Recommendations for an Amphibian Monitoring Pilot Study in the Lower Athabasca Region of Alberta

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Report to the Ecological Monitoring Committee for the Lower Athabasca, Alberta

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Executive Summary

The Ecological Monitoring Committee for the Lower Athabasca (EMCLA) has decided that a pilot study is needed to determine if regional, long-term monitoring of the distribution and abundance of amphibians in the Lower Athabasca Planning Region (LAPR) of north-eastern Alberta can be done efficiently and effectively. Five amphibians inhabit this region; three of these species are listed at provincial and/or federal levels. Many amphibian populations are declining around the globe, and declines in a number of species have been documented in Alberta. Because amphibian species are considered sensitive indicators of environmental quality, play important roles in the ecosystems of northern Alberta, and may be impacted by anthropogenic disturbance, monitoring and tracking trends in abundance and distribution of these species on a regional scale in the LAPR is important to inform management. Therefore, the purpose of this report is to provide recommendations for development of an amphibian monitoring pilot study in the LAPR for 2012.

To inform development of an amphibian monitoring pilot program, existing data on amphibian abundance and distribution in Alberta were compiled into a single database. Data were obtained from 36 sources, representing 11,778 sampling points, some with many observations; 2,263 points were from within the LAPR. Analysis of these data indicated optimal seasonal and diurnal timing to detect wood frogs, boreal chorus frogs, Canadian toads, and western toads using passive call surveys, and suggested that all species could be detected using evening call surveys, with the two frog species calling in the early spring, and the toads calling in the late spring/early summer. The probability of observation and occupancy, and the detection rates for these species were also calculated. The probability of observation and occupancy

were relatively high for the two frog species, and low for the two toad species. Detection rates were high for the boreal chorus frog, and moderate for the other three species. Note that northern leopard frogs were not included in these analyses as they are restricted to the extreme northeast of the LAPR and therefore are not useful in a regional monitoring program.

A maximum entropy (MaxEnt) model was constructed to illustrate the relative occurrence of the different amphibian species throughout Alberta, including the LAPR. Wood frogs and chorus frogs were found in most of the province and throughout the LAPR. Western toads were found in the western part of the province, but appear to be expanding east into the lower portion of the LAPR. The Canadian toad was distributed in the eastern half of the province, and had a strong presence in parts of the LAPR, though there are indications this species has been declining in the recent past.

Based on preliminary analyses of existing data and monitoring design considerations we developed the following recommendations for the 2012 amphibian monitoring pilot study:

1. Identify habitat and anthropogenic features that influence amphibian distribution and abundance.
2. Use automated bio-acoustic recording devices to determine the seasonal and diurnal call phenology for amphibian species.
3. Adopt existing standardized protocols for passive call surveys, with some modifications related to timing of surveys.
4. Evaluate use of visual encounter surveys for young-of-the-year at a subset of sites to determine recruitment at breeding sites.

5. Continue to acquire spatial habitat data to support development of spatial amphibian distribution and abundance models.
6. Collaborate with the yellow rail monitoring program in data collection; this will include using the same sampling sites, when possible, for both automated recorders and passive call surveys.
7. Evaluate whether it is feasible to use the ABMI's systematic grid for sampling amphibian populations, either by using current ABMI sampling points, or using ABMI grid data (e.g. location of wetlands of various types near ABMI sampling points) to identify potential sampling sites.

Glossary of Terms

Abundance – Number of individuals of a species observed using either passive or playback sampling. Data has a range from 0 to infinity and should be viewed as a count per unit time and space. Points where species were not observed are recorded.

Detection rate – The proportion of observations of a species that occur at the same point when revisited multiple times within the same year. For example, if an observer went to the same point four times in the same year and found the species at the point twice the detection rate would be 0.5.

FWMIS – Fisheries and Wildlife Management Information System hosted by Alberta Sustainable Resource Development. http://www.srd.alberta.ca/FishWildlife/FWMIS/

Incidental observations – Incidental observations are from FWMIS and/or occurred before or after a survey that estimated abundance. Incidental observations are equivalent to **presence**. Incidental observations are used to create resource selection function and MaxEnt models.

MaxEnt – MaxEnt stands for maximum-entropy and refers to a species distribution model developed for use with presence-only data.

N-mixture models – Form of modelling for count data collected using repeated visits to the same location within the same season. Allows estimation of detection rate and corrects observed counts which are best viewed as relative measures of abundance into actual abundance. If actual abundance is measured in a known area, the actual abundance measure can be converted to density.

Occupancy models - Form of modelling for detected/ not detected data collected using repeated visits to the same location within the same season. Allows estimation of detection rate and corrects probability of observation into absolute occupancy probability if certain assumptions are met.

Passive call surveys – Surveys in which humans (as opposed to automated recorders) listen at a specific site (e.g. a wetland), usually for a specified amount of time, to detect calling amphibian species.

Passive sampling – Surveys where species were and were not observed based on observers listening for acoustic cues.

Point – A spatial location where a survey was done. Incidental observations are NOT described as points.

Presence – Locations where a species was observed but no sampling protocol was recorded. This type of data does not record the locations where observers may have searched and did not find a species. No zeros exist for such data. Whether species were detected using playback or passive listening is typically not known.

Probability of observation (point) = (# points where species observed/ # points visited). A point is a single location where a restricted time and space search was conducted by an observer that could have detected a species. Most points have a single survey but some have 2 to 12 surveys per point within a year.

Probability of observation (survey) = (# surveys where species observed/ # surveys conducted). A survey is a sample where a species was or was not observed at a point but that point might be sampled multiple times.

Probability of occupancy (point) – Probability a species was present at a point after being corrected for observation error caused by having a detection rate < 1. Conceptually, sites where species were never detected have a probability of the species being there and it was simply missed because the detection rate was low.

Survey – A timed period of observations where species were recorded over some distance using either playback or passive sampling. Incidental observations are not surveys.

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Introduction

Amphibians play key ecological roles as predators and prey, represent significant biomass in some ecosystems, and transfer energy between aquatic and terrestrial habitats (Burton and Likens 1975a,b; Gibbons et al. 2006; Regester and Whiles 2006; Regester et al. 2006; Whiles et al. 2006). These animals are considered sensitive indicators of environmental quality (Wake 1991; Blaustein et al. 1994; but see Kerby et al. 2010), and are currently threatened by many anthropogenic activities (Collins and Storfer 2003). Recent declines in amphibian populations at local, regional, and global scales (Blaustein et al. 1994; Houlahan et al. 2000; Corser 2001; Carrier and Beebee 2003) have led to increased monitoring and conservation efforts related to this taxon (Corn et al. 2005; de Solla et al. 2005).

Because of the sensitivity of amphibians to a variety of environmental perturbations, and the fact that multiple potential impacts may act synergistically (Blaustein and Kiesecker 2002; Collins and Storfer 2003), it is important to monitor amphibian populations to ensure appropriate management activities can be undertaken when necessary. Management actions in response to changes in amphibian populations should be based on appropriate data. Therefore, the Ecological Monitoring Committee for the Lower Athabasca (EMCLA) has determined that a pilot study is needed to test whether conducting long-term monitoring of the distribution and abundance of amphibian species in the Lower Athabasca Planning Region (LAPR; Figure 1) of northeast Alberta, Canada, can be done efficiently and effectively.

The ultimate goal of the amphibian monitoring program is to measure the current distribution and relative abundance of amphibian species in the region, and track changes in these parameters over time and in response to anthropogenic activities. The first step toward this goal is to use a pilot study to identify optimal sampling protocols for the LAPR to maximize the probability that amphibians will be detected where they occur, and to ensure data are collected as efficiently as possible. In addition, the pilot study will generate data necessary to calculate the number of sample sites and duration of monitoring necessary to detect a precise and significant trend in distribution and abundance of the different target amphibian species in the LAPR over time. Lastly, the pilot study will examine relationships between habitat characteristics and anthropogenic footprint and the distribution and abundance of the target amphibian species at the landscape scale, and generate data to develop a predictive tool for mapping potential distribution of these species based on habitat factors.

There are five species of amphibians in the LAPR region: wood frog (*Lithobates sylvaticus*), boreal chorus frog (*Pseudacris maculata*), boreal toad (*Anaxyrus boreas boreas*), Canadian toad (*Anaxyrus hemiophrys*), and northern leopard frog (*Lithobates pipiens*) (Russell and Bauer 2000). The wood frog and boreal chorus frog are considered secure at both provincial and federal levels, while the remaining three species are all designated at some level provincially and/or federally (Table 1). To date, relatively little work has been done on these species in the LAPR region, with the exception of surveys and research done in areas of industrial activity (e.g. forestry, oil sands mining). Although some of these species have been studied in other regions, parameters such as phenology and habitat needs may vary across ecoregions for the same species (Constible et al. 2010); therefore, in order to make informed decisions regarding long-term amphibian monitoring in the region, a pilot study is necessary to collect data relevant for LAPR. Note that the northern leopard frog, although it occurs in the LAPR, is not recommended as part of a regional monitoring program as this species has only been documented in the Canadian shield ecoregion in the extreme northeast of the LAPR (Figure 2). Therefore, this report concentrates on the remaining amphibian species in the LAPR: wood frog, boreal chorus frog, Canadian toad, and western toad.

Figure 1. Location of the Lower Athabasca Planning Region (LAPR) in Alberta. The LAPR is outlined in red on the map.

This report outlines recommendations for the development of a pilot study for monitoring amphibians in the LAPR of northeastern Alberta. This includes the data, statistics and monitoring design elements used to inform these recommendations, specific recommendations for design of the pilot study and the data that will be generated by the pilot program, which will be implemented in 2012.

Table 1. Amphibian species that occur in boreal Alberta, and their present provincial and federal designations.

Scientific name	Common name	Alberta status[1]	Alberta legal designation[2]	COSEWIC designation[3]
Lithobates sylvaticus	Wood Frog	Secure	na[4]	na
Lithobates pipiens	Northern Leopard Frog	At risk	Threatened	Special concern (Western Boreal/Prairie populations)
Pseudacris maculata	Boreal Chorus Frog	Secure	na	na
Anaxyrus boreas boreas	Boreal Toad (a subspecies of the Western Toad, *Anaxyrus boreas*)	Sensitive	na	Special concern
Anaxyrus hemiophrys	Canadian Toad	May be at risk	Data deficient	Not at risk

[1] ASRD 2010b

[2] Fish and Wildlife Division 2008

[3] COSEWIC 2010

[4] na = not assessed

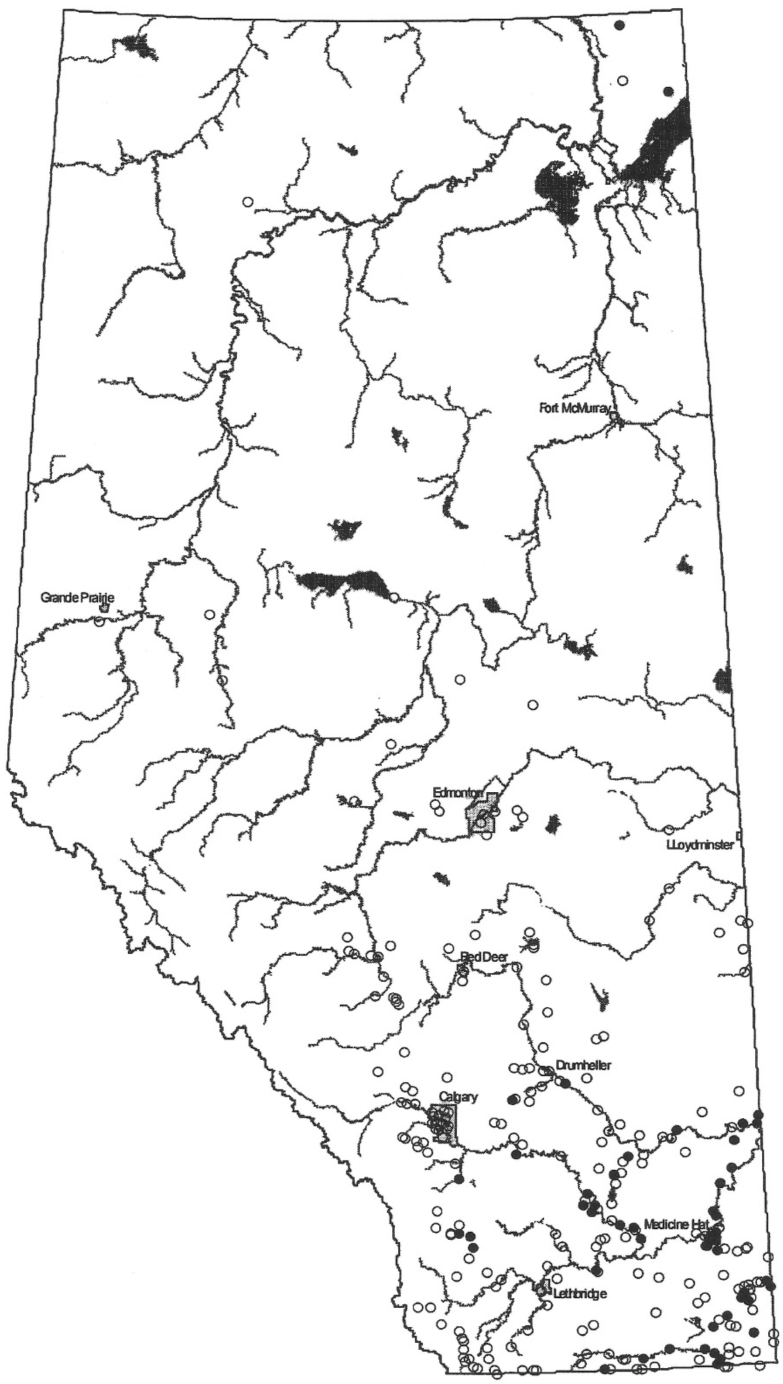

Figure 2. Distribution of northern leopard frogs based on a recent (2000-2001) survey. Solid circles indicate sites where one or more leopard frogs were found, while open circles are sites where surveys were done but no leopard frogs were observed. Note absence of this species from most of northeast Alberta. Figure adapted from Alberta Sustainable Resource Development (2003).

Data, statistical and design considerations of the amphibian monitoring pilot study

Existing amphibian data and known distribution in Alberta

All existing data on the distribution and abundance of amphibian species found in the LAPR were obtained, where possible, and compiled into a database, called Amphibia_ver1 (Bayne 2011); the structure of this database is explained in Appendix A. Note that this database contained data from outside the LAPR for the species of interest, as these data were used in preliminary analyses of distribution, detectability, and phenology; more focused analyses will be possible after the amphibian monitoring pilot project, which will collect data specific to the LAPR. The data used in the preliminary database were received from 36 different people or groups; these included consultants, researchers, volunteer monitoring programs, the Alberta Biodiversity Monitoring Institute, and government monitoring programs, amongst others.

Data included in Amphibia_ver1 were collected in diverse ways, making it difficult to compare directly between different projects, as there was a lack of a common sampling method. Sampling methods included hand capture, incidental observation (an amphibian was heard or seen during other activities), passive sample (passive call surveys), breeding (search of entire perimeter of a pond for evidence of breeding activity), telemetry (radio-tracking studies), traps (pitfall traps and other types of capture devices), and visual surveys (visual searches for evidence in ponds for evidence of breeding; differed in terms of protocol details from the "breeding" category above). The most commonly-reported method was incidental encounters, with passive and trap sampling being the next most common methods (Table 2); much of the trap sampling data was related to one project, the Researching Amphibian Numbers in Alberta (RANA) project, which used pitfall trapping at a number of sites throughout Alberta over a 10-year period. Pitfall trapping is used relatively little in most amphibian monitoring programs, as it is a labour-intensive activity, meaning relatively few sites can be sampled in the same time that many sites could be visited using a passive call survey approach.

Table 2. Number of records for species of amphibians in database, by method of sampling.

Species	Sampling method						
	Hand capture	Incidental	Passive	Breeding	Telemetry	Trap	Visual
Boreal Chorus	27	9765	1915	73	N/A	294	9
Western Toad	171	2685	452	5	32	622	4
Canadian Toad	3	1179	197	1	18	148	1
Northern Leopard Frog	0	2185	0	0	N/A	102	0
Wood Frog	86	9306	943	57	N/A	1815	31
No amphibians	N/A	N/A	893	9	N/A	1529	846
Total	287	25120	4400	145	50	4510	891

Sampling design information gained from Amphibia_ver1

Methods

There are a very large number of data types and methods used in Amphbia_ver1, which hinders our ability to generalize the results from these different methods as easily as for owls and yellow rails, where sampling methods are more standardized. Therefore, for amphibians we focus on the efficacy of passive surveys based on sampling calling adults. Future reports will evaluate the value of the other datasets.

Passive surveys

Passive surveys generally involve listening for adult amphibians calling near wetlands, and all passive surveys in the present database took place near wetlands. To evaluate species-specific responses to hour of day and week of year using passive surveys we used a mixed effects logistic regression. Ideally, PCODE (conditions at the time of survey – if known – such as date, time, weather conditions) and XY_KEY (spatial coordinates of survey point) would be nested as random effects but models with these terms would typically not solve with the current dataset because there were too many missing covariate combinations to allow model convergence. After evaluating several ways to account for spatial clumping of surveys we included PCODE as a random effect to account for spatial variation in amphibian abundance among different regions of the province where different projects took place, and to account for sampling methods that differed among projects. This differs from the owl analysis, where a much larger sample size was available allowing for a more complex model to be solved.

Passive call surveys generally occurred at 8 P.M. and 4 A.M. between week 19 and 27. Figures 3-10 highlight how the relative probability of observation changed from hour of day and week of year based on odds-ratios. Odds-ratios are used to compare whether the probability of a certain event occurring is the same for two groups. Ratios greater than 1 suggest that the event is more likely to occur in the first group, which the opposite is true when the ratio is less than 1; a ratio of 1 suggests that the event is equally likely for both groups. In the present analysis, the reference state for hour of day (first group) was set to 0 (12:00 to 12:59 AM). Therefore, any hour-of-day with a value > 1 had a higher probability of observing an amphibian relative to hour 0, while those with odds-ratios < 1 had a reduced probability of observing an amphibian relative to hour 0. Week-of-year can be interpreted in the same way except the reference condition was week 23. Error bars represent 95% confidence intervals.

Influence of hour of day on detections using passive call surveys

Different species of amphibians may call at different times of the day, making it challenging to efficiently sample all species that might be calling at a site on any given day. Preliminary analysis of the available data can be used to help guide design for future survey programs. Note, however, that the data collected will be influenced not only by when amphibians are calling, but also when observers are at a site to hear them calling. For example, the current Alberta Amphibian Volunteer Monitoring Program (Alberta Conservation Association and Alberta Sustainable Resource Development 2010) specifies that passive call surveys begin at dusk, or shortly thereafter. Therefore, most of the data available for the preliminary analyses presented here are based on evening surveys. However, when amphibians actually call may be influenced by a number of factors, including environmental conditions (e.g. air or water temperature). Mean ambient temperature and length of the active season generally decrease with increasing latitude, so we might expect to see shifts in phenology toward more daylight calling and breeding activity in northern regions (Terhivuo 1988); certainly, wood frogs and boreal chorus frogs will actively call and breed in the middle of the day in some regions of the boreal mixedwood forest (B. Eaton, personal observation).

Analysis of the Amphibia_ver1 dataset suggested that wood frogs sampled by passive listening were observed at all times of the day. While probability of observation was generally higher in the evening prior to midnight it was not statistically different than any other time (Figure 3). Boreal chorus frog showed a relatively consistent calling pattern. Typically, there was a higher probability of hearing this species before 1 AM (Figure 4). According to the amphibian data we were able to amass, boreal chorus frogs were virtually never observed during daylight hours using passive surveys. This may have been an artifact of the protocols used to collect the data (e.g. starting surveys at dusk), as other time periods may have been sampled only rarely. Boreal chorus frogs certainly call during the day in the Edmonton area and in the boreal forest (B. Eaton, personal observation).

Western toads sampled by passive call surveys were observed at all times of the day. Probability of observation was generally higher after midnight, but it was not statistically different than any other time (Figure 5). In contrast, Canadian Toads were never observed during daylight hours and showed a much more consistent change over the length of a day than any other species, with most calling between 10 PM and 2 AM (Figure 6).

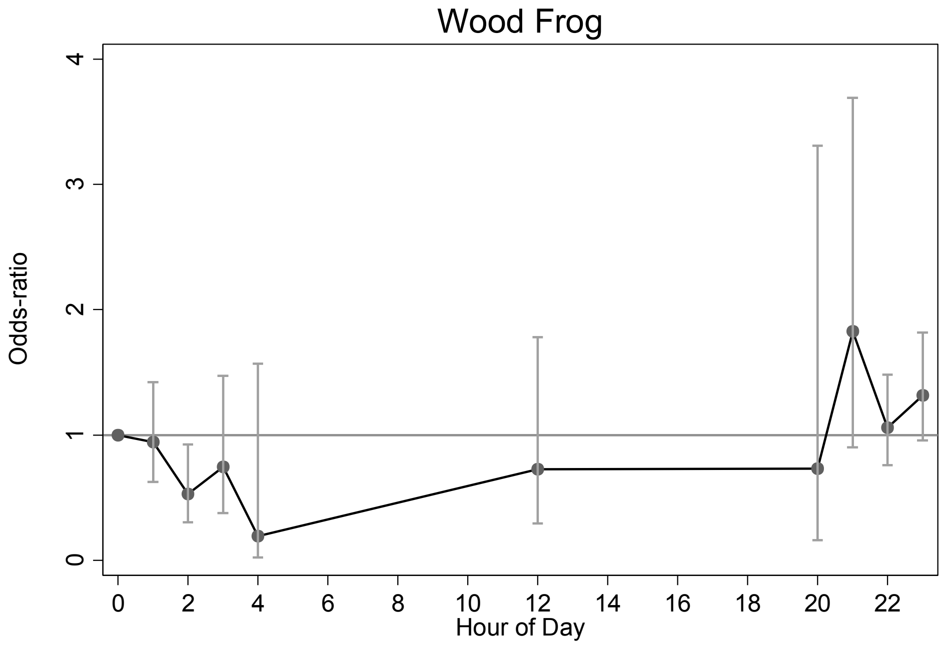

Figure 3. Probability of hearing a wood frog during passive call surveys in relation to time of day.

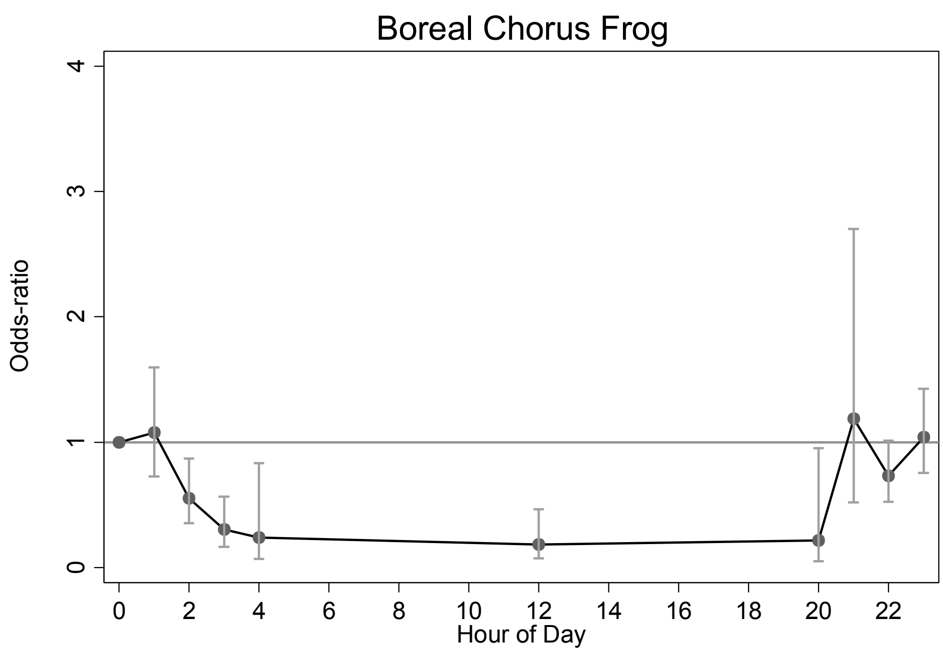

Figure 4. Probability of hearing a boreal chorus frog during passive call surveys in relation to time of day.

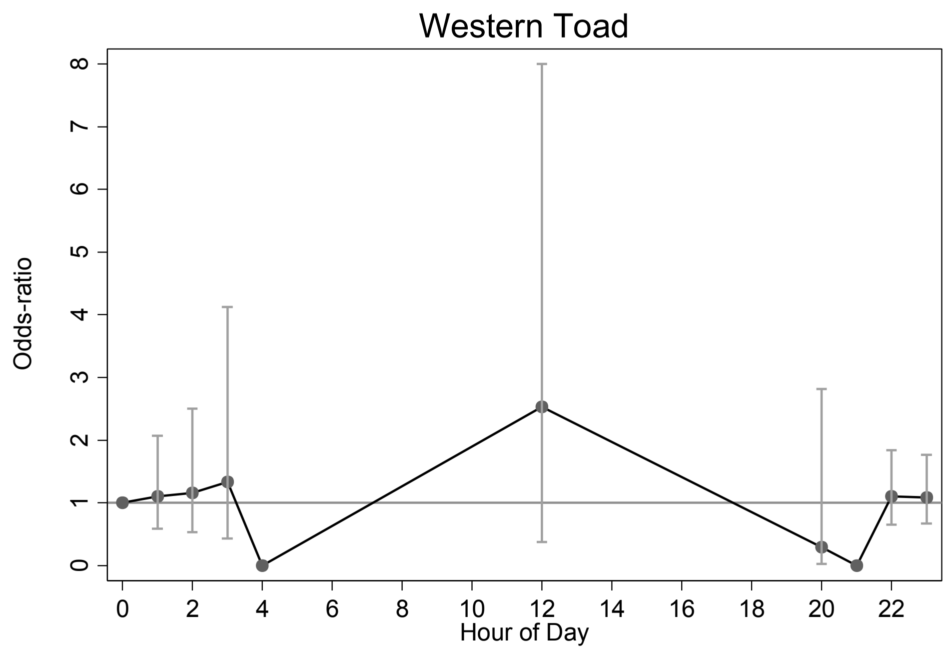

Figure 5. Probability of hearing a western toad during passive call surveys in relation to time of day.

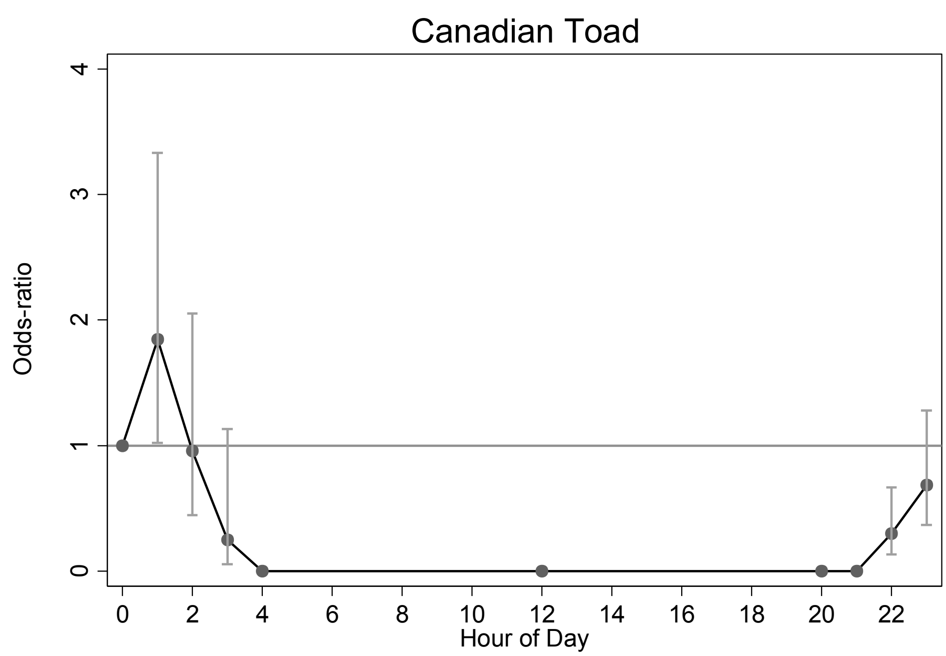

Figure 6. Probability of hearing a Canadian toad during passive call surveys in relation to time of day.

Influence of time of year on detections using passive call surveys

The breeding periods of amphibian species may differ over the course of the active season. In northern regions, the first species to emerge from hibernation include wood frogs and boreal chorus frogs, as these species are freeze tolerant (MacArthur and Dandy 1982, Storey and Storey 1984, 1986). Adult wood frogs, for example, overwinter in upland forest adjacent to breeding ponds (Regosin et al. 2003, 2005), allowing them to enter breeding ponds early in the season where they breed over a one to two week period. This behaviour is thought to reduce egg and tadpole cannibalism (Petranka and Thomas 1995).

In contrast, toads are not freeze tolerant, being forced to burrow down into the soil or find suitable microhabitats (e.g. squirrel middens) to escape the frost. Canadian toads usually hibernate in sand or gravel substrate (Kuyt 1991; Constible et al. 2010), while western toads overwinter in squirrel middens, animal burrows, and peat hummocks (Browne and Paszkowski 2010). Toads probably have to wait longer before emerging from hibernation to breed because they must wait for the substrates in which they are buried to thaw before they can become active.

Analysis of the Amphibia_ver1 dataset suggested that wood frogs sampled by passive listening were more likely to be observed early in the active season, with observations of this species dropping off after week 23 (Figure 7). Boreal chorus frogs were more likely to be encountered during surveys early in the active season, but the observation rate was quite variable from week 19 to 22 (Figure 8); the reason for this variability is unknown at this time. The only week that seemed to have particularly low detections of boreal chorus frogs was week 27 (Figure 8).

The probability of hearing a western toad during passive call survey was variable for the first part of the active season, and then dropped off after week 24 (Figure 9). Similarly, Canadian toads were more likely to be observed up to week 23 (Figure 10).

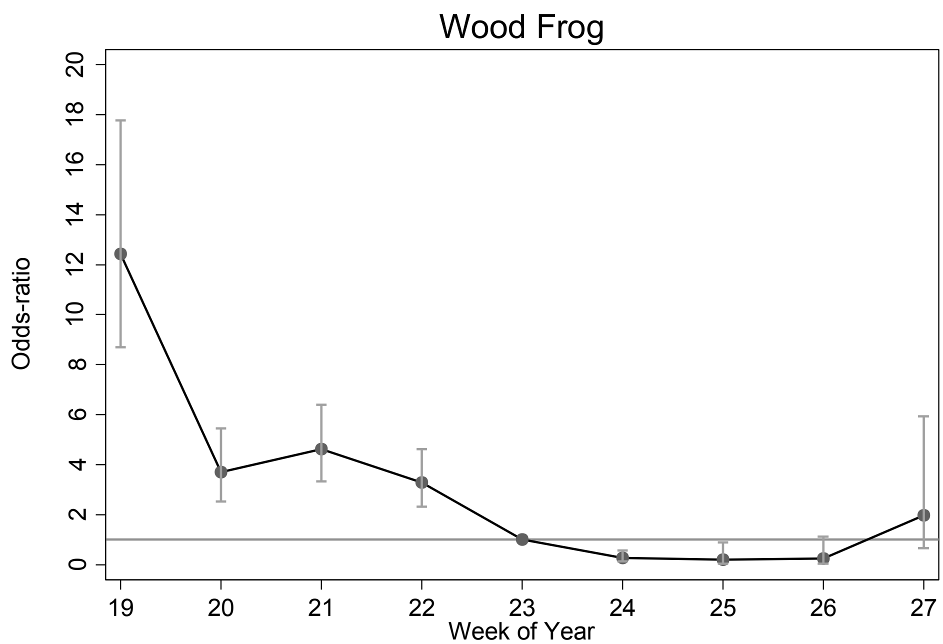

Figure 7. Probability of hearing a wood frog during passive call surveys in relation to week of the year.

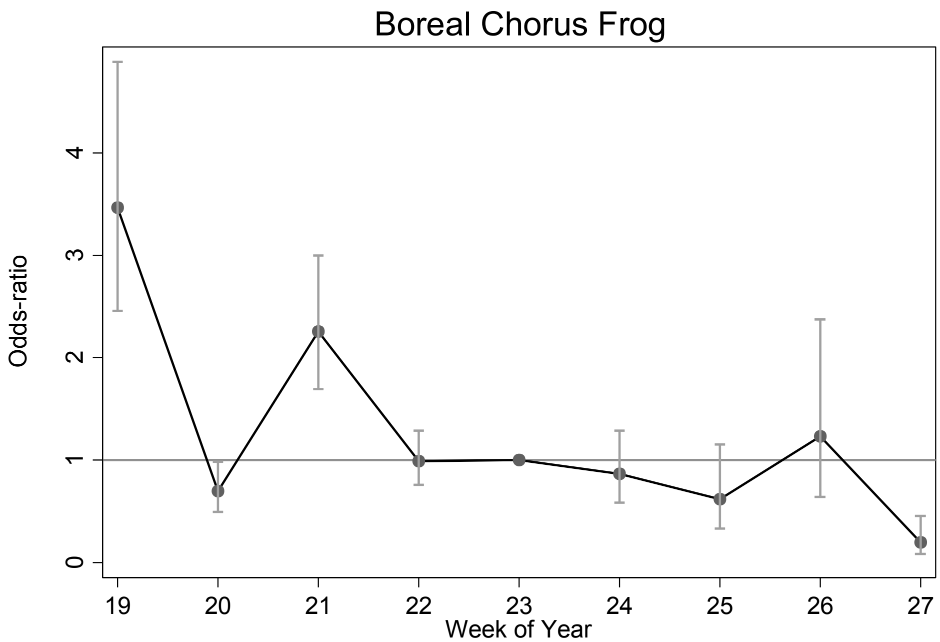

Figure 8. Probability of hearing a boreal chorus frog during passive call surveys in relation to week of the year.

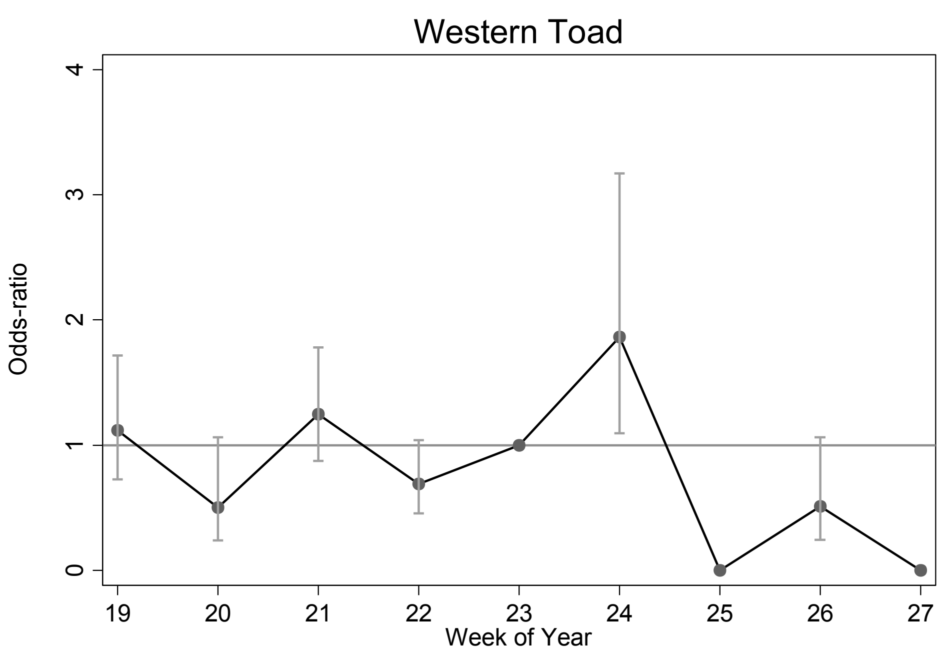

Figure 9. Probability of hearing a western toad during passive call surveys in relation to week of the year.

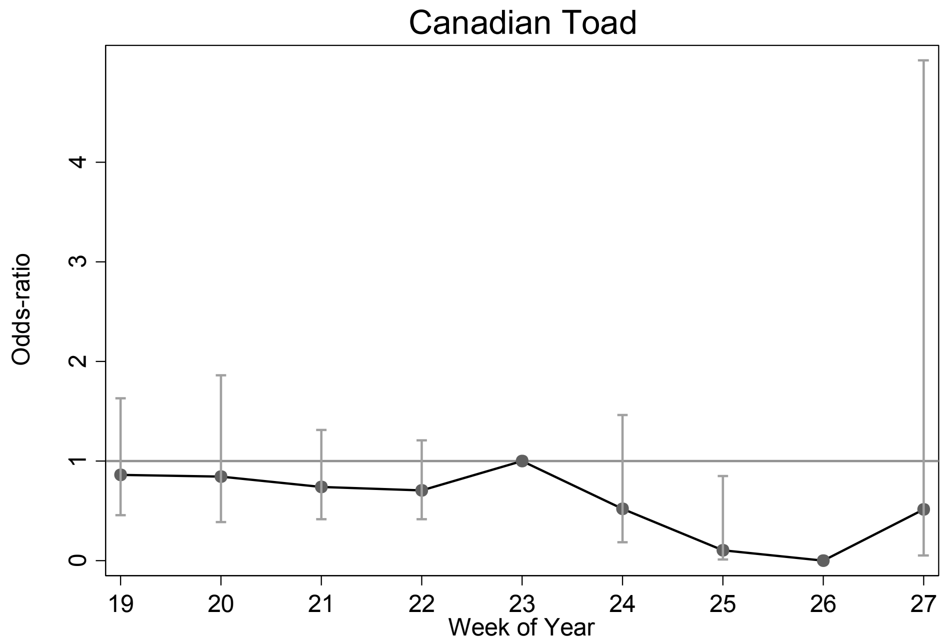

Figure 10. Probability of hearing a Canadian toad during passive call surveys in relation to week of the year.

Detection rate and abundance using passive counts

The previous analyses used probability of observation, which does not account for detection error. We used passive survey data to estimate amphibian abundance corrected for detection error at the point level. Data came from 2263 points, all found in the LAPR. Of these points, 795 were visited 2 to 4 times, for a total of 3095 surveys. This type of data allows estimation of amphibian abundance, occupancy, and detection rate via Royle's n-mixture model (Royle and Nichols 2003). However, there were many very large and many very small values which generates computational difficulties for this technique. Instead, we use Mackenzie's occupancy method which accounts for detection rates less than 1 and can provide a more accurate estimate of the occurrence of a species if the assumption of population closure is met (MacKenzie et al. 2002). This means that between visits the species was either always present or always absent when observers visited. Any zeros at points where the species was previously or later found are assumed to be caused by detection error (i.e. population closure assumption). With the data currently available we cannot test the assumption that the population is closed.

The results for occupancy models predicting probability of occupancy of a point for each species (Table 3) suggest that species such as the wood frog are observed at relatively high numbers of the sites passively surveyed, while the two toad species are much less likely to be found at survey points. Interestingly, detection rates for the toad species were moderate and very similar, suggesting that, once one of these species is detected at a site, there is a reasonable probability of detecting the species there again. The probability of occupancy was high for both wood frogs and boreal chorus frogs, and low for the two toad species (Table 3), suggesting that more sampling sites will be needed to provide good data on toad distribution and relative abundance than for the two frog species .

Table 3. Naïve probability of observation, detection rate, and corrected probability of occupancy for 4 amphibian species found in the Lower Athabasca Planning Region. 95% confidence intervals are shown in brackets. This preliminary analysis is based on data derived from multiple sources; data derived from the proposed pilot project would provide a more realistic indication of the value of these parameters for amphibian in the LAPR.

Species	**Probability of observation (Point)** [1]	**Detection rate**[2]	**Probability of occupancy (Point)** [3]
Wood Frog	0.355	0.326 (0.284-0.369)	0.915 (0.797-1)
Boreal Chorus Frog	0.638	0.736 (0.708-0.764)	0.819 (0.784-0.853)
Western Toad	0.158	0.475 (0.419-0.532)	0.285 (0.256-0.313)
Canadian Toad	0.062	0.407 (0.260-0.554)	0.126 (0.081-0.170)

[1]Probability of observation (point) = (# points where species observed/ # points visited). A point is a single location where a restricted time and space search was conducted by an observer that could have detected a species. Most points have a single survey but some have 2 to 12 surveys per point within a year.

[2] Detection rate – The proportion of observations of a species that occur at the same point when revisited multiple times within the same year. For example, if an observer went to the same point four times in the same year and found the species at the point twice the detection rate would be 0.5.

[3] Probability of occupancy (point) – Probability a species was present at a point after being corrected for observation error caused by having a detection rate < 1. Conceptually, sites where species were never detected have a probability of the species being there and it was simply missed because the detection rate was low.

Amphibian distribution in Alberta

To evaluate whether we could effectively stratify future amphibian sampling to increase efficiency of data collection we used all observations of each species to create species distribution maps. The models were computed using presence in one hectare cells with the following variables estimated for every hectare in Alberta:

1) Climate ,
2) Landcover as derived from Alberta Ground Cover Classification (2005 - Canada, 30 m resampled to 100 m),
3) Peatland types based (Vitt et al. 1996),
4) Terrain,
5) Geology – Different classifications of aggregates and surficial deposits.

There are numerous ways to make a species distribution map and for this report we used MaxEnt. MaxEnt is a machine learning tool that allows users to take presence-only species records and model the environmental conditions where they are found relative to what is available (Phillips et al. 2006). MaxEnt minimizes the relative entropy between two probability densities (one estimated from the presence data and one from the available landscape) based on a series of environmental covariates. The end result of the model is a relative ranking of which areas the species is more or less likely to be observed. A common approach to species modelling of all of the rare animals and plants was used in this report by using the same modelling framework and same model covariates. Future work will investigate how inclusion of greater specificity in vegetation covariates and wetland types influences the animal models in particular. The numbers reported in the legend associated with the modelled range for each species should NOT be directly compared as this requires a correction for abundance which has not yet been implemented.

A major challenge in presence only modelling is defining the available landscape. When taken from systematic or random survey designs, the available landscape can and should be viewed as all possible locations within the overall statistical population that is sampled. With haphazard data collection, as we have in this database, it is less clear what the available population is. In this model run, we considered the available population to be any possible XY location where a bird or amphibian survey had been reported as being conducted. By constraining the available landscape to these points we should not over-predict areas that have never been sampled. However, in using this definition of what is available there is the potential bias that some species will not have been recorded in an area because the methodology that was used in that region had a much lower chance of observing that particular species. Future work will refine the definition of "available" to see how this definition influences model results.

Below is a short description of the model results for each species. Note we do not go into a full description of the model covariates that drive these results, rather highlight major patterns as these will change as we refine our definition of “available”. In each image, reds indicate the areas most likely to have the species, greens are moderately likely to have the species, and blues are areas where the species is least likely to be found based on the definition of available described above. White dots show the presence locations used for training the model and violet dots show test locations for validating the model.

The wood frog is predicted to occur across Alberta (Figure 11); they are commonly found in LAPR. The Wood Frog had a training Area Under the Receiver Operating Curve (AUC) of 0.772, indicating reasonable discrimination ability between presence locations and the available landscape. This is expected given the generality of this species and that all surveys were done near wetlands. The top three variables influencing the wood frog model were mean growing season precipitation, mean annual temperature, and mean maximum temperature.

The boreal chorus frog is predicted to occur across Alberta based on range maps (Figure 12). The boreal chorus frog model had a training AUC of 0.734 indicating reasonable discrimination ability between presence locations and the available landscape. This is expected given the generality of this species and that all surveys were done near wetlands. The top three variables influencing the Boreal Chorus Frog model were number of growing degree days above 5, mean maximum temperature, and mean annual temperature.

The western toad is predicted to be restricted to the western half of Alberta based on IUCN distribution maps. Alberta SRD suggests it stretches further west in a narrow area. However, Alberta SRD states the distribution of the western toad in the northern region of the province may actually be more extensive than previously determined. Based on the species identification provided by each project, the western toad is found much further east into the LAPR, almost to the Saskatchewan border (Figure 13). The model AUC was 0.894. Summer moisture index, mean annual precipitation, and surficial geology were the best predictors.

The Canadian toad is predicted to be restricted to the eastern half of the province based on distribution maps from Alberta SRD. There are a few observations in our database that are slightly outside this range but they are relatively few. Model prediction AUC was 0.901. The top three variables were growing degree days above 5 degrees Celsius, continentality (the tendency for areas in the interior of large continents to exhibit wider temperature ranges than coastal areas), and mean temperature in warmest month. The LAPR seems to have an area of particularly high suitability in the NE corner (Figure 14).

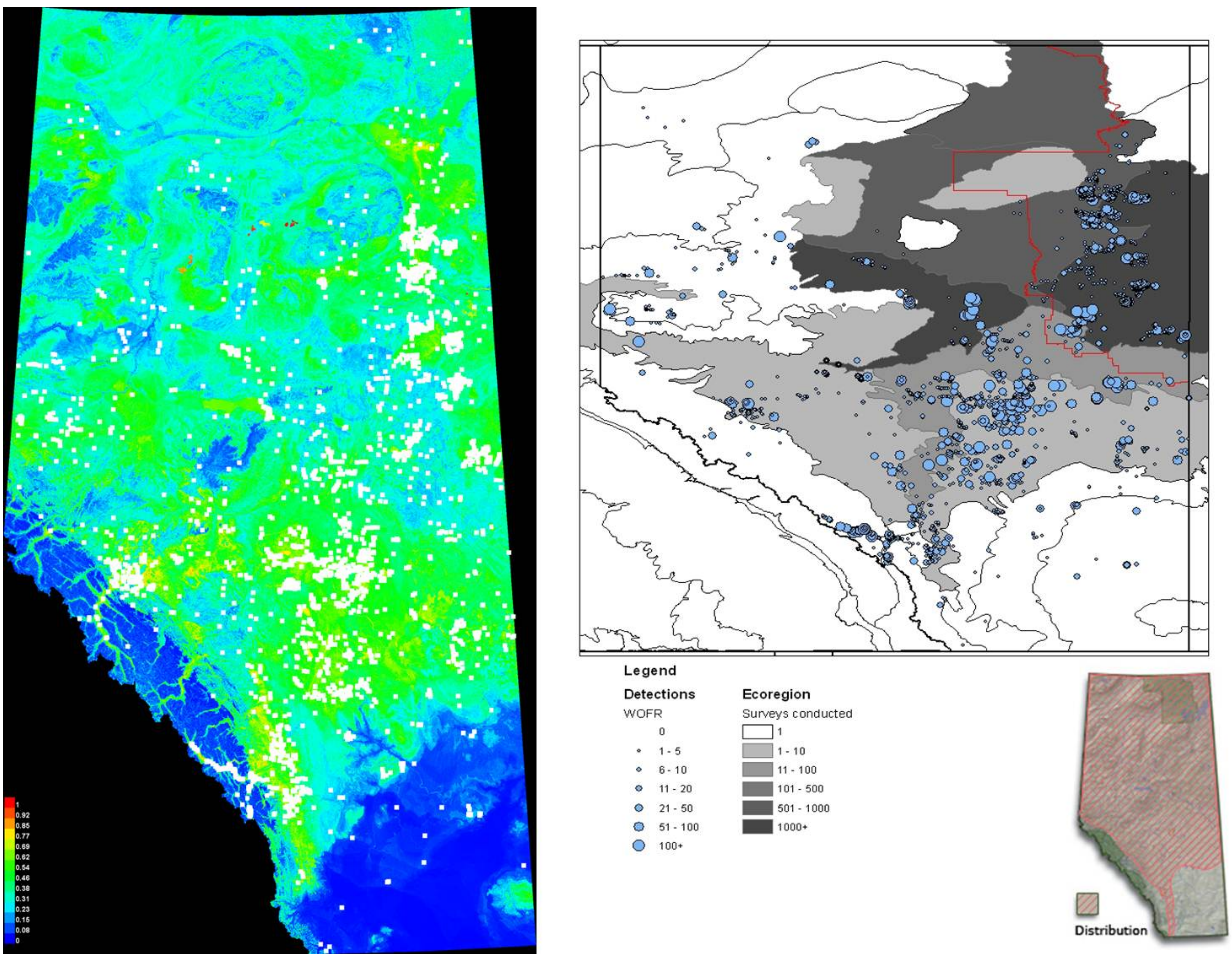

Figure 11. Wood frog distribution model for Alberta. The map on the left of the figure shows the MaxEnt output, while the map on the right shows the data points using in developing the model. The map in the lower right corner shows the range based on maps from the Alberta Sustainable Resource Development website (http://www.srd.alberta.ca/FishWildlife/WildSpecies/Amphibians/Default.aspx).

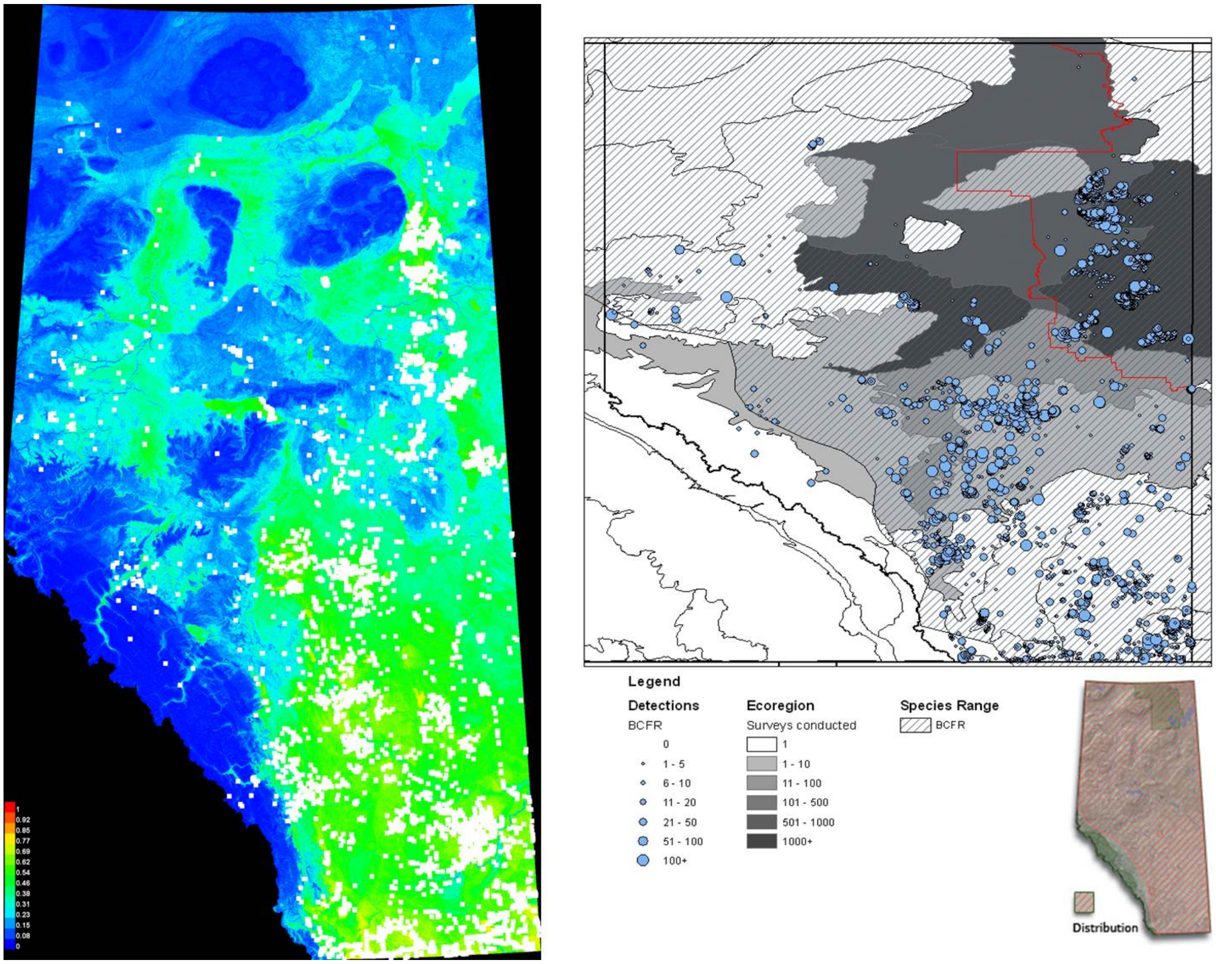

Figure 12. Boreal chorus frog distribution model for Alberta. The map on the left of the figure shows the MaxEnt output, while the map on the right shows the data points using in developing the model. The map in the lower right corner shows the range based on maps from the Alberta Sustainable Resource Development website (http://www.srd.alberta.ca/FishWildlife/WildSpecies/Amphibians/Default.aspx).

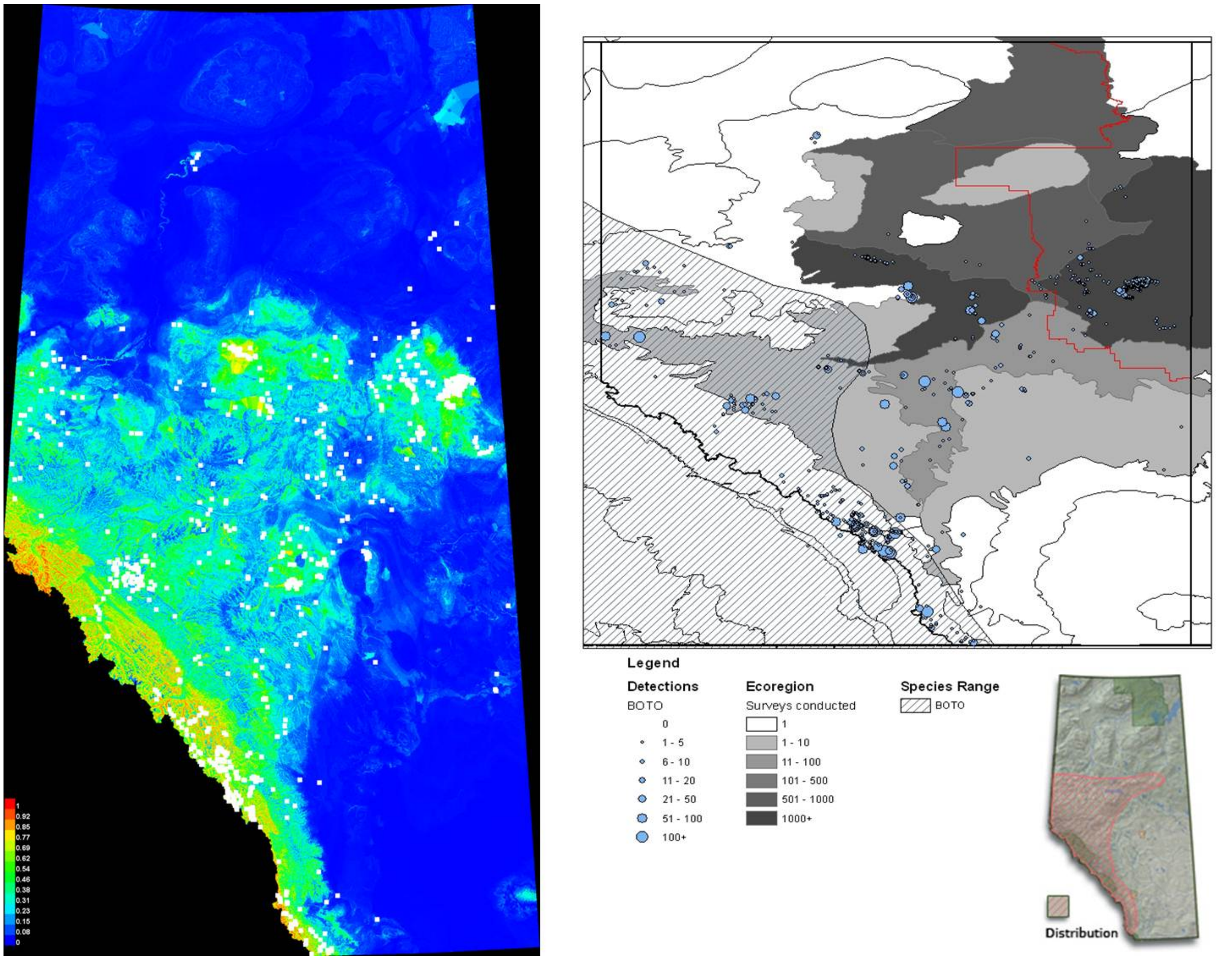

Figure 13. Western toad distribution model for Alberta. The map on the left of the figure shows the MaxEnt output, while the map on the right shows the data points using in developing the model. The map in the lower right corner shows the range based on maps from the Alberta Sustainable Resource Development website (http://www.srd.alberta.ca/FishWildlife/WildSpecies/Amphibians/Default.aspx).

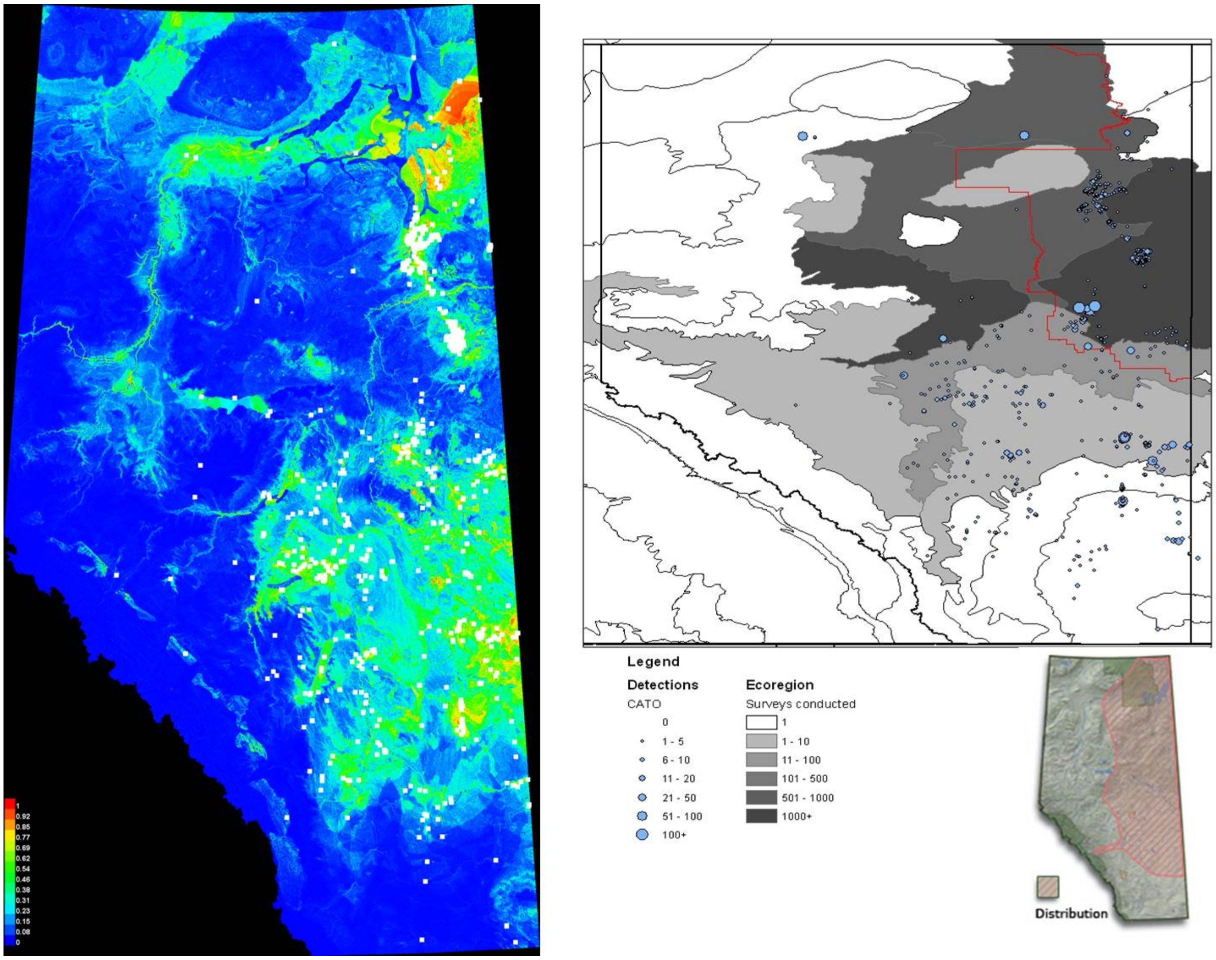

Figure 14. Canadian toad distribution model for Alberta. The map on the left of the figure shows the MaxEnt output, while the map on the right shows the data points using in developing the model. The map in the lower right corner shows the range based on maps from the Alberta Sustainable Resource Development website (http://www.srd.alberta.ca/FishWildlife/WildSpecies/Amphibians/Default.aspx).

Recommendations for the northeast Alberta amphibian monitoring pilot study

The recommendations made in this section are based on preliminary analyses of a dataset that combined information from a number of different sources. Therefore, these recommendations should be taken as preliminary as well; numbers provided, in terms of how many sites should be sampled or how many visits should be made to a site, are informed by logistical considerations, the analysis presented here, and the experience of others as reflected in the scientific literature. These numbers may change in the process of actually implementing the pilot amphibian monitoring program. In some cases, data from a pilot program is needed to actually answer questions such as how many sites should be monitored, and this will be one of the next steps toward implementing a regional amphibian monitoring program.

Amphibian species that should be sampled during the pilot study

Wood frogs and boreal chorus frogs should be monitored as general indicators of environmental quality in the LAPR, as they are widespread and usually locally abundant. Canadian toads should be monitored as well, as this species appears to be more sensitive to environmental perturbation, and has more stringent habitat needs (e.g. specific overwintering habitat). Although the Canadian toad is more geographically limited, a significant part of its range occurs in the LAPR, and it is amenable to sampling methods also used for the wood and boreal chorus frogs. In addition, there are concerns that this species is declining in Alberta, as the proportion of observations of this species has declined in recent years compared to those of other species in the province (wood frog, boreal chorus frogs, western toad), despite the fact that more observers are reporting amphibian data than ever before (Browne 2009). At the moment, Canadian toads appear to be quite common in the area of the mineable oil sands in the LAPR region (Figure 15). However, there may be a disproportionate number of projects or surveys targeting this species in the region associated with mineable oil sands leases (e.g. EIA's, monitoring, reclamation activities); much of the remainder of the region has not been surveyed for amphibians, or Canadian toads have not been detected in these areas (Figure 16). Understanding the distribution and abundance of the species throughout the region would provide a much better picture of the status and trends in this species in what appears to be the main bastion of the species in Alberta. In addition, examining the regional status of the species would provide insight into the response of the Canadian toad to industrial activity; it may be that toads are responding positively to anthropogenic structures such as dykes associated with mineable oil sands areas, as these provide good overwintering habitat. If, however, the wetlands associated with these dykes and constructed and are suboptimal for egg and larval development, as has been suggested for anthropogenic structures such as borrow pits (Stevens et al. 2006), or the dykes themselves are actually poor overwintering sites, then these areas may be ecological traps. Ecological traps occur when an organism responds to cues that indicate good habitat quality in natural environments, but which are misleading when applied to sites of anthropogenic origin or which have been altered (Schlaepfer et al. 2002).

Although the western (boreal) toad is not currently thought to be widespread in the LAPR, it should be sampled as well, as this species appears to be expanding into eastern Alberta (Wind and Dupuis 2002), and the MaxEnt modeling reported in this document suggests this species has penetrated almost to the Saskatchewan border in the region. This perceived expansion may simply be detections of the boreal toad in areas where it existed but previously went unobserved because of lack of sampling effort and/or low abundance. In either case it is important that monitoring include both toad species. Canadian and boreal toads are closely related, may be able to interbreed (Cook 1983; Eaton et al. 1999), and boreal toad males are larger than male Canadian toads and may therefore be able to outcompete them for mates. Therefore, it will be important to monitor these species to determine if they exhibit linked changes in abundance and distribution and whether those changes are related to changes in land use or cover related to human activity. In addition, since the breeding periods of these two species overlap, as do breeding habitats, it is efficient to monitor both species at the same time.

Northern leopard frogs are restricted geographically to the extreme northeast of the LAPR (Figure 2) and are therefore not useful as a regional indicator for the LAPR, though there may be impetus to monitor populations in northeastern Alberta because this is a listed species with a mandated recovery plan.

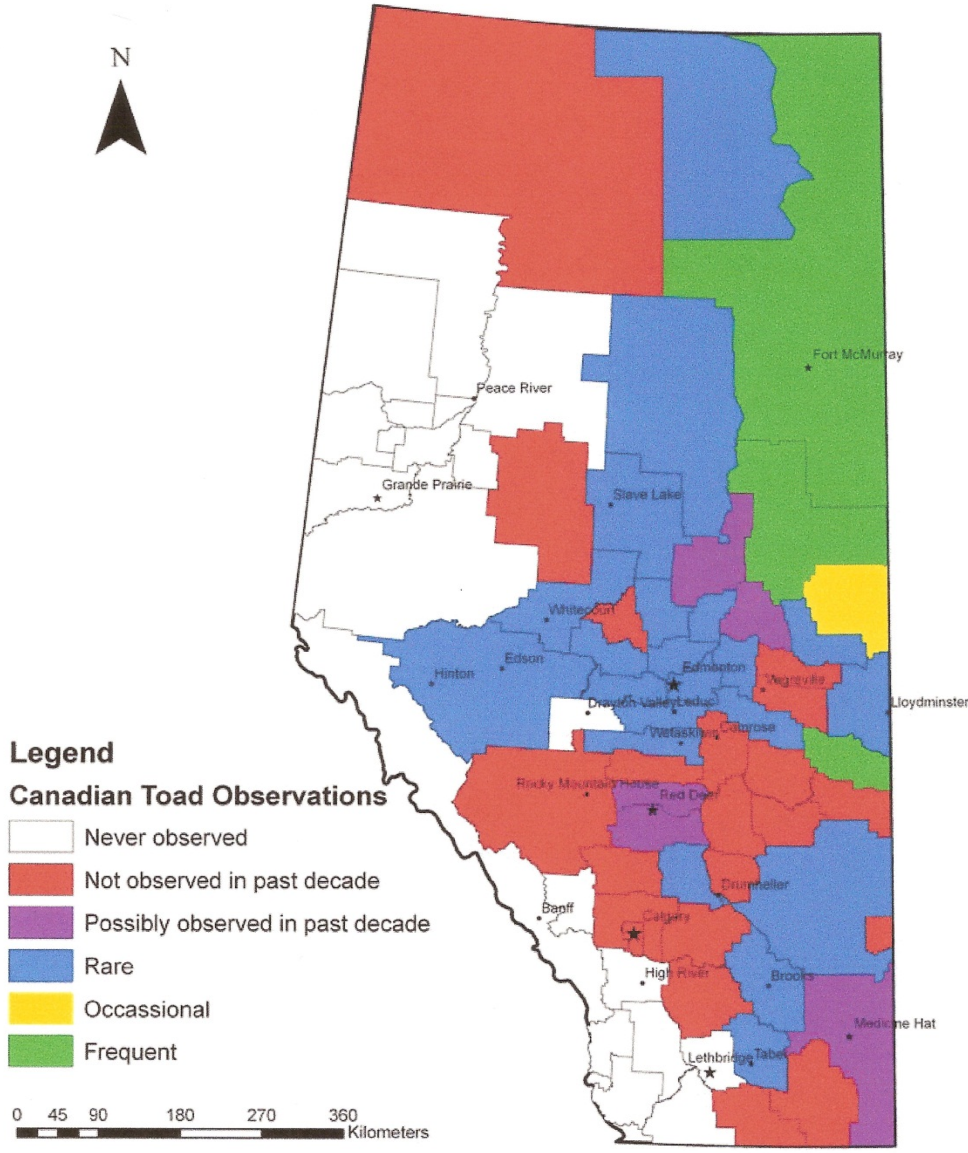

Figure 15. Distribution of past and current observations of Canadian toads in Alberta, summarized by county (from Browne 2009).

a. 1895-1997 b. 1998-2007

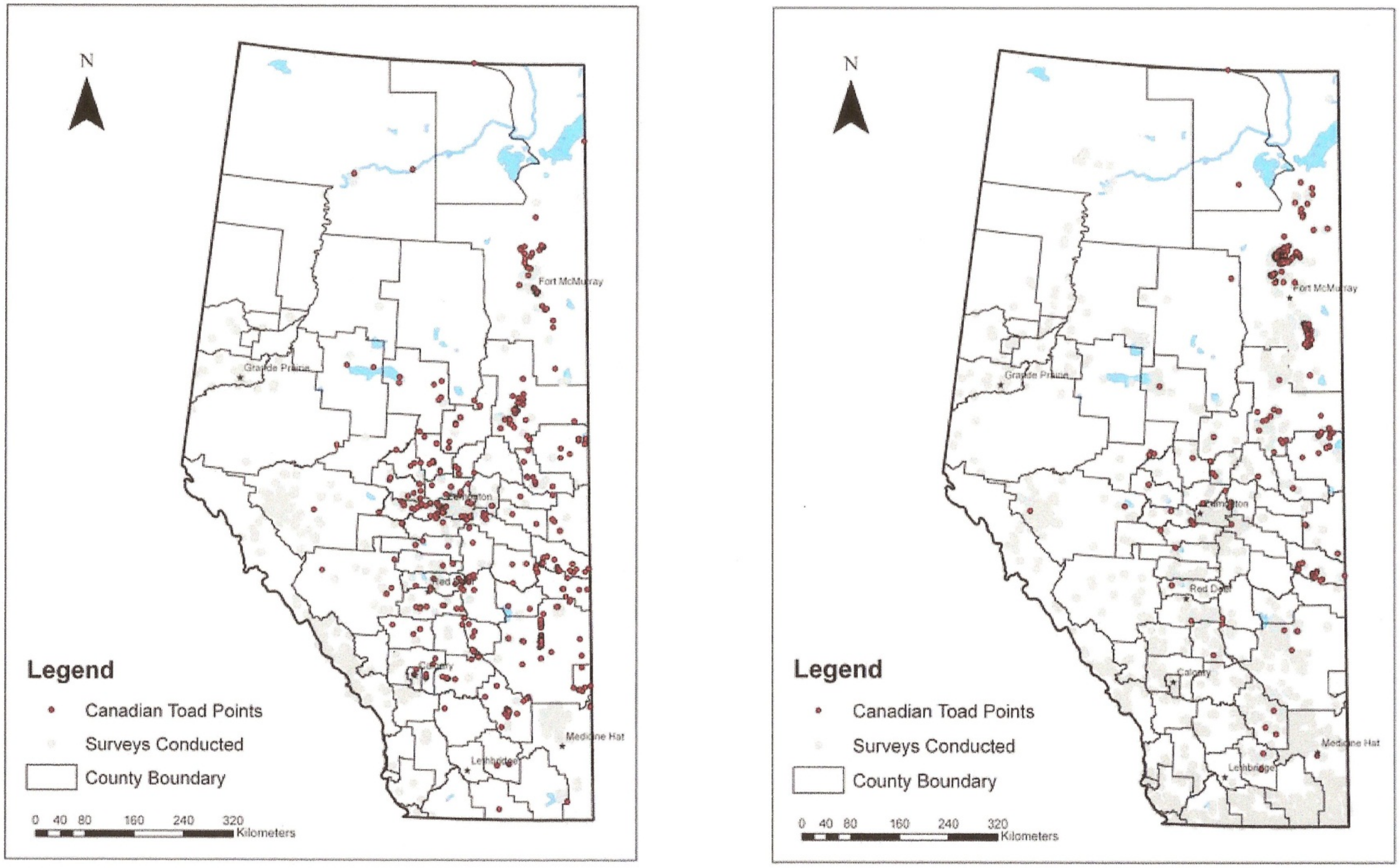

Figure 16. Summary of Canadian toad observations from 1895-1997, and from 1998-2007. Coloured dots represent locations where Canadian toads have been observed, while grey dots represent locations where surveys were done and Canadian toads were not observed, or other amphibian species were reported. Lack of observations in an area may result from lack of observers or low abundance of toads, resulting in low detection rates. Note the decline in Canadian toad observations from the central part of Alberta between the two time periods.

Identify habitat and anthropogenic features that influence amphibian distribution and abundance

Development of a regional scale amphibian monitoring program will depend on utilizing available knowledge and datasets to design appropriate sampling protocols, and identifying existing knowledge gaps. Detectability of a species (the probability that a species will be detected at a site if it actually occurs there; MacKenzie at al. 2002) can vary across species (de Solla et al. 2005), habitat (Bailey et al. 2004), season (Weir et al. 2005), and years (Schmidt 2005), and is influenced by sampling effort (Pierce and Gutzwiller 2004; de Solla et al. 2005). In order to identify factors that may influence detectability (e.g. species-habitat associations, anthropogenic features, phenology), analyses of existing data and collection of data during a pilot program should be used to guide development of a monitoring program which maximizes the detection probability for amphibian species.

The present document represents the first step in developing guidance for a regional amphibian monitoring program for the LAPR based on existing data. Additional work to refine habitat associations, relationships between amphibian distribution and abundance and anthropogenic features, and phenology patterns specific to the LAPR for each species of interest would be useful so sampling effort can be stratified to maximize monitoring efficiency (Mazerolle et al. 2005; Steelman and Dorcas 2010). For example, the Wet Areas Mapping dataset might prove useful in identifying potential sampling sites; a similar approach, using soil maps, was able to identify target sites for amphibian sampling that were missed using National Wetland Inventory data (Bowen and Gafvert 2009).

The pilot program for amphibians should be designed to examine a number of factors related to habitat and anthropogenic features. Habitat factors might include wetland size and type, while anthropogenic features might include level of habitat fragmentation or linear disturbance. A small number of factors should be identified based on additional, more refined, modeling; for each of these factors to be examined during the pilot, a minimum of 5 sampling sites should be chosen to allow appropriate statistical analysis. Ultimately, species-habitat associations could be used to generate predictive maps of potential amphibian distribution based on habitat data.

Use automated recording systems to document amphibian calling phenology

Automated acoustic recording systems (ARS) should be deployed at a number of wetlands early in the season (e.g. before any amphibians begin to call; ideally deployment will occur before wetlands begin to thaw) and set to record for the first 10 minutes of each hour, 24 hours a day, until mid-July. This will provide data on seasonal and diurnal phenology of breeding for all four of the amphibian species we are recommending should be monitored in the LAPR, and these data can be used to optimize passive call surveys (Dorcas et al. 2009). Recording data can be used for a number of purposes: (1) determining optimal periods for passive call surveys on a seasonal and diurnal basis for each species of interest, (2) determining the optimal length of the sampling period (e.g. how long should surveys last), and (3) to verify passive call surveys done at the same site in which recorders are deployed. This work will be done in conjunction with the yellow rail sampling program to maximize the efficiency of the pilot program, and to explore potential efficiencies that could be incorporated into a full-scale monitoring program in the future.

Standard passive call surveys (see below) should be conducted at each of the sites with automated recorders to determine the rate at which human surveyors can detect amphibians using standard protocols. This can be accomplished by triggering the automated system to record at the same time as the passive call survey is being conducted at a site, and then comparing the species detected and the category of calling intensity (see below) assigned using call surveys and analysis of the automated recording.

We suggest that at least 20 automated recorders be deployed at wetlands in the LAPR during the pilot program.   Current cost for these units is approximately $700 per unit, plus analysis software ($500; only one purchase is necessary for each computer used in analysing the call data), memory cards, batteries, mounting hardware, etc.; total cost for each fully deployed unit is approximately $850. These costs will be shared between the yellow rail and amphibian pilot projects.

If possible, recorders should be deployed at sites relatively near to weather stations, or remote weather stations (approximately $1500 each) that record wind speed, rainfall, barometric pressure and light intensity (note that the automated acoustic recorders store air temperature data already) should be purchased and deployed with the acoustic recorders. This approach will supply data on what environmental factors influence amphibian calling behaviour, and can be used to optimize the amphibian monitoring program and interpret the results of future monitoring efforts.

Use passive call surveys to document amphibian distribution and relative abundance

Passive call surveys are recommended for monitoring amphibian species in the LAPR, as call surveys are relatively efficient mechanisms for evaluating the status of amphibian populations over space and time, and are the method used by most amphibian monitoring programs in North America (Dorcas et al. 2009). Surveys should be done at a minimum of 80 sites, including the 20 where automated acoustic recorders will be used, and 20-40 ABMI wetlands. Sites should be distributed along the latitudinal gradient present in the LAPR, to allow determination of how the phenology of the target species changes with latitude. To make the pilot project as efficient as possible, however, it is recommended that sampling sites be located in clusters so that a number of individual sites can be sampled in a single day. Given that amphibians have relatively restricted dispersal abilities (Marsh and Trenham 2001), sites that are at least 5 km apart should be independent.

Passive call surveys should follow the accepted protocol used by the Amphibian Volunteer Monitoring Program (Alberta Conservation Association and Alberta Sustainable Resource Development 2010), with the exception that surveys should be done at various times throughout the day and evening (rather than just at dusk or shortly thereafter) to determine when amphibian species in the LAPR are most likely to be detected. Because of safety issues, daytime surveys would be preferable for passive call surveys in a fully-implemented amphibian monitoring program, if the timing is appropriate for detecting the species of interest. This needs to be tested during the pilot project.

The Amphibian Volunteer Monitoring Program protocol specifies:

1. that observers start surveys at dusk or shortly thereafter (note that during the pilot project call surveys would be done at various times during the day and night to determine optimal periods for detecting target amphibian species),
2. find an optimal listening point at a site (e.g. downwind),
3. wait for several minutes after arriving at a site to begin the survey (this will be fixed at a specific time, such as 5 or 10 minutes, during the pilot),
4. spend at least 5 minutes listening for anuran calls (this will be standardized during the pilot program, when data will be collected on amphibian calls over longer periods at some sites to determine the relationship between length of time listening and ability to detect a species at a site),
5. record the species heard using a scale of 1 to 3; 1 = individuals can be counted, with no overlapping calls; 2 = individuals can be counted, but some calls overlap; 3 = individuals cannot be counted, full chorus, calls overlap,
6. make multiple visits to a site to increase chance of detecting a species; we recommend 4 visits be made to a site during the pilot project, with a minimum of 24 hours between visits.

Research has indicated that categories of relative abundance used in passive call surveys are positively correlated with population parameters such as chorus size (e.g. the number of males calling at a specific time; Shirose et al. 1997), the number of egg masses in a pond (Stevens and Paszkowski 2004), and population size (Nelson and Graves 2004). Some research suggests that population indices derived from passive call survey programs may be unrelated to population size, although some strategies (e.g. multiple surveys of each site) may be used to improve abundance estimates based on call surveys (Corn et al. 2011). Detection of most species, if they are present and calling, occurs within the first few minutes of call surveys, with a sharp decrease in return for effort after this period (Shirose et al. 1997; Gooch et al. 2006; Tupper et al. 2007).

Surveys should be done at appropriate dates and times for each of the four species, based on the patterns identified in this document. Thus, two distinct sets of surveys will be necessary: an early one for wood frogs and boreal chorus frogs, and a later one for western and Canadian toads. Optimal survey periods, based on the analysis presented in this document, for wood frogs and boreal chorus frogs appears to be early to mid-May, and late-May to mid-June for the toads; note that breeding periods can shift between years, so this is just a guideline. On a diurnal basis, the optimal survey period for all four species appears to between 10 PM and 2 AM; this can be verified for the LAPR using automated recorders, as discussed above, and by conducting passive call surveys throughout the day and night.

Amphibian calling activity is related to a variety of environmental factors, potentially influencing the ability of a monitoring program to detect amphibian species at a site (Royle 2004; Weir et al. 2005; Cook et al. 2011). Calling activity is related to parameters such as temperature, light intensity, and barometric pressure, and effects of these factors often differ among species (Oseen and Wassersug 2002; Steelman and Dorcas 2010). These parameters should be recorded during passive call surveys or obtained from local weather stations whenever possible; the automated recorders discussed above can record air and water temperature (using an external thermometer). Analysis of data related to amphibian behaviour (e.g. calling) in light of environmental factors could maximize the efficiency of amphibian monitoring programs by identifying particular conditions that maximize the probability of detection (Tupper et al. 2007).

Monitoring should be done at potential breeding sites; all of the species in the LAPR breed in standing water, though the range of habitat used varies with species (Russell and Bauer 2000). For example, a variety of factors influence actual use of particular aquatic habitats as breeding sites. These include hydroperiod (Wellborn et al. 1996), canopy cover over the pond (Schiersari 2006), and presence of aquatic predators at potential breeding sites (Resetarits and Wilbur 1989; Hopey and Petranka 1994; Hecnar and M'Closkey 1997; Alford and Richards 1999). However, the four species to be sampled in the pilot project exhibit enough overlap in breeding habitat type that it should be possible to optimize the efficiency of the monitoring program by sampling one to a few habitat types (e.g. wetlands of specific types).

The analysis presented in this document did not address specific characteristics of the habitats where amphibian sampling has occurred, but this should be done before the pilot project begins. This analysis should include determination of habitat features (e.g. wetland type, size, depth, etc.) where appropriate surveys were done and each species was, or was not, found to determine what habitat types could be sampled to monitor all of the amphibian species of interest. The pilot project should sample these habitat types (or a subset thereof, depending on how many are identified); to maximize efficiency, this should be done in conjunction with identification of potential wetlands for sampling yellow rails.

Use visual encounter surveys to document distribution and relative abundance of amphibian metamorphs

In addition to the passive call surveys recommended above, we suggest using visual encounter surveys at a subset of sites to document reproductive success of amphibian species that called at a site, and relative quality of the young-of-the-year (YOY) produced at a site. Sites can be chosen for visual surveys randomly (e.g. 25% of sites will be randomly chosen), by species of interest (e.g. all sites where toads were detected during the call survey will be sampled using visual surveys), or by potential impact from anthropogenic activity (e.g. all sites within *x* km of major anthropogenic activity will be sampled). For the pilot project, we recommend using visual encounter surveys to sample all sites where Canadian and/or western toads were detected using call surveys (because there are likely to be fewer of them and less is known about these species), 10 sites where wood frogs were detected calling, and 10 sites where boreal chorus frogs were heard during call surveys.

It is important to document recruitment of YOY into local amphibian populations in order to get a true indication of the quality of that site, and the potential impact of anthropogenic activity on amphibian populations. For example, wetlands constructed using tailings water during the reclamation process in the mineable oil sands region may be relatively inhospitable to amphibians (Pollet and Bendell-Young 2000), though the level of toxicity in these wetlands seems to decline over time (Hersikorn et al. 2010; Hersikorn and Smits 2011). Adult amphibians may live for a relatively long period of time in northern populations - wood frogs live a maximum of four to five years in populations in southern Quebec (Bastien and LeClair 1992; Sagor et al. 1998), Canadian toads in Alberta live up to 7 – 12 years (Eaton et al.

2005), while western toads live up to 8 years (Garret 2005) – so it is possible to detect these species breeding at a site for multiple years before a decline would be noticed if recruitment success is not documented.

Visual encounter surveys are done by walking along the shoreline of a wetland and scanning the terrestrial and aquatic habitats 1 m from the shoreline, for a pre-set distance. We recommend that surveys be done along a 400 m transect centred on the station used during passive call surveys. Animals encountered should be captured, when possible, and identified to species, assigned to an age class, weighed and measured (snout-to-vent-length, SVL), and released at the capture site. The time taken to complete the survey should be recorded, as well as a description of weather during the survey and habitat characteristics of the area surveyed.

Information on metamorph size and weight can be used to indicate the quality of individuals emerging from a wetland, while the number of animals encountered provides a rough indication of the productivity of each site in a given year. Two surveys, at least 24 hours apart, should be done at each site, timed to maximize the probability of encountering the target species. Therefore, surveys for frogs should be done in late June – late July, while those for toads should be done in mid to late August. These are general guidelines, and should be refined using literature, expert opinion of those who have worked on amphibians in the LAPR, and based on data collected during the pilot project.

Collaborate with the yellow rail monitoring program in data collection

We recommend collaborating with the yellow rail monitoring pilot study by surveying for yellow rail and amphibians at the same sites. Amphibians and yellow rails all use wetlands, so performing surveys for both groups at the same sites would be efficient. The pilot test will allow us to determine if there is sufficient overlap in habitat use by the two groups to warrant combining surveys for amphibians and yellow rails in a long term monitoring program.

Evaluate whether it is feasible to use the ABMI's systematic grid for sampling amphibians

We recommend incorporating ABMI wetland sampling sites into the amphibian pilot program to support an assessment of whether amphibian monitoring could be incorporated into the ABMI sampling program. There are 235 ABMI sites within the LAPR, which may be enough to detect regional trends in target amphibians, assuming the majority of these sites contain suitable habitat for these species. Precision analysis to determine how many sites would need to be sampled to detect trends in amphibian abundance has not yet been done, so it is difficult to determine if sampling just the ABMI sites would provide sufficient statistical power; precision analysis should be done as part of the pilot program.

There may be several advantages to collaborating with ABMI in the long-term monitoring program, including: (1) unbiased determination of sampling sites, as the ABMI sampling grid is based on a spatially stratified design across the province on a 20 x 20 km grid with local randomization of each point on that grid; (2) costs of amphibian monitoring could potentially be minimized by building the program it into the existing ABMI program; (3) there is an existing ABMI protocol for identifying wetlands using remote sensing data within 10 km of ABMI sites, resulting in a database of wetlands that could be potentially sampled, either within the ABMI program or as an addition to it; (4) the ABMI has developed protocols for measuring land cover and land use based on air photos around each of their sampling points, data which would be useful in measuring the response of amphibian abundance and distribution to anthropogenic effects.

There are two potential disadvantages to incorporating amphibian monitoring into the ABMI program as it currently exists. These include: (1) selection of wetlands for sampling within the ABMI is based on the presence of more than 1 ha of open water, a depth of 0.5 m or greater in July, well-developed wetland vegetation zones (e.g. emergent zone, wet meadow zone), permanence; not all amphibian species may use these particular wetland types; and (2) current timing of visits to ABMI wetland sites will not allow passive call surveys for all of the target species, as wood frog and chorus frog breeding takes place too soon to be captured by ABMI field crews, though the timing may be appropriate for toads at some sites.

We recommend that an assessment of the feasibility of incorporating amphibian monitoring into the ABMI program include comparison of wetlands sampled by the ABMI to a random sample of other wetland types in the region to determine if there are potential biases in terms of amphibian detectability at AMBI wetlands. This could be accomplished by using the database of wetlands developed by the ABMI during their wetland selection process to randomly select additional wetlands for sampling, with the caveat that, to maintain logistic efficiency for the pilot program, these sites should be accessible by ground vehicle. In addition, the selection of wetland types (e.g. based on size, vegetation characteristics, etc.) to be used in the pilot should be kept small to ensure that there is statistical power to compare amphibian detection rates, abundance, etc., between these types. If there are biases in the ABMI wetland sampling protocol that have a significant impact on the ability of the amphibian monitoring program to detect trends in amphibian occurrence and/or abundance, then incorporation of amphibian sampling into the ABMI will not be possible. As it stands, the timing of the passive call surveys will probably not work for incorporation of amphibian monitoring fully into the existing ABMI program, but other elements of the ABMI, such as land use and land cover data, and access to a database of potential sampling wetlands, might be useful in a long-term amphibian monitoring program.

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Appendix A - Structure of Amphibia_ver1 database

Amphibia_ver1 is a database hosted on the BOREAL server at the University of Alberta (boreal.biology.ualberta.ca/BOREAL). The data in Amphibia_ver1 is stored in SQL Server 2008 which is password protected. Access to these data can be made via Open Database Connectivity standards (hereafter ODBC) as described in Appendix 2. Requests to access the data can be made to Suzanne Cote (scote@ualberta.ca) and upon approval a user name and password will be provided by Dr. Erin Bayne (bayne@ualberta.ca). Any software that allows ODBC can be used to access the database.

For the EMCLA team, a Microsoft Access front-end to access the database is available at (https://sharepoint.abmi.ca/emc/pt/). How to download and use the front-end is described in Appendix 2. A front-end is a software interface that allows a user to call data from SQL Server and was used to run the queries that provide the information in this report. The original data provided by different parties that was combined to create Amphibia_ver1 is stored in the EMCLA extranet as a series of Microsoft Excel tables.

Amphibia_ver1 consists of 6 main tables. Variables in each table are described in Appendix 3.

1) tblPROJECT identifies the parties that contributed data. The details of the methods that were used to collect the data are also listed here. Whether or not ancillary data like weather or time of survey were provided by the project is also listed. Limitations on use are described here. The primary key for this table is PCODE.
2) tblXY gives the spatial coordinates of each point where a survey was done. Data are provided as latitude and longitude in decimal degrees. An accuracy assessment of the location where the survey was done is provided. Accuracy was based on whether a

global positioning system (hereafter GPS) was used, locations were scrambled (ABMI), or data came from approximate locations (i.e. section or township ID's given). The primary key for this table is XY_KEY.

3) tblPKEY gives the details of the conditions at the time of survey. Variables like date, time, and weather at the exact time of the survey (if recorded) are reported here. The primary key for this table is PKEY.
4) tblCOUNT gives the number of individuals counted at each location. A species column also exists. If no amphibians were detected in a survey the species is called NONE and is given a count of zero for #Individuals. #Individuals records whether more than one amphibian of a species was counted. The primary key for this table is RECORDID.
5) tblPROTOCOLS lists the method used to make an observation of an amphibian. The primary key is SurveyType.
6) tblSPECIES_CODES lists the common and scientific name that identifies the code used to describe each species. SPECIES is the primary key.

Tables can be joined in one to many relationships to extract the elements of the data that are required. Figure A1 shows the relationships between tables in the database.

Figure A1. Relationships between core data tables in Amphibia_ver1 database.