# Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring

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File: 1290-022.10
March 2017


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## ACKNOWLEDGEMENTS

At its best, biology is a collaborative effort with a common set of goals. This project embodies those ideals, and would not have been possible without the participation and open collaboration of many individuals, organizations, and agencies. We gratefully acknowledge the contributions of Helen Davis, Frank Doyle, Michelle Evelyn, Greg Ferguson, Jeremiah Kennedy, John Deal and Wayne Matkoski, Aimee Mitchell, Jill Robinson, and Tania Tripp, who generously shared their survey data, reports, and expertise. We would also like to thank all those people who assisted us with accessing stored data, particularly Jesse Patterson, Lea Gelling, Sean Pendergast, and Joel Gillis as well as Dick Cannings and Chris Chutter who contributed to surveys and helped compile and organize records for earlier versions of the database.

The compilation of over 900 records for coastal western screech-owl would never have been possible without the more than 220 individuals who took the time to carefully record their presence and shared these data. We also acknowledge those organizations, including Bird Studies Canada, eBird, and the Conservation Data Centre, that collect and store these valuable records. Finally, none of this would be possible without the funding provided by agencies such as the Bridge River Fish and Wildlife Restoration Program, Fish and Wildlife Compensation Program, Habitat Stewardship Program, Habitat Acquisition Trust, Fraser Valley Conservancy, BC Conservation Corps, University of Northern British Columbia, Simon Fraser University, Ministry of Environment, and the Ministry of Forests Lands and Natural Resource Operations. Too many species that are difficult to detect, due to their elusive habits and activity patterns, go unnoticed and are poorly understood. We appreciate all those people, paid professionals and dedicated volunteers alike, who have devoted time and effort towards survey of western screech-owl in BC and who have contributed their data towards this initiative.

## EXECUTIVE SUMMARY

The western screech-owl is federally designated as Special Concern under Schedule 1 of the *Species at Risk Act*, SC 2002, c. 29, (SARA). This species is on the provincial Blue-list (CDC 2015) and is listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

In December 2017, Hemmera Envirochem Inc. ("Hemmera") was retained by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) to compile existing occurrence records for the coastal subspecies of western screech-owl (*Megascops kennicottii kennicottii*) throughout its range in British Columbia (BC). Analysis of this compiled dataset was used to develop an informed design for long-term population trend monitoring.

The western screech-owl detection records complied for this project (n=2,834) represent the most comprehensive dataset for the sub-species compiled to date in BC. Records were collated from multiple observers, and from both formal and informal surveys, completed between 1969 and 2016. Of these records, 1,901 were compiled and maintained separately from the main database of accepted records due to a lack of coordinate data, coordinate inaccuracy and other discrepancies and uncertainties that could not be resolved. The resulting provincial database for the coastal subspecies of western screech-owl (hereafter referred to as the 'database'), is comprised of 933 accepted records with reliable location data and plausible habitat association and observation density. Accepted western screech-owl detection records and previous formal survey results are summarized in this report. This database will be submitted to the Conservation Data Center and the Region 1 (Vancouver Island and Central Coast) office of the BC MFLNRO as a component of project deliverables.

Previous formal survey data was analyzed to inform recommendations for effective trend monitoring, using an occupancy modeling approach to assess variation in the proportion of sites occupied by owls (i.e., occupancy) as an indicator of population change. Consideration of inventory results, published reports, and historical survey data suggest that the coastal subspecies of western screech-owl has declined substantially over the previous 15 years within the Vancouver Island region, particularly between 2005 and 2008. Reasons for decline are attributed to large-scale forest, urbanization, range expansion of barred owl (*Strix varia*) into the region, and reduced availability of wildlife trees. Estimates of current occupancy and detection probability determined for the Vancouver Island region were 10-20% and 30-40%, respectively. Under these current occupancy characteristics, an optimal survey design was presented using a rotating sampling approach across prioritized study areas to detect long-term trends. Unfortunately, the effort necessary to meet sampling requirements is likely prohibitive. Unless occupancy and/or detection probability proves to be greater than estimated, there may be no practical means to detect future population trends for the coastal subspecies of western screech-owl in BC.

Alternative objectives for future monitoring are discussed. These include more modest survey efforts to provide estimates of occupancy and detection probability in areas for which historical data is available for comparison and to survey in hyper-maritime habitats where barred owl may be less abundant. It is posited that within these mesic areas of stunted forest growth occupancy of coastal western screech-owl may be higher.

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# 1.0 INTRODUCTION

The coastal sub-species of western screech-owl (*Megascops kennicottii kennicottii),* hereafter referred to as "coastal screech-owl", is listed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2012) and is blue-listed by the British Columbia (BC) Conservation Data Center. Despite significant concern and compelling anecdotal evidence of a severe range-wide population declines, the coastal screech-owl is not currently included in the Species at Risk category, under the Government Actions Regulation of the Forest and Range Practices Act (FRPA). As such, there is currently no available legal mechanism in place to conserve habitat for coastal screech-owl in BC.

Under the Federal *Species at Risk Act* (SARA), a federal recovery strategy is anticipated for coastal screech owl which may include the identification of Critical Habitat to promote recovery of western screech-owl within coastal areas of the species range in BC. In order to mitigate threats to coastal screech owl habitat on crown forest lands, the species would have to be added to the category of Species at Risk under FRPA. This would enable the establishment of wildlife habitat area (WHA) designations, which would be supported by a current and accurate database of extant coastal screech-owl occurrence records. In the interim, this information is immediately required to focus inventory efforts and develop more meaningful and effective methods for population trend monitoring.

The objectives of this project include: 1) compilation of existing records for coastal screech-owl from all available previously recorded data; 2) development of a monitoring program designed to improve understanding of the current extent, distribution and habitat association of coastal screech-owl and inform estimates of population trend. Both study objectives are required to inform effective recovery planning for the coastal screech-owl population in BC.

## 2.0 SPECIES INFORMATION

The western screech-owl (*Megascops kennicottii*) is a non-migratory resident nocturnal owl species that occurs throughout much of western North America (Johnsgard 1988). The species is described as a small greyish-brown owl with prominent ear-tufts and yellow eyes. Individuals weigh between 100-305 grams, with a body length of 19-25 cm and a wingspan of 55-62 cm. Within British Columbia, there are two recognized subspecies, the interior *M. k. macfarlanei* and the coastal *M. k. kennicottii* (Cannings and Angell 2001). The coastal screech-owl is restricted to western BC, where it is known to breed from the South Coast and continuing north to Alaska.

Resident western screech-owl are considered monogamous (Herting et al. 2001), retaining the same mate for life, however re-pairing is suspected if one mate dies or vacates the territory. Western screech-owls are generally thought to be associated with lower elevation (below 600 m) valley bottom deciduous or mixed deciduous/coniferous forests within riparian habitats (Johnsgard 1988, Tripp 2004, Hobbs 2013*a*). Nest cavities typically occur in areas dominated by black cottonwood (*Populus trichocarpa*), trembling aspen (*Populus tremuloides*), birch sp. (*Betula sp.*) and big-leaf maple (*Acer macrophyllum*) (BC Ministry of Water, Land and Air Protection 2004). The western screech-owl has been confirmed nesting in several coniferous and deciduous tree species including Pacific madrone (*Arbutus menziesii*), Douglas fir (*Pseudotsuga menziesii*), big leaf maple, western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*) and Gary oak (*Quercus garryana*) (J.Hobbs, pers obs). Nests have been observed between 1.2 to 12.2 m high, in the bole of the tree. Western screech-owl is a secondary cavity nester; typically nesting in tree deformities including natural and excavated cavities. The species has also been observed using chimney-nest structures in the hollow bole of the tree after the top has broken off (pers.obs). The species is also recognized for its propensity to nest in human-made nest-box structures however most nests likely occur in natural cavities or in abandoned cavities excavated by Northern Flickers (*Colaptes auratus*) and Pileated Woodpeckers (*Dryocopus pileatus*).

Annual home range sizes in BC (based on telemetric monitoring of the interior *macfarlanei* subspecies) have been estimated between 65 ha (Davis and Weir 2009) and 76.9 ha (Hausleitner and Dulisse 2011) and juvenile straight-line dispersal distances of 14 to 38 km were reported, with a maximum total (cumulative) dispersal distance of 207 km (Hausleitner and Dulisse 2011). Outside the species' BC range (**Figure 1**) studies in Southern Idaho by Ellsworth and Belthoff (1997) demonstrated average female dispersal of 14.7 km (n=13) and average male dispersal of 5.1 km (n=15). This pattern is synchronous with studies conducted on spotted owls with females, demonstrating larger average natal dispersal movements relative to males (Forsman et al. 2002).

Breeding typically begins with territorial defense (vocalization), pair bonding and courtship (commencing in late February and early March in most coastal areas); followed by copulation, egg-laying and nesting. Pairs incubate for ~30 days and, after hatching, the nestling phase of the life cycle generally lasts another 20-30 days. Typically nesting occurs between April 1st and June 30th; however, nesting dates appear to be geographically asynchronous across the province (Hobbs 2013*a*). Juveniles typically fledge from the nest sometime in late May or early to mid-June; however, interior screech-owl surveys in the Flathead in 2012 confirmed fledging dates as late as July 10-14 (n=4) (Hobbs 2013*b*). Clutch sizes between 1-5 young have been recorded in BC (Cannings and Angell 2001, J. Hobbs pers. obs.). During the post-fledging period the juveniles occupy the nest territory, generally remaining within 500m of the nest tree, while they are tended to by the adults. The juveniles begin to vocalize in early July and, as flight capabilities improve, juveniles move increasingly further from the nest as the post-fledgling season advances (J.Hobbs, pers.obs). Juvenile dispersal occurs in early August through September (Hausleitner and Dulisse 2011). During this phase both adult and juvenile territorial responsiveness peaks again.

An estimate of suitable screech-owl habitat, pre-European contact, suggests that this species was likely much more common in the Lower Mainland portion of the species' range in BC. This is particularly true in the South Coast region where urban and agricultural development is extensive within areas of estimated former suitable habitat.

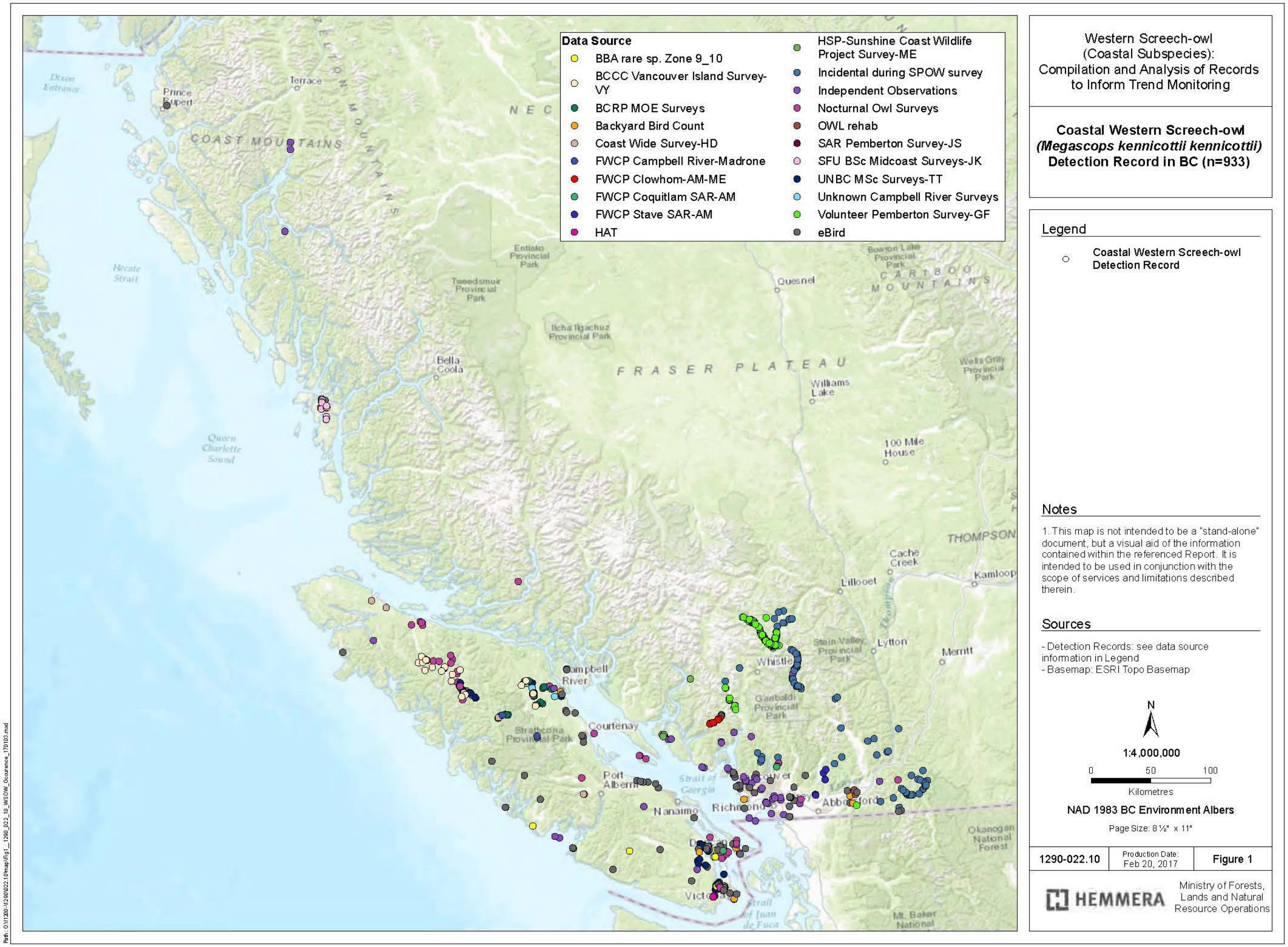


**Figure 1 Coastal Western Screech-owl (*Megascops kennicottii kennicottii*) Occurrence Records in BC (n=933)**

## 2.1 Goals and Objectives

The initial objectives of this project were to:

1. Compile existing records from all available formal and informal survey data collected, to date, for the coastal subspecies of western screech-owl;
2. Analyze previous formal survey data to develop study design recommendations to facilitate an optimized (efficient) monitoring program designed to:
    a. Inform future estimates of population trend for western screech-owl;
    b. Improve understanding of the current extent, distribution and habitat association of the coastal subspecies of western screech-owl.

To inform objective two we collated, reviewed, analyzed and summarized all historical survey data (including null records) of coastal western screech-owls in the province. This approach was necessary to inform estimates of population parameters required for power analyses conducted as part of the study design. This report provides a summary of available formal survey data, including survey methods employed across the province for coastal screech-owls to date.

# 3.0 METHODS

## 3.1 COMPILATION OF PREVIOUS WESTERN SCREECH-OWL RECORDS

In 2012, Jared Hobbs compiled a database of coastal western screech-owl detections in the province. This database was consistent with an independent database developed previously and maintained voluntarily by Jared Hobbs, for the interior sub-species (*M.k. macfarlanei*), and was intended to provide complementary information for western screech-owl occupying coastal habitats in BC. The original 2012 database contained 1,028 historical records for the province. However, as this was largely a voluntary effort, resources were not available to verify the accuracy and independence of all records. Records incorporated into the 2012 version of the coastal western screech-owl database included a number of professional surveys as well as eBird data, Christmas Bird Count (CBC) data, Breeding Bird Atlas data and independent survey results.

In March 2015, as a deliverable for the South Coast MFLNRO region (under contract for Kym Welstead), Hemmera (Jared Hobbs (Hemmera Technical Expert) and Chris Chutter (Hemmera Intermediate Biologist)) updated the 2012 database by soliciting additional (new) records from eBird, Christmas Bird Counts (CBC), Breeding Bird Atlas (BBA), animal rehabilitation centers and subsequent studies conducted by professional biologists (e.g., Frank Doyle, Helen Davis, and Jill Robinson). All records compiled for the 2015 database were examined to eliminate redundant (repeated) records, to correct erroneous location coordinates (where feasible) and to remove records with a high degree of imprecision (i.e., generalized location provided with no precise location coordinate or descriptor to facilitate accurate mapping). The addition of new detections initially resulted in a compilation of over 1,800 records, but after extensive review only 553 records were accepted within the coastal subspecies known extant range in BC. This reduction was required to eliminate redundant (i.e., repeated) records and eliminate records with inaccurate UTMs from citizen-science programs including: Christmas Bird Count Data (CBC) (n=110), Breeding Bird Atlas (BBA) (n=47), Bird Studies Canada (n=33). Citizen science data from these sources was included in the original 2012 database, but upon review it became evident that the site coordinates provided were merely assigned to a centroid for the nearest city, survey route or 10 $km^2$ grid cell. As these locations lacked precision they were extracted from the 2015 provincial western screech-owl database and included in a separate database of records representing observations recorded without precise location coordinates. The same lack of coordinate precision was true for 113 records generously provided by the O.W.L. rehabilitation centre in the Lower Mainland.

In March 2017, as a deliverable for the West Coast MFLNRO region, Jared Hobbs (Hemmera Technical Expert) and Jeannine Randall (Aurora Ecological - Intermediate Biologist) updated the 2015 database by soliciting additional (new) records. This effort was undertaken as a required component of this project to inform analysis and survey design recommendations. New records were solicited from all known sources including updating data from eBird, the BC Breeding Bird Atlas, the Backyard Bird Count program, volunteer Nocturnal Owl Surveys, incidental observations, and formal screech-owl surveys. Records were again inspected to exclude all duplicate records and identify those with inaccurate or imprecise coordinates[1]. Over 1,900 initial records were compiled yielding 933 unique records with coordinates verified as accurate. In addition, an intersect query was run to provide geophysical data including the region, ecosection, biogeoclimatic ecosystem classification (BEC) zone and variant, and elevation. The number and percentage of detections was then summarized for each of these attributes. An intersect query with vegetation resources inventory (VRI) data was also run for all verified coordinates to identify more specific habitat characteristics as available (e.g., forest stand age, crown cover).

### 3.2 COMPILATION OF ALL PREVIOUS WESTERN SCREECH-OWL SURVEY DATA

Survey data was solicited from all known sources and was summarized for each project with the following information: 1) objectives (e.g., inventory, research); 2) the principal investigator(s)/project lead(s); 3) target species; 4) timing; 5) methods (e.g., call playback, multi-species calls, duration of listening periods); 6) survey design and station allocation; 7) source of funding for the survey; and any other pertinent information such as missing information (e.g. GIS coordinates).

### 3.3 DEVELOPMENT OF PROGRAM DESIGN FOR TREND MONITORING

We analyzed all previous available western screech-owl survey data to develop recommendations for future assessment of population trends for the coastal population of western screech-owl. However, much of the information regarding occupancy and detection rates is likely also pertinent for the interior *macfarlanei* sub-species as the two sub-species share similar ecology and life history characteristics. A thorough review of species assessments, technical reports, peer-reviewed literature, and survey data (as summarized in **Section 3.1**) was completed to inform optimal survey design to ensure efficient use of resources in future potential monitoring attempts. This section outlines the methods used to determine the effort required to identify trends under various potential scenarios. Recommendations are based on the use of occupancy modeling, including calculation of detection probability, to account for imperfect detection of owls during surveys. Recommendations are also based on power analyses that utilize historical data to estimate model parameters, including **detection probability** and **occupancy**, allowing derivation of sample size requirements and optimal allocation of survey effort. Finally, the limitations of existing data, and the likelihood of detecting changes in occupancy under current conditions, are discussed in **Section 5**.

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[1] For all preceding database versions, the degree of confidence and precision associated with volunteer (citizen-science) and data and incidental observations is generally not reported; by contrast collection of this data is standard practice in formal screech-owl survey methodology. As such, the precision rating assigned to data from informal surveys is unresolved (coded as "Not Available" in the database).

### Occupancy Modeling

Occupancy modeling is a widely used and efficient method for monitoring species that occur in low densities and are difficult to detect and enumerate accurately (MacKenzie et al. 2002, Kissling et al. 2010). The method determines the probability of detecting an owl when it is present (i.e., detection probability) and incorporates that information into estimates of occupancy to account for the potential to miss individuals during surveys. Occupancy modeling utilizes maximum likelihood estimation to determine the probability of various models to be true for a given dataset of ones (presence records) and zeroes (absence records). In its simplest form, the method determines what combination of occupancy and detection probability are the most likely for any given set of data and provides estimates of precision for these parameters based on the number of sample sites, repeated surveys, and consistency of detection probability across sites where individuals are recorded at least once. Occupancy models can easily accommodate missing records, but assume no false positives and stable occupancy within seasons (i.e., species are only detected when they are present and do not leave or move between sites). Occupancy modeling has a variety of utilities in addition to the derivation of occupancy and detection probability estimates. The model can accommodate covariates such as habitat characteristics or the presence of other species that might influence occupancy or detection probability (e.g., barred owl) (MacKenzie et al. 2006). Additionally, the likelihood of different models for a given dataset can be compared to determine which factors of interest best explain variation in the data.

As a first step, a literature review was conducted to determine if any alternatives to standard survey designs (in which all sites are surveyed an equal number of times in each year) might provide any gains in efficiency. Alternative designs include “removal design”, “rotating panel design”, and “double sampling” which, respectively, involve surveying at sites until an owl is observed and then re-allocating effort to other sites, conducting repeated surveys at a sub-set of sites following surveys at a larger initial number of sites, and sampling a range of sites in year one of a study and a rotating sub-sample of fewer sites in others (MacKenzie and Royle 2005, Bailey et al. 2008). Data sets collected according to occupancy modeling designs (e.g., presence absence data from repeated surveys at a series of sites) were analyzed with PRESENCE software developed by Mackenzie et al. (2002).

### Power Analysis

Power analyses were conducted to determine the number and allocation of surveys required to detect a statistically significant change in occupancy following a closed form formula derived by Guillera-Arroita and Lahoz-Monfort (2012). This formula is specifically designed to estimate power to detect differences in occupancy (e.g., year one versus year x) while accounting for imperfect detection. Power ($G$) to detect a difference in occupancy is a function of the following variables, each of which is positively related to power (i.e., $G$ increases with each of the following):

- Proportion of occupied sites (occupancy: $\Psi$):

- Probability of detecting an owl when it is present (detection probability: *p*);
- Size of the difference of interest (effect size: *R*);
- Threshold probability for determining a difference to be statistically significant (significance level: α);
- Number of independent sites surveyed (sites: *S*);
- Number of independent surveys conducted at each site (repeated surveys: *K*);

Estimates of occupancy and detection probability are required for power analysis and are most accurate if they can be derived from the same region and season where studies are to be conducted. Survey data from the west coast region were reviewed and all data sets that met the following criteria were analyzed with PRESENCE software to provide estimates of occupancy and detection probabilities: 1) Surveys conducted within the early breeding season during the courtship period (mid-March through early May) when owl response to call playback is expected to be highest in the West Coast MFLNRO region[2]; 2) Minimum of two repeated surveys at stations (preferably 3 or more); 3) Minimum of three screech-owl records (for detection probability). Data collected under inclement weather or noisy conditions were excluded from estimates of occupancy and detection probability.

The next step in the power analysis was to determine a biologically meaningful effect size (e.g., magnitude in change of occupancy) that the study will be designed to detect. Declines of 10%, 20%, 30%, and 50% have important consequences for owl populations that correspond to varying conservation status categories (COSEWIC criteria C1, C1, A2, and A1/A2 respectively (IUCN Red List 2001, COSEWIC Wildlife Species Assessments (detailed version) 2015)). Following the determination of occupancy and detection probability estimates, a sensitivity test was conducted to determine the lowest possible effect size that surveys would be likely to detect. The sensitivity test is an iterative approach in which effect size (*R*) is varied with the other parameters held constant at plausible values to determine what level of *R* is required to meet the desired power.

Convention for significance level (α) and power (*G*) is to set α equal to 0.05 and *G* to 80% (β=0.2). In other words, studies are typically designed to restrict the probability of finding a difference when one does not exist (type I error) to 5% while allowing 20% probability of concluding that there is no difference or trend in the data when one exists (type II error). In wildlife monitoring studies, there is a greater conservation consequence if we fail to detect a population decline (e.g., failure to act in response to potential species extinction or extirpation) than if we falsely conclude that there is a decline (Di Stefano

2 Within the breeding season, western screech-owl are likely most responsive to acoustic lure surveys during courtship. Fledging timing (30-32 days) and dates (June 8-12) of the interior screech-owl sub-species (*M.k.macfarlanei*) indicate that the courtship period of screech-owls in southern BC is centered between mid-March through to early April (Hobbs 2013*a*, *b*). Kissling et al. (2010) found coastal screech-owl detection probabilities were highest between March 30 and May 18 in southeast Alaska (i.e., during a seven week period in late April). Courtship and breeding are initiated earlier in more southerly regions (e.g., the West Coast MFLNRO region). Given these estimates of courtship timing and duration and considering inter-annual variation in the timing of breeding, surveys are recommended within a nine to ten week period from mid-March through April,

2003, Field et al. 2005, Guillera Arroita and Lahoz Monfort 2012). Thus, it is recommended that the significance level matches power (i.e., α:β =1) so that there is an equal probability of type I and type II error. As part of the sensitivity test for effect size, we therefore recommend a 1 to 1 ratio of these parameters with the highest level of each that allows detection of a meaningful effect size.

Following estimation of occupancy and detection probability parameters and determination of the most appropriate effect size, significance level, and power threshold, an iterative approach was used to determine the optimal allocation of effort across sites and repeated surveys.

Many of the factors listed above that contribute to the power to detect change in occupancy can be optimized to maximize power. The recommended monitoring program would optimize power for these factors as follows:

*Occupancy* - Study areas and sites that host high densities of coastal screech-owl are prioritized. Monitoring efforts should be focused in regions and habitats with biophysical characteristics where coastal screech owls have been detected previously in relatively high densities. While this strategy may fail to detect trends in areas or habitats where coastal screech owls occur in lower densities, data from those areas would be insufficient to detect such trends regardless.

*Detection probability* - The probability of detecting an owl when present is influenced by the likelihood that it will respond to call-playback and the likelihood that the surveyor will hear the call (Kissling et al. 2010). The use of call-playback has been shown to increase detection rates 16 fold and is an obvious tactic to increase detection probability (Kissling et al. 2010). Detection probability can also be increased by reducing the distance between survey stations to improve coverage of animal territories, and increase the proportion of territories surveyed within close range (see **Section 5.0** for a detailed discussion (Deal and Lamont 1996)). Surveys conducted under calm weather conditions and during periods when owls are most vocal and responsive to call playback will also increase detection probability.

*Effect Size* – The likelihood of detecting a trend or difference in occupancy is lower on a year to year basis as compared to alternate years or three to five year periods. Thus, the recommended temporal resolution of surveys will depend on the power to detect trends so that effort is not wasted on periods within which differences will likely be statistically insignificant. Additionally, surveys are recommended at sites where estimates of occupancy are available from previous years allowing estimates of trends to leverage historical data wherever possible.

*Number of sites and surveys per site* – Power increases with both the number of sites (*S*) in the study and the number of repeated visits to sites (*K*); however, increases in power reach a stable asymptote for repeated visits more quickly than for total sample sites as estimates of detection probability improve little with more than five or six surveys per site (Field et al. 2005, MacKenzie and Royle 2005). Thus, for any given combination of occupancy (Ψ) and detection probability (*p*) there is an optimal number of repeated surveys (*K)* and once this is reached power can only be improved by increasing the number of sites (*S*).

Data from studies that met the criteria for occupancy modeling were assessed in a GIS platform to estimate territory size based on clustering of presence records and taking into consideration the previously published estimates for western screech-owl and comments from surveyors. These territories were then used to group stations into occupancy sites (*S*) and, subsequently, develop occupancy models to define occupancy and detection probability using PRESENCE software.

Given the potential for population trends to vary across regions and study areas, power analyses were conducted to determine sample sizes required to assess change at individual study areas rather than across larger areas or regions (e.g., Vancouver Island). This approach is justified because greater sampling efforts are required if the degree or direction of change varies by area, but studies designed with sufficient power to detect changes within each area will always be sufficient to detect consistent trends across areas or regions.

# 4.0 RESULTS

## 4.1 ANALYSIS OF RECORDS IN THE WESTERN SCREECH-OWL DATABASE

The Western Screech-owl coastal subspecies (*Megascops kennicottii kennicottii*) BC database is comprised of data compiled from sources as detailed below. This effort was initiated in 2012, updated by J. Hobbs and C. Chutter in 2015, and updated again as part of this project in 2017 to include all detection records through December of 2016.

The compiled database contained 933 unique observations with reliable georeferenced location information. An additional 1,901 observations with either no georeferenced location information, or location information that was inaccurate due to collection methods, were excluded from the main database. While these excluded records cannot be accurately mapped, they may allow subsequent inference regarding population trends on a temporal scale. Thus, these records were also submitted as a deliverable for this study separately from the records with verified accurate location data.

The remaining 933 records in the provincial coastal screech-owl database include observations documented between 1969 and 2016. These records are recommended for consideration for management and for mapping as element occurrence records by the BC CDC. These records can be summarized as follows: formal surveys accounted for 379 owl detections from 2000 to 2016, while observations from informal surveys, citizen science initiatives, and incidental observations (including incidental observations from formal surveys) accounted for 554 owl detections from 1969 to 2016. Observations and survey effort from formal surveys are summarized in **Table 1** while those from informal surveys, citizen-science projects and incidental observations are shown in **Table 2**.

**Table 1 Summary of Coastal Screech-owl (WSOW) Detections and Survey Effort from Previous Formal Surveys.**

| Survey Source | Survey Years Summarized | Total WSOW records | Number of Stations* | Total survey events | WSOW per survey event |
|---|---|---|---|---|---|
| 1995-2015 Canfor Nimpkish Owl Surveys[1] | 1995-1997<br>2003-2006<br>2013-2015 | 474 | Not available | 3000 | 0.16 |
| 1997 Clayoquot Owl[2] Survey | 1997 | 21 | Not available | 72 | 0.29 |
| 2000-2007 BCRP MOE Survey | 2000, 2002, 2003, 2006, 2007 | 50 | 60 | 774 | 0.06 |
| 2002-2003 UNBC MSc Surveys-TT | 2003 | 80 | 303 | 403 | 0.19[3] |
| 2002-2003 Survey data received from TT | 2002, 2003 | 27 | 32-60 | 149 | 0.18[3] |

| Survey Source | Survey Years Summarized | Total WSOW records | Number of Stations* | Total survey events | WSOW per survey event |
|---|---|---|---|---|---|
| 2008 BCCC Vancouver Island Survey-VY | 2008 | 18 | 354 | 355 | 0.05 |
| 2012-2013 FWCP Alouette SAR-AM | 2012, 2013 | 0 | 49 | 142 | 0 |
| 2013 SAR Pemberton Survey-JS | 2013 | 3 | 23 | 24 | 0.13 |
| 2013-2016 FWCP Clowhom SAR-AM-ME | 2013-2016 | 28 | 40-72 | 278 | 0.10 |
| 2014 Coast Wide Survey-HD | 2014 | 5 | 201 | 386 | 0.01 |
| 2014-2016 HSP Sunshine Coast Wildlife Project Surveys-ME | 2014-2016 | 5 | 19-113 | 157 | 0.04 |
| 2015 FWCP Campbell River Madrone | 2015 | 2 | 130 | 166 | 0.01 |
| 2015 MFLNRO Hemmera | 2015 | 0 | 52 | 52 | 0 |
| 2015-2016 CRD HAT Highlands Survey-JR | 2015 | 13 | 57-64 | Not available | Not available |
| 2015-2016 FWCP Coquitlam SAR-AM | 2015 | 0 | 28 | 28 | 0 |
| 2015-2016 FWCP Stave SAR-AM | 2015, 2016 | 5 | 231 | 520 | 0.01 |
| 2015-2016 HSP-WPT and Associated SAR-Fraser Valley Conservancy Survey-AM | 2015, 2016 | 3 | 44-55 | 100 | 0.05 |
| 2015-2016 Volunteer Surveys Pemberton-GF | 2015, 2016 | 117 | 154-464 | 1167 | 0.10 |
| 2016 SFU BSc Midcoast Surveys-JK | 2016 | 23 | 74 | 188 | 0.12 |

1 For multiyear studies where the station number is not consistent the range of station numbers is given.
2 Detections are not included in the database due to lack of available geospatial data.
3 Detection rate inflated relative to other surveys due to targeted surveying in known WSOW territories.

**Note:** While WSOW per survey event provide a measure of owl detection frequency that accounts for variation in survey effort, this metric may still be biased by several factors: survey timing/season; call-playback methods (e.g., some single species calls, others multi-species calls); survey objectives (e.g., some surveys targeted sites where owls were known to be present); weather and background noise. Comparisons between surveys must consider these potential sources of variation in detection probability.

**Table 2 Summary of Data Sources from Previous Informal Surveys (i.e., Citizen-Science) and Incidental Observations with Spatial Information**

| Year | Description | Lead | Total WSOW records | Precision |
|---|---|---|---|---|
| 1969-2016 | eBird | Agency | 136 | Not available |
| 1970-2016 | Independent observations | Various | 124 | Various |
| 1992-2016 | Incidental detections collected during SPOW Surveys | MFLNRO | 118 | Various |
| 1999-2011 | Backyard Bird Count | Agency | 8 | Not available |
| 2008-2012 | BC Breeding Bird Atlas | C. Di Corrado | 9 | Not available |
| 2014 | OWL rehab records | O.W.L. | 2 | Not available |
| 2000-2016 | Nocturnal Owl Surveys | Agency | 60 | Various |
| 2001-2007[1] | UNBC-MSc Surveys | T. Tripp | 70 | Accurate |
| 2000-2016 | Incidental observations during formal surveys | Various | 27 | Various |

[1] Detections from 2003 are listed under formal surveys.

All 933 coastal screech-owl observations were reconciled against Digital Elevational Modelling (DEM), biogeoclimatic information, ecosection and population unit mapping. This process provided additional habitat information for each observation record to guide future inventory and management effort. Vegetation Resources Information (VRI) data could not be determined for the majority of verified coastal screech owl record coordinates. VRI data is not readily available for a majority of the landbase on Vancouver Island because it is maintained by private Tree Farm License (TFL) land-owners. Results are not summarized here as they are incomplete, but are presented in the database for record locations where VRI data could be determined (n= 426).

The majority (53%) of western screech-owl records were reported at elevations below 200 m above sea level (ASL). Forty-one percent of records were between 200-399 m ASL. The remaining 5% of records were between 401 m and 852 m ASL with the exception of 3 records above 1000 m with a maximum elevation of 1243 m (**Figure 2**).

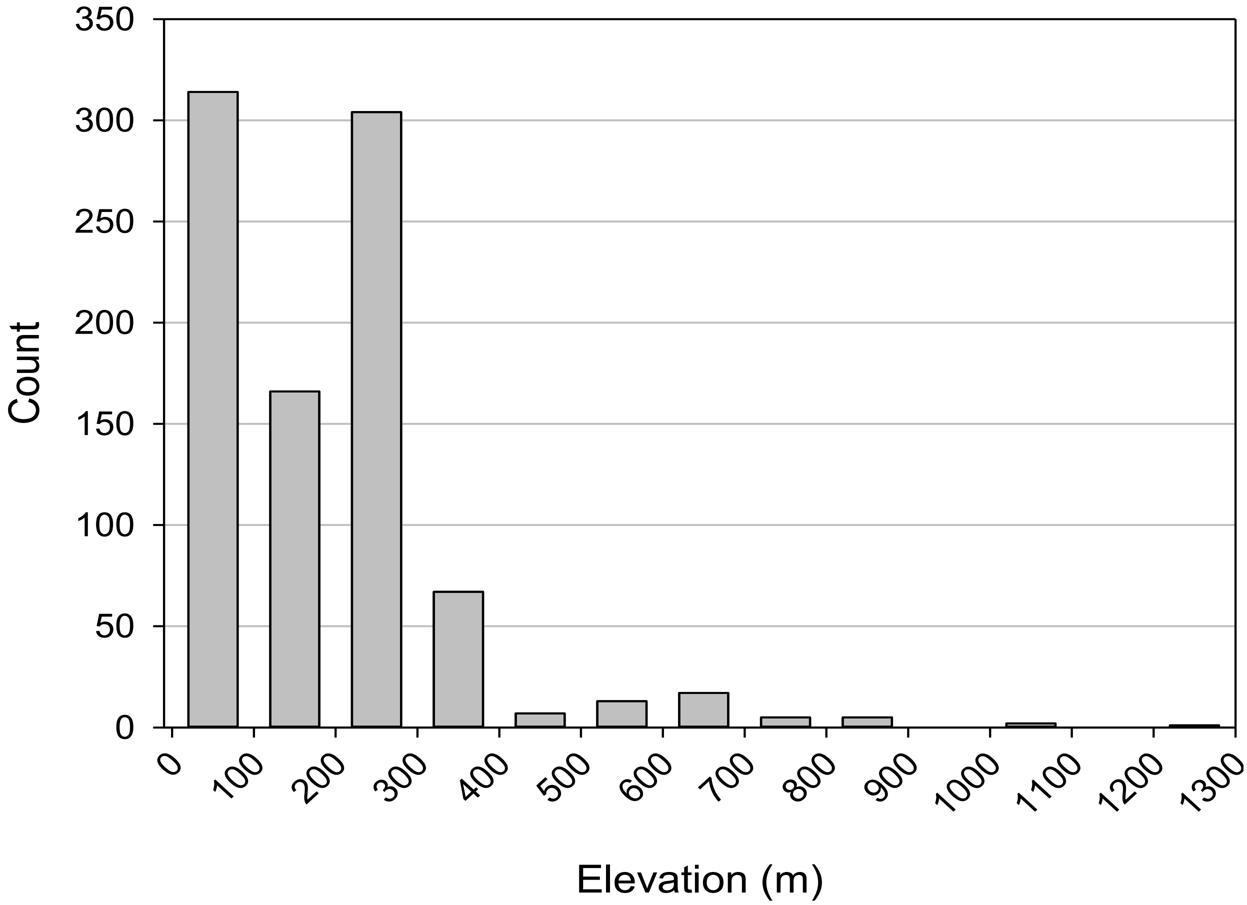



**Figure 2 Histogram of Elevations for Coastal Screech-owl Detection Records with Accurate Coordinates in the Database (n = 901)**

**Note:** Records are not corrected for survey effort and may underrepresent elevations surveyed less intensively.

Ten population units were mapped to define areas with distinct biophysical characteristics and to facilitate future resource management planning objectives (**Figure 3**). The distribution of observations within each population unit is summarized in **Table 3**. The majority of records in the database are reported from population units on Vancouver Island (49%) and the Lower Mainland (16%) population units. It is important to note that the percentages presented in **Table 3** are biased by inconsistent survey effort across population units. Survey effort was greatest in the Lower Mainland and South Island regions resulting in more records from those population units. Thus, the percentages are not directly representative the distribution of coastal screech-owls in BC.

**Table 3 Observation Frequency of Coastal Screech-owl by Population Unit**

| Population Unit | # | Percentage |
|---|---|---|
| Lower Mainland | 153 | 16% |
| Midcoast | 24 | 3% |
| Mid-Island | 16 | 2% |
| North Gulf Islands | 7 | 1% |
| North Island | 194 | 21% |
| Northcoast | 4 | <1% |
| South Island | 259 | 28% |
| Southcoast | 1 | <1% |
| Sunshine Coast | 47 | 5% |
| Transition Zone | 228 | 24% |
| **Number of Observations (total)** | **933** | **100%** |

An analysis of the distribution of accepted observations, by biogeoclimatic ecosystem classification (BEC) zone, revealed that a majority of accepted observations (61%) occurred within the Coastal Western Hemlock (CWH) BEC unit. Twenty-six percent (26%) occurred within the CDFmm (moist maritime) Coastal Douglas-fir BEC unit[3]. The remaining ten percent (10%) occurred primarily within the IDFww (wet warm) Interior Douglas-Fir BEC unit with several records (<1%) reported in Mountain Hemlock (MH) and Coastal Mountain-Heather (CMA) zones (**Table 4**).

**Table 4 Observation Frequency of Coastal Screech-owl by BEC Zone**

| Biogeoclimatic Ecosystem Classification (BEC) Zone | # | Percentage |
|---|---|---|
| Coastal Douglas-Fir (CDF) | 238 | 26% |
| Coastal Mountain-Heather (CMA) | 4 | <1% |
| Coastal Western Hemlock (CWH) | 560 | 60% |
| Interior Douglas-Fir (IDF) | 95 | 10% |
| Mountain Hemlock (MH) | 3 | <1% |
| BEC not assigned | 33 | 4% |
| **Number of Observations (total)** | **933** | **100%** |

3 These results likely reflect observer and effort bias as described for population units; caution should be applied during interpretation regarding habitat preference exhibited by western screech-owl.

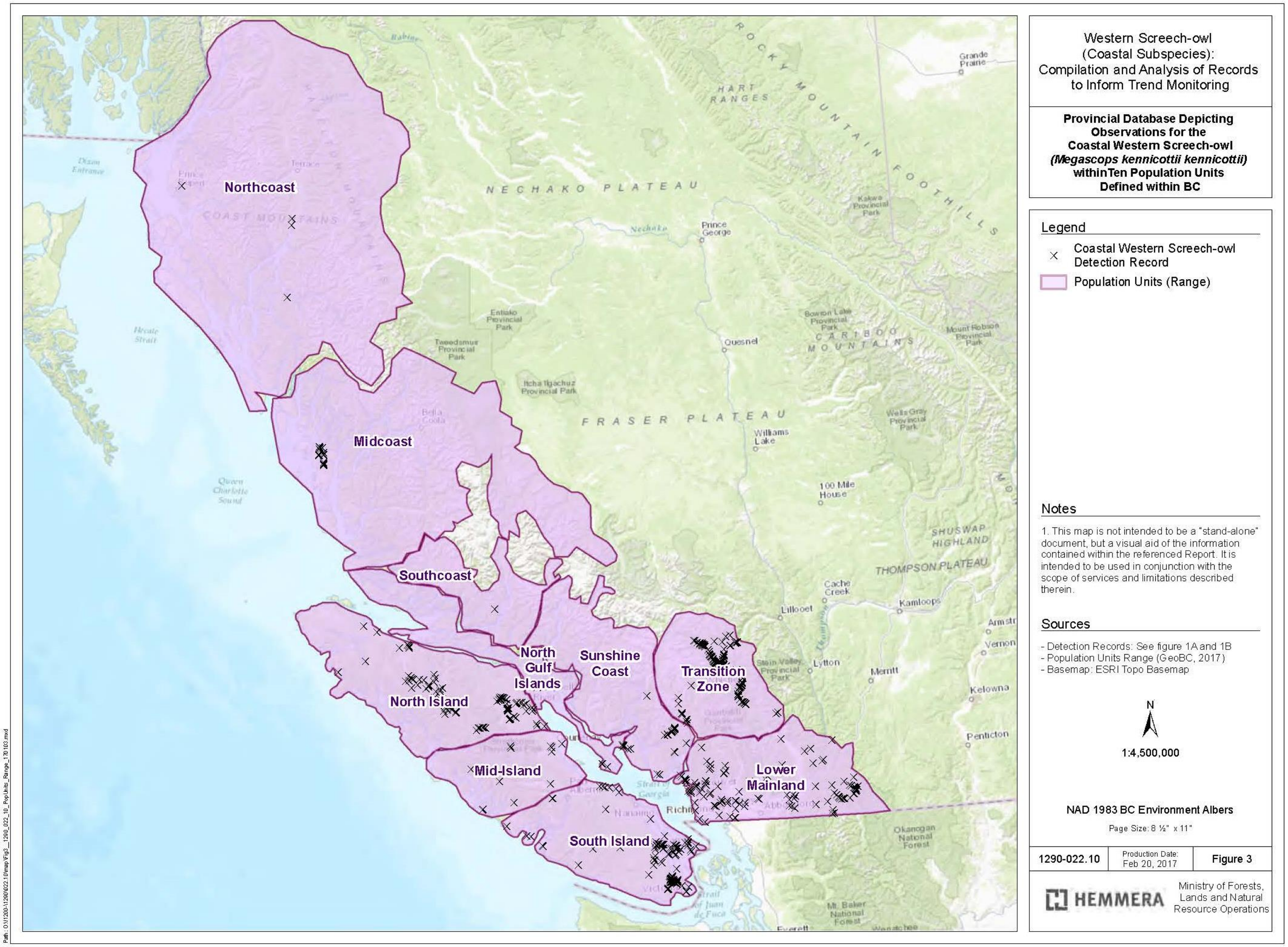



**Figure 3** **Provincial Database Depicting Detection Records of Coastal Western Screech-owl (*Megascops kennicottii kennicottii*) for Population Units Defined within BC**

### 4.2 COMPILATION OF ALL PREVIOUS WESTERN SCREECH-OWL SURVEY DATA

Survey summaries are presented below in chronological order based on the first year of surveys:

<u>1995-2015 Canfor Nimpkish Owl Surveys</u>

Surveys were conducted for inventory purposes over a discontinuous 12 year period in the Nimpkish area of Vancouver Island (northern Vancouver Island). Multi-species call playback methods were applied with up to five species of owl as target taxa (western screech-owl, great horned owl (*Bubo virginianus*), northern pygmy-owl (*Glaucidium gnoma swarthi* (Vancouver Island subspecies), barred owl, and northern saw-whet owl (*Aegolius acadicus*), but the order and number of species surveyed at each station was variable among years. From 1995 to 1997 all five owl species were surveyed together using nocturnal call playback surveys, with the territorial call of all species broadcast at each survey point in succession from the smallest to the largest species. The calls of each species were broadcast four times followed by one minute of silent listening for maximum station duration of 27 minutes. During these years transects of 1 to 13 stations spaced 1 km apart were surveyed. Between 2000 and 2002 only northern pygmy owls were surveyed, and in subsequent years they were inventoried separately from the other target species. Additional changes in 2003 include an increased interstation distance (1,600 m), and addition of a two minute pre-survey listening period. In addition, listening time (after call broadcasts) was extended to a five minute duration, extending the total station time to approximately 45 minutes. From 2004 onward, listening time after call broadcasts was reduced from five minutes to three minutes. The number of replicates per station also varied among years. In 1995 stations were surveyed twice (2 surveys per station; 336 total survey events) and in 1996 and 1997 stations were surveyed five times (5 surveys per station; 323 survey events in 1996; 315 survey events in 1997). For 2003-2015 most stations were replicated three times (3 surveys per station). All surveys were conducted in the spring between February 17 and May 27. The primary surveyor was Wayne Matoski with funding provided by Canfor and oversight provided by John Deal (Canfor biologist).

<u>1997 Clayoquot Owl Survey</u>

Surveys were conducted for inventory purposes in the Clayoquot sound region of Vancouver Island primarily by Stefan Ross and Marnie Eggen. The purpose of this survey was to determine the presence of multiple owl species (western screech-owl, great horned owl, northern pygmy-owl, barred owl, and northern saw-whet owl) during the breeding season. Surveys were completed between February 15 and May 15 using nocturnal call playback surveys. Surveys began with a 10 minute silent listening period for spontaneous calls followed by broadcasts of audio recordings of each of the five owl species surveyed in order from the largest to smallest owl species. Calls of each species were broadcast for five minutes with eight minutes of listening in between species (except barred owl where the listening period was 20 min). Six transects were established with transects spaced 800 m apart, but the total number of stations is not clear from the report. Most stations were surveyed twice (2 surveys per station; 72 total survey events), once between February 15 and April 4 and once between April 6 and May 15. Funding for this project was provided by Forest Renewal BC. No locations (GIS coordinates) were collected or provided so data from this survey was not included in the provincial western screech-owl database.

2000-2007 BCRP MOE Survey

Surveys were conducted for inventory purposes in the Campbell River watershed area of Vancouver Island for five years between 2000 and 2007; no surveys were conducted in 2001 or 2005. Surveys used a multispecies call-playback approach following RISC (2001) standards. Small (western screech-owl, northern pygmy-owl, and northern saw-whet owl) and large (great horned owl and barred owl) owls were surveyed on separate nights and calls were played in order from the smallest to largest species. Northern pygmy-owl were surveyed during small owl surveys in 2000, 2002, and 2003, but were inventoried separately in 2006 and 2007. Each survey station began with two minutes of silent listening, if no owls were detected then four call sets consisting of 20-30 second broadcasts followed by 30 seconds of silence. Call bouts were followed by a five minute silent listening period, if no owls were detected than the territorial call of the next species was played but if an owl was detected then no additional calls were broadcast at that station. Five transects consisting of 12 stations (60 total stations) spaced 800 m apart were established and surveyed three times (3 surveys per station) during the spring breeding season (February, March, April) in 2000, 2002, and 2003. Every station was surveyed for small owls (800 m spacing) but larger owls were only surveyed at every second station (1600 m spacing). Survey effort was reduced in 2006 and 2007 (2 to 3 surveys per station). Complete survey data is not available for the first three years of this project, but the total number of survey events is estimated to be ~774. Funding for this project was provided by BC Hydro Bridge Coastal Fish and Wildlife Restoration Program.

2002-2003 UNBC MSc Surveys

Surveys were conducted to address research objectives. As such, survey efforts focused on areas with historical detections of western screech-owl on Vancouver Island. The purpose of this work was to characterize vocal individuality of male western screech-owls. Recordings were collected from multiple locations (303 total stations in 2003; total number of stations not known for 2002), and many stations were replicated (403 total survey events), but replication was not completed in a systematic way or with standardized interstation spacing as the goal of the study was to record calls at occupied sites. The majority of these surveys were conducted by Tania Tripp towards the completion of her MSc at the University of Northern British Columbia.

2002-2003 Survey data received from Tania Tripp - uncertain source

Survey data were collected in 2002, 2003. Surveys appear to be western screech-owl specific and are conducted in the Campbell River watershed area of Vancouver Island (60 total stations in 2002; 32 total stations in 2003). Station spacing was approximately 800 m and stations appear to be similar to those used in the 2000-2007 BCRP surveys but the exact source and purpose of these surveys was not provided. Most stations were only replicated once (1 survey per station; 149 total survey events) and the rationale used to determine replicates, when they did occur, is not known.

2008 BCCC Vancouver Island Survey

Surveys were conducted for the purpose of documenting site occupancy by western screech-owls in the Port Alberni, Campbell River, Woss, and Nimpkish areas (north Vancouver Island). Species-specific call playback surveys were conducted between May 16 and July 15 following RISC (2006) protocols. The territorial call of a male screech owl was broadcast for one minute followed by four minutes of listening time, this was repeated up to three times for a total 15 min station, unless an owl was detected in which case broadcasting was stopped immediately but the surveyors continued to listen for additional owls for the remainder of the fifteen minute station duration. Survey effort consisted of 38 transects and 353 total stations. Transects were placed to target favourable habitat (i.e., riparian areas) and inter-station spacing was approximately 500 m. There was some overlap in the Campbell River area with the BCRP 2000-2007 stations. Stations were generally not replicated (1 survey per station; 355 total survey events). The primary surveyor was Vicky Young and surveys were funded through the BC Conservation Corps.

2012-2013 FWCP Alouette SAR

Surveys were conducted in the Alouette Watershed as part of a multi-taxa species at risk project (southwest BC mainland). Western screech-owl specific stations (49 total stations) were established and surveyed once in the fall (Sept of 2012) and the same stations were surveyed twice the following breeding season (February-March 2013) for 143 survey events collectively. Survey spacing was not given in the report and no western screech-owls were detected. Funding was provided by the Fish and Wildlife Compensation Program (FWCP) and the primary surveyor was Aimee Mitchell with Athene Ecological.

2013 SAR Pemberton Survey

No report was written for this survey effort, but the purpose of these surveys was to inventory western screech-owl site occupancy in the Pemberton area (southwest BC mainland). Surveys were conducted mainly on one night (September 9th) with 23 total stations surveyed. One station was surveyed twice, all other stations were surveyed once (1 survey per station; 24 total survey events). Survey spacing is not known, as no report was produced for this work. Three screech-owls were detected and two owls of other species. The project was under the supervision of John Surgenor, but the primary surveyors were Jess Findlay, Dennis Lynch, Ellen Hancock and Kendra Morgan with training provided by Jared Hobbs.

2013-2016 FWCP Clowhom SAR

Surveys were conducted to assess site occupancy by western screech-owls as part of a larger project assessing species at risk in the Clowhom Watershed (southwest BC mainland). Surveys were conducted according to RISC standards (2006) in late March and Early May of 2014, April and July of 2015, and March of 2016. Stations consisted of an initial one minute silent listening period followed by one minute of call playback followed by three minutes of silence, this process was repeated for a total of 15 minutes per station or until an owl was detected in which case no more calls were broadcast. Survey stations (40 total stations) were spaced 400-500 m apart and were established in the initial year of the project and repeated in subsequent years. Additional stations were established (32 stations) as needed to cover appropriate habitat that was discovered during the course of surveying or to move survey efforts away from barred owl territories. Some stations were replicated (surveyed more than once a season) but a systematic rationale for replication was not given in the report. The total number of survey events was 278. Project leaders were Michelle Evelyn and David Stiles in partnership with Chris Currie and Aimee Mitchell and funding was provided by the Fish and Wildlife Compensation program.

2014 Coast Wide Survey

Surveys were conducted to inventory western screech-owls at locations in the North Coast, Midcoast, Northern Gulf Islands, and Northern and Southern Vancouver Island in late February, March, and early April. Call playback surveys were conducted according to RISC (2006) standards. Stations started with a two minute silent listening period for spontaneous vocalizations followed by a one minute broadcast of western screech-owl territorial call (either male or female) and a four minute silent listening period repeated twice for a total station time of 17 minutes. Call playback was immediately discontinued if larger owls were detected. Stations (201 total stations) were spaced at least 600 m apart and most were repeated twice; sites on Quadra Island were repeated three times (2 to 3 surveys per station). The total number of survey events was 386. Project leaders were Helen Davis and Frank Doyle and funding was provided by the Ministry of Environment under the supervision of Dave Fraser.

2014-2016 HSP Sunshine Coast Wildlife Project Survey

Surveys were conducted to inventory western screech-owls on the Sunshine Coast as part of a multi-taxa inventory called the Sunshine Coast Wildlife Project (southwest BC mainland). Western screech-owl call playback surveys were conducted in May of 2014, Sept of 2015, and March of 2016. Most stations (19 total stations in 2014, 113 total stations in 2015, 21 total stations in 2016) were not replicated (1 survey per station; 157 survey events) and station spacing appears to be 400-500 m. The project lead for these surveys was Michelle Evelyn and funding was provided by the Habitat Stewardship Program.

2015 FWCP Campbell River Madrone

Surveys were conducted to inventory of western screech-owl occupancy in the Campbell River Watershed (Vancouver Island). Diurnal call playback surveys (55 stations) were completed in conjunction with inspecting nest boxes installed in 2002 and 2006, and nocturnal call playback surveys (109 stations) were performed at previously established stations (BCRP 2000-2007) spaced at 800 m intervals along six transects. Stations began with a two minute silent listening period to detect spontaneous owl calls and if none were heard a broadcast of a the territorial call of a male western screech-owl was broadcast five times (for a total of approximately 10 minutes) followed by a two minute listening period. Initial nocturnal surveys were completed in March and four of the six transects were replicated (1 to 2 surveys per station) in June. Diurnal surveys were conducted opportunistically in May and June. Surveys were conducted following RISC (2006) protocols for a total of 166 survey events. The project lead for these surveys was Tania Tripp; funding was provided by the Fish and Wildlife Compensation Program (FWCP).

2015 MFLNRO Hemmera

Surveys were conducted to inventory western screech-owl occupancy at selected (previously occupied) sites in the lower mainland. Surveys of 52 total stations were conducted over a four day period (April 6-April 10) following RISC (2006) standards using 15 minute call playback stations. Stations were not replicated (1 survey per station; 52 survey events) and were spaced a minimum of 500 m apart, but station spacing was not standard as surveys were conducted in non-contiguous habitat. No western screech-owls were detected on these surveys. Project leads were Jared Hobbs and Chris Chutter on behalf of the Ministry of Forests, Lands, and Natural Resource Operations.

2015-2016 CRD HAT Highlands Survey

Surveys were conducted to inventory western screech-owl occupancy in the Victoria CRD. In both years surveys took place between February and March following RISC (2006) standards for survey conditions. Survey stations (64 total stations in 2015; 57 total stations in 2016) were spaced approximately 800 m apart and targeted historical sites and suitable habitat. Stations began with a two minute silent listening period to detect spontaneous owl calls and if none were heard the territorial call of a male western screech-owl was broadcast five times (for a total of approximately 10 minutes) followed by a two minute listening period. Surveys were repeated at least once (at least 2 surveys at each station; total number of survey events not available) within a three week period avoiding areas where owls had previously been detected. The project lead for these surveys was the Habitat Acquisition Trust (contact: Jill Robinson) with technical assistance from Tania Trip (Madrone Environmental Services) and funding was provided by the Habitat Stewardship Program.

2015-2016 FWCP Coquitlam SAR

Surveys were conducted in the Coquitlam area (southwest BC mainland) to assess site occupancy by western screech-owls. A report for these surveys is not yet available but surveys were conducted according to RISC (2006) standards and survey stations (28 total stations) were spaced between 250-500 m apart (Mitchell personal communications). No replicates were conducted (1 survey per station; 28 survey events). Surveys were conducted in the fall (September-October) of 2015 and resurveyed in the spring of 2016 (data is not yet available). The project lead for these surveys was Aimee Mitchell (Athene Ecological) and funding was provided by the Fish and Wildlife Compensation Program.

2015-2016 FWCP Stave SAR

Surveys were conducted as part of a multi-taxa species at risk inventory in the Stave Watershed (southwest BC mainland) for the purpose of providing information on site occupancy by western screech-owls. Surveys were conducted at 231 call playback stations following RISC (2006) standards. The male territorial call was broadcast at call playback stations, which were completed in a total of 17 minutes unless an owl was detected in which case no more calls were broadcast. Survey stations were established (between 250-500 m apart) and initially surveyed in the fall (September-October) of 2015 and resurveyed in the spring (February-March) of 2016. No stations were replicated in 2015 (1 survey per station); some stations were replicated in 2016 (2 surveys per station) but a systematic rationale for replication was not given in the report. The project lead for these surveys was Aimee Mitchell (Athene Ecological) and funding was provided by the Fish and Wildlife Compensation Program.

2015-2016 HSP-WPT and Associated SAR-Fraser Valley Conservancy Survey

Surveys were conducted to inventory western screech-owl site occupancy in the Fraser Valley area (southwest BC mainland) as part of a project assessing screech-owl occurrence at western painted turtle sites. Western screech-owl specific nocturnal call playback surveys were conducted following RISC (2006) standards at stations (44 total stations established in 2015; 11 stations added in 2016) spaced every 250-500 m along transects located in suitable riparian habitat. The male territorial call was broadcast at call playback stations, which were completed in a total of 17 minutes unless an owl was detected in which case no more calls were broadcast. Surveys were completed in the fall of 2015 (September-October) and the spring of 2016 (April). Few stations were replicated within seasons (1 survey per station; 100 survey events). The project lead for these surveys was Aimee Mitchell (Athene Ecological) and funding was provided by the Fraser Valley Conservancy and the Habitat Stewardship Program.

2015-2016 Volunteer Survey Pemberton

Surveys were conducted to inventory western screech-owl site occupancy in the Pemberton, Chilliwack, and Squamish areas (southwest BC mainland). Surveys followed a combination of RISC (2006) standards and the Yukon Nocturnal Owl Survey program protocol (Takets et al. 2001). Survey stations consisted of a one minute broadcast of the male territorial call of a western screech-owl followed by four minutes of silent listening. These steps were repeated for a total station time of fifteen minutes. Stations (154 total stations) that were spaced approximately 400 m apart were established and surveyed in Pemberton in the fall (October) of 2015 and repeated in the spring (February-June) of 2016. Few stations were replicated in 2015 (1 survey per station) but most stations were replicated three times in 2016 (3 surveys per station). Additional stations were also established in Pemberton, Chilliwack and Squamish in 2016 (310 additional stations). The project lead for these surveys was Greg Ferguson; conducted voluntarily for the BC Ministry of Environment.

2016 SFU BSc Midcoast Surveys

Surveys were conducted for research purposes. The general purpose of this study was to test the hypothesis that the western portions of the Central and North Coasts of BC could provide western screech-owls with a refuge from barred owl predation. Surveys were initiated 30 minutes after sunset and stations consisted of a two minute acclimation period followed by four minutes of silent listening and then a broadcast of 30 minutes of a recording of a territorial call of a male western screech-owl followed by an additional one minute of silent listening. The recordings were then broadcast again for an additional 30 seconds followed by a final two minutes of silent listening. A barred owl call playback was added at the end of every third station. Call playback surveys were conducted in the Bella Bella area between Feb 22 and March 22 in 2016 along transects consisting of 74 stations spaced between 400-600 m apart and were replicated two to three times (2 to 3 surveys per station). These surveys were conducted as part of the completion of a BSc. Honours project by Jeremiah Kennedy at Simon Fraser University (Kennedy 2016).

## 4.3 DEVELOPMENT OF STATISTICAL TREND MONITORING STUDY DESIGN RECOMMENDATIONS

### Occupancy Modeling Approach

A review of studies that simulated bias and power of standard survey designs relative to alternative designs indicated that no efficiencies would be gained by removal sampling, double sampling, or a rotating panel design within study areas (MacKenzie and Royle 2005, Bailey et al. 2008). Thus, a standard design with the same number of surveys at all sites and across survey years is recommended.

### Estimates of Occupancy and Detection Probability

Due to a lack of repeated surveys, historical survey data were generally insufficient for determination of coastal screech-owl detection probabilities. Two notable exceptions were the Bridge Coastal Fish and Wildlife Restoration Program (BCRP) surveys from Campbell River conducted in 2006, and surveys conducted by J. Kennedy in the Midcoast region around Bella Bella in 2016. Published results from occupancy studies of coastal screech owl in southeast Alaska provided additional estimates of occupancy and detection probability (Kissling et al. 2010). Occupancy and detection probabilities from these surveys are reported in **Table 5**.

**Table 5 Occupancy and Detection Probability Estimates from Historical Surveys and Published Reports**

| Study Area | Year | Occupancy Estimate (SE) | Detection Probability (SE) | Station Spacing | Source |
|---|---|---|---|---|---|
| Southeast Alaska | 2005 | 0.62[1]; 0.21[2] | 0.33 (0.09) | 1,600 m | (Kissling et al. 2010) |
| Campbell River, BC | 2006 | 0.32 (0.23) | 0.33 (0.25) | 800 m | BCRP MOE Survey |
| Bella Bella, BC | 2016 | 0.81[3]; 0.59[4] | 0.32[4] (0.14) | 400 m | (Kennedy 2016) |

[1] at sites without big owls (0.11 SE).
[2] at sites with big owls (0.11 SE).
[3] occupancy estimate (0.05 SE) accounts for variables affecting detection probability (e.g., wind, noise) and assumes independent stations (i.e., one territory per station: J. Kennedy, pers. comm.).
[4] occupancy estimate (0.25 SE) and detection probability calculated with a null occupancy model assuming smaller territory sizes (two stations spaced 400 m apart per territory) than in other regions (J. Kennedy, pers. comm.).

**Note:** Estimates of detection probability exclude surveys with high levels of background noise and are from periods of peak response rates. Detection probabilities reflect the probability of detecting owls within an owl territory, not at a survey station with the exception of the southeast Alaska study where station spacing was sufficiently great to ensure each station was within an independent territory: 1,600 m.

It should be noted that the three studies analyzed to derive detection probability included surveys with multi-species call-playback (including large owls (great horned owl (*Bubo virginianus*), and/or barred owl (*Strix varia*)) in at least some surveys and may therefore underrepresent detection probability. The most reliable estimate of detection probability for surveys on Vancouver Island is derived from the 2006 BCRP survey data (0.33: **Table 5**). No other survey datasets apart from those listed in **Table 5** met the criteria for determination of detection probability. Occupancy varied widely across studies and was higher in southeast Alaska[4] and Bella Bella than at Campbell River; however, detection probability was similar across the three surveys.

[4] Considering only one station was surveyed per owl territory in the southeast Alaska study, detection probabilities were likely higher per survey in this study and would have been greater had multiple stations been sampled within territories via closer station spacing as in the other two surveys.

While detection probability could not be determined from other historical datasets from Vancouver Island and the Midcoast region, naïve estimates of occupancy were determined based only on the estimated proportion of occupied territories. These are presented in **Table 6** with naïve estimates from study areas for which unbiased occupancy was determined through repeated surveys as presented above.

**Table 6 Naïve Estimates of Coastal Screech-owl Occupancy from Surveys Conducted on Vancouver Island and the Midcoast Regions**

| Survey Location | Survey Year | Occupied Sites | Total Sites Surveyed | Naïve Occupancy | Source |
|---|---|---|---|---|---|
| Campbell River | 2000[1] | 8 | 23 | 0.35 | BCRP MOE Survey |
| Campbell River | 2002[1] | 12 | 22 | 0.55 | BCRP MOE Survey |
| Campbell River | 2003[1] | 11 | 19 | 0.58 | BCRP MOE Survey |
| Campbell River | 2006[2] | 7 | 30 | 0.23 | BCRP MOE Survey |
| Campbell River | 2007[3] | 1 | 33 | 0.03 | BCRP MOE Survey |
| Campbell River | 2008[4] | 4 | 39 | 0.10 | BCCC Vancouver Island Survey |
| Campbell River | 2014[5] | 2 | 22 | 0.09 | Coast Wide Surveys |
| Campbell River | 2015[6] | 1 | 57 | 0.02 | FWCP Madrone |
| Victoria | 2002[7] | 12 | 33 | 0.36 | UNBC MSc Surveys |
| Duncan | 2002[7] | 9 | 20 | 0.45 | UNBC MSc Surveys |
| Nimpkish | 2008[8] | 12 | 100 | 0.12 | BCCC Vancouver Island Survey |
| Bella Coola | 2014[9] | 0 | 18 | 0.00 | Coast Wide Surveys |
| Bella Bella | 2016[10] | 13 | 38 | 0.34 | SFU BSc Midcoast Surveys |

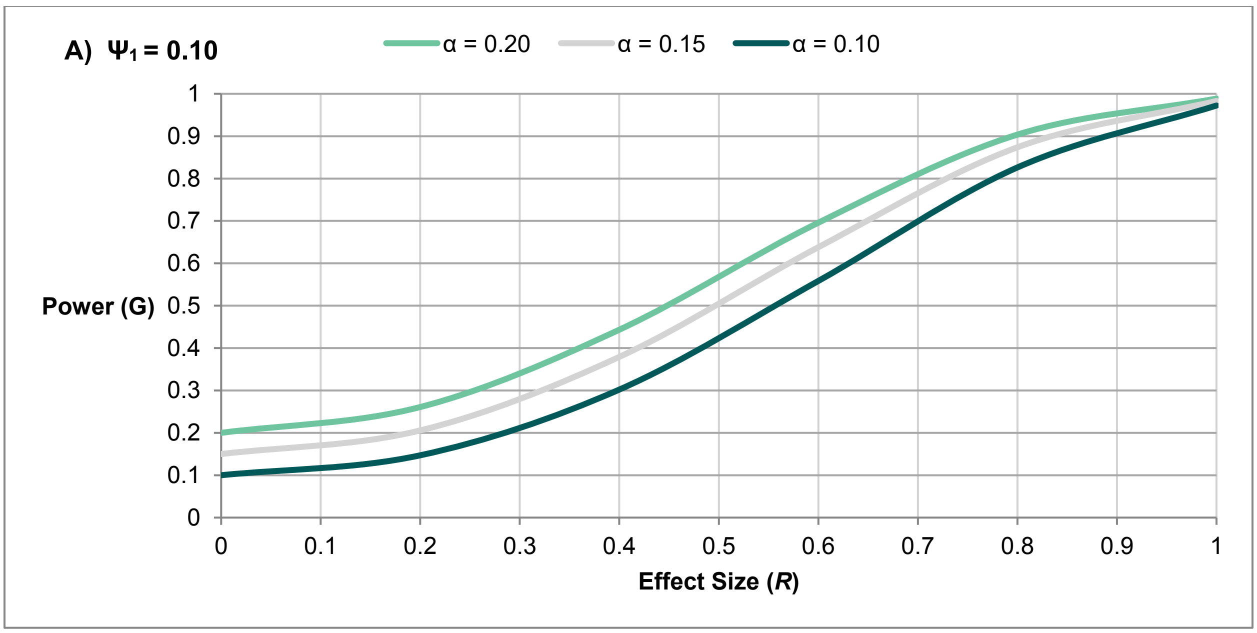
1 incomplete survey data
2 three surveys per station and multiple detections
3 three surveys per station but only one detection
4 one survey per station conducted in May and June
5 one survey per station in late February and March
6 one set of surveys in March, others in mid-May and early June.
7 repeated visits to sites with previous detections of owls
8 one set of surveys conducted in June
9 two repeated surveys in March and April
10 three repeated surveys in February and March

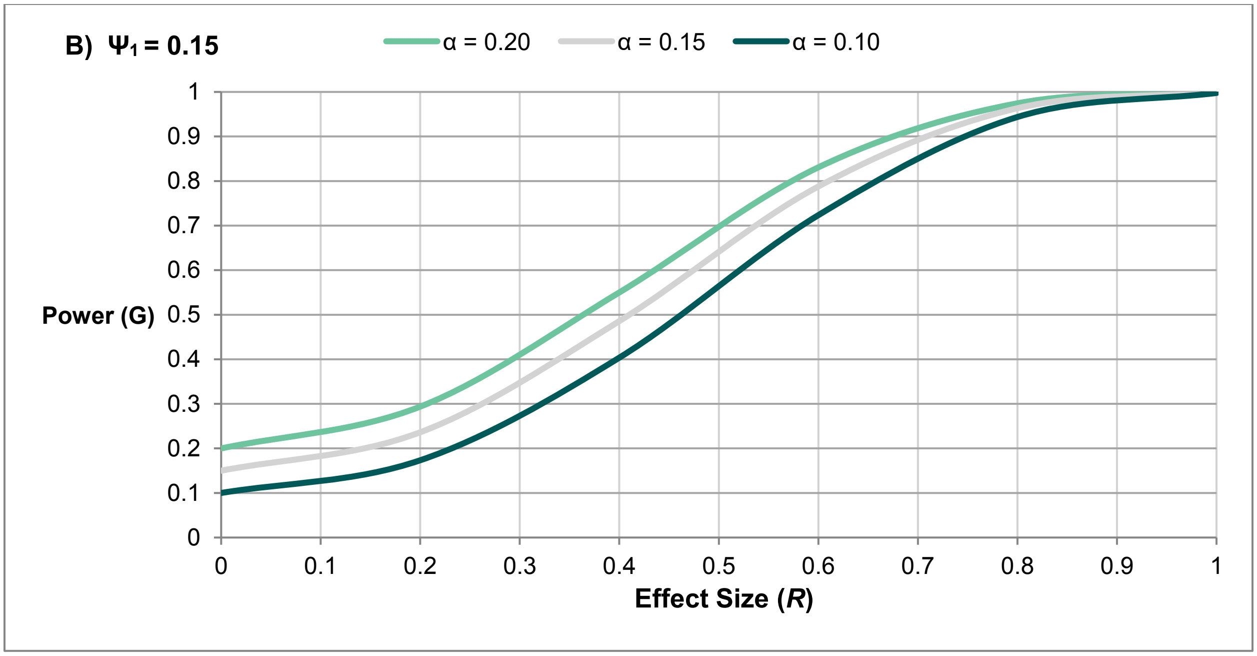
**Note:** Naïve occupancy estimates do not account for imperfect detection (negative bias) or potential variation in detection probability across areas and years (unknown bias). Site columns represents the number of owl territories not survey stations.

Naïve occupancy estimates presented in **Table 6** suggest occupancy was lower after 2006 (range: 0.02 to 0.12) as compared to estimates from 2006 and prior years (range: 0.23 to 0.58). These estimates are biased low as a result of imperfect detection. For example, the naïve occupancy estimates from Campbell River 2006 and Bella Bella 2016 are 10% and 25% lower than occupancy estimates determined with PRESENCE software that accounts for detection probability (**Table 5**, **Table 6**). The occupancy determined from 2016 surveys around Bella Bella is far higher and does not appear to be representative of current occupancy on Vancouver Island or other sites in the Midcoast region (e.g., Bella Coola: **Table 6**). Consequently, existing survey data was unable to provide a representative estimate of current occupancy for any Vancouver Island area that accounts for detection probability (see **Discussion**). Instead, the range of recent naïve occupancies determined from surveys on Vancouver Island was used to estimate a range of likely occupancy in the region by applying a negative bias correction of 10 to 33%. This method yielded potential occupancies ranging from 0.05 to 0.20. Power analyses were conducted using this range of potential occupancy.

**Determination of Effect Size, Significance level, and Power threshold**

Power curves illustrating sensitivity of the study design to changes in significance level and initial occupancy (i.e., current occupancy) are presented in **Figure 4**. The sensitivity analysis showed studies could not be designed to detect an effect size smaller than *R*=0.5 (i.e., a 50% change in occupancy), while satisfying a one to one ratio of potential type I and type II error (i.e., α:β =1), with a power threshold of at least 80% (**Table 7**). Achieving an 80% power threshold also required an initial occupancy of at least 0.20. Consequently, significance level was set at α=0.20, the power threshold was set at 80% (β=0.20), and occupancy was set at 0.20 for subsequent sensitivity analyses conducted to refine and optimize the proposed study design.





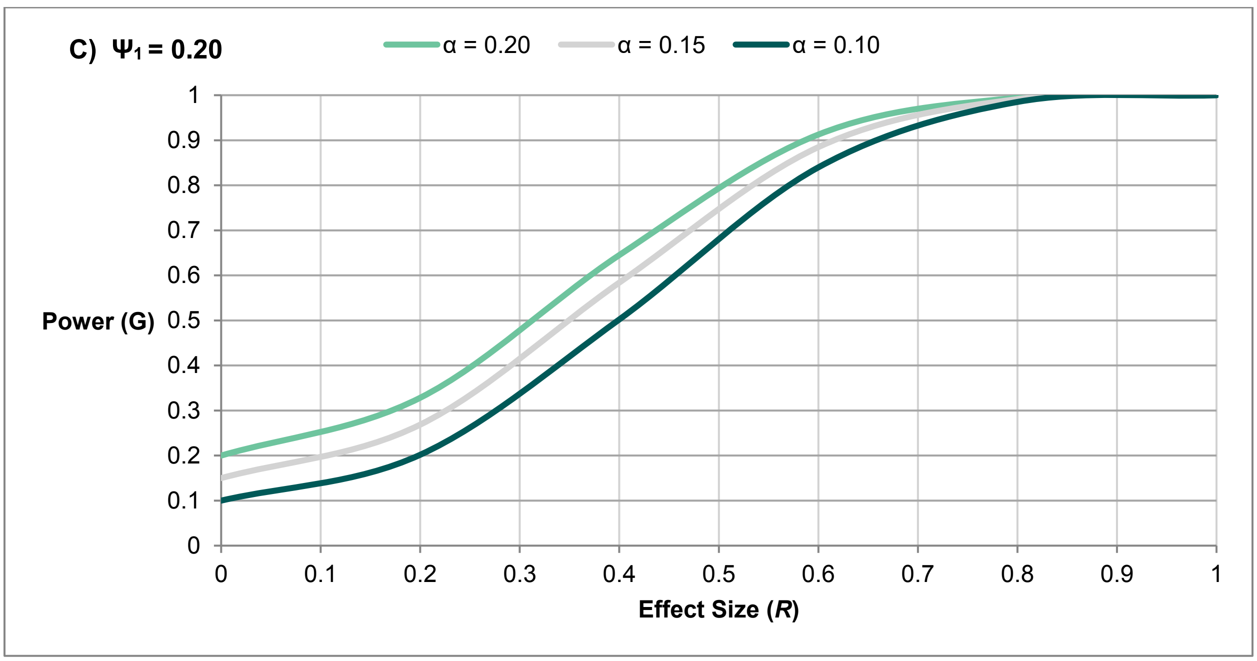




**Figure 4 Power Curves Illustrating the Probability of Detecting Various Magnitudes of Change in Occupancy (Effect Size) at Three Significance (α) and Initial Occupancy Levels ($\Psi_1$)**

**Note:** Power curves under initial occupancy rates of 0.10, 0.15, and 0.20 are presented in panels A, B, and C, respectively. *R* is specified as the proportional difference in occupancy ($\Psi_2 = \Psi_1 - R$). Thus, a positive *R* values represent a decline while a negative value represent an increase in occupancy (e.g., *R*=0.5 represents a 50% decline). Parameter constants used to generate power curves were those determined for the optimized study design: p=0.33, *K*=6; and *S*=132.

**Table 7 Effect Sizes Required to Meet Power Threshold for One to One Ratios of Type I and Type II Error Probability (α = β)**

| Initial Occupancy | α, β = 0.10 (Power Threshold 90%) | α, β = 0.15 (Power Threshold: 85%) | α, β = 0.20 (Power Threshold: 80%) |
|---|---|---|---|
| $\Psi_1 = 0.10$ | 0.88 | 0.78 | 0.69 |
| $\Psi_1 = 0.15$ | 0.75 | 0.66 | 0.58 |
| $\Psi_1 = 0.20$ | 0.66 | 0.57 | 0.50 |

**Note:** Parameter constants used determine effect sizes were those determined for the optimized study design: p=0.33, *K*=6; and *S*=132.

**Optimization of Survey Spacing, Survey Timing and Determination of Sample Size Requirements**

An important consideration in these analyses, and for the entire monitoring program design, is defining the relationship between survey stations, owl territories, and occupancy sites (*S*). Given the territory sizes described above (average 1,200 m length) territories are likely to overlap multiple survey stations unless stations are spaced at least 1,600 m apart. To account for the discrepancy between detection range around survey stations and screech-owl territory size, all stations within a territory should be considered as a sub-sample and taken together as a single site (*S*) for which one record of presence/absence is input into datasets used to develop occupancy models. This design defines the owl territory as the sample unit (i.e., site (*S*)) rather than survey station, thereby ensuring that the same owl is not detected within two sites in subsequent surveys (i.e., sample independence), an explicit assumption of occupancy models. Under this design, an owl detected at one of two survey stations that a territory overlaps is recorded as a presence record at a single site. Similarly, if there are no records at two stations within a single territory, those stations are taken together as a single absence record.

To assess the sensitivity of power to variation in station spacing, separate analyses of occupancy and probability detection were made using sub-sets of the BCRP Campbell River survey data from 2006 which employed 800 m station spacing. In the first analysis, a sub-set of every second survey station was used to estimate occupancy and detection probability with 1,600 m station spacing data. In the second analysis, stations were grouped in pairs and the entire dataset was utilized. Resulting occupancy estimates were similar ($\Psi$ = 0.33 and 0.32), but detection probability doubled from $p$ = 0.16 to 0.33 between the 1,600 m and 800 m spacing datasets. Detection probabilities for intermediate (e.g., 1,200 m) and lesser (600 m) station spacing was estimated assuming proportional changes of detection probability with station spacing (**Table 8**). This assumption is supported theoretically, as the probability of detecting an owl within a territory should be proportional to the percent of the territory surveyed, and empirically from the analyses of BCRP data described above. A sensitivity analysis was conducted to determine optimum station spacing by calculating occupancy for four potential spacing designs with the estimated number of territories (given an estimated territory length of 1,200 m along riparian corridors) that could be covered with 200 survey stations (**Table 8**). For this sensitivity analysis, all other parameters influencing power were held constant at levels anticipated for the region.

**Table 8 Sensitivity Analysis of Power to Detect Changes in Occupancy with 15% Initial Occupancy and Various Station Spacing Distances**

| Station Spacing | Detection Probability (*p*) | # of Sites (*S*) | Power (*G*) | # of Sites Required for 80% Power | # of Stations Required for 80% Power | Total Surveys Required for 80% Power |
|---|---|---|---|---|---|---|
| 1,600 m | 0.16 | 267 | 0.46 | 888 | 666 | 2,664 |
| 1,200 m | 0.24 | 200 | 0.59 | 403 | 403 | 1,612 |
| 800 m | 0.32 | 133 | 0.60 | 258 | 387 | 1,548 |
| 600 m | 0.40 | 100 | 0.59 | 203 | 406 | 1,624 |

**Note:** Parameter constants used for sensitivity analysis: Stations=200, Ψ= 0.15, *K*= 4; *R*=0.5, α=0.20. Sites (*S*) represent the number of owl territories covered by survey stations. 80% power is equivalent to *G* = 0.80.

The station spacing sensitivity analysis found that the greatest power to detect changes in occupancy would be obtained with station spacing of 800 m (**Table 8**). Given the unreasonably high number of stations (minimum 386) required under occupancy of 0.15 (**Table 8**), power analyses were also conducted assuming a higher level of occupancy (0.20). Results of the sensitivity analysis under 20% occupancy also suggest that 800 m spacing provides the greatest power for detecting change (**Table 9**).

**Table 9 Sensitivity Analysis of Power to Detect Changes in Occupancy with 20% Initial Occupancy and Various Station Spacing Distances**

| Station Spacing | Detection Probability (*p*) | # of Sites (*S*) | Power (*G*) | # of Sites Required for 80% Power | # of Stations Required for 80% Power | Total Surveys Required for 80% Power |
|---|---|---|---|---|---|---|
| 1600 m | 0.16 | 267 | 0.53 | 661 | 496 | 1,983 |
| 1200 m | 0.24 | 200 | 0.68 | 297 | 297 | 1,188 |
| 800 m | 0.32 | 133 | 0.69 | 188 | 282 | 1,128 |
| 600 m | 0.4 | 100 | 0.68 | 146 | 292 | 1,168 |

**Note:** Parameter constants used for sensitivity analysis: Stations=200, Ψ=0.20, *K*=4; α=0.20, *R*= 0.5. Sites (*S*) represent the number of owl territories covered by survey stations. 80% power is equivalent to *G* = 0.80.

Another sensitivity test was conducted to determine the most efficient combination of station spacing and number of repeated surveys by determining the number of stations and total surveys ($S*K$) required to achieve a power of 80% with 600 m and 800 m spacing. Results indicate that station spacing of 600 m with four or five survey replicates or 800 m with five or six replicates will provide the most efficient allocation of survey effort (**Table 10**). Station spacing of 800 m provides slightly more power and would allow the most efficient use of available resources. Under this allocation of effort, five surveys at 227 stations (1,133 total surveys) or six surveys at 201 stations (1,206 total surveys) appear to provide the most efficient design to detect a 50% decline in occupancy. Fewer total surveys would be required at four replicates (1,128), but would require 282 appropriate locations for survey stations.

**Table 10 Sensitivity Analysis of Power to Detect Changes in Occupancy by Number of Repeated Surveys and Station Spacing**

| Station Spacing | Detection Probability (*p*) | Repeated Surveys (*K*) | # of Sites (S) Required for 80% power | # of Stations Required for 80% Power | Total Surveys Required for 80% Power |
|---|---|---|---|---|---|
| 600 m | 0.4 | 3 | 196 | 392 | 1,176 |
| | | 4 | 146 | 292 | 1,168 |
| | | 5 | 129 | 258 | 1,290 |
| | | 6 | 121 | 242 | 1,452 |
| 800 m | 0.32 | 3 | 289 | 434 | 1,301 |
| | | 4 | 188 | 282 | 1,128 |
| | | 5 | 151 | 227 | 1,133 |
| | | 6 | 134 | 201 | 1,206 |

**Note:** Ψ=0.20, α=0.20, *R*= 0.5, # of stations determined as the number of stations per site which is defined as the estimated home range of coastal screech-owl of 1,200 m length. Optimal allocations with the lowest balance of stations and total surveys are highlighted for both 600 m and 800 m station spacing. The bottom row is the most representative of the power curve shown in Figure 2. The sites column represents the number of owl territories covered by stations for the various spacing distances.

For optimization of detection probability, historical survey data was reviewed to determine time periods with the highest detection rates of western screech-owl. This is expected to be during the courtship period (i.e., late February, March, and early April) (Hobbs 2013*a*, *b*). Surveyor detection of calls is negatively impacted by background noise, precipitation, and wind. Threshold standards for noise and wind are set in the 2006 RISC protocol. Records for which thresholds were exceeded and where precipitation was recorded were excluded from analyses used to determine occupancy and detection probability in this report.

Detection probability also varies by the distance of surveyors from western screech-owls (Deal and Lamont 1996) and is, consequently, influenced by interstation spacing. Records from northern Vancouver Island indicate that 42% of coastal screech-owls are detected within 100 m of stations, 87% are detected within 300 m of stations, and 98% are detected within 400 m (**Table 11**). Territory size of western screech-owls in riparian habitat is estimated to be somewhere in the range of 65 to 77 hectares (Davis and Weir 2010). Thus, screech-owl territories are often larger than the range within which owls are usually detected (400 m radius equates to 800 m diameter/total range), so interstation spacing greater than 800m can decrease the proportion of territories surveyed and can decrease detection probability to a proportional extent. Detection probability can be further increased by decreasing interstation spacing within 800 m, which increases the proportion of area surveyed with the highest detection probability (i.e., within 300 m). However, the gain in detection probability provided by decreasing interstation spacing within 800 m is less than proportional as overlapping detection probabilities from adjacent stations are not additive.

**Table 11 Number and Percent of Coastal Screech-owl Detections by Distance from Survey Station**

| Distance (m) | % Detected | # Detected |
|---|---|---|
| 0-100 | 42% | 55 |
| 100-200 | 25% | 33 |
| 200-300 | 20% | 26 |
| 300-400 | 11% | 14 |
| 400-500 | <1% | 1 |
| >500 | <2% | 2 |
| Total | 100% | 131 |

**Note:** Data calculated from information presented by Deal and Lamont (1996)

Final sensitivity analyses were conducted to determine the optimal survey design (i.e., number of repeated surveys) under alternative detection probability and occupancy levels. The optimal number of repeated surveys remains five for all likely levels of occupancy (0.10 to 0.50), but decreases as detection probability increases (**Figure 5**). The optimal number of repeated surveys under detection probabilities of 0.4 and 0.5 are four and three, respectively.

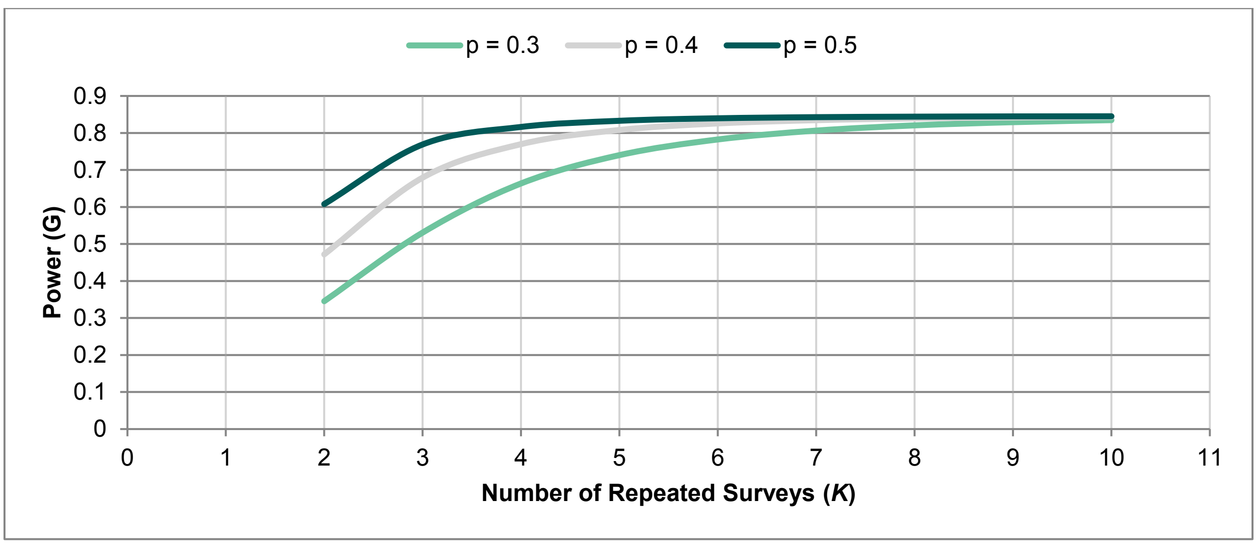



**Figure 5 Power Curves Illustrating the Probability of Detecting a Change in Occupancy (Effect Size) with Three Detection Probabilities (p) and Various Numbers of Repeated Surveys (*K*)**

**Note:** Parameter constants used to generate power curves: Ψ=0.20, α=0.20, *R*= 0.5, *S*=132.

# 5.0 DISCUSSION

Western screech-owl was historically recognized as locally abundant in BC, but substantive declines were suspected by the mid 1990's (Fraser et al. 1999). These concerns prompted status updates by COSEWIC in 2002 (COSEWIC 2002) and 2012 (COSEWIC 2012) which suggested a potentially range wide population decline in BC. A review of the COSEWIC (2012) population size and trend estimates found that conclusions of a declining population and the subsequent status update were warranted (Gahbauer and McCracken 2014). It is widely recognized that coastal screech-owl populations within the Lower Mainland and Vancouver Island have been in decline in recent years (Tripp 2004, Elliott 2006, COSEWIC 2012, Gahbauer and McCracken 2014, H. Davis and Doyle 2014, Dave Fraser pers. com.). On southern Vancouver Island, this understanding has been further supported by voluntary western screech-owl monitoring that has showed substantial declines within known territories between 1997 and 2012 (J. Hobbs pers. obs.); of 19 territories with multiple detections in the highlands only four remain active today despite repeated surveys over multiple years by several individuals and organizations. Within the Lower Mainland, historical records indicate that screech-owls persisted within remaining patches of naturally vegetated habitat even after they were isolated by development, but recent surveys indicate that these territories are no longer occupied. Extant territories persisted in areas within the UBC endowment lands (1993), Stanley Park (2011), Cultus Lake (2009), North Chilliwack (2010), Burns Bog (1995), and Burnaby Lake (2010); however, surveys of these locations in 2015 failed to detect any evidence of continued occupancy (Hobbs and Chutter 2015).

This report provides additional evidence of population declines that have occurred to date through review of survey results that account for survey effort (**Table 1**) and for variation in interstation spacing across studies (**Table 6**). **Consideration of inventory results, published reports, and historical survey data point to a population decline on Vancouver Island centered around the years 2005, 2006, and 2007 as previously suggested by Gahbauer and McCracken (2014)**. Unfortunately, the diversity of study objectives and survey methods employed to collect the existing data for coastal screech-owl and the lack of repeated surveys from such surveys do not provide directly comparable estimates of occupancy or population size. Historic differences in survey methods present confounding factors that preclude the use of statistical analyses to determine the significance or exact rate of declines that have occurred to date; however, the weight of evidence for a decline in coastal screech-owl populations is substantiated by this exhaustive compilation of detection records and survey data. The in-depth consideration afforded to the data compiled for this report suggests that dramatic declines in western screech-owl populations in coastal BC have already occurred. Future declines will likely be relatively subtle and more challenging to detect given current (reduced) occupancy rates. The ability to detect a trend in a species' population is negatively related to population size because the error of population size estimates and indices (e.g., occupancy and detection probability) grows proportionally bigger relative to the true value as population sizes decrease (Taylor and Gerrodette 1993).

Reasons for decline are attributed to large-scale forest harvest (particularly on Vancouver Island and the Sunshine Coast), urbanization (particularly within the Greater Victoria and Vancouver areas), range expansion of the barred owl into the region, and reduced availability of wildlife trees as a result of human safety management in urban parks and as mandated during forestry activities. Depredation by barred owls (I. Taylor pers. obs., J. Hobbs pers. obs.) is increasingly suspected to be a significant cause of decline for the western screech-owl. Suppositions regarding the influence of barred owl depredation have been further supported by more formal research conducted on Bainbridge Island in Washington (Acker 2012), in southeast Alaska (Kissling et al. 2010), and from informal survey data (as summarized in Gahbauer and McCracken 2014). Barred owls were not part of BC's avifauna until approximately 70 years ago, their rapid population expansion since that time represents a threat to screech-owls that they may not be equipped to deal with (COSEWIC 2012). Continued decline is expected based on anticipated continued habitat alteration within portions of the species range and continued influence from depredation by the now sympatric barred owl.

Monitoring trends in owl populations is complicated by imperfect detection. Surveys will often fail to detect an owl when it is present if the owl is unresponsive to call playback (i.e., low detection probability) or surveyors do not hear and record the owl (Kissling et al. 2010). Such instances of imperfect detection are common in owl surveys and occur for a variety of reasons that cannot always be controlled (e.g., inclement weather, background noise, etc.). An important consequence of imperfect detection is that it can lead to a negative bias in estimates of population size when individuals are not detected (MacKenzie et al. 2002). Various methods have been derived to account for imperfect detection by assessing the probability of detection through repeated surveys at locations where the animal of interest is present (Vojta 2005). Occupancy modeling is a method that was developed relatively recently for this purpose (MacKenzie et al. 2002, Vojta 2005) and is particularly effective because it simultaneously assesses and incorporates detection probability into estimates of occupancy (the proportion of occupied sites). Given the low densities of owls and the binary nature of owl survey data (presence (1); absence (0)) occupancy is generally recognized as the preferred metric for modeling habitat relationships and for monitoring long term trends of owl populations (Guillera Arroita et al. 2010, Kissling et al. 2010). Occupancy models have been shown to provide unbiased estimates of occupancy where detection probability is greater than 30% (MacKenzie et al. 2002) and can also account for variation in detection probability across areas and time periods. Variation in detection probability has been observed in a range of species including western screech-owl and other owl species, demonstrating the utility of the method and the need to account for such bias when assessing temporal or spatial variation in occupancy (Olson et al. 2005, Kissling et al. 2010).

It is disconcerting to note that power analyses indicate that future declines in occupancy would need to be at least 50% in order to detect a change while allowing a 20% risk of both Type I and Type II error ($\alpha$, $\beta$ = 0.20). Since 50% changes in occupancy are unlikely to occur in consecutive years, a rotating sampling approach that focuses monitoring efforts at no more than two areas per year is recommended for long term monitoring. If trend monitoring is attempted, under current suspected relatively lower occupancy rates, study areas should be surveyed as intensively as possible every two to three years to assess long term trends to avoid expending effort in interim years when smaller changes in occupancy are less likely to be detected. Unfortunately, the amount of effort necessary to obtain 80% power of detecting change in occupancy at even just one area is likely prohibitively expensive and not logistically feasible. Current occupancy rates and detection probability rates calculated in this analysis suggest five repeated surveys are required at 227 stations within a study area. This equates to over 180 km of survey transects totalling over 1,100 total survey stations, and requires more than 90 survey nights to complete (assuming survey crews conduct a standard transect of 12 survey stations per night). This level of effort would require three two-person crews surveying for approximately 35 nights during the period of peak detection (estimated to be early March to mid-April on Vancouver Island). This level of effort is likely not practical given existing resources typically allocated in BC. Thus, unless occupancy or detection probability proves to be greater than estimated, there may be no way to detect future changes in population abundance and density with a feasible amount of effort.

There is some potential for detection probabilities to be increased relative to those reported to date if focused single-species call playback methods are consistently employed. Evaluations of survey data demonstrate that single species call-playback have higher response rates for western screech-owl when compared to multi-species call playback methods used in some studies. Unfortunately, only surveys that employed multi-species call playback methods were available for estimation detection probability obtained for this study. For example, the 2006 BCRP MOE surveys conducted in Campbell River were comprised of 74 large owl surveys (including barred owl) and 98 small owl surveys (western screech-owl and northern saw-whet owl). Large owl surveys yielded a 4% detection rate (owls per survey) of western screech-owl as compared to 6% from small owl surveys. Thus, the reported detection probability (0.33), based on the average detection rate of 5%, would have likely been somewhat higher using only small owl or western screech-owl calls; potentially as high as 40%. Power to detect changes in occupancy is increased at 40% detection probability (**Figure 5**), so the total number of surveys required under an optimal design drops to about 775 equating to 65 survey nights. This is a slightly more manageable number, but is still predicated on occupancy of 0.20 which is a generous assumption on the very high end of what the existing survey data suggests as a likely for coastal screech-owls in BC.

Specification of occupancy models to include covariate effects such as survey year, timing, or habitat characteristics could lead to improvements in precision of occupancy and detection probability estimates relative to those assumed for power analyses. While this could potentially reduce sample size requirements to detect changes in occupancy, and could be explored with further sensitivity analyses, the work was beyond the scope of this. It is also very unlikely that any associated gains in statistical power, should they prove to exist, would be sufficient to change the conclusions of the study (i.e., reduce the level of effort required to a practicable level).

# 6.0 MANAGEMENT RECOMMENDATIONS

In the context of our analysis, it is apparent that adherence to recommendations required for statistically rigorous trend monitoring are cost-prohibitive. Power analyses suggest that rigorous trend monitoring data would require a minimum of 227 stations, with five repeated surveys completed at each station, within a study area. This effort would need to be repeated over multiple non-consecutive years. In addition, the ability to detect a change in population size would be limited to an 80% probability of detecting a trend with a magnitude of 50% or greater between survey years. More subtle changes in population trend, although meaningful, would go undetected. In addition, there is some evidence to suggest that the era of more dramatic decline in the coastal region of the species range may have already occurred. As such, future trend in a depressed population will likely be more subtle and hence undetectable. Finally, in consideration of the short survey period (courtship) within which surveys to inform trend analysis must be completed, the number of sites and surveys required to detect a trend is likely not practicable.

Regardless of the feasibility of trend monitoring, this report provides novel and useful estimates of detection probability for coastal screech-owl and meets the study objective by identifying an optimal survey design that could be applied to meet a range of monitoring and research objectives. In consideration of feasibility, an alternate objective would be to more confidently define current occupancy levels and site specific estimates of detection probabilities in areas where historical survey data is available to provide further inference on the declines that have occurred to date. Current estimates of occupancy and detection probability for coastal screech-owl are a data gap and would be a great improvement over the naïve estimates determined from historical surveys. Occupancy and detection probability could be defined with more modest efforts (e.g., at fewer sites) than required to detect changes in population size or occupancy. Surveys conducted in accordance with the optimal survey design (e.g., five repeated surveys with 800 m station spacing) would allow the most efficient method to accurately and precisely determine current occupancy rates for the coastal population of western screech-owl. We recommend a minimum of three repeated surveys and a maximum station spacing of 800 m for all future monitoring efforts of coastal screech-owl.

To inform long term trends, if that remains as a management objective, future monitoring efforts should be prioritized in areas in which historical data is available and where resources to support surveys (e.g., funds, staff, collaborating with academic institutions and students, active volunteer bases) are greatest. Suggested priority areas include: Victoria, Duncan/Campbell Bay, Campbell River, and Nimpkish regions (as evidenced by high density of historical occurrence records in these areas (see **Figure 1**)). The level of effort expended at each priority area will depend on resources available to the survey. Assuming that a study designed to detect trend (i.e., five repeated surveys at 227 stations) is not feasible, three repeated surveys with 800 m spacing that covers all areas surveyed in previous years (or as many as resources allow) is recommended to obtain estimates of occupancy and detection probability and compare with naïve estimates of occupancy from previous survey years.

As an alternative, and contrary to the recommendations rationalized in this report, a different approach may be the best available option in the context of existing available resources. If calculation of trend consistent with recommendations made in this report is not an objective, MFLNRO may instead chose to simply analyze the database of detection locations for western screech-owl to generate a sub-list of previously active sites to simply assess current occupancy status at previously known extant sites. This information may provide an indication, and further evidence, to support accepted theories of a provincial range-wide decline of the species. The information could also be used to further inform detection rate if repeated surveys are conducted at confirmed occupied sites.

The optimized study design recommendations presented in this report are in line with guidance provided by Mackenzie and Royle (2005) for occupancy modeling studies, and flexible power analysis tools developed by Guillera-Arroita and Lahoz-Monfort (2012) are available to assess the statistical power of alternative designs or occupancy parameters. For example, three or four repeated surveys would likely provide the most efficient use of resources under detection probabilities of 0.5 and 0.4, respectively. We also stress the value of conducting surveys for all independent studies using consistent methods to facilitate future comparisons and analysis of survey results across studies. Specifically, repeated surveys must be conducted on separate nights to ensure sample independence. Apart from station spacing and replication, survey protocols should follow RISC standards (2006) for owls with single species call-playback stations with 15 minute total listening duration at each station. Observers should record the following information: time, survey time, distance and direction of owl detection and sex and call type for each owl response.

Additional options for future study include further survey efforts in habitats where barred owl may be less abundant and, in turn, where healthier populations of coastal screech-owl may still exist. Potential areas have been described for bog habitats in the central coast region; these habitats may also occur on the west coast of Vancouver Island where relatively little survey effort has been applied to date. Occupancy modeling could also be used to investigate environmental factors that may exclude barred owl or otherwise support higher occupancy by coastal screech-owl by including such factors (e.g., habitat characteristics, barred owl presence) as covariates.

Finally, another area of potential study is assessment of detection probability in the fledging period during summer months when juvenile screech-owls can be detected. Incidental observations by J. Hobbs suggest that detection probability may be higher during this period than during the breeding period, but, to our knowledge, sufficient survey data is not currently available to test this hypothesis.

## 7.0 CLOSURE

Collation of existing data, including review and compilation of formal and informal datasets to support the power analysis, was led by Jared Hobbs with support provided by Jeannine Randall. Recommendations for occupancy modelling, based on statistical review of required parameters, were completed by Toby St. Clair with oversight and direction provided by Jared Hobbs. Reporting was a collaborative effort, by all three authors.

We sincerely appreciate the opportunity to have assisted you with the anticipated information requirements for this project. If there are any questions, please do not hesitate to contact the undersigned by phone or email.

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