Coastal Western Screech-Owl Occupancy Analysis to Inform Study Design – 2020

Western Screech-owl (*Megascops Kennicottii*)

Photo Credit: Jared Hobbs

Nahwitti Bog, Northern Vancouver Island

Photo Credit: Bernard Schroeder

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EXECUTIVE SUMMARY

The western screech-owl (*Megascops kennicottii*) is a non-migratory, nocturnal owl species. Due to compelling and continued evidence of widespread population declines for the sub-species of western screech-owl (*M. k. kennicottii*) that resides and breeds along the coast of British Columbia (BC), the West Coast Regional office of the Ministry of Forests, Lands Natural Resource Operations and Rural Development (MFLNRORD) initiated compilation and analysis of occurrence records and survey data in 2017. This report provides analysis and interpretation of results from follow-up surveys for coastal screech-owl conducted in 2018 and 2019 on northern Vancouver Island. Of specific interest in these surveys was the potential for mature and old-growth bog forests and low-productivity forests to support high occupancy rates of coastal screech-owl relative to low and declining rates reported from southern Vancouver Island and the Lower Mainland regions in recent years (i.e., since the mid-2000s).

The objectives of this update to coastal screech-owl occupancy analysis and survey design were to: 1) summarize occupancy statistics (the proportion of occupied territories within suitable habitat and the probability of detecting an owl within a territory when present) of coastal screech-owl from survey data; 2) conduct power analyses to determine the level of effort required to detect changes in occupancy of various magnitudes and factors affecting occupancy; and 3) determine optimal allocation of survey efforts under the observed conditions to inform the design of future studies.

Call-playback broadcast (CPB) surveys were conducted along transects (12 to 14 sites per transect) in three areas in 2018 and 2019 covering five areas across years (one area was surveyed in both years). CPB surveys were complimented with autonomous recording unit (ARU) deployments set to record acoustic data (e.g., nocturnal owl calls) along the same transects (four to eight ARU locations per transect) each year.

Surveys recorded naïve occupancy rates ranging from 31% to 100% across transects, representing substantially higher population densities than those reported from other recent studies where estimated occupancy was generally <20% and often <10%. The results of modeling analyses that account for incomplete detection indicate corrected occupancy rates of 50% to 100% within the areas surveyed. Analyses found that occupancy rates were negatively impacted by the presence of barred owl (*Strix varia*). Occupancy rates of screech-owl in areas apparently unoccupied by barred owl were estimated near 100%. Analyses also found some support for a negative relationship between coastal screech-owl occurrence and canopy closure (i.e., the extent of vegetated cover of the forest canopy). Within transects where barred owls were detected, coastal screech-owl were detected more often where canopy closure was greater, increasing from 40% to 50% occupancy among survey sites with 0% to 30% canopy closure, to >75% occupancy among sites with 70% to 100% canopy cover.

The probability of detecting screech-owls when present (i.e., detection probability) was typically greater than 50% (range: 38% to 94%) under dry conditions and temperatures above freezing. This is high compared to an average of 33% from data collected from across coastal British Columbia through 2016, primarily from southern Vancouver Island and the Lower Mainland.

Compared to the results of prior power analyses conducted on the data collected through 2016, results from the 2018 and 2019 surveys suggest relatively high power to detect change within low-productivity bog forest (Coastal Western Hemlock [CWH], very wet hypermaritime [vh]) habitat. This result is driven by the relatively high rates of occupancy and detection probability recorded in 2018 and 2019 and is consistent with results from surveys of similar habitat on the central coast of BC. Results from the 2018 and 2019 found the greatest power to detect change were in areas unoccupied by barred owl where effect sizes around 30% could be detected with 25 sites and 90% power. In areas with multiple records of barred owls, occupancy rates, and the power to detect change in occupancy were found to be lower. Specifically, power analyses found that as many as 50 to 100 sites may be required to detect differences of only 50% within such areas.

Regarding allocation of survey effort, the three surveys conducted per site in 2018 and 2019 were shown to be appropriate in most cases. However, a third survey adds relatively little power to detect change in areas with high detection probability (e.g., ≥80%) as compared to areas where coastal-screech owl response rates are lower. Rather than conducting three surveys in areas with high detection probability, efforts could be more effectively allocated to areas with low detection probability (i.e., <50%) where a fourth survey was shown to almost double the power to detect change. Another recommendation for allocation of survey effort is to continue to survey at least one of the same transects each year so that inter-annual variation is not confounded with factors varying across transects. Maintaining a greater proportion of surveys in the same location across years (i.e., two of three transects) is preferable if the primary objective is detecting change in occupancy rates over time. Alternatively, the greater variety and area of habitats that could be covered by rotating a greater proportion of sites may provide more power to assess the factors that drive differences in occupancy. Thus, the extent to which transects are rotated versus maintained across years depends on the long-term objectives. These trade-offs and other cost-benefits of survey design options are discussed in greater detail within the report.

Regarding survey methods, the addition of ARU deployments to compliment CPB surveys provided valuable information that improved the interpretive power of occupancy modeling analyses. ARU data provided verification of the effectiveness of CPB methods for detection of coastal screech-owl with CPB detections at almost all sites near ARUs at which screech-owls were detected. Furthermore, the ARU results identified some areas of barred owl occupancy where this competing and potentially predatory species went unnoticed during CPB surveys. Given the apparent influence of barred owl presence on occupancy rates of coastal screech-owl, it is recommended that ARU deployments are continued as part of screech-owl monitoring efforts in addition to CPB surveys using screech-owl territorial defense calls. Further consideration should be given to determine if ARU methods could meet long term monitoring objectives independent of CPB surveys. In the meantime, however, it would be prudent to continue using CPB survey methods for this and other long-term studies to provide continuity in data collection and ensure the development of comparable datasets.

This Executive Summary is not intended to be a stand-alone document, but a summary of findings as described in the following Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

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1.0 INTRODUCTION

This Work was performed in accordance with Contract No. GS20NAN430 between Hemmera Envirochem Inc. (Hemmera), a wholly owned subsidiary of Ausenco Engineering Canada Inc. (Ausenco), and the Ministry of Forests, Lands Natural Resource Operations and Rural Development (MFLNRORD), West Coast Region, dated January 7, 2020. This Report has been prepared by Hemmera, for sole benefit and use by MFLNRORD. In performing this Work, Hemmera has relied in good faith on information provided by others (e.g., survey data), and has assumed that the information provided by those individuals is both complete and accurate.

1.1 Background

The western screech-owl (*Megascops kennicottii*) is a non-migratory, nocturnal owl species that occurs throughout much of western North America (Johnsgard 1988). Within British Columbia (BC), there are two recognized subspecies, the interior *M. k. macfarlanei* and the coastal *M. k. kennicottii* (Cannings et al. 2020). The coastal screech-owl, hereafter referred to as WESOke, is restricted to western BC, where it is resident and breeds from the South Coast region to Alaska with an estimated population size of 1,000 to 3,000 individuals (COSEWIC 2012, B.C. Minist. of Environment. 2020). WESOke in BC have generally been associated with low elevation (below 600 m) valley bottom deciduous or mixed deciduous/coniferous forests within riparian habitats (Johnsgard 1988, Tripp 2004, Hobbs 2013, Hemmera 2017). However, WESOke also occur within coastal hypermaritime habitat around Victoria, the southern Gulf Islands of BC and have recently been documented within low productivity bog forest habitat on the central coast (Kennedy 2016). A summary of WESOke nesting habitat and breeding behaviour is provided within Hemmera's initial occupancy analysis and study design report (Hemmera 2017).

Although WESOke is blue-listed (i.e., Special Concern) within the province of BC (B.C. Minist. of Environment. 2020), it has been listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada since 2012 (COSEWIC 2012) and was up-listed from special concern to threatened under the Species At Risk Act (SARA) in 2017 (Government of Canada 2017). Despite compelling evidence of widespread population declines, WESOke 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 no legal mechanism in place to conserve their habitat in BC. However, a recovery strategy is anticipated under the Federal *Species at Risk Act* (SARA), which may include the identification of Critical Habitat to promote recovery of WESOke within coastal areas of the species range in BC.

This update to WESOke occupancy[1] analysis and study design follows up on work initiated and directed by MFLNRORD's West Coast Regional office in 2017 through 2019. In 2017, Hemmera, on behalf of MFLNRORD, compiled and analysed survey and detection data for WESOke to assess population trends and inform study design for future monitoring efforts (Hemmera 2017). Hemmera compiled detection records from 1969 through 2016 and reviewed all available survey data, technical reports, and relevant scientific literature available through 2016 to determine WESOke occupancy[1] rates and detection probabilities[2]. Occupancy and detection probability statistics derived from this comprehensive review were

[1] "Occupancy" refers to the proportion of areas/sample units in which a species occurs. Occupancy, or occupancy rate, is a measure of population state used in place of abundance or density for species like owls that are difficult to detect and enumerate accurately.

[2] "Detection Probability" refers to the probability of detecting a species within a sample unit (e.g., WESOke territory) when present.

used to determine the level of effort required to detect future changes in WESOke occupancy (i.e., population trends) and to provide recommendations to optimize allocation of survey efforts given the limited resources available for monitoring. The 2017 analyses found that recent occupancy rates were low relative to those documented in the 1990's and early 2000's. Due to the low estimates of WESOke occupancy documented from most studies (0.05 to 0.20) conducted through 2016, the number of survey sites required to detect significant changes was cost-prohibitive and exceeded the extent of accessible habitat in most study areas, with one notable exception. Surveys conducted within patches of mature and old growth forest amongst low productivity bog and bog forest habitat on the central coast of BC (Coastal Western Hemlock [CWH], very wet hypermaritime [vh] habitat) documented occupancy rates as high as 0.81 (Kennedy 2016). Recommendations for future monitoring provided in the 2017 report included surveying other areas with predominantly low productivity bog and bog forest habitat in mature CWHvh forests to assess whether the relatively high WESOke occupancy rates observed at sites on the central coast are characteristic of similar habitat elsewhere in the province. Consequently, in 2018 and 2019, MLFNRORD contracted WESOke surveys within predominantly low productivity forests interspersed with bog habitat on northern Vancouver Island.

1.2 Objectives

This report details the methods and results of surveys and analyses conducted on the 2018 and 2019 WESOke survey data and discusses the implications of those results to inform the design of future survey efforts. The specific objectives, as per the contract commitments, are to:

- Summarize occupancy statistics (occupancy rates and detection probability) of WESOke from 2018 and 2019 call-playback surveys on northern Vancouver Island;
- Complete power analyses to determine optimal allocation of call-playback survey effort, and the level of effort required to detect changes in occupancy of various magnitudes for this population;
- Create power curves showing power to detect change in occupancy under different allocations and levels of survey effort; and
- Provide recommendations on optimal survey effort and design for population monitoring and for research into factors influencing occupancy.

These objectives were considered within the context of the following long-term monitoring objectives (J. Cragg, pers. comm.):

- Determine WESOke occupancy rates across all potentially suitable habitat types and quantify the differences between them to assess the value of hypermaritime bog and bog forests relative to other habitat types such as more productive closed canopy CWH forests.
- Determine the importance of habitat variables for WESOke (e.g., prey abundance, nest sites) relative to competition/predation pressures from barred owl (*Strix varia* – hereafter "BDOW"), a larger owl which has expanded its range and densities within coastal BC over the past few decades.
- Determine differences in occupancy resulting from habitat fragmentation of hypermaritime bog and bog forest habitat.

2.0 METHODS

2.1 Western Screech-owl Call-Playback Surveys

In 2018 and 2019, call-playback broadcast (CPB) surveys were conducted at sites along service roads (i.e., road accessed transects) within predominantly low-productivity bog and bog forest habitat on northern Vancouver Island. CPB surveys were conducted by Bernard K. Schroeder and Guy Monty of Bernard K. Schroeder consulting and were complimented with Autonomous Recording Unit (ARU) deployments in both years. The specific methods for CPB surveys and ARU deployment and programing are provided along with rationale for the selection of specific survey sites within their 2018 and 2019 monitoring reports (**Appendix A**). In brief, single species WESOke territorial defense calls were used according to RISC protocols and recommendations from the Hemmera (2017) report. Three transects were surveyed in each year. Survey transects were located along the Nahwitti and Fisherman Rivers in 2018, in two areas adjacent to the Shushartie River in 2019, and within Nahwitti Bog in both 2018 and 2019 (**Figure 1**). Surveys were conducted using 400 to 600 meter (m) spacing between sites except in areas with more extended gaps between stands of forested habitat (e.g., large cut blocks or areas of bog habitat). Surveys were conducted during breeding territory initiation and defense periods (late February through early April) when response rates to CPB are highest (Hausleitner 2006, Kissling et al. 2010) (**Table 1**). Surveys were conducted along transects in each year with 12 to 14 CPB stations per transect. Transects were typically surveyed three times per year on separate nights, except for the Nahwitti River transect which was only surveyed twice in 2018 due to inclement weather.

It should be noted that while logistics necessitated surveying along roads, occupancy rates may vary between areas intersected by roads and more contiguous habitat. Thus, the surveys conducted in this study should be considered “index surveys”. Index survey data are considered valid for comparative purposes with other habitats sampled under the same conditions (i.e., fragmented by roads) but occupancy rates within unfragmented habitats may vary from those reported here.

Table 1 Dates and locations of call-playback surveys for coastal western screech-owl conducted on Northern Vancouver Island in 2018 and 2019

Transect	2018				2019		
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 1	Survey 2	Survey 3
Nahwitti Bog	-	Mar 18	Mar 22	Mar 24	Feb 28	Mar 27	Mar 30
Nahwittii River	-	Mar 19	Mar 21[1]	Mar 23[1]	-	-	-
Fisherman River	Mar 2	-	Mar 20	Mar 23	-	-	-
Shushartie North	-	-	-	-	Feb 27	Mar 26	Mar 31
Shushartie South	-	-	-	-	Feb 26	Mar 28	Mar 29

Note: “-“ indicates no surveys conducted. [1]Incomplete transect with some sites surveyed during the 3rd survey period and some sites surveyed during the 4th survey period.

Analyses were conducted under the assumption of defended territory sizes roughly equivalent to survey site spacing (i.e., 300 to 500 m). This implies that each survey site represents a potential WESOke nesting territory where individuals are assumed to be present during each survey if the territory is occupied. There is no direct evidence on the size of WESOke defended territories within low-productivity CWH forests, and broader ranges (e.g., 65 ha (Davis and Wier 2008), 77 ha (Hausleitner and Dulisse 2011)) have been documented for western screech-owl in the interior and other parts of their range. However, nest spacing of 300 to 400 m was documented by Kennedy (2016) within low-productivity habitat on the central coast of BC, and a review of studies by Cannings et al. (2020) suggests similar nest spacing (300 m) for WESOke under ideal conditions in the Pacific Northwest. Furthermore, there were several instances of immediate WESOke responses to CPB at adjacent stations during the 2018 and 2019 surveys, indicating unique individuals and, thus, unique territories at the survey site spacing applied during this study.

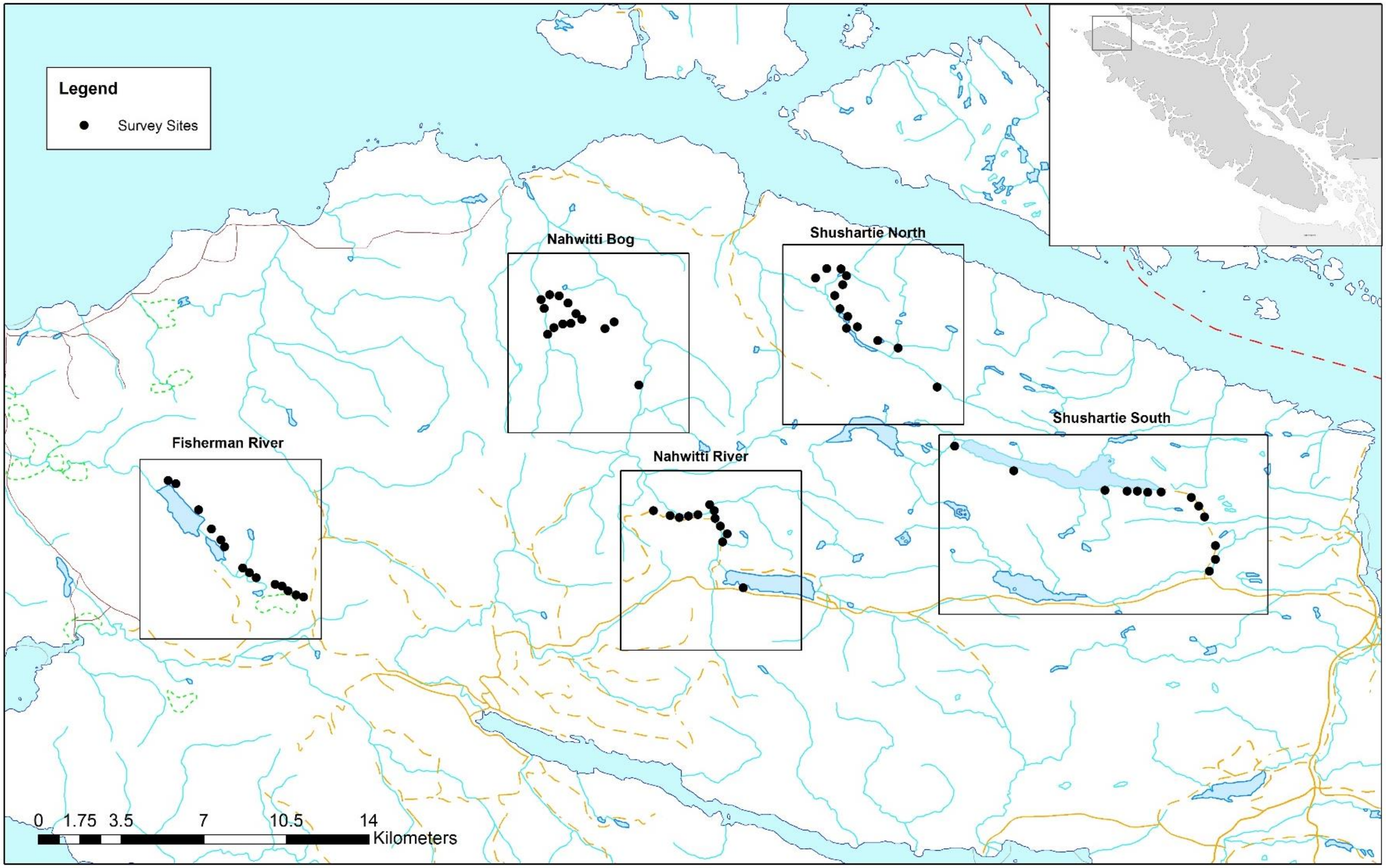


Figure 1 Coastal western screech-owl call-playback survey site locations by transect on northern Vancouver Island (2018, 2019)

2.2 Occupancy modeling

Occupancy modeling is an analytical method used as part of research or monitoring efforts for species that occur in low densities and are difficult to detect (MacKenzie et al. 2002). The method is often applied to owl studies (e.g., Olson et al. 2005, Bailey et al. 2009, Kissling et al. 2010, Clement et al. 2019, Mangan et al. 2019) as it explicitly accounts for the probability that a species occupying a territory may go undetected during a survey. Occupancy modeling utilizes maximum likelihood estimation to determine the most probable rates of occupancy (Ψ) and detection probability (*p*) given a dataset of "presence" and "no detection" records from repeated surveys (hereafter referred to as a 'detection history'). In its simplest form, the method determines what combination of occupancy and detection probability are the most likely for a given set of presence/no detection data. Occupancy analyses can provide estimates of precision for these parameters based on the number of sample sites and repeated surveys, as well as the consistency of detection probability across sites where the target species is recorded at least once. Occupancy models can also include covariates to assess or account for the influence of factors such as habitat characteristics and sampling conditions on occupancy and detection probability.

Appropriate application of occupancy models for determining occupancy status within a territory or sample area requires that each survey site is independent from others and the focal species is/are either present or absent within the sample area during all surveys (i.e., no movement between sample areas so that occupancy status of sample areas does not change over the course of surveys) (MacKenzie et al. 2002, Hayes and Monfils 2015). Evidence for the independence of sample sites from 2018 and 2019 surveys is provided in the last paragraph of **Section 2.1**. The assumption that occupancy status does not change over the course of surveys, termed "closure", can be relaxed for studies assessing usage of sample areas as opposed to occupancy (Latif et al. 2016). In this study, the assumption of closure is met because WESOke maintain and defend territories during the breeding season, when surveys were conducted, and are not known to vocalize outside of defended territories (J. Hobbs, pers. comm.).

MFLNRORD's objectives for long-term monitoring include assessing the influence of habitat variables and barred owl (BDOW) on the WESOke population. Various measures of habitat and BDOW presence/activity levels were considered for inclusion in occupancy models to assess the influence of these variables on WESOke occupancy as an index of population state. Habitat variables for which data were collected at all stations are listed below:

- Elevation
- Canopy closure (percent within 20 m around CPB survey station)
- Number of snags (within 20 m around CPB survey station)
- Rank of the number of mature deciduous trees
- Rank of the percent of deciduous trees in forest
- Rank of understory vegetation

Rankings for the habitat variables listed above are presented within **Appendix B**. An additional habitat variable considered for inclusion in occupancy models was a high level habitat classification (hereafter "habitat class") used to classify transects as one of three types: bog (predominantly open habitat with patches of stunted forest), low productivity forest (predominantly stunted forest with patches of open bog), or high productivity forest (predominantly forested with moderate to full size trees and patches of stunted forest).

Given that one objective of the 2018 and 2019 WESOke surveys was to assess occupancy within low-productivity CWH hypermaritime habitats for comparison with other habitat types, multiple habitat variables were considered and evaluated for inclusion within model selection procedures. Selecting a single variable for inclusion in modeling analysis avoids the potential for data dredging (i.e., finding a spurious relationship of a covariate within a sample dataset by assessing numerous variables). Using a single habitat variable also reduces the potential for multi-collinearity to confound the results given that many habitat covariates are correlated (i.e., vary in tandem and not independently from one another). Using professional judgement, modeling was conducted with the habitat covariate that was anticipated to best represent forest productivity and for which the best data was available. Canopy closure and habitat class both reflect forest productivity, but canopy closure data were collected in the field at each survey site whereas habitat class was assigned afterwards at the transect level. Thus, of the two, canopy closure was considered the more accurate covariate and provided greater resolution given the site-specific data.

As BDOW presence within an area can influence the occupancy and detection probability of other owl species (Mangan et al. 2019), two sources of BDOW data were evaluated for potential model inclusion. Call-playback response data were available from all survey sites, however, autonomous recording units (ARU) deployed at some locations on each transect (**Figure 1**) recorded BDOW where they were not detected by CPB surveys. Given the potential for BDOW to influence WESOke occupancy, measures of BDOW presence/activity incorporating the results of ARU monitoring were considered more likely to appropriately reflect the influence of BDOW on WESOke occupancy than the CPB data alone. Since ARU data was not available at each site, results of BDOW were generalized to the transect area (i.e., to all sites within each transect). Transects were classified in each year as including both CPB and ARU detections of BDOW, multiple ARU detections of BDOW, or as unoccupied by BDOW where ≤ 1 detection of BDOW were recorded by ARU or CPB (**Table 2**).

Covariates considered within models due to anticipated influence on detection probability were those defining distinct temporal or spatial variability within which weather conditions (e.g., wind, temperature), habitat (e.g., vegetation thickness), and WESOke response rates (e.g., peak of breeding season vs. early/late breeding season) can vary. Survey condition and transect were considered as covariates within models given that survey conditions varied across survey nights and habitat, respectively. Survey year was also included as a covariate within models so that surveys conducted during the same survey in separate years (e.g., survey 1 in 2018 and 2019) were always treated as distinct sampling conditions.

To determine which covariates, if any, best accounted for variation in occupancy and detection probability, a model comparison approach was used. The covariates identified for inclusion in the modeling analyses (**Table 2**) were used to develop a set of models that included all possible combinations of covariates as well as models which assumed constant occupancy (i.e., no covariates affecting occupancy). The only covariate which was included in all models was survey year, which as mentioned above, was necessary to distinguish survey conditions in separate years.

Table 2 Parameters, covariates, and levels of covariates assessed within models fit to coastal western screech-owl occupancy rates and detection probability

Parameters	Covariate	Levels of Covariate	Definition
Occupancy (Ψ)	Canopy Closure	0-100%	Percent of area covered by mature tree crowns within a 20-meter radius around CPB survey station.
	BDOWDetect	Unoccupied Multiple ARU ARU+CPB	Classification of the extent to which BDOW was detected within transects. The Unoccupied level indicates the area around the transect is not occupied by BDOW. It includes survey sites within transects from which BDOW were not detected by CPB and inconsistently detected (≤1 detection at any survey site) by ARU. The Multiple ARU level indicates the area around transects is occupied by BDOW with relatively low CPB detection rates. It includes transects where BDOW were detected at multiple ARUs on multiple occasions, but with no CPB not detections. The ARU+CPB level indicates the area around transects is occupied by BDOW with higher CPB detection rates. It includes transects in which BDOW was detected at multiple sites and occasions by both ARU and CPB methods.
Detection Probability (*p*)	Year	2018 2019	Year in which surveys were conducted. Distinguishes sample conditions during the same survey in separate years (e.g., Survey 1 in 2018 vs 2019).
	Survey Condition	Survey 1 Survey 2 Survey 3 Survey 4	Unique survey conditions encompassing one to three consecutive nights. Accounts for variability in temperature and other weather conditions as well as differences in WESOke response rates at different times of the breeding season. Survey 1, 2, and 3 from 2018 and 2019 considered separately (i.e., as distinct survey conditions) due to inclusion of Year in all models.
	Transect	Nahwitti Bog Nahwitti River Fisherman River Shushartie North Shushartie South	Areas where transects were conducted with distinct habitat features (e.g., vegetation thickness).

Note: ARU – Autonomous Recording Unit, BDOW – Barred owl, CPB – call-playback broadcast survey; WESOke – Western screech owl. Data for the covariates identified above were determined for each survey station for each year wherever possible.

Following selection of the model set, all models were fit to the WESOke survey data from 2018 and 2019 using maximum likelihood estimation with the RMark statistical package in R using RStudio (R version 3.5.3). The analysis provides estimates of occupancy (Ψ) and detection probability (*p*) for each level of discrete covariates (i.e., variables with categories) and defines the relationship of continuous covariates with occupancy rates. Models were ranked using Akaike's Information Criteria (AIC) to determine the models, and covariates considered within the models, that best accounted for variation in the WESOke survey data. AIC is an information-theoretic approach that does not restrict variable inclusion into a model based on a variable's significance level (Burnham and Anderson 2002). Models were ranked using Akaike's Second-Order Information Criterion for small sample size (AIC_c) where the highest rank is assigned to the model with the lowest AIC_c value and ΔAIC_c is the difference between each model and the highest ranked model. Models with $\Delta AIC_c < 2$ are considered to have substantial empirical support, models with $\Delta AIC_c \geq 2$ but less than 4 have moderate support, models with $\Delta AIC_c > 4$ are considered to have less support, and models with $\Delta AIC_c > 10$ possess virtually no support (Burnham and Anderson 2002). The specific support for each model, relative to others, is specified with an AIC model weight which sum to 1.0 (i.e., 100%) across all models. Final estimates of, and confidence intervals around, Ψ and *p* were determined using an average of estimates for these parameters across models where the average was weighted towards estimates from the best fit models (i.e., those with the lowest AIC_c values) according to the model weight assigned by the AIC model comparisons.

While model comparisons can identify the best fit model(s) within a model set, a separate analysis is needed to provide a measure of how well survey data fit the model(s). Thus, a goodness of fit test was conducted with PRESENCE software (version 2.12.37) using methods described by MacKenzie and Bailey (2004). This method calculates Pearson chi-square statistics describing the fit of the observed data to the model. The method then compares those statistics to others from data generated with a bootstrapping procedure based on the model predicted values of Ψ and *p* to assess how the observed data deviates from expectation. For this analysis, we used bootstrapping to generate 100 data sets with associated Pearson chi-square (X^2) and test statistics based on the model parameters of the highest ranked model (with $\Delta AIC_c = 0$). A well fit model provides an observed Pearson chi-square statistic close to the average of those generated by bootstrapping analyses. Where this is not the case, a variance inflation factor can be adjusted, and a quasi-likelihood version of AIC (QAIC) can be applied for model selection (MacKenzie and Bailey 2004).

2.3 Power Analyses

Power analyses were conducted according to the methods of Guillera-Arroita and Lahoz-Monfort (2012) using the occupancy rates and detection probabilities observed across levels of the covariate(s) describing the most variation in occupancy, as determined through the model comparison method described above. Specifically, two sets of power curves were developed to illustrate the power to detect change of various magnitudes while varying the number of sites, repeated surveys, and detection probability:

1. Effect sizes (R) ranging from 0 to 1 with 12, 25, 50 and 100 survey sites
2. Repeated surveys (K) ranging from 2 to 7 under minimum, mean, and maximum detection probabilities (p) from each level of the BDOWDetect covariate

Power analyses were conducted under various effect sizes. Declines of 30% and 50% over 10 years have important consequences for owl populations that correspond to endangered and threatened conservation status categories (COSEWIC criteria A1/A2/A3/A4 [IUCN Red List 2001, COSEWIC Wildlife Species Assessments (detailed version) 2015]). For populations with ≤ 2,500 or ≤ 10,000 mature individuals, declines of 20% within 5 years or 10% within 10 years, respectively, can also trigger conservation status listings and are relevant given an estimated WESOke population size of 1,500 to 3,000 (COSEWIC 2012). In addition to the analyses conducted to produce power curves, a series of analyses were conducted to determine the lowest possible effect size that surveys would be likely to detect at the level of effort applied in 2018 and 2019 and the sensitivity of statistical power to variation in the level and allocation of effort (i.e., number of sites and number of repeated surveys) under detection probabilities observed during surveys.

Convention for power analyses is to determine the level of effort required to provide 80% certainty of detecting a difference between sample groups or periods if one exists ($G = 0.80$) while restricting the probability of finding a difference when one does not exist (type I error) to 5% ($\alpha = 0.05$). In other words, conventional α and G thresholds restrict the probability of type I error to 5% while allowing a 20% probability of concluding that there is no difference when one does exist (type II error) (β=0.20 [β=1-G]). 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 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. To assess the sensitivity of statistical power to effect size, we applied a 1 to 1 ratio of these parameters using α and β values of 0.10 and 0.20. Thus, estimated effect sizes under which 80% and 90% power to detect change is anticipated were calculated and summarized under varying numbers of repeated surveys and survey sites as described above. Power curves were developed using α and β values of 0.10 to assess power to detect change given a 10% probability of both type I and type II error.

3.0 RESULTS

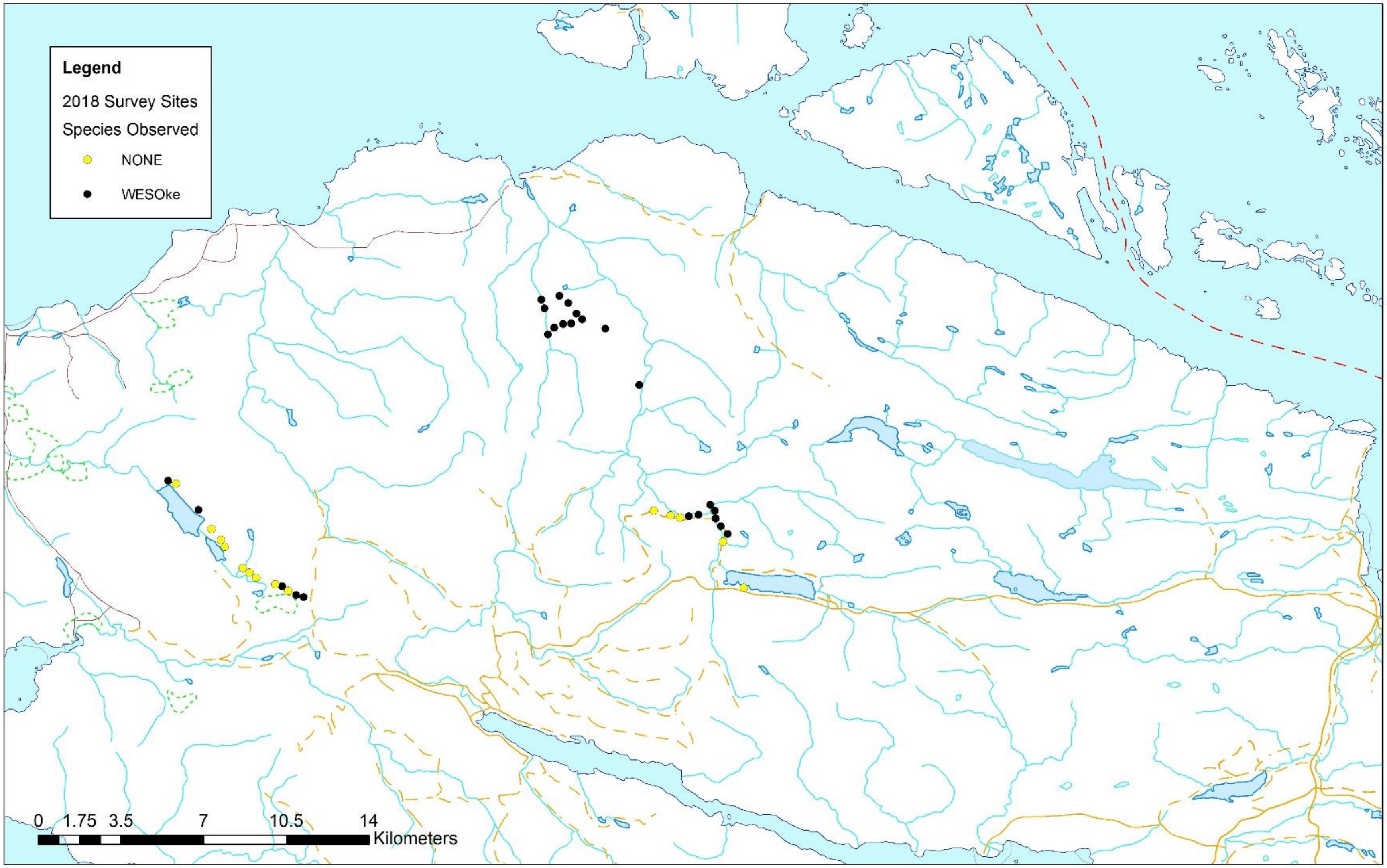
3.1 Survey Results

WESOke were detected by CPB and ARU surveys methods within all transects in both 2018 and 2019. Call-playback surveys detected WESOke at 31% to 100% of sites across transects and years (**Table 3, Figure 2, Figure 3**). The lowest rates of naïve occupancy (i.e., proportion of survey sites where owls were detected) were observed within the Shushartie North transect where BDOW were detected most often and where mean levels of canopy closure were highest relative to other transects (**Table 3**). The highest rates of naïve occupancy were observed along the Nahwitti Bog and Shushartie South transects in the absence of BDOW detections and within predominantly bog habitat and low productivity forest, respectively. The highest rates of WESOke naïve occupancy (1.00) were observed under variable degrees of canopy closure (20.4% to 42.6%). WESOke were detected by CPB within all transects where they were detected by ARU (**Figure 4**, **Figure 5**); however, BDOW were not detected by CPB within two transects (Nahwitti River, Fisherman River) where ARUs did detect them (**Figure 2**, **Figure 4**). Given the results of ARU and CPB surveys, two of the three transects in each year were classified as BDOWDetect level "unoccupied (**Table 3**). The only transects in which BDOW were observed more than once were Fisherman River, with multiple ARU detections, and Shushartie North, with multiple ARU and CPB detections.

Table 3 Results of CPB and ARU surveys for coastal western screech-owl conducted within northern Vancouver Island in 2018 and 2019

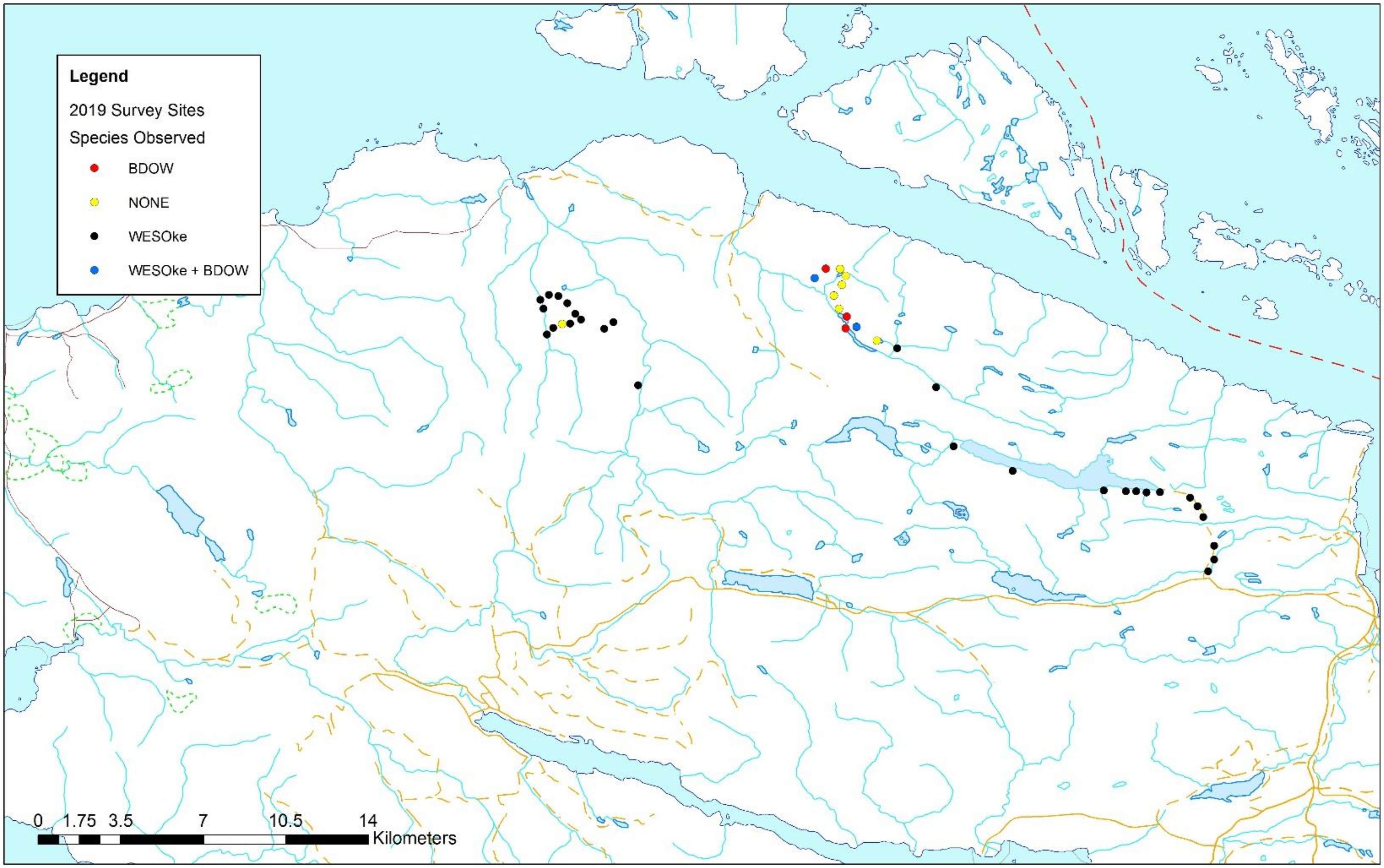
Year	Transect	No. of Survey Sites	No. of Repeated Surveys	Naïve[1] WESOke Occup.	Naïve BDOW Occup.	BDOW Call Bouts/Hour ARU (total hrs)	BDOW[2] ARU Detect.	BDOW Detect Level	Mean % (SD) Canopy Closure
2018	Nahwitti Bog	12	3	1.00	0	0 (532)	0/4	Unocc.	20.4 (9.4)
	Nahwittii River	12	2	0.58	0	0.03 (522)	1/4	Unocc.	34.2 (15.9)
	Fisherman River	14	3	0.36	0	0.18 (633)	4/5	Mult. ARU	38.2 (14.2)
2019	Nahwitti Bog	14	3	0.93	0	0 (2318)	0/8	Unocc.	20.4 (9.4)
	Shushartie North	13	3	0.31	0.62	0.64 (1965)	4/6	ARU+CPB	44.5 (15.0)
	Shushartie South	13	3	1.00	0	0 (1659)	0/6	Unocc.	42.6 (14.7)

Note: CPB – Call-playback broadcast, ARU – Autonomous Recording Unit, BDOW – Barred owl, WESOke – coastal sub-species of western screech-owl. [1]Naïve occupancy is the proportion of survey stations where owls were observed by CPB, not accounting for incomplete detection. [2]Proportion of sites surveyed by ARU where BDOW was detected with the total number of ARU survey sites as the denominator.



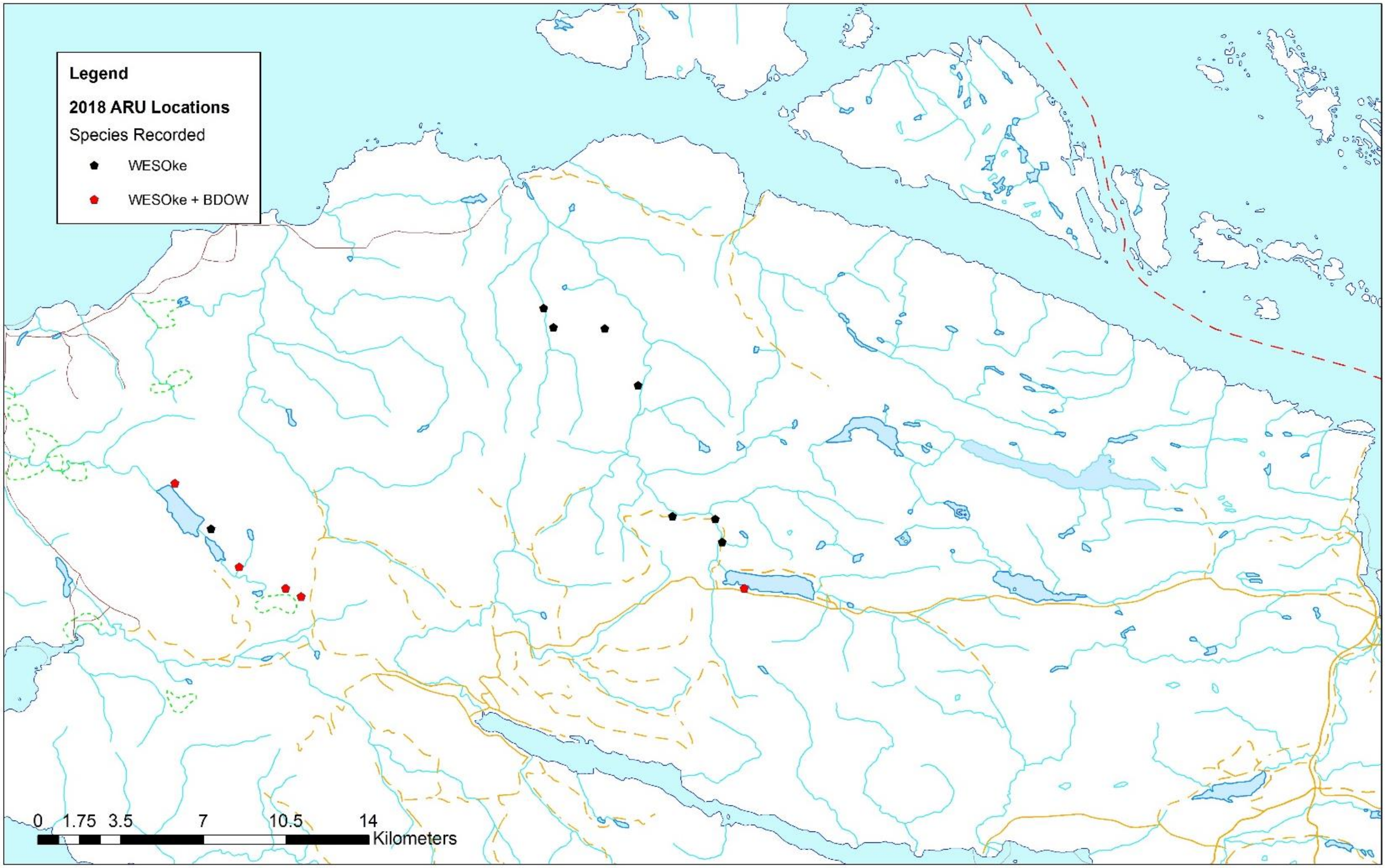
Note: WESOke – western screech-owl (coastal sub-species)

Figure 2 Call-playback broadcast (CPB) survey locations and owl detections from surveys conducted in 2018



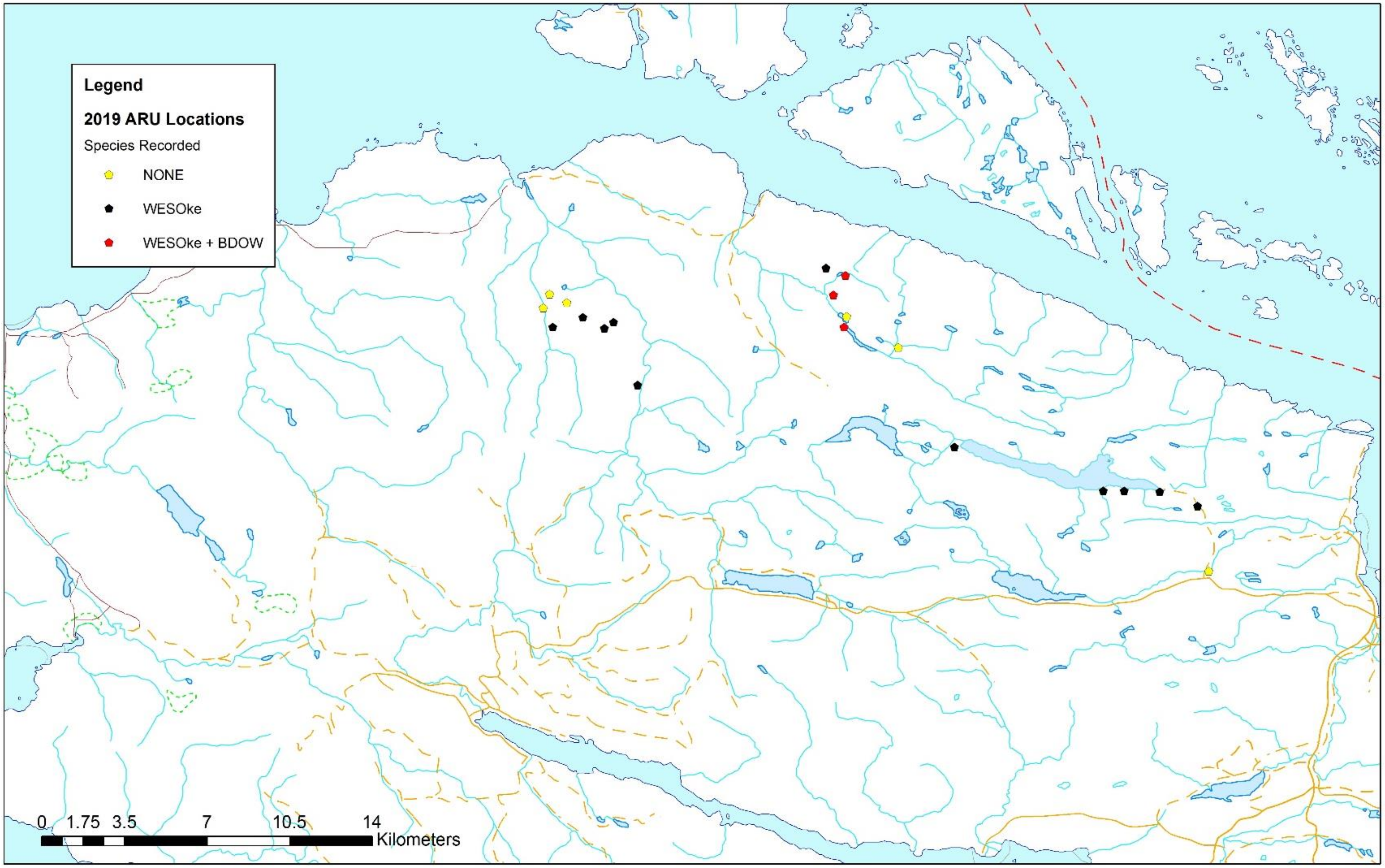
Note: WESOke – western screech-owl (coastal sub-species), BDOW – barred owl

Figure 3 Call-playback broadcast (CPB) survey locations and owl detections from surveys conducted in 2019



Note: WESOke – western screech-owl (coastal sub-species), BDOW – barred owl

Figure 4 Autonomous Recording Unit (ARU) deployment locations and owl detections from surveys conducted in 2018



Note: WESOke – western screech-owl (coastal sub-species), BDOW – barred owl

Figure 5 Autonomous Recording Unit (ARU) deployment locations and owl detections from surveys conducted in 2019

3.2 Occupancy Modeling

Occupancy model fitting and comparisons indicate that detection probability varied across surveys, years, and transects, while occupancy rates were influenced most by the presence of BDOW followed by canopy closure (**Table 4, Figure 2**). There was also some support for a null model in which occupancy was constant across all covariates (i.e., no effect of covariates on occupancy rate) (**Table 4**). The top three models, fit with $\Delta AIC_c < 2$, had 93% of the support from the 2018 and 2019 survey data based on model weighting. Thus, these models were the dominant contributors to model averaged parameter estimates for covariates. Summed AIC weights across models indicated BDOW presence (∑ BDOWDetect = 0.68) had the most influence of WESOke occupancy, followed by canopy closure (∑ CanopClose = 0.45), and the null model (∑ = 0.25). WESOke occupancy within transects where BDOW was detected on multiple occasions by ARU or CPB (BDOWDetect levels: Multiple ARU, ARU+CPB) were significantly lower than within transects with one or no detections (BDOWDetect levels: Unoccupied), as demonstrated by the lack of overlapping confidence intervals around occupancy estimates (**Table 5**). Although WESOke occupancy was lowest within transects where BDOW was detected by CPB in addition to ARU (BDOWDetect level: ARU+CPB), the difference in occupancy estimate relative to Multiple ARU transects (0.09) was not significant given overlapping 95% confidence intervals (**Table 5**). WESOke occupancy was not influenced by canopy closure within sites with one or no BDOW detections, as occupancy was near 100% across the full range of CanopClose values. However, model averaging parameter estimates indicate that WESOke occupancy increases with canopy closure within transects where BDOW was detected on multiple occasions by ARU or CPB. Within such transects, WESOke occupancy increased from 40% to 50% among survey sites with 0% to 30% canopy closure, to >75% occupancy among sites with 70% to 100% canopy cover (**Figure 6**).

Detection probabilities ranged from 0.38 to 0.94 under favorable survey conditions (i.e., temperatures above freezing, no or light precipitation) and were highest in areas where WSOWke occupancy were greatest (e.g., Nahwitti Bog, Shushartie South) (**Table 6**).

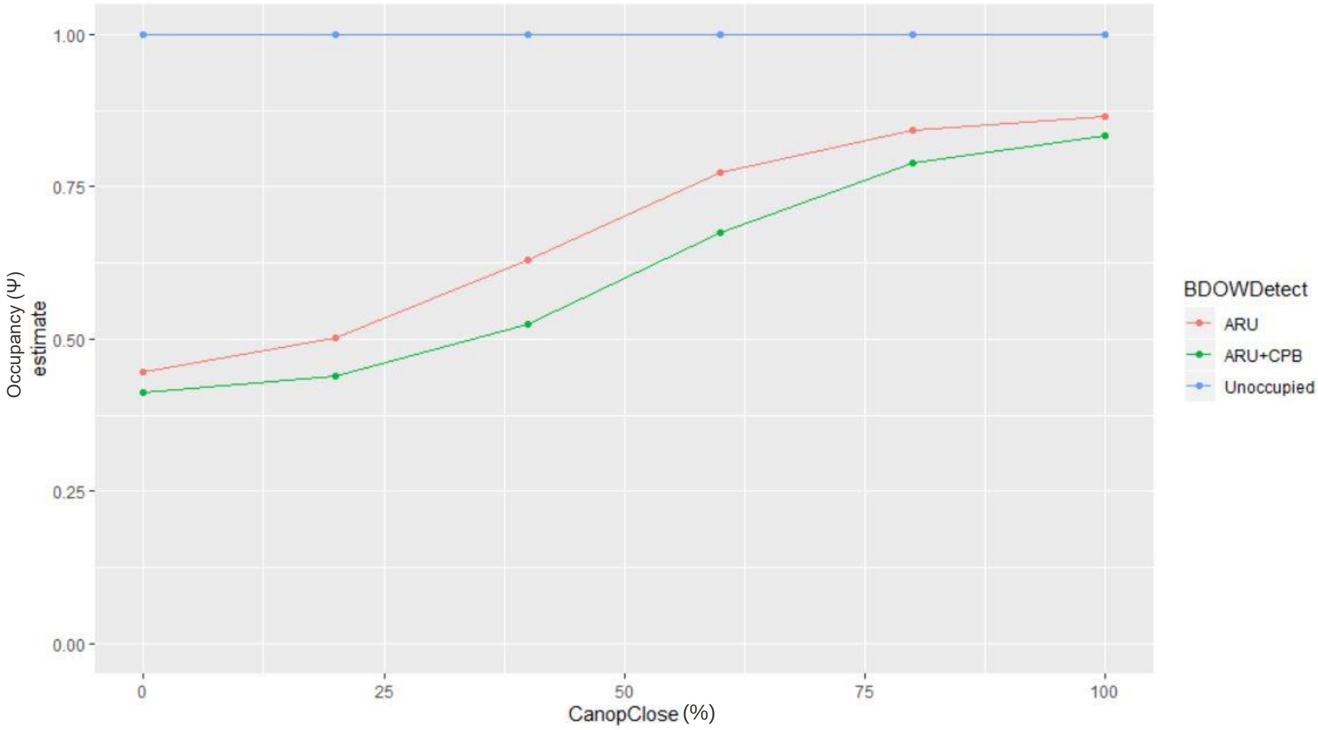
The assessment of model fit conducted for the highest ranked model indicated good fit of the data to the model for most of the observed detection histories ($X^2 < 2.0$). However, detection histories observed from four stations within the Fisherman River transect in 2018 varied from model expectations, particularly those in which WESOke were only detected during the first survey ($X^2 = 41.5$). Due to the discrepancies between observed and expected detection histories, primarily from Fisherman River, the observed test statistic was 3.4 times greater than the average bootstrapped generated test statistic ($X^2_{observed} / \bar{X}^2_{bootsrapped} = 3.4$, defined as ĉ). This result indicates that there was more variation in the observed data than expected by the model. Thus, the observed ĉ value of 3.4 was applied as a variance inflation factor and a quasi-likelihood version of AIC (QAIC) was used to conduct an adjusted model selection process (MacKenzie and Bailey 2004).

Model selection results and estimates of occupancy and detection probability under variance adjusted QAIC model comparisons generally aligned with the unadjusted results (assuming ĉ ≈ 1) presented below, with two notable exceptions. There was less support ($\Delta AIC_c<5$ rather than $\Delta AIC_c<2$) for models with transect as a detection probability covariate. This result indicates that variation in survey conditions (e.g., temperature, precipitation) may have greater influence over *p* than habitat features (e.g., vegetation thickness) or BDOW presence. Also, variance adjusted models yielded a smaller range of detection probabilities (p = 0.22 to 0.79) compared to the unadjusted results (**Table 6**).

Table 4 Model set and model comparison results from coastal western screech-owl occupancy analyses using Akaike's information criterion (AIC) ranking and weighting

Detection Probability (*p*)	Occupancy (Ψ)	Number of Parameters	AIC_c	ΔAIC_c	Weight
Year + Survey Cnd. + Transect	CanopClose + BDOWDetect	13	234.18	0.00	0.45
Year + Survey Cnd. + Transect	*Constant*	10	235.33	1.14	0.25
Year + Survey Cnd. + Transect	BDOWDetect	12	235.48	1.29	0.23
Year + Survey Cnd. + Transect	CanopClose	11	238.04	3.86	0.06
Year + Survey Cnd.	CanopClose + BDOWDetect	9	245.46	11.28	0.00
Year + Survey Cnd.	BDOWDetect	8	246.63	12.45	0.00
Year + Transect	*Constant*	7	259.07	24.89	0.00
Year + Transect	BDOWDetect + CanopClose	10	259.20	25.01	0.00
Year + Transect	BDOWDetect	9	260.60	26.41	0.00
Transect + Year	CanopClose	8	261.56	27.37	0.00
Year + Survey Cnd.	CanopClose	7	265.53	31.35	0.00
Year + Survey Cnd.	*Constant*	6	265.91	31.73	0.00
Year	BDOWDetect + CanopClose	6	270.19	36.01	0.00
Year	BDOWDetect	5	272.29	38.10	0.00
Year	*Constant*	3	297.25	63.07	0.00
Year	CanopClose	4	297.27	63.09	0.00

Note: Models including the term "*Constant*" indicate that the associated parameter (Ψ) is the same across all surveys and stations and the parameter does not change with any covariate.



Note: Unoccupied – coastal screech-owl (WESOke) occupancy from transects in which barred owl (BDOW) were not detected by call-playback broadcast (CPB) surveys and inconsistently detected (≤1 detections at any survey site) by autonomous recording units (ARU); ARU – WESOke occupancy from transects in which BDOW were detected at multiple ARUs on multiple occasions, but with no CPB not detections; ARU+CPB – WESOke occupancy from transects in which BDOW was detected at multiple sites and occasions by both ARU and CPB methods.

Figure 6 Coastal western screech-owl occupancy rates in supported models (ΔAIC_c<2) under different levels of barred owl detections and across estimates of canopy closure

Table 5 Model averaged coastal western screech-owl (WESOke) occupancy results

Levels of BDOWDetect Covariate	WESOke Occupancy (Ψ) Parameter Estimate	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
ARU+CPB	0.49	0.38	0.05	0.95
Multiple ARU	0.58	0.33	0.09	0.95
Unoccupied	1.00	<0.01	>0.99[1]	1.00[1]

Note: BDOW – Barred owl. [1]Lower and upper confidence intervals around the Ψ parameter estimate for "Unoccupied" transects could not be determined by model averaging and were taken from the best fit model for which the parameter estimate was also 1.00.

Table 6 Model averaged coastal western screech-owl detection probabilities results under variable survey conditions across years, and across transects

Transect	2018				2019			Range Under Favorable Conditions[3]
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 1	Survey 2	Survey 3	
Nahwitti Bog	-	0.94	0.88	0.68	0.17[3]	0.74	0.58	0.58-0.94
Nahwittii River	-	0.49	0.31[1]	0.12[1]	-	-	-	0.49
Fisherman River	0.15[2]	-	0.53	0.26[2]	-	-	-	0.53
Shushartie North	-	-	-	-	0.09[2]	0.54	0.38	0.38-0.54
Shushartie South	-	-	-	-	0.31[2]	0.86	0.75	0.75-0.86

Note: [1]Survey conducted over two nights: Survey 3 had periods of moderate rain, Survey 4 had steady snow at times and temps down to -2 °C. [2]Low detection probability during temps ranging from 1 to -6 °C with most surveys conducted at or below zero. [3]Range under favorable conditions excludes estimates of detection probability from surveys conducted under freezing temperatures or moderate to heavy precipitation.

3.3 Power Analysis

Power curves were generated from analyses conducted on occupancy estimates from each level of the BDOWDetect covariate (Unoccupied, Multiple ARU, ARU+CPB), as model comparison analyses indicated this covariate had the greatest influence on WESOke occupancy. Average detection probabilities used to generate power curves for each level of BDOWDetect were calculated as the mean value across transects surveyed conducted under favorable survey conditions (**Table 6**). Estimated effect sizes under which 80% and 90% power to detect change is anticipated are presented in **Table 7**, **Table 8**, and **Table 9**.

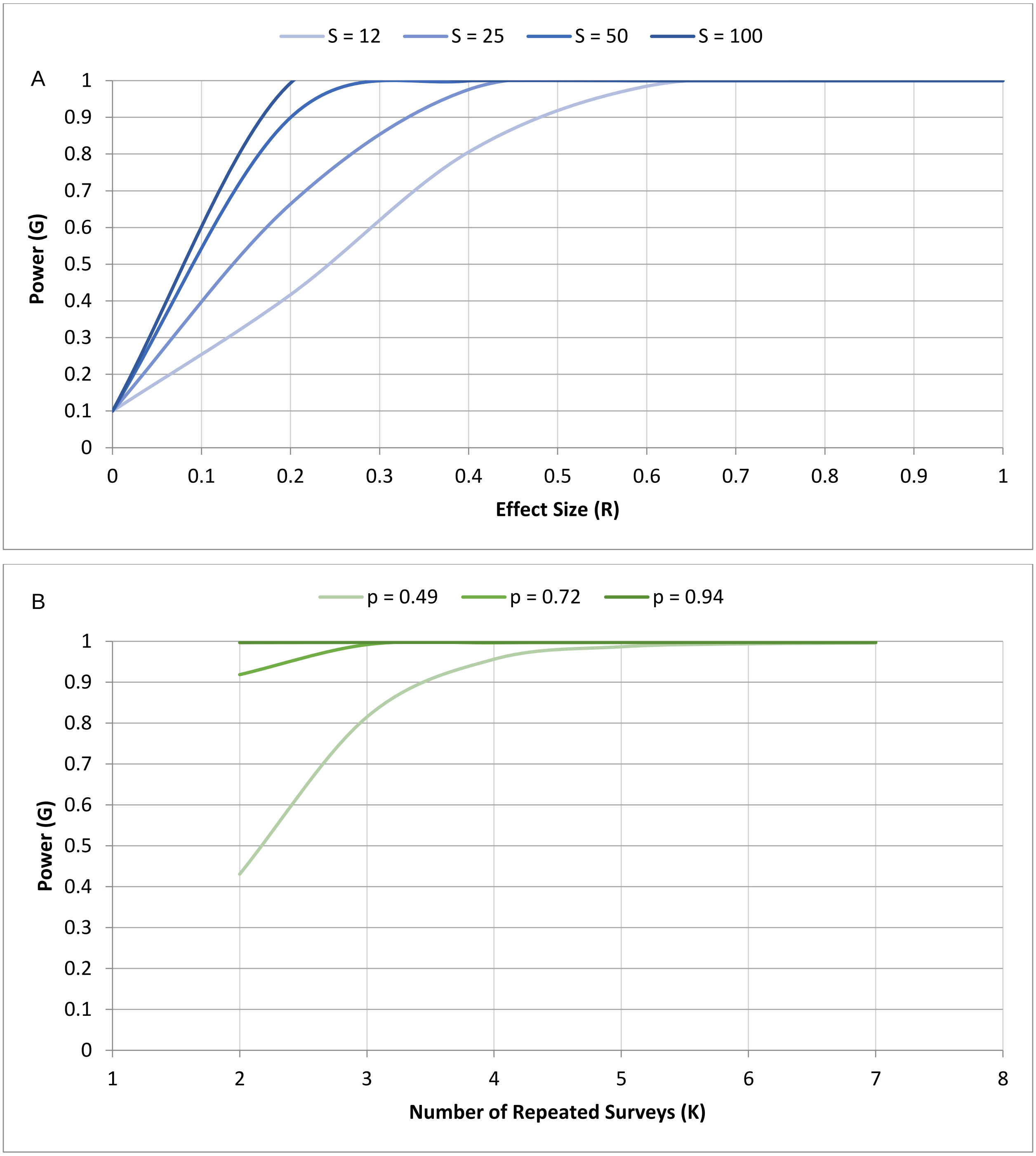
Power curves presented for the Unoccupied level of the BDOWDetect covariate illustrate power to detect change in WESOke occupancy under the conditions present within the Nahwitti Bog, Nahwitti River, and Shushartie South transects, where BDOW were seldom or not at all detected during surveys (**Figure 7**). Due to the high rates of occupancy (near 100%) and detection probability (mean 0.72) observed within these transects, analyses indicate generally strong power to detect change. More specifically, power curves assuming three repeated surveys suggest that survey efforts under these conditions would have 90% power to detect a ~48% change in occupancy with 12 survey sites and a ~33% change with 25 sites. However, even with the high rates of occupancy and detection probability observed, 50 sites would be required to have the same power to detect a 20% change in occupancy and additional sites would yield diminishing returns in power, requiring over 100 sites to detect a change of 10% or less, even if the standards for effect threshold (α) and power (G) are relaxed to 0.20 and 80%, respectively (**Table 7**). Additionally, high detection probability at these sites results in limited gains in power with more than two repeated surveys (**Table 7, Figure 7**), although there were occasions with lower detection probabilities (minimum 0.49) under which power almost doubles with a 3rd survey and increases substantially with a 4th survey (**Figure 7B**). Power curves illustrating the power to detect change in occupancy under a range of observed detection probabilities (**Figure 7B)** were developed assuming 50 survey sites, roughly equivalent to the level of effort that would be achieved by four of the transects applied in this study.

Table 7 Estimated effect sizes of WESOke occupancy detectable with 80% and 90% power under varied numbers of repeated surveys and sites from transects with no CPB barred owl detections and ≤1 detection by ARU

Power (%) Effect threshold (α)	Repeated Surveys (K)	Estimated Effect Size (R) Under Various No. of Sites			
		12 Sites	25 Sites	50 Sites	100 Sites
80% α = 0.20	2	0.45	0.32	0.22	0.15
	3	***0.33***	0.21	0.15	0.14
	4	0.31	0.18	0.14	0.13
90% α = 0.10	2	0.59	0.43	0.33	0.21
	3	***0.48***	0.33	0.20	0.17
	4	0.45	0.30	0.18	0.17

Effect Size (R) ≤ 0.20
0.30 ≥ Effect Size (R) > 0.20
0.50 ≥ Effect Size (R) > 0.30
Effect Size (R) > 0.50

Note: WESOke – western screech owl (coastal sub-species), CPB – Call-playback broadcast, ARU – Autonomous Recording Unit. Determinations based on occupancy of 0.99 and detection probability of 0.72 (mean across all combinations of transects and survey conditions for surveys conducted under favorable conditions). Bolded and italicised values describe effect sizes detectable under the level of effort applied within a single transect in this study.



Note: The following values are held constant unless otherwise specified: Ψ = 0.99; α = 0.10; R = 0.3; p = 0.72; S = 50; K=3; where Ψ = occupancy documented within transects unoccupied by barred owl, α = significant effect threshold, R = effect size, *p* = detection probability, S = number of survey sites, K = number of repeated surveys.

Figure 7 Power curves demonstrating the power to detect change in coastal western screech-owl occupancy in areas unoccupied by barred owl and illustrating sensitivity to (A) the number of sample sites under the mean detection probability, and (B) the number of repeated surveys under the range of observed detection probabilities

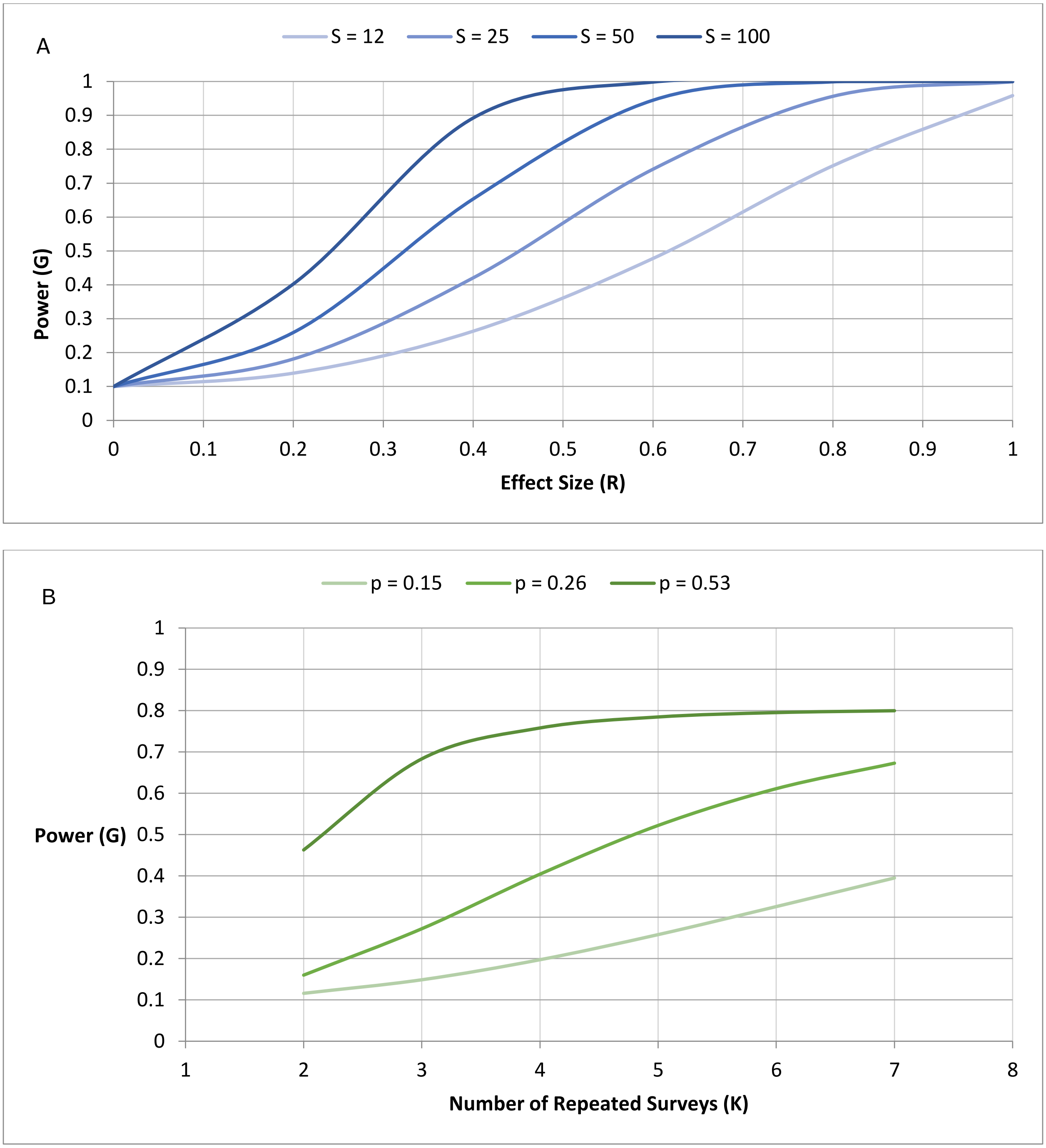
Relative to areas unoccupied by BDOW, there will be low power to detect change or differences in WESOke occupancy where multiple ARU detections of BDOW but no CPB detections were recorded (e.g., Fisherman River; BDOWDetect level: Multiple ARU) (**Figure 8**). Power curves suggest that, under the reported occupancy (0.58) and detection probability (0.53) and an alpha level of 0.10, the survey effort applied to most transects in this study (S=12, K=3) would only provide 90% power to detect an 89% or greater change in WESOke occupancy. Under these conditions, 50 sites would provide 90% power for detection of a 56% change (i.e., effect size) in WESOke occupancy, but more than 100 sites would be required to detect a change of 30% (**Table 8**, **Figure 8A**). If effect (α) and power (G) thresholds are relaxed to 0.20 and 80%, respectively, 50 sites with three repeated surveys would provide the power necessary to detect changes of under 50%, and 100 sites could detect changes around 30% (**Table 8**). The levels of detection probability observed at these sites result in gains in detectable effect size of 8 to 19% with a 3rd repeated survey and an additional gain of 3 to 5% with a 4th survey (**Table 8, Figure 8**). Power curves illustrating the power to detect change in occupancy under the range of observed detection probabilities (**Figure 8B**) were developed assuming 100 survey sites, roughly equivalent to the level of effort that would be achieved by eight transects or three years of surveys at the level of effort applied in this study.

Table 8 Estimated effect sizes of WESOke occupancy detectable with 80% and 90% power under varied numbers of repeated surveys and sites from transects with multiple (>1) ARU detections of barred owl

Power (%) Effect threshold (α)	Repeated Surveys (K)	Estimated Effect Size (R) Under Various No. of Sites			
		12 Sites	25 Sites	50 Sites	100 Sites
80% α = 0.20	2	0.93	0.72	0.54	0.40
	3	***0.75***	0.56	0.42	0.32
	4	0.71	0.52	0.38	0.29
90% α = 0.10	2	NA	0.92	0.72	0.54
	3	***0.94***	0.73	0.56	0.41
	4	0.89	0.68	0.52	0.38

Legend
0.30 ≥ Effect Size (R) > 0.20
0.50 ≥ Effect Size (R) > 0.30
Effect Size (R) > 0.50
NA – Insufficient sites to detect any effect size with the specified power

Note: WESOke – western screech-owl (coastal sub-species). Determinations based on occupancy of 0.58 and detection probability of 0.53 (detection probability under favorable survey conditions). Bolded and italicised values describe effect sizes detectable under the level of effort applied within transects.



Note: The following values are held constant unless otherwise specified: Ψ = 0.58; α = 0.10; R = 0.3; p = 0.53; S = 100; K=3; where Ψ = occupancy documented within transects with multiple barred owl detections by ARU, α = significant effect threshold, R = effect size, *p* = detection probability, S = number of survey sites, K = number of repeated surveys.

Figure 8 Power curves demonstrating the power to detect changes in coastal western screech-owl occupancy in areas with multiple (>1) ARU detections of barred owl and illustrating sensitivity to (A) the number of sample sites under the mean detection probability, and (B) the number of repeated surveys under the range of observed detection probabilities

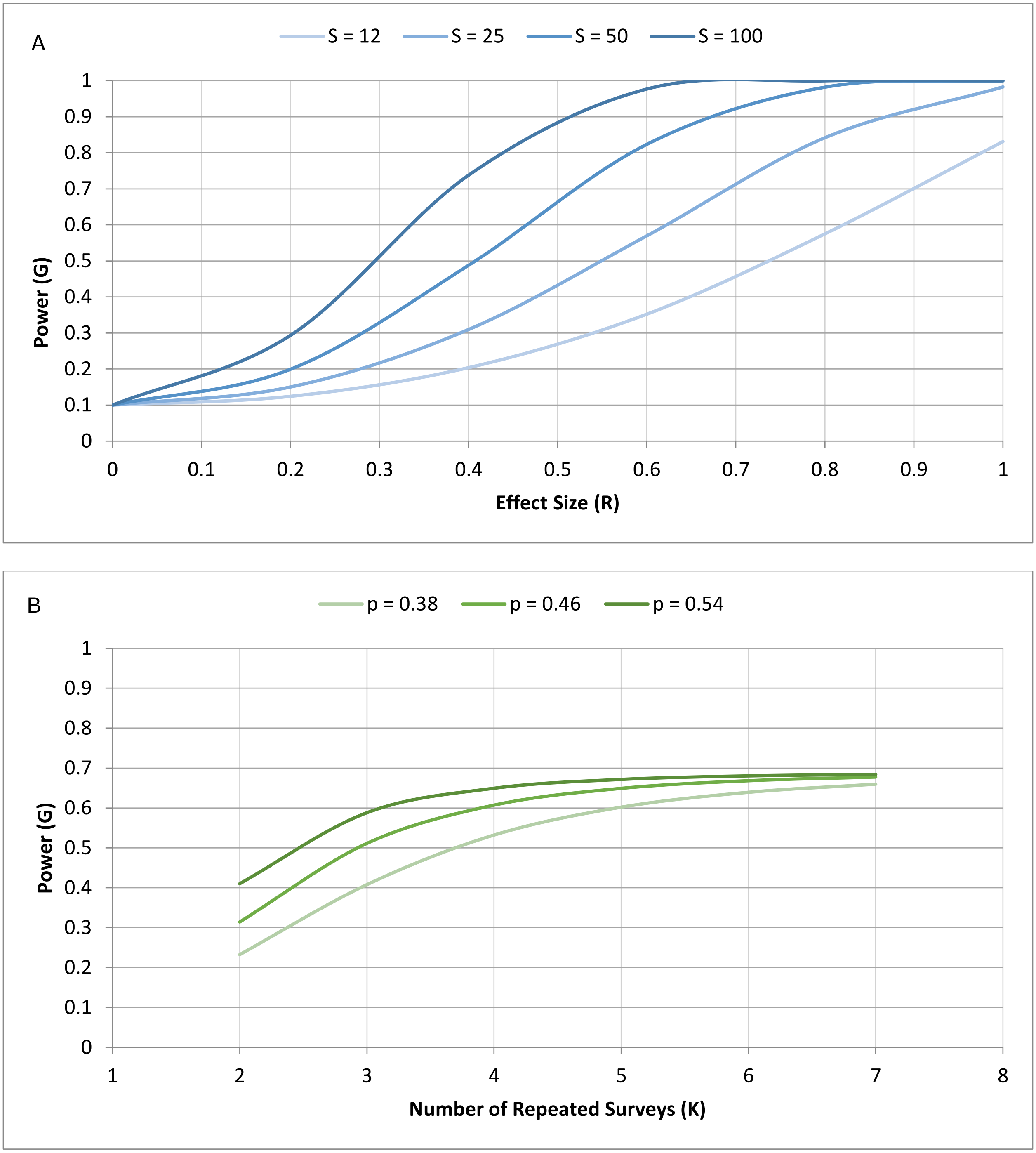
Power curves presented for the ARU+CPB detection level of the BDOWDetect covariate represent the power to detect change or differences in occupancy within the Shushartie North transect, where BDOW presence and/or response levels are indicated to be greatest of all areas surveyed (**Figure 9**). With relatively low rates of occupancy (0.49) and moderate detection probability (mean 0.46), analyses indicate relatively low power to detect change under conditions observed in areas with ARU+CPB detections of BDOW. The power curves indicate that survey efforts under these conditions would require more than 100 sites to provide 90% power to detect a 50% change in WESOke occupancy (**Figure 9**). The survey effort applied to most transects during this study (S=12, K=3) would be insufficient to detect an effect size <80% with 80% or 90% power. Approximately 50 sites would be required to detect an effect size of 50%, with effect (α) and power (G) thresholds reduced to 0.20 and 80%, respectively (**Table 9**). The levels of detection probability observed at these sites result in gains in detectable effect size of 15 to 22% with a 3rd repeated survey, and an additional gain of 7 to 9% with a 4th survey (**Table 9, Figure 9**). Power curves illustrating the power to detect change in occupancy under the range of observed detection probabilities (**Figure 9B**) were developed assuming 100 survey sites, roughly equivalent to the level of effort that would be achieved by eight transects or three years of surveys at the level of effort applied in this study.

Table 9 Estimated effect sizes of WESOke occupancy detectable with 80% and 90% power under varied numbers of repeated surveys and sites for study areas with multiple ARU and CPB detections of barred owl

Power (%) Effect threshold (α)	Repeated Surveys (K)	Estimated Effect Size (R) Under Various No. of Sites			
		12 Sites	25 Sites	50 Sites	100 Sites
80% α = 0.20	2	NA	0.89	0.69	0.52
	3	***0.89***	0.68	0.52	0.37
	4	0.80	0.61	0.46	0.34
90% α = 0.10	2	NA	NA	0.89	0.68
	3	***NA***	0.87	0.67	0.52
	4	0.98	0.78	0.60	0.45

0.50 ≥ Effect Size (R) > 0.30
Effect Size (R) > 0.50
NA – Insufficient sites to detect any effect size with the specified power

Note: WESOke – western screech owl (coastal sub-species). Determinations based on occupancy of 0.49 and detection probability of 0.46 (mean across all combinations of transects and survey conditions for surveys conducted under favorable conditions). Bolded and italicised values describe effect sizes detectable under the level of effort applied within transects.



Note: The following values are held constant unless otherwise specified: Ψ = 0.49; α = 0.10; R = 0.3; p = 0.46; S = 100, K=3; where Ψ = occupancy documented within transects with barred owl detections by ARU and CPB, α = significant effect threshold, R = effect size, *p* = detection probability, S = number of survey sites, K = number of repeated surveys.

Figure 9 Power curves demonstrating the power to detect changes in coastal western screech-owl occupancy in areas with barred owl detections from both ARU and CPB surveys and illustrating sensitivity to (A) the number of sample sites under the mean detection probability, and (B) the number of repeated surveys under the range of observed detection probabilities

4.0 DISCUSSION

Apart from the development of this report, the objectives of the study were to: 1) summarize occupancy and detection probability statistics for WESOke from 2018 and 2019 survey data; 2) determine the level of effort required to detect changes in occupancy of various magnitude and factors affecting occupancy; and 3) determine the optimal allocation of survey effort under the observed conditions to inform the design of future studies.

4.1 Occupancy and Detection Probability Estimates Relative to Prior Findings

Occupancy rates observed during this study are high (ranging from 0.49 to 1.00) relative to those reported in Hemmera's 2017 review in which were typically <0.20 and often <0.10 (Hemmera 2017). Survey and occupancy modeling results from the 2018 and 2019 northern Vancouver Island study provide encouraging evidence that low-productivity CWH hypermaritme forests support relatively abundant populations of WESOke in BC outside the central coast.

Another interesting finding from this study was relatively high WESOke response rates (i.e., detection probability) in areas with higher occupancy rates. Detection probabilities exceeded 0.70 during multiple surveys (**Table 6**), more than double the rate reported from most prior studies from which we determined an average detection probability of 0.33 (Hemmera 2017). Increased detection probability under high occupancy rates may be due to more active territory defense or competition for mates in areas where WESOke density is higher. Alternatively, the presence of BDOW could reduce responsiveness of WESOke if vocalizations increase harassment or risk of predation where the two species co-occur (Olson et al. 2005). Reduced response rate in the presence of BDOW has been documented in multiple studies of spotted owl (*Strix occidentalis*) conducted in Oregon and Washington (Olson et al. 2005, Bailey et al. 2009, Mangan et al. 2019). In the analyses conducted for this study, the impact of BDOW presence on WESOke detection probability was accounted for within the transect covariate as BDOW presence varied by transect. The highest detection probabilities were found within Nahwitti Bog and Shushartie South, two of the three transect areas unoccupied by BDOW (**Table 6**).

Estimates of WESOke occupancy could be refined with improved measures of covariates or if alternative covariates can be identified to provide better fit of models to the data. Model comparison results applied in this study supported a constant occupancy model with an estimated WESOke occupancy rate of 1.0 (i.e., 100%) in all areas, but also supported occupancy estimates of less than 0.42 in areas where BDOW are present. Contradictory results such as these reduce our confidence in the accuracy of model averaged estimates and would likely be avoided with better fit models.

4.2 Level of Effort Required to Detect Change in Occupancy

Power analyses presented here and within peer-reviewed scientific literature (e.g., MacKenzie and Royle 2005), consistently show that higher occupancy and detection probabilities provide more power to detect change or differences in occupancy. While the level of effort expended in 2018 and 2019 has provided valuable information and may be enough to detect changes in population as small as 20% in areas where occupancy is near 100%, greater survey effort would be needed in areas where BDOW occur. More specifically, while 12 to 25 sites will allow for detection of changes in magnitude of 50%, or even 30% in areas where occupancy is close to 100% (**Table 7**), detecting changes of 20% would require 50 or more sites.

Detecting change in occupancy rates in areas occupied by BDOW, where WESOke occupancy was 0.49 (BDOWDetect level ARU+CPB) and 0.58 (BDOWDetect level Multiple ARU), will require greater effort. Specifically, more than 50 sites would be needed to have 90% power of detecting a 50% change in occupancy while maintaining an equal probability of type I and type II error (i.e., α = 0.10). Greater numbers of sites would be required to detect smaller differences or changes in occupancy (e.g., >100 sites to detect a 30% change). This can be accomplished by adding additional sites within survey years or continuing surveys in multiple years. The results of analyses presented herein reflect the power to detect a difference in occupancy between two seasons with the same number of sites surveyed in each season (Guillera Arroita and Lahoz Monfort 2012). In other words, the results reflect power to detect the specified magnitude of change between two independent (either in space or time) single-season studies (e.g., 2018 vs. 2019). Extending studies beyond two survey years will provide additional power and can reduce the number of sites required to detect differences in occupancy rates.

A 90% power threshold, where α and β = 0.10, allows for a 10% probability of incorrectly concluding a significant change or difference in occupancy when one does not exist (type I error) and a 10% probability of not detecting a change when one does (type II error). While smaller numbers of sites can provide significant results if α and β thresholds are relaxed to 0.20, this would result in a 40% cumulative likelihood of type I or II error, which may fail to provide the degree of certainty necessary for management decisions. Alternatively, α and β thresholds of 0.125 (allowing for 87.5% power to detect change) would provide the same total likelihood of error as the conventional standard for power analysis (25%, where α = 0.05; β = 0.20) and allow for a modest decrease in sample size requirements relative to a threshold of 0.10 required for 90% power.

The level of effort required to detect change in occupancy will be reduced if alternative covariates can be identified, or measures of covariates considered here are improved, to better account for variation in survey results. Improved standardisation of survey conditions or inclusion of detection probability covariates such as temperature, precipitation, and wind speeds in place of the survey condition covariate could be explored as potential means of improving model fit.

4.3 Optimal Allocation of Survey Effort

Optimal allocation of survey effort can be informed by results of sensitivity analyses presented in **Table 7**, **Table 8**, and **Table 9**. These results indicate that a maximum of three repeated surveys is most appropriate in areas with detection probability ≥70% (**Figure 7**), while a fourth survey may be beneficial in areas where detection probability is lower, particularly where <50% (**Figure 8B, Figure 9B**). These results align with those reported by Mackenzie and Royle (2005) in an assessment of optimal study design which suggest a maximum of two repeated surveys in areas where detection probability is close to or exceeding 80% as was often the case within the Nahwitti Bog and Shushartie North transects (**Table 6**). Thus, if surveys are continued and detection probability can be maintained above 75% in these transects, power would likely be gained by re-allocating the effort required for a third survey at such sites to areas with lower detection probability. In the case of the areas assessed on northern Vancouver in this study, this could be applied by reducing effort within areas unoccupied by BDOW (e.g., Nahwitti Bog, Shushartie North) to two repeated surveys and adding a fourth survey in areas with lower detection probability (e.g., Fisherman River, Shushartie South). For areas of interest that have yet to be surveyed for WESOke, prior deployment of ARUs could inform the presence of BDOW and, thus, the optimal number of repeated surveys.

Trade-offs in the allocation of survey effort across sites and years are also important to consider within the context of resource availability over the long- and short-term. Increasing the number of sites from 50 to 100 or 200 can double or triple the power to detect change during studies conducted over one to three years (MacKenzie 2005). However, the gains in power attained by increasing the number sites diminish over time if surveys continue in subsequent years. For example, if resources are available for 10 years of surveys, a study with 100 or 200 sites might only provide marginally more power than a study with 50 sites (MacKenzie 2005). Similar diminishing rates of return on power are evident within **Figure 7A**, where an increase from 12 to 25 sites provides the same gains in power as an increase from 25 to 50 and relatively little power is gained by increasing the number of sites to 100.

In a multi-year study, effort can be allocated at the same sites each year (e.g., simple design) or rotated across different areas (e.g., rotating design) to assess different habitats or to encompass a broader portion of an area of interest (MacKenzie and Royle 2005). Surveying all new sites each year is not recommended as variation across habitats would be confounded with inter-annual variation (MacKenzie 2005). A hybrid design, in which most survey areas stay the same across years and some are rotated out, allows for modeling to accurately account for and assess temporal trends as well as factors varying across survey areas. Such a hybrid approach also provides the flexibility to adapt to unforeseen changes to the study area (e.g., fire, logging) (C. Schwarz, pers. comm). If the study objectives are primarily to assess temporal trends, it is likely best to rotate relatively few areas each year (e.g., one of three in the case of this study). However, if the objectives are primarily to assess the influence of variables such as the presence of BDOW or canopy closure, it may be more informative to sample a broader variety of habitat at the cost of reducing certainty in interannual trends in occupancy. If long-term funding is available and there is no immediate need to identify factors influencing occupancy, both objectives could be achieved by rotating a small proportion of sites each year over several years.

An important consideration regarding allocation of survey efforts is the research objective. Data from the 2018 and 2019 surveys demonstrate a stark difference in WESOke occupancy rates between areas occupied by BDOW versus not. The 2018 and 2019 surveys resulted in near 100% occupancy of sites when BDOW were not detected. Thus, evidence from these surveys indicates that WESOke likely occupy all CWH hypermaritime habitat when BDOW occurrence is absent or irregular and provide no variability in occupancy with which to assess WESOke habitat preferences in the absence of BDOW. While inference on covariate relationships with WESOke occupancy would be limited in areas with near 100% occupancy, additional survey data from such areas could be used to track long term trends in occupancy (e.g., impacts from intrusion of BDOW should it occur in the future). Furthermore, occupancy models coding for three states of occupancy (unoccupied, occupied by a single WESOke individual, occupied by a WESOke breeding pair) could be used to assess change in, or covariates affecting, the proportion of sites occupied by breeding pairs. Such models, known as multi-state models, require more data than the models applied in this study (i.e., single-state models) and would, thus, likely require more survey effort.

Further use of single-state models can be used to verify and refine our understanding the factors driving variability in WESOke occupancy within areas occupied by BDOW. Findings from the 2018 and 2019 surveys from northern Vancouver Island indicate that WESOke occupancy is near 100% where BDOW is absent and where BDOW is present WSOWke are more abundant in habitat with greater canopy closure. This suggests that BDOW presence is driving WESOke occupancy rates rather than habitat productivity as indicated by the extent of vegetative cover. While a positive relationship between canopy closure and

WESOke occupancy was not anticipated in this study considering the high occupancy rates of WESOke observed in more open bog and bog forest habitats, the finding is in line with expectations from surveys in river valley, mixed deciduous habitat (see habitat scores within **Appendix B**). Increased canopy cover may provide shelter from predation in habitat where BDOW are present. Subsequent studies may endeavour to assess the impact of additional habitat variables on WESOke occupancy or an adapted version of canopy closure that encompasses a broader area (i.e., beyond the 20 m around CPB sites) to see if the positive relationship identified in this study can be confirmed. Another challenge to consider is how to distinguish between habitat and BDOW effects on WESOke occupancy within habitat occupied by BDOW. Having better evidence at the survey site level of where BDOW occur may help to tease out the effect of BDOW from habitat. This could be accomplished using expanded application of ARU survey methods given that BDOW were more often detected by ARU than by CPB with WESOke territory defense calls.

Considering that the presence of BDOW has an important influence on WESOke occupancy rates, continued use of ARUs is recommended for future studies. Given the advantages of ARU over CPB survey methods for multi-species detections, further consideration should also be given to the potential for ARU methods alone to effectively meet the objectives of long-term monitoring. Using ARUs alone for screech-owl studies may prove challenging given the number of sites required to detect change in occupancy and the cost of ARUs. Furthermore, replacing CPB with ARU surveys would also require proof that ARU survey data would be comparable to historical data from CPB surveys. Comparable data would be necessary to provide continuity in the development of long-term and broad-spatial scale data sets which could be key resources for assessment of factors that influence occupancy and drive population trends. Until this is shown and standardized protocols for ARU monitoring of screech-owls have been developed and vetted, it would be prudent to continue using CPB survey methods for this and other long-term studies.

4.4 Long-term Monitoring Objectives

In addition to meeting the study objectives, the results and discussion above also address and inform some of MFLNRORD's long-term monitoring objectives for WESOke. Occupancy rates for WESOke were not consistent across the habitat types examined in this study (e.g., bog, low-productivity forest, high productivity forest). While occupancy rates were 1.00 in bog habitat and were lowest within high productivity forests within the Shushartie North transect, they were highly variable across low-productivity forests (e.g., Shushartie South, Fisherman River) (**Table 3**). Instead, results from 2018 and 2019 indicate that the presence of BDOW and associated competition/predation pressures were a better descriptor of WESOke occupancy. Analysis of additional habitat may reveal alternative habitat characteristics that better account for WESOke occupancy. For example, and as proposed by MFLNRORD, the extent of forest fragmentation by forestry activity or forest fragmentation by bog habitat may account for additional variation in WESOke occupancy. Surveys conducted within habitat fragments of various sizes can be conducted to assess potential influence on occupancy (e.g. Gerber et al. 2012). Alternatively, canopy closure data from a broader area (e.g., 200 m around CPB sites) would likely better represent the habitat available to WESOke within their defended territories.

Additionally, to determine the importance of such habitat variables relative to pressures from BDOW, future studies could remove BDOW from habitats in some areas to observe how WESOke occupancy rates vary relative to similar habitats where BDOW are present using a before-after, control-impact (BACI) study design. Application of a BACI design would allow for an assessment of how habitat covariates influence WESOke occupancy in the absence of BDOW and to accurately assess how the presence of BDOW influences WESOke occupancy within each habitat the design is applied to.

4.5 Additional Considerations

Additional information on the size of defended territories and/or the distance between WESOke nests within CWH hypermaritime habitat would help to confirm the validity of the occupancy analyses. Should home range sizes prove to be larger than the spacing between survey sites, the dataset would potentially be reduced to a smaller sample size which would confer less power to detect change. While the available evidence from this and other studies supports nest spacing of 300 to 400 m, it would be valuable to confirm this finding. Finally, collection of information on WESOke productivity would provide an important index of population health. Locating and monitoring nests at sites where pairs are detected during surveys could inform whether low-productivity CWH hypermaritime habitats are sources or sinks for the broader WESOke population and would indicate whether populations in such habitats can be expected to persist or decline in isolation or within the context of a more broadly declining population.

5.0 CLOSURE

In closing, we would like to acknowledge the efforts of individuals and institutions that contributed to and facilitated the collection of survey data, analysis and interpretation of the study findings, as well as presentation of results. This work would not have been possible without the continued investment of staff and funding resources from the West Coast Regional office of MFLNRORD. We also recognize MFLNRORD’s contributions to the report, including assistance in mapping and figure production as well as thoughtful discussions regarding long-term monitoring objectives for WESOke and revisions of draft reports. In addition to diligent data collection and management provided by Bernard K. Schroeder Consulting, follow-up discussions regarding observations from the field (e.g., WESOke home range) were integral to informing the analysis and recommendations for study design. Furthermore, we would like to acknowledge the organizers of, and participants in, the Western Screech-owl Working Group meeting in Burnaby, BC (January 2020) for providing insights that informed our interpretation of results and recommendations for future monitoring. Finally, we acknowledge Dr. Carl Schwarz for clear and insightful instruction and resources regarding methods of occupancy modeling and power analyses provided during an occupancy modeling course organized by the Columbia Mountains Institute in Revelstoke, BC (February 2020).

We sincerely appreciate the opportunity to have assisted MFLNRORD with this project. If there are any questions, please do not hesitate to contact the undersigned by phone at 604.669.0424.

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6.0 REFERENCES

B.C. Minist. of Environment. 2020. Species Summary: Megascops kennicottii kennicottii. B.C. Conservation Data Centre. <http://a100.gov.bc.ca/pub/eswp/>.

Bailey, L. L., J. A. Reid, E. D. Forsman, and J. D. Nichols. 2009. Modeling co-occurrence of northern spotted and barred owls: accounting for detection probability differences. Biological Conservation 142:2983–2989.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: A practical information-theoretic approach. Second Edition. Springer-Verlag, Berlin.

Cannings, R. J., T. Angell, and Patten, M. A. 2020. Western Screech-owl (Megascops kennicottii), version 1.0. Birds of the World (P.G. Rodewald, Editor). <https://birdsna.org/Species-Account/bna/species/wesowl1/introduction>.

Clement, M., K. Barrett, and R. Baldwin. 2019. Key habitat features facilitate the presence of Barred Owls in developed landscapes. Avian Conservation and Ecology 14.

COSEWIC Wildlife Species Assessments (detailed version). 2015. Committee on the Status of Endangered Wildlife in Canada. <http://www.cosewic.gc.ca/rpts/Detailed_species_assessments_e.pdf>.

COSEWIC. 2012. COSEWIC assessment and status report on the western screech owl *kennicottii* subspecies *Megascops kennicottii kennicottii* and the western screech-owl *macfarlanei* subspecies *Megascops kennicottii macfarlanei* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. <http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_western_screech-owl_1012_e.pdf>. Accessed 16 Nov 2016.

Davis, H., and R. Wier. 2008. Western Screech-owl Conservation along the Shuswap River. Bridge Coastal Restoration Program.

Field, S. A., A. J. Tyre, and H. P. Possingham. 2005. Optimizing allocation of monitoring effort under economic and observational constraints. Journal of Wildlife Management 69:473–482.

Gerber, B. D., S. M. Karpanty, and J. Randrianantenaina. 2012. The impact of forest logging and fragmentation on carnivore species composition, density and occupancy in Madagascar's rainforests. Oryx 46:414–422.

Government of Canada. 2017. Canada Gazette Part II. Canada Gazette 151:186–187.

Guillera Arroita, G., and J. J. Lahoz Monfort. 2012. Designing studies to detect differences in species occupancy: power analysis under imperfect detection. Methods in Ecology and Evolution 3:860–869.

Hausleitner, D. 2006. Inventory Methods for Owl Surveys Version 1.0. Prepared for Ecosystems Branch of the Ministry of Environment for the Resources Information Standards Committee (RISC).

Hayes, D. B., and M. J. Monfils. 2015. Occupancy modeling of bird point counts: implications of mobile animals. The Journal of Wildlife Management 79:1361–1368.

Hemmera. 2017. Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring. Prepared for Ministry of Forests, Lands and Natural Resource Operations.

Hobbs, J. 2013. Western Screech-Owl Conservation and Management for the Bridge-Seton Area. 2012 Survey – Final Report. Prepared for Fish and Wildlife Compensation Program and Habitat Conservation Trust Foundation.

IUCN Red List. 2001. IUCN Red List Catergories and Criteria: Version 3.1. IUCN Species Survival Commission, Gland, Switzerland.

Johnsgard, P. A. 1988. North American owls: biology and natural history.

Kennedy, J. 2016. Shelter in the open - open habitats as a possbile refuge for a threatened forest owl. Simon Fraser University, Burnaby BC.

Kissling, M. L., S. B. Lewis, and G. Pendleton. 2010. Factors influencing the detectability of forest owls in southeastern Alaska. The Condor 112:539–548.

Latif, Q. S., M. M. Ellis, and C. L. Amundson. 2016. A broader definition of occupancy: Comment on Hayes and Monfils. Journal of Wildlife Management. 80 (2): 192-194. 80:192–194.

MacKenzie, D. I., and L. L. Bailey. 2004. Assessing the fit of site-occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9:300–318.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. Andrew Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of applied Ecology 42:1105–1114.

MacKenzie, D. I. 2005. What Are the Issues with Presence-Absence Data for Wildlife Managers? The Journal of Wildlife Management 849–860.

Mangan, A. O., T. Chestnut, J. C. Vogeler, I. K. Breckheimer, W. M. King, K. E. Bagnall, and K. M. Dugger. 2019. Barred Owls reduce occupancy and breeding propensity of Northern Spotted Owl in a Washington old-growth forest. The Condor 121:duz031.

Olson, G. S., R. G. Anthony, E. D. Forsman, S. H. Ackers, P. J. Loschl, J. A. Reid, K. M. Dugger, E. M. Glenn, and W. J. Ripple. 2005. Modeling of site occupancy dynamics for northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918–932.

Di Stefano, J. 2003. How much power is enough? Against the development of an arbitrary convention for statistical power calculations. Functional Ecology 17:707–709.

Tripp, T. M. 2004. Use of bioacoustics for population monitoring in the western screech-owl (Megascops kennicottii). University of Northern British Columbia.

APPENDIX A

Western Screech-owl Inventory in the West Coast Region Reports (2018 and 2019) from Bernard K. Schroeder Consulting

Western Screech-Owl in the West Coast Region: Inventory of CWH Hypermaritime Habitats using Call Playback Surveys and collection of automated recordings, 2018.

ATTN: Jenna Cragg

FROM: Bernard K. Schroeder

Introduction

The Western Screech-Owl (*Megascops kennicottii kennicottii*) is listed as Threatened in Canada (COSEWIC 2012) due to significant declines in the southern parts of its' range in the lower mainland and east and south Vancouver Island. Threats include nesting habitat loss due to urbanization and forestry practices, road kill as well as predation by increasing populations of Barred Owls. Declines have also been reported in Alaska, however, relatively little is known about abundance in central and northern coastal forests on the BC coast.

This survey of Western Screech-Owl (*Megascops kennicottii kennicottii*) in the West Coast Region: Inventory of CWH Maritime and Hypermaritime Habitats and collection of automated recordings for the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD)(Project) focused on potential Western Screech-Owl (WSOW) habitat found in the Biogeoclimatic subzone CWH vh1, in old/mature structural stage, low productivity, low elevation forest. Site series 01 or 11 in this BGC subzone was a focus of attention, but the Project was not restricted to those site series. The overall strategy was to find WSOW presence or occupancy in areas of this subzone on Crown land on Vancouver Island.

In order to quickly and efficiently sample as extensive an area as possible and maximize the value of effort to budget, the Project prioritized areas with road vehicle access and a lower degree of fragmented habitat. Calling stations were situated in areas where potential WSOW habitat intersected with resource roads. In fragmented habitat along transect routes, call playback stations were more widely spaced.

The Project was initiated by map review and meeting with MFLNRORD staff to confirm preferred survey locations and routes. The Project team conducted a reconnaissance of candidate areas and layout of survey routes, flagged and georeferenced call playback stations and completed habitat assessment at stations on February 28 and March 1. Three replicate surveys were completed in three areas of West and North Vancouver Island along roads in Fisherman River, Nahwitti River and Nahwitti Bog. Snow prevented access to the Shushartie River watershed during the reconnaissance trip.

Methodology

Surveys followed methods in Inventory Methods for Owl Surveys (RISC 2006) and recommendations in Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring (Hemmera 2017) using single species call-playback stations with 15 minute total listening duration at each station. A transect with a minimum of 12 calling stations constituted a survey. Surveys were repeated 3 times on separate nights during favourable weather windows from March 2 to March 25, 2018. Inter-station distances were generally between 300 and 400 metres with some placed farther apart depending on the extent of habitat intersection with the transect route. Surveys commenced at least 30 minutes after sunset and were finished by 30 minutes before sunrise. Observers recorded: time, survey time, distance and direction of owl detection, sex and call type for each owl response.

The Project focused on three habitats in two North Island watershed areas, Fisherman River and Nahwitti River. More extensive and less fragmented areas of potential WSOW habitat with partial road access on Crown land in the CWH vh1 subzone are found in the northern part of Vancouver Island. These include the Fisherman River, Nahwitti River, Shushartie River, Stranby River and the Nahwitti Bog, a ~10,000 ha area of table bog habitat characterized by stunted Yellow Cedar, Shore Pine and Western Hemlock tree patches interspersed with open areas of hummock forming peat mosses.

A total of 13 automated recording units (ARU's) were deployed along three transect routes in selected areas of potential WSOW nesting habitat. Automated Recording Units (ARU) (Wildlife Acoustics SM3's and SM-4's) were installed during reconnaissance of survey locations and were set to record nightly from sunset to midnight for a maximum of six hours. The ten SM-4 recorders were also set to record from 1.5 to 0.5 hrs before sunrise.

Results

During nine surveys on three transects, a total of 59 Western Screech Owl responses were observed in two watersheds on North Vancouver Island. Two of the nine surveys were incomplete due to unacceptable sampling conditions. The Nahwitti Bog transect was the most productive, with 90% response rates from WSOW (**Table 1**).

Three complete repetitions of 14 call playback locations were completed at the Fisherman River transect on March 2, 20 and 23 (**Table 1**). On March 2, an estimated five WSOW's responded from four of 14 stations and a sixth WSOW was observed flying across the road between station FI12 and FI13. At FI12 there was a pair duetting with bouncing ball and double trill calls. A Northern Saw-whet Owl (NSWO) was also observed flying along the road in the same area. On March 20, two WSOW responses were detected at two of 14 stations. A NSWO was also detected at one station. On March 23, one WSOW response was detected at one of 14 stations. NSWO's were detected at 3 of 14 stations. Rain shower activity prior to sunset could have had an adverse effect on response rates during the second and third surveys.

Three repetitions of 12 call playback locations were initiated at the Nahwitti River transect on March 18, 21 and 23 (**Table 1**). Two of the surveys were hampered by unacceptable survey conditions. On March 18, 11 WSOW's were detected responding from seven of 12 stations; two of them females. On March 21, no owls were detected at the three stations surveyed before steady rain prevented completing the whole transect. On March 23, one response from one WSOW was detected at one of eight stations surveyed before increasingly steady snowfall prevented completing the survey transect.

Three repetitions of 12 call playback locations were completed at the Nahwitti Bog transect on March 19, 22 and 24 (**Table 1**). On March 19, an estimated 13 WSOW's responded from 10 of 12 call playback locations including one female solicitation call. On March 22, an estimated 14 WSOW's responded from 11 of 12 survey locations including visuals of a pair at station NH7. The pair called from low in shrubs beside the road upon stopping the vehicle, flew approximately 30 metres farther along the road and flew into the forested patch where they were seen perched briefly on low branches using a spotlight. On March 24, 12 WSOW responses were detected at nine of 12 stations and NSWO's were detected at two of 12 stations.

Table 1. Call playback results during Western Screech Owl surveys.

Survey ID	Date	WSOW Female	WSOW Male	NSWO	Grand Total
FI-S1	2018-03-02	2	3	0	5
FI-S2	2018-03-20	0	2	1	3
FI-S3	2018-03-23	0	1	2	3
NA-S1	2018-03-18	2	9	0	11
NA-S2	2018-03-21	0	0	0	0
NA-S3	2018-03-23	0	1	0	1
NH-S1	2018-03-19	1	12	0	13
NH-S2	2018-03-22	3	11	0	14
NH-S3	2018-03-24	2	10	2	14
Grand Total		**10**	**49**	**5**	**64**

Discussion

It is understood that Western Screech Owl response rates are sensitive to precipitation. Response rates appear to be adversely affected by precipitation occurring earlier on the survey day, particularly when leaf drip persists into the evening. Light snow flurries where they are intermittent may not have as adverse effect as light rain.

Since there is such significant precipitation in hypermaritime habitat types, WSOW calling occurrence may be lower on the whole than in drier habitats elsewhere. This weather effect could influence detectability by surveyors and possibly by predators.

This Project found high response levels in the Nahwitti Bog, an expansive area of open bog interspersed with stunted old growth tree patches. Owls were detected in the tree patches and associated with the larger tree structures contained within.

Survey results with high response rates in parts of this study area, particularly on the Nahwitti Bog, may indicate a typical pre-development population pattern of Western Screech Owls. A healthy natural density of owls may occur throughout the undisturbed areas of old growth forest in this region. There are historical records of WSOW on the Nahwitti Bog from August 2005 (McIntosh et al. 2006), where two WSOW's were observed exhibiting territorial behaviours from a yellow cedar located near a hard edge.

Northern Saw-whet Owls were detected during the 2018 survey, but larger owls such as Barred Owls were not detected. However, there are historical records of Barred Owl in the Nahwitti watershed in the bog habitats from August 2005 (McIntosh et al. 2006).

References

COSEWIC. 2012. COSEWIC assessment and status report on the Western Screech-Owl *kennicottii* subspecies *Megascops kennicottii kennicottii* and the Western Screech-Owl *macfarlanei* subspecies *Megascops kennicottii macfarlanei* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 30 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Hemmera Envirochem Inc. 2017. Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring. Prepared for Ministry of Forests, Lands and Natural Resource Operations, Nanaimo, BC.

McIntosh, K.A., B.K. Schroeder, D. Nagorsen, H. Roemer and I. Robertson. 2006. Nahwitti Wind Energy Project: Wildlife and Vegetation Assessment. Prepared for Nomis Power Corporation, Vancouver, BC.

RIC (Resources Inventory Committee). 2006. Inventory Methods for Owl Surveys. Standards for Components of British Columbia's Biodiversity No. 42. Prepared by D. Hausleitner for Ecosystems Branch of the BC Ministry of Environment. Available online at: ftp://nris.mt.gov/Public/Maxell/Owl_Surveys/BC_Inventory_Methods_Owls_2006.pdf accessed on February 15, 2018.

Western Screech-Owl Inventory in the West Coast Region: Inventory and collection of automated recordings on North Vancouver Island, 2019.

Memo Report – Results Summary

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Introduction

The Western Screech-Owl (*Megascops kennicottii kennicottii*) is listed as Threatened in Canada (COSEWIC 2012) due to significant declines in the southern parts of its range in the lower mainland and east and south Vancouver Island. Threats include nesting habitat loss due to urbanization and forestry practices, road kill as well as predation by increasing populations of Barred Owls. Declines have also been reported in Alaska, however, relatively little is known about abundance in central and northern coastal forests on the BC coast.

This Western Screech-Owl Inventory in the West Coast Region: Inventory and collection of automated recordings on North Vancouver Island for the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) (Project) focused on re-visiting the north Island area sampled in 2018. The objective was to re-sample one 2018 transect and conduct call-playback surveys in two new transects and to set up 20 Automated Recording Units (ARU's) throughout the Project area. As in 2018, potential Western Screech-Owl (WSOW) habitat found in the Biogeoclimatic subzone CWH vh1, in old/mature structural stage, low productivity, low elevation forest was sampled. The Project focused on, but was not restricted to site series 01 or 11 in this BGC subzone. The overall strategy was to expand the search for WSOW presence or occupancy on Crown land in watersheds on North Vancouver Island.

As in 2018, the Project sampled habitat edges along resource roads, prioritizing areas where habitat straddled the road. Calling stations were situated where potential WSOW habitat intersected and, for the most part crossed resource roads. In more fragmented habitat along transect routes; call playback stations were more widely spaced.

The Project was initiated by map review and meeting with MFLNRORD staff to confirm preferred survey locations and routes. The Project team conducted a reconnaissance of candidate areas and layout of survey routes, flagged and georeferenced call playback stations, completed habitat assessment and set up ARU's at stations. Three replicate surveys were completed on two trips in three areas of North Vancouver Island along roads in Nahwitti Bog and Shushartie River.

Western Screech-Owl Inventory in the West Coast Region: Inventory and collection of automated recordings on North Vancouver Island, 2019.

Methodology

Surveys followed methods in 'Inventory Methods for Owl Surveys' (RISC 2006) and recommendations in 'Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring' (Hemmera 2017) using single species call-playback stations with 15 minute total listening duration at each station. A transect with a minimum of 13 calling stations constituted a survey. Surveys were repeated 3 times on separate nights during favourable weather windows from February 26 to March 31, 2018. Inter-station distances varied between 300 and 4,000 metres depending on the extent of habitat intersection with the transect route. Surveys commenced at least 30 minutes after sunset and were finished by 30 minutes before sunrise. Observers recorded: time, survey time, distance and direction of owl detection, sex and call type for each owl response.

The Project focused on three habitats in two North Island watershed areas, Nahwitti River and Shushartie River. More extensive and less fragmented areas of potential WSOW habitat with partial road access on Crown land in the CWH vh1 subzone are found in the northern part of Vancouver Island. These include the Fisherman River, Nahwitti River, Shushartie River, Strandby River and the Nahwitti Bog, a ~10,000 ha area of table bog habitat characterized by stunted Yellow Cedar, Shore Pine and Western Hemlock tree patches interspersed with open areas of hummock forming peat mosses.

A total of 20 ARU's were deployed along the three transect routes in selected areas of potential WSOW nesting habitat. ARU's used were Wildlife Acoustics SM-4 model ARU's were installed during reconnaissance of survey locations and were set to record nightly from sunset to sunrise.

Results

The 2019 survey project followed similar timing to 2018; initial site layout and ARU deployment in late February with one survey round and a second trip in late March to complete three rounds. In 2018, only one survey was completed on the first field visit in early March, which did not provide a thorough sample of owl activity at this time. In 2019, ARU's were set up on February 20-21, the first round of surveys conducted February 26-28.

During nine surveys on three transects, a total of 73 WSOW responses were observed in two watersheds on North Vancouver Island. Very little owl activity was observed during the first round of surveys in each area on the last three nights of February; similar timing to the first survey on March 2 in 2018. Sustained clear and calm weather produced good sampling conditions, but extreme cold for the region with snow and ice cover persisted during this period. The survey team noted no Pacific Treefrog or insect activity, unlike the same time in 2018, where frogs were already vocal. The second and third replicate surveys on each transect yielded an average 93% of the total screech-owl responses. The Shushartie South transect was the most productive, with 89% response rates from WSOW (**Table 1**) during the second and third rounds. ARU recordings should be successful at documenting the onset of WSOW vocal activity this year.

Table 1. Call playback results during Western Screech Owl surveys.

SURVEY AREA	WSOW Female	WSOW Male	WSOW UnClassified	WSOW Total
NAHWITTI BOG	3	15	8	26
2019-02-28			1	1
2019-03-27	1	10	4	15
2019-03-30	2	5	3	10
SHUSHARTIE NORTH	1	5	3	9
2019-02-27		1		1
2019-03-28	1	2	2	5
2019-03-31		2	1	3
SHUSHARTIE SOUTH	6	25	7	38
2019-02-26	1	2		3
2019-03-26	3	10	3	16
2019-03-29	2	13	4	19
Grand Total	10	45	18	73

Three complete repetitions of 14 call playback locations were completed at the Nahwitti Bog transect on February 28, March 27 and 30 (**Table 1**). On February 28, one WSOW responded from one of 14 stations. A Northern Saw-whet Owl (NSWO) was also heard. On March 27, 15 WSOW responses were detected at 12 of 14 stations. A NSWO was also detected at one station. On March 30, 10 WSOW responses were detected at eight of 14 stations; at five of eight stations, WSOW were calling upon arrival and no calls were broadcast. These stations coincidentally had generally lower levels of Pacific Treefrog noise. The level of Pacific Treefrog noise could have had an adverse effect on being able to hear WSOW responses during the second and third surveys at the Nahwitti Bog.

Three repetitions of 13 call playback locations were initiated at the Shushartie North transect on February 27, March 28 and 31 (**Table 1**). On February 27, one WSOW was detected from one of 13 stations. On March 28, three WSOW were heard responding from three stations; two additional WSOW were heard calling incidentally when stopped at km 19 along the Georgie Lake FSR at a location that had been proposed for surveys but was dropped due to removal of the forested habitat between the road and the riparian. This location is 1,300 metres downstream from station SN13. The owls were heard calling from the riparian area 200 – 300 m away from the road. However, on March 28, nine Barred Owls (BDOW) were detected from seven calling stations and three NSWO from three stations. On March 31, two WSOW responses were heard from two stations; and WSOW calling was heard incidentally at the km 19 location again. On this date, two BDOW were heard at 2 stations and five NSWO were heard at five stations.

Three repetitions of 13 call playback locations were completed at the Shushartie South transect on February 26, March 26 and 29 (**Table 1**). On February 26, three WSOW's responded from two of 13 call playback locations. A Great Horned Owl (GHOW) was detected at the first two stations; estimated to be the same one. On March 26, an estimated 16 WSOW's responded from 10 of 13 survey locations including an incidental visual of a single WSOW flying across the opening at station SS11, at the fish hatchery while driving back after surveys. An unidentified owl glided across the opening at SS13 during the survey that was most likely a WSOW. Two NSWO were also detected from two stations on this night. On March 29, 17 WSOW responses were detected at 13 of 13 stations; at three stations WSOW's were calling upon arrival and no calls were broadcast. An additional 2 WSOW were detected incidentally; one visual of a gray adult flying across the road near SS13 and an audio of another downstream while stopped at km 19 (Part of Shushartie North transect area). One NSWO was also detected at one station.

Discussion

During the first round of surveys in late February, very low WSOW call responses were observed. The team noted very cold weather (eg. lows of -6 C° at night) and no Pacific Treefrog or insect activity. This Project found high response levels on the Nahwitti Bog transect continued for a second year, though Pacific Treefrog noise may have hampered hearing owls at some stations. The 2 new transects surveyed in the Shushartie presented an interesting contrast in activity; at Shushartie South there were high levels of WSOW activity, including responses at all 13 calling stations on the last survey with unsolicited calling at three stations, while at Shushartie North there were BDOW's and NSWO's but few WSOW's.

Barred Owls were detected during 2 of 3 surveys on the Shushartie North transect, but were not detected on the other two transects where most Western Screech-owl activity was evident. The Shushartie North transect also had a wider variety of forested habitat and some more productive stands where the team anticipated WSOW activity. Great-horned Owls were detected on the Shushartie South transect during the first survey in late February, but not after. Northern Saw-whet Owls were detected at all three areas; most being heard on the Shushartie North transect.

References

COSEWIC. 2012. COSEWIC assessment and status report on the Western Screech-Owl *kennicottii* subspecies *Megascops kennicottii kennicottii* and the Western Screech-Owl *macfarlanei* subspecies *Megascops kennicottii macfarlanei* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 30 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Hemmera Envirochem Inc. 2017. Western Screech-Owl (Coastal Subspecies): Compilation and Analysis of Records to Inform Trend Monitoring. Prepared for Ministry of Forests, Lands and Natural Resource Operations, Nanaimo, BC.

RIC (Resources Inventory Committee). 2006. Inventory Methods for Owl Surveys. Standards for Components of British Columbia's Biodiversity No. 42. Prepared by D. Hausleitner for Ecosystems Branch of the BC Ministry of Environment. Available online at: ftp://nris.mt.gov/Public/Maxell/Owl_Surveys/BC_Inventory_Methods_Owls_2006.pdf accessed on February 15, 2018.

APPENDIX B
Habitat Data Collection Form and Rankings

WSOW HABITAT ASSESSMENT FORM – COMPLETED FOR ALL STATIONS

General Location ________________________ **Observer(s)** ____________________________ _ **Day** ___ **Month** ____ **Year**________

Station ID	Z	Easting	Northing	Mature Deciduous Pts	Understory Pts	Edge Type Pts	% Ctwd Pts	Overall Rating (out of 10)

1. Site ID: unique name and number; typically abbreviation based on location and/or transect
2. Station Easting/Northing: the UTM coordinates of the approximate centre of the habitat. These can be projected coordinates if required.
3. Mature Deciduous – number of mature broadleaf deciduous trees within the survey radius: >10=4 points, 3-9=2 points, 1-2=1 point, 0=0 points
4. Understory – indicate if the understory is **dense, moderate or sparse: D**ense = 2 points; Moderate = 1 point; Sparse = 0 points
5. Edge Type – indicate if edge is **soft** or **hard:** Soft = 2 points; Hard = 1 point
6. % Deciduous (within 200m survey radius): this is the percentage of total trees within the survey radius that are deciduous. > 80 % = 2 points; 30-79%=1 points; < 30%= 0 points

Additional notes:

- Stations should be assessed a maximum of 400 metres apart if the habitat is contiguous
- If a site scores 8 out of 10 or higher, it should be surveyed for WSOW
- If a site is surrounded by hard edge then only survey sites where habitat is >10ha.