# Recommendations for an Owl Monitoring Pilot Study in Northeast Alberta


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## Executive Summary

Owls are elusive, which makes them difficult to study and monitor. Therefore, little information exists on owl distribution throughout Alberta's northeast: how owl occurrence varies in natural and human-impacted landscapes; the trends in owl occurrence and abundance through time; or how cumulative effects of human land-use affect owls through time. An owl monitoring program for northeast Alberta that is intended to inform land-use decisions must address these questions. We used existing data and expert advice to guide recommendations for an owl monitoring program that would be sufficiently rigorous to address these questions. We compiled existing data on owl occurrences from multiple sources into a central database. We analysed these data to determine some technical details of owl surveying and estimate the degree of survey effort required to detect trends in owl occurrence through time. From this analysis, informed by expert opinion, we made the following recommendations for an owl monitoring pilot study to be implemented in 2012:

1. Standardized call-survey protocols for owl detection should be adopted.
2. Nocturnal and diurnal surveys should be conducted in the pilot to survey all owl species in northeast Alberta, and the value of diurnal surveys weighed against their cost.
3. Pilot monitoring should include two separate spring surveys, and the value of the second surveys weighed against their cost.
4. Pilot monitoring should occur on a subset of sites on ABMI's systematic sampling grid, and the systematic "impact-targeted" additional grids, in northeast Alberta.
5. A cluster design should be developed for monitoring short-eared owls.
6. Presence-absence should be the target state variable for owl monitoring, with abundance, occupancy and detectability modelled within a suitable analytical framework.
7. Pilot program surveys should be temporally and spatially replicated within each sampling site, and estimate precision provided by each approach should be weighed against cost.
8. A 20-year commitment to owl monitoring is needed to detect trends and relationships in owl occurrence.
9. Analysis of existing owl occurrence data should be conducted concurrently with the Pilot, to inform design and logistical trade-offs.

## Introduction: Owls in Alberta's Northeast Boreal Forest

Ten species of owls occur in north eastern Alberta, including barred, boreal, great gray, great horned, long-eared, northern hawk, northern pygmy, northern saw-whet, short-eared, and snowy owl. Barred, great gray, and northern pygmy owl are considered *Sensitive* in Alberta (ASRD 2010). Northern hawk owls were changed from *Sensitive* (2005) to *Secure* in 2010, but with an acknowledged lack of information on population trends (ASRD 2010). Short-eared owls are listed as *May be at Risk* (ASRD 2010). Because of their status, barred and short-eared owls have been identified as priority species for management in Alberta's northeast. Frequency of occurrence and range size varies among these species, as do life-history traits (Table 1), and all these parameters will affect a monitoring program's ability to detect change in abundance through time (Hilty and Merenlender 2000).

Owls are elusive species and, therefore difficult to monitor and study. The known habitat preferences and ecology of Alberta's owl species, and owls' utility as indicators of ecosystem integrity an function, were reviewed in the document *"Priority Questions for Monitoring Rare and Elusive Species in Northeast Alberta"* (Fisher *et al.* 2011). In general, owls inhabiting northeast Alberta could be fit into one of two categories: (1) species we know are adversely affected by loss of habitat (particularly older forests); (2) species whose response to human-land use remain largely unknown; and (3) species whose basic habitat preferences remain largely unknown. Many owl species in the boreal forest of north eastern Alberta use mature and old trees for most daily activities (reviewed in Fisher *et al.* 2011). The cumulative effects of anthropogenic activities tend to decrease the percent cover of old forests across the boreal forest landscape, thereby removing owl habitat. The regional consequences of this habitat disturbance are currently unknown, but are expected to decrease owl abundance and distribution (reviewed in Fisher *et al.* 2011). For some owl species old-forest associations are less apparent, but their reliance on several different, adjacent land-cover types suggests that anthropogenic development may affect these owls' distribution and abundance.

Table 1-1. Attributes of the 10 owl species potentially occurring in northeast Alberta. Owl species occupy different habitats and display different diel and phonological activity patterns.

| Common name | *Species name* | Alberta Status | Primary habitat | Additional habitat | Diel activity pattern | Residence |
|---|---|---|---|---|---|---|
| Barred owl | *Strix varia* | *Sensitive* | dense older forests (cavity nester) | adjacent open country | nocturnal; crepuscular in winter | annual |
| Boreal owl | *Aegolius funereus* | *Secure* | conifer forests | other northern forests | nocturnal | summer-breeder; possibly annual (don't know) |
| Great gray owl | *Strix nebulosa* | *Sensitive* | conifer  and mixedwood forests | boreal/foothill forests | crepuscular; diurnal in winter | annual (summer-breeder)-nomadic winter irruptions |
| Great horned owl | *Bubo virginianus* | *Secure* | open forest (breeding) | open woods/rivers | crepuscular | annual |
| Long-eared owl | *Asio otus* | *Secure* | forest; dense willow hedgerows | open | nocturnal | summer-breeder |
| Northern hawk owl | *Surnia uvula* | *Secure* | Burns; open areas with pockets of forest brushy openings | muskegs | diurnal | summer-breeder; nomadic winter irruptions |
| Northern pygmy owl | *Glaucidium gnoma* | *Sensitive* | open conifer / mixedwood | foothills/ mountains | diurnal | annual – unknown |
| Northern saw-whet owl | *Aegolius acadicus* | *Secure* | mixedwood forest with some conifer | parkland / foothills/ mountains | nocturnal | annual (summer-breeder) |
| Short-eared owl | *Asio flammeus* | *May be at risk; SARA Special Concern* | open / forest | wetlands | diurnal | summer-breeder IRRUPTIVE |
| Snowy owl | *Nyctea scandiaca* | *Secure* | rolling hills | open areas / forest | diurnal and nocturnal | winter |

Based on what we do know about owls in Alberta's northeast, the primary priority questions for owl monitoring are:

1. How are owl species currently distributed throughout Alberta's northeast?
2. How does owl occurrence and abundance vary in natural and human-impacted landscapes?
3. What are the trends in owl occurrence and abundance through time?
4. How do cumulative effects of human land-use affect trends in owl occurrence and abundance?
5. What specific aspects of industrial activities, if any, are driving the relationship between owl population trend and human land-use?

We used existing data and expert advice to develop recommendations for an owl monitoring program that would be sufficiently rigorous to answer these questions. Several jurisdictions have implemented owl monitoring programs; these are reviewed in Takats *et al.* (2001), and the relative merits of each program has been used to inform this program, in addition to analyses of existing data on owls in Alberta. First, we compiled existing data on owl occurrences from multiple sources into a database, *Strigidae_ver1.* We used these data to create maps of owl distribution throughout Alberta, though these were biased to areas where surveyed had occurred, and these areas are very limited. We also analysed existing detection rates of owls gathered under current survey guidelines, to inform our survey design. We conducted occupancy analysis to determine probabilities of detecting owls given they are present, and how this might affect monitoring program design. Finally, we conducted a precision analysis to illustrate the degree of survey effort required to detect trends in owl occurrence through time. We used this information to form recommendations for designing an owl monitoring pilot study in northeast Alberta in 2012.

## Primary Recommendations for an Owl Monitoring Pilot Program in Northeast Alberta

We have conducted preliminary analyses of previously compiled data that have yielded insights on probability of detection, occupancy, abundance, and precision of expected trends, which together form the basis for primary principles and recommendations for a pilot owl monitoring program in 2012. These recommendations are listed here; the balance of the Report provides the technical analyses and justifications for these recommendations.

1. *Standardized call-survey protocols for owl detection should be adopted.*

The standardized protocol designed by owl experts across North America (Takats *et al.* 2001), based on eliciting and recording owl vocalisations (Johnsgard 1988; Mosher and Fuller 1996; Laidig and Dobkin 1995; Duncan and Duncan 1997; Takats 1998) should be adopted for surveys done in the LAPR. These protocols incorporate best available information on owl ecology, activity patterns, and calling rates, and provide the best available option for surveying owl occurrence in northeast Alberta. The Weyerhaeuser variant of this protocol (Appendix 1) provides the most reasonable balance in detectable responses between multiple species, so should be adopted for multi-species owl monitoring in the northeast.

2. *Nocturnal and diurnal surveys should be conducted in the pilot to survey all owl species in northeast Alberta, and the value of diurnal surveys weighed against their cost.*

Owl species vary in their diel activity patterns; during the breeding season most are nocturnal, some are diurnal, while others are crepuscular (Table 1-1; Figures 2-4). Surveys conducted in the hours between sunset +30 min. and sunrise -30 min. have detected all nocturnal and crepuscular species potentially occurring in northeast Alberta (reviewed in Takats *et al.* 2001; Figures 2-4). For the pilot, we recommend randomizing the timing of nocturnal surveys within this timeframe to prevent biasing detection rates for early or late callers. Northern hawk owls and pygmy owls are diurnal (Table 1-1; Figures 2-4) so diurnal surveys must be conducted monitor all owl species in the LAPR. We recommend that pilot surveys do nocturnal and diurnal surveys at each location to weigh the cost of conducting the diurnal survey against the value of the information gained, to inform the future program.

3. *Pilot monitoring should include two separate spring surveys, and the value of the second surveys weighed against their cost.*

Peak calling times for owls vary among species, and geographically within a species (see Figures 2-3). Existing nocturnal owl monitoring programs in Alberta survey twice: between March 20 – April 10, and again between April 11 and May 5. Surveying in both time periods increases the probability that species that call early in the spring as well as late in the spring are detected. Surveying both time periods will also help to confirm that a site is occupied by a breeding owl. Birds detected in the first survey period could still be winter/spring vagrants, and not breeders; confirming presence in both time periods, or only during the latter survey, should be considered more complete evidence of occupancy (for the purpose of breeding) than a single detection in the earlier survey. We recommend the pilot program survey within each of these timeframes. The date of each survey session survey should be randomized among locations and among repeat visits across years, to account for differences in call rates with time of year. The advantage that two spring surveys convey to the precision of trend estimates should be weighed against the cost of repeated visits, to inform the future program.

4. *Pilot monitoring should occur on a subset of sites on ABMI's systematic sampling grid, and the systematic "impact-targeted" additional grids, in northeast Alberta.*

Most owl species in the northeast are likely relatively common and well-distributed. For those species, the ABMI systematic design provides a robust probabilistic design. Currently, a transect-based stratified-random design is widely used for owl monitoring in jurisdictions across North America (Takats *et al.* 2001). This design stratifies a landscape based on reliable road access and habitat type, and randomly selects 14.4-km transects in which to survey 10 stations, equally spaced. This design, though robust and useful for volunteer programs, relies on feasible road access; road access is not always present across northeast Alberta, and could bias results if owl occupancy varies with distance to road. Most importantly, a stratified design is not possible when monitoring over long time-frames since these strata might change over time. Weighting observed trends by strata requires that the strata remain constant over time. If the definition of a strata changes, it is very difficult to assess the implications for inferring estimates of abundance or occupancy to the entire statistical population. Alternative designs that target rare or clumped animals, such as adaptive, two-phase, or sequential sampling designs (Smith *et al.* 2004; Manly 2004; Christman 2004) may increase probability of detection, but currently there is no evidence to suggest they are necessary, or which alternative might be more effective at detecting multiple owl species. ABMI's systematic sampling grid will (1) allow statistical inference across landscapes, (2) minimise potential road and habitat bias, (3) capitalise on existing operational logistics, (4) provide data on owl prey (songbirds) communities for questions of predator-prey interactions, (5) provide data on large woodpeckers that excavate cavities, upon which many smaller forest owls rely upon to nest and breed; and (6) provide ABMI habitat data for analyses and modelling of the effects of human land-use on owl populations, a main objective of owl monitoring (Fisher *et al.* 2011). On this last point, it should be noted that trying to identify human effects on species using a systematic design tends to under-sample human impacts, as these are clustered on the landscape. A monitoring program can compensate by augmenting the systematic grid with "off-grid" points in a stratified design to increase sampling coverage of areas with human land-use. The ABMI has done this for their monitoring programs, and their off-grid points should be surveyed for owls to provide a suitable gradient of natural and human-impacted sites for analysis.

5. *A cluster design should be developed for monitoring short-eared owls, and considered for snowy owls.*

Short-eared owls (*Asio flammeus*) are elusive and relatively unknown as they are highly nomadic and irruptive (Clayton 2000). They are biogeographically widespread, but local abundance fluctuates widely through time. The same may be true of snowy owls (*Nyctea scandiaca*), which can display population irruptions (Boxall and Lein 1982). For these reasons very little information on these species has been garnered to date from research, or from our analysis of data in *Strigidae_ver1*. These species' variability in time suggests that systematic sampling will not adequately monitor trends in their occurrence. We recommend that adaptive cluster sampling (Thompson 1990) be adapted to monitoring short-eared owls, since they are an EMCLA priority species and are federally listed as a species of *Special Concern*. A similar design may be considered for snowy owls. An adaptive cluster design starts with a standard probabilistic design, such as the systematic ABMI grid. If results from this design (detections) meet a specified criterion, then additional units are sampled; if not, sampling is restricted (see Smith *et al.* 2004 for comprehensive review of cluster sampling designs and variants). Development of criteria and adaptive sampling protocols based on analysis of existing data, as well as a plan for implementation, should accompany the owl pilot program in 2012.

6. *Presence-absence should be the target state variable for owl monitoring, with occupancy and detectability modelled within a suitable analytical framework.*

Call surveys yield presence-absence (or "occurrence") data. Changes in local persistence at regional scales - ultimately the biological parameter of conservation and management interest - is more likely detected as changes in occurrence at a site than by changes in population (which is hard to reliably measure) or behavior (which is difficult to link to persistence). Abundance data may be garnered from surveys where >1 individuals are recorded at a site, but each site will likely house only a few individuals, and this additional information does not necessarily convey greater power to trend analyses. In some conditions, abundance can be estimated from repeated detection data (Royle and Nichols 2003), provided that methods to test for and model the vital assumption of closure are implemented (Bayne *et al.*, in review). Methods to estimate abundance from repeated detections should be explored within the pilot program, and ancillary data needed to inform this process should be gathered as identified. As a basic target, presence-absence data should be modelled to account for imperfect detectability (MacKenzie *et al.* 2002; MacKenzie 2005). Accurately sampling species' probability of occupying a site (occupancy, $\psi$) depends on the species' presence at time of sampling, and the probability of detection ($p$), the probability of detecting that species when it is, in fact, present. As $p$ is typically less than one (MacKenzie *et al.* 2002), unadjusted counts of occurrence are negatively biased (MacKenzie *et al.* 2006). Estimated occupancy corrects for this bias. Occupancy is flexible, robust, easier to quantify on large scales than are most demographic metrics, and provides a transparent estimation of $p$ (Thompson 2004; MacKenzie *et al.* 2006).

7. *Pilot program surveys should be temporally and spatially replicated within each sampling site, and estimate precision provided by each approach should be weighed against cost.*

Estimation of probability of detection (*p*) and occupancy (ψ) require replication of surveys that are independent of one another, such that the probability of detecting a species in one survey does not affect that probability in another survey (MacKenzie *et al.* 2002, 2006). Temporal replication – multiple visits to a site – is the typical approach for occupancy monitoring, but may be logistically taxing in short timeframes in which breeding owls call, and at remote locations. Spatial replication can sometimes be substituted as a logistical alternative. Spatial replication can inform estimates of *p* and ψ at the level of the site, rather than each point-count station, and is useful for landscape-level analysis of occupancy (MacKenzie *et al.* 2006). However, temporal and spatial replication have different effects on estimates of *p* and ψ depending in the temporal and spatial variability in species' distribution. The pilot owl program should conduct spatially and temporally replicated surveys, and these data should be analysed to examine how replication influences *p*, to inform trade-offs between power and logistics (*e.g.* Bailey *et al.* 2007). For spatial replication, the 1.6-km spacing between sites currently used in standardized surveys across North America (Takats *et al.* 2001) conveys independence among replicates (Takats 1998). Data would also be comparable with other surveys in Alberta and across Canada. For temporal replication, surveys should be repeated fairly closely together – within days at most, and under similar environmental conditions that might affect detectability such as weather and moon phase. In either case, automated recorders may provide a logistically feasible option for temporally replicated surveys. A broadcast-and-recording system could be developed that incorporates the Weyerhaeuser protocol and surveys a site multiple times over two separate spring surveys with the dual purpose of increasing detection of species that call slightly later or earlier in the year, and informing estimates of probability of detection.

8. *A 20-year commitment to owl monitoring is recommended to detect trends and relationships in owl occurrence.*

Detecting a 3% change per year in owl occurrence with at most a 5% error rate will require monitoring for at least 17 years. It is important to note, however, that this target was derived for a subset of some of the more common, and more detectable, owls. Of these, only one is listed as *Sensitive* in Alberta. The duration of the monitoring program will likely need to be increased for rarer species which are more susceptible to anthropogenic disturbance. Sampling duration is the most important variable affecting trend detection; it is more important than all other variables, though different technical configurations of monitoring can shorten this duration to some degree. Data garnered from the owl pilot program should be analysed to inform precision analyses targeted to the LAPR to confirm this timeline. A commitment to long-term monitoring is the primary factor needed to successfully stage an owl monitoring program in northeast Alberta.

9. *Analysis of existing owl occurrence data should be conducted concurrently with the Pilot, to inform design and logistical trade-offs.*

The analyses we performed were preliminary and designed to inform the basics of a pilot program for owl monitoring. As the need arises for specific decisions about pilot program implementation, additional data analyses (such as occupancy analyses with detection covariates to inform precision analyses) will be needed to inform specific trade-offs between logistics and statistical rigour in trend estimation. Conducting these analyses is an ongoing and iterative process that should accompany the pilot program in 2012.

## ***Strigidae_ver1*: A database of owl occurrences in Alberta**

*Overview*

This is an overview of the owl database, *Strigidae_ver1*. This database was created for the Environmental Monitoring Committee of the Lower Athabasca region (hereafter EMCLA). In creating this database, we compiled any bird monitoring data in the province of Alberta where there was a possibility of detecting owls, as well as owl-targeted surveys (for sources, see Fisher *et al.* 2011). The goal of creating *Strigidae_ver1* was to consolidate as much information on owl observations as possible to:

1. determine the types of, timing, and number of surveys required to detect owls of different species.
2. develop *preliminary* habitat selection and species distribution maps to be used in the design of an adaptive monitoring program.
3. use this information to identify how monitoring of owls in the Lower Athabasca Planning Region (LAPR), might fit into larger provincial monitoring plans related to nocturnal species.

Most of the following analyses are based on observed occurrences and do not account for imperfect detectability (MacKenzie *et al.* 2002; see section on Occupancy Analysis). Nonetheless observed occurrences can provide important information on patterns of detection, occurrence, and distribution. The following results are presented to illustrate the information that can be garnered from *Strigidae_ver1* to inform guidelines for owl monitoring. Additional analysis should be conducted in an occupancy modelling framework that accounts for probability of detection.

*Glossary of Terms*

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

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

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

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

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

Passive sampling – Surveys where species were and were not observed based on observers listening for acoustic cues. Typically such projects were recording all bird species heard.

Playback sampling – Surveys where species calls were broadcast alone or with other species calls to elicit a response. Some playback sampling includes as initial silent listening period prior to playback.

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

Presence – Locations where owls were observed without a sampling protocol. This type of data does NOT record the locations where observers may have searched and did not find a species. Whether species were detected using playback or passive listening is typically not known.

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

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

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

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

Route – A spatial cluster of survey locations along a road where more than one point was surveyed, typically surveys on a route were done on the same day by the same observer.

Species codes – A 4-letter code used as an abbreviation for a species. Barred owl = BADO or BARR; boreal owl = BOOW; great gray owl = GGOW; great horned owl = GHOW; long-eared owl = LEOW; northern hawk owl = NHOW; northern pygmy owl = NPOW; northern saw-whet owl = NSWO; short-eared owl = SEOW; snowy owl = SNOW.

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

*Structure of Strigidae_ver1 database*

Strigidae_ver1 is a database hosted on the BOREAL server at the University of Alberta (boreal.biology.ualberta.ca/BOREAL). The data in Strigidae_ver1 is stored in SQL Server 2008 which is password protected. Restricted access to these data can be made via Open Database Connectivity standards (hereafter ODBC) as described in Appendix 1. Requests to access the data are restricted to the project team and can be made to Suzanne Cote (scote@ualberta.ca) and upon approval a user name and password will be provided by Dr. Erin Bayne (bayne@ualberta.ca). Any software that allows ODBC can be used to access the database.

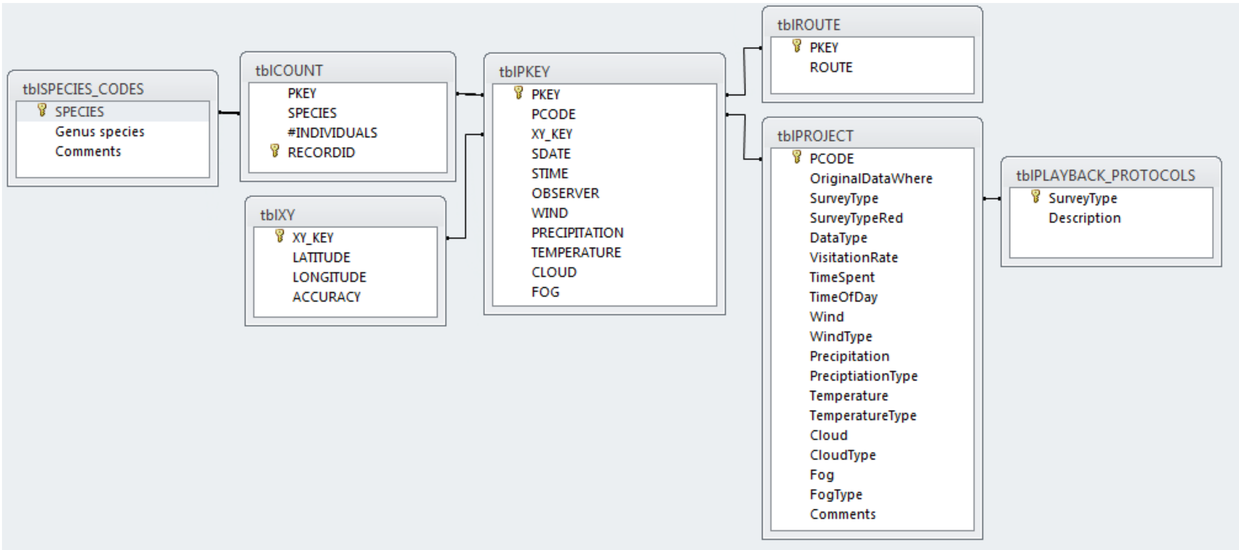
For the EMCLA team, a Microsoft Access front-end to access the database is available at (https://sharepoint.abmi.ca/emc/pt/). Appendix 2 describes how to download and use the front-end. A front-end is a software interface that allows a user to call data from SQL Server and was used to run the queries that provided the information in this report. The original data provided by different parties that was combined to create Strigidae_ver1 is stored in the EMCLA extranet as a series of Microsoft Excel tables.

Strigidae_ver1 consists of 7 main tables. Variables in each table are described in Appendix 3.

Strigidae_ver1 consists of 7 main tables. Variables in each table are described in Appendix 3.

1) tblPROJECT identifies the parties that contributed data. The details of the methods that were used to collect the data are also listed here. Whether or not ancillary data like weather or time of survey were provided by the project is also listed. Limitations on use are described here. The primary key for this table is PCODE.
2) tblXY gives the spatial coordinates of each point where a survey was done. Data are provided as latitude and longitude in decimal degrees. An accuracy assessment of the location where the survey was done is provided. Accuracy was based on whether a global positioning system (hereafter GPS) was used, locations were scrambled (ABMI), or data came from approximate locations (i.e. section or township ID's given). The primary key for this table is XY_KEY.
3) tblPKEY gives the details of the conditions at the time of survey. Variables like date, time, and weather at the exact time of the survey (if recorded) are reported here. The primary key for this table is PKEY.
4) tblCOUNT gives the number of individuals counted at each location. A species column also exists. If no owls were detected in a survey the species is called NONE and is given a count of zero for #Individuals. #Individuals records whether more than one owl of a species was counted. The primary key for this table is RECORDID.
5) tblPLAYBACK_PROTOCOLS lists the exact sequence and duration of different playback surveys. The primary key is SurveyType.
6) tblROUTE gives an identifier that identifies a series of points that are clustered together along the same survey route (i.e. same segment of road). PKEY is primary key.
7) tblSPECIES_CODES lists the common and scientific name that identifies the code used to describe each species. SPECIES is the primary key.
8) Tables can be joined in one to many relationships to extract the elements of the data that are required. Figure 1 shows the relationships between tables in the database.

Figure 2-1 – Relationships between core data tables in Strigidae_ver1 database.




*Summary of owl information in Strigidae_ver1*

*Strigidae_ver1* has 12,928 observations of 12 owl species. Of these, 7,236 were incidental observations (95.3% were already in FWMIS). A total of 110,865 abundance surveys were done at 26,106 points across Alberta. Of the abundance surveys, 17,805 were done using playback for one or more owl species and 93,060 were from passive sampling. Seventy-two different people or groups provided data to *Strigidae_ver1*. Table 2-1 summarizes the number of observations of the 12 owl species by sampling method. Note, some of the incidental observations in FWMIS may have been derived from data originally collected by abundance surveys and is something that will be identified in version 2 of the database. However, many of the observations of owls in this database are not currently in FWMIS.

Table 2-1 – Number of observations of various species of owls in *Strigidae_ver1* database by survey method. The percentage of abundance surveys where an owl was observed is also reported.

| SPECIES | Incidental | Passive | Playback |
|---|---|---|---|
| Barred Owl (BADO) | 513 | 7 | 446 |
| Barn Owl | 1 | 3 | 0 |
| Boreal Owl (BOOW) | 206 | 5 | 1179 |
| Burrowing Owl (BUOW) | N/A | 3 | 0 |
| Great Gray Owl (GGOW | 622 | 24 | 253 |
| Great Horned Owl (GHOW) | 1765 | 217 | 1381 |
| Long-eared Owl (LEOW) | 169 | 3 | 165 |
| Northern Hawk Owl (NHOW) | 584 | 13 | 98 |
| NO OWLS OBSERVED | N/A | 92675 | 12498 |
| Northern Pygmy Owl (NPOW) | 172 | 8 | 216 |
| Northern Saw-whet Owl (NSWO) | 1866 | 5 | 1533 |
| Short-eared Owl (SEOW) | 1144 | 95 | 3 |
| Snowy Owl (SNOW) | 191 | 0 | 0 |
| Unknown Owl | 3 | 2 | 33 |
| Probability of observation (Survey, Any owl species) | N/A | 0.004 | 0.298 |

*Sampling design information gained from Strigidae_ver1*

Passive versus playback sampling

If we ignore environmental covariates and other nuisance factors, there was a large difference in the probability of passive sampling (survey) observing an owl of any species was (0.004) relative to playback surveys (0.298). Many factors are confounded with sampling method in *Strigidae_ver1* making it difficult to determine the actual magnitude of difference in probability of observation between passive and playback surveys.

1) The mode for hour of day when passive surveys were done was 4:00 to 4:59 AM (during songbird surveys). Playback surveys were done between 10:00 and 10:59 PM. The silent listening component of playback surveys could be compared to

passive sampling in songbird surveys to compare call rates, although this analysis is confounded by time of day.

2) Playback surveys were more likely to be done from early to late April than were passive surveys, which tended to be done in the last week of May and first three weeks of June (songbird surveys). There was very little overlap between the week of year when playback and passive surveys were done.
3) All playback surveys were done from roads while only 59% of the passive surveys were done from roads.
4) Playback surveys have two minutes of silent listening followed by call playback; using existing data in *Strigidae_ver1,* additional analyses should examine detectability in the first two minutes compared to detectability after playbacks commence to determine the relative increase in probability of detection.

*Timing of surveys*

Passive sampling was not done at times viewed as standard for sampling owls as they were typically targeted to sampling diurnal species. It is clear that owls are more likely to be observed very early in the morning, near sunrise, during passive surveys. They are virtually never observed during daylight hours relative to sampling effort (Figure 2-2).

Playback sampling was generally done in the evening or night although daytime surveys were conducted by many projects (Figure 2-2). To evaluate species-specific responses to hour of day and week of year, we used a mixed-effects logistic regression. In this analysis we controlled for PCODE as a fixed effect and XY_KEY as a random effect. The random effect was included to account for lack of independence among observations from repeated surveys at the same point. The fixed effect for PCODE was to: A) account for spatial variation in owl abundance among different regions of the province where different projects took place; and B) account for sampling methods that differed among projects. Ideally, PCODE and XY_KEY would be nested random effects, but models with these terms would typically not solve because there were too many missing covariate combinations to allow model convergence.

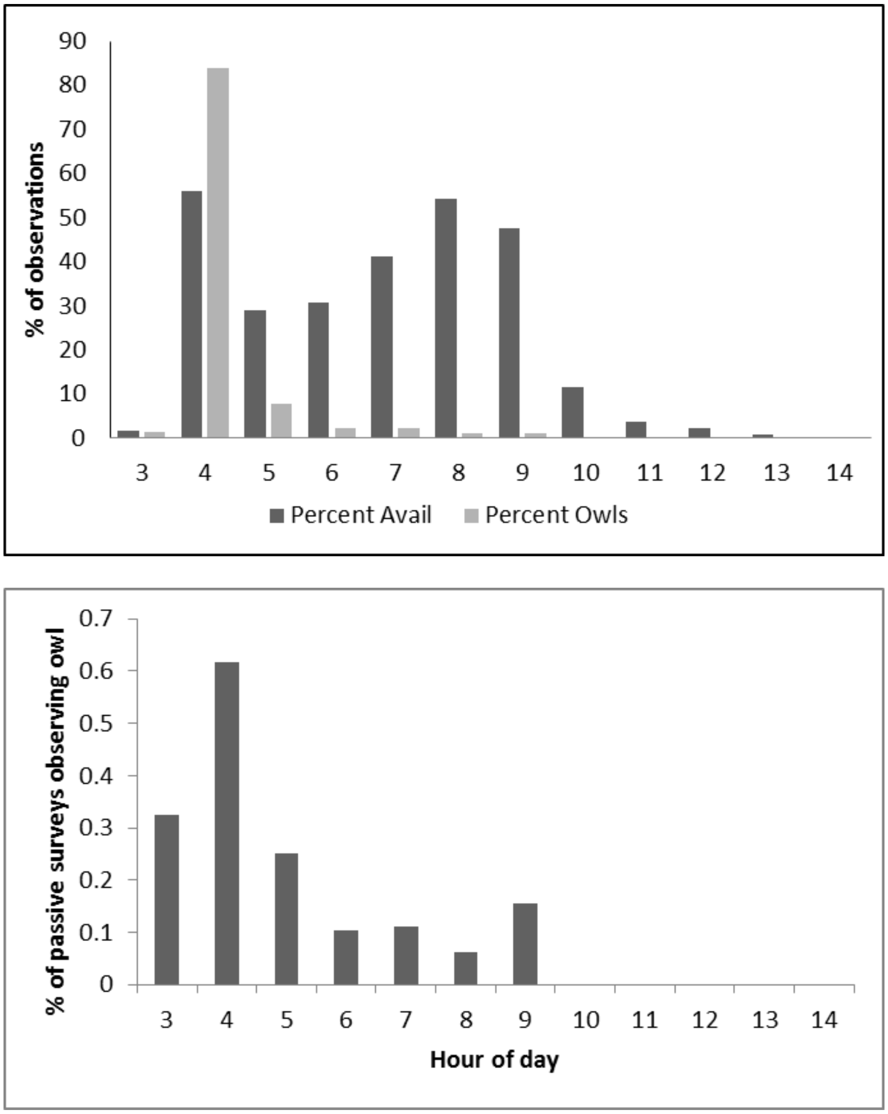
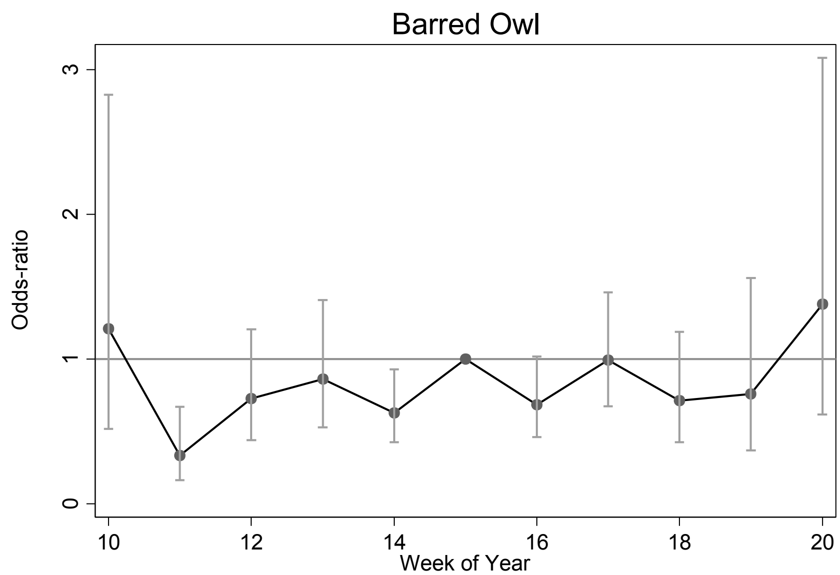



Figure 2-2. TOP: Percentage of all passive surveys done at different hours of the day (PercentAvail = dark gray) and the percentage of owl observations coming from passive surveys that occurred at different hours of the day (Percent Owls = light gray). BOTTOM: Percentage of surveys recording any species of owls using passive sampling at different hours of the day.

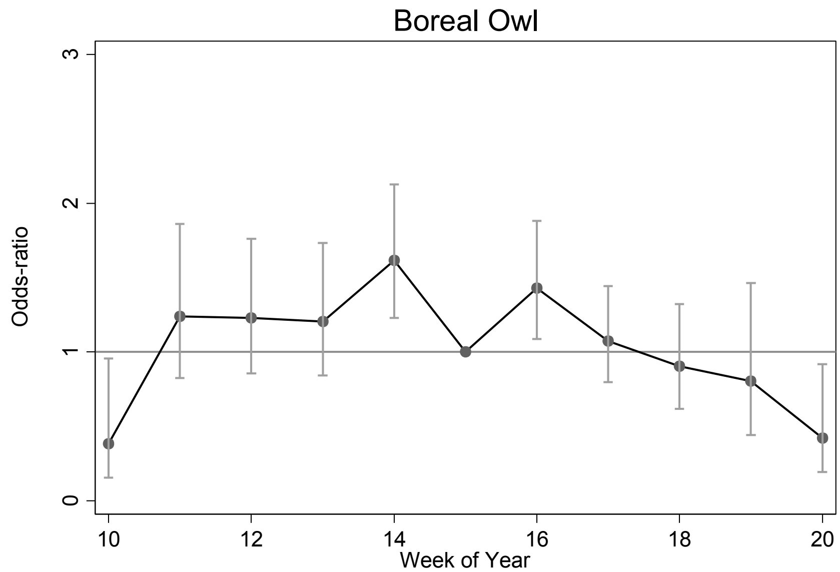
PCODE had to be dropped as a fixed effect for Long-eared Owl, Northern Hawk Owl, and Northern Pygmy Owl for similar reasons. The graphs highlight how the relative probability of observation changed from week of year and hour of day based on odds-ratios. For week of year, our reference condition was week 15 (Week of April 15th). Any week with a value > 1 had a higher probability of observing an owl relative to week 15 while those with odds-ratios < 1 had a reduced probability of observing an owl relative to week 15. Hour of day can be interpreted in the same way except that the reference state is set to 0 (12:00 to 12:59 AM). Error bars represent 95% confidence intervals.

Figures 2-3. Note that these analyses are based on combined data from across the province. Results might be different if surveys are separated geographically, as phenology can vary two weeks across Alberta latitudes.

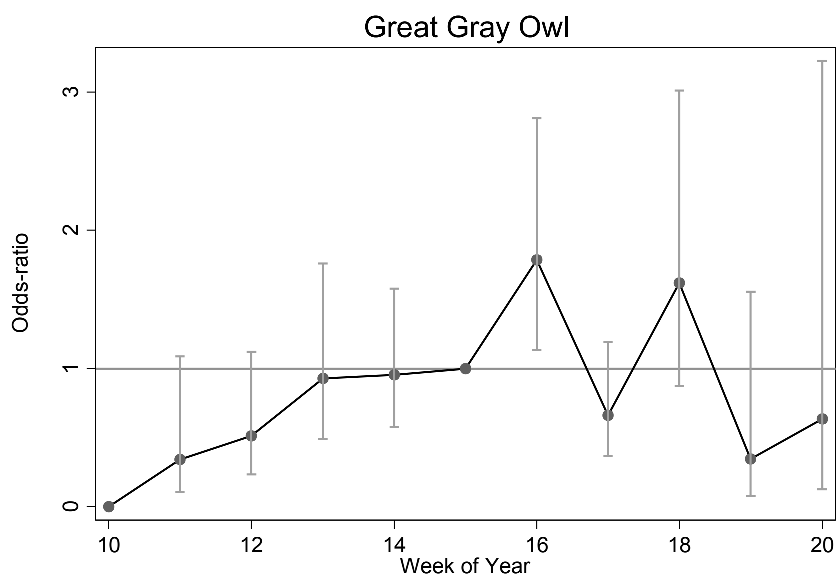
A) Barred Owls had an equal probability of observation between week 10 and 20.



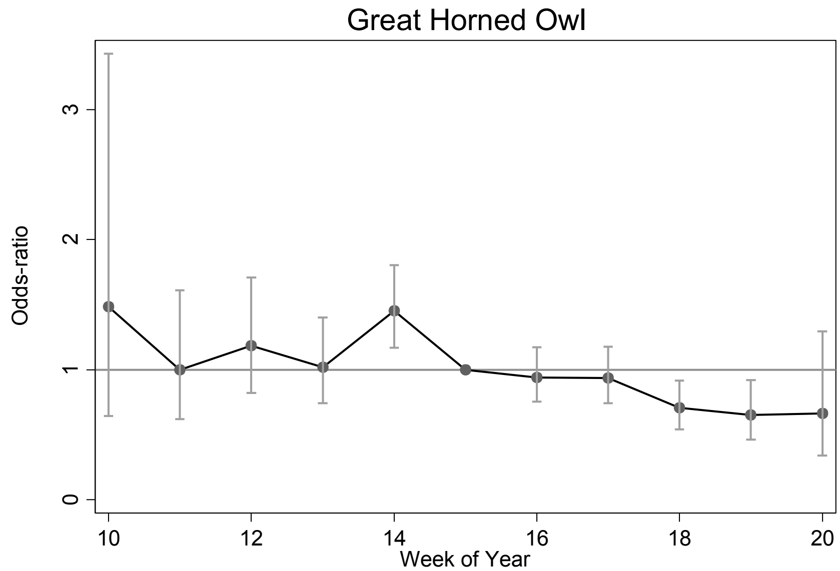
B) Boreal Owls had lower probability of observation during week 10 and 20 but was relatively constantly for rest of survey season. Note that owls calling in May are likely unmated “floaters”, not mating individuals, so surveys past May 5 are not



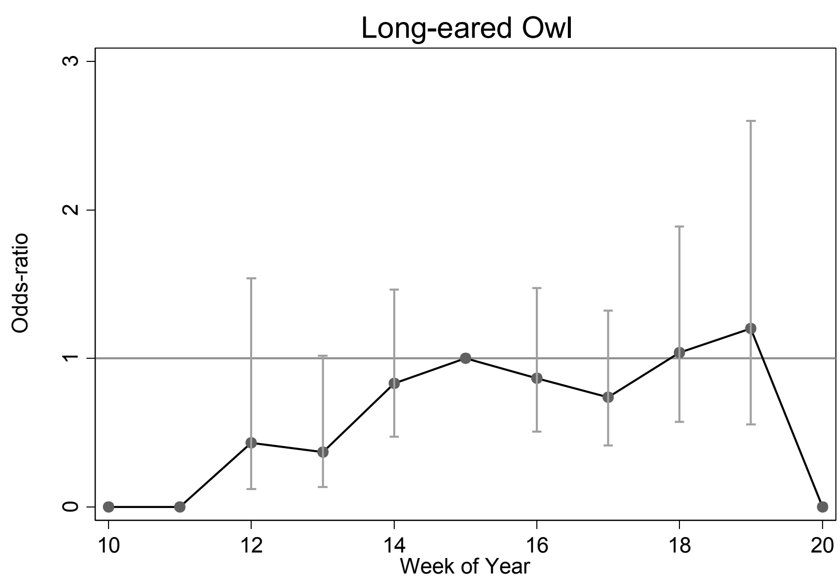

C) Great Gray Owls were not found in week 10 and showed a trend to high probability of observation after three weeks although differences were not significant



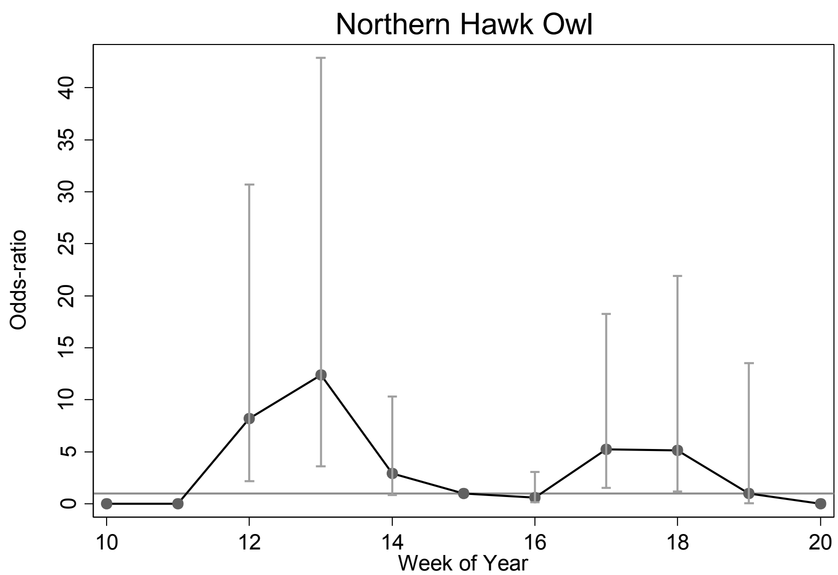
D) Great Horned Owls had a constant probability of observation until week 18.



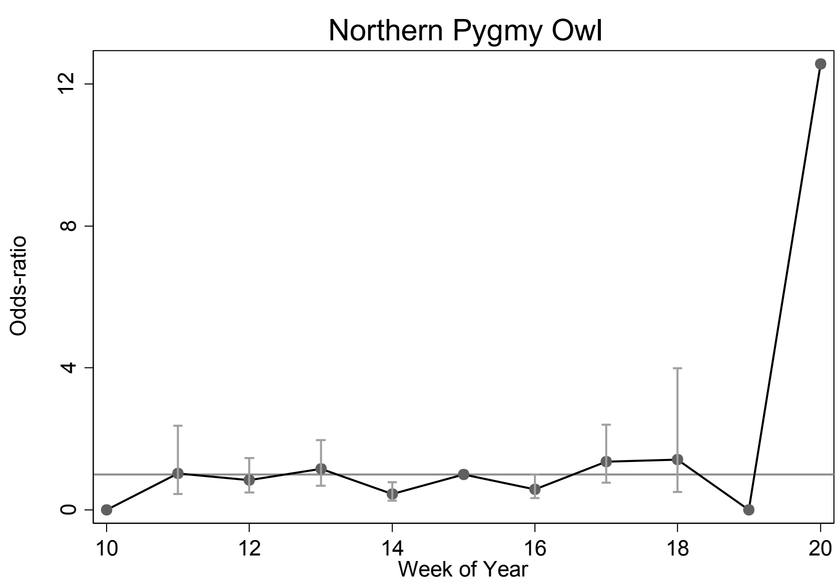

E) Long-eared Owls were not found in week 10 or 11 and had reduced probability of observation for weeks 12 and 13. The probability of observation was relatively constant until week 20 when no Long-eared Owls were observed.



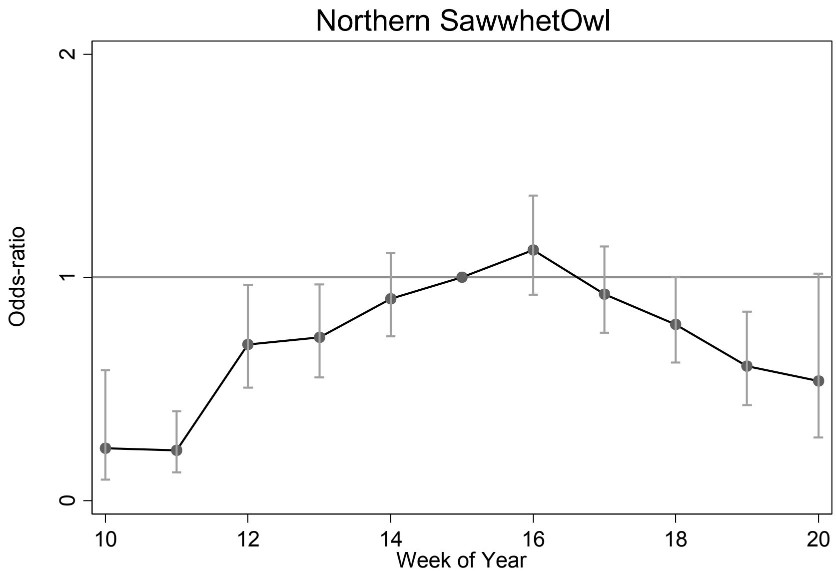
F) Northern Hawk Owl did not show a consistent pattern and had extremely large confidence intervals.




G) Northern Pygmy Owl showed a large spike in week 20 but this should be viewed as an outlier as it was caused by one project. For remainder of sampling season there is a relatively constant probability of observation.

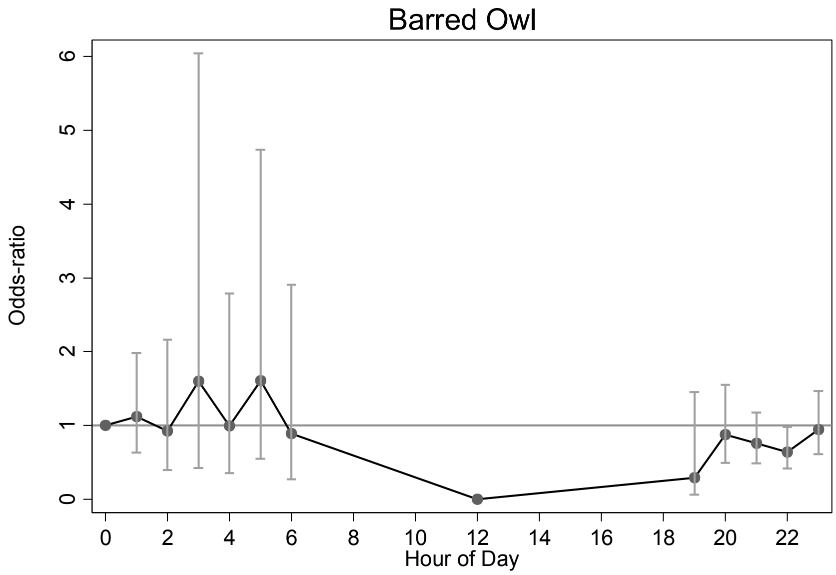


H) Northern Saw-whet Owl had highest probability of observation during the middle of the sampling season and were less likely to be observed early or late.

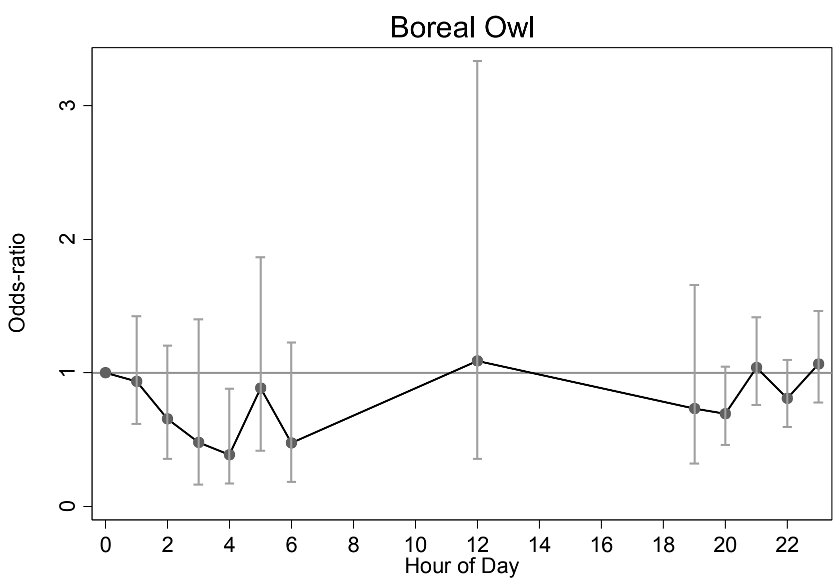


Figures 2-4. For hour of the day, we found that:

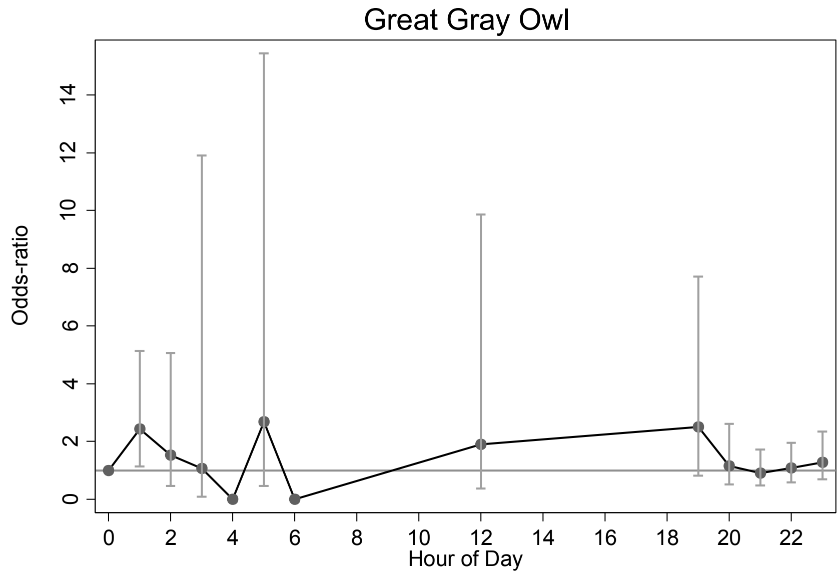
A) Barred Owls were slightly less likely to be observed before midnight and never were observed during the day.



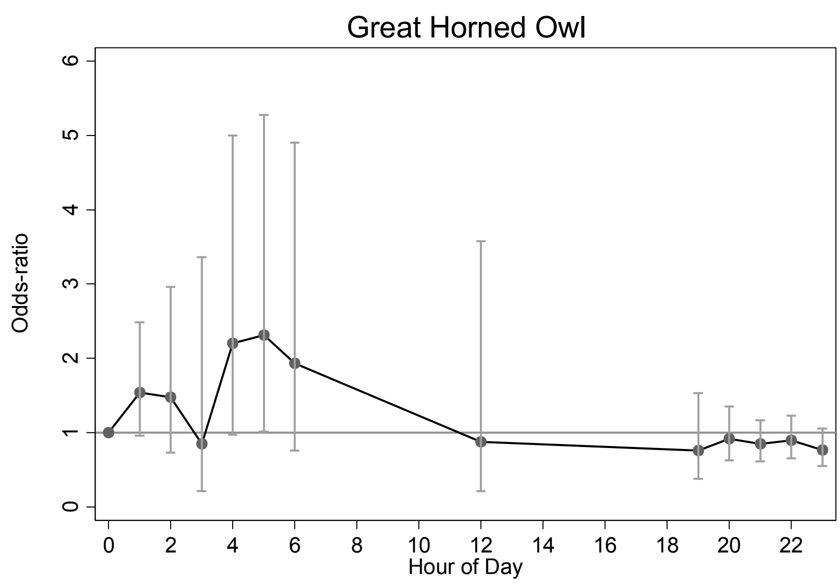

B) Data suggest boreal owls were frequently observed during diurnal surveys although this likely represents data error. Nightly calling frequently begins within an hour of sunset and continues throughout night (Palmer 1987).



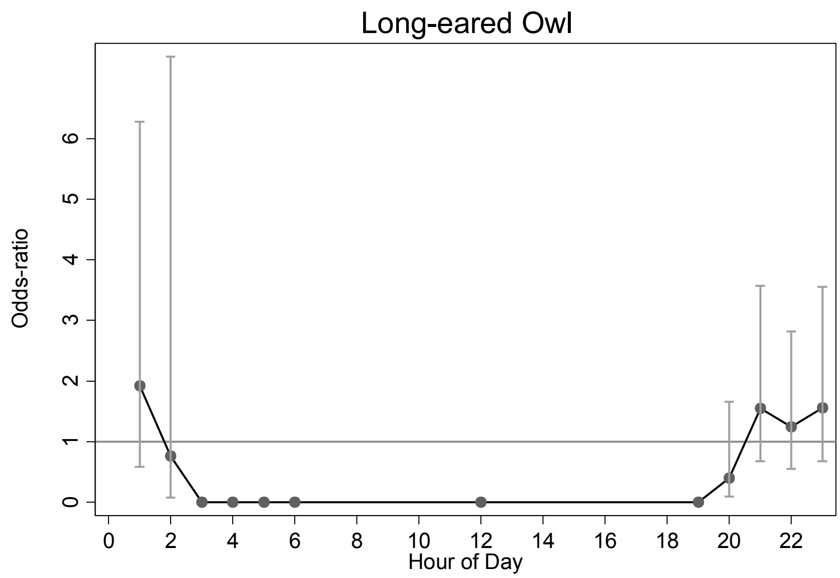
C) Great Gray Owls had very large confidence intervals so it is difficult to make strong recommendations but there seemed to be little difference in probability of observation at any hour including the daytime.



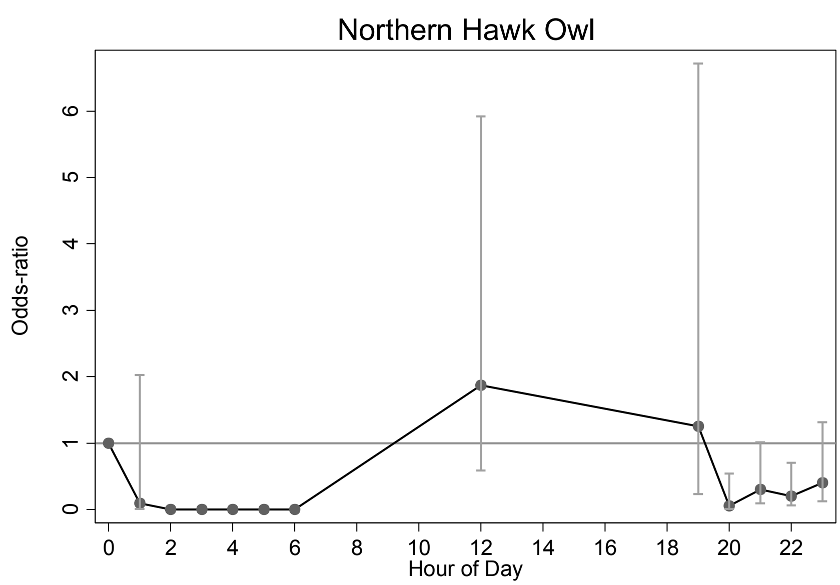

D) Great Horned Owls tended to be more likely to be observed after midnight and there was a reasonably high probability of observing them during daylight hours. However, the 95% confidence intervals were much wider for these periods of time than before midnight.



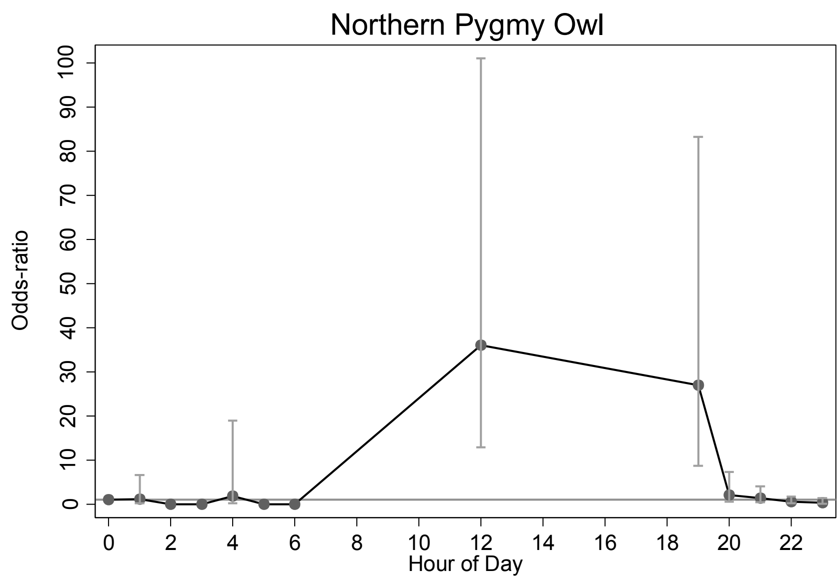
E) Long-eared Owls were only observed at night.



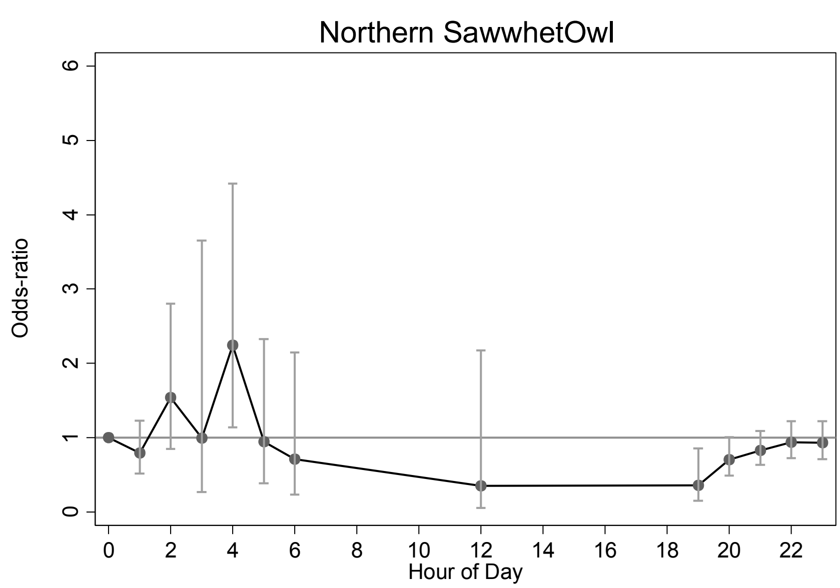

F) Northern Hawk Owls are more likely to be observed during daylight hours. Note this graph does not include an Environment Canada project that used playback of Northern Hawk Owls and recorded no other species. Inclusion of this study shows that afternoon surveys and early evening surveys are the best for observing this species.



G) Northern Pygmy Owls are far more likely to be observed during the day. While they have been rarely observed at night there is no difference in probability of observation during the nocturnal period. Note this result is primarily driven by a single project.




H) Northern Saw-whet Owls were more likely to be found after midnight although 95% confidence intervals were quite wide for these hours. There was a steady increase in probability of observation as the night progresses.



*Methodological factors influencing probability of observation using playback surveys*

When using playback methods to increase the probability of observing an owl, there are unlimited numbers of combinations of different owl calls and duration that can be used. We kept track of the method used in the database. To evaluate how playback method influenced the probability of observation of each species we used a mixed-effects logistic regression. In this analysis we controlled for hour of day and week of year as fixed effects. XY_KEY was treated as a random effect. We replaced PCODE with playback method as a fixed effect and controlled for spatial location by including latitude, longitude, and their interaction (standardized to zero mean and unit variance). Table 2-2 shows the odds-ratios for the different methods using the method Playback – 6 species as the reference category. We caution that these results should be viewed conservatively. While we have statistically removed the effects of space and time, the non-random allocation of the different methods in relation to environmental variation not considered may still confound these results.

*Route level abundance, occupancy, and detection rate*

All of the analyses above evaluate point-level use of areas by owls. The area sampled by a single survey point is relatively small, and most owls have home ranges much larger than this. Thus, any trend monitoring or impact assessment based on a point-level analysis will tend to emphasize what areas are being used by owls rather than on how many individuals there are in an area. An alternative approach is to estimate "abundance" by having multiple sampling points in an area the size of a home-range, or larger. Visiting larger sampling units multiple times allows estimation of density of owls if the assumption is made that the sampling unit is closed to owl movement into, and out of, that sampling unit, or if these movements are accounted for in the model.

Table 2-2. Summary table for each owl species showing probability of observing an owl species for different methods of playback. Playback Type Code is the name of the playback method as described in the database. Species broadcast is a list of the species whose calls were played in the order they were played (more details on the timing of the different playbacks are available in *Strigidae_ver1*). For each species we show the odds-ratio showing the relative change in probability of observation of six different owl species relative to the 6-species method of playback. A value < 1 indicates that this playback method resulted in fewer observations of that species than the 6-species method while a value > 1 indicates that this playback method resulted in more observations. Note that this analysis groups and does not account for potential differences in geographic location, call duration, or survey duration.

| Playback Type | Species Broadcast | # Surveys | BADO | BOOW | GGOW | GHOW | LEOW | NSWO |
|---|---|---|---|---|---|---|---|---|
| 6-SPECIES | NSWO,BOOW,LEOW, BADO,GGOW,GHOW | 408 | 1 | 1 | 1 | 1 | 1 | 1 |
| CDB | BADO | 1863 | 8.7 | 0.1 | 0.12 | 0.99 | 0 | 9.9 |
| CDF | BOOW,GGOW,BADO | 5662 | 5.4 | 0.07 | 0.06 | 0.59 | 0.60 | 11.6 |
| CDP | NSWO,LEOW,GHOW | 3025 | 0.5 | 0.01 | 0.01 | 1.07 | 1.20 | 8.4 |
| GOLDER | BOOW,GGOW,BADO | 760 | 8.0 | 5.6 | 2.8 | 0.65 | 0.04 | 2.0 |
| WEYCO-DIURNAL | NPOW,NHOW | 1637 | 0 | 0.01 | 0.07 | 0 | 0 | 0.09 |
| WEYCO-NOCTURNAL | NSWO,BOOW,LEOW, GGOW,BADO | 2491 | 27.1 | 0.18 | 0.38 | 0.65 | 0.76 | 24.4 |

To examine site- *vs.* route-level occurrence rates, we used a subset of the data where people conducted their surveys along a route that was larger than the average home range of most owl species. Counts of owls from routes (10.3 ± 3.4 points per route (SD)) were summed to determine the total number of individuals present in that route. Some routes were sampled more than once within the same year allowing estimation of owl abundance, occupancy, and detection rate *via* Royle's n-mixture model (Royle and Nichols 2003). This model corrects for detection rates less than 1 (*sensu* MacKenzie *et al.* 2002) and can provide a more accurate estimate of bird abundance if the assumption of population closure is met. With the data currently available we cannot test the assumption that the population is closed however. In this model, we corrected for the number of points sampled on each visit to a route.

Table 2-3. Average abundance, detection rate, and probability of occurrence of owl species along survey routes in Alberta. Data are not corrected for spatial location, environmental covariates, imperfect detectability, or factors influencing probability of detection. Values in brackets are 95% confidence intervals. Models are corrected for number of survey points per route.

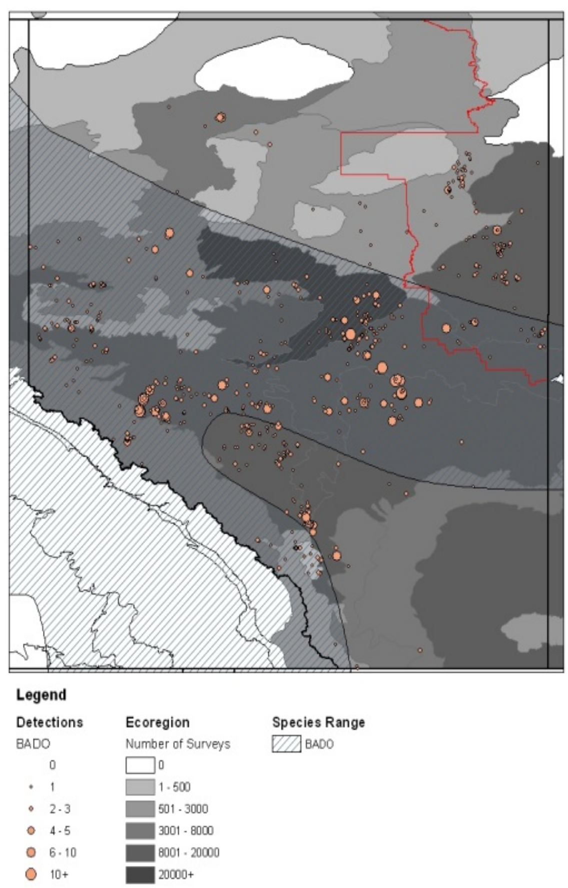
| Species | Avg. Route Abundance | Detection Rate | Probability of Occurrence (Route) |
|---|---|---|---|
| BADO | 1.52 | 0.669 | 0.782 |
| | (1.44-1.60) | (0.638-0.700) | (0.764-0.800) |
| BOOW | 1.51 | 0.406 | 0.780 |
| | (1.34-1.69) | (0.367-0.448) | (0.743-0.819) |
| GGOW | 0.6 | 0.295 | 0.453 |
| | (0.46-0.75) | (0.232-0.357) | (0.375-0.532) |
| GHOW | 3.40 | 0.312 | 0.970 |
| | (N/A) | (0.298-0.325) | (N/A) |
| LEOW | 0.45 | 0.307 | 0.363 |
| | (0.31-0.59) | (0.213-0.400) | (0.273-0.454) |
| NHOW | 0.28 | 0.517 | 0.246 |
| | (0.23-0.33) | (0.479-0.555) | (0.209-0.284) |
| NPOW | 0.62 | 0.283 | 0.463 |
| | (0.46-0.79) | (0.212-0.354) | (0.373-0.553) |
| NSWO | 3.40 | 0.337 | 0.967 |
| | (N/A) | (0.325-0.349) | (0.966-0.967) |

*Owl distribution in Alberta*

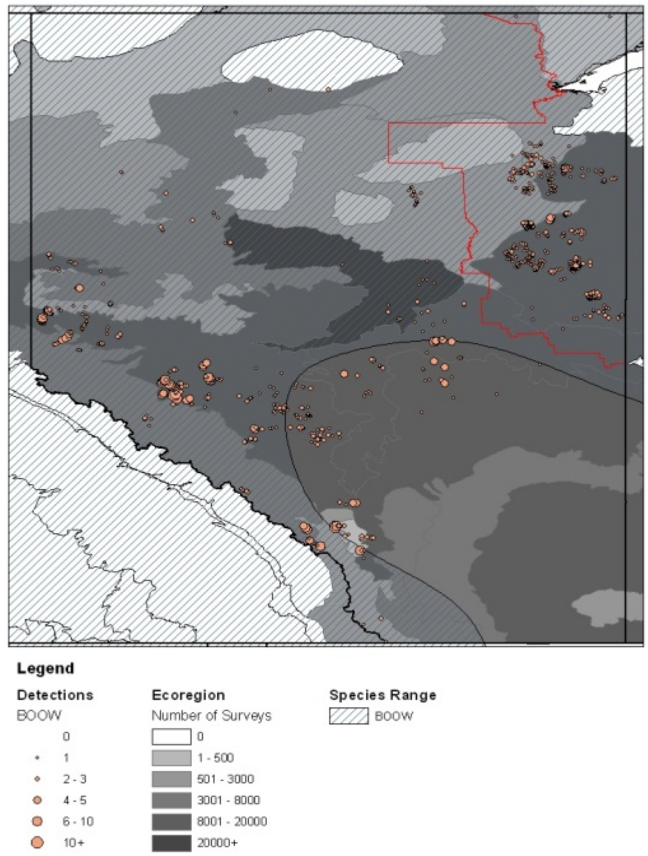
The data compiled in *Strigidae_ver1* can be used to create predictive models and maps of expected owl occurrence in Alberta based on known occurrences. These presence-only maximum-entropy (MAXENT) models (Phillips *et al.* 1996) estimate the probability of occurrence of owls at a site based on quantified relationships between habitat characteristics and owl observations calculated from existing data. However, these models are highly biased by differential survey effort; at the provincial scale, large regions have been surveyed differently or not at all, and so appear to have low predicted owl occurrence where this may not be true. MAXENT models were created for owls from *Strigidae_ver1* data, but were heavily biased because of the fundamental differences created by playback versus passive surveys, and the geographic locations where these were conducted. Further work accounting for biases introduced by survey technique, differential effort, and imperfect detectability needs to be done before these models can reliably inform owl distribution in Alberta. In the interim, observations from *Strigidae_ver1* were simply plotted in GIS.

Figures 2-5.

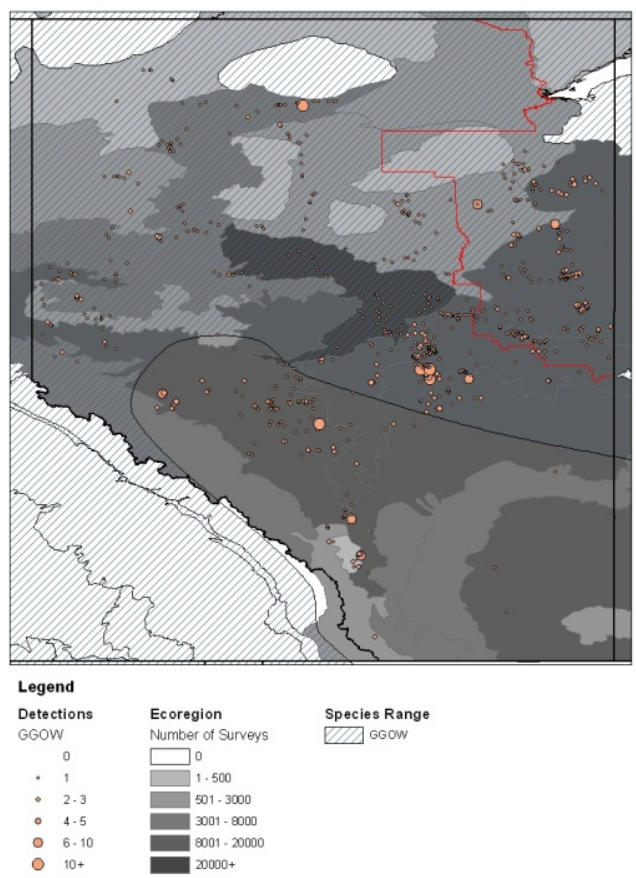
Barred Owl distribution reflects current range maps (Priestley 2004), plus more detections in the LAPR and a significant number in the foothills region near Edson, Drayton Valley, Rocky Mountain House, and Grande Prairie, reflecting considerable survey effort by Weyerhaeuser (Priestley and Priestley, unpubl. data).



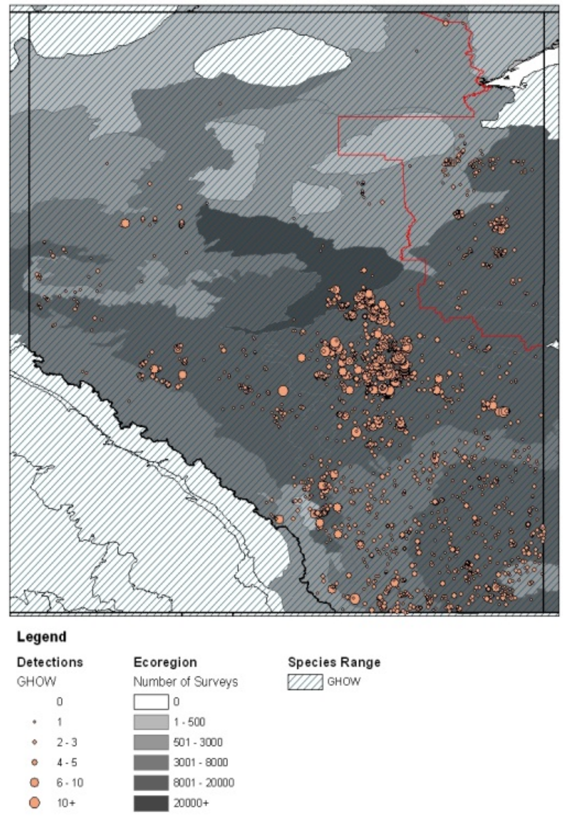
Boreal Owl ranges across boreal Alberta as predicted, although the range seems to extend further south than predicted.



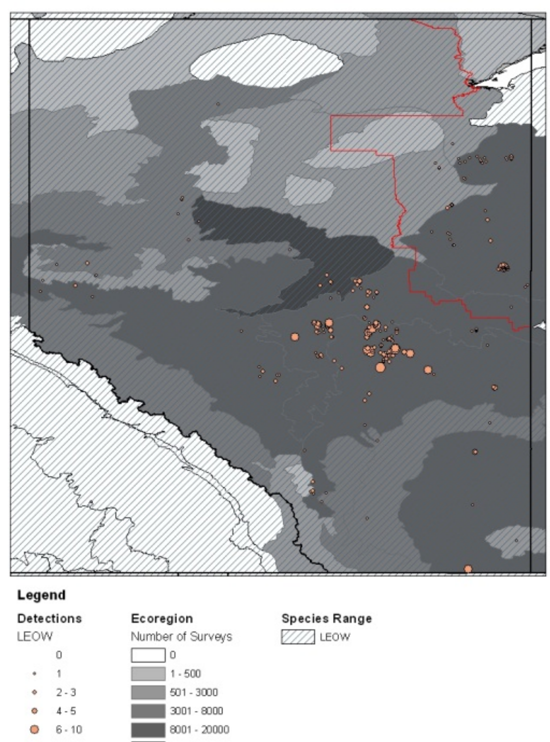

Great Gray Owls are found throughout boreal. These data suggest the range extends much further south in Alberta than standard range maps predict.



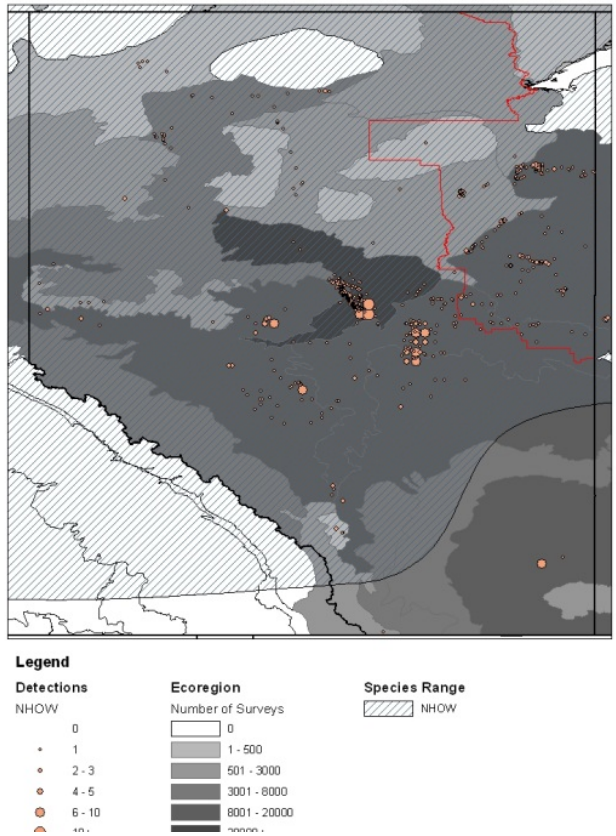
Great Horned Owl occurs throughout the province.



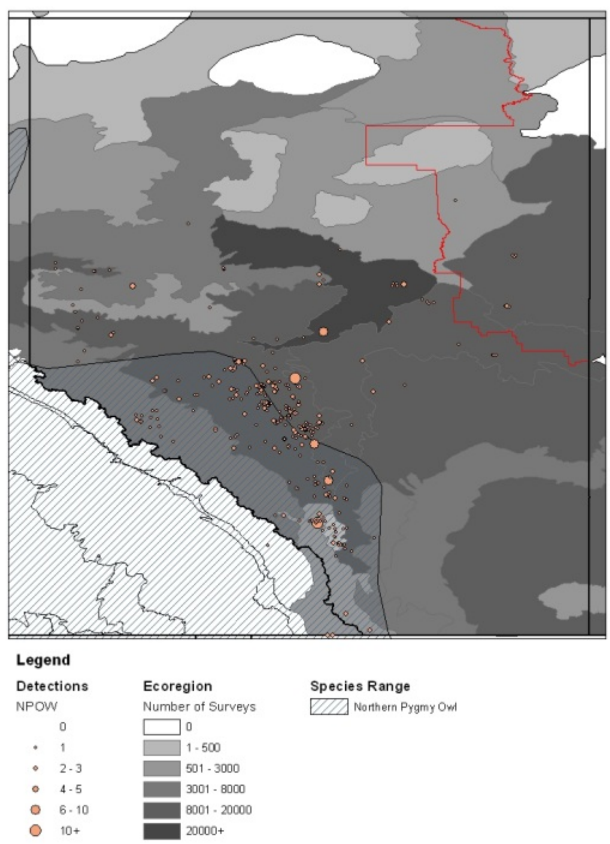

Long-eared Owl range extends across the province.
They have been observed mostly in LAPR and areas NW of Edmonton.



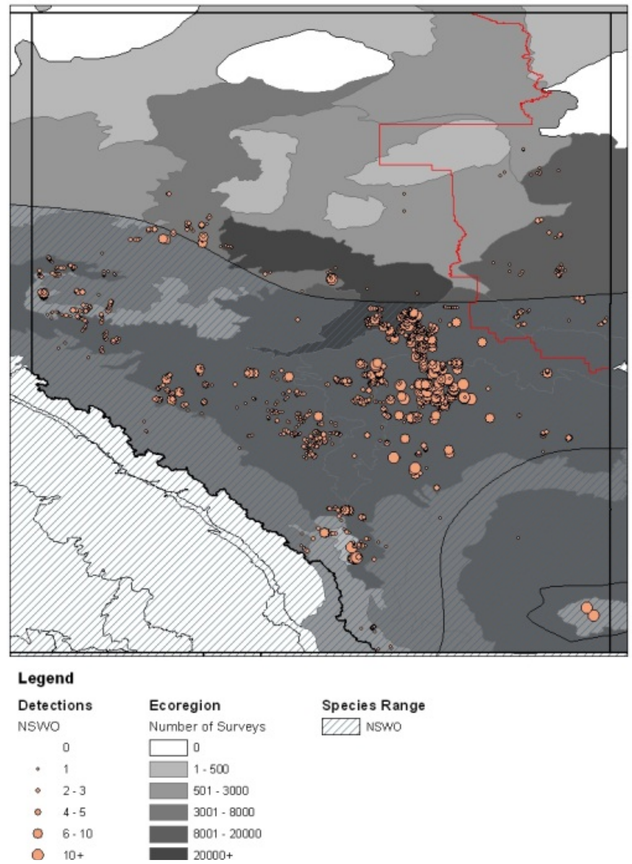
Northern Hawk owl range extends across the province. They are typically found in recently burned forested areas and distribution patterns are heavily influenced by studies that have focused on burned areas.



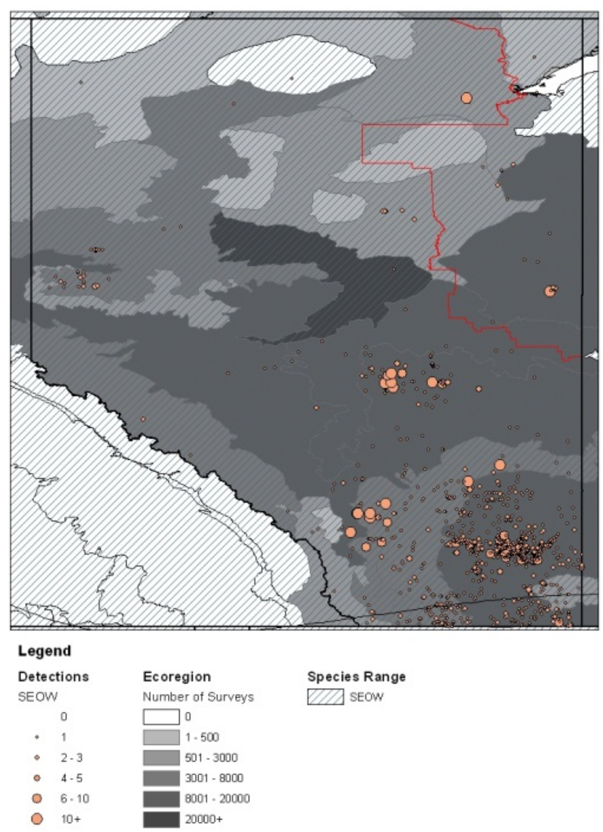

Northern Pygmy Owl range is the western portion of the province, although they have been observed in the LAPR.



Northern Saw-whet Owl range is predicted to be in the southern half of the boreal and aspen parkland. However, data from the LAPR indicate they range considerably farther north although they are not particularly common in northern areas.




Short-eared Owl range extends across the province but most of the observations of this species come from the aspen parkland and prairie regions.



## Expected Precision of Trends for an Owl Monitoring Program

### *1. Introduction*

An owl monitoring program must be statistically rigorous enough to distinguish real change in occurrence and abundance from random variation, while being sensitive enough to detect change when it actually occurs (Gibbs *et al.* 1998). Further, breeding owl populations naturally fluctuate due to variable food availability, and a monitoring program designed to inform land management needs to be able to distinguish natural population changes from anthropogenically-induced changes. These demands are further complicated when target species are elusive with variable, often low, detectability (Green and Young 1993; Thompson 2004). False absences are a notable problem, so the probability of detecting a species given it is there (*p*), and the factors that affect *p*, must be quantified (MacKenzie *et al.* 2002, 2006). The power of a monitoring program to detect population change is dictated by several parameters (Gibbs 1998; Field *et al.* 2005; MacKenzie and Royle 2005; Bailey *et al.* 2007), including:

1. mean and variance of *p* for a species;
2. mean and variance of the population metric (abundance, occupancy, *etc.*)
3. sample size of sites monitored;
4. duration and interval of monitoring;
5. the desired magnitude and direction of trends to detect.

The last three parameters are fixed by the researcher, as assessed by precision analysis. The first two parameters are ecological quantities that need to be measured to inform the precision analysis. To that end, we used data compiled in *Strigidae_ver1* (for sources see Fisher *et al.* 2011). These datasets varied from incidental observations to targeted owl surveys. The latter were generally standardized across space and time, with quantified effort, and consisted of some repeat surveys that allowed estimation of *p*. We analyzed these datasets to provide estimates detectability and precision of trends through time.

The goal of this work was to predict how precisely trends will be estimated by a monitoring program for owls in the Lower Athabasca area. The work uses data from *Strigidae_ver1* to derive parameters on the abundance and variability of nocturnal owl species. Those parameters are then used to simulate data for monitoring programs with a variety of design options, and to calculate precision of the trend estimates the designs are expected to produce. A simple site-level occupancy/detectability was also conducted with the compiled data. A precision analysis incorporating the occupancy results has not yet been conducted, but is recommended for future analyses.

***2. Datasets***

We only used projects that use playback, because passive surveys (many diurnal) had far fewer owls, and the intent is to use playback in the northeast monitoring. For summaries of detection rates in the northeast and other regions, we used all playback projects. For detectability analysis, we used only projects that had multiple visits to a site within a year. For annual variability, we only used projects that visited sites in more than one year.

Presence/absence

We used presence/absence of a species at a playback station as the abundance metric. Most records had counts of 0 or 1. There is therefore relatively little additional information about population abundance in the counts compared to presence/absence.

Species

The analyses were done for barred, boreal, great horned, great gray and northern saw-whet owls. The first 3 are common in all studies, great grays are rare in most studies, and saw-whet owls were common in the larger studies but rarer in smaller EIA-type studies. Other owl species are diurnal or have too few records for analysis.

Identifying revisited sites

Various systems were used for identifying transects and stations in the different projects, and not all datasets provided this information. Instead, the compiled database identified sites by latitude, longitude, and date and time of survey. Records from different dates with exactly the same latitude and longitude are clearly revisits, but location error sometimes gave different co-ordinates for the same site. Latitude and longitude were therefore rounded to the nearest ~200m to identify repeated sites. A few actual revisits may have been considered new sites with this procedure, but this is a small proportion of the total records.

Most owl-targeted surveys in *Strigidae_ver1* have been standardized to about 10 stations per transect, for logistical reasons. At the time this work was done, the use of latitude and longitude to identify sites in the database means that there was no easy way to tell which stations were part of the same transect. As a result, no formal analysis has been done of the trade-off between number of sites per transect and number of stations.

## *3. Occupancy/detectability analysis*

### *3.1. Methods – Occupancy/detectability*

Occupancy analysis was conducted for each project-year (*i.e.*, a year of monitoring for a project) that had >40 revisited sites. Project-years with fewer sites provided too few detections for a meaningful analysis. The analysis was done by project-year, because a basic parameter of interest for precision analysis is the year-to-year variability in a species' occurrence (or occupancy and detectability). Doing the analysis separately by year, rather than using year as a factor in the analyses, allowed models with different covariates to be used each year where this was appropriate. Five projects provided a total of 26 project-years. All but four of these project-years involved only 2 visits to each site. (In some cases there were more visits to some of the sites, but too few to analyse those additional visits). The analyses were run for each of the 5 species that had more than 10 detections in a project-year. The models usually did not converge when there were fewer than this many detections.

Twenty-one models were used in an AIC framework (Akaike's Information Criterion; Burnham and Anderson 2002), representing all combinations of 7 detectability models and 3 occurrence models. The detectability models were: 1) Null (single mean for all sites), 2) Day, 3) Day + $Day^2$, 4) Time of day, 5) Time + $Time^2$, 6) Day + Time + Day*Time, 7) Latitude + Longitude. Day was expressed as days since January 1. Time of day was expressed as hours since noon. The models with quadratic terms can represent maximum or minimum detectability at some time within the survey season or within the night. The occupancy models were: 1) Null (uniform occupancy across the study area), 2) Latitude + Longitude, 3) Latitude + Longitude + Latitude*Longitude. Weather covariates were not used in detectability models because few projects recorded these and they used different measurement systems, there was little variation in some variables (*e.g.*, only a few days with snow), and other variables were correlated with day of year (*e.g.*, temperature). Information on weather effects could be useful for detailed monitoring protocols, but is less important for estimating trend precision.

The single-season analysis of MacKenzie *et al.* (2002) was conducted using function "occu" in package "unmarked" in statistical software R (R Foundation for Statistical Computing 2009). For each analysed species and project-year, we summarized the observed detection rate (number of occurrences divided by total number of sites), and detectability, occupancy and their standard errors from the AIC-best candidate models. For combinations of species and projects that had 3 or more years with detectability/occupancy estimates, we also summarized the mean, year-to-year coefficient of variation (CV = standard deviation/mean) and first-order autocorrelation of each parameter, as well as the grand mean of the parameters for each species. These values – modified for spatial differences between the analysable sites and the LAPR study area (see next section) – will be part of a future precision analysis based on occupancy.

### *3.2. Results – Occupancy/detectability*

Seventy-one combinations of species and project-year from *Strigidae_ver1* could be analysed. The most common best models for detectability were day (increase or decrease in detectability with day of year) and null (uniform detectability), followed by time of day and $time^2$. The latter typically showed highest detectability in early to mid-night. Spatial gradients in occupancy were included in the best models about half the time, most often in the ANOS project, which has a large spatial distribution. Details of the best models for each species and project-year have not yet been examined, although these can inform specific sampling design.

Table 3-1. Best detectability/occupancy models for 71 combinations of owl species and project-year.

| Detectability/Occupancy | Count |
|---|---|
| Null/Null | 10 |
| Day/Null | 12 |
| Time/Null | 9 |
| Time2/Null | 7 |
| Null/LatLong | 10 |
| Day/LatLong | 13 |
| Time/LatLong | 4 |
| Time2/LatLong | 5 |
| LatLong/LatLong | 1 |
| | 71 |

The observed detection rate, and estimated detectability and occupancy for each combination of species and project-year are in Appendix 2. The results for projects with ≥3 analyzed years are summarized in Table 3-2, along with the grand mean across all analysed project years (including projects with <3 analysed years).

The observed (uncorrected) detection rate ranged from 1.5-14.4% across the 5 species, with lowest values for great gray owls and barred owls, and highest for northern saw-whet owls. Observed detections were moderately higher for project-years with detectability / occupancy analyses (because these required a minimum of 10 observations of the species). Estimated detectability averaged between 25.1% and 31.5% for the species, except great gray owls had an estimated detectability of only 14.8%. With the low probabilities of detection, occupancy was considerably higher than observed detection probability, ranging from 30.1% of sites occupied by barred owls to 53.1% of sites occupied by saw-whet owls.

Table 3-2. Observed detection rates, and estimates of detectability and occupancy for 5 species in individual multi-year projects and averaged across all analysed project-years.*

| | | Observed (%) | | Detectability (%) | | Occupancy (%) | |
|---|---|---|---|---|---|---|---|
| **Species** | **Study** | **Mean** | **Annual CV** | **Mean** | **Annual CV** | **Mean** | **Annual CV** |
| Barred Owl | Takats CDB | 5.99 | 0.14 | 41.51 | 0.45 | 16.57 | 0.41 |
| | Weyerhaeuser | 7.59 | 0.38 | 18.10 | 0.35 | 44.90 | 0.37 |
| | Grand Mean* | 7.15 | 0.26 | 31.45 | 0.40 | 30.11 | 0.39 |
| | All observed | 4.82 | | | | | |
| Boreal Owl | Takats CDB | 12.10 | 0.48 | 37.55 | 0.27 | 33.67 | 0.53 |
| | Weyerhaeuser | 11.40 | 0.42 | 25.06 | 0.70 | 55.91 | 0.46 |
| | Grand Mean* | 10.81 | 0.45 | 29.32 | 0.49 | 46.96 | 0.50 |
| | All observed | 7.67 | | | | | |
| Great Horned Owl | Takats CDB | 6.77 | 0.22 | 26.81 | 0.23 | 24.67 | 0.12 |
| | Weyerhaeuser | 5.35 | 0.36 | 9.94 | 0.86 | 78.46 | 0.44 |
| | Grand Mean* | 8.26 | 0.29 | 25.15 | 0.55 | 45.52 | 0.28 |
| | All observed | 7.43 | | | | | |
| Great Grey Owl | Weyerhaeuser | 4.42 | 0.40 | 14.75 | 0.69 | 50.53 | 0.82 |
| | All observed | 1.51 | | | | | |
| Northern Sawwhet Owl | Takats CDB | 8.60 | 0.70 | 26.22 | 0.19 | 32.75 | 0.59 |
| | Weyerhaeuser | 15.15 | 0.23 | 27.26 | 0.39 | 60.97 | 0.27 |
| | ANOS CDF | 15.15 | 0.45 | 31.06 | 0.45 | 54.58 | 0.40 |
| | Grand Mean* | 14.12 | 0.46 | 29.10 | 0.34 | 53.15 | 0.42 |
| | All observed | 14.35 | | | | | |

* Grand mean for observed only calculated for project-years where detectability/occupancy could be analysed. "All observed" is the mean observed for all project-years, including those with too few detections for detectability/occupancy analysis.

The coefficients of variation (CV) in Table 3-2 are for the year-to-year variation of a parameter within a project. (Standard errors of the detectability and occupancy estimates are in Appendix 1). The CV of occupancy for a species is generally the same as or higher than the CV of observed detection rate. That is, there is as much or more year-to-year variation in occupancy as in uncorrected observed detection rate.

***4. Multi-season occupancy: Spatial vs. temporal replication***

A logical goal for a long-term owl monitoring program is to estimate changes in site occupancy by owls through time. Sites can remain occupied from one year to the next; occupied sites can go 'extinct', or empty sites can be recolonized. MacKenzie *et al.* (2003) offer an analytical framework of occupancy dynamics through time, yielding estimates of local extinction and colonization. From a population of sampling units, a subset are selected and surveyed for the species. Units are closed to changes in occupancy during a common 'season', typically a year. Units must be repeatedly surveyed within a season, and may be surveyed over multiple seasons. The resulting data describe a combination of (1) true presence/absence of the species each season, and (2) observed data conditional upon true occupancy state of the site. The data obtained by repeat surveys within a season allows us to distinguish these two components, by modeling of probability of detection and occupancy, local extinction, and recolonisation at each site using a first-order Markov process where the probability of occupancy at a site in year 2 is contingent on occupancy in year 1.

In this framework surveys are typically repeated temporally, with revisits within a season; estimates of occupancy are then valid at each survey point. However, surveys can instead by replicated spatially, with simultaneous visits at multiple points within a larger "site"; estimates of occupancy are then valid at this larger "site" level, not at each survey point (MacKenzie *et al.* 2006). However, there are some assumptions required of this approach, mostly involving the spatial distribution of the target species at each larger "site". If a species has high site fidelity and is spatially clustered, spatial variability may exceed temporal variability. In this case the substitution of spatial replicates for temporal replicates may actually reduce probabilities of detection and decrease precision of estimates of occupancy, extinction, and recolonisation. The ecology of barred owls fits this description (see review in Fisher *et al.*

2011), so we hypothesized that replacing temporal replication with spatial replication may result in different parameter estimates and degrees of precision, weakening support for conclusions drawn from these analyses.

### *4.1 - Methods*

To test this hypothesis we used the program *Presence2* ver. 3.2 (Hines 2006) to model multi-season occupancy of nocturnal owls. We used data from the Weyerhaeuser projects (1999-2010) including all three regions (Grande Prairie, Drayton Valley, Edson). Each owl survey route had 12 stations that could be surveyed for 2 rounds. The model is robust to missing data, as surveys are only conducted every three years in each region. We ran 4 different model specifications (MacKenzie *et al.* 2003) to estimate probability of detection (p), occupancy ($\psi$), probability of site extinction ($\varepsilon$), probability of site recolonisation ($\gamma$), and net “site growth rate” ($\lambda$). We used AIC scores to select the best-supported model and reported parameters from this model.

In analysis 1, we treated each survey station as an independent site (n=694) and each round (n=2) as an independent survey (temporal replicate) to estimate parameters. In analysis 2, we treated each route as an independent site (n=58) and each station (n=4) as an independent survey (spatial replicate) to estimate parameters. We assumed a single visit to each station, so we used only round-1 data. We assumed 4 spatial replicates, so used stations 1-4 on each route.

### *4.2 – Results*

Temporally replicating surveys yielded reasonable estimates of *p* (0.16, SE=0.03) and reasonable estimates of occupancy (Figure 3-0). Patch colonisation exceeded patch extinction, so $\lambda$ was >1 and $\psi$ increased through time; we could detect and model these changes in barred owl occupancy over a 10-year span. This model likely approximates ecological reality, with the *caveat* that this is the simplest model possible and does not include any site- or sampling-level covariates, which account for variability and provide more precise parameter estimates.

Spatially replicating surveys yielded similar estimates of *p* (0.15 se=0.05) but markedly less precise estimates of occupancy (Figure 3-0). The initial estimated ψ was high, but with very large error bars. Estimated occupancy dropped markedly, then regained and levelled off. Error was always high through time, and no change in occupancy was detectable over the remainder of the 10-year span. Estimated λ=1 past year 2000, suggesting no decrease or increase through time. This trend likely does not approximate ecological reality, as large fluctuations of barred owls in the initial period are not reflected by data or ancillary observations.

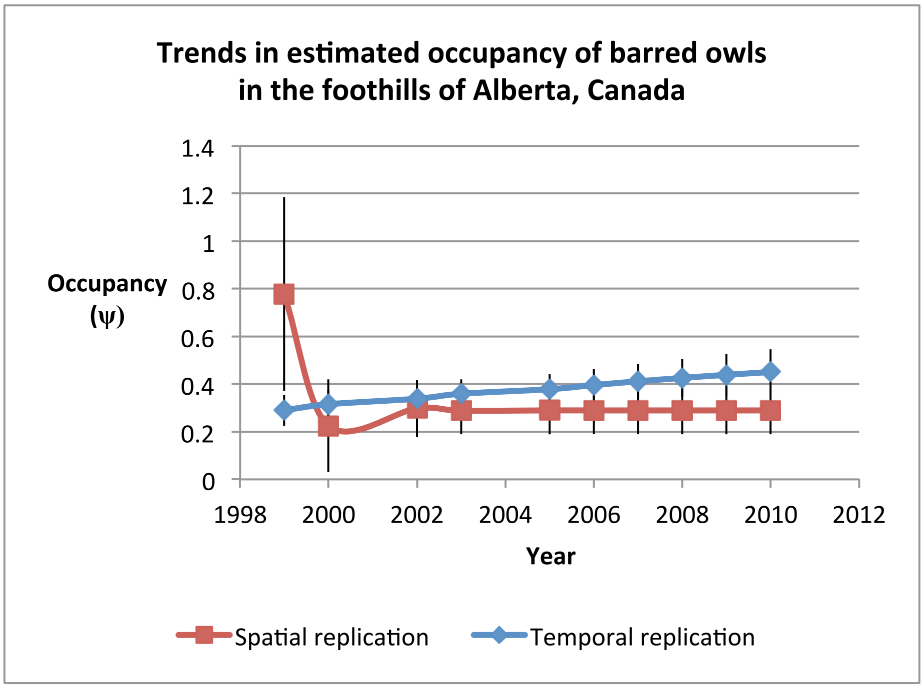



Figure 3-0. Trends in estimated barred owl occupancy, derived from estimates of site extinction and recolonisation, from temporally replicated (blue line) and spatially replicated (red line) surveys.

*4.3 – Conclusions*

Species are almost never surveyed with 100% accuracy and missed detections can severely bias estimates of trends in occupancy through time (MacKenzie *et al.* 2003, 2006), especially for rare, elusive, or clustered species (Thompson 2004). Surveys repeated within a season are crucial to estimating missed detections and correcting occupancy estimates. Spatial and temporal surveys provide alternatives to accomplish this goal, but we show that they are not interchangeable. We recommend that this limited analysis be augmented with a more in-depth analysis of owl survey data in *Strigidae_ver1* to support an evaluation of statistical and logistical trade-offs (*sensu* Bailey *et al.* 2007) that will inform decisions on apportioning owl surveying effort in northeast Alberta.

***5. Variance components for precision analysis***

Without information on which sites were on which transects (unavailable at time of the precision analysis, but currently available), the monitoring design was treated as visits within sites, and sites within years. This assumes no structure among sites – *i.e.*, each one is an independent random sample of the study area. Parameters needed to simulate data from this design for the precision analysis include:

<u>1. Grand mean</u>.

The grand mean is simply the overall rate of detection for an owl species. One complication is that the studies with multiple years of repeat visits are not in the LAPR area, and so may have higher or lower abundances of the owl species. To check this and adjust the grand mean to LAPR values, simple mean detection rates were calculated for the 3 main studies that provided parameters, and for other owl monitoring projects in the southern LAPR and northern LAPR. Results suggest barred owls are less common in LAPR than in the intensively studied areas, boreal and great grey owls are more common, and great horned owls are the same. Northern saw-whet owls appear much less common in the LAPR, which may be due to their western range, or it may be because the EIA-type surveys in the LAPR have not emphasized detecting this species.

Table 3-3. Observed detection rates (%) for owl species in the intensive studies that provided parameter values and in LAPR area projects[1].

| | BADO | | BOOW | | GHOW | | GGOW | | NSWO | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area or Study** | **Mean** | **CI** | **Mean** | **CI** | **Mean** | **CI** | **Mean** | **CI** | **Mean** | **CI** |
| Takats | 5.55 | (4.61-6.60) | 11.18 | (9.88-12.60) | 5.50 | (4.57-6.55) | 1.08 | (0.69-1.62) | 6.81 | (5.78-7.97) |
| Weyerhaeuser DV | 3.15 | (2.54-3.86) | 4.97 | (4.20-5.83) | 2.55 | (2.01-3.20) | 1.75 | (1.30-2.30) | 7.52 | (6.58-8.55) |
| Weyerhaeuser GP | 6.30 | (5.03-7.78) | 10.79 | (9.13-12.62) | 2.91 | (2.06-3.99) | 2.28 | (1.53-3.26) | 12.44 | (10.67-14.38) |
| ANOS NW | 1.88 | (1.23-2.75) | 1.81 | (1.17-2.66) | 4.34 | (3.33-5.56) | 0.94 | (0.50-1.60) | 12.24 | (10.55-14.08) |
| ANOS central | 1.79 | (1.28-2.42) | 1.31 | (0.88-1.86) | 13.59 | (12.22-15.07) | 0.65 | (0.37-1.08) | 14.20 | (12.80-15.70) |
| ANOS S | 1.59 | (0.99-2.42) | 7.12 | (5.79-8.64) | 5.45 | (4.29-6.81) | 1.21 | (0.69-1.96) | 8.86 | (7.38-10.52) |
| Average | 4.01 | | 7.49 | | 5.34 | | 1.34 | | 9.52 | |
| S LARP | 3.28 | (1.76-5.55) | 19.44 | (15.66-23.69) | 2.53 | (1.22-4.59) | 2.27 | (1.04-4.27) | 2.53 | (1.22-4.59) |
| N LARP | 2.12 | (1.24-3.37) | 18.18 | (15.57-21.03) | 8.34 | (6.52-10.48) | 3.24 | (2.13-4.71) | 1.25 | (0.60-2.28) |
| Average | 2.70 | | 18.81 | | 5.43 | | 2.76 | | 1.89 | |

[1] Values differ from Table 3-2, because the value here includes all sites, not just those with the maximum number of repeated visits used in the occupancy analysis.

Note: Averages for the main studies treat each of the 3 studies equally.

2. Variance among years, and site-to-site variability

Variance among years and site-to-site variability were estimated using a general linear mixed model, with year as a fixed factor and site as a random effect. This model was run for each species, for each of the three projects with large multi-year datasets (Takats, Weyerhaeuser and ANOS). Year was treated as a fixed, rather than random, effect here because random effects models produce unstable (and clearly wrong) estimates of two random effects when there are far more levels of one variable (*i.e.*, hundreds of sites compared to 5-10 years). Site was not nested within year, because sites and year are partially crossed in the available studies (most sites are sampled in most years, but all sites are not sampled every year). This analysis was done with function “lmer”, using a logit-linked binomial distribution. The variance estimates were combined among studies using a simple average (excluding values from ANOS for two species, where the model failed to converge because of years with almost no detections of the species). The model did not work for great gray owls for any of the projects, because the species was often absent or nearly absent.

Results show higher variance components for site than year, as expected because variation among individual sites almost certainly has to be higher than variation in the average rate of detecting the species from year to year. Site variation is relatively higher for barred owls and lower for saw-whet owls. Boreal and great horned owls have similar intermediate values of the variance parameters, although boreal owls are more common.

Table 3-4. Parameter estimates for simulating data for estimating trend precision for four owl species, based on averages of empirical estimates from 3 studies.

| | **Grand Mean Main Studies** | **Grand Mean LARP** | **Logit Var Year** | **Logit Var Site** |
|---|---|---|---|---|
| Barred Owl | 0.040 | 0.027 | 0.195 | 4.869 |
| Boreal Owl | 0.075 | 0.188 | 0.316 | 1.929 |
| Great Horned Owl | 0.053 | 0.054 | 0.256 | 1.856 |
| Northern Sawwhet Owl | 0.095 | 0.019 | 0.329 | 0.891 |

3. Autocorrelation of variance among years.

Autocorrelation of variance among years was assessed separately, by fitting a first-order autoregression model to the observed annual detection probabilities and using AIC to compare to a model without autocorrelation. Higher-order autocorrelation was not assessed in most cases, because of short time series and high variability. Only two of the 15 combinations of species and project showed first-order autocorrelation (Boreal and Saw-whet owls in Takats' study). In both cases the correlation was negative (high years following low years, and vice versa). Given that there is no strong biological reason to expect true negative autocorrelation, and with only 5 years available in the Takats' study, we chose to ignore temporal autocorrelation in the data simulation. Longer time series and larger datasets might show positive autocorrelation, particularly for species like great horned owls that can show multi-year cycles. (We also checked for autocorrelation in the yearly occupancy estimates from the detectability modeling. Again, only two combinations of species and project showed autocorrelation, and both values were negative.)

## *6. Expected precision of trend estimates*

### *6.1. Methods – precision*

The precision analysis first simulated data with various sampling designs, using the parameters derived above, then calculated the trend that those data would produce. The procedure was repeated 200 times. The resulting distribution of the 200 trend estimates was used to estimate the expected standard error of the trend estimate with that design. This analysis uses observed detection rate as the index of a species' abundance. A similar analysis using occupancy corrected for detectability has not yet been completed but is recommended.

Figure 1 outlines the steps in the data simulation:

1. The grand mean was estimated as the mean rate of detection of the species in the LAPR area (Table 3).
2. The user-specified number of years of monitoring and the true population trend were used to produce the true mean detection rate for each year: True mean year *i* = Grand Mean x $((100+\text{True trend})/100)^i$, where the true trend is specified as %/yr.
3. The true yearly means were converted to the logit scale, and values sampled from the normally-distributed logit-scale annual variation (Table 3-4)[2] added to each to give the realized mean for each year on the logit scale.[3] No yearly autocorrelation was used, because of little or no evidence for autocorrelation in the empirical data.
4. For each realized yearly value, logit scale values were generated for each of a user-specified number of sites by sampling values from the normally distributed logit scale site-to-site variability (Table 3-4). In designs that revisit the same sites periodically, the same site value is used each time a site was revisited (*i.e.*, the value for a site relative to the yearly mean is a permanent feature of a site; if a particular site has double the

[2] It is reasonable to use these logit scale variances even though the grand mean is different in the LAPR area, because the analysis is conducted on the logit scale at this point. With the low probabilities for owl detections, the logit scale is almost identical to the log scale here, so the assumption is that the annual and site-to-site variances remain proportional to the grand mean.

[3] There is also a procedure to adjust for the fact that adding variation on the logit scale biases the mean on the ordinal scale (similar to the difference between a geometric and arithmetic mean). This ensures that the overall long-run mean detection probability remains that specified by the true yearly mean. The same procedure is also applied when logit scale variance is added at the site level.

average probability of having an owl detection on the first visit, it will have double the probability on the second visit, even though the average for the second year will be different than the first.)

5. Presence/absence for a user-specified number of visits per year was generated for each site using a binomial distribution, with the mean equal to the site mean (back-transformed from the logit scale).

These data were then used in a standard log-link regression with year to estimate trend as percent change per year. The standard deviation of the 200 iterations of this Monte Carlo procedure is a direct estimate of the expected standard error (SE) of the trend estimate with that design[4]. The SE is a direct measure of the uncertainty, or lack of precision, of the trend estimate. It is most easily understood using 95% confidence intervals, which are approximately ±2 SE. For example, with a SE of 5%/yr, a trend estimate of -3%/yr would have 95% confidence intervals of -13%/yr to +7%/yr (and would not be "significantly" different from 0%/yr in an out-dated null hypothesis test).

[4] The number of iterations is arbitrary, and was only limited by time to complete the analysis. 200 iterations does produce some moderate uncertainty in the resulting SE. Slight differences in the expected SE for different designs should not be interpreted as meaningful.

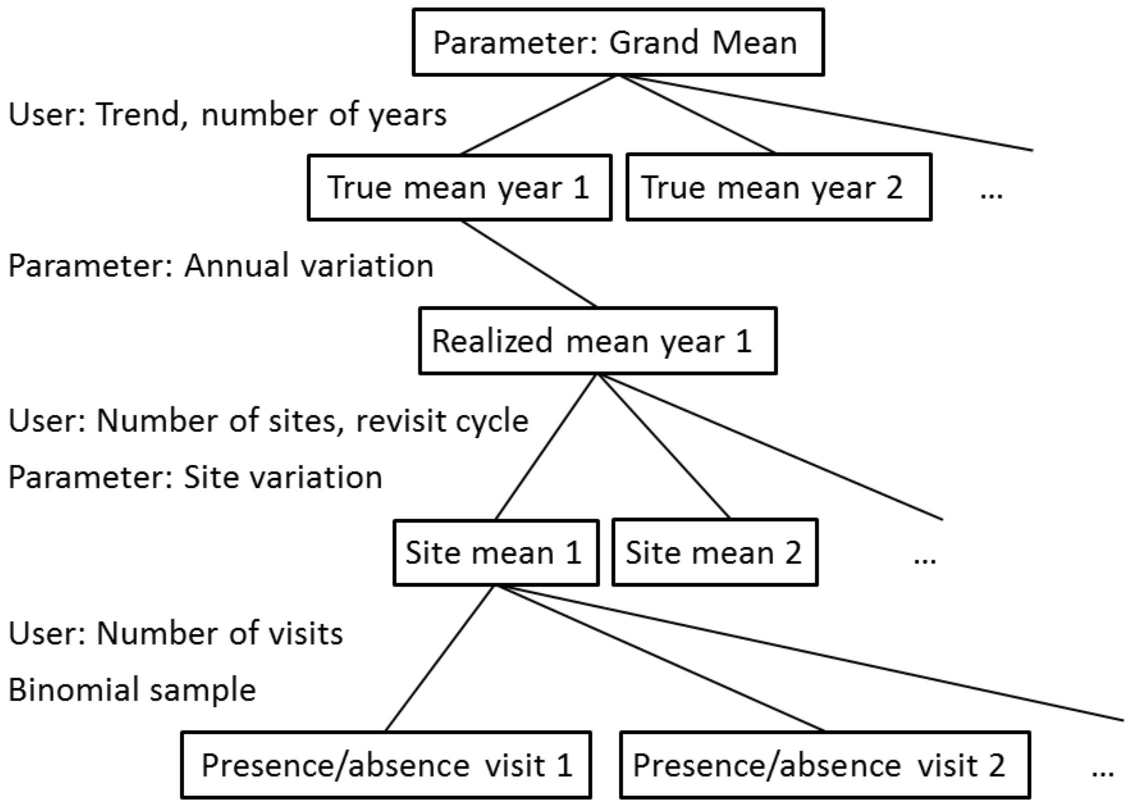



Figure 3-1. Outline of data simulation for the precision analysis.

Precision estimates were generated for 40 designs for each species to allow several comparisons:

<u>1. Duration of monitoring and number of sites</u>

Designs included the 20 combinations of four monitoring durations – 5, 10, 20 and 30 years – and five numbers of sites monitored per year – 50, 100, 200, 400 and 800 (remembering that this analysis is entirely at the site scale; with 10 sites per route, there would be 5, 10, 20, 40 and 80 routes per year.) These simulations all used 1 visit per site per year, a 5-year revisit cycle and a true trend of 0 (*i.e.*, no population change).

<u>2. Number of visits per year</u>

An additional set of designs used the same four monitoring durations and 50, 100 and 200 sites per year, but with 4 visits per site per year. These values are compared to the single visit results with 200, 400 and 800 sites per year, so that the total number of surveys per year is the same. This comparison assesses the trade-off between more sites or more visits per site.

3. Revisit cycle

In addition to the 5-year revisit cycle used above, designs were run with revisit cycles of 1 year (*i.e.* the same sites used each year) and no revisits (random sites chosen every year). This was done for 10 years of monitoring at 200 sites per year with 1 visit per site per year. This comparison asks whether it is more efficient to revisit sites yearly, periodically or never.

4. True trend

The above runs all use a true trend of 0%/yr. Previous analyses have shown that the expected precision of the trend estimate changes little for trends that are moderately different from 0. However, precision can be affected by the actual value of the trend for two reasons: i) Large changes in the overall population abundance change the importance of the binomial sampling error, because this becomes more important as a species becomes rarer or less important as the species increases. ii) The log-link regressions to estimate trend tend to have more uncertainty when trends are extreme, particularly with shorter time series. Runs were therefore conducted with true trends of -10%/yr, -3%/yr, 0%/yr, +3%/yr and +10%/yr, with 10 years of monitoring at 200 sites per year and 1 visit per site per year. The population abundance would decline 65% in 10 years with a -10%/yr trend, and increase 160% with +10%/yr.

*6.2. Results – precision*

Results are tabulated in Appendix 4.

*6.2.1. Monitoring duration and number of sites*

Figure 3-2 shows the expected precision of the trend estimate (SE, in %/yr) as a function of the number of years of monitoring and number of sites monitored per year (with one visit per site per year). The most important feature to point out is that the SE of the trend estimates are large, at least for the initial years. A traditional goal of monitoring programs is being able to declare a 3%/yr change in a species statistically “significantly” different from no change with only a 5% error rate. The analysis suggests that goal will take at least 17 years of monitoring (intersection of dashed blue line with results curves in Figure 3-2).

The strongest effect is clearly monitoring duration.  As similar previous analyses have found, the SE of the trend estimate decreases approximately as monitoring duration to the 1.5 power. Doubling the monitoring duration decreases the expected SE to about $1/2^{1.5}$, or 0.35 of its original value.  Equivalently, precision increases by 2.83-fold when duration is doubled.

The effect of increasing sites monitored per year is more complicated.  When site variability is high relative to annual variability or overall abundance is very low (=high binomial sampling error), the SE of the trend estimate can decrease almost as the square root of number of sites.  Quadrupling the number of sites would almost halve the standard error.  But when annual variability and abundance are both relatively high, increasing the number of sites has a more limited effect (as in boreal owls in Figure 3-2).

The species differences are understandable from their grand mean and the yearly versus site variance.  In particular, barred and saw-whet owls start with high expected SE's because they are rare in the LAPR area and therefore binomial sampling error has a large effect.  In contract, boreal owls have a lower SE after a short monitoring duration, but the decrease in SE is not quite as dramatic over time, because the species has a high annual variability.

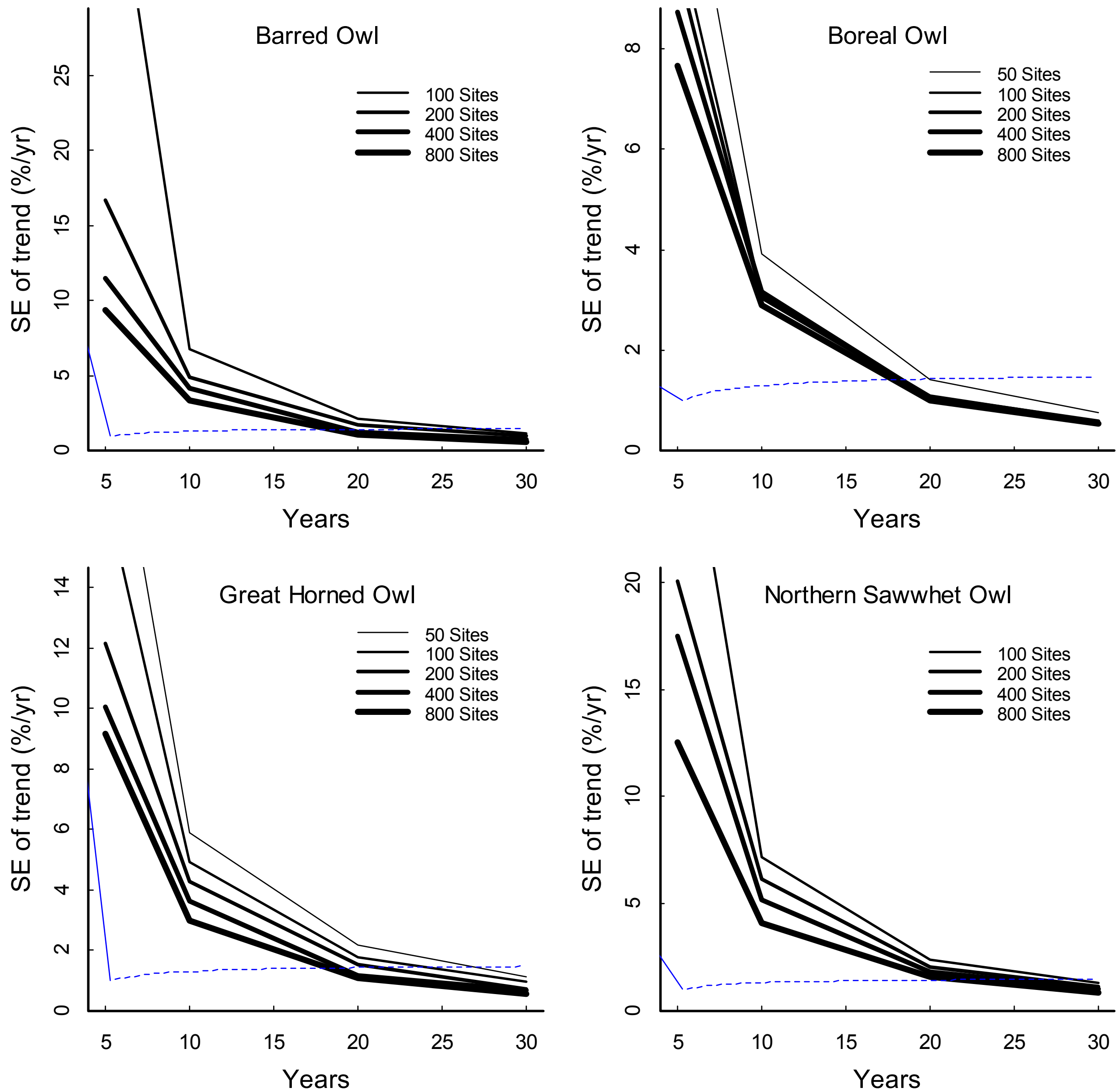



Figure 3-2. Expected SE of the trend estimate for four species of owls in the LAPR area, with 50, 100, 200, 400 or 800 sites monitored per year for 5-30 years. (Results for 50 sites are not shown for barred or saw-whet owls, because there were often too many years with no detections of these rare species for the regression to run.) Note the different y-axis scales. Results shown for 5-year revisit cycle and true trend of 0%/yr. Dashed blue line indicates the SE required to have a 95% chance of rejecting a null hypothesis of no change if the actual change is +3%/yr or -3%/yr.

*6.2.2. Visits per year*

For the same total number of surveys per year, there is relatively little difference between more sites with 1 visit to each or fewer sites with multiple visits (Figure 3-3). Using 4 visits per site only produced slightly higher expected SE's than single visits at 4 times as many sites. The increase in SE with 4 visits is about the amount that a single additional year of monitoring would overcome. Runs with 2 visits per year (not shown) were about intermediate (and probably within the margin of error of the analysis).

The expected change in precision is small with different allocation of effort to more sites versus multiple visits to sites per year, so this design decision should mainly be based on other considerations. A main one is whether there is benefit in being able to do single-season occupancy/detectability analyses on the data. An analysis of the effects of using occupancy/detectability on trend precision has not yet been done. Preliminary analyses show that imperfect detection may have may have an effect if there are strong site-level or annual covariates of detectability. There was wide uncertainty on the detectability estimates in the simple site-level occupancy analyses of the owls, and the detectability corrections did not appear to reduce annual variability, and increased it in some cases. In theory, the trend estimates should not be any more precise because no new information is being added to the analysis when detectability is calculated, unless there are strong covariate relationships. A more formal analysis of this question should be done during the pilot stage of the project (2012). There may also be some benefit to repeat surveys in a year to detect different species at a site that are active at different parts of the season. However, surveying different sites through the season would also capture the various species, just with less information on which species co-occur at particular sites.

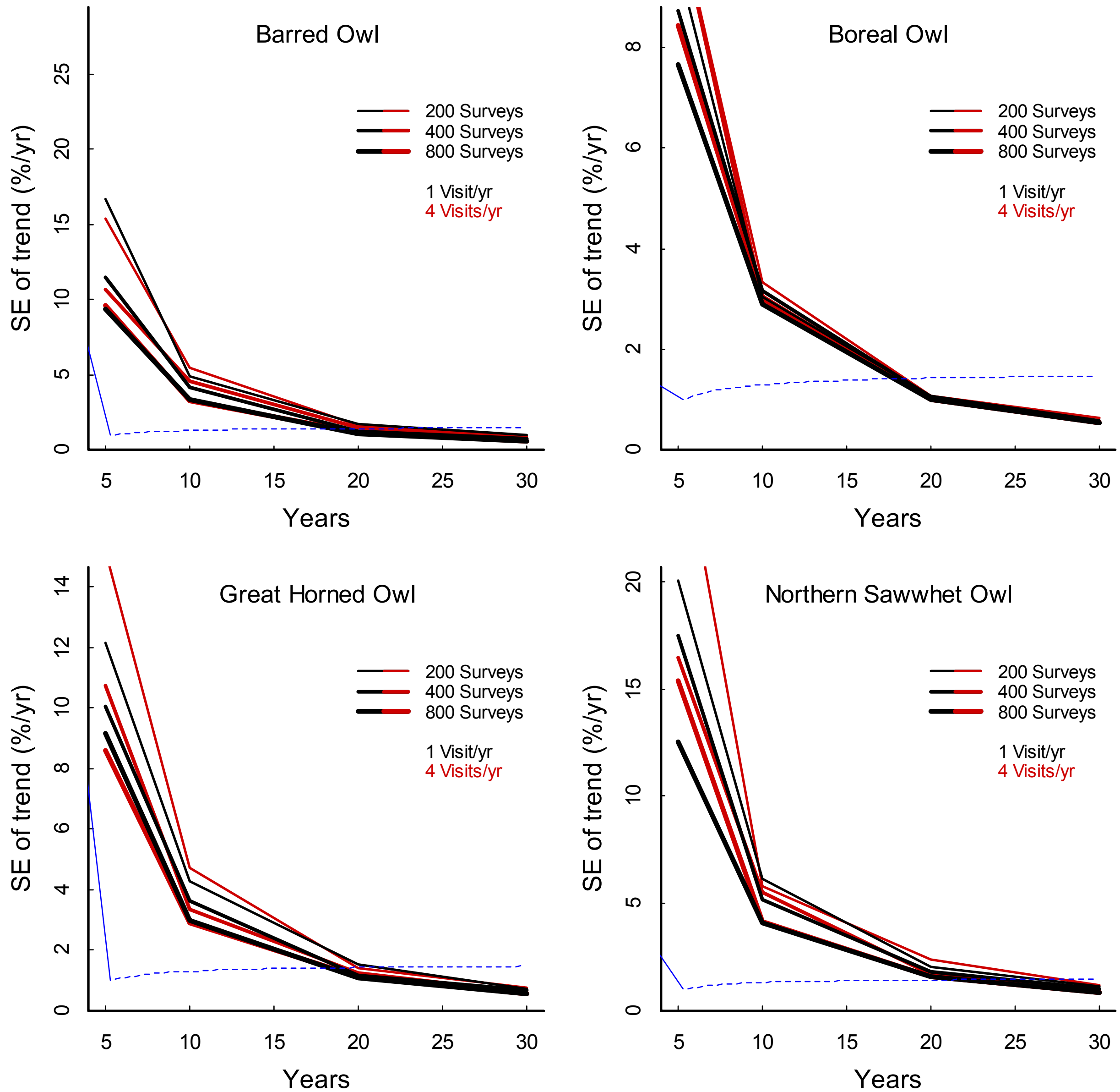


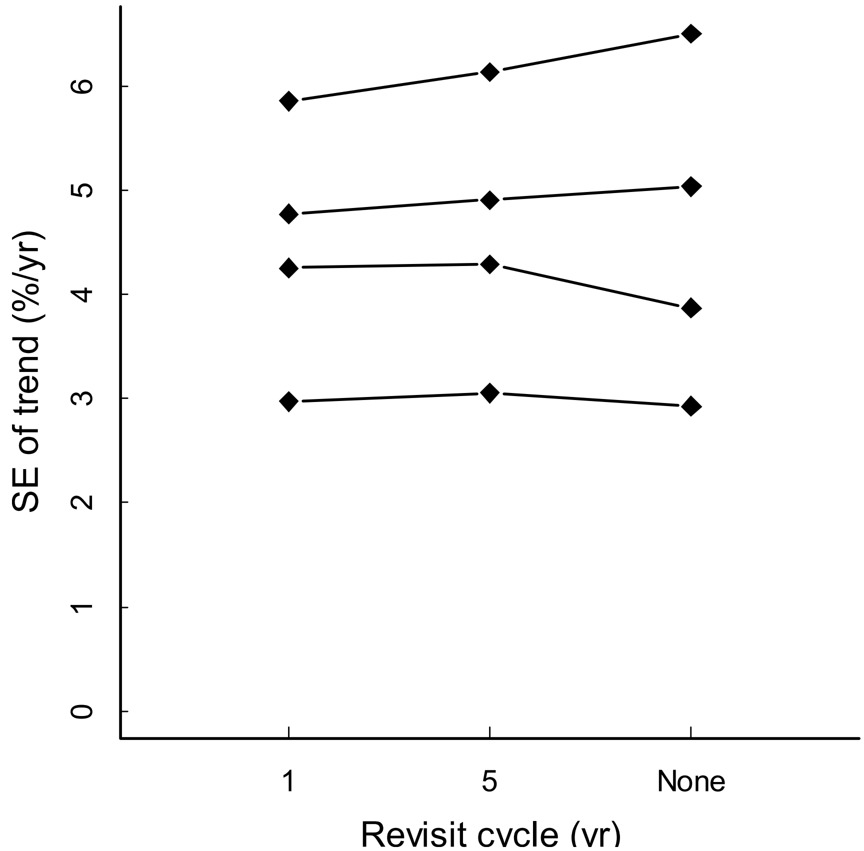

Figure 3-3. Expected SE of the trend estimate for four species of owls in the LAPR area, with 200, 400 or 800 surveys per year, with either 1 visit per site per year (black), or 4 visits per site per year (red). With 4 visits, the 200, 400 and 800 surveys would be done at 50, 100 and 200 sites, respectively. Note the different y-axis scales. Results shown for 5-year revisit cycle and true trend of 0%/yr. Dashed blue line indicates the SE required to have a 95% chance of rejecting a null hypothesis of no change if the actual change is +3%/yr or -3%/yr.

*6.2.3. Revisit cycle*

Surveying the same sites every year tends to produce slightly lower SE's on the trends than having a 5-year revisit cycle or using different sites every year (Figure 3-4), with some uncertainty in individual points. However, any difference is negligible compared to the effects of monitoring duration and total number of sites. More important factor in deciding on revisit cycles might include:

1) The ability to capture the effects of concentrated development. Having a larger pool of sites, each revisited less frequently, might be more effective at representing landbase change over time.
2) Opportunities to develop relationships with habitat and footprint variables. Again, a large sample base of sites surveyed over several years may be more effective for developing relationships that help explain what is causing observed changes.
3) Additional information from repeat visits to sites. There may be value in information that can only be collected from yearly visits to sites, such as turn-over of occupancy and possibly better estimates of annual variability.
4) Logistical issues. There may be substantial overhead in establishing routes that can be surveyed at night in winter, which would favour revisiting a smaller pool of known sites. These factors are likely more important than precision issues in deciding on the size of the pool of sites and their revisit frequency (given a certain total yearly effort).

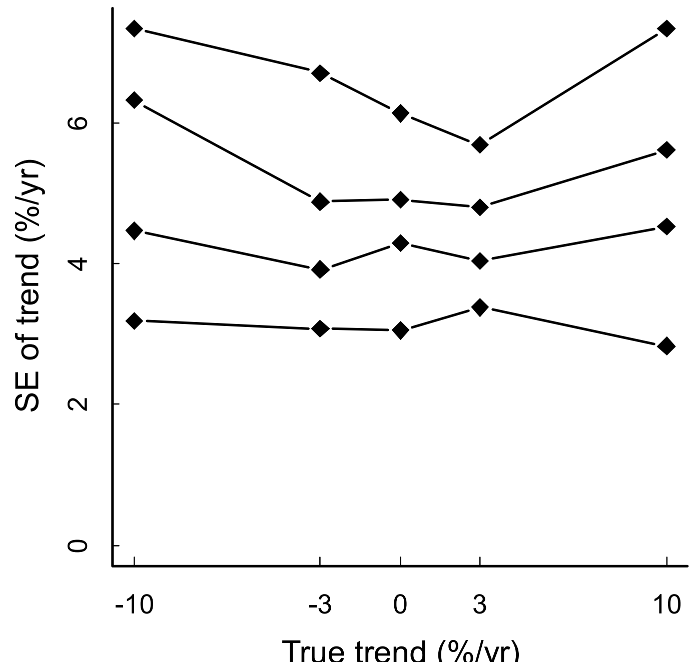
Figure 3-4. Expected SE of the trend estimate for four species of owls (separate lines) in the LAPR area, with sites revisited every year, every 5 years or never (*i.e.*, new sites every year). Results are for 10 years of monitoring with 200 sites per year and 1 visit per year.




*6.2.4. True trend*

Results in Figures 3-1 to 3-4 were presented for runs that assumed a true trend of 0%/yr. Runs with different true trend (Figure 3.5) suggest that for the species that are less precisely estimated (rarer species), trend results will be less precise if there are strong negative trends, and possibly if there are strong positive trends. The effect of negative trends is expected, because as a species becomes rarer, the influence of binomial sampling error increases. In the situations simulated here, there is only a moderate effect of extreme trends on increasing the SE for rare species. One or two more years of monitoring would overcome that difference if the species really was decreasing at an extreme rate. The results based on 0%/yr true trends presented above should therefore apply to almost any actual trend.

Figure 3-5. Expected SE of the trend estimate for four species of owls (separate lines) in the LAPR area with true trends ranging from -10%/yr to +10%/yr. Results are for 10 years of monitoring 200 sites per year with a single visit per site per year.




*6.3. Other information goals*

A secondary objective of the monitoring is being able to relate differences or changes in owls' abundances to land-use practices. Based on ABMI experience, if the monitoring sites are located randomly or systematically in space – as opposed to some sites targeting certain land-use practices – at least several hundred sites will need to be surveyed to find even basic relationships between the relatively common owl species and human footprint. A more formal analysis of this question could be undertaken for owls using known footprint values around ABMI sites and the owl parameters developed for the trend precision analysis.

*6.4. Summary*

- Predicted SE's of trend estimates are high for owls, which are generally rare and show high annual variability in detections.
- Based on this analysis, a standard monitoring goal of being able to distinguish a 3%/yr change from no change would take at least 17 years of monitoring. It is important to note, however, that this target was derived for a smaller subset of some of the more common owls. Of these, only one is listed as *Sensitive* in Alberta. If the intent of the monitoring program is to monitor the impacts of human landscape disturbance on owl

presence/abundance, then the duration of the monitoring program would need to be increased for rarer species which are more susceptible to anthropogenic disturbance.

- SE's of trends decrease most rapidly with the number of years of monitoring. Doubling the monitoring duration reduces SE's by about 65%. The most important part of a monitoring design is commitment to long-term continuity.
- For the rarer species and those with less annual variation, SE's of trends decrease almost with the square root of number of sites. Quadrupling the number of sites monitored per year would almost halve the SE.
- For a given amount of total monitoring effort per year, visiting sites more than once increases SE's only moderately. The values of different types of information are probably more important considerations in deciding how many times to visit sites per year (again, given a certain total number of surveys per year).
- Revisiting sites each year, on a 5-year cycle, or never (i.e., new sites each year) makes little difference in expected precision. Logistical and other considerations are more important for this element of monitoring design.
- Precision may be slightly worse than expected if the species is showing strong trends. (But, of course, precision would be less important in that case, as it would be clear the species is showing some degree of decline.)
- This type of analysis is meant for guidance in designing monitoring programs and forming broad expectations of results. There are many caveats:
    - The parameter estimates underlying the analysis are weak, because existing programs were not specifically designed to provide these parameters, and – despite great effort – owls are simply difficult species for which to collect good information.
    - The parameter estimates are also not specifically for the LAPR area, except limited information on general detection rates.
    - The analysis assumes a continuous trend over time, plus stable annual variability. Different temporal patterns, such as occasional sudden declines in response to catastrophic events, will produce greater uncertainty in the trend estimates.

- The results are based on current protocols and fairly simple analyses. Alternative field methods, supplementary information and more sophisticated analyses of the actual data may be able to improve precision. On the other hand, they will introduce new uncertainties, at least until a pilot study provides information to analyse their expected performance.

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## Appendix 1: Recommended Pilot Protocols for Owl Monitoring in Northeast Alberta

1. Owls will be surveyed on the ABMI systematic survey grid.
2. Stations will be separated by 1.6 km.
3. Surveys will be conducted between March 20 and May 5.
4. Nocturnal surveys will start one half hour after sunset, and finish no later than one half hour before sunrise. Diurnal surveys will be conducted between sunrise and sunset.
5. Surveys will start with a two minute silent listening period.
6. Surveys will follow a sequence of listening and broadcasting designed to detect multiple owl species (Table App-1).
7. Surveys will be conducted under the conditions: wind speeds <20 km per hour (Beaufort 3 or less), no precipitation, and temperatures > -15$^{o}$C.
8. Surveyors will record:
    i. site and station ID
    ii. surveyor ID
    iii. date of survey
    iv. start and finish time at each station
    v. wind estimation at start of survey and peak wind gust during survey
    vi. codes for background noise
    vii. owl species detected by 4-letter code
    viii. direction to owl (degrees)
    ix. distance to owl in categories (<200, 200-500, 501-1000, >1000 m)
    x. time of each detection event within the survey
    xi. temperature, cloud cover, moon phase

Table App-1: Call-broadcast survey protocols for multiple owl species.

| Call type | Time (min : sec) | Cumulative time |
|---|---|---|
| silent listening | 2:00 | 2:00 |
| northern saw-whet owl call broadcast | 0:20 | 2:20 |
| silent listening | 1:00 | 3:20 |
| northern saw-whet owl call broadcast | 0:20 | 3:40 |
| silent listening | 1:00 | 4:40 |
| boreal owl call broadcast | 0:20 | 5:00 |
| silent listening | 1:00 | 6:00 |
| boreal owl call broadcast | 0:20 | 6:20 |
| silent listening | 1:00 | 7:20 |
| long-eared owl call broadcast | 0:20 | 7:40 |
| silent listening | 1:00 | 8:40 |
| long-eared owl call broadcast | 0:20 | 9:00 |
| silent listening | 1:00 | 10:00 |
| great gray owl call broadcast | 0:20 | 10:20 |
| silent listening | 1:00 | 11:20 |
| great gray owl call broadcast | 0:20 | 11:40 |
| silent listening | 1:00 | 12:40 |
| barred owl call broadcast | 0:20 | 13:00 |
| silent listening | 1:00 | 14:00 |
| barred owl call broadcast | 0:20 | 14:20 |
| silent listening | 1:00 | 15:20 |
| barred owl call broadcast | 0:20 | 15:40 |
| silent listening | 1:00 | 16:40 |

## Appendix 2. Detailed detectability/occupancy results for 5 owl species.

| Barred Owl | | Visits | Observed | Detectability | Det SE | Occupancy | Occ SE |
|---|---|---|---|---|---|---|---|
| TAKATS_CDB | 1995 | 4 | 6.63 | 25.16 | 7.48 | 26.34 | 7.81 |
| | 1996 | 3 | 4.58 | 23.23 | 10.88 | 19.70 | 8.91 |
| | 1997 | 2 | 6.63 | 61.54 | 15.88 | 10.78 | 3.76 |
| | 1998 | 3 | 6.20 | 61.25 | 12.86 | 9.76 | NA |
| | 1999 | 2 | 5.91 | 36.36 | 18.55 | 16.26 | 8.26 |
| | Mean* | | 5.99 | 41.51 | | 16.57 | |
| | CV* | | 0.14 | 0.45 | | 0.41 | |
| TAKATS_CDF | 2000 | 2 | 12.50 | 66.67 | 15.71 | 18.75 | 6.44 |
| | 2004 | 2 | 5.66 | | | | |
| WEYCO_NOCTURNAL | 1999 | 2 | 8.33 | 20.78 | 14.30 | 40.09 | 28.23 |
| | 2000 | 3 | 6.67 | 19.10 | 9.62 | 36.27 | 15.07 |
| | 2002 | 2 | 1.49 | | | | |
| | 2005 | 2 | 4.76 | 16.76 | 12.93 | 29.00 | 19.58 |
| | 2007 | 2 | 6.34 | 8.33 | 7.88 | 76.17 | 69.26 |
| | 2008 | 2 | 6.37 | 15.84 | 11.09 | 40.34 | 25.66 |
| | 2010 | 2 | 13.05 | 27.79 | 25.20 | 47.55 | 50.83 |
| | Mean* | | 7.59 | 18.10 | | 44.90 | |
| | CV* | | 0.38 | 0.35 | | 0.37 | |
| ANOS_CDF | 1998 | 2 | 2.78 | | | | |
| | 1999 | 2 | 2.27 | | | | |
| | 2002 | 2 | 4.00 | | | | |
| | 2003 | 2 | 2.49 | | | | |
| | 2004 | 2 | 1.60 | | | | |
| | 2005 | 2 | 1.72 | | | | |
| | 2006 | 2 | 5.00 | 26.08 | 17.28 | 20.40 | 11.68 |
| | 2007 | 2 | 1.09 | | | | |
| | 2008 | 2 | 2.72 | | | | |
| | 2009 | 2 | 3.13 | | | | |
| | 2010 | 2 | 3.36 | | | | |
| GOLDER_CNRL | 2008 | 2 | 0.00 | | | | |
| Grand mean | | | 7.15 | 31.45 | | 30.11 | |
| Grand mean - all | | | 4.82 | | | | |

* Mean and CV of Observed only use years where detectability/occupancy could be estimated

| Boreal Owl | | Visits | Observed | Detectability | Det SE | Occupancy | Occ SE |
|---|---|---|---|---|---|---|---|
| TAKATS_CDB | 1995 | 4 | 21.08 | 34.39 | 6.08 | 59.27 | 7.71 |
| | 1996 | 3 | 8.50 | 33.92 | 10.81 | 25.10 | 11.75 |
| | 1997 | 2 | 9.18 | 55.45 | 14.86 | 16.72 | 4.80 |
| | 1998 | 3 | 14.73 | 33.23 | 7.64 | 44.52 | 8.83 |
| | 1999 | 2 | 6.99 | 30.77 | 16.65 | 22.72 | 11.94 |
| | Mean* | | 12.10 | 37.55 | | 33.67 | |
| | CV* | | 0.48 | 0.27 | | 0.53 | |
| TAKATS_CDF | 2000 | 2 | 12.50 | 33.33 | 17.57 | 37.50 | 19.01 |
| | 2004 | 2 | 7.55 | | | | |
| WEYCO_NOCTURNAL | 1999 | 2 | 9.90 | 10.58 | 9.37 | 93.49 | 80.31 |
| | 2000 | 3 | 6.94 | 12.97 | 4.45 | 53.50 | 19.87 |
| | 2002 | 2 | 7.46 | | | | |
| | 2005 | 2 | 10.71 | 13.28 | 2.45 | 80.20 | NA |
| | 2007 | 2 | 10.73 | 24.84 | 8.27 | 43.19 | 14.36 |
| | 2008 | 2 | 9.43 | 31.84 | 9.88 | 28.97 | 8.14 |
| | 2010 | 2 | 20.69 | 56.83 | 8.31 | 36.11 | 7.75 |
| | Mean* | | 11.40 | 25.06 | | 55.91 | |
| | CV* | | 0.42 | 0.70 | | 0.46 | |
| ANOS_CDF | 1998 | 2 | 4.86 | | | | |
| | 1999 | 2 | 2.73 | | | | |
| | 2002 | 2 | 6.00 | 41.95 | 15.73 | 10.39 | 5.00 |
| | 2003 | 2 | 2.21 | | | | |
| | 2004 | 2 | 2.51 | 2.52 | 0.88 | 99.52 | 18.06 |
| | 2005 | 2 | 1.72 | | | | |
| | 2006 | 2 | 1.92 | | | | |
| | 2007 | 2 | 3.28 | | | | |
| | 2008 | 2 | 1.09 | | | | |
| | 2009 | 2 | 0.63 | | | | |
| | 2010 | 2 | 3.78 | | | | |
| GOLDER_CNRL | 2008 | 2 | 12.32 | 23.84 | 10.07 | 53.16 | 17.72 |
| Grand mean | | | 10.81 | 29.32 | | 46.96 | |
| Grand mean - all | | | 7.67 | | | | |

Mean and CV of Observed only use years where detectability/occupancy could be estimated

| Great Horned Owl | | Visits | Observed | Detectability | Det SE | Occupancy | Occ SE |
|---|---|---|---|---|---|---|---|
| TAKATS_CDB | 1995 | 4 | 6.33 | 22.13 | 7.32 | 28.58 | 9.15 |
| | 1996 | 3 | 6.21 | 27.33 | 10.89 | 21.22 | 7.10 |
| | 1997 | 2 | 5.61 | 22.48 | 18.22 | 25.10 | 18.60 |
| | 1998 | 3 | 8.91 | 35.32 | 11.61 | 23.76 | 9.78 |
| | 1999 | 2 | 4.84 | | | | |
| | Mean* | | 6.77 | 26.81 | | 24.67 | |
| | CV* | | 0.22 | 0.23 | | 0.12 | |
| TAKATS_CDF | 2000 | 2 | 3.13 | | | | |
| | 2004 | 2 | 7.55 | | | | |
| WEYCO_NOCTURNAL | 1999 | 2 | 6.25 | 6.27 | 2.45 | 99.59 | 8.87 |
| | 2000 | 3 | 5.56 | 5.83 | 3.56 | 95.31 | 50.55 |
| | 2002 | 2 | 0.00 | | | | |
| | 2005 | 2 | 7.94 | 9.87 | 3.57 | 81.17 | NA |
| | 2007 | 2 | 2.68 | 26.87 | 19.52 | 10.14 | 6.82 |
| | 2008 | 2 | 3.54 | 3.53 | 1.50 | 99.96 | 2.66 |
| | 2010 | 2 | 6.16 | 7.27 | 6.92 | 84.61 | 78.10 |
| | Mean* | | 5.35 | 9.94 | | 78.46 | |
| | CV* | | 0.36 | 0.86 | | 0.44 | |
| ANOS_CDF | 1998 | 2 | 10.42 | 39.23 | 17.58 | 26.56 | 14.81 |
| | 1999 | 2 | 7.73 | 26.61 | 12.01 | 29.79 | 11.76 |
| | 2002 | 2 | 13.00 | 19.02 | 4.56 | 67.26 | 7.49 |
| | 2003 | 2 | 12.71 | 30.64 | 8.25 | 41.49 | 13.25 |
| | 2004 | 2 | 7.31 | 45.97 | 12.61 | 16.88 | 5.81 |
| | 2005 | 2 | 6.65 | 18.74 | 9.41 | 34.70 | 16.26 |
| | 2006 | 2 | 18.46 | 37.92 | 7.68 | 49.21 | 8.63 |
| | 2007 | 2 | 12.77 | 42.22 | 13.54 | 31.29 | 8.46 |
| | 2008 | 2 | 6.52 | 47.58 | 13.36 | 14.38 | 4.89 |
| | 2009 | 2 | 9.38 | 35.84 | 9.22 | 24.65 | 7.67 |
| | 2010 | 2 | 9.24 | 17.58 | 6.02 | 50.39 | 14.03 |
| GOLDER_CNRL | 2008 | 2 | 4.35 | | | | |
| Grand mean | | | 8.26 | 25.15 | | 45.52 | |
| Grand mean - all | | | 7.43 | | | | |

Mean and CV of Observed only use years where detectability/occupancy could be estimated

| Great Grey Owl | | Visits | Observed | Detectability | Det SE | Occupancy | Occ SE |
|---|---|---|---|---|---|---|---|
| TAKATS_CDB | 1995 | 4 | 0.60 | | | | |
| | 1996 | 3 | 1.31 | | | | |
| | 1997 | 2 | 0.51 | | | | |
| | 1998 | 3 | 1.94 | | | | |
| | 1999 | 2 | 1.08 | | | | |
| TAKATS_CDF | 2000 | 2 | 0.00 | | | | |
| | 2004 | 2 | 0.00 | | | | |
| WEYCO_NOCTURNAL | 1999 | 2 | 0.00 | | | | |
| | 2000 | 3 | 6.39 | 19.75 | 8.36 | 31.61 | 12.07 |
| | 2002 | 2 | 0.75 | | | | |
| | 2005 | 2 | 2.38 | | | | |
| | 2007 | 2 | 3.90 | 21.49 | 14.58 | 22.06 | 16.53 |
| | 2008 | 2 | 1.89 | | | | |
| | 2010 | 2 | 2.96 | 3.02 | 1.77 | 97.92 | 42.66 |
| | Mean* | | 4.42 | 14.75 | | 50.53 | |
| | CV* | | 0.40 | 0.69 | | 0.82 | |
| ANOS_CDF | 1998 | 2 | 1.39 | | | | |
| | 1999 | 2 | 0.91 | | | | |
| | 2002 | 2 | 2.00 | | | | |
| | 2003 | 2 | 1.10 | | | | |
| | 2004 | 2 | 1.60 | | | | |
| | 2005 | 2 | 0.00 | | | | |
| | 2006 | 2 | 1.54 | | | | |
| | 2007 | 2 | 1.82 | | | | |
| | 2008 | 2 | 0.00 | | | | |
| | 2009 | 2 | 0.00 | | | | |
| | 2010 | 2 | 3.78 | | | | |
| GOLDER_CNRL | 2008 | 2 | 1.45 | | | | |
| Grand mean | | | 4.42 | 14.75 | | 50.53 | |
| Grand mean - all | | | 1.51 | | | | |

Mean and CV of Observed only use years where detectability/occupancy could be estimated

| Northern Sawwhet Owl | | Visits | Observed | Detectability | Det SE | Occupancy | Occ SE |
|---|---|---|---|---|---|---|---|
| TAKATS_CDB | 1995 | 4 | 5.72 | 20.61 | 8.51 | 27.91 | 9.61 |
| | 1996 | 3 | 4.58 | 29.09 | 13.66 | 16.46 | 6.58 |
| | 1997 | 2 | 4.59 | | | | |
| | 1998 | 3 | 15.50 | 28.95 | 7.84 | 53.88 | 11.80 |
| | 1999 | 2 | 3.23 | | | | |
| | Mean* | | 8.60 | 26.22 | | 32.75 | |
| | CV* | | 0.70 | 0.19 | | 0.59 | |
| TAKATS_CDF | 2000 | 2 | 10.42 | | | | |
| | 2004 | 2 | 7.55 | | | | |
| WEYCO_NOCTURNAL | 1999 | 2 | 12.50 | 15.85 | 3.24 | 78.84 | 9.35 |
| | 2000 | 3 | 11.94 | 18.13 | NA | 65.18 | NA |
| | 2002 | 2 | 3.73 | | | | |
| | 2005 | 2 | 13.89 | 45.21 | 11.87 | 31.55 | 9.61 |
| | 2007 | 2 | 21.46 | 31.62 | 5.03 | 72.07 | 13.65 |
| | 2008 | 2 | 14.62 | 26.58 | 12.74 | 55.24 | 30.35 |
| | 2010 | 2 | 16.50 | 26.16 | 3.35 | 62.96 | 8.08 |
| | Mean* | | 15.15 | 27.26 | | 60.97 | |
| | CV* | | 0.23 | 0.39 | | 0.27 | |
| ANOS_CDF | 1998 | 2 | 27.08 | 52.57 | 10.88 | 51.19 | 13.41 |
| | 1999 | 2 | 5.00 | 37.33 | 17.73 | 14.18 | 8.33 |
| | 2002 | 2 | 16.50 | 18.33 | 2.88 | 90.00 | 0.37 |
| | 2003 | 2 | 12.15 | 23.65 | 7.87 | 51.32 | 14.79 |
| | 2004 | 2 | 17.12 | 33.26 | 7.06 | 52.99 | 12.03 |
| | 2005 | 2 | 11.33 | 26.56 | 9.45 | 42.63 | 15.93 |
| | 2006 | 2 | 21.54 | 48.83 | 10.18 | 44.45 | 7.37 |
| | 2007 | 2 | 17.15 | 21.91 | 4.05 | 77.36 | NA |
| | 2008 | 2 | 5.98 | 8.19 | 3.29 | 76.09 | 0.51 |
| | 2009 | 2 | 6.25 | | | | |
| | 2010 | 2 | 17.65 | 39.95 | 11.26 | 45.57 | 14.34 |
| | Mean* | | 15.15 | 31.06 | | 54.58 | |
| | CV* | | 0.45 | 0.45 | | 0.40 | |
| GOLDER_CNRL | 2008 | 2 | 72.46 | | | | |
| Grand mean | | | 14.12 | 29.10 | | 53.15 | |
| Grand mean - all | | | 14.35 | | | | |

Mean and CV of Observed only use years where detectability/occupancy could be estimated

## Appendix 3. Autocorrelation analysis results

| | | | Intercept | AR1 | Sigma_with_AR | Sigma_no_AR | AIC_AR | AIC_no_AR |
|---|---|---|---|---|---|---|---|---|
| OBSERVED DETECTIONS | | | | | | | | |
| | Barred Owl | Takats | -2.665 | -0.238 | 0.094 | 0.099 | 9.451 | 7.655 |
| | | Weyerhaeuser | -2.776 | 0.527 | 0.335 | 0.428 | 19.582 | 17.926 |
| | | ANOS | -3.668 | -0.359 | 0.154 | 0.180 | 16.898 | 16.371 |
| | Boreal Owl | Takats | -2.123 | -0.652 | 0.113 | 0.181 | 11.672 | 11.894 |
| | | Weyerhaeuser | -2.119 | 0.504 | 0.114 | 0.143 | 11.937 | 10.240 |
| | | ANOS | -3.708 | 0.053 | 0.405 | 0.406 | 27.280 | 25.302 |
| | Great Horned Owl | Takats | -2.782 | 0.057 | 0.109 | 0.109 | 10.344 | 8.356 |
| | | Weyerhaeuser | -4.024 | 0.210 | 5.985 | 6.241 | 38.610 | 36.683 |
| | | ANOS | -2.206 | -0.058 | 0.124 | 0.125 | 14.261 | 12.300 |
| | Great Grey Owl | Takats | -7.158 | 0.592 | 4.842 | 6.063 | 37.753 | 36.481 |
| | | Weyerhaeuser | -4.868 | -0.594 | 3.538 | 5.327 | 36.443 | 35.574 |
| | | ANOS | -5.751 | -0.064 | 6.981 | 7.014 | 58.599 | 56.644 |
| | Northern Sawwhet Owl | Takats | -2.712 | -0.606 | 0.161 | 0.295 | 13.999 | 15.317 |
| | | Weyerhaeuser | -1.992 | 0.465 | 0.260 | 0.325 | 17.504 | 16.004 |
| | | ANOS | -1.928 | -0.335 | 0.342 | 0.374 | 25.644 | 24.408 |
| ESTIMATED OCCUPANCY | | | | | | | | |
| | Barred Owl | Takats | -1.568 | 0.424 | 0.144 | 0.171 | 11.585 | 10.425 |
| | | Weyerhaeuser | -0.192 | -0.061 | 0.423 | 0.426 | 17.886 | 15.913 |
| | | ANOS | Occupancy analysis ran in too few years | | | | | |
| | Boreal Owl | Takats | -0.799 | -0.542 | 0.343 | 0.445 | 16.962 | 16.172 |
| | | Weyerhaeuser | 0.414 | 0.093 | 1.532 | 1.545 | 25.620 | 23.638 |
| | | ANOS | 1.587 | 0.000 | 13.997 | 13.997 | 16.953 | 14.953 |
| | Great Horned Owl | Takats | -1.146 | -0.876 | 0.006 | 0.020 | -1.850 | -0.234 |
| | | Weyerhaeuser | 3.299 | -0.604 | 5.429 | 10.092 | 34.702 | 34.898 |
| | | ANOS | -0.657 | 0.121 | 0.483 | 0.489 | 29.242 | 27.354 |
| | Great Grey Owl | Takats | Occupancy analysis ran in too few years | | | | | |
| | | Weyerhaeuser | 0.606 | 0.000 | 5.310 | 5.310 | 19.523 | 17.523 |
| | | ANOS | Occupancy analysis ran in too few years | | | | | |
| | Northern Sawwhet Owl | Takats | -0.781 | 0.080 | 0.533 | 0.538 | 12.638 | 10.656 |
| | | Weyerhaeuser | 0.476 | 0.001 | 0.431 | 0.431 | 17.980 | 15.980 |
| | | ANOS | 0.228 | 0.122 | 1.042 | 1.058 | 34.838 | 32.938 |

## Appendix 4. Precision results
## -Expected SE of trend (%/yr) for each of the designs in the main comparisons.

| | | | | | Expected SE of Trend Estimate (%/yr) | | | |
|---|---|---|---|---|---|---|---|---|
| Monitoring Duration (yr) | Sites/Year | Visits/Site/Year | Revisit Cycle (yr) | True Trend (%/yr) | Barred Owl | Boreal Owl | Great Horned Owl | Northern Sawwhet Owl |
| 5 | 50 | 1 | 5 | 0 | 25.02 | 13.21 | 21.98 | 19.85 |
| 10 | 50 | 1 | 5 | 0 | 6.22 | 3.91 | 5.91 | 6.38 |
| 20 | 50 | 1 | 5 | 0 | 2.34 | 1.42 | 2.18 | 2.19 |
| 30 | 50 | 1 | 5 | 0 | 1.27 | 0.75 | 1.13 | 1.24 |
| 5 | 100 | 1 | 5 | 0 | 44.18 | 10.35 | 17.17 | 31.02 |
| 10 | 100 | 1 | 5 | 0 | 6.79 | 3.08 | 4.94 | 7.17 |
| 20 | 100 | 1 | 5 | 0 | 2.14 | 1.09 | 1.78 | 2.40 |
| 30 | 100 | 1 | 5 | 0 | 1.15 | 0.59 | 0.95 | 1.31 |
| 5 | 200 | 1 | 5 | 0 | 16.70 | 9.66 | 12.14 | 20.08 |
| 10 | 200 | 1 | 5 | 0 | 4.91 | 3.05 | 4.29 | 6.14 |
| 20 | 200 | 1 | 5 | 0 | 1.68 | 1.06 | 1.53 | 2.05 |
| 30 | 200 | 1 | 5 | 0 | 0.95 | 0.59 | 0.73 | 1.10 |
| 5 | 400 | 1 | 5 | 0 | 11.48 | 8.73 | 10.05 | 17.53 |
| 10 | 400 | 1 | 5 | 0 | 4.15 | 3.17 | 3.63 | 5.20 |
| 20 | 400 | 1 | 5 | 0 | 1.25 | 1.05 | 1.18 | 1.81 |
| 30 | 400 | 1 | 5 | 0 | 0.76 | 0.55 | 0.67 | 1.00 |
| 5 | 800 | 1 | 5 | 0 | 9.33 | 7.65 | 9.16 | 12.51 |
| 10 | 800 | 1 | 5 | 0 | 3.38 | 2.89 | 2.98 | 4.10 |
| 20 | 800 | 1 | 5 | 0 | 1.10 | 1.00 | 1.10 | 1.61 |
| 30 | 800 | 1 | 5 | 0 | 0.59 | 0.54 | 0.54 | 0.84 |
| 5 | 50 | 4 | 5 | 0 | 15.33 | 10.76 | 15.20 | 27.68 |
| 10 | 50 | 4 | 5 | 0 | 5.44 | 3.32 | 4.72 | 5.81 |
| 20 | 50 | 4 | 5 | 0 | 1.61 | 1.06 | 1.42 | 2.36 |
| 30 | 50 | 4 | 5 | 0 | 0.91 | 0.63 | 0.74 | 1.16 |
| 5 | 100 | 4 | 5 | 0 | 10.67 | 10.69 | 10.75 | 16.50 |
| 10 | 100 | 4 | 5 | 0 | 4.59 | 3.00 | 3.35 | 5.54 |
| 20 | 100 | 4 | 5 | 0 | 1.45 | 1.03 | 1.23 | 1.72 |
| 30 | 100 | 4 | 5 | 0 | 0.72 | 0.57 | 0.60 | 0.94 |
| 5 | 200 | 4 | 5 | 0 | 9.58 | 8.44 | 8.59 | 15.40 |
| 10 | 200 | 4 | 5 | 0 | 3.28 | 3.03 | 2.89 | 4.17 |
| 20 | 200 | 4 | 5 | 0 | 1.17 | 1.00 | 1.13 | 1.58 |
| 30 | 200 | 4 | 5 | 0 | 0.61 | 0.54 | 0.57 | 0.82 |
| 10 | 200 | 1 | 5 | 10 | 5.62 | 2.83 | 4.52 | 7.34 |
| 10 | 200 | 1 | 5 | 3 | 4.80 | 3.38 | 4.04 | 5.68 |
| 10 | 200 | 1 | 5 | 0 | 4.91 | 3.05 | 4.29 | 6.14 |
| 10 | 200 | 1 | 5 | -3 | 4.88 | 3.07 | 3.92 | 6.71 |
| 10 | 200 | 1 | 5 | -10 | 6.32 | 3.19 | 4.46 | 7.34 |
| 10 | 200 | 1 | 1 | 0 | 4.77 | 2.97 | 4.25 | 5.85 |
| 10 | 200 | 1 | 5 | 0 | 4.91 | 3.05 | 4.29 | 6.14 |
| 10 | 200 | 1 | none | 0 | 5.03 | 2.93 | 3.87 | 6.51 |