EMCLA AMPHIBIAN MONITORING

USING WILDLIFE ACOUSTICS SM2 DETECTOR

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EXECUTIVE SUMMARY:

In 2012, the EMCLA (Environmental Monitoring Committee of the Lower Athabasca) monitored amphibians in the Lower Athabasca region of Alberta. We used the Wildlife Acoustics Songmeter SM2 (http://www.wildlifeacoustics.com/) recorder and standard nocturnal point counts to detect amphibians near wetlands and some upland forest sites in the Lower Athabasca region.

We sampled for amphibians at 29 sites which were about the size of a township. A site consisted of 6-10 stations where a single audio recorder was placed for a total of 273 stations. Stations were about 1km apart. Specifically, we sampled for amphibians and other acoustic species along the edge of roads, forest interiors, and predominately at wetland edges as part of the larger EMCLA program.

For amphibians we listened to 23,060 recordings in 1-minute segments. We then calculated the probability of observation per minute, which is the product of whether the species was present and gave a call that the observer detected. Five amphibians were detected in the following rank order: Boreal Chorus Frog (16.5%) > Wood Frog (12.8%) > Western Toad (1.4%) > Canadian Toad (0.6%) > Northern Leopard Frog (0.01%). The Northern Leopard Frog detection has been debated by experts who have listened to the recordings. This station was at McLelland Lake where CATO were also located so we plan to place more recorders in this area. Collapsing the data into simple presence - not observed per station, we found the Boreal Chorus Frog (60%) > Wood Frog (48%) > Western Toad (13%) > Canadian Toad (3%) > and possibly a Northern Leopard Frog at one station.

Using these data we created a presence – “absence” model using logistic regression for each species that included proportion MARSH, SWAMP, FEN, BOG, UPLAND within 100metres as well as distance to OPEN WATER. The number of minutes of recording that were processed was included as a covariate as well as average Julian date for the recordings processed. Only recordings from 8 PM to 6 AM were included in this analysis because amphibians were rarely detected outside these times. There were no significant differences between habitat classes for the toads but there were significant differences for the frogs.

A more detailed presence – available model was created for CATO using all known presences of the species as of October 2012. This model while “predictive” also

showed the generality of the CATO and provided relatively little insight as to where sampling should occur to maximize CATO detections.

ARUs were equal or better at detecting amphibians than human observers.

All results in this report should be viewed as preliminary and are subject to change as more analysis is done and ARU recordings processed.

CANADIAN TOAD HABITAT SELECTION:

We detected Canadian Toads during 24 unique 10-minute periods using ARUs. These detections occurred at 7 stations. The maximum number of toads detected per station was 2. Spatial coordinates are reported in UTM Zone 12 – NAD 83.

Table 1 – Locations where CATO were located by ARU.

CODE	SITE	SITE#	STATION	EASTING	NORTHING	#IND
CATO	Bohn Lake (Janvier)	12	WI3	490502	6197842	1
CATO	CNRL Primrose/ Wolf Lake	29	WSC2	518770	6056927	1
CATO	Cowper Lake	14	RC2	526436	6185704	1
CATO	McLelland Lake	28	WC4	478448	6372707	2
CATO	McLelland Lake	28	WI3	479373	6374633	2
CATO	Pony Creek	13	WSI1	509283	6187905	1
CATO	Suncor-MacKay River	26	WSI1	443487	6324806	1

The habitat where we located CATO was highly variable. Most of the locations were in or adjacent to wetlands, but one CATO was located at a road station in a fen and another was very close to a processing plant near a stream. In the attachment, we show images of the sites where CATO were located. Our results are consistent with the data we accumulated from FWMIS and company databases in the development of previous reports. What is obvious is that there is no clear “habitat strata” that must be sampled to increase detection of CATO. CATO may have very specific habitat requirements but these are not well described by current GIS data layers or at the scales we have considered thus far. We are currently investigating if the Alberta Wet Areas Mapping Layer aids in predicting small bodies of water or areas that have wetter soils to see if we can improve prediction.

Using the ARU data alone, there were no significant relationships derived for CATO and any habitat variables. Figure 1 shows the probability of observation when we created habitat classes based on a majority rule using the Alberta wetland layer within 100 metres of the survey point. More data is required to draw firm conclusions about differences in habitat selection for the CATO as none of these differences were significant. Distance to open water was not a significant predictor either. The only significant predictors were the date of survey, average survey hour, and the number of minutes of ARU processing done. This indicates that more listening to ARU recordings may further increase detections, as CATO do not seem to call that frequently. We are currently working on an automated recognizer to see if we can increase processing speed for this step. A more detailed used versus available model for CATO is provided below that uses all known CATO locations in the province. It too shows an wide breadth of habitats used by the CATO and no strong patterns of habitat use or selection.

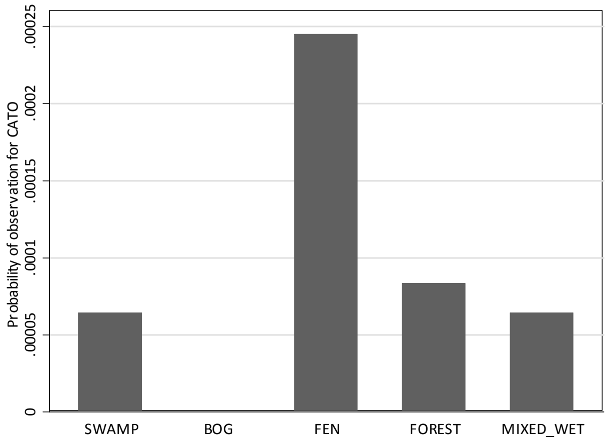

Figure 1 – Probability of observation of CATO in five different habitat classes (within 100 m of survey point). Results are shown for average time of day and average Julian date and after 60 minutes of listening.

WESTERN TOAD:

We detected WETO during 72 unique 10-minute periods. These detections occurred at 34 stations. The maximum number of toads detected per station was 2. The habitat categories were not statistically significant predictors of WETO. Nor was the distance to open water. The only significant predictors were the date of survey, average survey hour, and the number of minutes of observation. This indicates that more processing of ARU recordings may increase detections, but also that WETO have relatively general habitat requirements based on the coarse habitat categories used here. Trends were strong however and suggest WETO is more likely to be found in bogs and fens than in more upland areas.

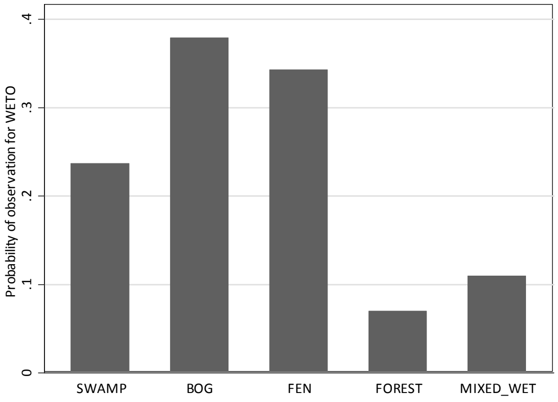

Figure 2 - Probability of observation of WETO in five different habitat classes (within 100 m of survey point). Results are shown for average time of day and average Julian date and after 60 minutes of listening.

BOREAL CHORUS FROG:

We detected BCFR during 596 unique 10-minute periods. These detections occurred at 163 stations. The maximum number of frogs detected per station was TMTC (Too many to count). The habitat categories were statistically different with the highest probability of observation being in SWAMP and lowest in FOREST. Distance to open water was significant and showed a distinct threshold at 600 metres. BCFR were ubiquitous in areas near open water and only dropped in probability of observation when the ARU was 500-600 metres from open water. Even then the probability of observation remained quite high suggesting ephemeral water or even areas with moist soils provide habitat for calling adults.

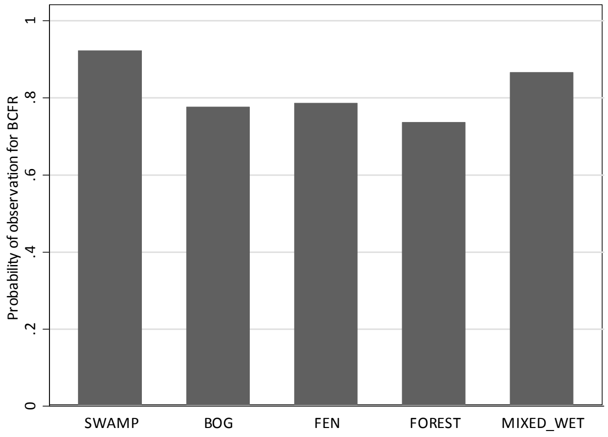

Figure 3 - Probability of observation of BCFR in five different habitat classes (within 100 m of survey point). Results are shown for average time of day and average Julian date and after 60 minutes of listening. Distance to near water is set to 50m.

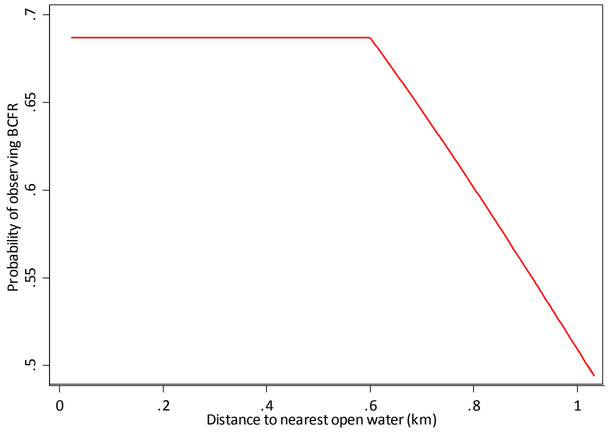

Figure 4 - Probability of observation for BCFR as a function of distance to nearest open water.

WOOD FROG:

We detected WOFR during 544 unique 10-minute periods. These detections occurred at 130 stations. The maximum number of frogs detected per station was TMTC (Too many to count). The habitat categories were statistically different with the probability of observation being lowest in BOG than all other categories. Distance to open water was also significant but showed a distinct threshold at 500 metres. In contrast to BCFR, WOFR probability of observation was more tightly linked to open water proximity. WOFR seemed to be more likely observed close to open water than the other amphibians but still are relatively easy to find at distances > 500 m from wetlands.

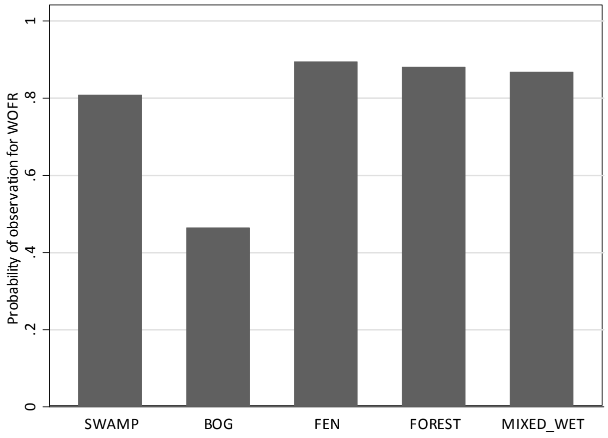

Figure 5 **-** Probability of observation of BCFR in five different habitat classes (within 100 m of survey point). Results are shown for average time of day and average Julian date and after 60 minutes of listening. Distance to near water is set to 50m.

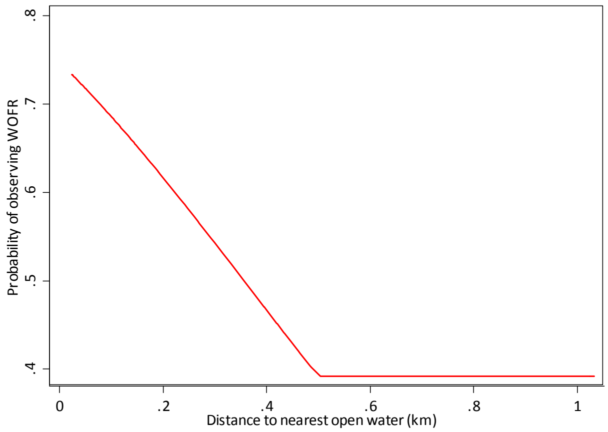

Figure 6 **-** Probability of observation for WOFR as a function of distance to nearest open water.

CANADIAN TOAD – USED VERSUS AVAILABLE MODEL:

We re-analyzed historical and integrated the 2012 Canadian toad data from the LAPR. Specifically, we compared habitat at Canadian toad locations to where we surveyed in 2012 to identify whether we under-sampled Canadian toad habitat based on previous detections by other surveys. We also summarized habitat characteristics at sites where Canadian toad were detected and statistically compared them to habitat at sites where they were not detected using a resource selection function (RSF) modeling approach (Boyce and MacDonald 1999; Manly 2002).

We measured remotely sensed habitat covariates at historic Canadian toad locations collected in 2011 (Eaton et al. 2011). Then we compared that to remotely sensed habitat measured at ARU sites surveyed in 2012. The purpose was to test whether we could accurately predict Canadian toad occurrences using remotely sensed habitat data and whether we adequately sampled Canadian toad habitat as part of the 2012 pilot monitoring program.

We measured habitat within 100 m (fine-grained scale) and 1,000 m (coarse-grained scale) circular radius buffers at each historic Canadian toad location and ARU site. The fine-grained scale represents the immediate wetland type used by Canadian toads, whereas the coarse-grained scale may represent the wetland complex used by Canadian toads. The habitat covariates that we measured were:

- vegetation cover type (Castilla et al. 2012)
- wetland type (Ducks Unlimited 2012)
- moisture regime (Alberta Environment and Sustainable Resource Development [AESRD] 2011)
- canopy cover density (AESRD 2011)
- human footprint type (ABMI 2012)

We summarized average values of each habitat covariate within buffers and conducted a Mann-Whitney U test with Bonferroni corrected p-values (i.e., $p<0.0007$) to compare whether habitat types sampled at ARU sites were statistically different from habitat at historic sites where Canadian Toads were known to have occurred.

We compared habitat covariates measured at historic locations to habitat measured at randomly sampled locations within the LAPR (i.e., at 5 km intervals). We modelled Canadian toad occurrence using logistic regression models that included different combinations of covariates, including wetland types (i.e., bogs, swamps, marshes, rich graminoid fens, rich shrub fens and other fens) and vegetation cover types (i.e., forest, shrub, grass, other). We fit a model for covariates measured within 100 m buffers (fine-grain scale) and one for covariates measured within 1,000 m buffers (coarse-grain). Model fit and parsimony were compared using Akaike Information Criterion (AIC), where models with low AIC values have relatively good statistical fit without being overfit (i.e., more covariates than necessary) to the data (Burnham and Anderson 1998). Model(s) that had delta AIC <2 from the minimum AIC value model (Burnham and Anderson

1998) were considered the top models at modelling the relationship between Canadian toad presence and habitat. We calculated a k-fold cross validation to see how predictive each model was, where the model is fit using 80% of the data and its predictability is tested on the withheld 20% of the data for five iterations (Boyce et al. 2002). Finally, we calculated a spatial prediction of Canadian toad relative probability of occurrence across the LAPR at 100 m and 1,000 m scales.

Results

Canadian toad locations were typically located in mesic and wet soil moisture environments at both fine- and coarse-grain scales (Table 2). Canadian toad also used open habitats (i.e., <31% canopy closure) with little forest cover perhaps with the exception of some black spruce and aspen forests. Canadian toad primarily occurred in upland sites, but also occurred in some fen types, treed bogs and shrubby areas, and conifer swamps. Canadian toad occurred in a variety of vegetation types, including shrublands, grasslands and forests and were present in areas with some low-human density industrial activity but otherwise were located in areas with little human footprint.

We found that according to Mann-Whitney U tests (Table 3) we did not under-sample Canadian toad habitat in 2012. We may have under-sampled slightly mesic ($z = -4.486$, $p < 0.0001$), balsam polar ($z = -5.805$, $p < 0.0001$), developed ($z = -3.560$, $p < 0.0001$) and footprinted ($z = -4.696$, $p < 0.0001$) sites at the fine-grained scale, and balsam poplar ($z = -4.989$, $p < 0.0001$), uplands ($z = -5.511$, $p < 0.0001$), mixedwood forest ($z = -5.295$, $p < 0.0001$) and some footprint types at coarse-grained scale.

RSF models fit at fine- and coarse-grained scales that included both wetland and landcover covariates ranked highest according to AIC scores (Table 4). Proportion of grassland, shrubland, conifer and mixed-broadleaf forests were retained as landcover covariates at the fine-grained scale (Table 5). Proportion of upland, swamp, bog, rich fens, emergent marsh, and graminoid, shrubby and treed poor fens were retained as wetland covariates at the fine-grained scale (Table 5). Proportion of upland, swamp, shrubby and treed bogs, graminoid, shrubby and treed rich fens, emergent marsh, and graminoid, shrubby and treed poor fens were retained as wetland covariates at the coarse- grained scale (Table 5).

In the fine-grained RSF model, Canadian toad avoided sites with a high proportion of developed, grassland and upland forest landcover types (Table 5). They strongly avoided shrubby poor fens. At the coarse-grained scale, Canadian toad avoided sites with a high proportion of developed, grassland and forest landcover types. They also avoided shrubby bogs, emergent marshes and shrubby poor fens.

RSF models were on average good predictors of Canadian toad habitat selection at fine- ($\rho_{avg} = 0.76$) and coarse-grained ($\rho_{avg} = 0.90$) scales according to k-fold cross validation (Table 6). The coarse-grained model validation should be used with caution, however, as the k-fold models may be overfit to data. We found negative statistical relationships between Canadian toad occurrence and all landcover and wetland types at this scale, perhaps indicating the model was overfit and that in reality none of the covariates predicted Canadian toad habitat selection particularly well.

We produced a predictive model of Canadian toad occurrence across the LAPR using our RSF model (Fig. 7). **We caution that this RSF model should not be widely applied to predict Canadian toad occurrence at this time, particularly for mitigating anthropogenic impacts on Canadian toad or their habitat.** We apply our model simply because no other regional-scale model of Canadian toad distribution exists. Our model should be refined with more refined remote sensing products and should focus on presence-absence or count data as available with ARUs as detections increase. .

Table 2. Proportion of habitat in 100 m and 1,000 m buffers around historic Canadian toad locations in the Lower Athabasca Planning Region (LAPR) of northeast Alberta.

	Buffer radius around historic Canadian toad detections	
Habitat Feature (mean proportion of buffer, standard deviation in parantheses)	100 meter	1,000 meter
*Moisture Class**		
No data (blank)	0.23 (0.33)	0.13 (0.23)
Dry	0.01 (0.07)	<0.01 (0.02)
Mesic	0.40 (0.38)	0.44 (0.27)
Wet	0.36 (0.38)	0.35 (0.26)
Aquatic	0.01 (0.09)	<0.01 (0.01)
*Canopy Closure Class**		
<6% forest canopy closure	0.42 (0.36)	0.25 (0.24)
6-30% forest canopy closure	0.09 (0.21)	0.10 (0.11)
31-50% forest canopy closure	0.15 (0.25)	0.17 (0.14)
51-70% forest canopy closure	0.24 (0.28)	0.29 (0.18)
>70% forest canopy closure	0.10 (0.23)	0.11 (0.14)
*Dominant Forest Species**		
No forest species	0.42 (0.36)	0.25 (0.24)
White Spruce	0.03 (0.10)	0.04 (0.06)
Black Spruce	0.16 (0.26)	0.20 (0.18)
Lodgepole Pine	0	0
Jack Pine	0.05 (0.17)	0.06 (0.12)
Balsam Fir	0	<0.01 (<0.01)
Tamarack	0.05 (0.19)	0.05 (0.11)

	Buffer radius around historic Canadian toad detections	
Habitat Feature (mean proportion of buffer, standard deviation in parantheses)	100 meter	1,000 meter
Trembling Aspen	0.26 (0.33)	0.29 (0.21)
Balsam Poplar	0.01 (0.07)	0.01 (0.04)
Paper Birch	0.01 (0.07)	0.01 (0.02)
*Sub-dominant Forest Species**		
No forest species	0.71 (0.31)	0.56 (0.25)
White Spruce	0.05 (0.13)	0.06 (0.06)
Black Spruce	0.05 (0.16)	0.05 (0.07)
Lodgepole Pine	0	0
Jack Pine	0.03 (0.10)	0.04 (0.05)
Balsam Fir	<0.01 (0.02)	<0.01 (0.01)
Tamarack	0.04 (0.15)	0.06 (0.10)
Trembling Aspen	0.04 (0.11)	0.06 (0.06)
Balsam Poplar	0.07 (0.20)	0.09 (0.15)
Paper Birch	0.02 (0.08)	0.01 (0.03)
Wetland Class[†]		
Upland	0.61 (0.35)	0.64 (0.25)
Emergent Marsh	0.02 (0.06)	<0.01 (0.01)
Meadow Marsh	<0.01 (0.01)	<0.01 (0.01)
Graminoid Rich Fen	0.01 (0.07)	<0.01 (0.02)
Graminoid Poor Fen	<0.01 (0.03)	<0.01 (0.02)
Shrubby Rich Fen	0.05 (0.13)	0.03 (0.06)
Shrubby Poor Fen	<0.01 (0.01)	<0.01 (0.01)
Treed Rich Fen	0.07 (0.12)	0.07 (0.07)
Treed Poor Fen	0.09 (0.16)	0.10 (0.10)

	Buffer radius around historic Canadian toad detections	
Habitat Feature (mean proportion of buffer, standard deviation in parantheses)	100 meter	1,000 meter
Open Bog	0	<0.01 (<0.01)
Shrubby Bog	<0.01 (0.02)	<0.01 (<0.01)
Treed Bog	0.04 (0.10)	0.04 (0.07)
Shrub Swamp	0.04 (0.13)	<0.01 (0.02)
Hardwood Swamp	0.01 (0.05)	<0.01 (0.02)
Mixedwood Swamp	<0.01 (0.02)	<0.01 (0.01)
Tamarack Swamp	<0.01 (0.03)	<0.01 (0.01)
Conifer Swamp	0.03 (0.08)	0.06 (0.07)
Landcover Class‡		
Water	0.12 (0.28)	0.10 (0.19)
Snow/Ice	0	0
Rock/Rubble	0	<0.01 (0.01)
Exposed Land	0.04 (0.18)	0.02 (0.08)
Developed	0.13 (0.22)	0.05 (0.06)
Shrubland	0.10 (0.24)	0.08 (0.14)
Grassland	0.13 (0.26)	0.08 (0.10)
Agriculture	0.01 (0.09)	0.01 (0.07)
Conifer Forest	0.22 (0.34)	0.32 (0.26)
Broadleaf Forest	0.18 (0.31)	0.24 (0.21)
Mixedwood Forest	0.08 (0.20)	0.09 (0.10)
*Human Footprint Class***		
Residential Urban	<0.01 (0.05)	<0.01 (0.02)
Residential Rural	<0.01 (0.02)	<0.01 (0.02)
Urban/Rural Greenspace	<0.01 (0.04)	<0.01 (0.02)

	Buffer radius around historic Canadian toad detections	
Habitat Feature (mean proportion of buffer, standard deviation in parantheses)	100 meter	1,000 meter
High-human Density Commercial/Industrial	0.03 (0.17)	0.02 (0.11)
Low-human Density Industrial	0.10 (0.23)	0.08 (0.15)
Hard linear road/rail/industrial features >20 m wide	<0.01 (0.02)	<0.01 (<0.01)
Hard linear road/rail/industrial features 10-20 m wide	<0.01 (0.02)	<0.01 (<0.01)
Soft linear urban/industrial features 10-20 m wide	0.03 (0.07)	0.01 (0.01)
Soft linear urban/industrial features 2-10 m wide	0.01 (0.02)	0.01 (0.01)
Vegetated Road	0.01 (0.02)	<0.01 (<0.01)
Vegetated verges and ditches along roads	0.02 (0.05)	<0.01 (0.01)
Dugout	<0.01 (0.01)	<0.01 (<0.01)
Lagoon	0	<0.01 (0.02)
Reservoir	<0.01 (0.05)	0
Agriculture	0.01 (0.10)	0.01 (0.07)
Pasture	0	<0.01 (<0.01)
Forestry Clear Cut	0.04 (0.06)	0.05 (0.04)

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* Source: Alberta Environment and Sustainable Resource Development. 2011. Alberta Vegetation Inventory (AVI) Crown Polygons. Government of Alberta, Edmonton, Alberta. Available from: http://www.srd.alberta.ca/LandsForests/VegetationInventoryStandards.aspx

† Source: Canadian Wetland Inventory. 2012. Ducks Unlimited. Available from: http://maps.ducks.ca/cwi/

‡ Source: Alberta landcover classification map. 2012. Alberta Biodiversity Monitoring Institute. Available from: http://abmi.ca/abmi/home/home.jsp

** Source: Alberta human footprint classification map. 2012. Alberta Biodiversity Monitoring Institute. Available from: http://abmi.ca/abmi/home/home.jsp

Table 3. Significant differences between proportion of habitat in 100 m and 1,000 m buffers around historic Canadian toad locations and autonomous recording unit (ARU) sites in the Lower Athabasca Planning Region (LAPR) of northeast Alberta. Over-sampling is indicated by ↑ and under-sampling by ↓. Mann-Whitney test z values and p-values are indicated in parenthesis.

	Buffer radius around historic Canadian toad detections	
Habitat Feature (significant Mann-Whitney test)	100 meter	1,000 meter
*Moisture Class**		
No data (blank)	-	-
Dry	-	-
Mesic	↓ ($z = -4.486$, $p < 0.0001$)	-
Wet	↑ ($z = 7.669$, $p < 0.0001$)	↑ ($z = 8.169$, $p < 0.0001$)
Aquatic	-	-
*Canopy Closure Class**		
<6% forest canopy closure	-	-
6-30% forest canopy closure	↑ ($z = 4.144$, $p < 0.0001$)	↑ ($z = 6.081$, $p < 0.0001$)
31-50% forest canopy closure	-	↑ ($z = 6.233$, $p < 0.0001$)
51-70% forest canopy closure	-	-
>70% forest canopy closure	-	-
*Dominant Forest Species**		
No forest species	-	-
White Spruce	-	-
Black Spruce	-	-
Lodgepole Pine	↑ ($z = 5.126$, $p < 0.0001$)	↑ ($z = 7.699$, $p < 0.0001$)
Jack Pine	-	-
Balsam Fir	-	↑ ($z = 5.425$, $p < 0.0001$)
Tamarack	-	-
Trembling Aspen	-	-

	Buffer radius around historic Canadian toad detections	
Habitat Feature (significant Mann-Whitney test)	100 meter	1,000 meter
Balsam Poplar	↓ ($z = -5.805$, $p < 0.0001$)	↓ ($z = -4.989$, $p < 0.0001$)
Paper Birch	-	-
*Sub-dominant Forest Species**		
No forest species	-	-
White Spruce	-	↓ ($z = -4.001$, $p < 0.0001$)
Black Spruce	-	↑ ($z = 5.518$, $p < 0.0001$)
Lodgepole Pine	↑ ($z = 4.153$, $p < 0.0001$)	-
Jack Pine	-	↑ ($z = 5.885$, $p < 0.0001$)
Balsam Fir	-	-
Tamarack	-	-
Trembling Aspen	-	-
Balsam Poplar	-	↓ ($z = -6.413$, $p < 0.0001$)
Paper Birch	-	-
Wetland Class[†]		
Upland	-	↓ ($z = -5.511$, $p < 0.0001$)
Emergent Marsh	-	-
Meadow Marsh	-	-
Graminoid Rich Fen	-	-
Graminoid Poor Fen	↑ ($z = 4.183$, $p < 0.0001$)	-
Shrubby Rich Fen	-	-
Shrubby Poor Fen	-	-
Treed Rich Fen	↑ ($z = 5.608$, $p < 0.0001$)	↑ ($z = 8.119$, $p < 0.0001$)
Treed Poor Fen	-	-
Open Bog	-	↑ ($z = 4.875$, $p < 0.0001$)

	Buffer radius around historic Canadian toad detections	
Habitat Feature (significant Mann-Whitney test)	100 meter	1,000 meter
Shrubby Bog	-	-
Treed Bog	-	↑ ($z = 4.980$, $p < 0.0001$)
Shrub Swamp	↑ ($z = 3.736$, $p = 0.0002$)	↑ ($z = 5.390$, $p < 0.0001$)
Hardwood Swamp	-	-
Mixedwood Swamp	-	↑ ($z = 4.554$, $p < 0.0001$)
Tamarack Swamp	-	↑ ($z = 3.684$, $p = 0.0002$)
Conifer Swamp	-	-
Landcover Class[‡]		
Water	-	-
Snow/Ice	-	-
Rock/Rubble	-	-
Exposed Land	-	-
Developed	↓ ($z = -3.560$, $p = 0.0004$)	-
Shrubland	-	-
Grassland	-	-
Agriculture	-	↑ ($z = 4.571$, $p < 0.0001$)
Conifer Forest	-	-
Broadleaf Forest	↑ ($z = 6.218$, $p < 0.0001$)	↑ ($z = 8.038$, $p < 0.0001$)
Mixedwood Forest	-	↓ ($z = -5.295$, $p = 0.0004$)
*Human Footprint Class***		
Residential Urban	-	-
Residential Rural	-	↓ ($z = -3.869$, $p = 0.0001$)
Urban/Rural Greenspace	-	-
High-human Density Commercial/Industrial	-	-
Low-human Density Industrial	↓ ($z = -4.696$, $p < 0.0001$)	↓ ($z = -7.445$, $p < 0.0001$)

	Buffer radius around historic Canadian toad detections	
Habitat Feature (significant Mann-Whitney test)	100 meter	1,000 meter
Hard linear road/rail/industrial features >20 m wide	-	↓ (z = -5.364, p < 0.0001)
Hard linear road/rail/industrial features 10-20 m wide	-	↑ (z = 3.812, p = 0.0001)
Soft linear urban/industrial features 10-20 m wide	-	↑ (z = 4.013, p = 0.0001)
Soft linear urban/industrial features 2-10 m wide	-	-
Vegetated Road	-	-
Vegetated verges and ditches along roads	-	-
Dugout	-	-
Lagoon	-	-
Reservoir	-	-
Agriculture	-	-
Pasture	-	-
Forestry Clear Cut	-	-

* Source: Alberta Environment and Sustainable Resource Development. 2011. Alberta Vegetation Inventory (AVI) Crown Polygons. Government of Alberta, Edmonton, Alberta. Available from: http://www.srd.alberta.ca/LandsForests/VegetationInventoryStandards.aspx

† Source: Canadian Wetland Inventory. 2012. Ducks Unlimited. Available from: http://maps.ducks.ca/cwi/

‡ Source: Alberta landcover classification map. 2012. Alberta Biodiversity Monitoring Institute. Available from: http://abmi.ca/abmi/home/home.jsp

** Source: Alberta human footprint classification map. 2012. Alberta Biodiversity Monitoring Institute. Available from: http://abmi.ca/abmi/home/home.jsp

Table 4. Ranking of resource selection function (RSF) models for Canadian toad at small (100 m buffer) and large (1,000 m) scales in northeast Alberta.

	100 meter buffer			1,000 meter buffer		
Model	AIC	ΔAIC	AIC weight	AIC	ΔAIC	AIC weight
Wetland + Landcover	881.6	0.0	1.000	765.75	0.00	1.000
Wetland	904.0	22.4	0.000	878.29	112.54	0.000
Landcover	928.0	46.5	0.000	894.70	128.95	0.000

Table 5. Beta coefficients, standard errors, z and p-values of covariates used to model Canadian toad habitat selection at small (100 m buffer) and large (1,000 m buffer) scales in northeast Alberta.

	100 meter buffer				1,000 meter buffer			
Covariate	β	SE	z	p-value	β	SE	z	p-value
Water	-2.60	1.36	-1.910	0.056	-2.74	4.25	-0.640	0.519
Developed	-3.69	1.34	-2.760	0.006	-11.47	4.53	-2.530	0.011
Grassland	-3.12	1.38	-2.250	0.024	-10.17	3.91	-2.600	0.009
Shrubland	-2.66	1.41	-1.890	0.059	-5.26	4.09	-1.290	0.198
Conifer Forest	-4.12	1.36	-3.020	0.002	-10.56	3.80	-2.780	0.005
Mixed and Broadleaf Forests	-3.58	1.34	-2.680	0.007	-7.70	3.75	-2.050	0.040
Upland	3.24	1.43	2.270	0.023	-61.57	35.39	-1.740	0.082
Swamp	2.01	1.47	1.370	0.170	-61.47	35.55	-1.730	0.084
Bog	1.15	1.57	0.730	0.463	-	-	-	-
Shrubby Bog	-	-	-	-	-109.48	43.22	-2.530	0.011
Treed Bog	-	-	-	-	-67.24	35.35	-1.900	0.057
Rich Fens	2.14	1.44	1.480	0.139	-	-	-	-
Graminoid Rich Fen	-	-	-	-	-51.32	36.12	-1.420	0.155
Shrubby Rich Fen	-	-	-	-	-50.99	36.12	-1.410	0.158
Treed Rich Fen	-	-	-	-	-62.94	35.31	-1.780	0.075
Emergent Marsh	3.59	1.98	1.820	0.069	-92.11	39.31	-2.340	0.019
Graminoid Poor Fen	1.25	1.86	0.670	0.500	-61.66	35.73	-1.730	0.084
Shrubby Poor Fen	-12.97	4.53	-2.860	0.004	-156.45	49.67	-3.150	0.002
Treed Poor Fen	2.52	1.51	1.670	0.095	-57.77	35.22	-1.640	0.101
Constant	1.39	1.95	0.710	0.478	71.09	35.87	1.980	0.047

Table 6. Spearman correlation coefficients (*ρ*) from k-fold cross validation of resource selection function models of Canadian toad in northeast Alberta at two different scales (100 m and 1,000 m).

	Spearman ρ	
Group	100 meter buffer	1,000 meter buffer
1	0.72	0.92
2	0.89	0.94
3	0.68	0.84
4	0.80	0.85
5	0.70	0.94
Average	0.76	0.90

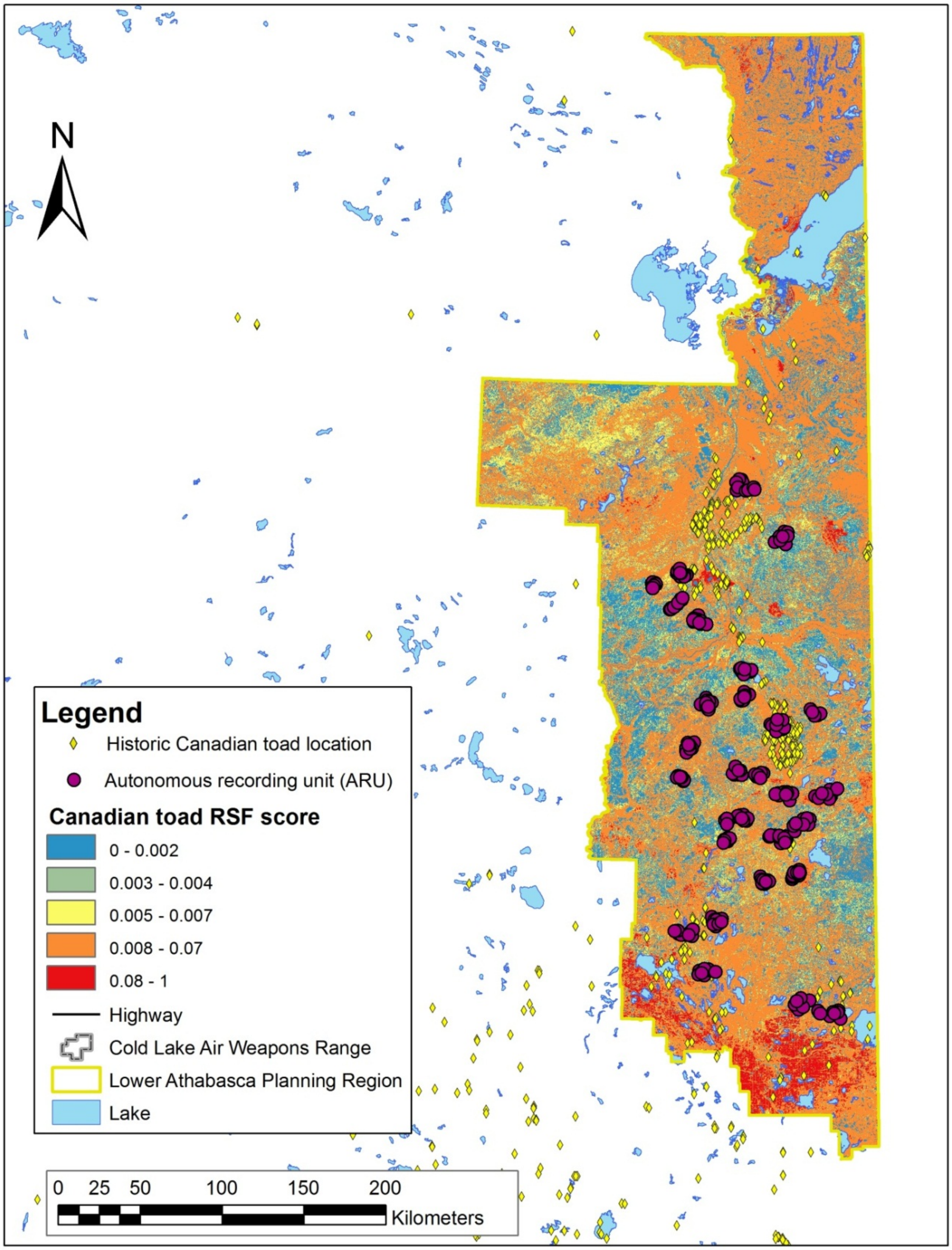

Figure 7. Map of historic Canadian toad locations, 2012 autonomous recording unit (ARU) sample sites relative to Canadian toad resource selction function (RSF) scores in northeast Alberta. RSF scores are classfiied into geometrical intervals to ensure the same number of values within each class because RSF data are not normally distributed.

SEASONALITY OF CALLING:

Using the 1-minute intervals, we created a mixed model to evaluate when the probability of observation per minute was highest seasonally for ARU recordings processed between 8 PM to 6 AM. There was considerable seasonal variation between species in their peaks. This model accounts for the station where the recording was made and shows a higher probability of observation early in the season for WOFR > CATO > BCFR > WETO .

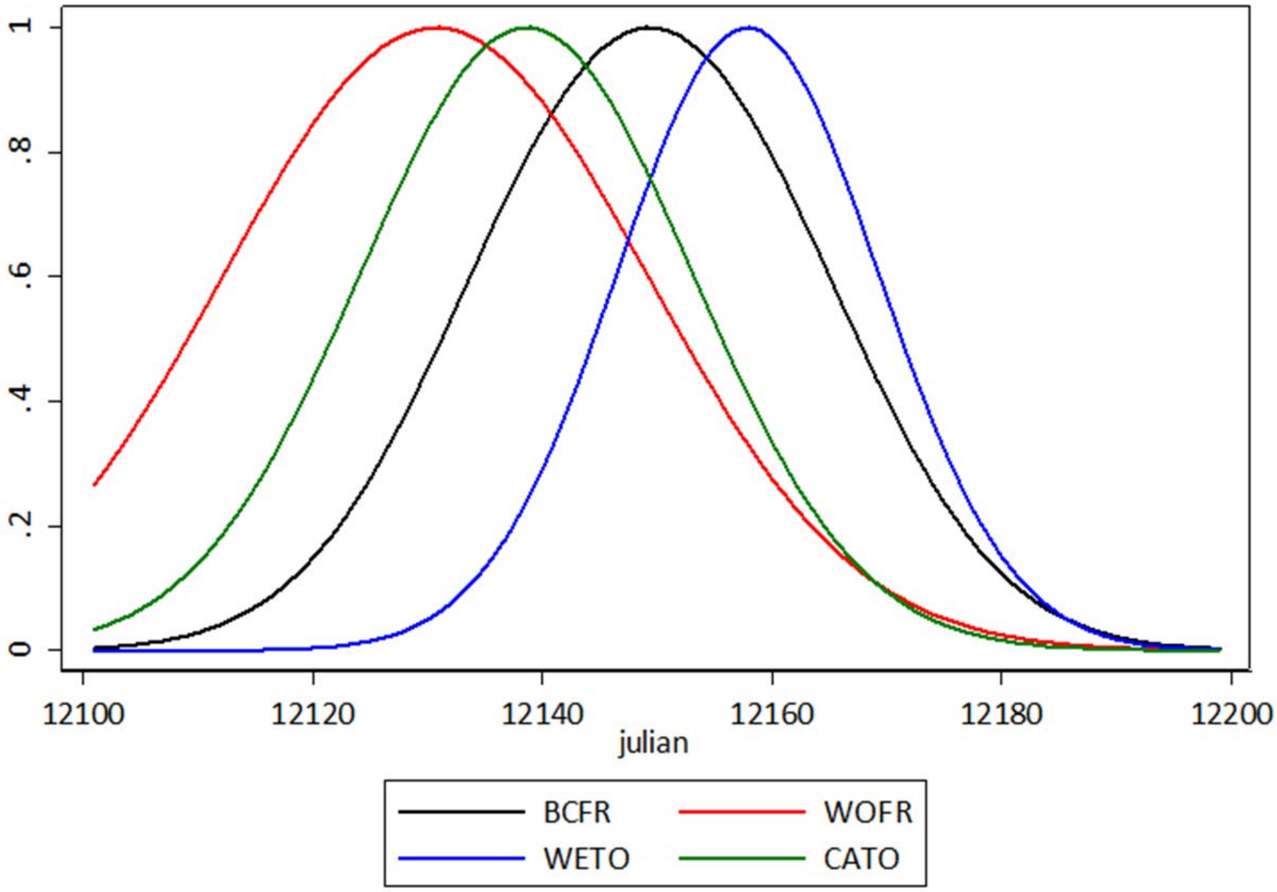

Figure 8 - Standardized rates of probability of observation among 4 species. Peak is the standardized maximum probability of observation for each species. Day 130 is May 10 and Day 160 is June 8 which is the span between the peaks of the different species.

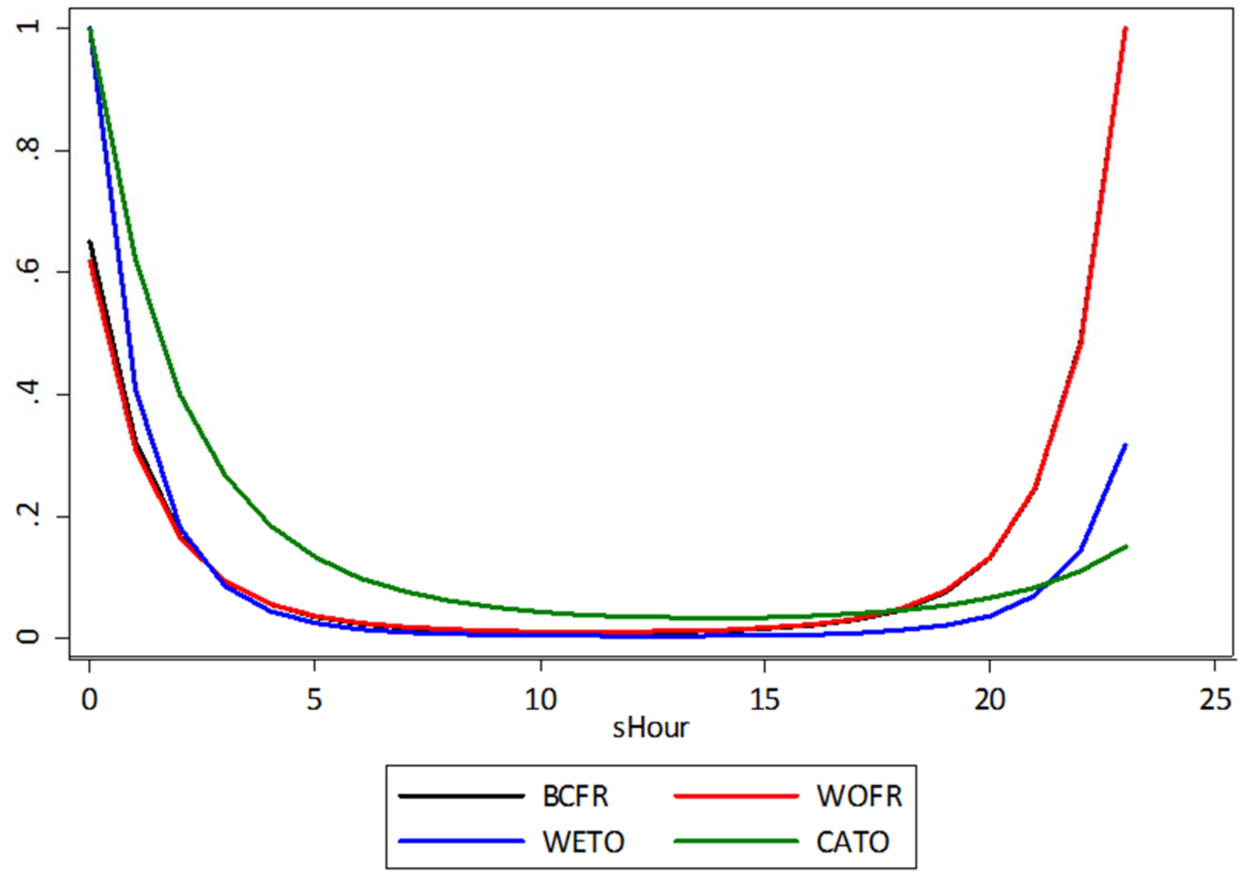

Figure 9 – Standardized rates of probability of observation among 4 species. Peak is the standardized maximum probability of observation for each species by hour of day.

COMPARING ARU to HUMAN OBSERVERS:

When we placed the ARUs out, we also had a person visit 214 of the same locations between 10 PM and 4 AM. This was done primarily to conduct Yellow Rail playback surveys. During the playback we also had a 5-minute passive listening period where we also recorded the presence of other species. ARUs were more likely to detect amphibians than passive human listeners.

There are multiple reasons for this. First, with the ARUs we can invest considerably more time listening to other time periods when the amphibians were calling. Second, amphibians may stop calling when humans are present because of presumed predation risk and disturbance. Third, the timing of human surveys may be less optimal than what is possible with the ARUs.

Table 7 – Comparison of probability of observation via ARU vs HUMAN point count.

Species	**ARU (n = 273)**	**Human (n = 214)**
BCFR	**59.7**	**45.3**
CATO	**0.9**	**2.6**
NLFR	**0.04**	**0**
WOFR	**18.2**	**47.6**
WETO	**12.5**	**8.0**

IMPLICATIONS FOR AMPHIBIAN MONITORING:

The results from the ARU pilot program suggest ARUs are a promising tool for improving monitoring of amphibians in the Lower Athabasca as part of other monitoring initiatives. More species were detected and with greater frequency than using human observers. Second, there is very little evidence that stratification of wetlands needs to take place to monitor amphibian numbers. All 4 main species are relatively general in their habitat requirements allowing systems like ABMI to be used as the core tool for tracking population change via a system grid that uses ARUs. The fundamental requirement is that ABMI or a similar program place recording units at sites during the month of May and record nocturnal calls. CATO being the species of greatest concern is of primary interest to many agencies. There is little evidence to support a specific habitat or strata (from currently available GIS layers) where sampling should be located to maximize detections. ABMI locations in the Lower Athabasca are located within wetlands (bogs, fens, swamps etc) in proportion to their availability so should be able to detect amphibians in proportion to their availability as well. The observed probability of observation for CATO is low but within the realm of several species that ABMI is tracking for trend. ABMI also has a designated open water wetland to sample at each site so this provides another location for sampling amphibians more effectively but would require that ARUs be placed in such environments.

To track trends in CATO, the preliminary results from the ARUs suggest that such an approach integrated with available monitoring programs like ABMI could achieve the desired result. More formal power analyses will be forthcoming after another season of ARU data collection.