5.4 Hibernation

In total, 13 of the 16 translocated leopard frogs were observed or located underwater over the tracking period. Nine of these 13 frogs remained underwater for more than seven consecutive days (Table 4), while five frogs were located underwater for two consecutive days or less (Table 5). Of the nine frogs that remained underwater for more than seven consecutive days, four frogs (Frog 6, Frog A, Frog E, and Frog 10) appeared to have survived to the initiation of hibernation. However, due to traumatic injuries, a lower probability exists that Frog 10 survived to the initiation hibernation.

Table 4 Water and air quality parameters at each frog location upon initial submergence date. All frogs shown in table remained underwater for at least seven consecutive days.

Frog	Submergence Date	Water Temp (°C)	Dissolved Oxygen (mg/l)	Air Temp (°C)		Average Air Temp (°C) 3 Days Prior	
			mg/l	High	Low	High	Low
6	29 Sep-10 Feb	4.1 (30 Sep)	11.05 (30 Sep)	3	-2	10.0	-5.7
9	01 Nov-09 Nov	0.7	11.52	6	-15	6.3	-6.7
10	01 Nov-06 Dec	0.6	13.16	6	-15	6.3	-6.7
A	09 Nov-10 Feb	0.4 (08 Nov)	11.56 (08 Nov)	18	-	15.5	-4.0
B	13 Nov-06 Dec	0.5 (14 Nov)	11.90 (14 Nov)	2	-4	8.5	-4.5
C*	01 Nov-13 Nov	0.6	13.16	6	-15	6.3	-6.7
D	01 Nov-23 Nov	0.5	12.07	6	-15	6.3	-6.7
E	01 Nov-18 Jan	0.8	12.75	6	-15	6.3	-6.7
F**	01 Nov-09 Nov	0.7	12.19	6	-15	6.3	-6.7

(*) Transmitter malfunctions first noted 7 November and signal ceased on 13 November.
(**) Frog F in beaver dam between 3 November and 9 November; not known if in or underwater.

Table 5 Water and air quality parameters at each frog location upon submergence date(s). All frogs shown in table remained underwater for two consecutive days or less.

Frog	Date(s) Located Underwater	Water Temp (°C)	Dissolved Oxygen (mg/l)	Air Temp (°C)		Air Temp (°C) 1 Day Prior	
			mg/l	High	Low	High	Low
1	07 Oct	5.3	13.27	16	-4	15	-4
2	05 Oct	3.8	10.73	10	-6	14	0
4	30 Sep	4.2	10.41	3	-2	10	-6
	05 Oct	2.8	11.83	10	-6	14	0
	17 Oct	5.5	11.95	13	-2	-	-
7	03 Oct	5.7	90.4 %	11	-6	6	-6
8	30 Sep	4.6	11.99	3	-2	-	-

5.4.1 Individual frog activity accounts for frogs that initiated hibernation

Frog 6

Frog 6 was released into a section of Beaver Creek influenced by the spring fed creek, and down stream of the "lower weir", on 28 September. On 29 September Frog 6 was located underwater approximately 6 m from its initial release site. The frog was located under a large log lying on the bottom of Beaver Creek, positioned perpendicular to the flow of water. The log was located at the confluence of a small tributary creek and Beaver Creek. A willow bog that is supplied by a tributary of Beaver Creek, and possibly ground water, fed the small tributary creek. The substrate in this area consisted of primarily mud and silt with some small fragments of woody debris. Water depth was approximately 0.5 m. Frog 6 remained under the log for at least 23 days before it changed locations. Water temperature and dissolved oxygen content ranged between 3.9 °C to 6.3 °C and 10.01 mg/l to 13.32 mg/l, respectively during this period. On 21 October, Frog 6 relocated under a branch on the bottom of the creek approximately 18 meters downstream from its last location. Between 26 October and 8 December Frog 6 continued to travel underwater and downstream along Beaver Creek towards the Raven River, selecting logs, undercut banks and other debris as cover. On 22 December Frog 6 was observed on the bottom of the Raven River approximately 30 m downstream of the confluence of Beaver Creek. During the tracking period Frog 6 travelled a total distance of 334 m, presumably underwater. During the period of 22 December to 10 February water temperature and dissolved oxygen levels at the frog location in the Raven River ranged between 1.3 °C to 2.5 °C and 9.73 mg/l to 10.72 mg/l, respectively. Water depth was approximately 1-1.5 m. The substrate in the immediate area of the frog consisted primarily mud and silt, with proximal hard gravel ridges. The mud/silt substrate on which the frog was resting was located in a slight depression on the streambed resulting in slower rate of water flow over the bottom and slightly deeper water. The frog was positioned on its belly, perpendicular to the current, and with limbs held loosely away from the body. The frog was not handled due to the low probability of placing it back into its original resting location, however it appeared to be in good condition. Frog 6 was radio tracked to it's last known location until 17 April 1999. Between 17 April and 01 May 1999 an exhausted search of the creek bottom in the last known location of Frog 6 was undertaken. No frog or shed transmitter was located.

Frog A

On 29 October 1999 Frog A was released approximately 4 m upstream of the "upper weir" into Beaver Creek and a considerable distance upstream of the confluence of Beaver Creek and the spring fed creek. Frog A was located underwater on 1 November approximately 30 m upstream from its initial release site and just downstream of a small beaver dam. On 7 and 8 November, Frog A was observed partially out of the water on the downstream edge of the small beaver dam described above. From 8 November onwards Frog A remained underwater in a localized area approximately 20 m down stream of the beaver dam. Movements of Frog A ceased on 13 November in this location and no further visuals of this frog were achieved until 6 December. Water temperatures and dissolved oxygen levels recorded at this location on 14 November were 0.3 °C and 10.45 mg/l, respectively. Between 14 November and 6 December water temperatures and dissolved oxygen levels declined from 0.3 °C to 0.1 °C and 10.45 mg/l to 5.99 mg/l. By 6 December ice thickness at this location was estimated to be greater than 90 cm and was partly due to the influence of seeps and/or runoff in the area that added additional layers of ice on top of the existing ice. A visual observation of Frog A and note of aquatic parameters occurred on 6 December. The frog was found on its belly, on the bottom of the creek in approximately 60 cm of water (under the ice) with minimal water flow. The frog was positioned on a soft mud substrate with its limbs held loosely away from its body. Profuse aquatic plant growth occurred within centimetres of the frog. Upon inspection, Frog A could be described as slightly bloated with its mouth open and tongue swollen and protruding. A white membrane covered each eye and the skin appeared to be the process of slothing or deteriorating. Overall Frog A appeared to be in poor health. No noticeable movements of Frog A occurred between 6 December and 10 February and dissolved oxygen levels dropped markedly to 1.10 mg/l by 18 January 2000. On 2 March 2000 the section of Beaver Creek where Frog A was last located was frozen to the bottom with an ice thickness of over 100 cm.

Frog E

Frog E was released on 29 October 1999 along a narrow section of Beaver Creek, downstream of the "upper weir" and upstream of the confluence of the spring fed creek. Frog E was first located underwater on 1 November approximately 22 m down stream of its release site at the base of a beaver dam. Between 1 November and 9 November Frog E travelled an additional 53 m in a

down stream direction along Beaver Creek, negotiating two beaver dams along the way. During this period water temperatures and dissolved oxygen ranged between 3.1 °C to 4.4 °C and 11.71mg/l to 12.75 mg/l, respectively. Beaver Creek along most of this stretch was relatively narrow with abundant emergent vegetation along the banks. By 13 November Frog E moved another 14 m downstream along the bank of the creek and just upstream of a beaver dam. At this location the frog was positioned underwater near an entrance of an animal burrow which was located on the bank of the creek. The water depth in the immediate area in front of the hole in the bank was slightly deeper than the surrounding creek (possibly a result of a run to the burrow). Frog E remained stationary at this location for 25 days. Dissolved oxygen levels in the creek at this location dropped over the 25 day period from 11.60 mg/l to 4.73 mg/l as did the water flow rate. A visual observation of Frog E and note of aquatic parameters occurred on 6 December. The frog was positioned on its back, on a soft mud substrate, with its limbs held loosely away from its body. Ice thickness and water depth in this area, at the time, was approximately 30 cm. The immediate area was void of vegetative cover. Frog E was removed from the water for a closer inspection and was described as slightly bloated with its mouth open and tongue swollen and protruding. A white membrane covered each eye and the skin appeared to be the process of slothing or deteriorating (Photo 13). Overall Frog E appeared to be in poor health. Frog E was placed back underwater in the same location it was retrieved; however it was placed on its belly rather on its back (how it was found). Between 8 December and 22 December Frog E moved a final 2 m down stream along the same bank of the creek and was observed on its back once again. Dissolved oxygen levels continued to drop to 3.41 mg/l on 22 December and 1.00 mg/l by 18 January 2000. Frog E was inspected and determined deceased on 18 January 2000.

Frog 10

Frog 10 was also released on 29 October 1999 along a narrow section of Beaver Creek, downstream of the "upper weir" and upstream of the confluence of the spring fed creek. On 1 November Frog 10 was located underwater in thick vegetation along the edge of the creek. Over the next eight days (to 9 November) Frog 10 remained in a relatively localized area 4 m down stream from its initial release site. Over this period the greatest movement exhibited by Frog 10 was 6 m over a 24 hr period. Beaver Creek at this location is no more than 2 m wide and approximately 0.5 m deep. An abundance grasses and sedges, as well as woody debris from the

beaver dam, line the edges of the creek. The creek bottom was void of vegetation, but had some woody debris. Water temperatures and dissolved oxygen levels on 8 November, in this area, were 0.3 °C and 11.40 mg/l, respectively. Between 8 November and 13 November, Frog 10 travelled approximately 20 m downstream of its last recorded location. At this new location, Beaver Creek roughly doubles in width resulting in decreased water flow. At this location, on 14 November, the water temperature was 0.3 °C and dissolved oxygen levels were 11.87 mg/l. Movements by Frog 10 ceased on 14 November or were not significant enough to detect with the telemetry equipment. Between 17 November and 6 December water temperatures eventually levelled out a 0.1 °C and dissolved oxygen level decreased from 8.42 mg/l to 6.87 mg/l. A visual observation of Frog 10 and note of aquatic parameters occurred on 6 December upon which the frog found to be deceased. The frog was found completely concealed in thick aquatic vegetation on the bottom of the creek proximate to a mud substrate void of vegetation. The water depth was approximately 60 cm, with an ice thickness of approximately 30 cm. Upon closer inspection of Frog 10, pale fungal hyphae were present on the surface of most of the skin. In addition, two small perforations (2-5 mm in diameter) were observed on the caudal aspects of the hind limbs with an associated absence of a portion of muscle. Unlike Frog A and Frog E, Frog 10 did not appear bloated, however its mouth was slightly open and tongue swollen and protruding. A white membrane also covered each eye and the skin appeared to be the process of slothing or deteriorating.

6.0 DISCUSION

6.1 Telemetry

The skin of most of species amphibians, including the leopard frog, is delicate, allowing the animal to facilitate respiration and/or transpiration. As a result, the physical effect of the harness design and transmitter placement on the skin of each frog was carefully monitored whenever possible. The effectiveness of the telemetry equipment and transmitters was also evaluated during the tracking period.

When fitted with a transmitter, most frogs initially appeared to be encumbered; temporarily losing equilibrium, often jumping with awkward hops and landing off balance, and unable to right themselves when on their back. In addition, some male frogs emitted short renditions of spring vocalizations and other calls in the form of low grunts. Female frogs also emitted some

sounds when initially fitted with transmitters. These, however, were in the form of low grunts or moans. These observations were similar to that reported by Wendlandt (1999) and, in time, all frogs appeared to have accepted the assembly. During this study, increased coordination and mobility were observed when a looser harness was placed on the frogs. Naturally, a harness needed to be small enough to slide snugly over the thighs of the frog in order to decrease the chance of harness (transmitter) being shed.

A concern involving the transmitters was identified during the course of the study involving Frog D. Frog D was discovered frozen in ice along the edge of the creek. It is unknown whether or not this frog had expired prior to being entombed in ice. However, the possibility exists that the antenna of the transmitter became frozen in the encroaching ice as the frog hibernated near the shore. Unable to shed the trapped transmitter, Frog D would have been unable to escape the ice. This event may also contribute to the shedding of transmitters by frogs that are able to free themselves from their trapped transmitter.

A further concern was raised regarding harnesses kept on frogs during the course of hibernation. Hutchinson and Dady (1964) observed an increase in body weight in *Rana pipiens* during submergence. They found an average increase in weight of 14.3 % after 62.5 hours of cold submergence. Christiansen and Penny (1973) observed a 16.1 % increase in body weight of leopard frogs when submerged in deoxygenated water at 5°C for 2-8 weeks. Preliminary results of necropsied frogs fitted with transmitters, sent to the Canadian Co-operative Wildlife Health Centre showed no signs of negative ramifications of the harness design used in this study (Trent Bollinger, pers. comm.). Health inspections in the field of Frog 6 showed no physical effects of the harness; however, an observed fluctuation in body weight was noted. Frog 6 weighted 86g prior to release on 28 September. On 29 October, Frog 6 was weighed again and found to be 88g, an increase in body weight of 2.3 %. On 8 December Frog 6 was weighed again and found to be only 82g, a 6.8% decrease in body weight. Since no injuries were observed on the frog and the frog appeared to be in good health, small weight gains appear to have minimal effect on frogs fitted with transmitters. T. Bollinger (pers. comm.) noted that fat reserves appeared to be concentrated above the waist and not localized near the harness. It was not known whether Frog 6 remained completely submersed underwater between each date that it was weighed.

6.2 Movement Patterns and Activity

Research on movements in amphibians has focused on breeding migrations (Van Gelder et al. 1986, Sinsch 1987), post breeding activity (Ruth et al. 1976) and emigrations of young of the year from breeding ponds (Dole 1971). Movement patterns during the course of this study was conducted on adult leopard frogs and was limited to fall and winter aquatic movements. Due to the secretive nature and often inaccessible microhabitats selected by the frogs, visual observations were only possible on 44 occasions out of 198 confirmed locations.

The translocated leopard frogs were released at precise (potential) overwintering sites along Beaver Creek in late fall, thereby negating the need to migrate to hibernacula. All frogs collected for the study were suspected to overwinter in a creek system (Drainage K) within their natal habitat and appeared to have adopted, and possibly recognized, Beaver Creek as a potential overwintering site. Seventy-five percent of the frogs remained within 2 m of the water edge (or in the water) during the tracking period. Hines et al. (1981) reported that leopard frogs began to congregate in hibernacula in conjunction with four to seven days of 10 to16 °C temperatures, coupled with freezing night-time temperatures. Air temperature in the area, five days prior to release, were 8-14 °C with night-time temperatures of 3 to -7 °C. These air temperatures may have discouraged the frogs from leaving the waters edge. From 29 September until 13 November, when the last frog submerged, recorded night-time temperatures never exceeded 0 °C.

It is commonly believed that amphibians preferentially disperse in association with rainfall (Gibbons and Bennett 1974), under nocturnal conditions and in conjunction with rapid drops in barometric pressure (Dole 1971). During the tracking period, precipitation was recorded in the form of rain, wet snow and snow, however, was not believed to be a factor in frog movements. Precipitation fell in the form of wet snow on two occasions (30 September and 1 October) after the first release of Frogs 1 through 8, and prior to 21 October when some frogs were still found to be out of the water. However, associated air temperatures during these events remained below 5 °C and were likely too cool to support terrestrial movements. Brooks (1918) noted in laboratory conditions leopard frogs exhibit sluggish behaviour when air temperatures fall below 10 °C and Wendlandt (1999) reported that frogs appeared slow-moving when temperatures dropped to 9 °C or less. By 21 October, the remaining frogs were primarily found underwater,

and therefore ensuing precipitation would not have been a factor in subsequent movements. Of the 44 direct visual observations, frogs were observed on 12 occasions in terrestrial situations and completely out of water. At these times air temperature ranged from 4 °C to 19 °C, however on all occasions frogs demonstrated minimal movements when observed by the researcher.

Because frogs were only tracked during the day, it is not known what extent, if any, frogs moved nocturnally. However, due to subzero night-time temperatures during the course of the study, only nocturnal aquatic movements or underground (within creek banks) would be possible. Only one frog (Frog 6), out of 198 field observations of all frogs, demonstrated signs of activity that was not researcher induced (i.e., flushing or disturbing the frogs in some way). Frog 6 was observed crawling underwater, approximately 25 cm from the bank of Beaver Creek on 29 October.

It is unclear what percentage of time the frogs travelled over land since no over land movements by the frogs were observed. All frogs, with the exception of frogs depredated and Frog F (found frozen 8 m from shore) remained within 2 m of the waters edge. For this reason it was suspected frog movements primarily occurred in the water, underwater or at very least within 2 m of the shoreline of the creek systems. It can be concluded that nearly all frog movements from the second release occurred under water due to the formation of ice along the creek. The proximity to the waters edge frequently assured the frogs availability of ground moisture, thick vegetation to ward off light frost and nearby aquatic protection from freezing temperatures - particularly at night. Translocated leopard frogs held in captivity prior to being fitted with transmitters were observed on numerous occasions resting underwater in the large outdoor holding cage on mornings following subzero night-time temperatures. Leopard frogs in the wild may behave similarly. They were all capable of slow swimming movements and their eyes remained closed with the translucent nictitating membrane drawn over each eye.

6.3 Habitat Selection

A wide variety of terrestrial aquatic microhabitats along Beaver Creek were selected over 198 field observations of the 16 translocated leopard. Dole (1965) reported that *Rana pipiens* typically spend more than 95% of the day sitting in a "form", (small clearing of damp soil) or

make use of cavities, crevices and other forms of cover rather than making "forms". The purpose of these "forms" may be to preserve and obtain moisture (Dole 1967). Additional benefits include predator avoidance and higher or lower microclimate ambient temperatures. The majority of the frogs found terrestrially in this study appeared to have adopted this behaviour, at least during the day.

During 198 field observations eighteen percent of the frogs during the course of this study were observed or located underground (within the creek bank) and 21% of the frogs were observed or located under objects on land. Frogs frequently remained under these forms of cover for up to 7 consecutive days. Leopard frogs that selected these subterranean microhabitats may have done so in order to avoid fluctuating ambient temperatures. Porter (1972) observed similar behaviour patterns in nature, and induced *Rana pipiens* to seek a retreat beneath objects in an aquarium when air temperatures were reduced to 8 °C. As with many amphibians that occur in climates that experience freezing temperatures, leopard frogs utilize seasonally stored body fat in order to sustain bodily functions during periods when food supply is unavailable and during hibernation (Brenner 1969). Environmental temperatures influence body fat utilization (Brenner 1969) and directly affect the metabolic rate of ectothermic animals (Cook 1949) as well as general activity. Leopard frogs during this study may have also selected these retreats to reduce their metabolic rate by remaining cool, as well as to remain out of site of predators.

6.4 Hibernation

Many ranid anurans, such as the leopard frog, overwinter in aquatic habitats (Wright and Wright 1949, Porter 1972) to avoid freezing temperatures. These aquatic environments may include springs, creeks, ponds and other water bodies of varying depth that possess critical water quality parameters supportive of overwintering leopard frogs. These include suitable dissolved oxygen levels, sufficiently low water temperatures and bottoms that remain free of ice. Emery et al. (1972) and Merrell (1977) reported a few poorly documented cases of *Rana pipiens* overwintering out of water under objects or underground. However, no frogs were observed to have initiated hibernation at these locations during this study.

Hibernation is most likely triggered by air temperatures (Licht, 1991) and water temperatures (Oliver 1955), however photo period and frog physiology can not be discounted. In total, nine frogs remained underwater for at least seven consecutive days and of these nine frogs, four were considered to have survived to hibernation. However submergence dates are somewhat subjective for eight of the nine frogs due to the formation of ice along the banks of the creek preventing frogs from leaving the water. Frog 6 was the only frog that was not inhibited from leaving the water at any point during the entire duration of the study. Frog 6 was released into a section of Beaver Creek that was influenced by the spring fed creek and consequently remains ice-free all year.

6.5 Mortality

Mortality can occur during the fall and winter as a result of depredation, desiccation, inability to find appropriate hibernacula, frost, freezing, anoxia, lack of sufficient fat stores and disease (Hine et al. 1981). At least 44 % of the translocated leopard frogs during this study experienced mortality prior to the initiation of hibernation. During a three year fall mortality survey, conducted to assess the extent and characteristics of leopard frog mortality associated with fall hibernation in Wisconsin it was found that 4% to 23% (and as high as 100% on some transects) of the frogs observed over the course of three years experienced mortality (Ruth et al. 1976). Wendlandt (1999a) reported that of six leopard frogs fitted with transmitters, three were depredated, two shed their transmitters and one initiated hibernation. This translates into at least 50% mortality (discounting the two shed transmitters and frog that initiated hibernation), but may be as high as 83% if these three remaining frogs also failed to survive. During this study, mortality could have increased to as high as 69% if frogs that shed transmitters and lack information on timing of death are considered to have failed to survive. For example, three transmitters were found with the harness completely intact. The first of the three shed transmitters (from Frog 5) was found on land approximately 3 m from Beaver Creek. The second (from Frog 1) was found within the matrix of a beaver dam, and was most likely shed as the frog worked its way through constricted confines of the dam. The third shed transmitter (from Frog B) was found underwater in Beaver Creek within meters of the location of the first shed transmitter. The possibility exists that the first and third transmitter shed may be the result from depredation of the frogs. Evidence from Frog 9 which was discovered depredated under ice

along the edge of the of Beaver Creek supports this theory. Although the corpse of the frog was practically reduced to a skeleton, the harness and transmitter was completely undamaged. It is therefore conceivable that a small predatory animal, such as a shrew, may be capable of eating a frog away from the harness and transmitter, leaving the intact transmitter and harness behind.

8.0 RECOMMENDATIONS

A) Rediotelemetry

1) Leopard frogs fitted with transmitters should be held in captivity, under controlled conditions, for at least five days prior to release back into the wild. During this period the frogs can adjust and become accustomed to the harness and transmitter and the researcher can monitor the health and behaviour of the frogs.

2) An outdoor cage that is predator and escape proof should be used to temporarily house translocated frogs for acclimatization and quarantine purposes. A large cage open to the environment and simulating natural conditions may reduce stress on captive frogs and produce a more reliable test of transmitter fit.

3) In order to minimize stress on the harnessed frogs in the field, they should be disturbed and handled as little as possible. Unnecessary harassment of the frogs may lead to increased depredation, shedding of the transmitter and stress to the animal.

4) To decrease the encumbrance of the transmitter/harness, frogs with a mass supportive of a 2% to 6% transmitter-to-body weight ratio should be selected.

5) Attention and caution should be exercised regarding herpetiles fitted with radio transmitters utilizing aquatic hibernacula that experience ice formation. A potential problem may exist where the transmitter antenna becomes frozen into forming ice, thereby trapping the individual.

6) When ideal hibernacula sites are identified, leopard frogs collected for translocation purposes should be released as late as possible prior to the onset of freezing nightly temperatures to reduce loss to predators, shedding of harness and stress to the animal.

7) Temperature sensing transmitters offer a variety of benefits over non-sensing transmitters and should be utilized when possible. Benefits include longer battery life (up to 8 months vs. 4 months), decreased need to retrieve and handle hibernating frogs, and opportunities to determine hibernacula (ambient) temperatures based on the pulse rate nominal of the transmitter.

8) Male leopard frogs (despite their smaller mass then females) may be the preferred candidates for carrying transmitters. With more significant thigh size-to-waist size ratio, harnesses fitted on male leopard frogs may fit more loosely then females. This would result in less constriction, bruising, and stress to the animal. In addition, because of the high mortality associated with frogs fitted with transmitters, female frogs critical to recruitment of source populations should be avoided.

B) Release Sites

1) Several shallow semi-permanent-to-permanent oxbows occurring just north and parallel to the Raven River should be further surveyed and investigated in order to assess their suitability for potential leopard frog breeding habitat.

2) In order to ensure sufficient oxygen levels supportive of overwintering leopard frogs, future releases should occur in sections of Beaver Creek that are influenced by the spring fed creek. Dissolved oxygen levels in Beaver Creek upsteam of the confluence of the spring fed creek may be too low following ice up.

3) Areas proximal to the Raven River should be further investigated as possible release sits of translocated leopard frogs. Although large predatory fish occur in the Raven River, high dissolved oxygen concentrations and low water temperatures are consistent with known leopard frog hibernacula.

4) In order to achieve a better understanding of aquatic wintering conditions at the Raven Brood Trout Station, ice thickness, water temperatures, dissolved oxygen levels, water flow rate and other water quality measurements should be monitored throughout the winter along sections of Beaver Creek and the Raven River.

C) Management Recommendations

1) Water quality parameters in wetlands within the historic range of the leopard frog should be investigated to better understand the range of water temperatures and dissolved oxygen levels necessary for winter survival. These wetlands should include sites currently occupied by frogs, sites no longer occupied (extirpated) by frogs and sites that could potentially support populations.

2) Key habitat elements that are necessary to the survival and growth of leopard frog populations, including breeding, summering and overwintering habitats should continue to be investigated.

3) Release sites used in 1999 and surrounding areas should be monitored for overwinter survival of captive reared juvenile leopard frogs. Pending the survival of juvenile leopard frogs released in the fall of 1999, initiate a second (2000) captive rearing program and release at the Raven Brood Trout Station.

4) The rearing ponds at the Raven Brood Trout Station should be used as sites for the captive rearing of leopard frog egg masses collected from predetermined source populations.

5) Pending survival success of overwintering juvenile leopard frogs in the east rearing pond, establish a captive-breeding program under controlled conditions at the Raven Brood Trout Station in which adults are overwintered in the same rearing ponds.

6) Captive reared leopard frogs should be translocated to release sites immediately following metamorphosis to avoid shortages in prey and resulting malnutrition upon transformation.

7) Re-establishing leopard frog populations in less controlled environments such as Crimson Lake, Buster Creek, Red Lodge Provincial Park, Chicken Creek or additional sites that are supportive of leopard frog ecological criteria should be considered. Post movement monitoring would be necessary to gauge success of any further translocations, however this could be less intense then the initial release phases.

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10.0 APPENDICES

Appendix A Total distances (m) travelled of translocated leopard frogs along Beaver Creek and the Raven River near Caroline, Alberta.

Distances (m) Travelled of Translocated Leopard Frogs																
Dates	**Frogs - First Release**								**Frogs - Second Release**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**A**	**B**	**C**	**D**	**E**	**F**
28 Sep - 29 Sep	2	4	5	4	2	6	6	2								
29 Sep - 30 Sep	2	0	0	4	1	2	0	8								
30 Sep - 03 Oct	4	0	44	9	3	0	2	30								
03 Oct - 04 Oct	0	0	400†	4	3	0	14	18								
04 Oct - 05 Oct	7	4		5		0	0	4								
05 Oct - 07 Oct	7	16		60		0	5	14								
07 Oct - 09 Oct	60	200†		16		0	6	6								
09 Oct - 12 Oct	0			52		0	26	50								
12 Oct - 14 Oct	0			0		0	46	139								
14 Oct - 17 Oct	1			52		0	36	34								
17 Oct - 18 Oct				6		0	0									
18 Oct - 19 Oct				0		0	6									
19 Oct - 21 Oct				0		-	2									
21 Oct - 26 Oct						18										
26 Oct - 28 Oct						3										
28 Oct - 29 Oct						7										
29 Oct – 01 Nov						22			3	4	30	4	2	4	22	36
01 Nov - 02 Nov						3			0	2	4	12	4	0	13	6
02 Nov - 03 Nov						4			0	1	8	13	4	0	0	2
03 Nov - 07 Nov						2			0	0	10	118	70	9	18	0
07 Nov - 08 Nov						1			0	3	0	10	0	2	22	12
08 Nov - 09 Nov						0			0	6	20	16	0	0	0	0
09 Nov - 13 Nov						14			0	22	0	6	0	0	14	90
13 Nov - 14 Nov						0			9	0	0	0		0	0	
14 Nov - 17 Nov						1			0	0	0	18		0	0	
17 Nov - 18 Nov						0			0	0	0	0		0	0	
18 Nov - 21 Nov						0			0	0	0	0		0	0	
21 Nov - 23 Nov						30			0	0	0	0		0	0	
23 Nov - 26 Nov						4			0	0	0	0		0	0	
26 Nov - 06 Dec						82			0	0	0	89			0	
06 Dec - 08 Dec						2			0		0				0	
08 Dec - 22 Dec						133					0				2	
22 Dec - 18 Jan						0					0				0	
18-Jan - 10 Feb						0					0					
Total Distance	**83**	**224**	**449**	**212**	**9**	**334**	**149**	**305**	**12**	**38**	**72**	**286**	**80**	**15**	**91**	**146**

(†) Distance influenced by unknown predator (frogs depredated).
(note) Frog movement less than 1 meter is not represented

Appendix B Summary of habitat selected and observations of translocated leopard frogs.

DATE	FROG			
	1	2	3	4
28-Sep	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG CREEK BANK	OBSERVED IN WATER ALONG CREEK BANK WITH MUD SUBSTRATE; NO AQUATIC OR TRESTRIAL COVER	OBSERVED IN VEGETATION (SPARSE GRASS) AND DEBRIS AT EDGE OF WATER ON BANK	OBSERVED IN WATER, IN THICK EMERGENT VEGATATION (GRASS) AND DEBRIS ALONG CREEK BANK
29-Sep	LOCATED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG CREEK BANK	LOCATED IN BANK; CAVITIES IN BANK CREATED BY ROOT SYSTEM OF FALLEN TREE	OBSERVED IN BANK, 0.2 M FROM WATERS EDGE (ONLY FROGS NOSE VISIBLE)	LOCATED IN WATER, IN THICK EMERGENT VEGATATION (GRASS) ALONG EDGE OF CREEK
30-Sep	LOCATED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG CREEK BANK	LOCATED IN BANK (SAME LOCATION AS ABOVE); NO AQUATIC VEGETATION IN THIS AREA	LOCATED IN BANK (SAME LOCATION AS 29 SEP)	LOCATED UNDER WATER, UNDER FALLEN ALDER OR IN WATER IN THICK VEGETATION (GRASS)
01-Oct	-	-	-	-
03-Oct	LOCATED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG BEAVER DAM	LOCATED IN BANK (SAME LOCATION AS 29 SEP)	LOCATED IN BANK	LOCATED UNDER OR IN WATER, IN BEAVER DAM
04-Oct	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG BEAVER DAM	LOCATED IN BANK (SAME LOCATION AS 29 SEP)	FOUND DEPREDATED APPROX. 200 M UPLAND OF LAST LOCATION	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG EDGE OF CREEK
05-Oct	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG BEAVER DAM	OBSERVED UNDER WATER, IN UNDER CUT IN BANK; FROG WEDGED AMOUNG SMALL ROOTS		LOCATED UNDERWATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG EDGE OF CREEK
06-Oct	-	-		OBSERVED IN THICK VEGATATION (GRASS) ON FLOODED LAND, 0.5 M FROM WATERS EDGE
07-Oct	LOCATED UNDERWATER, IN UNDER CUT IN CREEK BANK OR ALONG BANK; AQUATIC VEGETATION	OBSERVED ON MUD BANK WITH SPARSE GRASS, TUCKED INTO DEPRESSION ON BANK		OBSERVED IN THICK VEGATATION IN WATER ALONG SHORE OF CREEK; SAME GENERAL LOCATION AS 7 OCT
09-Oct	OBSERVED BASKING ON EDGE OF BEAVER DAM; MINIMAL COVER EXCEPT DEBRIS FROM DAM	FROG TRANSMITTER LOCATED TO AN ANIMAL BURROW APPROXI. 400 M FROM LAST LOCATION		OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG WATERS EDGE
12-Oct	LOCATED IN BEAVER DAM; IN CONTACT WITH OR UNDER WATER?	FROG TRANSMITTER RELOCATED TO A SQUIRREL MIDDEN 20 M FROM ABOVE LOCATION; RETRIEVED		OBSERVED ON MUD BANK WITH SOME DEBRIS AND SPARSE VEGETATION
14-Oct	LOCATED IN BEAVER DAM; IN CONTACT WITH OR UNDER WATER?			OBSERVED IN BANK; SAME GENERAL LOCATION AS 12 OCT (OUT OF WATER)
17-Oct	FROG TRANMITTER SHED; RETRIEVED IN BEAVER DAM, FROG LOST			OBSERVED UNDER WATER, ON AQUATIC VEGATATION, 0.5 M FROM SHORE
18-Oct				OBSERVED BASKING IN WATER, IN THICK EMERGENT VEGETATION (GRASS)
19-Oct				OBSERVED IN THICK GRASS AT WATERS EDGE (SAME LOCATION AS 18 OCT)
21-Oct				FOUND DEAD AT ABOVE LOCATION; NO SIGNS OF EXTERNAL TRUAMA (CAUSE OF DEATH NOT KNOWN)

Appendix B *continue*

DATE	FROG			
	5	6	7	8
28-Sep	OBSERVED IN WATER, IN THICK VEGATATION (GRASS) ALONG CREEK BANK	OBSERVED PERCHED ON EMERGENT LOG IN CENTER OF CREEK; NO COVER	OBSERVED IN WATER, IN THIN VEGETATION ALONG CREEK BANK	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS) ALONG CREEK BANK
29-Sep	LOCATED IN WATER, IN THICK EMERGENT VEGETATION ALONG CREEK BANK	LOCATED UNDER LOG JUST DOWN STREAM OF LAST OBSERVED LOCATION 28 SEP	LOCATED IN BANK OR UNDER LOG AT EDGE OF CREEK	OBSERVED ON CREEK BANK WITH THIN VEGATATION (GRASS)
30-Sep	LOCATED IN WATER, IN UNDER CUT IN BANK, UNDER BUSH OVER HANGING WATER	LOCATED UNDERWATER, UNDER LOG; CREEK BOTTOM SILT/MUD VOID OF AQUATIC VEGETATION	LOCATED IN BANK OR UNDER LOG AT EDGE OF CREEK	LOCATED ON BANK WITH THICK VEGATATION
01-Oct	-	-	-	OBSERVED UNDERWATER, IN AQUATIC VEGATATION
03-Oct	LOCATED IN WATER, IN UNDER CUT IN BANK OR EDGE OF CREEK IN THICK VEGETATION (GRASS)	LOCATED UNDERWATER AND SAME LOG AS 29 SEP	LOCATED UNDERWATER IN MIDDLE OF CREEK, UNDER LOGS IN WATER; BOTTOM VOID OF VEGETATION	LOCATED IN BANK, NEAR BEAVER DAM (OUT OF WATER)
04-Oct	TRANSMITTER SHED; FOUND UPLAND 2 M FROM LAST LOCATION	LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED UNDER OVER HANG IN CREEK BANK (OUT OF WATER)	OBSERVED IN BANK, NEAR BEAVER DAM (OUT OF WATER)
05-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED UNDER OVER HANG IN CREEK BANK (OUT OF WATER) (SAME LOCATION AS 4 OCT)	LOCATED IN BANK, NEAR BEAVER DAM (OUT OF WATER)
06-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	-	-
07-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED ON SPARSE GRASS ON CREEK BANK, DOVE INTO WATER	OBSERVED IN THICK VEGATATION (GRASS) ON SMALL ISLAND, IN CENTER OF CREEK
09-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED TUCKED UNDER DEBRIS ON CREEK BANK	OBSERVED IN THICK VEGATATION (GRASS) AT EDGE OF WATER
12-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED IN SPARSE GRASS ON CREEK BANK, AT WATERS EDGE	LOCATED UNDER BANK, IN WATER
14-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	OBSERVED IN THICK VEGETATION (GRASS) ON BANK	OBSERVED ON MUD SHORE, IN WATER
17-Oct		-	LOCATED IN CREEK BANK (IN CONTACT WITH WATER?)	FROG FOUND DEAD UNDER BANK (DEPREDATED)
18-Oct		-	OBSERVED IN LARGE HOLLOW IN CREEK BANK	
19-Oct		LOCATED UNDERWATER AND SAME LOG AS 29 SEP	LOCATED IN CREEK BANK	
21-Oct		-	FROG FOUND DEAD ON BANK, NEAR LAST LOCATION (CAUSE OF DEATH NOT KNOWN)	
26-Oct		OBSERVED UNDERWATER, UNDER STICKS ON CREEK BOTTOM; VOID OF AQUATIC VEGETATION		
28-Oct		LOCATED IN BANK; NOT KNOWN IF IN CONTACT OR UNDERWATER		
29-Oct		LOCATED TO AN AREA UNDERWATER, UNDER DEBRIS PILE OF LOGS AND TREE ROOTS		
01-Nov		LOCATED UNDERWATER, UNDER SAME DEBRIS PILE AS 29 OCT		
02-Nov		LOCATED UNDERWATER, UNDER SAME DEBRIS PILE AS 29 OCT		

Appendix B *continue*

DATE	FROG			
	5	6	7	8
03-Nov		OBSERVED UNDERWATER, UNDER SAME DEBRIS PILE AS 29 OCT		
07-Nov		LOCATED UNDERWATER, IN UNDER CUT IN BANK		
08-Nov		LOCATED UNDERWATER IN UNDER CUT IN BANK (SAME LOCATION AS 7 NOV)		
09-Nov		LOCATED UNDERWATER IN UNDER CUT IN BANK (SAME LOCATION AS 7 NOV)		
13-Nov		LOCATED IN BANK, IN CONTACT WITH WATER		
14-Nov		LOCATED IN BANK, IN CONTACT WITH WATER (SAME LOCATION AS 13 NOV)		
17-Nov		LOCATED IN BANK, IN CONTACT WITH WATER (SAME LOCATION AS 13 NOV)		
23-Nov		OBSERVED BETWEEN LOGS UNDERWATER; BOTTOM OF CREEK VOID OF AQUATIC VEGETATION		
26-Nov		LOCATED IN BANK OF CREEK; NOT KNOWN IF IN CONTACT WITH WATER		
06-Dec		LOCATED UNDERWATER, IN UNDER CUT IN BANK		
08-Dec		OBSERVED UNDERWATER, IN UNDER CUT IN BANK		
22-Dec		OBSERVED ON MUD/SILT BOTTOM OF RAVEN RIVER; VOID OF AQUAIC VEGETATION		
18-Jan		LOCATED TO SAME AREA AS 22 DEC (IN RAVEN RIVER)		
10-Feb		LOCATED TO SAME AREA AS 18 JAN (IN RAVEN RIVER)		

DATE	FROG			
	9	10	A	B
29-Oct	OBSERVED IN WATER, IN THICK VEGETATION (GRASS) ALONG CREEK BANK	OBSERVED IN WATER, IN THICK VEGETATION (GRASS) ALONG CREEK BANK	OBSERVED IN WATER, ON EDGE OF CREEK IN THICK VEGETATION (GRASS)	OBSERVED IN WATER, ON EDGE OF CREEK IN THICK VEGETATION (GRASS)
01-Nov	LOCATED UNDERWATER, UNDER A WILLOW OVER HANGING WATER, AT THE EDGE OF CREEK	LOCATED IN THICK VEGETATION (GRASS) UNDERWATER ALONG CREEK BANK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE, CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION
02-Nov	LOCATED UNDER WATER, UNDER A WILLOW AT THE EDGE OFCREEK (SAME LOCATION AS 1 NOV)	LOCATED IN THICK VEGETATION (GRASS) UNDERWATER ALONG CREEK BANK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED IN THICK GRASS IN OR UNDERWATER BY BEAVER DAM
03-Nov	LOCATED UNDER WATER, UNDER A WILLOW AT THE EDGE OFCREEK (SAME LOCATION AS 1 NOV)	LOCATED UNDERWATER, UNDER DEBRIS, ALONG CREEK BANK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED IN WATER, IN THICK VEGETATION (GRASS) ALONG EDGE OF CREEK
07-Nov	LOCATED UNDER WATER, UNDER A WILLOW AT THE EDGE OFCREEK (SAME LOCATION AS 1 NOV)	LOCATED UNDERWATER, UNDER DEBRIS, ALONG CREEK BANK	OBSERVED AT BASE OF BEAVER DAM IN WATER; OPEN WATER IN THIS AREA	LOCATED UNDERWATER, IN THICK GRASS ALONG CREEK BANK
08-Nov	LOCATED UNDER WATER, UNDER A WILLOW AT THE EDGE OFCREEK (SAME LOCATION AS 1 NOV)	LOCATED UNDERWATER, UNDER DEBRIS, ALONG CREEK BANK	OBSERVED AT BASE OF BEAVER DAM IN WATER; OPEN WATER IN THIS AREA	OBSERVED UNDERWATER AND UNDER ICE, IN THICK GRASS ALONG CREEK BANK

Appendix B *continue*

DATE	FROG			
	9	10	A	B
09-Nov	LOCATED UNDER WATER, UNDER A WILLOW AT THE EDGE OFCREEK (SAME LOCATION AS 1 NOV)	LOCATED IN THICK VEGETATION (GRASS) UNDERWATER ALONG CREEK BANK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	OBSERVED ON SHORE AT BASE OF BEAVER DAM; MINIMAL COVER, MUD AND DEBRIS SUBSTRATE
13-Nov	OBSERVED IN WATER, IN THICK VEGETATION (GRASS) ALONG EDGE OF CREEK	LOCATED IN DEBRIS, UNDERWATER, CENTER OF CREEK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN UNDER CUT IN BANK; THICK GRASS ALONG BANK
14-Nov	LOCATED UNDERWATER, EDGE OF CREEK, IN THICK GRASS	LOCATED ALONG SHORE, UNDERWATER AND ICE; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN UNDER CUT IN BANK; THICK GRASS ALONG BANK
17-Nov	OBSERVED UNDERWATER, IN THICK VEGETATION (GRASS) ALONG CREEK BANK	LOCATED UNDERWATER AND ICE, CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN DEBRIS ALONG EDGE OF CREEK; THICK GRASS ALONG BANK
21-Nov	LOCATED UNDERWATER, IN THICK VEGETATION ALONG CREEK BANK (SAME LOCATION AS 17 NOV)	LOCATED UNDERWATER AND ICE, CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN DEBRIS ALONG EDGE OF CREEK; THICK GRASS ALONG BANK
23-Nov	LOCATED UNDERWATER, IN THICK VEGETATION ALONG CREEK BANK (SAME LOCATION AS 17 NOV)	LOCATED UNDERWATER AND ICE, CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN DEBRIS ALONG EDGE OF CREEK; THICK GRASS ALONG BANK
26-Nov	LOCATED UNDERWATER, IN THICK VEGETATION ALONG CREEK BANK (SAME LOCATION AS 17 NOV)	LOCATED UNDERWATER AND ICE, CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK (SAME GENERAL LOCATION AS 9 NOV)	LOCATED UNDERWATER, IN DEBRIS ALONG EDGE OF CREEK; THICK GRASS ALONG BANK
06-Dec	FROG FOUND DEAD IN LAST LOCATION (DEPREDATED)	FROG FOUND DEAD IN THICK AQUATIC VEGETATION ON BOTTOM OF CREEK (CAUSE NOT KNOWN)	FROG OBSERVED HIBERNATING ON BOTTOM OF CREEK ON MUD WITH AQUATIC VEGETATION	TRANSMITTER FOUND ON BOTTOM OF CREEK, SLIGHTLY UNDER OVER HANG IN BANK
08-Dec			FROG OBSERVED HIBERNATING ON BOTTOM OF CREEK ON MUD WITH AQUATIC VEGETATION	
22-Dec			FROG OBSERVED HIBERNATING ON BOTTOM OF CREEK ON MUD WITH AQUATIC VEGETATION	
18-Jan			LOCATED TO SAME GENERAL AREA AS 22 DEC	
10-Feb			LOCATED TO SAME GENERAL AREA AS 18-JAN	

DATE	FROG			
	C	D	E	F
29-Oct	OBSERVED AT THE EDGE OF CREEK, IN WATER, IN THICK GRASS; BASE OF BEAVER DAM	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS)	OBSERVED IN WATER, IN THICK EMERGENT VEGETATION (GRASS)	OBSERVED AT EDGE OF CREEK, IN THICK GRASS AT BASE OF BEAVER DAM
01-Nov	OBSERVED UNDERWATER, IN BANK AT BASE OF BEAVER DAM	LOCATED UNDERWATER AND ICE, IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER AND ICE, IN THICK GRASS, NEAR SHORE	LOCATED UNDERWATER AND ICE, UNDER WILLOW ALONG CREEK BANK
02-Nov	LOCATED UNDERWATER, ALONG EDGE OF CREEK; ABUNDANT GRASS ALONG SHORE	LOCATED UNDERWATER AND ICE, IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	LOCATED UNDERWATER (SHALLOW) AND ICE NEXT TO BANK OF CREEK	LOCATED UNDERWATER AND ICE, ALONG EDGE OF CREEK
03-Nov	LOCATED IN THICK GRASS UNDERWATER AND ICE, ALONG CREEK BANK	LOCATED UNDERWATER AND ICE, IN CENTER OF CREEK; ABUNDANT AQUATIC VEGETATION	OBSERVED UNDERWATER (SHALLOW) AND ICE NEXT TO BANK OF CREEK	LOCATED UNDERWATER AND ICE IN CENTER OF CREEK
07-Nov	LOCATED UNDERWATER AND ICE IN THICK GRASS (TRANSMITTER MALFUCTIONING)	LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED IN DEBRIS, UNDERWATER AND ICE, CENTER OF CREEK	LOCATED IN BEAVER DAM, NOT KNOWN IF IN CONTACT WITH WATER
08-Nov	LOCATED UNDERWATER AND ICE IN THICK GRASS; SAME LOCATION AS 7 NOV (TRANSMITTER MALFUCTION)	LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED IN THICK GRASS UNDERWATER AND ICE AT EDGE OF CREEK	LOCATED IN BEAVER DAM, NOT KNOWN IF IN CONTACT WITH WATER

Appendix B *continue*

DATE	FROG			
	C	D	E	F
09-Nov	LOCATED UNDERWATER AND ICE IN THICK GRASS; SAME LOCATION AS 7 NOV (TRANSMITTER MALFUCTION)	LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED IN THICK GRASS UNDERWATER AND ICE AT EDGE OF CREEK	LOCATED IN BEAVER DAM, NOT KNOWN IF IN CONTACT WITH WATER
13-Nov	TRANSMITTER MALFUCTIONED; BATTERY PRESUMED DEAD, FROG LOST	LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED AT EDGE OF CREEK, UNDERWATER AND ICE	FROG FOUND FROZEN ON UPLAND NEAR CREEK (APPROX 8 M FROM FROZEN CREEK EDGE)
14-Nov		LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED AT EDGE OF CREEK, UNDERWATER AND ICE	
17-Nov		LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED AT EDGE OF CREEK, UNDERWATER AND ICE	
21-Nov		LOCATED UNDERWATER AND ICE ALONG EDGE OF CREEK; MUD/SILT BOTTOM WITH SPARSE EMERGENTS	LOCATED AT EDGE OF CREEK, UNDERWATER AND ICE	
23-Nov		FROG FOUND FROZEN IN ICE ALONG EDGE OF CREEK; IN SAME GENERAL LOCATION AS NOV 7	LOCATED AT EDGE OF CREEK, UNDERWATER AND ICE	
06-Dec			FROG OBSERVED HIBERNATING ON MUD/SILT BOTTOM OF CREEK	
08-Dec			FROG OBSERVED HIBERNATING ON MUD/SILT BOTTOM OF CREEK	
22-Dec			FROG OBSERVED HIBERNATING ON MUD/SILT BOTTOM OF CREEK	
18-Jan			FROG FOUND DEAD IN SAME LOCATION AS 22 DEC (CAUSE OF DEATH UNKNOWN)	

Appendix C Percent habitat utilization of translocated leopard frogs.

Percent Habitat Utilization of Translocated Leopard Frogs									
Habitat Selected†		Percent Habitat Utilization††							
		Frog							
		1 n=10	2 n=7	3 n=4	4 n=14	5 n=4	6 n=30	7 n=14	8 n=11
Out of Water	Dense Vegetative Cover							7.7	9.1
	Sparse Vegetative Cover		14.3	25.0	7.1			15.4	9.1
	No Cover	10.0			7.1				
	In/Under Creek Bank			75.0				23.1	27.3
	In Beaver Dam								
	Under Object							7.7	
	Total % Out of Water	**10.0**	**14.3**	**100.0**	**14.2**			**53.9**	**45.5**
In Water	Dense Vegetative Cover	60.0			57.1	50.0		7.7	27.3
	Sparse Vegetative Cover								
	No Cover		14.3				3.3		9.1
	In/Under Creek Bank						16.7		9.1
	In Beaver Dam								
	Under Object								
	Total % in Water	**60.0**	**14.3**		**57.1**	**50.0**	**20.0**	**7.7**	**45.5**
Underwater	Dense Vegetative Cover				7.1				9.1
	Sparse Vegetative Cover								
	No Cover						6.7		
	In/Under Creek Bank	10.0	14.3		7.1		10.0		
	In Beaver Dam								
	Under Object				7.1		56.7	7.7	
	Total % Underwater	**10.0**	**14.3**		**21.3**		**73.4**	**7.7**	**9.1**
Unknown*	Dense Vegetative Cover								
	Sparse Vegetative Cover								
	No Cover								
	In/Under Creek Bank		57.1			50.0	6.7	23.1	
	In Beaver Dam				7.1				
	Under Object	20.0						7.7	
	Total % Unknown	**20.0**	**57.1**		**7.1**	**50.0**	**6.7**	**30.8**	

(*) Position of frog with respects to water, not known; i.e. out of water, in water or underwater.
(†) Habitat selected during tracking based on frog observation or telemetric position.
(††) Percent of habitat utilized by each individual frog during tracking, where n= the number of times each frog was tracked to a location not influenced by a predator.

Appendix C *continue*

Percent Habitat Utilization of Translocated Leopard Frogs									
Habitat Selected†		Percent Habitat Utilization††							
		Frog							
		9 n=14	10 n=14	A n=18	B n=14	C n=8	D n=12	E n=16	F n=8
Out of Water	Dense Vegetative Cover								12.5
	Sparse Vegetative Cover								
	No Cover				7.1				
	In/Under Creek Bank								
	In Beaver Dam								
	Under Object								
	Total % Out of Water				**7.1**				**12.5**
In Water	Dense Vegetative Cover	14.3	7.1	5.6	21.4	12.5	8.3	6.3	12.5
	Sparse Vegetative Cover								
	No Cover			11.1					
	In/Under Creek Bank								
	In Beaver Dam								
	Under Object								
	Total % in Water	**14.3**	**7.1**	**16.7**	**21.4**	**12.5**	**8.3**	**6.3**	**12.5**
Underwater	Dense Vegetative Cover	42.9	64.3	83.3	21.4	62.5	25.0	18.8	12.5
	Sparse Vegetative Cover						66.7		12.5
	No Cover							68.8	12.5
	In/Under Creek Bank				21.4				
	In Beaver Dam								
	Under Object	42.9	28.6		28.6	25.0		6.3	12.5
	Total % Underwater	**85.7**	**92.9**	**83.3**	**71.4**	**87.5**	**91.7**	**93.9**	**50.0**
Unknown*	Dense Vegetative Cover								
	Sparse Vegetative Cover								
	No Cover								
	In/Under Creek Bank								
	In Beaver Dam								37.5
	Under Object								
	Total % Unknown								**37.5**

(*) Position of frog with respects to water, not known; i.e. out of water, in water or underwater.
(†) Habitat selected during tracking based on frog observation or telemetric position.
(††) Percent of habitat utilized by each individual frog during tracking, where n= the number of times each frog was tracked to a location not influenced by a predator.

Appendix D Water temperatures at each frog location measured over the tracking period.

Water Temperature (°C) at Each Frog Location								
Date	**Frog**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
28-Sep	6.3	6.3	6.3	5.8	5.8	6.3	6.3	6.3
30-Sep	4.6	4.1	4.6	4.2	4.2	4.1	4.6	4.6
03-Oct	6.2	5.1	5.7	4.6	4.6	5.1	5.7	6.2
04-Oct	6.5	5		4.5	4.5	5.9	6.4	6.5
05-Oct	5.1	3.8		2.8		5.2	5.4	5.3
07-Oct	5.3	5.6		5.8		5.5	5.5	5.4
09-Oct	6.2			5.7		6.1	6.3	6.3
12-Oct	5.2			5.2		5.2	5.3	5.4
14-Oct	4.8			5.3		4.7	5	3.1
17-Oct				5.5		-	5.7	
18-Oct				6.3		3.9	5.7	
19-Oct				5.9		-	5.8	
26-Oct						4.7		
28-Oct						3.9		

Date	**Frog**								
	9	**10**	**A**	**B**	**C**	**D**	**E**	**F**	**6**
29-Oct	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.1
01-Nov	0.7	0.6	1	0.5	0.6	0.5	0.8	0.7	4
02-Nov	0.5	0.6	0.7	0.6	0.6	0.6	0.5	0.7	4
03-Nov	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.7	4.3
07-Nov	0.5	0.5	0.7	0.4	0.4	0.7	1	0.4	4.4
08-Nov	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.3	3.8
14-Nov	0.3	0.3	0.3	0.3		0.2	0.3		3.6
17-Nov	0.4	0.4	0.3	0.4		0.2	0.4		3.4
23-Nov	0.1	0.1	0.1	0.1		0.1	0.1		3.3
26-Nov	0.1	0.1	0.2	0.1			0.1		3.4
06-Dec	0.1	0.1	0.1	0.1			0.1		3
08-Dec			-				-		3
22-Dec			0.1				0.1		2.5
18 Jan			0.2				0.1		1.3
10-Feb			-						1.4

Appendix E Dissolved oxygen levels at each frog location measured over the tracking period.

Dissolved Oxygen (mg/l) at Each Frog Location									
Date	**Frog**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
28-Sep	14.31	10.01	14.02	8.77	8.77	10.01	14.02	14.31	
30-Sep	11.99	11.5	12.61	10.41	10.41	11.5	12.61	11.99	
03-Oct	115.2%	92.4%	90.4%	98.5%	98.5%	92.4%	90.4%	115.2%	
04-Oct	14.31	9.24		11.71	11.71	11.91	12.98	14.31	
05-Oct	13.91	10.73		11.83		11.76	105.7%	15.15	
07-Oct	13.27	11.32		9.11		13.06	12.85	12.7	
09-Oct	13.75			10.14		13.18	13.3	14	
12-Oct	14.75			8.52		13.32	13.32	13.84	
14-Oct	13.56			8.95		13.05	13.82	11.75	
17-Oct				11.95		-	13.39		
18-Oct				11.77		10.65	13.39		
19-Oct				9.6		-	13.57		
26-Oct						10.65			
28-Oct						12.04			

Date	**Frog**								
	9	**10**	**A**	**B**	**C**	**D**	**E**	**F**	**6**
29-Oct	-	-	-	-	-	-	-	-	12.18
01-Nov	11.52	13.16	11.14	12.07	13.16	12.07	12.75	12.19	12.52
02-Nov	11.85	11.62	10.9	11.99	11.94	11.38	11.86	10.48	11.64
03-Nov	11.15	11.25	11.07	12.37	11.98	11.07	11.77	11.69	12
07-Nov	12.02	10.98	11.1	12.02	11.07	9.62	11.71	11.77	11.22
08-Nov	11.84	11.4	11.56	12.57	11.14	10.09	11.79	11.63	10.95
14-Nov	12.21	11.87	10.45	11.9		11.03	11.6		12.4
17-Nov	12.06	8.42	9.91	12.16		5.29	8.2		11.14
23-Nov	10.58	8.54	8.88	10.8			7.46		11.21
26-Nov	10.54	7.94	8.75	9.5			8.78		10.57
06-Dec	7.81	6.87	5.99	7.75			47.3		10.59
08-Dec			-				-		10.89
22-Dec			4.04				3.41		10.72
18-Jan			1.10				1.00		9.73
10-Feb			-						10.69

Appendix F Water temperatures recorded at specific water monitoring stations in the area surrounding the Raven Brood Trout Station near Caroline, Alberta.

Water Temperature (°C)												
Station	Date											
	14-Sep	20-Sep	27-Sep	4-Oct	13-Oct	18-Oct	26-Oct	8-Nov	9-Nov	18-Jan	10-Feb	02-Mar
1	11.8	9.0	6.5	2.1	3.1	3.3	3.0		0.4			NA
2	9.3	9.0	6.7	2.7	3.2	3.2	2.7		0.4	0.2		NA
3	16.2	13.4	7.6	4.2	5.4	4.2	4.5					
4	11.0	9.1	6.1	5.7	6.4	6.0	4.1					NA
5	7.9	7.3	6.0	4.2	4.4	4.7	2.7					NA
6	8.0	8.2	5.9	4.4	4.7	5.2	4.6	3.8				4.8
7	7.9	6.7	5.5	4.4	5.4	5.2	4.8	4.1				4.8
8	9.1	8.7	6.3	4.9	5.9	5.7	4.9	4.1				5.4
9	10.5	10.0	6.3	3.1	4.7	3.9	3.0	0.3				1.2
10		5.3	4.9	5.0	4.8	4.9	5.0		4.6			
11		10.6	5.8	2.4	3.2	3.3	2.8	0.2				NA
12		6.7	5.3	5.4	4.8	5.1	4.4					
13		11.2	6.8	2.8	4.9	4.4	3.0	0.1				NA
14	9.3	9.0	6.3	5.0	6.2	5.7	4.8	4.1				5.4
15	11.5	11.5	6.5	2.6	4.8	4.1	3.0	0.1				NA
16		9.2	5.2	2.1	3.4	3.5	2.2	0.1				0.1
17		9.3	5.8	4.5	5.8	5.4	4.5	2.8		1.3	1.4	2.5
18		7.9	5.9	4.7	4.3	4.9	4.7					
19 a				5.1	7.6	5.7	5.1		4.5	4.1	4.4	4.7
19 b				5.2	10.2	10.1	5.1		4.0	2.6	3.7	4.1
20 a				4.9	9.0	9.0	5.0		4.3	4.2	4.5	4.8
20 b				6.8	6.6	5.4	5.3		4.0	3.9	4.0	4.1

NA – Not available due to waterbody frozen to bottom.

Appendix G Dissolved oxygen concentrations recorded in waterbodies surrounding the Raven Brood Trout Station near Caroline, Alberta.

Dissolved Oxygen (mg/l & %)						
Station	Date					
	14-Sep		20-Sep		27-Sep	
	mg/l	%	mg/l	%	mg/l	%
1	8.2	76.2	5.77	50.4	8.61	69.5
2	6.8	60.0	6.21	54.1	8.1	66.5
3	8.43	87.4	4.45	42.7	2.53	20.3
4	1.82	16.3	0.12	1.0	0.72	6.0
5	4.43	37.2	2.84	23.0	3.23	25.2
6	10.34	79.9	8.29	70.4	12.64	100.7
7	0.43	3.7	10.77	88.2	11.68	92.7
8	13.77	119.4	13.48	115.5	14.31	116
9	8.87	79.2	8.88	78.2	10.01	81
10			9.35	74.0	10.68	83.6
11			9.43	84.7	8.77	70.0
12			6.86	55.8	8.43	66.4
13			8.01	72.9	8.75	72.0
14	11.41		12.7	109.9	14.02	113.6
15	7.85	72.5	8.3	75.7		
16			9.8	85.1	11.96	92.5
17			11.98	103.2	12.28	98.0
18			2.5	21.0	5.68	45.1
19 a						
19 b						
20 a						
20 b						
	4-Oct		13-Oct		18-Oct	
	mg/l	%	mg/l	%	mg/l	%
1	11.22	81.3	8.09	60.2	10.67	80.2
2	9.47	69.0	8.42	63.2	10.8	80.7
3	12.15	91.0	3.12	24.7	11.72	89.9
4	0.7	8.4	0.9	7.3	1.3	10.5
5	2.37	18.1	2.57	19.8	2.74	21.2
6	9.14	70.8	9.57	74.2	10.6	83.5
7	10.58	82.4	11.33	89.8	11.77	92.6
8	14.04	109.9	14.38	115.3	14.72	117.5
9	11.21	83.9	10.65	82.7	10.65	81.4
10	9.94	78.2	9.57	74.8	9.78	76.4
11	10.75	79.4	10.93	81.7	10.69	79.6
12	7.21	56.6	5.44	42.3	8.48	66.5
13	10.07	74.1	10.57	82.8	10.02	77.4
14	13.48	105.3	14.23	115.3	13.6	108.5
15	10.81	79.6	10.35	80.8	10.31	79.0
16	12.51	91.0	12.55	95.0	12.18	90.8
17	12.5	97.0	12.88	102.9	12.6	99.1

Dissolved Oxygen (mg/l & %)						
Station	Date					
	4-Oct		13-Oct		18-Oct	
	mg/l	%	mg/l	%	mg/l	%
18	4.18	32.5	5.08	38.8	5.18	40.6
19 a	5.28	41.3	9.76	82.6	8.23	65.0
19 b	6.38	50.1	10.92	97.8	13.56	119.5
20 a	5.08	40.0	7.62	62.5	6.64	52.6
20 b	9.5	78.8	11.01	95.4	12.93	112.5
	26-Oct		8-Nov		9-Nov	
	mg/l	%	mg/l	%	mg/l	%
1	10.89	81.5			10.39	72.0
2	11.1	81.7			11.56	79.9
3	12.28	95.5				
4	3.13	23.9				
5	4.63	34.0				
6	11.07	85.7	9.28	70.6		
7	11.6	90.6	9.97	76.4		
8	13.85	108.0	10.77	82.4		
9	11.1	83.4	9	62.1		
10	10.51	79.4			9.48	73.6
11	12.3	90.9	11.64	80.1		
12	8.6	66.5				
13	10.06	74.8	9.84	67.6		
14	13.1	102.2	10.88	83.4		
15	10.56	78.7	9.84	67.4		
16	12.69	92.8	12.61	86.4		
17	12.46	96.4	11.26	83.3		
18	5.31	41.6				
19 a	6.82	53.6			6.9	53.3
19 b	7.03	55.2			6.1	46.5
20 a	7.78	57.1			7.52	57.7
20 b	7.26	57.3			6.86	52.4
	18-Jan		10-Feb		02-Mar	
	mg/l	%	mg/l	%	Mg/l	%
1					Frozen to bottom	
2	1.10	7.5			Frozen to bottom	
3						
4					Frozen to bottom	
5					Frozen to bottom	
6					9.51	74.2
7					10.23	80.1
8					11.61	91.9
9					5.91	41.5
10						
11						
12						
13					Frozen to bottom	

Appendix G *continue*

	18-Jan		10-Feb		02-Mar	
	mg/l	%	mg/l	%	Mg/l	%
14					11.27	89.2
15					Frozen to bottom	
16					11.55	79.1
17	9.73	69.2	10.69	76.1	11.11	80.8
18						
19 a	7.13	54.6	7.67	58.3	6.29	49.0
19 b	6.34	46.8	7.08	54.7	6.20	47.5
20 a	6.93	53.4	6.95	53.6	6.94	54.4
20 b	6.11	46.5	6.90	52.7	5.84	44.7

Appendix H Water depth and moisture level data recorded at the eight oxbows located north of the Raven River (See Appendix I for the location of each oxbow).

06 October 1999

Oxbow	Water Depth (cm)	Percent (%) of Total Area			Vegetation
		Wet	Moist	Dry	
1	10	80	20	0	Grasses and sedges
2	0	0	70	30	Grasses and sedges
3	0	0	60	40	Grasses and sedges
4	4	15	70	15	Grasses, sedges and willows
5	0	0	30	70	Grasses and sedges
6	0	0	0	100	Grasses and sedges
7	0	0	0	100	Grasses and sedges
8	0	0	30	70	Grasses and sedges

18 May 2000

Oxbow	Water Depth (cm)	Percent (%) of Total Area			Vegetation
		Wet	Moist	Dry	
1*	2**	20	40	40	Grasses and sedges
2*	16-24	80	10	10	Grasses and sedges
3*	< 25	85	15	0	Grasses and sedges
4*	50	95	5	0	Grasses, sedges and willows
5	35	95	5	0	Grasses and sedges
6	0	0	100	0	Grasses and sedges
7	40	100	0	0	Grasses and sedges
8*	70	100	0	0	Grasses and sedges

(*) Breeding evidence i.e. egg masses observed or calling adult wood and/or chorus frogs heard.
(**) Oxbow 1 had > 30cm water depth on 12 May 2000 and approximately 40 egg masses were observed.

Appendix I Aerial photograph of oxbows located north of the Raven River (NW 6-36-5 W5M) and translocated leopard frog release sites.