EMCLA PILOT STUDY

BAT MONITORING USING WILDLIFE ACOUSTICS SM2BAT+ DETECTOR

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EXECUTIVE SUMMARY:

In 2012, the EMCLA (Environmental Monitoring Committee of the Lower Athabasca) did a pilot study of bats in the Lower Athabasca region of Alberta. We used the Wildlife Acoustics Songmeter SM2BAT+ (http://www.wildlifeacoustics.com/products/song-meter-sm2-bat-plus) recorder to detect bats in several different environments in the Lower Athabasca region.

We sampled for bats at 4 sites. A site consisted of 6 stations where a single bat detector was placed. Specifically, we sampled for bats along the edge of roads, forest gaps, and wetland edges. Stations were approximately one kilometre apart within an area approximately the size of a township.

Bat detections using the Songmeter recordings were calculated in two ways. First, we opened a random subset of the sound recordings in the program Adobe Audition after converting the files to WAV format. These were done blindly with no idea of whether or not a bat had been recorded. We visually scanned 100 recordings to see if we could observe bat calls. We then compared this to the software Kaleidoscope that identifies bats via an automated process. The two approaches agreed 100%.

The second step was to run all of the recordings through Kaleidoscope to identify species. The automated detector identified 8 potential species of bats. These included the Big Brown Bat (*Eptesicus fuscus*), Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (*Lasiurus cinereus*), Silver-haired Bat (*Lasionycteris noctivagans*), Keen's Bat (*Myotis keenii*), Little Brown Bat (*Myotis lucifigus*), Northern Myotis (*Myotis septentrionalis*), and Long-legged Bat (*Myotis volans*). However, only four of these species were detected with high confidence as measured by the automated recognizer.

In general, bats of all species were more likely to be found at wetland edges than at road or forest edges. Bat activity increased from early June to early July and generally was highest between midnight and one AM.

Comparisons of species identification between a human observer and the automated recognizer were high at the genera level BUT low at the species level. As none of the species identities were actually known, it is impossible to know whether the observer was incorrect, the automated recognizer, or both.

The author recommends that continued sampling with this technology occur. However, a research study is needed to create a library of bat calls for northern Alberta. This

would improve and validate species identifications and would allow Alberta specific recognizers to be developed. Group-level monitoring using automated recognizers ("i.e. *genera Lasiurus versus Myotis*) is sufficiently accurate at this time to move ahead with a bat monitoring program based on acoustics. Species-specific monitoring would require a detailed research study be completed beforehand and/or relianceon certification of the Kaleidoscope recognizer by outside agencies.

Integration of bat recorders into the ABMI (Alberta Biodiversity Monitoring Institute) is a realistic possibility. Work is needed to evaluate how bat sampling can best be integrated with nocturnal bird/ amphibian and diurnal bird surveys.

<u>All results in this report should be viewed as preliminary and are subject to change as more analysis and testing of Kaleidoscope settings are considered.</u>

INTRODUCTION:

Populations of bats are often monitored acoustically. Acoustic monitoring is possible because many species of bats echolocate while foraging at night. Echolocation is the process by which high-pitched sounds are emitted and their echoes interpreted by the bat to determine the direction and distance of objects in their environment. Bat echolocation occurs at ultra-sonic frequencies such that calls have to be recorded by specialized equipment that is then converted into sounds that people can hear and/or see on sonogram software. A variety of different detectors exist for recording bat calls including zero crossing detectors and full spectrum recorders that record at high sample rates. In this report, we evaluate the success of the Wildlife Acoustics Full Spectrum SM2BAT+ detector (http://www.wildlifeacoustics.com/products/song-meter-sm2-bat-plus) to detect bats in several different environments in the Lower Athabasca region. This unit is a full spectrum recorder than can covert the data to zero-crossing detections if desired.

Identifying bat occurrence is relatively easy with ultra-sonic recorders. Few species (with the exception of some insects) call in the sound frequency range used by bats. Combined with the relatively distinct visual patterns of most bat calls, visual scans and recordings converted to the range of human hearing are relatively effective at determining whether bats are using an area. However, for bat monitoring to become cost-effective, systems are needed that identify bats to the species level. Species-based identification is desirable for management of bats and to ensure that industrial projects are in compliance with environmental regulations related to specific bat species. The challenge with bat species identification is that significant variation in bat calls exists between and within species. Bats produce a wide range of calls that vary relative to their physical surroundings, including the presence of other bats. This results in calls sometimes converging across species.

In an effort to standardize bat monitoring across North America, there have been several attempts to develop computer based algorithms for automatic classification of bat calls. Discriminant Function Analysis, Artificial Neural Networks, Random Forest, and Support Vector Machines have been used with relatively small sets of known species recordings to create automatic bat identifiers in several areas of the world. Consistent determination of parameters in noisy environments has been challenging and the wide-spread application of these classifiers to regions outside where they were made is not 100% accurate. The company Wildlife Acoustics has gone a step further and developed a software program called Kaleidoscope. Kaleidoscope uses full spectrum recordings made by the Wildlife Acoustics Full Spectrum SM2BAT+ detector to get rid of noise, delete echoes, and use band-pass filters to detect, extract, and enhance the narrow-band signal of bat echolocation calls. Once the recordings are “cleaned” the software then uses a Hidden Markov Model to automatically identify the bat species call and provide a probabilistic statement about the certainty of the identification. The objective of this report is to discuss the efficacy of this software for detecting bats at EMCLA locations relative to a human observer looking at sonograms and to discuss the necessary steps for validating species identity in Alberta’s boreal forest. The Kaleidoscope software is currently being evaluated for its accuracy by the committee responsible for developing the Indiana Bat – Summer Survey guidelines which is a common standard used in bat monitoring. The following criteria are required for the software to be approved as an automated detector by the Indiana Bat – Summer Survey and may be something the monitoring agencies in Alberta also test.

1. The program must be quantitative and automated to ensure repeated consistency in analysis.

2. Any call identification analysis program must be based upon an extensive call library of free-flying bats. Program developers must provide the Service with a copy of their call library, which must indicate the number of calls per species, call recording location and the method of collection (e.g., free-flying bats, hand release, light tag).

3. Each program and/or its supporting materials must explicitly state which species and geographic area(s) it covers. Kaleidoscope uses a western North American dialect call library.

4. The program must include filtering to remove extraneous noise and non-bat files, as well as feeding buzzes, files with multiple bats, poor-quality passes that are recognizable as a bat but not to species, and medium-quality passes that are only recognizable to genus.

5. The program must include an “unknown” category for classifying calls that are not characteristic of species in the call library to ensure that such calls are not forced to make a species identification.

6. Accuracy rates of the program must be derived through cross-validation (e.g., qualitative assessment). Correct classification rates of files identified to individual bats species for the underlying analytical program within identification software, i.e., discriminant function analysis, neural networks, classification and regression tree (CART) or other statistical tests must be provided to show the initial basis used for maximum-likelihood estimator calculations. Minimum correct classification rate on the software’s training data must be 90% or better for all *Myotis* species that may occur within the range of the species of concern, in this case the Indiana bat. In Alberta, we may want to develop the standard to *Myotis septentrionalis,*

7. As species identifications are never perfect, all analysis programs must utilize a maximum-likelihood estimator approach to determine species presence at the site rather than relying on a single sequence. Post-hoc maximum-likelihood estimator p-values will be used to determine acceptance thresholds for final identification determination.

8. Results must include file level summaries (e.g., # of pulses, species IDs, unknown species, invalid), site/night analyses (e.g., # of files, # of invalid files, # of files ID’d to

species vs. unknown, IDs for each species), and the maximum-likelihood estimator value assignments.

METHODS:

In the spring/ summer of 2012, the EMCLA placed six Wildlife Acoustics Full Spectrum SM2BAT+ detectors at 4 sites. Sampling took place from May 31st to July 24th. At each site, four of the recorders were placed at the edge of the forest/ wetland interface (see picture). One recorder was placed in the interior of the dominant forest type in the site while a second recorder was placed in the same forest type but along a road edge.

Figure 1 - Method use to set bat microphone and SM2BAT+ at edge of wetland. Note the microphone in this setup is facing up which is not optimal when raining. It is recommended by manufacturer to be parallel or slightly down relative to the ground.

We set the SM2+BAT to track sunset time. We then started recording for eight hours beginning one hour before sunset. The files were recorded in 30 minute back to back segments. This was done to avoid automatic file splitting which can result in files of different lengths. We then used each ½ hour file as our sampling unit. Recorders were set to use Mountain Standard Daylight Savings time.

Frequency settings were set to a sample rate of 384,000 which allows us to detect calls up to 384 kHz. We used a single mono-L (left channel only). File compression was via WAC0 which is a lossless compression to reduce file size. A digital high pass filter was set to 16 kHz so that sounds below this frequency were not recorded. Our trigger level used a signal to noise ratio of 18 which measures the rolling-average power spectrum in the frequency band above 16 kHz. In other words, if a signal greater than 18 dB above the background noise and above 16 kHz was detected, a recording event was triggered and continued until there was no signal for 2 additional seconds. These settings were based on recommendations made by the manufacturer.

Using this approach, the SM2+BAT records only those sounds that are likely generated by bats and does not record any other information. Settings can be modified to record sounds at other frequencies, but this modification results in a very large file size.

All of these files are stored on a central server at the University of Alberta and can be accessed by external parties upon request.

Analysis

The first step in our analysis was to convert 25 files per site from the standard WAC format that the bat recordings are created on the recording unit into WAV format. This allowed us to visually scan the files in Adobe Audition. We then compared what we visually identified as bat calls to the files Kaleidoscope identified as having a bat presence with a known identity. Where we visually identified a bat as being present on the sonogram, Kaleidoscope agreed 100%. Thus, we do not discuss the results from the visual processing further as we are able to process all of the recordings made using Kaleidoscope.

Using Kaleidoscope, we batch processed all of the proprietary WAC format files. These were also converted to zero-crossing files using a Division Ratio of 8 so they could be visually examined in Anabat software. We filtered noise from the recordings and allowed the signal of interest to range from 16 to 120 kHz with a time range of 2 to 500 milliseconds. For classifiers, we selected the Western North American option from Bats of North America 0.4.0. We selected a 0 sensitive/ accurate classifier which means we balanced the frequency of false negatives and false positives based on ROC-AUC scoring. Based on the species identified we then evaluated whether Julian date, hour of day, and treatment (road edge, forest gap, or wetland edge) influenced probability of observation or number of bat pulses detected. We did this for all bats and for each bat species.

RESULTS:

A total of 2924 half-hour survey periods were conducted at the 24stations. Bats were detected in 13.3% of these survey periods. On a nightly basis, with a night being from 1 hour before sunset to ~ 5 AM, bats were detected in 32.9% of survey intervals. Bats were detected at least once at 83% of stations. We only treated pulses that were identified to species (regardless of accuracy) as evidence of bat detections.

Kaleidoscope identified 8 potential bat species at the 24 stations. However, four of the species whose calls were “potentially identified” had low classification accuracy and may have been identification errors rather than detections of rare species. The four species which Kaleidoscope had a reasonably high classification accuracy and were regularly detected were identified as LABO (Eastern Red Bat), LACI (Hoary Bat), LANO (Silver-haired Bat), and MYSE (Northern Myotis).

Using a multi-level mixed effects logistic regression (xtmelogit in Stata) we evaluated which factors influenced the probability of observation for bats. Specifically, we evaluated how Julian date, time of day, and treatment (forest, road edge, and wetland) influenced the probability of observing a bat of any species. Station identity was treated as a random effect to account for the lack of independence caused by sampling at the same station repeatedly. The model suggested that the probability of observing a bat was highest near midnight and dropped to zero by 4 AM. Bats were detected as early as 9 PM and increased steadily in probability of observation till midnight.

Accounting for station identity as a random effect, Julian date was not a significant predictor of bat observation. However, station identity and Julian data were highly confounded as we moved the sites about every 14 days. Bat probability of observation was highest at site 13 (27% of half-hour intervals had bats observed) which was surveyed in early July, intermediate at site 22 which was surveyed in late June (18% of half-hour intervals had bats observed), and lowest at site 15 and 26 which were surveyed in early to mid-June (4.9 and 5.9% probability of observation).

We could not detect a significant difference between location types. However, we had a relatively low sample size of road and forest interior locations. We were 1.3 times more likely to detect a bat at a wetland edge than in a forest gap. Bats were less likely (0.72 times) at a road edge than a forest gap. For security purposes we did not place the detector right at the edge of the forest/ ditch which is where bats are more likely to forage which may explain this difference. Ideally, bat detectors should be placed in open areas where foraging is likely to occur. Based on past experience, being closer to open water is also preferred but it can be more difficult to place the recorder.

Random-effects logistic regression — Number of obs = 2924
Group variable: **sitestnid** — Number of groups = 24

Random effects u_i ~ **Gaussian** — Obs per group: min = 4; avg = 121.8; max = 209

Wald chi2(13) = 119.83
Log likelihood = -708.89857 — Prob > chi2 = 0.0000

batdetect	OR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
shour						
1	.806633	.1756049	-0.99	0.324	.5264638	1.2359
2	.3894268	.0911134	-4.03	0.000	.2461908	.6159987
3	.0125809	.0076976	-7.15	0.000	.0037923	.0417369
4	2.41e-12	9.92e-08	-0.00	0.999	0	.
5	3.09e-12	1.55e-07	-0.00	1.000	0	.
19	8.97e-13	1.18e-07	-0.00	1.000	0	.
20	2.22e-12	1.05e-07	-0.00	1.000	0	.
21	.0817378	.0251278	-8.15	0.000	.0447452	.1493137
22	.4876437	.1101045	-3.18	0.001	.3132642	.759092
23	.7808568	.1702186	-1.13	0.256	.5093524	1.197084
julian	1.013571	.0255314	0.54	0.593	.9647451	1.064867
treatid						
2	.7208877	.9769169	-0.24	0.809	.0506238	10.26551
3	1.28302	1.388196	0.23	0.818	.1539057	10.69577
/lnsig2u	1.233302	.4427802			.3654686	2.101135
sigma_u	1.852713	.4101723			1.200495	2.859274
rho	.510612	.1106452			.3046231	.713059

Likelihood-ratio test of rho=0: chibar2(01) = **241.84** Prob >= chibar2 = **0.000**

Table 1 - Results of mixed effects logistic regression predicted bat probability of observation per ½ hour interval as a function of hour of day, Julian date, and treatment (Forest is the reference category, road edge = treatid2, and wetland edge = treatid3).

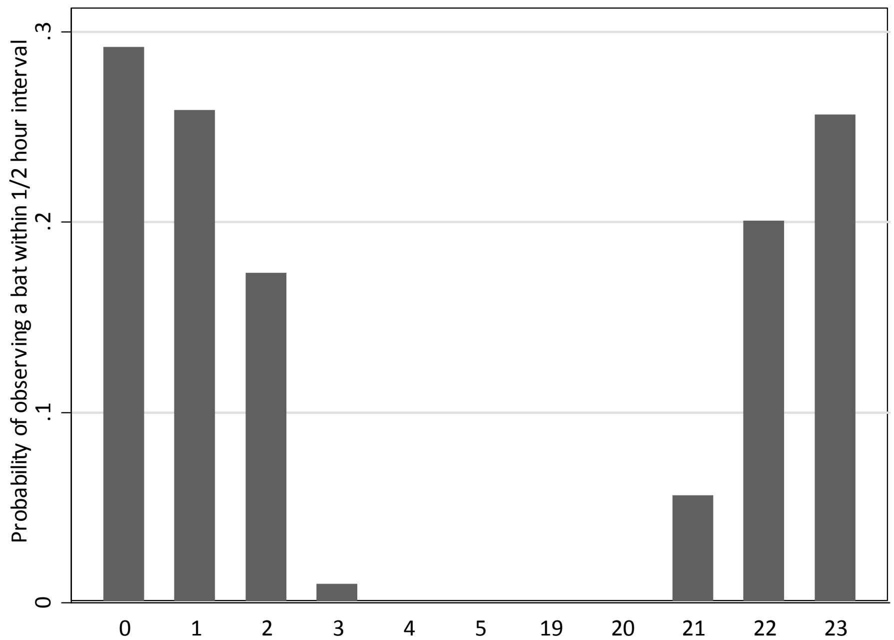

Figure 2 - Probability of observing a bat within a ½ hour sampling interval as a function of hour of day (0 = midnight).

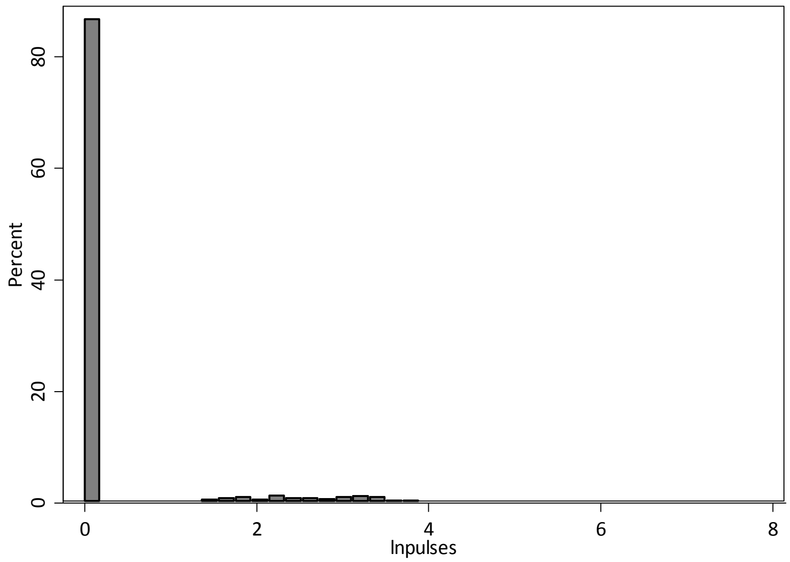

Figure 3 - The percentage of ½ hour survey intervals where a particular number (ln-pulse) of bat pulses were detected.

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Random-effects GLS regression                   Number of obs      =      2924
Group variable: sitestnid                       Number of groups   =        24

R-sq:  within  = 0.1219                         Obs per group: min =         4
       between = 0.3660                                        avg =     121.8
       overall = 0.1473                                        max =       209

                                                Wald chi2(13)      =    413.77
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
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lnpulses	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treatid						
2	-.1502431	.2154936	-0.70	0.486	-.5726028	.2721166
3	.17232	.1717904	1.00	0.316	-.164383	.5090231
julian	.0080525	.0037962	2.12	0.034	.0006121	.0154928
shour						
1	-.0671716	.0679994	-0.99	0.323	-.200448	.0661047
2	-.2810358	.0685192	-4.10	0.000	-.415331	-.1467406
3	-.7388529	.0686398	-10.76	0.000	-.8733844	-.6043214
4	-.7692135	.068821	-11.18	0.000	-.9041003	-.6343268
5	-.6997342	.0746181	-9.38	0.000	-.8459831	-.5534854
19	-1.155654	.168161	-6.87	0.000	-1.485243	-.8260642
20	-.808014	.0768965	-10.51	0.000	-.9587285	-.6572996
21	-.604853	.0676324	-8.94	0.000	-.7374101	-.4722959
22	-.1832117	.0675629	-2.71	0.007	-.3156326	-.0507909
23	-.0871033	.0677174	-1.29	0.198	-.219827	.0456205
_cons	-97.31283	46.21745	-2.11	0.035	-187.8974	-6.728284
sigma_u	.29334982					
sigma_e	.84522295					
rho	.10750637	(fraction of variance due to u_i)				

Table 2 - Results of mixed effects linear regression predicting bat use (ln-number of pulses) per ½ hour interval as a function of hour of day, Julian date, and treatment (Forest is the reference category, road edge = treatid2, and wetland edge = treatid3).

Since most agencies have the objective of monitoring specific bat species, we also evaluated how each species different between the different locations. Northern Myotis and Silver-haired Bats were more likely to be detected at wetland edges than at road edges or forest gaps. Hoary Bats were detected with equal frequency in the three treatments, while Eastern Red Bat had similar detection levels at forest gaps and wetlands but was never detected at road edge. The probability of observation increased with Julian date for all species. Survey hour patterns were similar for all species, with the peak of observations being near midnight and 1 AM.

Random-effects logistic regression — Number of obs = 2924
Group variable: **stnid** — Number of groups = 9

Random effects u_i ~ **Gaussian** — Obs per group: min = 114; avg = 324.9; max = 596

Wald chi2(13) = 59.27
Log likelihood = -480.63 — Prob > chi2 = 0.0000

myse	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treatid						
2	.242394	.8381538	0.29	0.772	-1.400357	1.885145
3	1.11825	.6148199	1.82	0.069	-.0867753	2.323274
julian	.0404201	.0077688	5.20	0.000	.0251935	.0556466
shour						
1	-.247891	.2554916	-0.97	0.332	-.7486454	.2528634
2	-.6786744	.2818604	-2.41	0.016	-1.231111	-.1262381
3	-20.83985	4635.43	-0.00	0.996	-9106.116	9064.437
4	-20.83628	4652.926	-0.00	0.996	-9140.404	9098.732
5	-20.70365	5407.886	-0.00	0.997	-10619.97	10578.56
19	-20.53975	9364.334	-0.00	0.998	-18374.3	18333.22
20	-20.85607	5550.661	-0.00	0.997	-10899.95	10858.24
21	-2.358986	.4856332	-4.86	0.000	-3.310809	-1.407162
22	-.7821194	.2848447	-2.75	0.006	-1.340405	-.223834
23	-.2881979	.2570136	-1.12	0.262	-.7919352	.2155394
_cons	-495.1013	94.59149	-5.23	0.000	-680.4973	-309.7054
/lnsig2u	-1.185266	.733995			-2.62387	.2533374
sigma_u	.5528696	.2029017			.2692985	1.135041
rho	.0850124	.057094			.0215685	.2814036

Likelihood-ratio test of rho=0: chibar2(01) = 17.50 Prob >= chibar2 = 0.000

Random-effects logistic regression — Number of obs = 2924
Group variable: **stnid** — Number of groups = 9

Random effects u_i ~ **Gaussian** — Obs per group: min = 114; avg = 324.9; max = 596

Wald chi2(13) = 77.01
Log likelihood = -416.09153 — Prob > chi2 = 0.0000

lano	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treatid						
2	.8231702	1.065455	0.77	0.440	-1.265084	2.911424
3	1.632967	.8127439	2.01	0.045	.0400187	3.225916
julian	.0656849	.0096383	6.81	0.000	.0467942	.0845757
shour						
1	.1836174	.2957675	0.62	0.535	-.3960763	.763311
2	-.5269278	.3418719	-1.54	0.123	-1.196984	.1431288
3	-2.315465	.6232293	-3.72	0.000	-3.536972	-1.093958
4	-20.30832	4627.436	-0.00	0.996	-9089.916	9049.299
5	-20.07088	5395.172	-0.00	0.997	-10594.41	10554.27
19	-21.30066	16059.1	-0.00	0.999	-31496.56	31453.96
20	-20.34976	5409.516	-0.00	0.997	-10622.81	10582.11
21	-1.488753	.4444635	-3.35	0.001	-2.359886	-.6176211
22	.0739218	.2995318	0.25	0.805	-.5131498	.6609933
23	-.1303476	.312352	-0.42	0.676	-.7425462	.4818511
_cons	-803.7108	117.4297	-6.84	0.000	-1033.869	-573.5528
/lnsig2u	-.6643427	.6250716			-1.889461	.5607752
sigma_u	.7173644	.2242021			.3887844	1.323643
rho	.1352647	.0731135			.0439269	.3474941

Likelihood-ratio test of rho=0: chibar2(01) = 43.80 Prob >= chibar2 = 0.000

Random-effects logistic regression — Number of obs = 2924
Group variable: **stnid** — Number of groups = 9

Random effects u_i ~ **Gaussian** — Obs per group: min = 114; avg = 324.9; max = 596

Wald chi2(13) = 113.30
Log likelihood = -448.07133 — Prob > chi2 = 0.0000

laci	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treatid						
2	-.7204279	1.08153	-0.67	0.505	-2.840189	1.399333
3	-.3428473	.7837209	-0.44	0.662	-1.878912	1.193218
julian	.090365	.0097184	9.30	0.000	.0713174	.1094127
shour						
1	.1778884	.2877361	0.62	0.536	-.3860639	.7418408
2	-.332021	.314919	-1.05	0.292	-.9492508	.2852089
3	-3.658303	1.027446	-3.56	0.000	-5.672061	-1.644545
4	-21.67574	8150.216	-0.00	0.998	-15995.81	15952.45
5	-21.28996	9594.982	-0.00	0.998	-18827.11	18784.53
19	-21.97949	18297.3	-0.00	0.999	-35884.04	35840.08
20	-21.7525	9510.196	-0.00	0.998	-18661.39	18617.89
21	-1.29991	.3929895	-3.31	0.001	-2.070155	-.5296643
22	.2916661	.283362	1.03	0.303	-.2637132	.8470454
23	.1312244	.2907882	0.45	0.652	-.4387101	.7011588
_cons	-1102.835	118.3492	-9.32	0.000	-1334.795	-870.8744
/lnsig2u	-.459306	.6040071			-1.643138	.7245262
sigma_u	.7948094	.2400353			.4397411	1.436577
rho	.1610882	.0816248			.055515	.3854873

Likelihood-ratio test of rho=0: chibar2(01) = 69.55 Prob >= chibar2 = 0.000

Random-effects logistic regression — Number of obs = 2924
Group variable: **stnid** — Number of groups = 9

Random effects u_i ~ **Gaussian** — Obs per group: min = 114; avg = 324.9; max = 596

Wald chi2(13) = 65.58
Log likelihood = -218.51413 — Prob > chi2 = 0.0000

labo	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
treatid						
2	-2.994095	1.204927	-2.48	0.013	-5.355708	-.6324818
3	-.2604388	.5591209	-0.47	0.641	-1.356296	.835418
julian	.111908	.0169615	6.60	0.000	.0786641	.145152
shour						
1	-.6557599	.403301	-1.63	0.104	-1.446215	.1346956
2	-1.689523	.5676363	-2.98	0.003	-2.80207	-.5769766
3	-21.00424	7654.683	-0.00	0.998	-15023.91	14981.9
4	-21.00847	7691.13	-0.00	0.998	-15095.35	15053.33
5	-19.49911	5639.471	-0.00	0.997	-11072.66	11033.66
19	-20.4601	10835.81	-0.00	0.998	-21258.25	21217.33
20	-20.10328	5506.387	-0.00	0.997	-10812.42	10772.22
21	-1.456745	.5211244	-2.80	0.005	-2.47813	-.4353598
22	-1.100665	.4629747	-2.38	0.017	-2.008079	-.1932518
23	-.0830248	.36128	-0.23	0.818	-.7911205	.625071
_cons	-1365.565	206.6936	-6.61	0.000	-1770.677	-960.4528
/lnsig2u	-1.686289	.9246634			-3.498596	.1260183
sigma_u	.4303552	.1989669			.173896	1.065037
rho	.0532954	.0466539			.0091081	.2563877

Likelihood-ratio test of rho=0: chibar2(01) = 4.64 Prob >= chibar2 = 0.016

Table 3 – Model results for 4 species of bats: Top Left – MYSE – Northern Myotis Bat, Top Right – LANO – Silver-haired Bat; Bottom Left - LACI – Hoary Bay; and Bottom Left - Eastern Red Bat – LABO.

While the automatic recognizer and software programming are quite accurate for detecting bats in general, their accuracy at species identification is an area of active scientific research. As described in detail in the Handbook of Inventory Methods and Standard Protocols for Surveying Bats in Alberta, there remains uncertainty about the use of ultrasonic bat detectors and automated recognizers. Unlike bird calls which are used to communicate with conspecifics, bat calls are designed to optimize object detection. Thus, they are functionally specific and have evolved to detect prey. As different calls may be more or less optimal for object detection in different environments, there has been selection for different species to use similar calls in similar habitats. Geographic variation, individual, sex, age, and colony specific variation have also been observed. The relative importance of these various factors and how they influence identification via acoustic bat detectors is an area of active research.

Kaleidoscope has dealt with this issue by using a large library of call types and a fairly conservative species identifier that has a variety of statistical functions to estimate certainty of identification. In this pilot study we did not have any known recordings, so we could not estimate the species identification error rate caused by regional dialects or habitat variation.

There were 990 recordings which Kaleidoscope identified to species. We picked 100 random sonograms and had a human observer identify these species blindly. The observer was told they could select from Northern Myotis, Hoary, Eastern Red, or Silver-haired Bat as these were the only species that Kaleidoscope suggested had a very high probability of being present. The observer could also select UNKNOWN.

When we compared the identification of two broad groups (*Myotis* versus *Lasiurus & Lasionycteris*), agreement between Kaleidoscope and the human observer was quite high at 93%. Most of the error at the group level was caused by humans identifying a call as *Myotis* and Kaleidoscope not assigning an identity. This suggests that Kaleidoscope is quite conservative in its identification of species within this group. When we compared species identity within *Lasiurus & Lasionycteris*, we found that there was strong agreement for Silver-haired Bat identifications between the software and the person (90% agreement). For the Hoary Bat however, identification consistency was low (53%), with the human observer often calling it a Silver-haired Bat and Kaleidoscope calling it a Hoary Bat. The figures below show some representative examples created by Kaleidoscope.

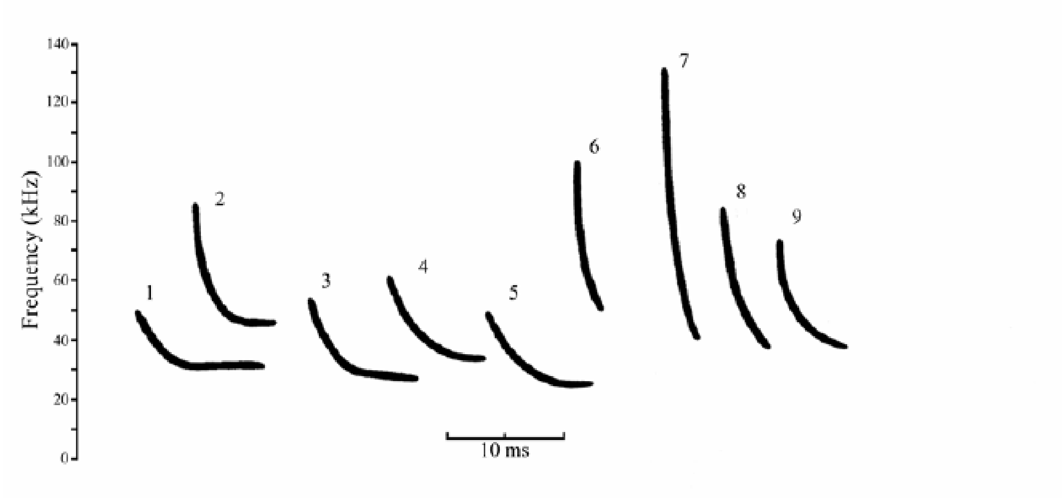
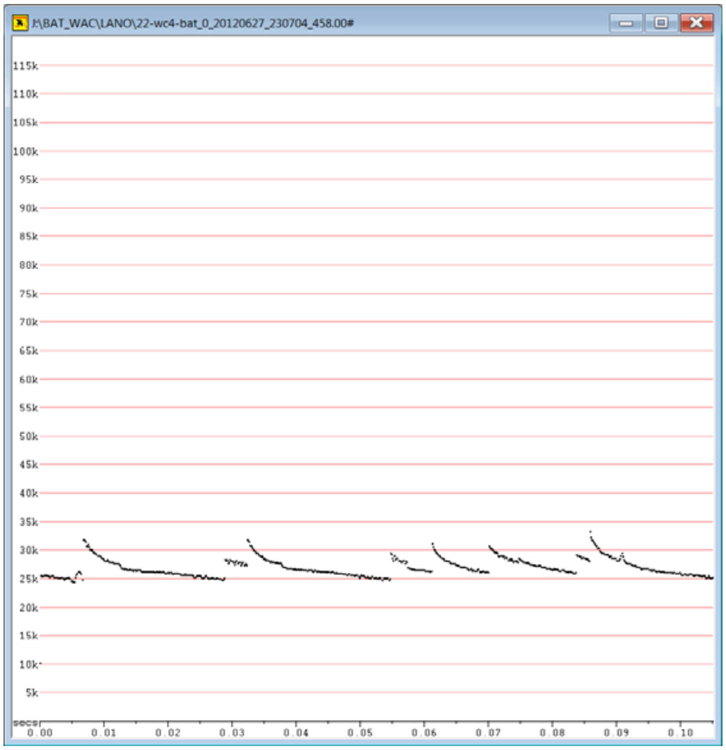


Figure 4 - Examples of sonograms (frequency vs. time) of search-phase echolocation calls for the nine species of bats in Alberta. 1. *Lasiurus cinereus*, 2. *Myotis volans*, 3. *Eptesicus fuscus*, 4. *Lasiurus borealis*, 5. *Lasionycteris noctivagans*, 6. *M. evotis*, 7. *M. septentrionalis*, 8. *M. lucifugus*, 9. *M. ciliolabrum*. Note that considerable intraspecific variation in echolocation calls can exist.



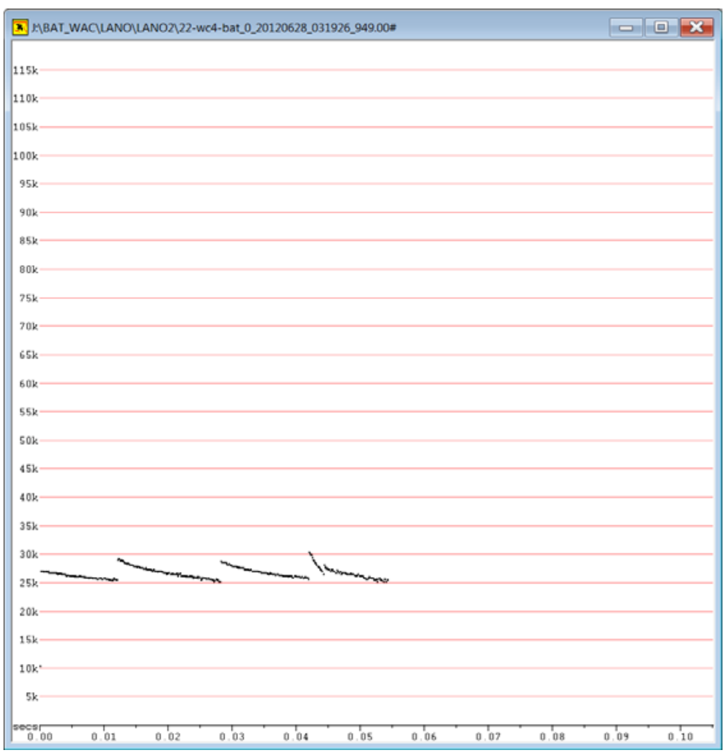
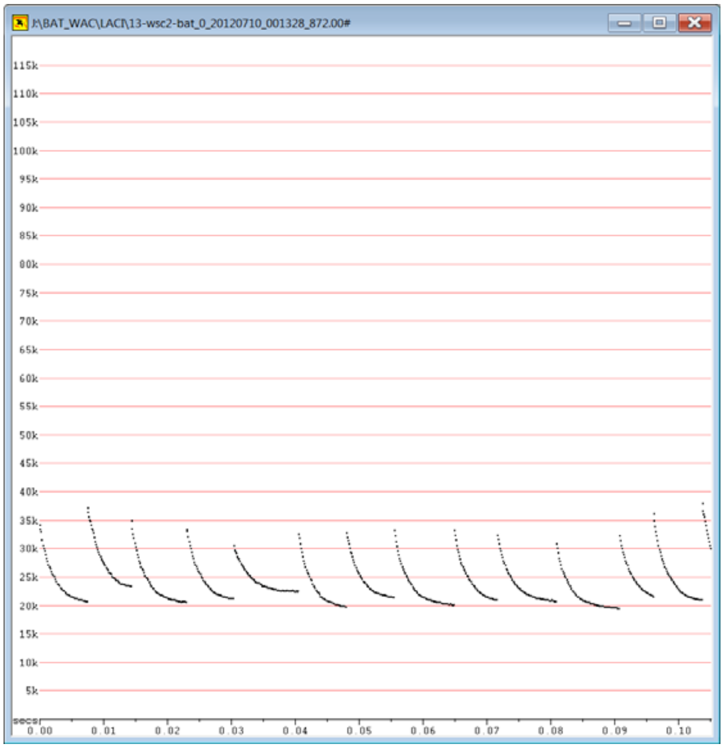


Figure 5 - Anabat visualization of bat calls that were identified by Kaleidoscope as Silver-haired Bat (*Lasionycteris noctivagans)*. Top is best id of Silver-haired Bat at

0.948 while bottom is identified as Silver-haired Bat at 0.433. These calls were recorded a day apart at the same station.



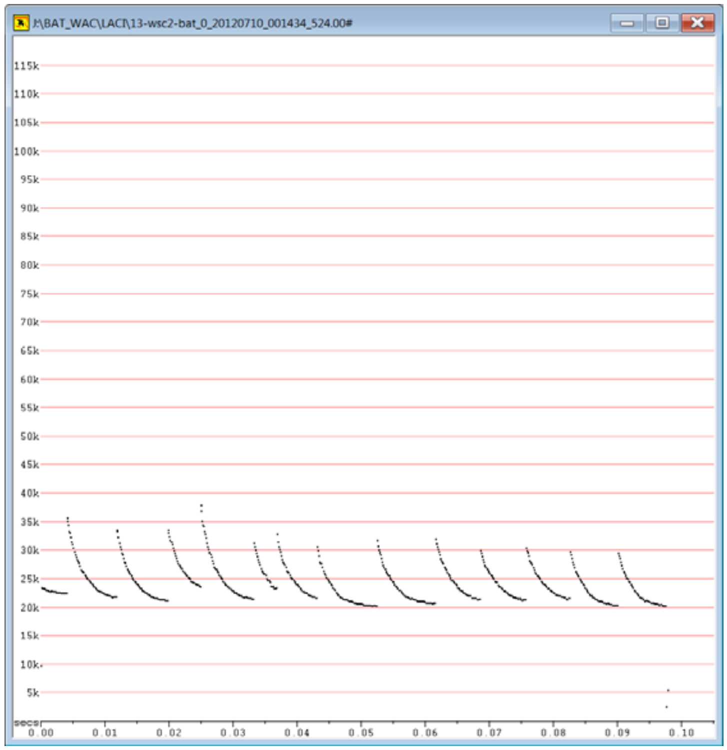
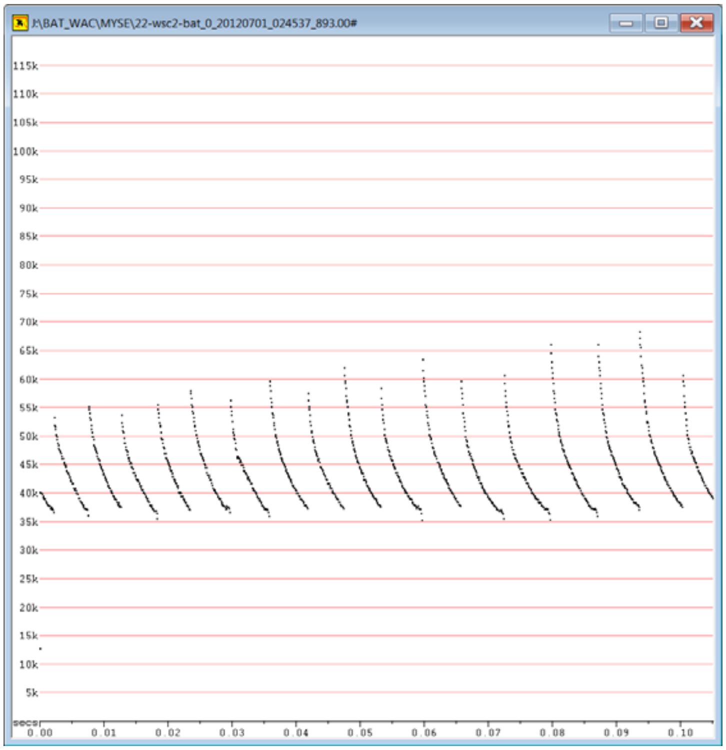


Figure 6 - Anabat visualization of bat calls that were identified by Kaleidoscope as Hoary Bat (*Lasiurus cinereus*) with different margin scores. Top is best id of Hoary Bat at 0.872 while bottom is identified as Hoary Bat at 0.699. These calls were recorded at the same station about 1 hour apart on the same day.



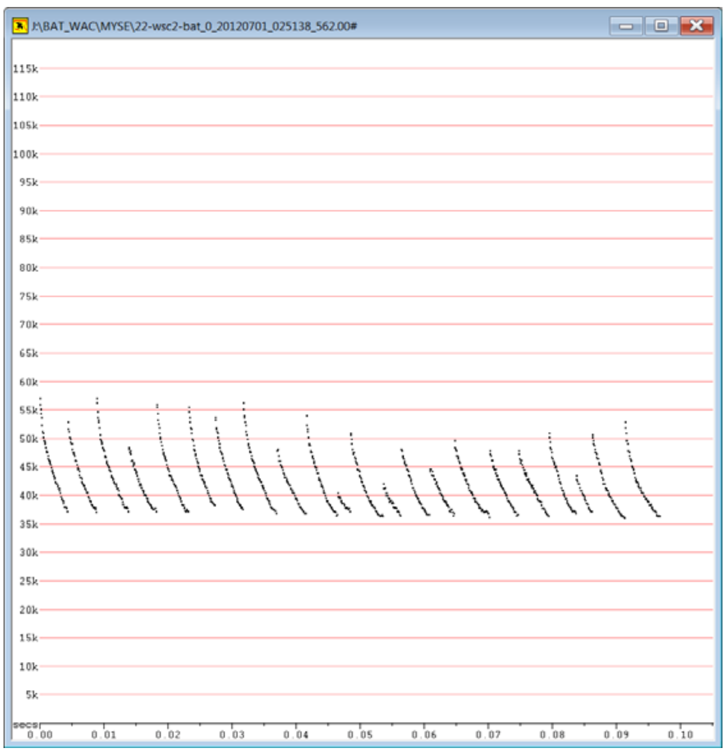


Figure 7 - Anabat visualizations of bat calls that were identified by Kaleidoscope as Northern Myotis Bat (*Myotis septentrionalis*). Top is best id of Northern Myotis at 0.913 while bottom is identified as Northern Myotis at 0.44. These calls were recorded at the same station about 6 minutes apart on the same day.

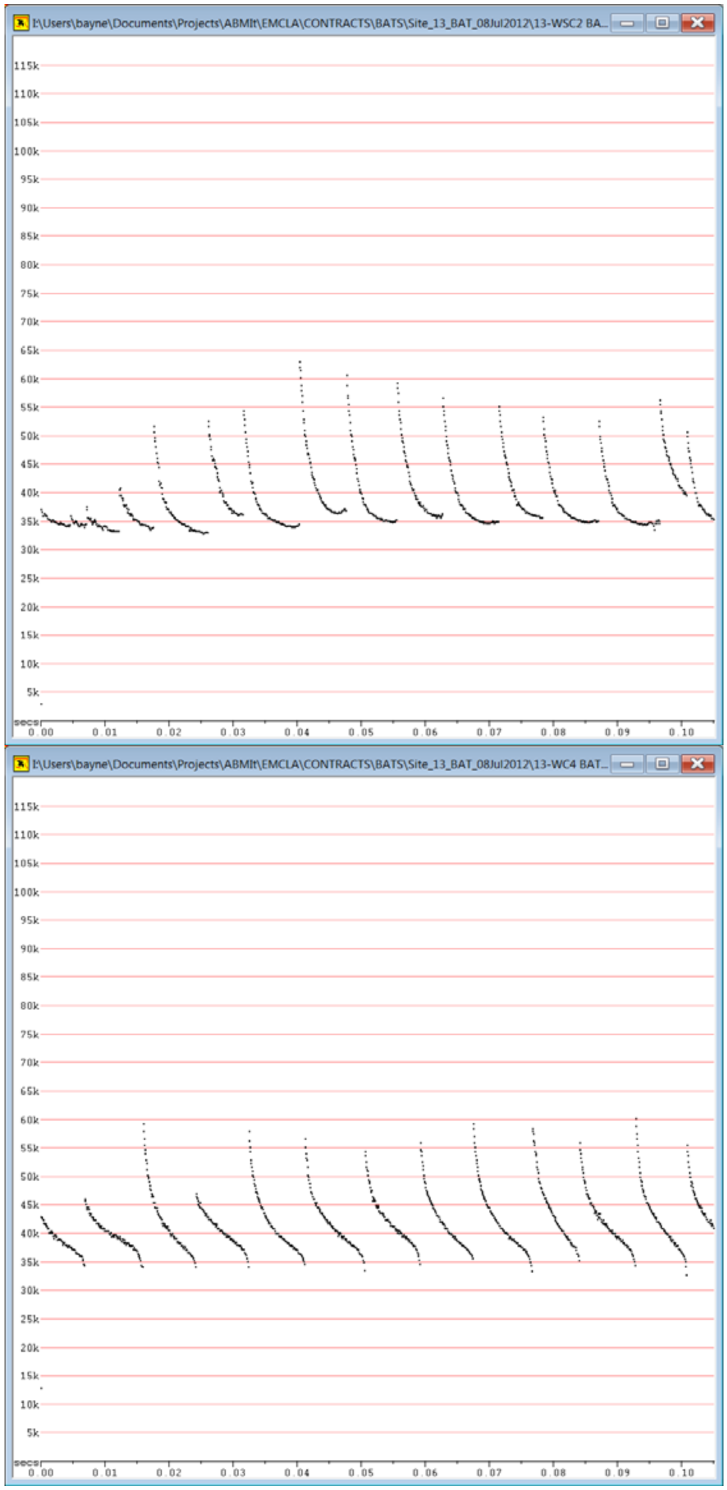


Figure 8 - Anabat visualizations of bat calls that were identified by Kaleidoscope as Eastern Red Bat (*Lasiurus borealis*). Top is best id of Eastern Red Bat at 0.875 while bottom is identified as Eastern Red Bat at 0.61. These calls were recorded at different stations within the same site several days apart.

DISCUSSION

The key questions asked by EMCLA for this report were:

1) Can Songmeter SM2 BAT+ equipment be effectively used to track bat occurrence and activity?

2) Where should the equipment be put to optimize sampling?

3) How well can bat species be identified?

4) What is the best ways to use this equipment to monitor bats in the oilsands?

5) What other research is needed to making bat monitoring possible?

ANSWER 1: Can Songmeter SM2 BAT+ equipment be effectively used to track bat occurrence and activity?

The Songmeters performed very well. Bat detections occurred at almost every station and did occur at every site. Bat activity patterns related to time of day, time of year, and related to habitat were as expected. How best to position the equipment needs to be investigated (microphone angle etc, height of microphone etc). However, our relatively small study detected numerous bats suggesting that our positioning was reasonable.

ANSWER 2: Where should the equipment be put to optimize sampling?

Our comparison of habitats was fairly standard and is based on the assumption that bats forage along edges. We have NOT looked at randomly placing the bat recorders in the forest or in the centre of wetlands so we cannot make any conclusions about how such a sampling strategy would work. Wetland edges seem to have the highest probability of observation of bats.

ANSWER 3: How well can bat species be identified?

Because we have no recordings where the species of bat was visually identified, we cannot conclude how well species were identified. We found few differences between a qualitative observation and Kaleidoscope at the group level that most bat monitoring has been done at. At the species level we had inconsistent identifications between the qualitative human and quantitative computer based identification This is not surprising, as highly trained observers have been shown to have published error rates of up to 40%.

In the Handbook of Inventory Methods and Standard Protocols for Surveying Bats in Alberta, there is a clear statement that "until identification issues have been dealt with, the conservative approach is to only use ultrasonic detectors for what they are designed for, to record bat activity and identify meaningful species groups". We cannot disagree with this statement at this time. We can state that "humans" are not necessarily better or worse than automated detectors--they are just different. However, automated detectors have the benefit that the criteria used are "always the same" while qualitative criteria are not particularly consistent between people. Similarly, to the author's knowledge there are no specific criteria published for bats in Alberta that could be used at this time to make such determinations so we have to rely on the best available recording libraries available. At this time, this seems to be what has been used by Kaleidoscope .

ANSWER 4: What is the best ways to use this equipment to monitor bats in the oilsands?

In our test, we used ½ hour recordings at bat stations as the unit for sampling. Further work is needed to test how using 1 hour, 1 night, or a week as the unit of sampling would influence conclusions. Station level sampling with an automated unit like the Songmeter SM2BAT+ provides a lot of temporal resolution but less spatial resolution. An alternative is to regularly move the recorder to many locations. We cannot compare the value of leaving a recorder for multiple days versus moving it regularly at this time.

The benefit of sampling stations is that over time many bats of different species can be detected. However, answering questions about habitat selection or human impacts then suffer from reduced replication of statistical treatments. An important caveat however is that having more data from a point allows Kaleidoscope to compute "certainty" statistics that are not available when recorders are moved regularly.

As bat detectors record ultra-sonic frequencies there is a suggestion that they can be mounted on motorized vehicles and recording done continually while driving slowly through an area. Sounds made by vehicles are simply scrubbed from the recordings and thus should not influence signal detection. How bats behave when a vehicle is passing through a location is not known. The benefit of this approach is that vast areas could be covered quickly for assessing bat use of different forest (i.e. drive a quad down cutlines or pipelines) or wetland types (a boat could be used to monitor shorelines).

ANSWER 5: What other research is needed to making bat monitoring possible?

It is the author's opinion that the Wildlife Acoustics Songmeter SM2BAT+ unit is a relatively cost-effective way of monitoring bats in the oilsands region. AESRD's objective to monitor Northern Myotis specifically is less certain however. While the Kaleidoscope software regularly identified this species as being present at our stations, we cannot quantify the accuracy of these designations. Genera level monitoring certainly is possible and will be reasonably accurate using Wildlife Acoustics software and equipment.

What is needed as next steps is to develop a better reference set of calls for bat species in Northern Alberta. Reference recordings of individuals of known species need to be made so that we can compare these sounds to those of unknown individuals. With this approach we could:

A) test the Kaleidoscope software;

B) develop our own recognizer if necessary;

C) set standards for Alberta to use as criteria for species identification by observers and automated recognizers.

Between EMCLA, numerous energy companies, and AESRD there are now about 50 Songmeter SM2BAT+ recorders available. The author suggests:

1) These units be deployed in the spring/ summer of 2013 to monitor bats at the group level near wetland edges of different types. These could be the same locations where EMCLA crews are already visiting to survey for birds. These sites provide a number of different upland and lowland forest - wetland edges.

2) A smaller number of the units should be attached to ATV's, and staff should drive at slow speeds on linear features and along shorelines in boats to determine the efficacy of transect sampling.

3) A bat capture expert should be hired to make ultrasonic reference recordings for particular bat species. Specifically, EMCLA would layout a grid of bat recorders at areas where bats are known to occur.

   The bat capture expert would then capture and visually mark the bats using a small chemi-luminescent light tag, such as a miniature light stick. The light tag will act as a short-term visual mark to keep track of the bat as it is being acoustically recorded on the recorder grid.

   Videography from multiple cameras (which could be provided by Bayne lab) of the bat could be used to determine the exact position of the bat while flying over the recorder grid. This would allow us to:

   a. Develop a call library.

   b. Determine the distance at which bat recorders detect different species.

4) Alternatively, we could affix radio-transmitters to various bat species and triangulate position from a series of VHF radio-receivers with the grid in place.

The Bayne lab has a series of automatic towers that might be suitable for this purpose but would have to be tested.

5) The author proposes that this project might be cost-effectively done at Lesser Slave Lake Bird Observatory. The benefit of this location is that mist-netting facilities are in place and "double high" nets have been created. This would allow increased capture of species that fly at higher heights (i.e. *Lasiurus borealis, L. cinereus and Eptesicus fuscus*) and could be piggy-backed on other projects done by Bayne lab.

6) It is the author's opinion that the only cost effective way to monitor bats in the oilsands is via ultra-sonic recordings because of the costs and intensive effort required for trapping programs which are the only way to monitor species that do not use hibernacula. Such programs are very invasive and need to be conducted by experts. There are relatively few trained bat biologists to allow a banding program for bats in Alberta that would have power to track trends across the oilsands region.

7) Technological improvements in species identification from acoustic recordings are continually occurring. By having the call library discussed above, Alberta should be able to set criteria that would allow for cost-effective acoustic monitoring of certain species of bats. Without such a library, any acoustic monitoring program should track trends in "bat groups" rather than being species specific. However, if the Kaleidoscope software is accepted more broadly as being an efficient recognizer for all areas of North America then this standard could simply be accepted as an Alberta standard.

8) Laying out such an acoustic monitoring program for bats would be easy to implement as part of the Alberta Biodiversity Monitoring Institute if sufficient resources for recorders were available. Recorders that detect bats and birds already exist and could be placed at wetland edges as part of ABMI's standard sampling grid. We do not have sufficient data at this time to assess the statistical power of such a plan but is something that should be done after the field season of 2013.

9) If bats and birds are to be recorded on the same Songmeter SM2BAT+ units, then only a single recording channel becomes available for birds. Comparisons about detection and abundance estimation of birds using two versus one channel should be done to ensure that bat recording does not negatively impact the quality of bird recordings.