TECHNICAL REPORT TO ENVIRONMENTAL MONITORING COMMITTEE OF LOWER ATHABASCA:

OWL MONITORING USING WILDLIFE ACOUSTICS ARU RECORDERS VERSUS STANDARD PLAYBACK METHODS

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The EMCLA owl monitoring program in 2012 had multiple objectives:

1) Use standard playback methods on roads to determine the probability of observation of owls in areas with high versus low energy sector footprint. Playback methods were intended to increase the probability of observation for owls but required field personnel to work at night during spring break-up season.

2) Compare playback results with those obtained using Autonomous Recording Units that passively record owl calls but that can also be used to record species other than owls. Goal was to determine if passive recorders could become a replacement system for all audio-based monitoring protocols currently in use in EMCLA region, including owls.

3) Determine what the data indicates about owl habitat use versus owl abundance. Compare various statistical approaches for dealing with audio detection data to determine the efficacy and efficiency of the different statistical techniques for understanding abundance, occupancy, and use.

4) Identify type of sampling, timing of sampling, and amount of sampling required for future monitoring /research programs for owls and how this might tie into future monitoring initiatives to track other species of organisms using acoustic cues.

In this report, we summarize the data and generate preliminary models from the owl monitoring project to:

1) Provide baseline information on the probability of observation and counts at different temporal and spatial scales in Lower Athabasca.

2) Use these data along with other information on owls in Alberta to understand whether the assumptions about detection probability, occupancy, detection-corrected counts, and distance-based density estimates are met and can be used to calculate absolute owl abundance.

3) Place owl monitoring in the context of monitoring all other organisms that give acoustic cues and identify how such information should be used to coordinate monitoring efforts among various groups.

All results and recommendations in this report are subject to change conditional on further analysis.

DESCRIPTION OF FIELD METHODS

Two types of monitoring were done in 2012 by EMCLA for owls.

Playback surveys consisted of a diurnal (Table 1) and a nocturnal survey (Table 2) that occurred along a road or pipeline. Along each road or pipeline, an observer drove an ATV or 4 x 4 truck. Playback surveys took place at 29 sites. Every 1.6 kilometres along the road or pipeline through a site the observer would stop. Each route was comprised of approximately 10 stops. At each stop, a playback sequence was broadcast and the owls detected before, during, and after each playback sequence recorded. The distance and bearing from the observer to the detected owl were recorded. Two visits about 3 weeks apart occurred to approximately the same location. Quite regularly we could not visit the exact stop because of road conditions. In some cases, we could not revisit the same route because of deteriorating road conditions during spring melt.

Table 1. Calling sequence for diurnal owl survey used by EMCLA

Call Interval	Call Type	Total Time	Cumulative Time
1	Northern Pygmy-Owl call	20 seconds	0:20
2	Silent listening	1 minute	1:20
3	Northern Pygmy-Owl call	20 seconds	1:40
4	Silent listening	1 minute	2:40
5	Northern Pygmy-Owl call	20 seconds	3:00
6	Silent listening	1 minute	4:00
7	Northern Hawk Owl	20 seconds	4:20
8	Silent listening	1 minute	5:20
9	Northern Hawk Owl	20 seconds	5:40
10	Silent listening	1 minute	6:40
11	Northern Hawk Owl	20 seconds	7:00
12	Final silent listening	1 minute	8:00

Table 2. Calling sequence for nocturnal owl survey used by EMCLA

Call Interval	Call Type	Total Time	Cumulative Time
1	Initial silent listening	2 minutes	2:00
2	Northern Saw-whet Owl call	20 seconds	2:20
3	Silent listening	1 minute	3:20
4	Northern Saw-whet Owl call	20 seconds	3:40
5	Silent listening	1 minute	4:40
6	Boreal Owl call	20 seconds	5:00
7	Silent listening	1 minute	6:00
8	Boreal Owl call	20 seconds	6:20
9	Silent listening	1 minute	7:20
10	Long-eared Owl call	20 seconds	7:40
11	Silent listening	1 minute	8:40
12	Long-eared Owl call	20 seconds	9:00
13	Silent listening	1 minute	10:00
14	Great Gray Owl call	20 seconds	10:20
15	Silent listening	1 minute	11:20
16	Great Gray Owl call	20 seconds	11:40
17	Silent listening	1 minute	12:40
18	Barred Owl call	20 seconds	13:00
19	Silent listening	1 minute	14:00
20	Barred Owl call	20 seconds	14:20
21	Silent listening	1 minute	15:20
22	Barred Owl call	20 seconds	15:40
23	Final silent listening	1 minute	16:40

The other approach was to use ARUs (Automated Recording Units). ARUs were located along road edges, forest interiors, and wetland edges. They were placed for 10-14 days and turned on every hour for 10-minutes. No owl calls were played and the system simply passive listened for owls for these extended periods of time. Each site had 6 recorders that were a minimum of 1km apart. Observers then listened to the recordings in the lab for a minimum of three different nights for each stop, generally at midnight. A subset of recordings was processed more extensively to get detailed data on owl calling behavior at different times of day and times of the year.

PLAYBACK VS. ARU FOR OWLS

The most common approach to surveying forest owls in Alberta has been to use playback (i.e. broadcasting the call of an owl through a loudspeaker) to elicit territorial individuals to call. The rationale of using playback versus passive listening is owl calling rates are thought to be quite low, although there have been few explicit tests to compare playback to passive listening. By playing intra and inter-specific calls, owls are thought to increase calling rate thereby increasing the probability of observation. Probability of observation influences the statistical power to detect trends and differences in spatial patterns of density, relative abundance, and habitat use by owls.

To test if playback methods increase the probability of observation, we compared road-based playback surveys to passive recordings taken by ARUs placed in the same sites but at different stations/ stops. Table 3 summarizes the raw probability of observation for playback-elicited surveys versus ARU recordings at the station/ stop level.

Comparing a single 10 minute passive listening period at midnight to a 20 minute long playback survey, there is evidence the probability of observation is higher using playback depending on the playback sequence used. At first glance, this suggests that playback increases calling rates, thereby increasing probability of observation based on a single sampling event. However, the time it takes to conduct many of the playback survey techniques is longer than a single passive sampling event (10 versus 20 minutes). From the passive recordings listened to thus far, when we listen for owls on two or more separate nights and calculate the cumulative probability of observation, 20 minutes of ARU listening generally results in similar probabilities of observation to a single 20 minute playback sequence done on a single night (Table 3 – ARU – At least two "visits"). Two 20 minute playback sequences have a cumulative probability of observation that is higher than two 10 minute passive listening sequences. However, the PB/ARU ratio is decreasing with increased visits suggesting the benefits of conducting two 20 minute playback sequences on different nights are not as great as listening to two different ARU recordings.

Determining how many 10 minute recording on different nights or at different times of the night will be required to match the probability of observation from a single playback session will require listening to more recordings on more nights to develop a cumulative probability of observation curve. However, based on the Playback to ARU ratio for the probability of observation from a single playback visit or single 10 minute listening period, it will range from 1.21 to 5.00 depending on species. Great Horned Owls, which are not part of the EMCLA playback protocol, were more likely to be observed using ARUs than playback. A total of 1 hour listening to passive recordings will result in a similar detection rate to a 20-minute playback sequence in the field at a minimum. We are currently working to determine how to decrease the actual time it takes to process 1-hour of field recordings for owls (i.e. by visually scanning sonograms for owl calls). Assuming the objective was to match the cumulative probability of observation of two playback sequences (40 minutes of playback) this ratio was less for most species suggesting the benefit of playback to passive recordings declines as you listen to more recordings. Three species (Barred Owl, Great Horned Owl, Northern Saw-whet Owl) were more likely to be detected via ARU after listening for 20 minutes than two playback sequences.

Table 3 - Probability of observation for forest owls based at single station based on passive listening using automated recording units (ARU) at midnight in EMCLA study area relative to road-based playback-elicited call surveys along roadsides done in various locations across Alberta with different playback sequences and at different times of day.

Single visit to a station								
Species	**ARU Night n=455**	**EMCLA Day n=587**	**EMCLA Night n=649**	**WEYCO Day n=1637**	**WEYCO Night n=2491**	**ANOS CDP n=3025**	**TAKATS CDB n=1738**	**TAKAT CDF n=390**
BADO	0.042	0.002	0.059	0.000	0.068	0.002	0.056	0.054
BOOW	0.020	0.002	0.062	0.001	0.111	0.002	0.114	0.100
GGOW	0.004	0.000	0.020	0.004	0.029	0.003	0.012	0.008
GHOW	0.073	0.005	0.063	0.000	0.044	0.162	0.055	0.054
LEOW	0.004	0.002	0.014	0.000	0.005	0.020	0.000	0.000
NHOW	0.000	0.007	0.002	0.009	0.000	<0.001	0.000	0.000
NSOW	0.037	0.002	0.046	<0.001	0.149	0.103	0.068	0.069
NPOW	0.000	0.007	0.000	0.106	0.002	0.000	0.007	0.000
SEOW	0.000	0.000	0.000	0.000	0.000	<0.001	0	0.000
AnyOwl	0.156	0.025	0.231	0.119	0.334	0.253	0.280	0.267
➢ **2 visits to the same station on two separate days within the same year**								
	n=156	**n=332**	**N=342**	**N=1569**	**N=1340**	**n=2146**	**n=680**	**n=279**
BADO	0.115	0.003	0.111	0.000	0.127	0.002	0.143	0.075
BOOW	0.058	0.003	0.117	0.001	0.207	0.003	0.293	0.140
GGOW	0.013	0.000	0.038	0.004	0.054	0.004	0.029	0.011
GHOW	0.167	0.009	0.120	0.000	0.082	0.228	0.141	0.075
LEOW	0.013	0.003	0.026	0.000	0.009	0.028	0.000	0.000
NHOW	0.000	0.012	0.003	0.01	0.000	<0.001	0.000	0.000
NSOW	0.090	0.003	0.089	<0.001	0.278	0.145	0.173	0.097
NPOW	0.000	0.012	0.000	0.110	0.004	0.000	0.019	0.000
SEOW	0.000	0.000	0.000	0.000	0.000	<0.001	0.000	0.000
AnyOwl	0.353	0.045	0.439	0.124	0.621	0.357	0.716	0.372

As owls have large home ranges and move widely, they may not always be present at the same station/ stop on different days. Thus, for the largest species (i.e. Barred Owl), many analysts use the route or site as the unit of measurement (presence of species along *x* stops or at *x* ARUs). At the site/ route level using two 10-minute ARU periods and two-20 minute playback sequences we found that the probability of observation using playback was higher for most species than ARUs.

In this scenario, we compared six stops on a route that were closest to the six ARUs within each site. We found higher probability of observation for playback-based routes than ARU-based sites. There are several explanations for this pattern.

First, the ARU sites may have been less likely to cross as many owl territories as the playback routes. The main axis of the minimum convex polygon for the ARUs was approximately 4 km long while the average playback route was 8 km.

The second is that playback actively moves the owl towards the observer, accomplishing the objective of increasing probability of observation BUT reducing the "accuracy" of the observation by altering the area where the owl is actively calling to be located "near a road in habitat that the owl may not regularly use".

The third is that listening to more ARU periods we will be able to detect the owl with equal frequency. ARU recordings and playback will result in similar detection rates if sufficient time is spent listening and the recorders are placed in optimal locations to detect the owls. The only way ARUs will not achieve the same probability of observation would be if the owls do NOT call naturally and only call in response to the presence of playback. This is not likely given owl calls are not solely for territorial defense but are also used for communication between males and females of the same species.

Table 4 **–** Probability of observation for forest owls at site level based on passive listening using automated recording units (ARU at midnight in EMCLA study area relative to road-based playback-elicited call surveys along roadsides done in various locations across Alberta with different methods and at different times of day. A site was defined as road-side route with 6 stops versus an ARU site which was a site within 6 ARU recorders.

Species	**ARU Night (n=27**	**EMCLA Day (n=31**	**EMCLA Night (n=31**	**WEYCO Day (n=151**	**WEYCO Night (n=122**	**ANOS CDP (n=217**	**TAKATS CDB (n=72**	**TAKAT CDF (n=29**
BADO	0.333	0.032	0.548	0.000	0.590	0.018	0.555	0.379
BOOW	0.296	0.032	0.581	0.013	0.680	0.014	0.708	0.689
GGOW	0.074	0.000	0.290	0.046	0.320	0.032	0.194	0.103
GHOW	0.518	0.065	0.581	0.000	0.492	0.820	0.514	0.517
LEOW	0.074	0.032	0.194	0.000	0.090	0.180	0.000	0.000
NHOW	0.000	0.065	0.032	0.100	0.000	0.005	0.000	0.000
NSOW	0.259	0.032	0.419	0.007	0.754	0.618	0.667	0.586
NPOW	0.000	0.097	0.000	0.569	0.041	0.000	0.139	0.000
SEOW	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000
AnyOwl	0.778	0.323	0.968	0.649	0.959	0.912	0.944	0.931

DO WE NEED TO COUNT OWLS AT STATION LEVEL?

An additional reason suggested for using playback techniques to survey owls, is human observers have the ability to count the number of owls heard at a point location (i.e. there was 1 versus 2 owls of a species calling). Humans listening to audio recorders sometimes find that determining the number of individuals calling is difficult, especially if the owls are a long distance from the recorder. We have been able to distinguish multiple owls on the same ARU recording however.

Counting the number of owls at each station matters if the number of owls commonly recorded during a survey is greater than one. Field based survey techniques should provide better resolution to detect changes in relative or absolute abundance over time if multiple owls are detected per point. However, if the maximum number of individuals of a species that are counted per survey (when owls are observed is typically 1 then obtaining this resolution may not be necessary).

The probability an owl was observed versus the numbers of owls observed during a survey at a stop was very similar (Table 5). During daytime surveys, we almost never detected more than one individual of a species. During nighttime surveys, we occasionally observed more than one individual of a species but this was rare with only four of the eight species having higher counts than probability of observation. For these four, the mean count was only 1.1 to 1.25 times higher than probability of observation. Pooling data from two visits to a station, we found the maximum number of owls observed was greater than the probability of observation.

At the site level, the number of owls observed was considerably larger than the probability of observation for almost all species (1 to 3 times higher). Count information at the site level (10 stops pooled or 6 ARUs pooled is a more precise metric for tracking change in owls). Understanding why the number of owls observed at the site level is higher than probability of observation is important for interpreting patterns in abundance and trend however. The first possibility is that there is more than one owl per species at the site level (10 stops), resulting in a higher count than the probability of observation. If true, the number of owls observed is recommended as the metric to track because counts are more likely reflective of true abundance. Alternatively, individual owls may be moving both within and between visits and thus are heard at more than one station within the same site. In this case, using probability of observation is more conservative as it does not double count the same individual which overestimates the number of owls occurring in an area. Further work with radio-marked individuals would be useful in determining how often the same owl is detected at different stations within the same site.

The number of times where more than one owl is detected at a station is quite low. Thus, recording the presence of owls at the station level and summarizing the number of stations within a site where owls were recorded as the "count" could be a reasonable metric for tracking owl abundance. The caveat to this is that owls can be double-counted at the site level and rules need to be developed that minimize this possible bias.

Table 5 –Mean count ± 1 standard deviation for single visit to a station and for a single visit to a site (6 stations for ARU and playback counts. The mean count ± 1 standard deviation for the maximum count from all visits to a station or site are also shown.

Species	ARU Avg. Count 1 Visit	ARU Max. Count 2 Visits	Playback Avg. Count 1 Visit	Playback Max. Count 2 Visits
Station				
BADO	0.048±0.244	0.126±0.383	0.071±0.306	0.129±0.406
BOOW	0.020±0.139	0.058±0.226	0.062±0.241	0.117±0.322
GGOW	0.004±0.066	0.012±0.109	0.022±0.156	0.038±0.206
GHOW	0.084±0.314	0.186±0.448	0.079±0.336	0.143±0.446
LEOW	0.004±0.066	0.012±0.109	0.014±0.117	0.023±0.151
NHOW	0.000±0.000	0.000±0.000	0.002±0.039	0.003±0.054
NSOW	0.042±0.221	0.096±0.334	0.051±0.240	0.088±0.313
NPOW	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
SEOW	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
AnyOwl	0.202±0.521	0.443±0.716	0.299±0.631	0.509±0.780
Site				
BADO	0.200±0.739	0.704±1.353	0.692±1.322	1.194±1.662
BOOW	0.082±0.307	0.333±0.555	0.585±0.900	0.903±1.012
GGOW	0.018±0.134	0.074±0.267	0.215±0.515	0.355±0.608
GHOW	0.345±0.851	0.926±1.357	0.723±1.463	1.226±1.927
LEOW	0.018±0.134	0.074±0.267	0.138±0.390	0.226±0.497
NHOW	0.000±0.000	0.000±0.000	0.015±0.124	0.032±0.180
NSOW	0.173±0.572	0.444±0.974	0.369±0.821	0.645±1.082
NPOW	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
SEOW	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000
AnyOwl	0.836±1.645	2.259±2.551	2.738±2.906	3.903±3.534

COST-BENEFIT ASSESSMENT

What is meant by effort differs substantially between the ARU and playback approaches. Choosing one method over the other must weigh the following issues:

1) Using the EMLCA playback approach for owls, an observer can visit approximately 10 stations per night (using a truck or ATV on a road per night when weather conditions are appropriate. Ten stations take approximately 3.5 hours to survey plus 1 hour of driving/ setting up between sample points for a combined survey field effort of ~4.5 hours per site per night. Each visit requires an equal amount of effort. While data acquisition is "instantaneous", data entry from field sheets takes about 2 hours per site. Combined, the number of hours to complete a single site for two visits as was recommended in last years EMCLA report is approximately 12-14 hours.

2) Placing 10 ARU units in a site, assuming they are placed along a road, takes approximately 100 minutes (10 minutes per station plus 60 minutes of drive/ setup time. Collection of ARUs takes a slightly shorter amount of time. If a project's objective was to not spend more time using ARU technology than it takes to do a playback assessment, this leaves approximately 6-7 hours of time for equipment maintenance, audio listening, and file processing.

3) Setup time of the ARUs in the office is difficult to calculate because it depends on whether the unit is straight out of the box or if you are using existing units. For this cost-benefit assessment we assume that all equipment has been labeled, SD cards prepared, and locking brackets constructed. Once this is done the user can simply drive them to the field, which require the amount of time described in 2. This is a significant upfront time cost however and should not be ignored. A guestimate is that it will take 15-20 minutes to setup each ARU in the office for a total of about 2 hours.

4) We have been "learning" how to create a system for downloading recordings from ARU, uploading/backup audio files to servers, and management of audio files. As such our time budgets on this aspect are very poorly established. A large part of what needs to be done if a move to ARUs is made is to develop efficient internet based upload systems for sound files. This step is done in bulk, so with an efficient system upload system it should not take the user much time to do so. However, upload times are measured in hours because of the large files sizes of audio recordings. Each 10 minute recording is stored as a WAC file which is about 50 MB.

5) Getting a file off the current server system, setting it up to listen to, listening to the file, and entering the data takes between 15-20 minutes per 10 minute recording. Assuming the user listens to 40 minutes worth of recordings per station, it will take about 10-13 hours to process 10 stations. Whether 40 minutes of observation is required needs more investigation.

6) Combining these very rough numbers together, the ARU system takes more time to get the same total listening length as owl playback. Adding a passive listening period for marsh birds and amphibians near wetlands adds an additional 12 minutes typically to an owl survey. However, timing of owl surveys during the year does not usually overlap timing required by other species so this is not recommended. With ARUs however these species will be detected near the end of owl surveys. As well ARUs are very effectively for monitoring woodpeckers and other resident songbirds that call more in the early spring as part of owl monitoring. Adding woodpeckers etc to owl surveys requires suboptimal sampling for woodpeckers as there calling peaks in early morning while diurnal owl surveys take place in late afternoon/ early evening

7) At face value, this would suggest that playback would be a more time and cost-efficient option than ARU. However, many other factors must be considered.

   a. Poor weather conditions means that playback surveys on energy sector leases often have to be cancelled. This costs a large amount of time in rearranging safety visits and permissions.

      Relationships with company personnel were strained occasionally in 2012 because we had to come back to achieve optimal weather for playback.

   b. Alternatively, playback data can be collected during poor weather but will be of poor quality because it is done in poor sampling conditions. ARUs can be put out in any conditions. ARUS can stay out for extended periods of time and thus can be optimized to achieve the best survey conditions possible for the period of observation.

      Scheduling conflicts are minimized with ARUs. We have developed protocols for deciding which recordings have suitable weather conditions and rarely do we not get a good window for recording when the ARUs are in place.

   c. Placing recorders out does not have to be done by external staff, resulting in a reduced need for travel costs, accomodations, etc. Employees of energy companies could be trained to distribute recorders and upload files to a server. External staff would then be required to process and listen to recordings.

      We are piloting this approach with at least a few SAGD and mine companies in 2013.

   d. ARUs must be purchased, along with SD cards, batteries, and file storage. These costs are significant. The upfront purchase cost of the ARU is approximately $700 with SD cards, brackets, and locks. Batteries must be purchased and replaced every month or so for ARU. The only addition equipment required by playback surveys that is not also required for ARU layout is the playback device which typically is a one time $200-300 expense but only one is required per observer. Batteries are often required and are replaced weekly.

Cheaper technological options are possible but must be custom built and require considerable testing before widespread implementation. Discussions would need to occur with computer scientists and engineers.

e. This year we required 9 TB of hard drive space to store all of the recordings we collected. This is doubled because we backed it all up (18 TB of data. A large investment in computer infrastructure is required to store audio recordings, although how much recording, how long it is stored, etc., can change computing infrastructure needs considerably.

We would like to partner with the Department of Computing Sciences at the University of Alberta to discuss how to create such a system but building such a system requires a long-term commitment outside current EMCLA funding envelope.

f. ARUs can be placed out during daylight hours. Playback must be done at night by people.

Safety issues are paramount. While we suffered no injuries there clearly is greater risk caused by working at night.

g. Being able to distribute recorders off-road during daylight hours is easier than moving to such sites at night and is considerably safer than having people walking into the forest interior at night to do playback.

Road-side surveys are biased to some degree as some owls may select and others avoid such areas. Playback surveys done on foot will allow two to three surveys per night at best based on distances between stations used in road-based playback surveys. When this is taken into account the cost of human-based playback off-road surveys are much less viable relative to ARUs. Thus, ARUs provide more flexibility in layout and sampling of habitat.

h. All species that give acoustic cues can be recorded by ARUs as long as they are activated at the right time of the year. During playback surveys for owls or rails, incidental sightings of other species can occur but often is not done because of the focus on recording species specific data and dealing with playback equipment.

This includes rails and amphibians as mandated by EMCLA. Passerine birds which are not part of the EMCLA mandate but are a high priority for

monitoring by JOSM can also be recorded.

i. ARUs and playback approaches both sample animals to an unknown distance. It is assumed that people can hear further than the ARU used in this study but this must be tested to determine the area sampled by the two techniques.

   This is a high priority for testing this year and the experiments are described in detail in Next Steps section.

j. ARU recordings can be listened to repeatedly to ensure proper identification. More statistical approaches to analyzing detection error are possible using ARU recordings. The ability to pause a recording when processing data reduces data transcription errors.

   Our data entry sheet for ARU data entry and approach allows for all "current statistical approaches" for estimating abundance, occupancy, singing rate, etc., with the exception of distance sampling. A project is proposed to determine whether distance can be estimated from recordings.

k. Owl calls are often quite faint on many of the recordings. Hearing these requires signal boosting and high volumes on listening equipment. Care needs to be taken to identify optimal volume level of recordings to ensure observer is listening at a safe level.

   Protocols are now available upon request.

l. Overlap with other species calls later in the season (i.e. amphibians seems to reduce the ability of observers to detect owls. Further investigation is required to see whether this bias can be removed statistically, through signal processing, or through different sampling layouts.

   This is something we will look at as we listen to more recordings from the May/ June period.

m. Human noise influences the ability of observers to hear owls on recordings. Presumably the same effect happens during playback. However, during playback owls tend to move towards playback as part of territorial defense, which may increase the change of detecting an owl in a noisy environment either visually or acoustically. However, human noise presumably also influences the ability of the owl to hear playback, decreasing the efficacy of this technique.

   Understanding how human noise influences the distance sampled is a key

aspect of this year's protocol development and is described in Next Steps.

n. As seen in this objective and below in objective 2, ARU recordings seem to have lower probability of observation than playback. This may create concerns among some about observation rates of ARUs. If an ARU protocol was used as the monitoring tool by EMCLA and found not to have achieved the desired precision at some time in the future, playback units could be added to the ARU system to make direct comparisons of owl observation before and after playback. Such a system would allow data standardization over time even which methodological shifts because both types of data could be collected.

   Work is taking place to build a cheap autonomous playback unit to link with the ARUs.

o. Based on these ideas, the EMCLA decided to further test the ARU protocol for owls in 2013. Playback surveys could be implemented by people on roads quite easily and cost-effectively. But how this would cost-effectively be added to a program that is off-road like ABMI is currently unknown. It is the general opinion that a non-road based playback program for owls alone would be cost-prohibitive. Final recommendations on the use of ARUs for owl recording as part of long-term monitoring will occur in 2014.

WHAT IS PROBABILITY OF OBSERVATION AND WHAT DOES IT TELL US?

Probability of observation is an instantaneous measure of how likely an observer is to observe an animal using a particular area. While a common metric in biodiversity monitoring and wildlife research, interpretation of this metric means in terms of habitat use and/or temporal trend is not well understood. It is often assumed that a difference in this metric between different environmental conditions or time periods means a change in size of the population or at least a change in the importance of the quality of an area for an individual animal. However, numerous issues must be resolved before it can be proven that a change in probability of observation is reflective of a change in a population or behavioral process.

1) With playback and passive recordings, the area sampled is ill-defined. Surveys based on sound that do not estimate the distance to a calling organism are effectively unbounded meaning that there is no definition of the area sampled. This matters for several reasons:

   a. Sound travels different distances in different vegetation and environmental conditions. For example, sound will travel considerably further and be more audible over a still lake than in an aspen forest when it is windy. Thus, the chance of detecting a species or multiple individuals of a species will be higher in more open vegetation in calm conditions than in closed vegetation during suboptimal sampling. As well, species that sing at different frequencies can be heard at very different distances meaning there is a different effective sampling area for each species.

   b. Anthropogenic noise can mask the calls of animals making them detectable over shorter distances than in non-noisy areas. Thus, changes in probability of observation in the oil-sands region may have more to do with differential sound propagation than actual changes in abundance or individual habitat selection.

   c. Changes in technology, observer ability, etc influence the area over which animals are sampled. Last year we conducted an experiment that compared the distance over which different recording technologies could detect known frequency sounds. This comparison needs to be made within and between the different Songmetre units that EMCLA is using, as well to understand how we can compare results from different technologies (i.e. ABMI recorders).

   d. Put simply, any and all statistical corrections that try to convert basic observational or count data to some measure of “importance” or “abundance” require an understanding of the area over which acoustic signals travel to understand what the data means. **This is a priority for EMCLA in 2013 and will involve experiments using sound playback. This is intended to provide data standards required for distance correction in different environments.**

2) Probability of observation is a biased estimate of the true use of an area by an animal. A crucial consideration is whether or not an animal can be present in the sampling area but not be detected by an observer because:

a. The acoustic cue given by the animal is missed by the observer and/or the observer misidentifies the cue. This is known as observer error. Observer error can be minimized by training in terms of misidentification. ARU technology allows the same recording to be listened to multiple times by different people, allowing double-observer approaches to be used to correct for misidentification. Resources such as sonograms and exemplar recordings allow observers to make comparisons to what they are hearing and seeing. This has been developed as part of our online data entry system which can be seen with permission at:
https://sharepoint.ualberta.ca/bayne/abmit/emcla/EMCLA%20Database/default.asp
E-mail Erin Bayne at bayne@ualberta.ca to obtain permission to visit the site.
As we listen to more recordings, we are developing a more complete exemplar set of recordings for comparison purposes that will be available to the general public.

b. The other aspect of observer error that is fundamental to both playback and ARU data is that different people have sensitivities to different sound frequencies at different distances. This means that calibration should be done for each person. This is very costly to calculate in the field. Differences between observers can be more easily tested in the lab and correction factors computed for each individual.

As part of our processing of ARU files we are developing a protocol to test each person against the other and to determine how each individual's ability to detect a signal is influenced by the signal strength as measured by sonogram software (decibels). We believe we can use this to compare different observer's ability to hear different distances in a recording. **This protocol is in development and will be discussed in forthcoming reports.**

3) The animal is present with an area that could be sampled by an observer if an animal gave an acoustical cue but no cue was given that could be detected. This occurs because the singing or calling rate (# of calls per unit time of an individual and/or species varies. If the variation is constant among environmental conditions or vegetation types then probability of observation remains a reasonable metric for making relative comparisons. However, a concern in the scientific literature currently is that variation in singing/ calling rate is not constant among vegetation types such that probability of observation provides a biased estimate of habitat use and possibly trends over time.

This problem is known as detection error. Understanding what "detection error" means and how we measure it is crucial for interpretation of this effect. If the individual was present within the sampling during the time of observation and could have been detected, this is detection error. To properly estimate detection error rates requires the animal be present in the area sampled when a survey was done. This is known as the closure assumption. If the closure assumption is met, one way to estimate detection error is to compute detection probabilities. Detection probability, when all the other sources of error (i.e. observer error and distances are understood), is a function of singing/ calling rate. Adjusting probability of observation to a new metric called occupancy can be done by computing singing/ calling rates. There are many ways to compute singing/ calling rate. One approach being used extensively in the literature is to repeatedly visit the same station at different times. This is known as the multiple visit approach and was recommended by Fisher et al. (2011) in the owl proposal to the EMCLA, albeit with caveats highlighted by Bayne.

Much of the literature on multiple visit approaches samples the same station on *x* different days. Visiting on a separate day ensures the assumption of independence is met. Independence means the observer is not biased to hearing the same species they heard in the previous visit. Independence is less of a concern than assumptions about closure, proper identification of species, and area sampled. ***Thus, visits do not have to occur on different days.***

Recommendations by the developers of the multiple visit approach suggest a large number of visits to the same station are required to get accurate estimates of detection probability for uncommon species. This is financially and logistically challenging and effectively trades off going to different stations (a key determinant of statistical power for trend and habitat modeling) versus accurately estimating detection probability.

The resources required to add multiple visits to standard playback methods are substantive. Thus, the efficacy of multiple visits and their interpretation must be critically evaluated to minimize costs and maximize data precision. In the next section, we go through an evaluation of the different ways repeat visit surveys can be used and discuss the pros and cons of each method and what they tell us about owl habitat use versus abundance.

CUMULATIVE PROBABILITY OF OBSERVATION, OCCUPANCY, & DETECTION ERROR: WHY MOVEMENT INFLUENCES INTERPRETATION

CAN SPACE REPLACE TIME TO ESTIMATE PROBABILITY OF OBSERVATION?

Visiting the same station on different days with playback is intended to: A) ensure that variation within and between species in singing/ calling rate as a function of weather, time of year etc are sufficiently randomized to reduce the chances of missing an owl observation; and B) to increase the chance that the observer and the owl interact in the same space thereby allowing the owl to hear the playback and give a response that the observer can detect.

The assumption that visiting on different days achieves these objectives has not been well tested. In our previous report on owls to EMCLA (Fisher et al. 2011) we found little evidence that the probability of observation using playback was influenced by the week of the year when data were collected (with exception of Northern Saw-whet Owl). Time of night when survey was done had larger effects, but was not particularly important as long as surveys were done between about 9 PM and 3 AM for the nocturnally active owls.

Thus, if the objective of a monitoring program is simply to determine the probability of observation of owls in an area, spending resources to come back on another night may be less desirable than simply putting more effort into sampling more stations within an area on a single visit.

Table 6 shows the cumulative probability of observation of owls using playback techniques on roads from across Alberta (uses data described in Table 3). Cumulative probability of observation is whether or not a species was detected with *x* amount of effort, not the number of times it was detected with that effort. This table compares the cumulative probability of observation achieved by going to a single station twice versus spending the same effort going to two stations within the same visit. This is also done for comparisons of 3 visits vs. 3 stations and 4 visits vs. 4 stations. If the goal is to maximize the probability of observation for an area, this table suggests that going to more points within an area is equally effective as visiting the same station multiple times on different days.

The reason this relationship exists is because owls move widely throughout the landscape and have relatively large home ranges compared to the distance over which owl calls can be heard. Thus, when visiting a station on any given night there is a certain probability that the owl will be present to hear the playback and give a cue that the observer can hear. Alternatively, the owl may simply be in an area of its home range outside the area over which the playback can be heard. Moving throughout an area and thereby trying to get to all areas of the home range in an effort to essentially find the owl, works as effectively as going back to the same place over several nights and waiting for the owl to move into the area where the playback can be heard.

Based on this analysis, extra effort invested in playback surveys on a single night could be equally effective in increasing the probability of observation for an area than coming back to the same station. The main assumption of this analysis is that the owl being detected is the same individual. As spatial extent increases there is a higher probability of counting two different individuals which alters what is being measured.

Table 6 - Cumulative probability of observation for multiple visits to the same stop compared to the same subset of data where the cumulative probability of observation for an equivalent effort placed to sampling a greater spatial extent during a single visit. Sample size changes because the amount of data available with multiple visits varied. Comparing estimates of 1 stop: *x* visits or x stops : 1 visit should be done cautiously because the spatial location and playback methods where the *x* visit data were collected vary. Comparisons between temporal versus spatial effort (i.e. 1 stop: 2 visits vs. 2 stops: 1 visit are directly comparable because they use identical datasets to compute estimates. These data come from surveys done across all of boreal Alberta.

Species	1 stop: 1 visit (n=8418	1 stop: 2 visits (n=2816	2 stops: 1 visit (n=2748	1 stop: 3 visits (n=488	3 stops: 1 visit (n=444	1 stop: 4 visits (n=102	4 stops: 1 visit (n=108
BADO	0.039	0.084	0.085	0.100	0.124	0.147	0.185
BOOW	0.067	0.133	0.139	0.227	0.259	0.314	0.351
GGOW	0.014	0.028	0.030	0.047	0.056	0.039	0.046
GHOW	0.090	0.151	0.150	0.156	0.189	0.196	0.241
LEOW	0.010	0.018	0.019	0.002	0.002	0.000	0.000
NHOW	<0.001	0.001	0.001	0.000	0.000	0.000	0.000
NPOW	0.002	0.005	0.004	0.004	0.007	0.029	0.046
NSWO	0.103	0.180	0.186	0.225	0.216	0.156	0.194
SEOW	<0.001	<0.001	<0.001	0.000	0.000	0.000	0.000
Any Owl	0.280	0.462	0.472	0.564	0.622	0.647	0.713

OCCUPANCY & DETECTION ERROR:
SEPARATE VISITS ON DIFFERENT DAYS

The rationale for coming back on different days for owls is that seasonal variation in calling rate may influence whether or not an owl responds to playback. Calling by owls is a form of territorial and/or mate defense that may change with the stage of breeding. Assuming that the assumption of closure has been met (i.e. the owl is present in the area sampled during two different days) then detection rate is a measure of how likely the species is to give a cue that the observer can record. The original logic of the two visits to the same station during playback surveys as envisioned by Fisher et al. (2011), was this approach would provide such an estimate which then could be used to correct naïve probability of observation to an occupancy estimate. Using playback data from across Alberta (Table 7), we found detection probability across species was about 0.25 for most species. This means that returning to the same station and using playback on a different day results in an owl of a single species being detected only 1 out of every 4 times.

Assuming the assumption of closure is met, this means that owls do not always respond to playback. If the assumption of closure is not met and the owl has left the sampling area, then this result suggests that 75% of the time when an observer is conducting a playback survey, the owl is in another location where the owl can't hear the playback and thereby give a cue that the observer can detect.

In contrast, ARUs have a much lower probability of detection (between 0.05 to 0.1). Admittedly, more recordings and data are needed to properly estimate this value. This difference suggests that playback DOES increase detection rate for owls considerably. However, why this occurs is not entirely clear. First, playback may elicit owls to call more frequently than what is recorded passively. Second, playback may cause the owls to move towards the observer thereby increasing the chance that the observer can detect an acoustic cue given by an owl. Owls can hear considerably further than humans, so playback likely draws owls towards the observer. Thus, the distance and area that you sample changes between passive and playback methods.

What is important to realize from this analysis, is that detection rate as estimated by returning to the same station on different days has a large effect on occupancy estimates depending on whether you use playback versus passive sampling. Naïve estimates of probability of observation are relatively similar between playback and passive sampling. However, when detection error is corrected for, occupancy estimates differ widely between the two approaches. If occupancy estimates are to be viewed as a measure of abundance, the two techniques would imply a 4-5 fold difference in the number of owls present in the landscape.

This may in part be a sample size issue for the passive listening done thus far. However, we believe it is a fundamental difference in interpretation caused by differential violations of the closure assumption of playback versus passive listening.

1) The area sampled by passive listening is probably smaller than that sampled by playback because owls move towards playback and this occurs because owls can hear

further than a human observer listening to an ARU.

2) Both playback and ARU recording assume that the owl is always present in the ill-defined sampling area which is very unlikely. It is more likely that the owl will move into the sampling area during a playback survey than during a passive survey thereby reducing the amount that occupancy estimates are corrected.

3) At this time our conclusion is that returning to the same **station** on different days whether by ARU or playback will **NOT** provide valid information about owl abundance unless additional information is collected. Occupancy in this context is probably best viewed as the probability an owl will use a particular area during the entire sampling season (i.e. the probability an owl would use an area sometime during March through end of April). The lack of information about the area sampled by playback and ARU passive listening limits interpretation of this metric to some ill-defined measure of relative use of habitat by owls not owl abundance.

Table 7 – Naïve estimates of probability of observation, occupancy, and detection rate for different species of owls as estimated by playback methods versus passive listening to ARU recordings on different dates within EMCLA area. In this example, the station is the unit of replication for estimating occupancy. Each station was visited 2 to 9 times on different days in these analyses.

2-5 playback visits on different dates (n=3148 stations			
Species	Naïve	Occupancy	Detection
BADO	0.082	0.175	0.251
BOOW	0.129	0.263	0.269
GGOW	0.029	0.085	0.175
GHOW	0.144	0.316	0.242
LEOW	0.017	0.038	0.238
NHOW	0.001	N/A	N/A
NPOW	0.009	0.023	0.198
NSWO	0.179	0.385	0.249
SEOW	<0.001	N/A	N/A
Any Owl	0.447	0.664	0.408
2-9 ARU visits on different dates (n=156 stations			
BADO	0.115	0.660	0.063
BOOW	0.057	0.992	0.021
GGOW	0.013	0.961	0.005
GHOW	0.167	0.401	0.183
LEOW	0.012	0.066	0.075
NHOW	N/A	N/A	N/A
NPOW	N/A	N/A	N/A
NSWO	0.090	0.262	0.146
SEOW	N/A	N/A	N/A
Any Owl	0.353	0.743	0.215

OCCUPANCY & DETECTION ERROR:
SITE LEVEL OCCUPANCY USING MULTIPLE TEMPROAL VISITS TO A SITE

While it may seem obvious that closure is violated at the station/ stop level, it is less certain whether it would be violated at the site or route level. This assumption is predicated on the notion that the home range of the owl is entirely within the area that is sampled. Often times, only a small portion of the home range may overlap the area sampled such that closure is violated. Identifying the number of stops or number of ARUs and the area over which they must be placed to ensure that the entire home range is encompassed within the sampling area is a fundamental unknown. As part of our proposed work plan within EMCLA we want to partner with Alberta Environment and Sustainable Resource Development to determine what a sampling grid would have to look like to achieve this for the Barred Owl.

Using repeat visit surveys to the same site, we found that the naïve probability of observation was somewhat higher when using playback over ARUs. Importantly however, detectability was much higher using playback. When you adjust naïve probability of observation for detection error you estimate occupancy rate. Our finding was the occupancy estimates were more similar to naïve estimates of probability at the site level than at the station level suggesting closure is more likely to have been achieved. In contrast, detectability at the site level using ARUs was much lower which resulted in much higher estimate of occupancy.

This finding requires more investigation and is influenced by the number of minutes ARUs are listened to. Identifying a site scale that works for all owls however is problematic. Thus, a major focus of the EMCLA program is identifying the scale of analysis that is appropriate for the species of interest based on the size of their home range.

Table 8 - Naïve estimates of probability of observation, occupancy, and detection rate for different species of owls as estimated by playback methods from road-side surveys versus passive listening to ARU recordings. In this analysis, the site is the unit of replication. Repeat visits on different days of the year are the replicates used to create detection histories. A site was defined as road-side route with 6 stops versus an ARU site which was a site with 6 ARU recorders.

Species	Naïve Prob.Obs. Playback n=293	Playback Occupancy Temporal	Playback Detection Temporal	Naïve Prob.Obs. ARU n=27	ARU Occupancy Temporal	ARU Detection Temporal
BADO	0.334	0.427	0.509	0.259	0.593	0.250
BOOW	0.461	0.560	0.558	0.296	0.998	0.148
GGOW	0.174	0.357	0.261	N/A	N/A	N/A
GHOW	0.553	0.703	0.511	0.444	0.907	0.285
LEOW	0.092	0.169	0.297	N/A	N/A	N/A
NHOW	0.010	0.012	0.534	N/A	N/A	N/A
NPOW	0.078	0.226	0.174	N/A	N/A	N/A
NSWO	0.621	0.725	0.594	0.185	0.197	0.749
SEOW	N/A	N/A	N/A	N/A	N/A	N/A
Any Owl	0.928	0.947	0.855	0.667	0.750	0.667

OCCUPANCY & DETECTION ERROR:
STATIONS AS SPATIAL REPLICATES USING A SINGLE VISIT TO A SITE

Given that owls move relatively large distances within their home ranges each night, an alternative approach to measuring occupancy and detection error is to replace temporal replication with spatial replication (Hines et al. 2010. Specifically, multiple survey stations can be selected from each site randomly and with replacement and are then surveyed a single time, usually on the same day (MacKenzie et al. 2006). This allows estimation of occupancy at the level of the sample unit (not at the level of the specific sites or locations within each unit). When the species occupies a sampling unit, but is not present at all stations within the sampling unit, detection probability consists of two components: 1) the probability that the species is present within the site and 2) probability of detection given that the species is present at the survey site. The stops along a road-side playback survey or the individual ARU units within a site sampled on a single night could be viewed as replicate surveys within the site which thereby is the unit of analysis.

There are two ways to model such data. The first is to assume that detection histories in the site are random, whereby the animal randomly moves throughout the site to generate a detection history. The other approach is to assume that there is some degree of spatial dependency between stations that are closer together which requires a Markovian spatial process model. Here we show the results from the random movement model.

Using the stops as spatial replicates we found that the occupancy and detection rates for owls were relatively similar between ARU and playback methods for most species (Table 9). Admittedly this comparison is not perfect as the area covered by stops on a playback route is different than the area sampled by 6 ARUs because of layout and the distance over which acoustic cues can be detected.

A challenge with using the space for time approach to measure occupancy is identifying: A) what the size of the sites should be; and B) how many stations have to be placed in a site to ensure sufficient precision; and C) knowing if this metric accurately reflects abundance given that multiple individuals could be detected within a site.

The key to using this analytical approach is ensuring that the site is scaled appropriately to the organism of interest and the scale at which sound transmits. In other words, the size of the sampling area for a site needs to be proportional to the home range of the animal of interest and how far that animal can be heard over. If the site is too big, then the estimate of abundance is a minimal estimator of abundance because more than one individual might be present. If the site is too small, then the assumption of closure will not be met. This results in a detection error estimate that is more likely to be caused by movement. Correcting occupancy estimates for detection error when movement occurs will lead to overestimates of animal abundance. Also you need to understand the distance over which sounds can be heard.

For this to be the modeling approach used in owl monitoring, several issues have to be addressed. This model assumes that observations of owls at different playback stations would be independent. It is highly plausible that owls move in response to playback and could in theory follow the observer from point to point creating a detection history that would result in a severe bias in occupancy estimation.

With passive listening, the timing of surveys would have to be varied. If you used data from all of the ARU recordings from the same date and time across a site you should get a detection history with a single 1 and the rest zeros. This would be caused by the fact that if only one is present it should only be detected at one recorder. To determine the spatial movement of an animal across the site and get a suitable capture history, it would be better to listen to different ARUs at different times of day and date.

In biodiversity monitoring all of these issues create a significant challenge because the home range size of different organisms varies widely, meaning that the site needs to differ in size for different species to estimate abundance. Sound transmission also varies amongst species so that the area sampled differs based on the frequency and amplitude at which a species calls. How to optimize the layout of playback stations or ARU locations at an appropriate scale for the largest number of species possible is a significant challenge that the EMCLA needs to address if the goal is to obtain a metric that reflects the true abundance of owls.

Table 9 - Naïve estimates of probability of occurrence, occupancy, and detection rate for different species of owls as estimated by playback methods from road-side surveys versus passive listening to ARU recordings. In this analysis, the site was the unit for which occupancy was estimated and the presence of a species at a station was the replicate samples used to create a detection history. A site was defined as road-side route with 6 stops versus an ARU site which was a site within 6 ARU recorders.

Species	Naïve Prob. Obs. Playback	Playback Occupancy	Playback Detection	Naïve Prob. Obs. ARU	ARU Occupancy	ARU Detection
BADO	0.159	0.299	0.124	0.109	0.197	0.205
BOOW	0.235	0.339	0.188	0.072	0.404	0.048
GGOW	0.074	0.281	0.051	0.018	N/A	N/A
GHOW	0.353	0.548	0.166	0.209	0.455	0.156
LEOW	0.047	0.181	0.051	0.018	N/A	N/A
NHOW	0.019	N/A	N/A	N/A	N/A	N/A
NPOW	0.101	0.163	0.156	N/A	N/A	N/A
NSWO	0.387	0.541	0.199	0.118	0.347	0.105
SEOW	N/A	N/A	N/A	N/A	N/A	N/A
Any Owl	0.775	0.867	0.337	0.372	0.633	0.239

OCCUPANCY & DETECTION ERROR:
"SUBVISIT" DETECTION ERROR

As the previous analyses in this section demonstrate, the assumption of closure is very important for interpreting what a particular method tells us about owl abundance versus owl use of an area. Ensuring that the area sampled is large enough to cover the entire home range of an animal is one way to ensure closure. The other, is to change the temporal extent over which repeat surveys are conducted to minimize the change of the animal moving during the period of observation.

ARU analysis is ideally suited to changing the temporal definition of a "visit". During the ARU recordings we recorded for 10 minutes each hour. With ARUs we can stop recordings, write down information, and then continue with listening. This makes it quite easy to determine exactly when a species gives an audio cue on the recording. In our database, we record the time within each 1 minute interval of the entire 10 minute period when an individual of a species was first heard. If we assume that during the 10 minutes when the listening was done that organisms do not move outside the area that the ARU can hear, our approach allows estimation of the minute by minute detection probability. Detection probability in this case mostly reflects an estimate of singing/ calling rate and is a more accurate measure of true detection rate using passive listening methods than listening to recordings on different days or potentially even different hours.

Table 10 shows the minute by minute detection rate of owls at the ARU locations. Different definitions of repeat samples are shown (10 – 1 minute repeat samples, 5 – 2 minute repeat samples, and 2 – 5 minute repeat samples. Occupancy estimation in this case is very similar to the naïve probability of observation. This is because the singing/ calling rate of owls within a 10-minute period is in fact quite high. For most species detected, an acoustic cue was given every 2nd minute. If an owl gave an acoustic cue in the first 5 minutes of a passive listening session, there was about a 75% chance they would give a cue that was detected in the 2nd five minute period.

Because the detection rate within a 10-minute period is so high, occupancy estimates from this approach do not change much relative to the naïve estimate of probability of observation. This does not mean that this is a good measure of true abundance however. Occupancy in this particular case is an instantaneous measure of habitat use by owls. In other words, it is the probability that an owl as present at a station at the same time that an observer was there (probability of use within the 10 minute period of observation). As stated earlier, most owls have home ranges that are likely larger than the area of observation for an ARU recorder such that only a portion of the owl's home range is within the sampling area of the ARU. Estimating density from such data requires information about the distance at which the owl was located and/or the proportion of the territory within the sampling area of the recorder.

An issue that should be considered when using this metric is that the presence of a second owl of the same or different species may alter the singing rate of the focal owl. Intra-specific competition may cause each owl to call at higher rates than when they are alone. Inter-specific competition could cause a reverse effect if smaller owls choose not to call when a larger and perhaps predatory owl calls. These effects can bias occupancy estimates if not taken into account. For example, if

Great Horned Owls move into more human disturbed areas, smaller owls may be present but less likely to call.

Table 10 - Naïve estimates of probability of occurrence, occupancy, and detection rate for different species of owls as estimated by ARU recordings. Here detection is measured using 1-minute, 2-minute, or 5-minute subintervals within a 10-minute recording as the temporal replicates. Detection rate measured in this way is a measure of calling rate by owls as closure is likely achieved.

10 ARU "subvisits" (n=464 point counts			
Species	Naïve	Occupancy	Detection
BADO	0.047	0.047	0.435
BOOW	0.019	0.020	0.327
GGOW	N/A	N/A	N/A
GHOW	0.081	0.081	0.470
LEOW	N/A	N/A	N/A
NHOW	N/A	N/A	N/A
NPOW	N/A	N/A	N/A
NSWO	0.041	0.041	0.500
SEOW	N/A	N/A	N/A
Any Owl	0.159	0.160	0.494
5 ARU "subvisits" (n=464 point counts			
BADO	0.047	0.048	0.544
BOOW	0.019	0.021	0.385
GGOW	N/A	N/A	N/A
GHOW	0.081	0.082	0.570
LEOW	N/A	N/A	N/A
NHOW	N/A	N/A	N/A
NPOW	N/A	N/A	N/A
NSWO	0.041	0.041	0.627
SEOW	N/A	N/A	N/A
Any Owl	0.159	0.161	0.602
2 ARU "subvisits" (n=464 point counts			
BADO	0.047	0.052	0.706
BOOW	0.019	0.033	0.364
GGOW	N/A	N/A	N/A
GHOW	0.081	0.089	0.712
LEOW	N/A	N/A	N/A
NHOW	N/A	N/A	N/A
NPOW	N/A	N/A	N/A
NSWO	0.041	0.043	0.774
SEOW	N/A	N/A	N/A
Any Owl	0.159	0.170	0.756

OCCUPANCY & DETECTION ERROR:
ROBUST MODELS OF MOVEMENT & SINGING RATE AT STATION LEVEL

A practical way to address the closure assumption is to sample populations using the robust design, which was originally developed for capture–recapture sampling (Rota et al. 2009. In the robust design, sampling consists of secondary sampling periods nested within primary sampling periods. Populations are assumed to be closed to demographic changes or movement between secondary sampling periods and open to demographic changes between primary sampling periods. Using this model at the stop level for the ARU data, we estimated the probability of occurrence during the two visits to a site on different days and the detection rate within the 10-minute sampling period where the recorder was monitoring owl calls.

This model is likely the most realistic way of measuring occupancy for owls at the station level as it ensures that the assumption of closure is met. The results from this model (Table 11) suggest:

A) When present, owls call relatively frequently within the sampling area of the ARU when measured on a minute by minute basis. In other words, owls do give cues that can be detected passively.

B) Owls move extensively and quite often are not present in the sampling area of an ARU or an observer using playback. 70-75% of the time owls are likely to have moved from a station where they have previously been recorded based on the robust model.

C) Station level surveys provide an index of owl use of habitat NOT measures of owl abundance. The smaller the home range of an owl species the more likely station surveys will tell us something about abundance but whether a single ARU can be used to estimate abundance for any owl species is not clear.

D) Only by pooling stations together can an estimate of owl abundance be generated that correlates with population size. Thus, the site needs to be the unit of replication for all future monitoring. More than one station is likely needed for most species. How large a site needs to be to estimate abundance depends on the species life history, their home range size, and how far different species’ calls transmit in different conditions.

Table 11- Naïve estimates of probability of occurrence, occupancy during the first and second visits on different days to the same station with ARU recorders. Detection rate for different species of owls as estimated by ARU recordings are done within a 10-minute period. The probability that an owl moves into or away from that station on the second visit are also shown.

ARU visited on 2 separate days within same year with 10-1 minute subsamples measured during each visit (n=156 stations							
Species	Naïve 1st visit	Naïve 2nd Visit	Occupancy on 1st Visit	Occupancy on 2nd Visit	"Arrive" on 2nd Visit	"Leave" by 2nd Visit	Subvisit Detection Rate
BADO	0.026	0.071	0.026	0.071	0.066	0.749	0.425
BOOW	0.019	0.038	0.020	0.039	0.040	1.000	0.327
GGOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GHOW	0.064	0.071	0.064	0.071	0.061	0.800	0.456
LEOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NHOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NPOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NSWO	0.038	0.019	0.045	0.019	0.007	0.571	0.469
SEOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AnyOwl	0.132	0.168	0.132	0.168	0.152	0.727	0.467
ARU visited on 2 separate days within same year with 2- 5 minute subsamples measured during each visit (n=156 stations							
BADO	0.026	0.071	0.031	0.086	0.079	0.694	0.571
BOOW	0.019	0.038	0.032	0.065	0.067	0.999	0.363
GGOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GHOW	0.064	0.071	0.069	0.076	0.066	0.783	0.727
LEOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NHOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NPOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NSWO	0.038	0.019	0.040	0.020	0.006	0.652	0.800
SEOW	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AnyOwl	0.132	0.168	0.143	0.182	0.163	0.704	0.717

OCCUPANCY & DETECTION ERROR:
ROBUST MODELS OF MOVEMENT & SINGING RATE AT SITE LEVEL

Based on our previous analyses, the robust model is likely to provide the best measure of habitat use at the station level based on ARUs. We also believe that this model will be of utility in estimating abundance at the site level by incorporating the various types of error associated with listening surveys. However, to the best of our knowledge there has not been any evaluation of how the robust model should be scaled from the station to a site level. We propose the following model be tested:

1) Visit *x* number of stations with ARUs level within a site. The site should be scaled appropriately for the species of interest based on literature review about owl home range size.

2) Have the ARUs all come on at exactly the same time and same date. As long as the recorders are far enough apart to not hear the same owl, you will have an independent series of replicates for that owl. The number of units will depend on size of home range and the area over which the ARU can hear owls.

3) If there is only one owl in the site then it should be detected at one recorder if it is giving an acoustic cue within the sampling area of an ARU, assuming spacing is correct. If it is not within range of an ARU then no owls should be detected.

4) Alternatively, an owl may be in range of an ARU but not provide an acoustic cue.

5) To estimate the frequency of an owl giving acoustic cues, the subvisit approach within each 10 minute interval can be used to estimate calling rate. Calling rate is measured by estimating the detection error which would be caused by an animal not giving a cue within a particular minute of the 10 minute sequence. The most appropriate sub-visit length must be determined.

6) Calling rate within the site is computed by determining whether any 1-minute interval, anywhere in the site, had an owl detected. In other words, the occurrence of any owl at any station within each of the 1-minute intervals of the 10-minute recordings made by each ARU becomes the detection history for the site.

7) The extinction rate parameter is, assuming the animal does not die or permanently emigrate, an estimate of the movement rate within the site by the owl. When the owl is not detected at any station this could be caused by the owl not being in the detection area OR the owl not giving an audible cue. This model should allow separation of those effects because the entire sampling area is being sampled instantanteously. As such the position of

the owl is fixed during the 10-minute interval of sampling.

8) With this information the occupancy rate for the entire site (which by design is large enough to include the home range of one owl) can be estimated. The number of sites occupied can then be used as an estimator of population size.

9) If more than one owl is present within the area, this approach can be estimated because detection would occur on two recorders simultaneously. An n-mixture modification of robust occupancy models for counts could also be employed.

10) Currently we can't test this model because we chose to randomly pick which owl times and days to listen to within each site. We are in the process of re-listening to create a matched set of observations that will allow us to test this idea using ARU data.

11) An additional component that could be added, conditional on budgets, is estimation of distance from the owl to the recorder. This modification to the model requires the development of two technologies however.

12) THIS ANALYTICAL APPROACH IS NOT POSSIBLE WITH PLAYBACK METHODS.

WHAT DO WE NEED TO DO TO TRACK "POPULATON SIZE" IN OWLS?

Which assumption about closure is correct has significant implications for interpreting the results from multiple-visit analysis and how such a strategy should be used in a monitoring design. When closure is met and detectability is low, estimates of occupancy relative to probability of observation change dramatically. Many researchers view occupancy as a better measure of relative abundance or absolute density than probability of observation. As detection rate is often considerably less than one then the number of animals estimated to be in an area will often be considerably higher using multiple visit analyses than naïve approaches that do not correct for detection error. However, if the assumption of closure is not met then the adjustment to occupancy rate can artificially inflate population size estimates because the detection error is confounded with movement which artificially alters detection rates.

Table 12 shows population estimates of owls in the Lower Athabasca region if we assume:

1) stations and sites were random samples from the region;

2) for naïve estimates based on probability of observation, detection rate assumed to be 100%;

3) for estimates derived at the station scale, owls were always present within a 800 metre radius of the station centroid;

4) for estimates derived at the site scale, owls were always present with 800 metres of the road;

5) only owls within 800 metres of survey locations were detected;

Table 12 demonstrates that there are significant differences in the absolute numbers of birds assumed to be in the Lower Athabasca using different techniques and survey times. Daytime surveys result in very low population estimates when using naïve methods because the probability of observing an owl is so low. This is partially because we do not use playback of the nocturnal owls at this time of the day and vice versa for diurnal species like the Northern Hawk Owl. Adjusting occupancy at the station level to adjust for detection error during the day, results in an estimate of population size that is 126 times larger than using probability of observation. At the site level, this difference is 15.4 times. At night, the difference between naïve and corrected population size estimates is at 7.6 times larger at the station level. At the site level, the difference is only 1.8 times.

WE STRESS THE ASSUMPTIONS REQUIRED TO ESTIMATE POPULATION SIZE OF OWLS ARE VIOLATED TO UNKNOWN DEGREES IN ALL DATA EVER COLLECTED ON OWLS. POPULATION ESTIMATES SHOWN HERE ARE INCORRECT AND ONLY PROVIDED AS AN EXAMPLE.

Our objective in showing this result is to demonstrate that naïve occupancy estimates are likely to too low because playback does not increase detection rate to 1. In contrast, multiple visit estimates are overestimated because the assumption of closure is likely violated as well as detection error being a problem. At the station level, the population estimates are too large to be taken as even reasonable. Detection rate cannot be properly estimated at the station level over two visits using playback OR ARUs when survey are done on different days because violations of closure are ensured. Other approaches to calculating detection rate at the station level that account for movement are possible but not using a human observer and playback techniques.

At the site level, particularly during the nighttime, multiple visit methods hold more promise as a sampling strategy. Occupancy and detection rate parameters were stable and could be estimated for most species at this scale and at this time of the day. At this spatial scale, there is a greater likelihood the assumption of closure is met because even though a species may move between stations, it is still detected within the site when visited on a different day. Importantly, this may not require visiting exactly the same stations on different visits. As well, while the assumption that closure is met increases as the size of the sampling increases relative to the size of the home range of the animal surveyed, it does not guarantee it. Both ARUs and playback may allow such estimates to be calculated. ARUs provide greater flexibility to get more refined estimates of detection error and movement rates. Further work is needed however to determine optimal ARU spacing and the number of recordings that must be listened to however.

Table 12 – Example that shows the magnitude of variation in population size estimates of owls derived from using station and site level data from playback for daytime and nighttime surveys done using naïve probability of observation and occupancy rate corrected for detection.

Species	**Daytime**		**Nighttime**	
	Population estimate based on station level density			
	Naïve	**Occupancy**	**Naïve**	**Occupancy**
Any Owl	2,197	7,742	18,108	38,929
Barred Owl	185	46,360	4,682	37,459
Boreal Owl	185	46,360	6,245	46,360
Great Gray Owl	0	0	1,405	3,904
Great Horned Owl	366	46,360	5,619	28,173
Long-eared Owl	185	46,360	1,247	3,162
N. Hawk Owl	366	413	158	46,360
N. Pygmy Owl	732	46,360	0	0
N. Saw-whet Owl	185	46,360	3,755	9,504
Sum of Owl Species	2,207	278,573	23,110	174,921
	Population estimate based on site level density			
Any Owl	1,656	2,980	4,491	4,565
Barred Owl	166	4,636	2,318	3,621
Boreal Owl	166	4,636	2,753	3,769
Great Gray Owl	0	0	1,014	1,467
Great Horned Owl	331	4,636	2,608	3,477
Long-eared Owl	166	4,636	869	1,159
N. Hawk Owl	166	166	145	4,636
N. Pygmy Owl	662	4,636	0	0
N. Saw-whet Owl	166	4,636	2,318	3,621
Sum Of Owl Species	1,821	27,982	12,025	21,749