Evaluation of the Adaptive Monitoring Framework (AMF) for Assessing the Status and Trend of Williamson's Sapsucker (WISA)

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1.0 Introduction

Williamson's Sapsucker (WISA) is a migratory bird and species at risk (COSEWIC) and is listed as Endangered under Schedule 1 of the *Species at Risk Act*. It is listed as Identified Wildlife under the *British Columbia Forest and Range Practices Act* (FRPA). A draft Recovery Strategy has been completed and development of the federal Action Plan will soon be under way.

The WISA Recovery Team (RT) met with ESSA Technologies Ltd. in a workshop in March, 2009 to develop a draft Adaptive Monitoring Framework (AMF, Marmorek and Pickard 2010). An AMF was developed for two primary reasons:

1. to track the status of WISA populations to ensure the various recovery actions are meeting the recovery goal of population maintenance; and
2. to evaluate a proposed management regime developed by the WISA RT for maintaining functional WISA habitat in a managed landscape ("Guiding Principles") to demonstrate it can be considered to "effectively protect" WISA critical habitat on non-federal lands as required under the Act.

The framework laid out the steps necessary to develop a rigorous monitoring design and was intended to develop over time as uncertainties were addressed. It was decided to use the number of positive call playbacks (CPBs) as the basis for monitoring WISA abundance over time. Developments related to data analysis and sample design are summarized in a flow chart (Figure 1) and described below. This report constitutes the first formal review (check in) of the work and results over this period in the context of the original goals of the AMF program.

2010

Based on recommendations that arose in the workshop, the AMF and associated analyses (Pickard and Marmorek, 2011), pilot data were collected in 2010 for three Areas of Occupancy (AO): Okanagan-Boundary (OK), Okanagan-West (West) and East Kootenay (EK). The 2010 sampling design (Pickard and Ainsworth, 2011) used:

OK/West/EK

- a stratified random design with three habitat suitability strata (moderate, low and very low)
- three repeat surveys at a random subset of sites to evaluate the probability of detection
- an extended protocol at a subset of sites to evaluate the utility of double sampling

2011

The initial sampling design used in 2010 was found to be inadequate for the EK AO as very few WISA were detected (Pickard and Ainsworth, 2011). Therefore, separate sampling schemes were proposed for the 2011 field season: one for the OK and West AOs and one for the EK AO. In 2011 (Ainsworth and Pickard, 2012), the sampling designs were:

OK/West

- A stratified random design with two habitat suitability strata (moderate and low)
- differentiation between sites with road and non-road access (with a buffer of 100m from the road)
- five repeat surveys at ALL sites to evaluate the probability of detection

EK

- dual frame sampling:

→ a list frame - all previous known nest sites

→ a stratified random sample of the area frame - all areas not included on the list frame

- documentation of all sightings, regardless of whether they occurred at a randomly selected point, to help build the list frame

In spite of the new sampling design in the EK, the number of WISA detections remained low. WISA calling behaviour, and thus detection, is dependent on breeding stage and it was hypothesized that the late start on the field season contributed to the small number of detections in 2011

2012

In 2012, the WISA RT decided to focus sampling effort on the EK in an attempt to better understand the dynamics in this AO. The dual frame methodology was implemented again, but the surveys were carried out earlier in the season to address the hypothesis that the low probability of detection for this AO in 2010 and 2011 was due to sampling late in the breeding season. However, the number of WISA detections remained very low in the EK. As in previous years, field crew stressed the limitations of applying the habitat suitability model to determine sampling locations. The difficulties associated with connecting the habitat model classes with GIS data for this AO led to sampling in unsuitable habitat.

Les Gyug voluntarily carried out CPB surveys along all public roads in the OK and West AOs. Thus the sampling designs were:

OK/West

- census of public road transects
- at least two repeat surveys at each site to evaluate the probability of detection

EK

- dual frame sampling (as above)
- documentation of all sightings regardless of whether they occurred at a randomly selected point to help build the list frame

2013

In 2013, another census of public road transects was carried out in the OK and West AOs with 2 repeat CPB surveys at each site. No data was collected from the EK AO.

The objectives of this report are to:

1) Provide a statistical summary and overview of the first four years of surveys (2010-2013) :
   i. occupancy, Ψ, of WISA at CPB stations by strata and regions
   ii. probability of detection, p, for the WISA CPB protocol by strata, regions, or with environmental covariates(e.g. weather or time of year)
   iii. abundance estimates by strata and regions
   iv. statistical power to detect a range of trends over specified periods (e.g. 5, 10, 25 years) using annual or periodic monitoring (e.g., 2, 5, 10 years) for the occupancy and abundance estimates
   v. details of the software or code used to develop estimates and statistical power.

2) Provide recommendations for adaptively improving the monitoring design based on the results of the first four years.

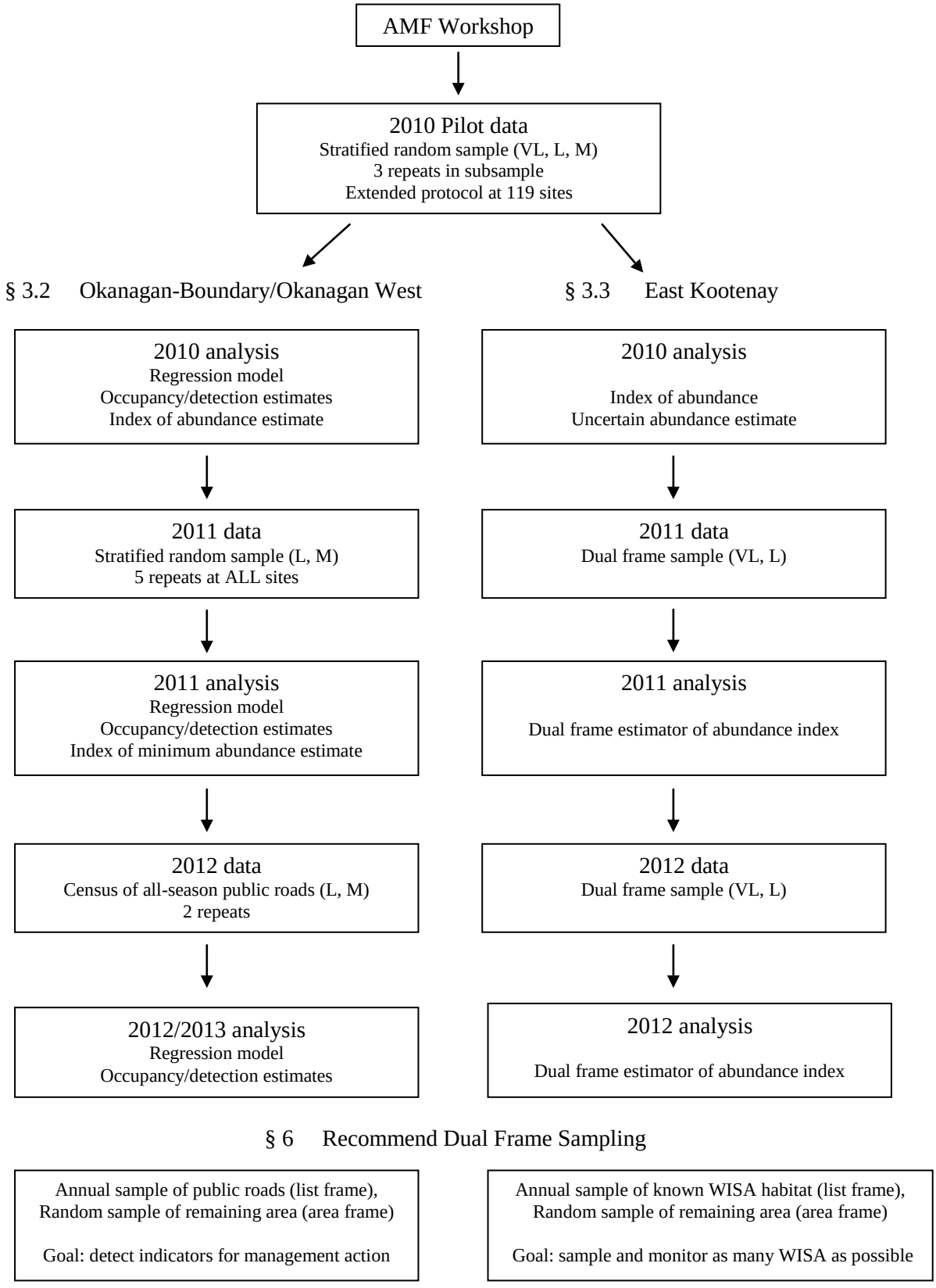

Figure 1. Flow chart of sampling designs and data analysis 2010-2013 and recommended future design

The review of the first four years of surveys led to the following recommendations for adaptively improving the monitoring design:

- implement a dual frame sampling design to monitor the OK, West and EK AOs
- clearly define inclusion/exclusion criteria to improve precision and reduce bias
- create clear operational definitions which relate directly to management objectives
- Use public roads as the list frame for dual frame sampling in the OK and West AO
- Use known WISA habitat for the list frame in the EK AO.

2.0 Review of Methodologies

The AMF workshop determined that the objective of monitoring was to generate an estimate of abundance of WISA in each AO. Several methodologies were used over the period 2010-2013. These are described below. Mark-recapture studies are often considered the best approach for generating an unbiased estimate of abundance. However, this approach was not considered by the RT. Mark-recapture methods require reasonably high frequency of recaptures, have a number of assumptions that may be difficult to meet for estimating abundance, and are likely to be labour-intensive to complete for the target population. Instead the RT decided to use a count based index of abundance using the number of call-playbacks (CPBs) observed (Marmorek and Pickard 2010). Count based indices are known to be biased estimators of abundance as they are related to abundance by the probability of detection (i.e., the probability to detect an individual given that it is present).

Therefore, to use count data as an index of abundance, we must either assume that the probability of detection does not vary in a systematic way or we must estimate it (Thompson 2002 – Chapter 4). Bird point counts similar to this study are widely used but often ignore the probability of detection and thus lead to bias due to underestimation (Pickard and Porter 2008).

2.1 Detection

2.1.1. Probability of Detection

Repeated surveys are strongly recommended for studies aiming to estimate the probability of detection of a species (MacKenzie et al. 2006). Zero-inflated binomial models (see Appendix B) can be used to estimate the probability of detection from replicate data. If it is reasonable to assume that the probability of detection is the same at all sites, the probability of detection can be estimated from repeated sampling of a subset of sites (MacKenzie et al. 2006, p173).

Repeated observations can be obtained in several ways:

- multiple visits to the site (i.e., on different days)
- multiple surveys per visit (i.e., on the same day)
- multiple surveyors sampling the same site
- sub-sampling a larger site

The most suitable approach depends on the species in question, but should attempt to meet the following assumptions: independent repeat surveys and constant probability of occupancy for all repeat surveys.

In practice, it is not possible to completely eliminate the effects of detection. However, if detection changes with time, the repeated samples need to be taken within a short time window. It is also useful to carry out sampling when the highest detection rates are anticipated.

The probability of detecting a WISA pair with a CPB procedure is strongly related to nesting behaviour. Birds tend to call during the nest building phase and quiet down during the incubation and nesting periods (Les Gyug and Penny Ohanjanian, pers. Comm.). Time could be included as a covariate which relates to

detection (and/or occupancy). However, as a general rule, it is more efficient to include important covariates in the study design rather than account for them in the analysis. Therefore, to improve efficiency, and get the highest detections rates, it is best to carry out repeat sampling within a short period of time, during the nest building phase.

2.1.2. Distance Estimation

Distance estimation is based on the concept that there is a relationship between the distance from the observer and the probability of detection (Pickard and Porter 2008). Buckland et al. (1993) describe the methods and assumptions for this approach in detail. It can be applied to both line transects and point counts. An advantage of this approach is that it does not require the size of the sampling unit to be fixed and known. The assumptions are:

- objects located directly on the line or point are detected with a probability of 1
- objects are detected at their initial location prior to any movement in response to the observer
- distances are measured accurately or distance groups are correctly assigned (e.g. 1-2m, 2-3m…)

It is difficult to accurately estimate the distance to a bird when it is not seen; there can be a great deal of variability between observers. Gyug screened and used the available WISA distance data to explore the detection function for CPBs. When the assumptions cannot be met it is better to simply report the observed counts rather than report an invalid density (Harris and Burnham 2002). On the other hand, repeat observations enable us to directly estimate probability of detection rather than assume a relationship with distance.

Repeat sampling was used in the EK in 2010 and in the OK and West in 2010, 2011, 2012 and 2013.

2.2 Stratification

Stratified random sampling can often be used to improve sampling efficiency. The population is divided into non-overlapping subpopulations and random sampling is done within each subpopulation or stratum. Stratified sampling is useful when (Cochran, 1977):

- we want to specify a given level of precision within each strata
- sampling within subpopulations is a natural way to sample, e.g., sampling within each AO
- the logistics of sampling differ by strata
- heterogeneous populations can be subdivided into homogenous subpopulations so that precise estimates can be obtained for each stratum and these can be combined into a precise population estimate

Stratification was used in 2010 in the East Kootenay and in 2010-2011 in the Okanagan-Boundary and West AO.

2.3 Habitat Suitability

Stratified random sampling is often based on habitat suitability classes. Gyug (2009a, 2010a, 2010b) has done extensive work creating habitat suitability models for WISA. Points within each habitat class can be chosen in several ways. One way is to assess the habitat at the point location. Another is to consider the maximum habitat within a given radius of the sampling point (e.g. 400m). For CPBs, using the maximum habitat within a given radius seems more appropriate as a CPB at a point location will detect birds within a radius of the point, not just at the point location. [1]

[1] Methods for assigning points to strata (i.e., AO, road access type, and habitat suitability class) varied during the 2010-2013 pilot study. 2010 – only plots with homogeneous habitat class were used. 2011 –road access was added and plots were defined based

Habitat suitability was assigned based on Gyug's habitat suitability model to assign strata to points.

2.4 Two Protocols (Double Sampling)

The term 'double sampling' has not been consistently used in the ecological literature. Our definition of double sampling, using two protocols, follows Thompson 2002 and Pollock et al. 2002: an initial sample is taken and only the auxiliary information is observed, then a smaller second sample (often a subset) is taken where both the variable of interest and the auxiliary information is observed. For example, wing length is a quick measurement often used to assess the body weight of insects.

This approach is often used in cases where there are two alternative field protocols: one that is costly and accurate and another that is cheaper but may not directly represent the response of interest. If a relationship can be built between the two variables then the more expensive variable needs only to be completed at a random subset of sites; the rest can be inferred from the relationship between the two variables.

Marmorek and Pickard (2010, Appendix C & Appendix D) outline an Extended survey protocol for WISA surveys. This protocol requires the observer to stay beyond the initial call-playback survey to carry out an extensive search which is assumed to have a probability of detection = 1).The intent of using the two protocol method is to compare the estimates obtained from the two protocols and assess whether it was possible to predict one from the other. For instance, if one bird is observed with the quick method, does that mean on average two birds are observed with the extended method? How often is a bird found using the extended method when no birds are observed using the quick method?

Double sampling was used in 2010 at a randomly selected subset of one hundred and nineteen locations.

2.5 Dual Frame Estimates

Dual frame sampling allows targeting resources in known habitats or easily sampled locations, but maintains fair representation of the entire area of interest. The objective of dual frame sampling is to improve accuracy and save money. The population of interest is broken into two categories similar to strata: the easily sampled census area known as the *list frame*, and the randomly sampled area known as the *area frame*. Methods for combining the estimates from the census data and the randomly selected data can be found in Cochran (1997). Haines and Pollock (1998) utilized this method for estimating the number of bald eagle nests. For example, their target area was broken down into: 1) all sites with known nesting history; 2) the remaining areas. A census was taken of old nest sites and a random sample was taken from the remaining areas. Efforts were made to ensure that sites randomly selected from the area frame (strata 2) were not included on the list frame (strata 1).

Dual frame sampling was used in 2011 and 2012 in the East Kootenay AO.

3.0 AMF baseline data: 2010-2013

3.1 Overview

In 2010 pilot data were collected to assess the utility of repeat sampling and double sampling. In each AO, three repeat samples were done at a subset of locations. An extended protocol was used at one hundred and nineteen locations. In subsequent years different sampling methods were used in the

on dominant (>80%) habitat class. 2012/2013 –all Ministry of Transport roads (no resource roads) were sampled and strata were defined post-hoc based on the maximum habitat class within a plot.

OK/West AOs and the EK AO, to address learning and questions from previous years. In the EK, a dual frame sampling method was used to sample known nest sites and a random sample of the remaining terrain in 2011 and 2012. In the OK and West AOs, a stratified random sample was taken with five repeat samples at each location in 2011. In 2012 and 2013, a census was taken of all public roads in the OK and West with two repeat surveys per site.

During the development of the AMF, it was decided that the number of CPB responses was to be used for the analysis of abundance. More than one WISA CPB response was rarely observed at any given CPB station. Therefore, it was decided that modelling occupancy (presence/absence) using a zero-inflated binomial distribution was appropriate. A point location was classified as occupied if a WISA was detected on at least one occasion at a given location in a given year.

3.1.1. Habitat Suitability

Stratified random sampling was based on habitat suitability class as derived by Gyug (2009a, 2010a, 2010b). The number of hectares of each habitat class is summarized in Table 1.

Table 1. Area in hectares by strata for each AO (Pickard and Marmorek 2011)

Habitat Suitability Class	Okanagan	West	East Kootenay	Total
Moderate	9861	6326	3225	19412
Low	24983	22543	25656	73182
Very low	30468	38162	48120	116750
Subtotal	65312	67031	77001	209344

3.1.2. Abundance

Estimating the status and trend of WISA abundance is critical to inform performance relative to the WISA recovery goal:

> *"The population and distribution objective for Williamson's Sapsucker is to ensure the persistence of the populations in Canada within each of the identified Areas of Occupancy (AO; Western, Okanagan-Boundary, and East Kootenay) by maintaining them at or above: 1) the current abundance; 2) the current distribution and AO, allowing for natural fluctuations in both cases."* Excerpt from Environment Canada (2013)

Due to low counts observed at CPB sites during the 2010-2012 pilot study, occupancy (i.e., presence of at least one WISA at a CPB site during at least one visit) rather than abundance was estimated (Ainsworth & Pickard 2011& 2012). Occupancy is a useful measure but one which is meaningless without some indication of scale. Occupancy is directly related to the size of the sampling unit (Figure 2). The same abundance of animals translates to a different occupancy rate, depending on the size of the unit sampled. Figure 2 illustrates how occupancy rate for a sampling unit of known size can be related to abundance (i.e., higher abundance will result in more occupied sampling units, and a higher occupancy rate). In general, MacKenzie et al. (2006) recommend that the sampling unit be:

> *"large enough to have a reasonable probability of the species being there (we suggest that the probability should be 0.2-0.8 in most situations), but small enough so that any measure of occupancy is meaningful and the site can be surveyed with a reasonable level of effort"*

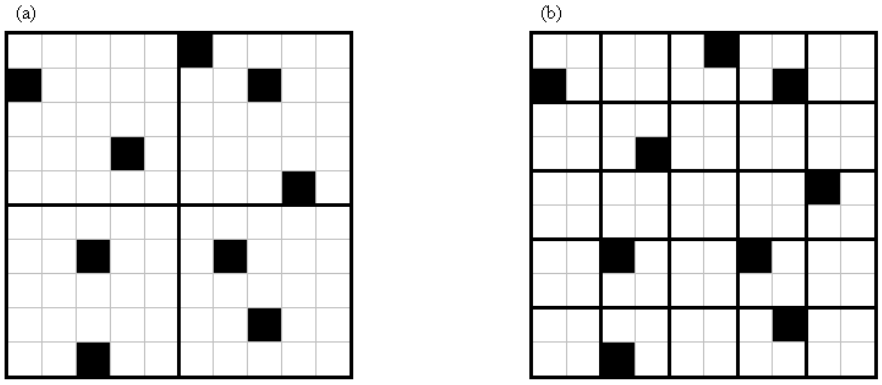

Figure 2. "Graphical representation of a one-hectare (100m x100m) area with the location of the target species indicated by the black cells. "Sites" have been defined at two different scales: (a) 50 m x 50 m; and (b) 20 m x 20 m." This figure illustrates the effect of sampling unit size on the occupancy rate, reproduced from MacKenzie et al. (2006).

CPB surveys are variable-radius point counts, and are more complex, in that the size of the sampling unit is not known with certainty. At the onset of this pilot study, the CPB protocol was thought to search a 400m radius (~50 ha) but that detectability within that area was unknown and WISA would respond infrequently from >400m).The assumption that a CPB survey searches a 400m radius unit equally, and searches none of the area outside of 400m (e.g., birds from outside the 400m radius never respond) is flawed (Gyug, unpublished data: of191 nests in the Okanagan and West found after CPB from 1997-2012, 32 (17%) were >400m from the CPB point). An additional complication for WISA, where a bird can be anywhere within its breeding territory at any given time, is that occupancy will also be directly related to scale in a separate fashion than discussed in the previous paragraph and shown in Figure 2. If the scale chosen is too small, a bird occupying the surveyed area one day, may not be occupying the same surveyed area during the next survey when it may be in a different part of its territory. Thus it would not be available for detection. An essential assumption of the occupancy methods is that occupancy does not change over the survey period, so scale is a critical consideration.

The estimated number of occupied sites in each strata and AO is a useful measure which is related to abundance (recall, for a fixed sample unit size, higher abundance results in higher occupancy rate) and can be used as an index of abundance[2] across years to assess status and trends in the population, assuming the methods remain consistent. We use the simplifying assumption that the CBP surveys search a 400m radius (50 ha) plot to provide context for the occupancy rates observed. The estimated number of occupied 50 ha sites is the index of abundance referred to in this report. If abundance were to increase to the point where it was common to observe large numbers of WISA at each site, then it would be worth exploring the use of abundance models rather than occupancy (refer to Chapter 5 of MacKenzie et al. (2006)). Given that the protocol targets breeding adults, if there are any territorial tendencies it may be unlikely to have many shared sites even if the population was large.

The Recovery Team should revisit the performance measure(s) used to evaluate abundance of WISA to determine which are the most biologically relevant. The original Recovery Team recommendation was to use the number of positive call play back detections with the intent of assessing the total number of individuals in the population regardless of age or sex (Marmorek and Pickard 2010). This report refers to the number of occupied 50 ha sites. If occupancy is used, the size of the site should be revisited to ensure the rates are measureable and meaningful. Alternatively, the number of sites with active nests could be

[2]The term 'Index of Abundance' refers to a biased measure of abundance, not true or absolute abundance.

used. None of these performance measures are perfect, however as long as the related assumptions are clearly understood and documented, they may all be useful.

Index of abundance estimates for each stratum were obtained by multiplying the area within that stratum by the occupancy rate per unit area (i.e., counting the total number of 50 ha sites in each stratum and multiplying by the occupancy rate). We assume that the probability of occupancy estimates were independent across strata. Thus, both point estimates and variance estimates could be summed. Each AO contained some areas identified as 'Nil' (i.e., not WISA habitat) by the habitat suitability models. No sampling occurred in these areas and so no inference was made to these areas. Zero density was not assumed in those regions as the historical data had observed WISA in those areas (Marmorek and Pickard 2010), rather the estimates exclude these areas.

3.2 Okanagan-Boundary & Okanagan-West Regions (2010-2013)

Random samples were drawn from the moderate, low and very low habitat suitability classes in 2010. The very low habitat suitability class was removed in 2011; very few birds were found in this stratum. In 2012 and 2013, a census was taken of all public roads. Appendix E provides a summary of data sources from 1996-2012.

The number of repeat samples differed by year. In 2010, CPBs were carried out three times at a subset of point locations. In 2011, CPBs were carried out five times at each point location. Since it is much cheaper to sample road sites, in 2011, enough road and non-road point locations were selected to allow a comparison of occupancy and detection at these two access types.

The 2012 and 2013 data consisted of two sets of CPB points. The first set was along the Oliver Breeding Bird Survey (BBS) Route. The second set included all roads kept open all year by the Ministry of Transportation and Highways within the OK and West AOs. Four-lane freeways were excluded. Using GIS, points were placed every 800m. All points within 300m of mapped low or better suitability habitat were sampled once between April 4 and 9, 2012 and again between April 17 and 21, 2012. These points were also sampled twice in 2013, between April 3 and 14.

The number of CPB stations sampled in the OK and West AOs is summarized by year, habitat and access in Table 2. Habitat suitability is classified as moderate (M), low (L) or very low (VL).

Table 2. Sample Sizes and Number of Repeats by Year, Habitat and Access OK and West

	2010: Subset with 3 repeats			**2011: 5 repeats**						**2012: 2-3 repeats Road only**			**2013: 2 repeats Road only**		
				Road			Non-road			Road			Road		
	VL	L	M	VL	L	M	VL	L	M	VL	L	M	VL	L	M
N	95	95	95	0	50	18	0	20	15	0	124	89	0	124	89
N with repeats	1	25	29	0	50	18	0	20	15	0	124	89	0	124	89

3.2.1. Occupancy & Detection

Repeat surveys were used to estimate the probability of detection and the probability of occupancy of a WISA pair at each point location. Raw occurrence rates were calculated using the short protocol (in 2010 both a long and short protocol were used), presence/absence data, and an assumption of perfect probability of detection (p_i=1, for all locations). Table 3 provides the number of occupied sites by year,

AO and habitat class. The increases from 2010 to 2011 were likely due to the sampling design, which involved five repeat surveys at each site, and surveying earlier in the season. The 2011 data allowed a comparison of road and non-road access. Forty-four percent of the road access sites were occupied, while 57% of walk in sites were occupied (χ^2_1=1.09, p=0.30).

Table 3. Number of occupied sites by Year, Area of Occupancy (AO) and Habitat

Strata	*Year*	*Okanagan*	*West*	*Total*
Very Low	2010	0/45 = 0%	0/50 = 0%	0/95 = 0%
	2011	na	na	na
	2012	na	na	na
	2013	na	na	na
Low	2010	4/45 = 8.9%	4/50 = 8%	8/95 = 8.4%
	2011	16/35 = 46%	14/35 = 40%	30/70 = 43%
	2012	17/42 = 40%	23/82 = 28%	40/124 = 32%
	2013	16/42 = 38%	28/82 = 34%	44/124 = 35%
Moderate	2010	14/45 = 31%	13/50 = 26%	27/95 = 28.4%
	2011	12/17 = 71%	8/16 = 50%	20/33 = 60%
	2012	17/31 = 55%	25/58 = 43%	42/89 = 48%
	2013	18/31 = 58%	27/58 = 47%	45/89 = 51%
SubTotal	2010	18/135 = 13.3%	17/150 = 11.3%	35/285 = 12.2%
	2011	28/52 = 54%	22/51 = 43%	50/103 = 49%
	2012	34/73 = 47%	48/140 = 34%	82/213 = 38%
	2013	34/73 = 47%	55/140 = 39%	89/213 = 42%

These naive estimates of probability of occupancy are improved by accounting for the probability of detection. A series of zero-inflated binomial models (ZIB, Appendix B) were used to simultaneously estimate the probability of occurrence, Ψ, and the probability of detection, p. The effects of strata, AO, road access and other covariates were explored. The use of ZIB models allowed us to assess the effects of covariates on both the probability of occupancy and the probability of detection.

Probability of Detection

In 2010, repeat samples were carried out at a subset of sites (Table 2). Thus, we obtained an estimate of the overall probability of detection: 0.31 with a 95% credibility interval of (0.19, 0.47). In 2011, five repeats were carried out at each site (Table 2). This provided a rich dataset for exploring covariates effects on detection. Road access, AO, and overcast conditions were found to be related to detection (model provided in Appendix B). The relationship between detection and access type was unexpected. As it turned out, different size speakers were used at road and non-road sites. Using these three covariates to predict probability of detection led to an estimate for each site depending on the covariate combination. The probability of detection ranged from 0.16 to 0.68 with an average of 0.49.

In 2012 and 2013 the probability of detection was estimated to be 0.77, 95% CI = (0.68, 0.84) and 0.55, 95% CI = (0.45, 0.65) respectively.

By Time of Year

The probability of detection changes over the course of the breeding season. To improve the probability of detection and decrease the chance of occupancy changing over repeat samples (e.g. due to nest failure), the 2011 data were collected early in the nesting season and within a short time frame. We expected the restriction of the time frame to result in a weaker association between date and probability of detection.

To see how a restriction of range can effect a correlation, imagine a scatter plot representing a strong positive relationship between two variables where the points fall into a skinny football shape. Encircling the data gives a thin, tilted oval. The tighter the oval is to a line, the closer the correlation to one. Now cover about 2/3 of the data in the oval (slide your hand in from the left), encircle the data again, the shape is much more circular, indicating a much smaller correlation. Consequently, it would be a mistake to use an insignificant relationship between probability of detection and date to justify relaxing the time frame restrictions.

Indeed, when the probability of detection was estimated by date (2012): April 4-9, 0.81 (0.69, 0.89); April 17-21, 0.73 (0.61, 0.82); May 2, 0.52 (0.34, 0.70); May 17, 0.46 (0.28, 0.69). As expected, it decreased with time.

Probability of Occupancy

The estimated probability of occupancy is summarized by Strata in Table 4. These estimates are plotted in Figure 3.

Table 4. Estimated probability of occurrence, Ψ, from the Zero-inflated binomial model. 2012 and 2013 data include only road sites.

Strata	Probability of Occurrence (95% credibility interval)			
	2010	2011	2012	2013
Very low	0.008 (0.00008,0.05)	na	na	na
Low	0.224 (0.09, 0.45)	0.45 (0.34,0.58)	0.34 (0.26, 0.43)	0.44 (0.33, 0.56)
Moderate	0.737 (0.44, 0.99)	0.66 (0.46,0.81)	0.50 (0.39, 0.61)	0.63 (0.47, 0.77)

As expected, the probability of occupancy was lower in the low habitat suitability class than in the moderate class. Note that the 2012 and 2013 data represents a census of all public roads and only road access sites were sampled. Therefore, the confidence interval is only meaningful if we think of this sample as representing a random sample from some larger population, say, surveys of similar years. Although there was not a significant difference between access types and occupancy in 2011, we need to be careful regarding bias introduced by looking at only road data. In fact, the power to detect a difference between occupancy rates of 0.57 and 0.44 with 68 road sites and 35 non-road sites is only 0.24 using a type I error of 0.05 and 0.35 using a type I error of 0.10. On the other hand, we have a power of 0.81 to detect a 0.26 difference in the occupancy rate (with a liberal type I error of 0.10). Therefore, a bias of smaller than 0.26, is not expected to be statistically significant for this data.

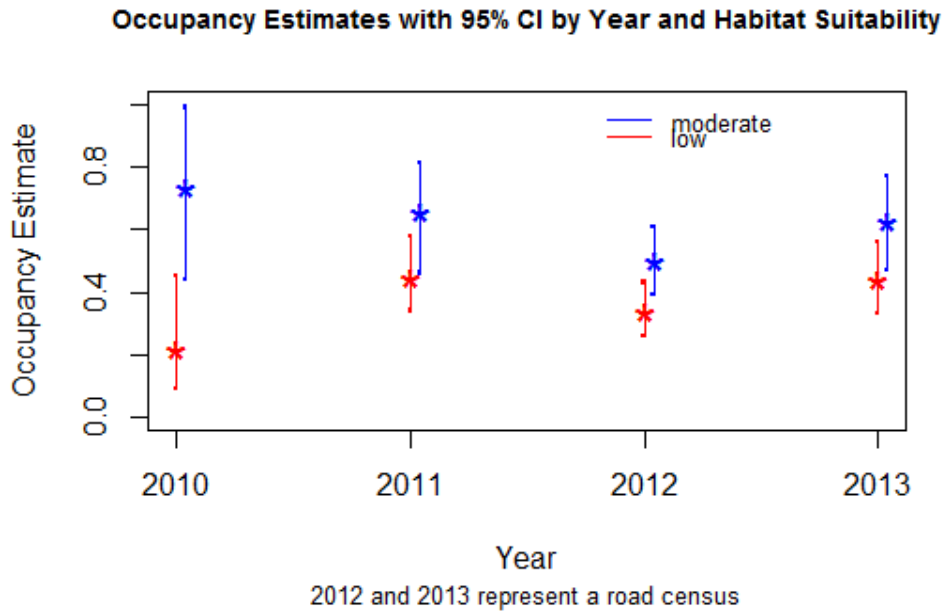

Figure 3. Occupancy estimates by year and habitat suitability class with 95% confidence intervals indicated by a dotted line.

3.2.2. Index of Abundance Estimates

Regression model estimates of Ψ for each habitat suitability class, and an assumed CPB point detection radius of 400m were used to obtain the index of abundance estimate for each AO and each habitat suitability class (Tables 5 and 6). Confidence intervals for totals across strata were calculated using appropriate methods for stratified random sampling (Appendix C). This abundance index is simply a metric by which to judge relative changes from year to year and should not be used to infer population size.

The 2012 and 2013 data represent a census of only road access sites. Therefore, the occupancy data for these years was not used to create index of abundance estimates for the population.

Table 5. Index of Abundance (95% CI) by Strata and AO - 2010

Habitat Suitability Class	Okanagan	West	Total
Very Low	5 (0, 33)	6 (0, 41)	11 (0, 74)
Low	111 (44, 222)	100 (40, 200)	211(84, 422)
Moderate	145 (86,193)	93 (55, 124)	238 (141, 317)

Table 6. Index of Abundance (95% CI) by Strata and AO – 2011

Habitat Suitability Class	Okanagan	West	Total
Low	224 (169, 288)	202 (152, 260)	425 (321, 548)
Moderate	129 (90, 159)	83 (58, 102)	212 (148, 261)

3.2.3. Extended Protocol (2010 only)

The extended protocol was used in 119 sites: 39 in the Okanagan, 24 in the East Kootenay, 56 in the West; 35 very low strata, 45 low strata, 39 moderate strata. Only two of the nine birds found using the extended protocol were found using the short protocol. This indicated a very low rate of detection for the short protocol. The extended protocol appeared to be more successful at detecting WISA.

The main concern with using an extended protocol is that birds are attracted from outside the habitat suitability radius used to sample locations. A potential flaw with this approach is that the more extensive CPBs could result in attracting an individual from outside the sampling unit. Expanding extended protocol counts to a larger area based on an assumption about the effective sample unit size may be problematic. Extended protocols may only be effective if a quiet search method is used that does not use an attractant. However, this could not be combined with the CPB protocol that uses an attractant (the CPB) since the detection functions for the two methods are likely to be very different.

The nine positive records in the extended protocol did not provide sufficient data to model the relationship between the short and extended protocols with any confidence. However, they did suggest that use of an extended protocol was more successful at detecting (or attracting) WISA.

3.3 East Kootenay Region

In 2010, it was decided to treat the EK AO separately from the OK and West AOs. The number of occurrences in the EK was substantially smaller and expert knowledge indicated that: the timing of surveys was too late; there were problems linking the habitat suitability model to GIS data(Ohanjanian, 2011).

Although we intended to use the same ZIB model as above for the OK and West AOs, the very small number of WISA detections (4 of 135 sites) in the EK in 2010 made it implausible. Instead, occupancy was estimated using the raw occupancy rate of 0.03 (95% CI=(0.008,0.074)). This provided a minimum estimate of the probability of occurrence as it assumed perfect probability of detection (probability of detection = 1). This was likely not a valid assumption so a sensitivity analysis was used. The 2010 probability of detection estimates and confidence bounds from the OK and West AOs were used to adjusted the raw probability of occurrence and obtain a range of plausible occupancy rates (Table 7).

Table 7. Estimated probability of occurrence,Ψ, within the EK AO by a variety of possible values for probability of detection.

	P = 0.19	P = 0.31	P = 0.47
Ψ_{raw} = 0.008	0.04	0.03	0.02
Ψ_{raw} = 0.030	0.16	0.10	0.06
Ψ_{raw} = 0.074	0.38	0.24	0.16

Based on the range of possible occurrence rates provided in Table 7, we obtained a range of estimates for the index of abundance in the EK AO in 2010. Table 8 provides minimum abundance estimates based on probability of occurrence of: 0.05, 0.10, 0.15, 0.25 and 0.35. Minimum abundance estimates for each stratum were obtained by multiplying the area within each stratum by the occurrence rate per unit area.

Table 8. Estimated minimum abundance given a range of values for the probability of occurrence

Habitat Suitability Class	Ψ = 0.05	Ψ = 0.10	Ψ = 0.15	Ψ = 0.25	Ψ = 0.35
Moderate	3	6	10	16	22

Low	26	51	77	128	179
Very Low	48	96	144	239	335

This gave a very wide range of possible values and led to a change in methodology. In order to improve estimation, it was recommended to use a dual frame sampling approach in 2011, where a census of known nest sites was combined with a random sample from the remaining terrain in 2011 (Pickard and Ainsworth 2011). The known nest sites provided a sample 'list frame' for the census. The remaining sites were sampled from the 'area frame' using stratified random sampling within habitat type and access.

In 2011, seven WISA detections were made at the 39 CPB stations on the list frame (Ohanjanian et. al. 2011). A stratified random sample of 220 sites was taken from the area frame. Due to logistic constraints, only 84% of the area frame was sampled (see Gyug, 2013, for details). We assumed the subsample of the low and very low habitat classes was representative of the area that could not be sampled. Five sites were found to be occupied. We chose to count WISA at two sites where there was no CPB response but WISA were seen in the area (thus these two detections are not included in Table 9 below). Thus, we counted two WISA detections in low suitability habitat and three WISA detections in very low suitability habitat.

In 2012, ten WISA detections were made at the 40 sites on the list frame (Ohanjanian, Isaac, and Davidson, 2012). A stratified random sample of 248 sites was taken. Two of the sites were combined as they were close together and the detected bird was seen at both sites. Thus, a total of eighteen WISA detections were made in 2012 in the EK AO

Initially, it was thought that the detection probability in the EK in 2010 was low due to sampling relatively late in the season. However, sampling started earlier in 2011 and 2012, yet very few WISA were detected. In 2011, seven of the 12 detections were from the list frame; in 2012 10 of the 18 detections were from the list frame. This suggests that targeting old nest sites was a useful way to identify higher occupancy sites.

3.3.1. Dual Frame Estimates

Dual frame sampling allowed targeting resources in known WISA habitats while maintaining fair representation of the entire EK AO. The AO was split into a list frame which included areas with a known history of WISA behaviour, and an area frame of the remaining area. History of WISA behaviour could have been defined as previously known nests (as used here) or locations with previous WISA detections (as recommended for the future). Here historical information dating back to 2005 was used to create the list frame of all nests founds by CPBs as well as one nest found by the public in 1996.

The performance or outcome measure could be defined in various ways. The EK dual frame study was designed to estimate the absolute abundance of nests. Similar but slightly different protocols were used to assess the nests than were used for the CPB surveys. Gyug et al (2013) reports the results of the nest abundance study. This was also unsuccessful at estimating absolute abundance reliably. To be consistent with the analysis for the OK and West, and due to the extremely low observations, this report uses all CPB detections, although this is not ideal given the inconsistency in how the CPB were used. Whichever outcome is chosen, the appropriate methods for combining estimates from the list frame and area frame can be found in Cochran (1997) and Haines and Pollock (1998). A screening estimator is defined by Haines and Pollock (1998) as:

$$\widehat{Y_s} = \sum_{h=1}^{l'} N_{A(h)} \quad \bar{y}_{NOL(h)} + \sum_{h=1}^{l} N_{L(h)} \quad \bar{y}_{OL(h)}$$

Again, a radius of detection was specified in order to transform occupancy into an abundance index. As per the discussion above, we chose the somewhat arbitrary radius of 400m (i.e., 50 hectare units) to

partition the landscape and get $N_{A(h)}$, the number of 50 hectare units in the area frame, and $N_{L(h)}$, the number of units on the list frame. We estimated, $\bar{y}_{NOL(h)}$, the mean number of occupied sites in the non-overlap domain and $\bar{y}_{OL(h)}$, the mean number of occupied sites on the list frame.

Using number of WISA detections and the appropriate variance estimator as per Haines and Pollock (pg 254, 1998), we obtained a screening estimator of the abundance index: **45** (sd = 43) in **2011** (Ainsworth and Pickard 2012**)**; and **32** (sd = 17) in **2012**. It is not valid to assume a normal distribution to calculate a confidence interval. This can easily be seen by noting that the resulting negative lower bound is not a valid estimate.

Further discussion and analysis of the EK data can be found in Gyug et al. (2013). In particular, they address the important issue of estimating a radius of detection for the CPB protocol and provide the square kilometres covered by each strata level within the sampled area frame. As noted, Gyug et al. (2013) estimated the mean number of nests. The use of positive CPB detections provides an estimate of occupancy and is considered a measure of relative WISA abundance. One problem with using detections is that the same WISA pair may be counted at more than one location. An absolute measure of abundance can be obtained from confirmed nests; nests do not move and will never be double counted. However, nests provide a conservative abundance estimate as it is not always possible to find a nest even when a WISA has been detected and is nesting in the area.

The historical database of all WISA CPB surveys (Appendix D) contains data collected using various sampling methods through a number of individual and government initiatives, often using ad hoc approaches. In fact, the historical methodology often mimicked a dual frame approach by sampling known nest sites as well as new locations. Indeed, if we discount data from sites with known historical use, the number of WISA detections by year drops substantially. For instance, if we remove CPB surveys at sites that had been surveyed in previous years, the number of WISA detections drops from 18 to 1. Again, this indicates that sampling known territory is the best bet for finding WISA in the EK.

The historical data (prior to 2010) was collected using surveyor choice of sites to sample by CPB.. However, in contrast to the 2010-2012 data, more WISA were detected. Table 9 shows the number of WISA detections at CPB stations by year (the 33 CPB stations in 1996 did not detect WISA and are not included). These numbers are based on the historical CPB database. From 2006-2009, the EK project usually used CPB to check re-occupancy of known nest sites and adjacent areas, and these were included in the CPB database. For the Okanagan and West, these same nest checks were included only in the observation database, and not in the CPB database. In 2011- 2012, the EK nest checks for the list frame were recorded in a separate sheet of an Excel file and only included in the observation database because the protocols for nest checks are not the same as for CPB. The main differences in numbers in Table 9 almost certainly reflect this shift of observations from one database to another, not any known difference in abundance. Therefore, it is important to look at the raw data and the specific purpose of the analysis to decide which points to extract for analysis. Figure 43 shows the location of all WISA detections included in the CPB and observation spatial databases. Further historical details are contained in Appendix D.

The implementation of a rigorous sampling plan in 2010 – 2012 explains some of the decrease in detections pre and post 2010. The rigorous sampling plan included randomly selecting locations based on strata chosen from the same habitat model that works very well in the OK and West AOs. However, connecting the habitat model predictions with GIS data is problematic in the EK. Prior to 2010 sampling in the EK was often done using an adhoc type of dual frame method. Any analysis of the historical data needs to consider all CPB surveys and how the data for each survey was collected.

Table 9. EK WISA detections for CPB stations by year.

	Number of CPB stations		
Year	no detections	≥ 1 detection using any method	% with detections
2005	69	0	0 %
2006	448	47	9.5%
2007	475	18	3.7%
2008	420	78	15.7%
2009	436	21	4.6%
2010	202	4	1.9%
2011	217	3	1.4%
2012	244	8	3.2%

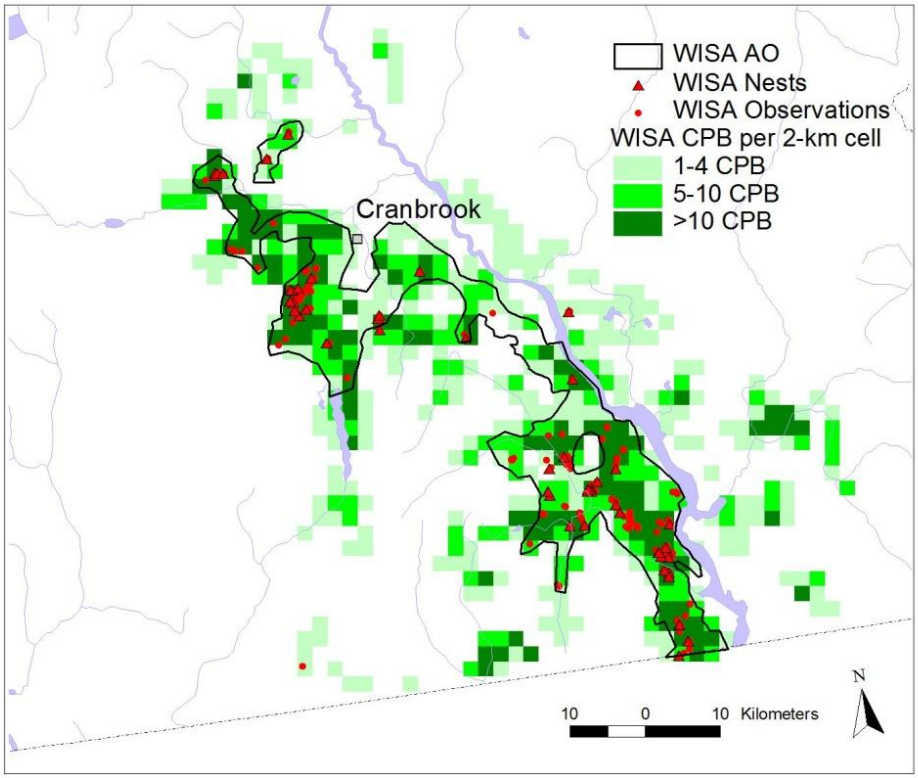

Figure 43. East Kootenay map of all CPB stations (green) and WISA detections (red) on a 2x2 km grid

4.0 Statistical Reliability

There are several aspects to statistical reliability: degree of precision, bias and statistical power. Precision refers to variability which can arise from methodological variability, random variation or process error. It is possible to have a very precise but biased measurement. That is, the measurement consistently hits the wrong target. Statistical power refers to the probability of detecting a real effect. It is important to note that there is a trade-off between power and type I error. Type I error refers to the probability of concluding that there is an effect when in fact there is not. For a given level of precision and a given

sample size, statistical power can be increased by allowing for a slightly larger type I error. This is advisable when the consequences of missing a real effect are greater than the consequences of erroneously concluding there is not an effect when in fact there is. That is, it is wise to trade in some type I error in order to gain power.

As discussed earlier, if we do not account for the probability of detecting a bird, we will likely end up with underestimates of occupancy (downward bias). Precision can often be improved by using stratified sampling. The power to detect a trend in WISA abundance is thus effected by: detection, false absence and stratification. A minimum sample size can be assigned based on each design consideration. The minimum requirements from each section can then be combined to make an overall decision on an appropriate level of sampling effort.

Gyug et al. (unpublished report) calculated the coefficient of variation (cv) for various methods used to collect WISA data. They found this to be a useful way to compare the precision of the various methods used to collect WISA data.

4.1 Sample size by stratum

4.1.1. Detection probability and repeat surveys

As stated in the methods (Section 2.1), even if we do not need an absolute measure of abundance (e.g. nests), to get an accurate index by which to monitor changes over time, we either need to assume a constant probability of detection across sites and years, or estimate it. If it is not possible to ensure that sampling is done at the same time each year, under similar environmental conditions and using exactly the same equipment (speakers or microphones of the same size), then it is not reasonable to assume that the probability of detection is constant.

In order to estimate detection we need repeat samples within a limited time window. The number of sites (n) and the number of repeat surveys (K) at each site for a given probability of occurrence (Ψ), probability of detection (p), and desired precision (SE) can be estimated from the following equation:

$$n = \frac{\psi}{Var(\hat{\psi})}\left[(1-\psi) + \frac{(1-p^*)}{p^* - Kp(1-p)^{K-1}}\right]$$

Equation 6.3, MacKenzie et al. (2006)

Ψ = probability of occurrence
K = the number of repeat visits
p* = the expected probability of detecting the species at least once in K repeat surveys
$= 1-(1-p)^K$
p= the probability of detecting the species given presence at the site

The probability of detection and probability of occupancy estimates provided in (Section 3.2.1) were used to choose the values for the sample size calculations (Table 10). Figure 54 (number of sites) and Figure 6 (total number of surveys) show how the width of the CI (precision) is impacted by, Ψ, p, and K. Each graph uses 2-5 repeats and a range of values for pand Ψ. As might be expected, as p decreases, K increases.

Table 10. OK and West AO, number of sites (n) and repeat visits (k) required to obtain a standard error (SE) of 0.1 by Ψ and p. This roughly corresponds to a 95% CI of +/- 0.2

Habitat Suitability Class	Ψ	P	K	SE	Number of sites (n)	Total number of surveys (n*K)
Moderate	0.66	0.4	3	.1	63	189
Low	0.45	0.4	3	.1	52	157
Moderate	0.66	0.4	4	.1	39	155
Low	0.45	0.4	4	.1	36	143
Moderate	0.66	0.4	5	.1	30	150
Low	0.45	0.4	5	.1	30	150

Precision is measured by the width of the confidence interval. Therefore, smaller widths are desirable. As would be expected, when the probability of detection is small, it is better to put survey effort into multiple repeats. On the other hand, if the probability of detection is reasonably large, we can focus on surveying more sites, with few repeats. We can see that it is worthwhile to make every effort to increase the probability of detection in order to increase efficiency.

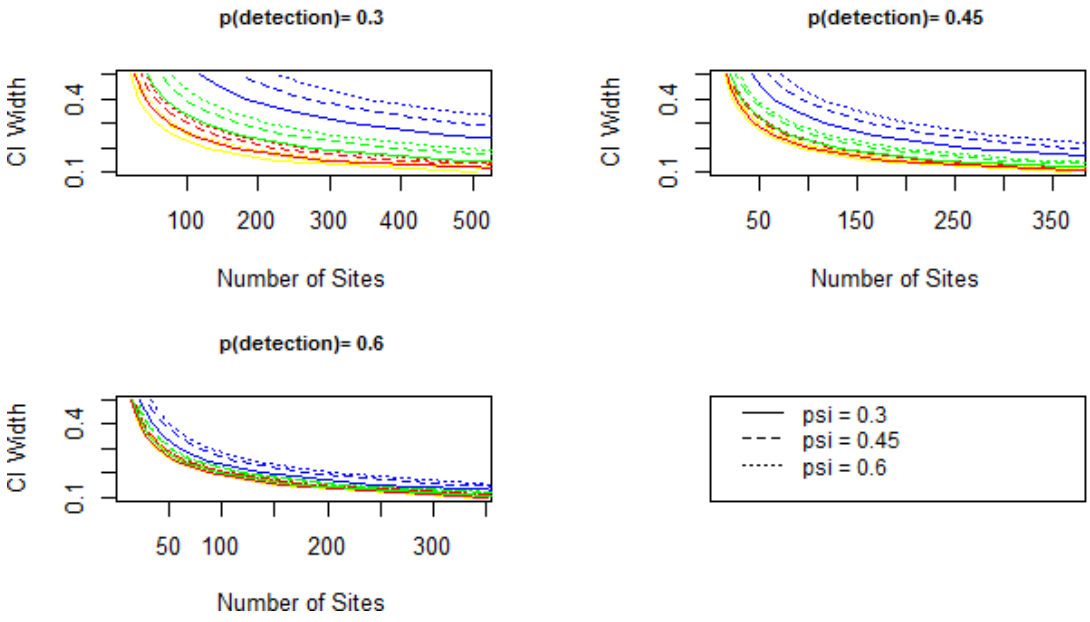

Figure 54. Sample size by width of confidence intervals using three values for the probability of occupancy (indicated by solid, dashed and dotted lines as per the legend), three values for the probability of detection and several values for the number of repeats: k=5 (yellow); k=4 (red); k=3 (green); k=2 (blue).

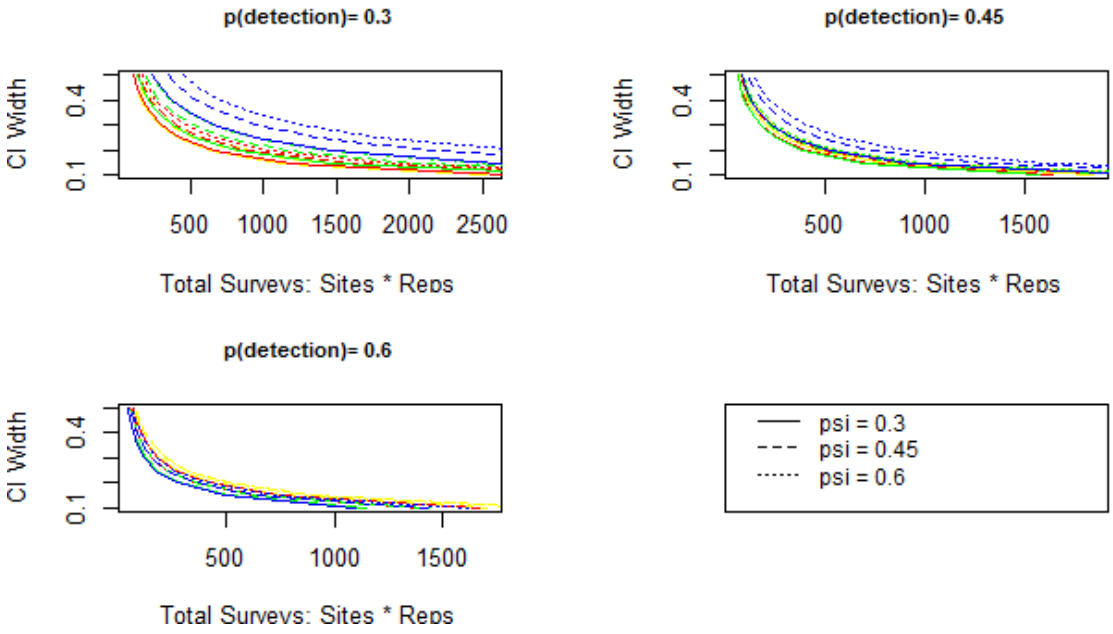

Figure 6. Total sample size by width of confidence intervals using threevalues for the probability of occupancy (indicated by solid, dashed and dotted lines as per the legend), threevalues for the probability of detection and several values for the number of repeats: k=5 (yellow); k=4 (red); k=3 (green); k=2 (blue)

4.1.2. Probability of false absence

The probability of observing a false absence (i.e., missing a WISA when it is present) can be estimated for a given p and K. MacKenzie et al. (2006) recommend targeting a false absence rate of between 0.05 and 0.15. As per Section 3, p for WISA ranged from approximately 0.3 to 0.7. Figure 7 shows the trade-off between K and p. If the p is at least 0.6, then three repeats are sufficient. Table 11 shows the numerical values for the false absence rate for a p of 0.4. In this case, MacKenzie et al.'s (2006) recommendation indicates the need for at least 4 repeat visits.

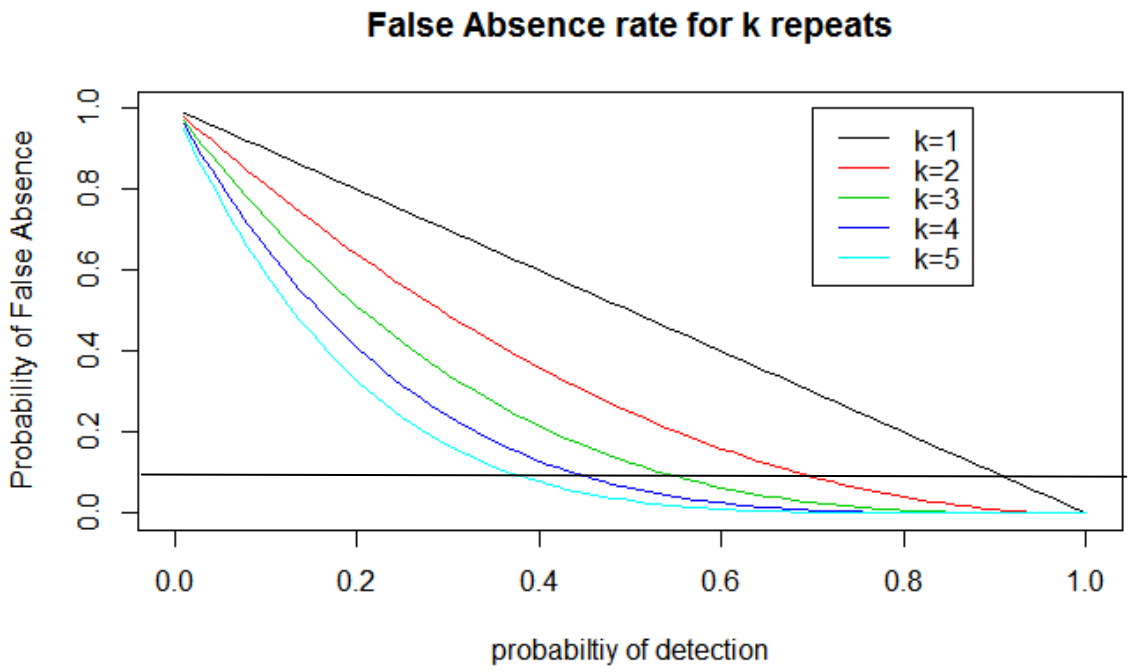

Figure 7. Probability of false absence by probability of detection and number of repeat surveys

Table 11. Probability of false absence for estimated detection probability, p=0.4, and varying number of repeat visits, K

K	P	False Absence
2	0.4	0.36
3	0.4	0.22
4	0.4	0.13
5	0.4	0.08
6	0.4	0.05
7	0.4	0.03

4.2 Power analyses to detect a trend in abundance

Given an estimate of the year-to-year variability and the number of years over which we are interested in detecting a trend, we can calculate the statistical power to detect a trend of a given size (Pickard and Marmorek 2011). Multiple years of data are needed to estimate the year-to-year variability, but it is reasonable to assume that the within year variability provides a lower bound on the year-to-year variability. We estimated the index of abundance for each stratum/AO by multiplying the area of a given stratum/AO by its occupancy rate (Section 3.2.2). Likewise, we can obtain an estimate of the variability in the abundance index for each stratum/AO from the SE of the occupancy rate multiplied by the ratio of the area in the stratum and the sample unit size. Notice that the standard error of the abundance index (Table 12) is dependent on the standard error of occupancy (Table 12) as well as the total area.

Table 12. Estimates of the standard error of the abundance index estimate for each stratum 2011

Stratum	Total	SE(Ψ)	hectares	hectares/50.27	SE(abundance index)
Moderate	212	0.093	16,187	322	30
Low	425	0.064	47,526	925	59

As mentioned above, for any power analysis, there is a trade-off between type I error (α) and type II error. Type I error (α) is the probability of concluding that there is an effect, when in fact there is none. Type II error = 1- power; it represents the probability of falsely concluding there is no effect when in fact there is. In this context, the null hypothesis is that there is no trend in abundance and the alternative (effect of concern) is a declining trend in abundance. Given that we are monitoring an endangered species, it is very costly to miss an effect when it actually exists (i.e., to fail to detect a declining trend). From a conservation point of view, a type II error is much more serious than a type I error (i.e., concluding there is a declining trend when in fact there is not). By relaxing the two-sided type I error to 0.1, we can increase the power to detect a trend in abundance, for a given sample size (or decrease sample size for a given power). We used a two-sided test, thus, maintaining a 0.05 chance of concluding there is a decline when there is not. An alternative approach is to use a one-sided test at level 0.05. However, choosing a one-sided test implies no interest in the possibility of detecting an increasing trend, which is not generally a chance we wish to take.

Figure 8, Figure 9 and Figure 11 show the power to detect a range of effect sizes (regression slope) by monitoring abundance over 30, 20 or 10 years at yearly intervals, every two years, three years, five years or ten years. A cv of 0.14 was used (as per 2011 abundance estimates). Both the moderate and low habitat estimates gave an estimated cv of approximately 0.14 so that the trend analysis was similar. Tables associated with Figures 8-10 can be found in Appendix E. We see that reducing the annual frequency has a big impact on power.

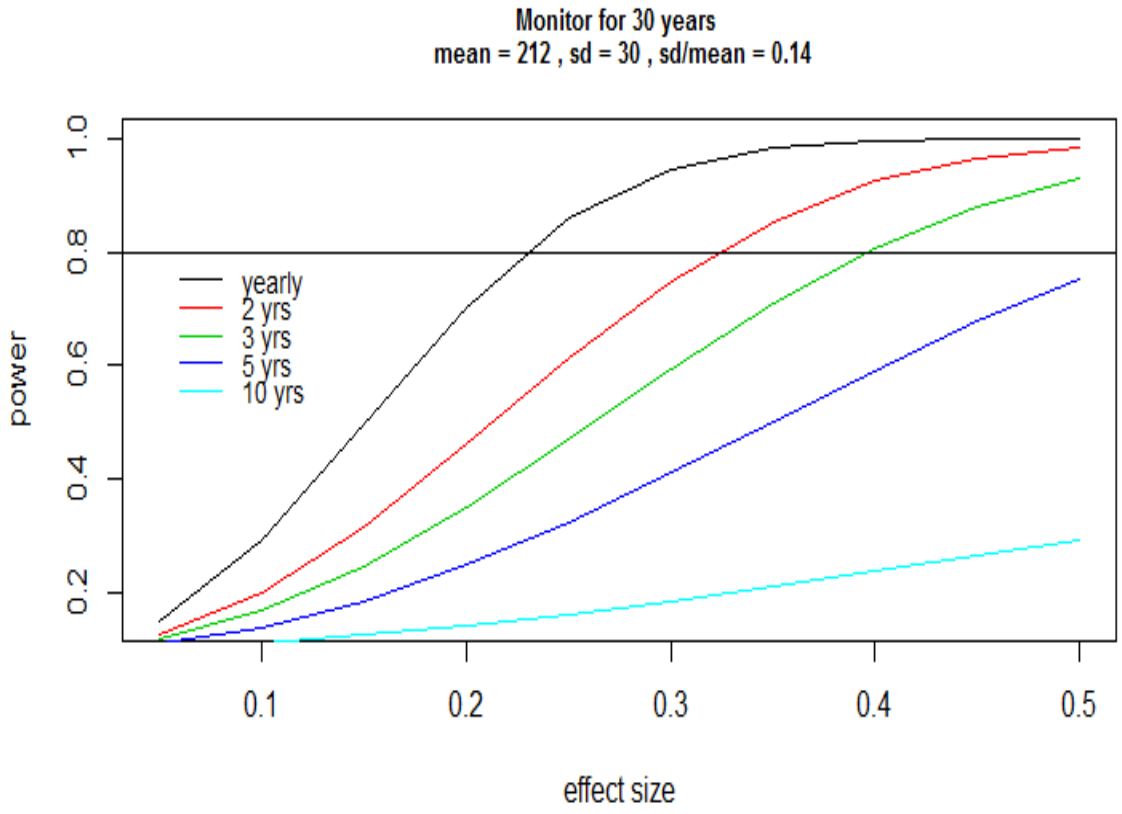

Figure 8. Power to detect a trend (effect size = slope of regression line) in index of abundance for monitoring every year, 2 years, 3 years, 5 years or 10 years with 30 years of monitoring

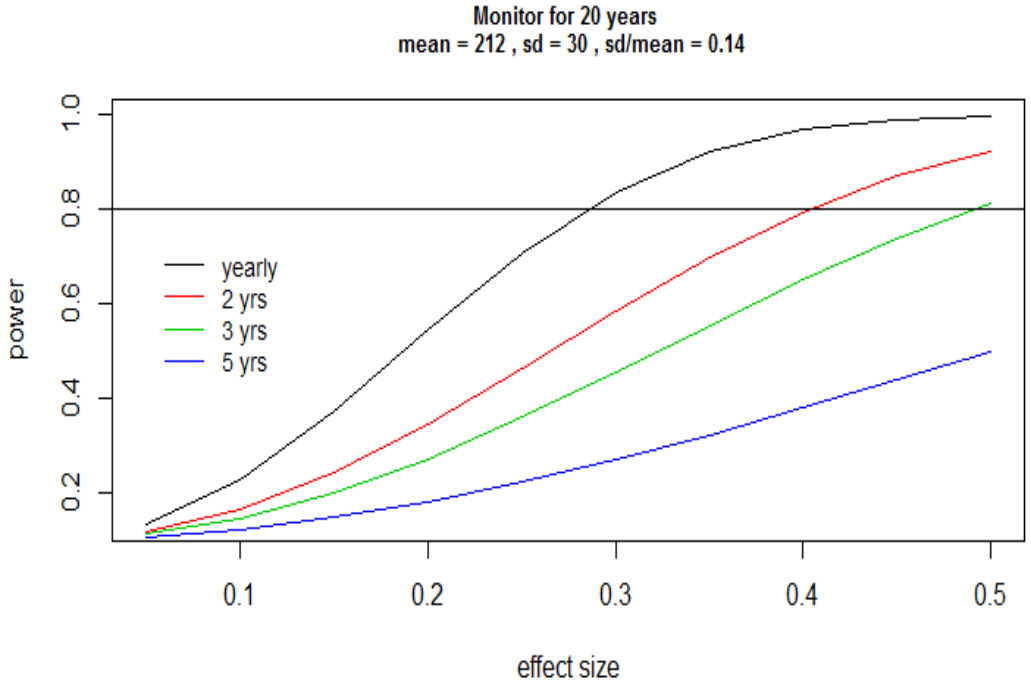

Figure 9. Power to detect a trend (effect size = slope of regression line) in index of abundance for monitoring every year, 2 years, 3 years, 5 years or 10 years with 20 years of monitoring

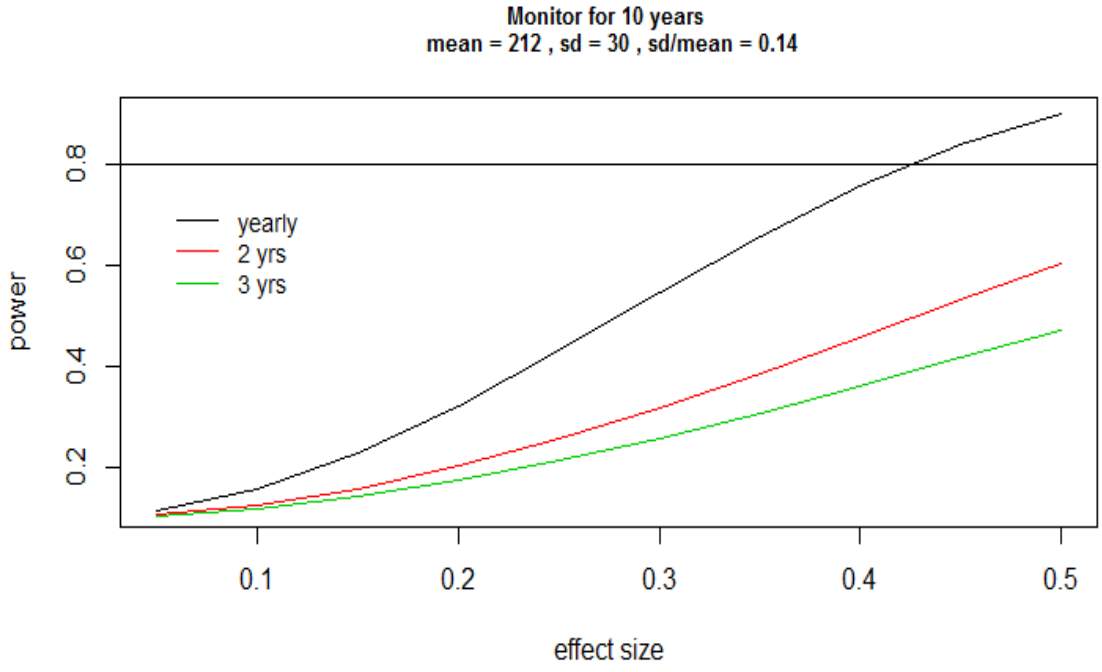

Figure 10. Power to detect a trend (effect size = slope of regression line) in index of abundance for monitoring every year, 2 years or 3 yearswith 10 years of monitoring

4.3 Power analysis to detect a trend in occupancy

Alternatively, we can consider the power to detect a trend in occupancy. The Cochran-Armitage test for trend (Nam, 1987) can be used to assess changes in the proportion of occupied sites. For instance, here we assess the sample size required to detect a 0.2, 0.16 or 0.12 decrease in occupancy.

In order to evaluate the size of trend detectible with annual monitoring over five years, we used a two-sided test with α=0.05 and α=0.10. Figure 10 shows the sample size required to detect a change in occupancy from 0.65 to 0.45, 0.49 or 0.53 (indicated with circles) and from 0.45 to 0.25, 0.29 or 0.33 (indicated with triangles) with 80% power. The size of the detectible trend is indicated using colors (0.20 in blue, 0.16 in green, and 0.12 in orange).Relaxing the type I error from 0.05 to 0.1 is particularly helpful at reducing sample size requirements (see Section 4.2) when the effect size is smallest (0.12 in orange). The numerical values associated with Figure 11 are provided in Appendix E.

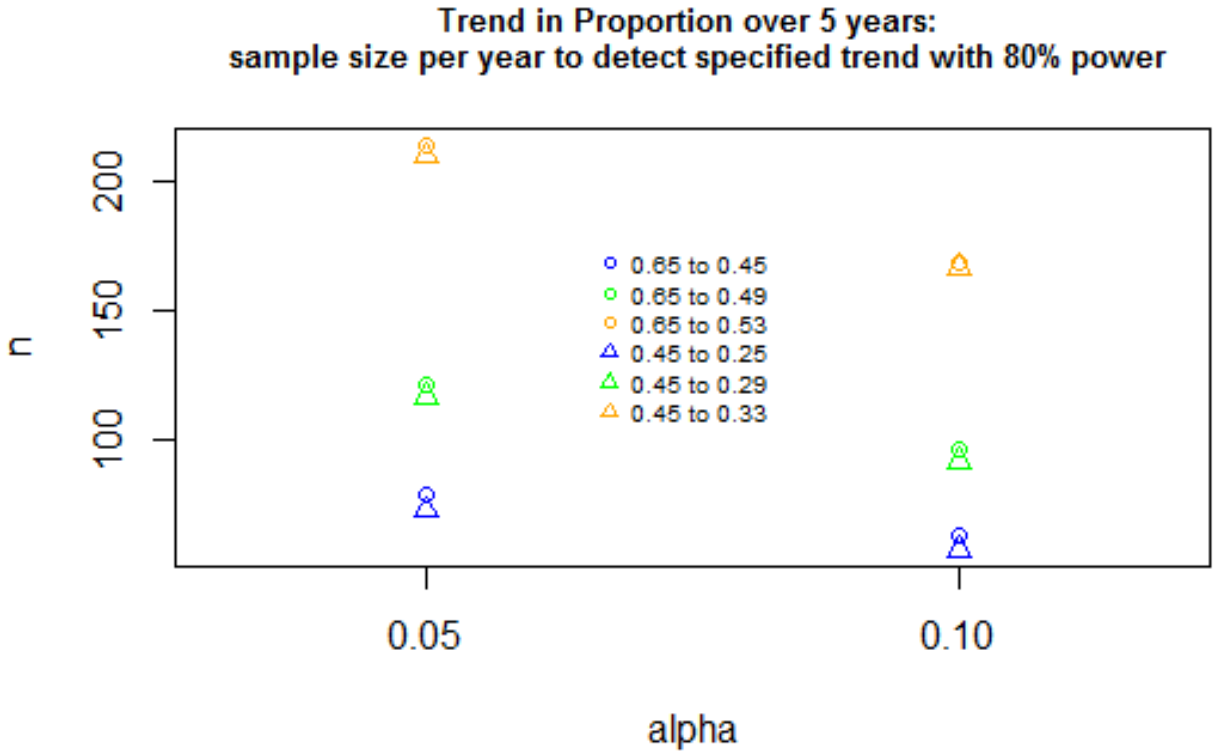

Figure 11. Power to detect a trend in occupancy for various occupancy estimates.

4.4 Sample Size Recommendations and Cost

Okanagan-Boundary and West AO

In order to detect a 0.20 decrease in occupancy over a fiveyear period, it is recommended to sample at least 60 sites in low suitability habitat and 65 in moderate habitat (Appendix E). Assuming it takes one day to sample 20 sites in the OK or West AO, the total cost per survey round in low and moderate habitat is just over six days. If a probability of detection of 0.7 can be obtained by sampling early in the season, two repeats would be sufficient to keep the false absence rate in check. Then, we would need 12 person days per AO. If separate estimates are not required for each AO and a combined estimate is acceptable,

the cost could be kept at 12 person days. To get separate estimates for each AO would require 24 person days. On the other hand, if we require three repeats, the cost goes up to 18 or 36 person days respectively (Table 13).

Table 13. Cost in person days of stratified random sampling and road census.

	Habitat Suitability	P(detection) = 0.7, 2 repeats	P(detection) = 0.55, 3 repeats
Stratified random sample by habitat suitability *	Low n=60	≅ 6 days (per AO)	≅ 9 days (per AO)
	Moderate n=65	≅ 6 days (per AO)	≅ 9 days (per AO)
	Total = 125	≅ 12 days (per AO)	≅ 18 days (per AO)
Road Census (potential bias)	Total	≅ 10 days	≅ 15 days

* Assuming approximately 20 samples per day in the OK and West AO

On the other hand, the cost of a road census of the OK and West is five person days per survey round for a total of 10 person days per year for tworepeats and 15 person days for three repeats. However, this cost savings comes with the risk of introducing bias and missing important changes in the remaining area. Therefore, if a yearly road census is implemented, it should be supplemented by random sampling of the remaining area at least every few years. Because of logistical restraints, wide-area sampling early in the season (i.e., snow) would have to be done at a different time, and would therefore introduce complications of comparing indices based on different detection functions.

Figures 8-10 show the large drop in power when the sampling frequency is dropped from yearly to every two years or more. The RT needs to carefully assess the trade-off between cost and generalizability. Specifically the RT needs to model the decision-making process and possible management responses in reaction to a given significant decrease, which would then guide how any sampling regime could, or would, feed into that process.

5.0 Discussion

The RT needs to determine the size of effect which needs to be detected by monitoring. The effect size should be a biologically meaningful value, i.e. tied to population persistence/recovery. This could be the annual % trend or a net % trend over a given time period. Once this goal is determined, an efficient monitoring program can be established. Until such time, trends that may be detected will not have any management response actions associated with them. The Recovery Strategy set an objective of maintaining populations at the current level within the range of natural fluctuations. Therefore the first goal of monitoring needs to be to detect the range of natural fluctuations. Once these are better defined and understood we can estimate the power required, and therefore the index, methods, sample size and cost that the monitoring program will require in order to be effective.

5.1 Detection and Repeat Sampling

In order to use count data as an index of abundance, we must either assume that the probability of detection does not vary in a systematic way or we must estimate it (Thompson 2002 – Chapter 4). For WISA, the probability of detection varies as behaviour shifts from territory establishment, to courtship and nest excavation, to incubation, to brooding of the young, and to feeding nestlings after the brooding period. Thus, the probability of detection will change over even relatively short periods within the breeding season. Therefore, from a practical standpoint, detection needs to be estimated unless sampling is done at a consistent time each year. In order to estimate detection, we need repeat samples from a site,

or we need to construct detection functions using distance sampling methods and these need to account for varying detection across the breeding season.

MacKenzie et al. (2006) strongly recommend completing repeats at all sites to estimate detectability. However, so long as there are a minimum of two repeats, it is generally more important to increase the number of sites (i.e., spatial replicates) for rare species, than for more common species. For more common species it is worth the effort to confirm presence and, therefore, more repeat visits are worthwhile (MacKenzie et al. 2006).

An alternative is to complete repeat surveys until the first positive observation. This is an adaptive sampling technique known as 'Removal Sampling' (MacKenzie et al., 2006). When occupancy is the primary objective, the most important piece of information is confirmation that the species is present at the site. Once an individual is detected, additional sampling only helps to estimate the probability of detection. The advantage of removal sampling is that the resources that would have been allocated to repeat visits can be reallocated to new spatial locations, thus improving the efficiency. MacKenzie et al. (2006) recommend targeting a false absence probability of between 0.05-0.15 and repeat sampling to a maximum of four surveys per site.

It is important to note that although date of survey was not a significant predictor of probability of detection (2011 regression analysis of OK and West AOs) this was in large part due to the study design; date was restricted at each sampled point so that occupancy would not change over the sampling period thereby invalidating occupancy methods and the estimation of detectability. The analysis of the 2012 data showed that the detection probability decreased with increasing calendar date. The strategy of sampling early in the nesting cycle needs to be maintained. Any further strategies to improve detection would improve efficiency.

5.2 Detection as a function of distance

Occupancy estimates at a given CPB point reflect detection within some radius of the point. It is not clear what this radius is and how detection decreases with distance. Nest location sampling had a well-defined detection curve that decreased with distance (Gyug, 2013), but such a curve has not been defined for CPB sampling alone. However, since the birds frequently approached the observer before responding to the CPB, a basic assumption of distance sampling is violated. Therefore, distance sampling methods cannot be used to estimate absolute abundance from bird detections alone. For occupancy analyses, the working model was to use a constant detection function over the circle defined with center at the CPB point and a radius of 400m. Detection is assumed to be zero outside the circle and to have constant probability, p, within the circle. This is almost certainly not the case, but the shape of any such detection function is unknown. It would be necessary to define the parameters of this detection function if we wish to compare relative abundance among different times in the breeding season when this detection function is almost certainly different.

5.3 Occupancy versus Abundance

Since the number of WISA detections on any given survey at a CPB point was rarely more than 1, occurrence (i.e., presence/absence) was modelled and used to obtain an index of abundance. Here, with so few counts greater than one, a ZIB model using presence/absence data for each site/time was appropriate. When sampling was carried out earlier in the season (early April) and the number of WISA detections at a given location was much more often greater than one, it may be appropriate to model the counts using, for example, a zero-inflated Poisson model to assess the effects of uncontrolled environmental variables and design variables within and/or across years.

5.4 Extended Protocol

The two-protocol or double sampling method was used in 2010 (Ainsworth and Pickard 2012). The*extended* protocol was used in addition to the standard protocol at a subset of sites. This extended protocol had a better detection rate than the standard protocol. However, if the extended protocol is considered, its impact on detection function parameters needs to be carefully considered as it may increase the frequency of pulling in birds from outside the assumed sample unit radius of 400m. The sampling radius could be adjusted; however, it is unclear what the new detection radius would be, or even whether the radius of 400m is appropriate and justifiable. The extended protocol should only be used if it is to be implemented at all locations. It is not felt to be appropriate as a way to capitalize on double sampling methods.

5.5 Habitat Suitability

There are a number of ways to assign habitat suitability to a given CPB point location. For example, one can use the suitability at the point location, the average suitability within a given radius, or the maximum habitat suitability within a given radius. Each may result in different analyses and different interpretations. One of the keys to creating a rigorous design is to carefully consider the definition and ensure that it is consistently applied to sampling allocation and data analysis across all years.

The other confounding factor with habitat suitability is that habitat polygons are frequently intertwined at a fine scale. Thus a sampling point which is theoretically in a low stratum, may detect a bird in a moderate suitability portion of the area sampled from that point. This is especially true in dense forest, where it is usually not possible to determine exactly where the bird responded from, and the birds often move before responding. This problem supports the recommendation to use the maximum habitat suitability within a given radius rather than the point itself to assign strata. Using nests as a measure of absolute abundance does not involve such a problem as the actual stratum at the nest location can be determined unambiguously.

The habitat suitability model works well in the OK and West AOs. However, it is difficult to utilize in the EK where there are very few WISA. In this AO it is essential to focus efforts in the highest use areas. Field crew have repeatedly voiced concerns that assigning sampling points using the habitat suitability model with current GIS data is problematic (Ohanjanian, 2011, Ohanjanian, pers. comm.). Although this could still be used as a starting point, local expert knowledge and some form of ground truthing needs to be incorporated into the point location selection process.

Regardless of the approach used to assign habitat suitability to a sampling point, so long as it is repeatable, the design is valid.However, the design is most efficient when the separation among strata is the strongest. Points may be post-stratified (to correct for any assignment errors) for the purposes of covariate analyses (e.g., improving our understanding of habitat use) but the original design should be used for estimating abundance. Overall estimates for the AO are comparable across years with any valid design (regardless of strata) but if there is interest in comparing within a stratum across years, it is necessary to use a consistent definition over time. Regardless, it is critical to clearly document the approach used each year and ideal to converge on a single method that is repeatable across years.

5.6 Stratification and Areas of Occupancy

Stratification into low and moderate-high strata appears appropriate for the OK and West AOs. The strata were distinct and they led to nearly non-overlapping confidence intervals for the probability of occurrence. However, in the EK, with so few birds, it is particularly important to focus sampling in the best possible habitat and yet these areas have not been effectively identified.

Based on the 2010-2013 data, it seems reasonable, for the time being, to estimate a single, combined occupancy estimate for the OK and West AOs as the occupancy and relative abundance of each stratum are not significantly different between the two regions. This could improve the accuracy of the estimates. However, if there is reason to believe that future trends in WISA abundance will differ between these AOs, it is important to maintain sufficient power within each AO. In either case, measures to ensure balance of effort across the two AOs need to be considered.

5.7 Road Access Sites

The relationship between access type and occupancy was not statistically significant in the 2011 univariate or regression analysis (road sites estimate of 44%; non-road sites estimate of 57%). This does not necessarily imply that the two access types have equivalent occupancy. As shown in Section 3.2.1, the study had limited power to detect a difference smaller than 0.26. Therefore, sampling within only one access type could introduce bias, especially if the proportion of samples is not representative of the proportion of the total area covered by road sites. An analysis could account for the sample weighting but would require information regarding the number of hectares covered by road and walk in access sites. A potential difficulty is the cost of maintaining this information as it changes over time.

Sampling road access sites is convenient and cost effective. Therefore, it may be a worthwhile exercise to simulate data to assess how small to moderate occupancy differences between road and non-road access affect the probability of occurrence estimates. In any case, the factors influencing the difference between road access and non-road access sites need to be carefully assessed. For instance, the differing protocols, and sampling seasons for road and non-road should be standardized. If this is not possible, they need to be modeled and accounted for to allow comparison between a road census and random sampling done for a subset of years. It is important to continue to assess the similarity/difference between habitats that have road and non-road access as the relationship may change in the future (e.g., differences may become more pronounced with more traffic).

5.8 Frequency of Long term Monitoring

There are two components to the question of long term frequency. The first is whether or not sampling of any kind should be done annually or at some less frequent scale. The second is whether or not the same sites should be revisited year after year or whether the sampling units should be a completely new randomized draw each year. Random sampling for each AO is necessary to detect an unbiased trend over time. During the first couple of years of this pilot monitoring framework, the annual designs were re-randomized each year. Panel designs that put roughly equal weight on re-visiting sites annually and re-randomized sites have been shown to be the most efficient way to estimate both status and trend (McDonald, 2003) but they are more complex to implement and require consistent long-term funding.

Once the objectives are clearly defined, the RT needs to decide on the long term plan for monitoring WISA in B.C. If there is consistent funding expected over time, it would make sense to develop a panel design that includes revisiting some sites across years. If there is not consistent funding expected, the re-randomized design has the advantage that it is very simple to implement and analyze and it is possible to always obtain valid estimates regardless of the available budget (although the precision will vary with effort). Once a panel design is begun, it is very difficult to deal with changes to the sampling frame, strata, or sample size and still maintain a valid design. For example, if strata change over time, due to, for instance, logging, then the panel design will be problematic. At this time, a simple design which is re-randomized each year is recommended for WISA in B.C.

6.0 Recommendations

The RT needs to decide on the performance measure and effect size that will be used to indicate the need for management action. Once this has been decided, another workshop should be held to carefully create a rigorous, long-term monitoring program. This should include careful delineation of all inclusion/exclusion criteria (e.g. date of sampling), operational definitions (e.g. whether the performance measure is defined as birds, pairs of birds or nests and how to allocate habitat suitability at a sample point), and the creation of a standardized database to store consistent data across all years. All definitions and protocols need to be discussed to ensure a common understanding. All procedures for the long term monitoring plan need to be carefully documented so that they can be duplicated every year. By creating a transparent, clearly laid out monitoring plan that can be implemented consistently over time, methodological variability and errors will be substantially reduced.

Specific recommendations are outlined below.

6.1 Standardized Methodology

The lessons learned in these first few years need to be used to create a standardized monitoring protocol that includes inclusion/exclusion criteria, operational definitions and a standardized database to maintain all variables used for monitoring purposes. For instance, the RT needs to decide on the best definition of how to assign habitat suitability to a sample point. Is it habitat suitability at the point location or the maximal habitat within some radius of the point? Once decisions are made, it is essential that the definition be used consistently for both sampling and analysis purposes across all years.

To improve efficiency, a monitoring database should be created and maintained by one organization. This organization should develop the database in consultation with a data analyst. At this time, all data are in a shared spatial database updated annually from data submitted as part of various Williamson's Sapsucker projects and sometimes the general public.It has been designed for spatial viewing but is quite inefficient for researchers, monitors and analysts to extract subsets of data for specific analyses. A standardized template could be used to extract data for Environment Canada's monitoring purposes. The database needs to be focused on the RT's specific monitoring goals. The temptation to collect potentially useful information for future use leads to substantial cost increases and complexity. The specific goal is to establish standardized, high quality data in as simple a format as possible while allowing for the possibility of adding new fields as needed in the future.

6.2 Detection

One of the main concerns for the monitoring program is to create an estimate of abundance (absolute or relative) that can be monitored over time. This can be done, as recommended in the AMF by counting WISA detections, or, by counting nests. Either way, the probability of detection needs to be addressed. In order to use count data as an index of abundance, we must either assume that the probability of detection does not vary in a systematic way or estimate it (Thompson 2002 – Chapter 4). Therefore the 2 options are:

1) Assume a constant probability of detection ifit is justified by:
   - → restricting monitoring surveys to a narrow time window early in the breeding season when detection is high and use the same time window consistently from year to year
   - → using the same CPB protocol and equipment for all surveys

→ limiting sampling to a reasonable set of environmental conditions which will maintain a constant detection rate

2) Estimate the probability of detection
→ to increase efficiency and decrease the number of repeat surveys required, sample early in the breeding season

Either way, the monitoring protocol needs to be reviewed to ensure that all possible ways of increasing the probability of detection have been exploited. As seen in Section 4, reducing the need for repeat surveys leads to large gains in efficiency.

6.3 Performance measure of Abundance

The RT may wish to revisit the performance measure of abundance they have selected. Given the findings from 2010-2013, do they still feel that the number of detections from CPBs is the most appropriate metric? Here, we use a somewhat arbitrary definition of detection radius in order to get an index of abundance from occupancy. Simply reporting occupancy is an option. However, it does not allow for an interpretation in terms of an index of the total number of WISA in each stratum or AO. For instance, the probability of occupancy is higher in moderate suitability habitat than in low suitability habitat. However, when we turn occupancy into an abundance estimate, we see that the low suitability habitat may account for more birds than moderate habitat. Only if we include density as a metric, rather than just occupancy, will numbers estimated in a higher density habitat reflect the true abundance. A simple analysis of occupancy does not provide this context.

Another option is to reconsider the use of annual nest locations as a metric. The advantage of this is that nests are stationary so that distance sampling methods can be used, and they will not be double counted by adjacent surveys. On the other hand, nests are time consuming to locate since they require extra nest surveys after the CPB surveys. However, this extra cost needs to be estimated and balanced off against any gain in information that can be used for management and status assessment.

6.4 Okanagan-Boundary and Okanagan-West AOs

In the Okanagan-Boundary and West AOs, continue to collect public road census data each year using at least two repeats. This is an efficient way to carry out yearly monitoring. When changes are observed, identify any linked changes in environmental or habitat variables, assess the remaining AO for similar changes, assess current WISA presence or abundance at such areas with similar changes, and explore the historical data to see if such changes have been associated with a decrease or increase compared to the current WISA presence or abundance.

In addition it is strongly recommended to continue some level of random sampling effort. Consistently surveying roads is an efficient way to monitor WISA; however, sampling only this subset of the AO introduces bias. It is not clear if this bias is negligible or if it will change over time. Therefore, some level of continued stratified random sampling is highly recommended unless the bias can be defined or accounted for. The RT needs to carefully assess any biases that may be introduced by focusing on a road census.

Therefore, it is recommended to implement a dual frame sampling plan where the list frame for this AO is road access sites and the area frame is all remaining areas in the AO. The list frame should be sampled every year. The area frame could be sampled at a less frequent scale. If the RT chooses this option, the number of hectares covered by the road census needs to be defined and a comprehensive power analysis

should be carried out to optimize the frequency and intensity of random sampling while allowing for differential effort in each stratum.

6.5 East Kootenay AO

Both historically and in the period from 2010-2012, the most successful way to find WISA in the East Kootenay has been to survey known WISA territories. We do not have the power to statistically detect relevant decreases in this population over a reasonable time period. However, it is still important to monitor this area in the most efficient, consistent way possible to develop the knowledge bases to supportadaptively implementing a more statistically rigorous design in future. In this region, where management or the identification of critical habitat depends on known nest or breeding pair locations, the most important thing is to find WISA. As Charles Babbage says, "Errors using inadequate data are much less than those using no data at all" (in Le and Zidek, 2006).

Therefore, we recommend continued use of the dual frame approach as well as the following:

- Relax the criteria for a positive identification. That is, count incidental sightings at sample locations.
- Focus sampling in areas with the highest probability of detecting WISA:
  - → In the past, the habitat suitability model was validated by overlaying habitat suitability classes over locations where WISA have been detected historically. Therefore, use a combination of the updated historical nest and historical detection data (CPB detections and incidental observations) and the habitat suitability model to further refine the areas to focus on in the EK
  - → Provide a mechanism for field crew to add sampling locations if incidental observations are made or if detections are reports by other means
  - → Prior to commencing field work, use local expert knowledge and ground truthing to validate sampling points selected from the habitat suitability model and GIS data
  - → Incorporate knowledge of carpenter ant habitat and carry out further investigation of WISA foraging behaviour in this AO
  - → If necessary, use telemetry to improve the understanding of habitat use in the EK
  - → The historical data (prior to 2010) was not collected in a rigorous way. However the updated database contains all CPB surveys and WISA nest data and could be used for exploratory analysis and hypothesis generation.

6.6 Summary of Recommendations

Over the course of this pilot study a great deal of information has been learned, and many uncertainties have been addressed. In 2010, we could only speculate on the usefulness of many of the proposed approaches. At this time, we feel there is sufficient data and experience to inform future WISA monitoring efforts. However, there are a number of decisions to make that require input by the RT and all contractors. The primary recommendation at this stage in theAdaptive Monitoring Program is to bring the RT together for a focused workshop with the contractors (analysts and monitors) to discuss the following recommendations:

- A simple, concise, database needs to be set up in consultation with a statistician. This database should only include data relevant to the monitoring program. Variables need to be defined as per the operational definitions laid out by the RT.

- The RT needs to clearly define the following and applythese definitions consistently for sampling, data collection and analysis across all years.
    - the performance measure to be used to assess a trend;
    - the effect sizes which are required for management action;
    - inclusion/exclusion criteria for sampling (i.e., how do we handle incidental observations);
    - operational definitions such as that used to define habitat suitability at a CPB point;
    - standardized sampling protocol.

- The trend in abundance (effect size) that can be detected with 80% power is substantially reduced by sampling at less than annual frequencies. A census of all road sites is a cost effective way to sample in the Okanagan regions. In order to capitalize on this cost savings and avoid introducing bias, we recommend using a dual frame sampling design in the Okanagan-Boundary and Okanagan-West regions. This census of the road sites and random sample (stratified) of the remaining area can be used to detect relevant indicators for management action.

- In the East Kootenay, a dual frame sampling design should be continued. Here a more flexible monitoring design should be implemented with the goal of finding and monitoring as many WISA as possible. We suggest relaxing the definition of previously known habitat from known nests to locations with previous WISA detections.

- Given the low power to detect trends in abundance, the original AMF questions shouldbe revisited and a more focused approach for tackling secondary questions may need to be considered (e.g., Before After Control Impact study of effects associated with harvest).

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Appendix A– 2010 and 2011 Objectives

In 2010 pilot data were collected for all three Areas of Occupancy (AO) according to recommendations that arose from: the March 9, 2010 workshop, the AMF, and subsequent analyses (Pickard and Marmorek 2011). The results of the 2010 monitoring effort were used to:

- Estimate the probability of detection using repeat sampling and evaluate the implications of: region, habitat strata, and date on the detection probability.
- Evaluate the use of a double sampling or two-protocol approach rather than a repeated sampling approach.
- Generate an estimate of abundance for each Area of Occupancy with appropriate confidence intervals.
- Use estimates of variability within and between strata to evaluate: the stratification itself and the sample size per strata. Use estimates of variability across years and the baseline estimates to assess the power to detect trends in abundance over time.
- Assess the use of strata based on existing habitat suitability models.
- Assess the logistics of a stratified random call-playback monitoring approach.
- Provide recommendations for improving the statistical performance of the monitoring design in 2011 and beyond.

In 2011 an adapted sampling plan was used to collect further data. These data were used to:

- Provide a statistical summary and overview of the results from 2011 call-playback (CPB) surveys
- Estimate:
    - → the probability of detection using repeat sampling and assess the effect of covariates on probability of detection
    - → the probability occupancy for habitat in the low and moderate suitability classes
    - → the index of abundance and it's 95% confidence intervals within each habitat stratum and across all strata, and
    - → the variance of the index of abundance within each habitat stratum and across all habitat strata
- Estimate the statistical power to detect trends for a range of conditions
- Estimate an abundance index for the East Kootenay AO using the appropriate methods for data obtained from dual frame

Appendix B - Zero-inflated Models for Occupancy and Detection

A good measure of occupancy accounts for detection probability. Zero-inflated models were originally formulated to accommodate the extra variability induced by having a larger number of zero counts than is accounted for by standard count distributions such as the binomial and Poisson distribution. The variance of these distributions is constrained as they only include one parameter which models both the mean and the variance.The model formulation for zero-inflated models has a natural interpretation in ecology. In a zero-inflated binomial (ZIB) model, the binomial component can be used to model the probability of detection while the zero component models occupancy. It can be used to simultaneously estimate the probability of occupancy, Ψ, and the probability of detection, p, incorporating covariates for both parts (Ψ and p).

The basic zero-inflated model (Lambert, 1992) is:

$$y_i \sim \begin{cases} f(\mu_i) & \text{with probability } \Psi_i \\ 0 & \text{with probability } 1\text{-}\Psi i \end{cases}$$

Here, $f(\,)$, denotes the binomial distribution, Binomial(k_i, p_i),with k_i, the number of surveys at point location i, and p_i, the probability of detection at point i. Covariates are incorporated using generalized linear models: $\text{logit}(p_i)= \alpha + \underline{\beta}_p X$; $\text{logit}(\Psi_i)= \alpha + \underline{\beta}_\Psi X$, where $\underline{\beta}_p$ and $\underline{\beta}_\Psi$ are vectors of regression coefficients, and X is a matrix of covariates which may be the same or different for the two components.

The basic model can be extended to allow detection probability to change over time and to accommodate time varying covariates, such as precipitation and cloud cover. Analysis is straightforward to implement in freely available software such as PRESENCE (Hines, 2006) or WinBUGS (Spiegelhalter, Thomas and Best, 1999). PRESENCE provides a wide range of models, is user friendly, and includes non-technical tutorials. It is straightforward to create a 'Model' table which provides several useful summary measures, such as the AIC values for all fitted models (see Burnham and Anderson, 1998 for a discussion of model fit). The model output page provides parameter estimates and important information regarding convergence.

WISA Covariates

The classical approach to modelling stratified data is to carry out estimation within each stratum, then combine the estimates using appropriate methods found in, for example, Cochran (1977). Here, the design involved three stratification variables (AO, habitat stratum, access type) with two levels each. Breaking the WISA data into the resulting eight stratification groups led to very few CPB points within each group. By combining statistically insignificant groups, we can decrease variability by increasing the sample size in each group. The trade-off was bias. Stratified sampling proportional to size is convenient in that the data self-weight. However, when optimal sampling allocation is used, sample sizes may favour, for example, sites which are cheaper to sample. Estimates based on collapsed strata are biased toward the strata with more weight. For example, by collapsing over access, our occupancy estimate was biased toward the true value for road access.

Covariates were classified as site- or survey-specific. Site-specific covariates were: habitat type (low and moderate suitability), road access (no road, road) and AO (Okanagan-Boundary and West). Survey-specific covariates can change over time. These included date of survey, time of day (transformed to decimal time), temperature, cloud cover, wind and precipitation (Table 14).

Table 14. Covariates considered for inclusion in each component of the model

Covariate	*Site Specific Covariate*	*Survey Specific Covariate*	*Used to predict Probability of occupancy, Ψ*	*Used to predict Probability of Detection, p*
Strata: low or moderate habitat suitability	X		X	X
Road Access	X		X	X
Area: Okanagan, West	X		X	X
Date		X		X
Time of day		X		X
Temperature		X		X
Cloud cover, indicator function cc=4		X		X
Precipitation, indicator function PRECIP="N"		X		X
Wind		X		X

Models were fit in two stages. First, indicator functions for all three stratification variables (moderate habitat, West, and road access) were included in both the occupancy and detection components of the regression model. In order to simplify analysis and maintain reasonable sample sizes, non-significant effects were removed. That is, we collapsed the data over stratification variables with non-significant differences. This necessitates the assumption that covariate effects are equivalent across strata levels and uses a common error variance. The best model here was used as a base for adding survey level covariates.

At the second stage of modeling, we added survey level covariates to the base model. Models included: the base model plus all survey level covariates; the base model plus each survey level covariates included one at a time. Once again, note that we assume equivalent covariate effects across the stratification variables not included in the base model. Since a mixture distribution was used, the stratification variables were included in both components of the model. This is a situation not covered in the standard sampling literature. Extensions of Cochran's (1977) methods for combining simple linear regression estimates across strata to regressions in the mixture distribution context would be useful.

The most intensive surveying happened in 2011. The five repeats per site provided a rich dataset for analyzing the covariate effects on occupancy and detection. The final regression model was:

$$\text{logit}(p_i) = -0.04 - 0.89*\text{West} + 0.79*\text{Road access} - 0.70*\text{overcast}$$
$$\text{logit}(\Psi_i) = -0.17 + 0.82*\text{Moderately Suitable Habitat}$$

Appendix C – Stratification Methods

With stratified random samples, estimates for each stratum are obtained by multiplying the area within that stratum by the occupancy rate per unit area. We assumed that probability of occupancy estimates were independent across strata.
Confidence intervals for totals across strata were calculated using the methods for stratified random sampling outlined in Cochran (1977). First mean estimates were obtained as follows:

$$V(\widehat{\Psi_{st}}) = \sum_{h=1}^{L} W_h{}^2 V(\widehat{\Psi_h})$$

where

$$V(\widehat{\Psi_h}) = \frac{S_h{}^2}{n_h}\frac{N_h - n_h}{N_h}$$

and $W_h{}^2 = N_h/N$

Here h denotes strata, L=2 is the number of strata levels, N is the total number of units, N_h is the total number of units in stratum h, n_h is the sample size in stratum h, and W_h is the stratum weight. We estimated $V(\widehat{\Psi_h})$ using the standard error of Ψ. This was obtained from PRESENCE. The total is easily calculated, as it is simply the mean multiplied by a constant. This provided the abundance index estimates in Table 7.

Appendix D – Historical Data: 1996-2012

Prior to implementing the AMF in 2010, a large amount of WISA data was compiled via a combination of road transects, arbitrary sampling, and random sampling. This data is organized in a comprehensive data base. The data dates back to 1996 and contains information on more than 16,000 surveys in B.C. Even after adjusting for inflated detection associated with the historical sampling methods (e.g., sampling known nest sites without formally using a dual frame design, unadjusted estimates from repeated sampling, survey points within 400m), many more WISA were detected historically in the East Kootenay. It can be broken down into two dbf files.

The first file (wisa_cpb_1996-2012b.dbf) includes 16,169 CPBs which were carried out, mostly, at locations that had not yet been surveyed for WISA. However, surveyors in the EK from 2006-2009 often used these to re-survey nest and other WISA locations known from prior years. Of these, 8,172 were within the Area of Occupancy (AO, 'the area currently occupied for breeding') (Gyug, 2007). The remaining 7,997 were carried out outside of the AO. The data used to create the AMF (Marmorek and Pickard, 2010) included only CPB stations. A CPB station is defined as any CPB carried out at a new location within the AO.

The second file (wisa_obs_1994-2012g.dbf) contains detailed information on all nest locations and the other WISA observations.

Figure 12 shows the location of all CPB stations and all WISA detections from 1996 to 2012. WISA detections from all methods (random, incidental, or via a CPB at a known location) are included. The map

is generated using a 5 x 5 km (500 ha) grid. In the field, 2 people can survey approximately 100 – 400 ha in a day depending on the terrain (Gyug, 2012, pers. comm.). Thus, the grid cells are slightly larger than the area that could be sampled in a single field day. Figure 43 provides a more detailed map for the East Kootenay using a 2x2 km grid.

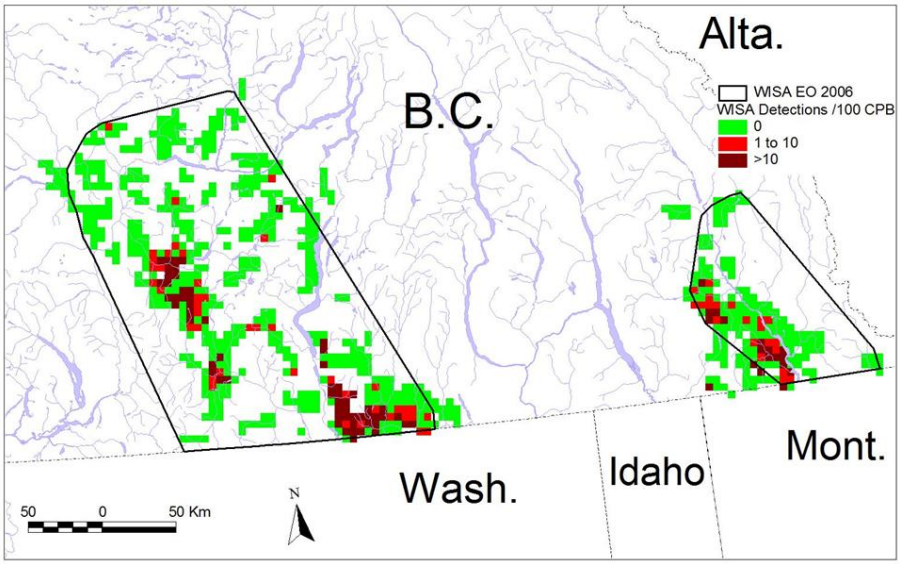

Figure 12. Map of all CPB stations (green) and WISA detections (red) on a 5x5 km grid

The survey effort from 1996 to present in the OK, West and EK Extent of Occupancy is summarized in Table 15 and Table 16 below. The sampling description column provides important information regarding: the type of data collection; and whether or not the location was close to another sampling point. For instance, it is important to note if a sampling point is close to another as points within 800m may lead to counting the same bird twice. The references provided are by no means comprehensive. There are many more references which need to be added to this list.

Table 15. Historical Data in for Okanagan-Boundary and West Areas of Occupancy (AO)

Year	CPB Station	Other	Sampling Description	References
1996		n = 19		
1997	Ok-Bdy n = 86 West n = 14	n = 106	n=23 <400m from previous n=179 Relative Density n=4 Repeat from previous year	
1998	Ok-Bdy n = 24	n = 22	n=10 <400m from previous n=2 no tape used n=33 Relative Density n=1 Wind > 4	
1999-2002	No data			
2003	Ok-Bdy n = 161		n=14 <400m from previous n=126 Relative Density n=21 Wind > 4	
2004	Ok-Bdy n = 478 West n = 73	n = 436	n=126 <400m from previous n=2 <800m from +ve n=33 nest search n=2 no tape used n=777 Relative Density n=46 Repeat from previous year n=1 Wind > 4	

2005	Ok-Bdy n = 371 West n = 112	n = 342	n=84 <400m from previous n=4 <800m from +ve n=177 Census Area n=20 nest search n=4 no tape used n=413 Relative Density n=123 Repeat from previous year	
2006	Ok-Bdy n = 174 West n = 584	n = 659	n=135 <400m from previous n=2 <800m from +ve n=52 Census Area n=6 no tape used n=1141 Relative Density n=68 Repeat from previous year n=13 Wind > 4	
2007	Ok-Bdy n = 38 West n = 414	n = 4141	n=447 <400m from previous n=107 Census Area n=15 no tape used n=3631 Relative Density n=393 Repeat from previous year	Gyug, L. (2007) Gyug, Ohanjanian, Steeger, Manley and Davidson (2007)
2008	Ok-Bdy n = 329 West n = 117	n = 97	n=11 <400m from previous n=46 BBS Route n=168 Census Area n=173 PN Random 45 min n=3 Random 45 min - invalid n=112 Relative Density n=30 Repeat from previous year	Gyug, L. (2008)
2009	West n = 2	n = 28	n=30 Relative Density	
2010 *	Ok-Bdy n = 228 at 135 stations West n = 264 at 150 stations		n=95 Random – Extended n=287 Random - First n=55 Random - Repeat 2 n=55 Random - Repeat 3	Marmorek and Pickard (2010) Pickard and Ainsworth (2011)
2011 *	Ok-Bdy n = 331 at 73 stations West n = 320 at 64 stations	n = 4	n=24 BBS Route n=126 Random - First n=126 Random - Repeat 2 n=126 Random - Repeat 3 n=126 Random - Repeat 4 n=126 Random - Repeat 5 n=1 Opportunistic	Gyug (2011) Gyug (2013) Ainsworth and Pickard (2012)
2012 *	Ok-Bdy n = 505 at 377 stations West n = 824 at 610 stations	n = 312	n=23 Opportunistic n=10 Relative Density n=224 Road Monitor - First n=213 Road Monitor - Second n=52 Road Monitor - Third n=61 Road Monitor – Fourth n=1037 WHA Search n=21 Wind > 4	Weldon and Hobbs (2012)

* 'Repeated' was used in 2010-2012 sampling (2010: k = 3 for a subset of stations; 2011, k=5 whenever possible at all stations)

Table 16. Historical Data in the 'CPB file' for the East Kootenay Areas of Occupancy (AO)

Year	CPB Data	Other	Sampling Description	References
1996	n = 33	n = 19	n=52 Cannings 1996	
1997-2004	No data			
2005	n = 69	n = 115	n=54 <400m from previous n=2 no tape used n=109 Relative Density n=19 Repeat from previous year	
2006	n = 495	n = 348	n=178 <400m from previous n=37 <800m from +ve	Ohanjanian, Manley, Davidson (2006)

			n=37 Census Area n=556 Relative Density n=13 Repeat from previous year n=22 Wind > 4	
2007	n = 493	n = 457	n=116 <400m from previous n=5 <800m from +ve n=40 Census Area n=306 Relative Density n=483 Repeat from previous year	Ohanjanian, Davidson, Hansen and Conroy (2007). Gyug, Ohanjanian, Steeger, Manley and Davidson (2007)
2008	n = 498	n = 438	n=102 <400m from previous n=21 Random 45 min n=544 Relative Density n=269 Repeat from previous year	Ohanjanian, Davidson, Hansen and Beare (2009)
2009	n = 457	n = 337	n=53 <400m from previous n=160 Census Area n=442 Relative Density n=139 Repeat from previous year	Ohanjanian, Davidson, Beare and Hansen (2009)
2010*	n = 206 at 135 stations		n=24 Random - Extended n=135 Random - First n=23 Random – Repeat 2 n=24 Random – Repeat 3	Marmorek and Pickard (2010) Pickard and Ainsworth (2011)
2011	n = 220	n = 136	n=220 Random – AA n=60 Random – RA n=3 Relative Density n=73 Repeat from previous year	Ohanjanian, P. (2011) Ainsworth and Pickard (2012)
2012	n = 252 at 248 stations		n=228 Random – AA n=20 Relative Density n=4 Repeat from previous year	Ohanjanian, Isaac and Davidson (2012) Gyug, Ohahjanian, Cooper and Steeger (2013)

Additional Historical Information for the East Kootenay

Prior to 2010, sampling in the East Kootenay included both new sampling or areas never before sampled as well as focusing on areas where previous sightings/nests had been observed. This strategy was informal and therefore inference from these observations would only be possible if the intent of each type of sampling had been recorded, or was known. In 2011, a formal dual frame design was adopted which builds on the intuitive idea of revisiting past nest locations but formalizes the process so inference is possible. Due to the informal nature of the earlier data collection these points were not considered to meet the criteria to be a CPB station and were therefore identified as 'other' in the database. Thus, the sample sizes reported in the AMF document (Marmorek and Pickard, 2011) are much smaller than those presented in the field reports.

In 2006, CPBs were used at 847 locations in the East Kootenays. In total 44 WISA detections were made. In 2007, survey areas were chosen in areas where forest cover mapping indicated there were older western larch and the results of the 2006 inventory (Ohanjanian et al. 2006). CPBs were located at previous nesting and detection sites, and at unsuccessful sites which may have been surveyed too late in the breeding season in 2006 (Ohanjanian et al. 2006). New locations were set up in a buffer area (within a 1.5 km radius) of nests found in the previous year in order to detect birds which may have moved. As well, new locations were added in priority habitats based on the habitat suitability model which targeted areas with mature and old growth western larch.

In 2007, a total of 33 adult WISA were found by sampling 953 CPB locations. The majority (16) were in the Strauss Road / Linklater /Englishman Creek area, seven were in Lower Sink Creek, six in East Kiahko, two at the junction of Plumbob and Caven Creek roads, and twoin Kimberley. The highest

concentration of WISA activity was in the Strauss Road /Linklater FSR area, west of the Koocanusa Reservoir. These had not been surveyed as extensively in 2006 (Ohanjanian et al. 2006), as it the habitat suitability model did not predict this as good habitat. However, field crew observed sapwells in those areas and therefore surveyed outside of the area specified by the model.

In 2008, surveys were expanded to include ninenewareas.Seventy three WISA were detected during CPBs: 60 paired, 13 singles, and four observed either incidentally or in another study (Ohanjanian 2008) for a total of 78 WISA (Ohanjanian, 2009). Fifteen active nests were found. The 73 positive CPBs was nearly double that found in the two previous years (33 detections in 2007, and 34 in 2006 (Ohanjanian et al. 2006, 2007)). The number of call playback locations was similar: 915 (2008), 950 (2007) and 847 (2006). These results were thought to be partially due to the discovery of new areas of occupancy.

In the winter of 2008/2009, a provisional Area of Occupancy (AO) was set up in the East Kootenay to help identify critical habitat. The first objective of the 2009 surveys was to search for WISA in un-surveyed areas inside and outside the AO and to locate and describe nest trees and their ecological context in order to address survey gaps. CPBs were set up at 400 or 800m intervals in previously un-surveyed areas (Ohanjanian et. al., 2009). Thirty WISA were detected on 618 CPB points. Seven of the nine nests found were in aspen trees. This was in sharp contrast to the fact that only one nest out of all of 32 nests found prior to 2009 was in an aspen (Ohanjanian et al. 2008). The relatively high proportion of aspen nest trees was thought to be due to the fact that sampling was focused on previously unsurveyed gaps in the provisional Area of Occupancy (Ohanjanian et. al., 2009). The second objective of the 2009 surveys was to search ten blocks of old-growth western larch stands for habitat modeling using CPB and concurrent tree count plots in 400m grid spacing (Gyug 2009b). Five WISA were detected on 176 CPB points.

In order to draw on local, expert knowledge, field crew leader Penny Ohanjanian was asked to provide a list of areas she felt were most important for sampling WISA. She provided the following ordered list of areas for monitoring WISA:

- *Highest* Kiahko, Plumbob/Caven/Chain Lks, Strauss/Linklater/
- *Medium* Peavine / S Star/ (less - than other 3)
- *Low* Lower Sink/Meadow Ck, Kimberley/Perry Ck/McGinty, Newgate Rd, Bloom Ck/Gold Mtn, Baker S.*(but needs to be redone in the future)*
- *Lowest* East side Koocanusa, Rocky/Chipka

Appendix E – Power Analysis Tables

The power to detect a linear trend in abundance is summarized in Table 17 and Table 18.

Table 17. Power to detect a non-zero trend (top row) over years (left column), Low stratum with base estimate of abundance index = 425, and SE(abundance index) =59, type I error rate of 0.1.

Years	Effect size (slope of line)						
0	0.05	0.1	0.15	0.2	0.3	0.4	0.5
5	0.11	0.12	0.15	0.19	0.29	0.41	0.54
10	0.12	0.16	0.23	0.33	0.56	0.77	0.91
15	0.12	0.20	0.31	0.45	0.74	0.92	0.98
20	0.13	0.23	0.38	0.56	0.85	0.97	1.00
25	0.14	0.27	0.45	0.64	0.92	0.99	1.00
30	0.15	0.30	0.51	0.72	0.95	1.00	1.00

Table 18. Power to detect a non-zero trend (top row) over years (left column), Moderate stratum with base estimate of abundance index = 212, and SE(abundance index) =30, type I error rate of 0.1.

Years	Effect size (slope of line)						
0	0.05	0.1	0.15	0.2	0.3	0.4	0.5
5	0.11	0.12	0.15	0.18	0.28	0.40	0.53
10	0.11	0.16	0.23	0.32	0.55	0.76	0.90
15	0.12	0.19	0.30	0.44	0.72	0.91	0.98
20	0.13	0.23	0.37	0.54	0.84	0.97	1.00
25	0.14	0.26	0.44	0.63	0.91	0.99	1.00
30	0.15	0.29	0.50	0.70	0.95	1.00	1.00

The power to detect a trend in occupancy is summarized in Table 19, Table 20, Table 21, and Table 22 .

Table 19. Power to detect a 0.20 decrease (from 0.45 to 0.25) in the proportion of sites occupied in low suitability habitat over a 5 year period using the Cochran-Armitage Test for Linear Trend

Power	Sample size per year: n	years	Total sample size over 5 years: N	Alpha	Beta	Proportions over years
0.75	50.00	5	250	0.10	0.25	0.45, 0.40, 0.35, 0.30, 0.25
0.78	55.00	5	275	0.10	0.22	0.45, 0.40, 0.35, 0.30, 0.25
0.82	60.00	5	300	0.10	0.18	0.45, 0.40, 0.35, 0.30, 0.25
0.84	65.00	5	325	0.10	0.16	0.45, 0.40, 0.35, 0.30, 0.25
0.87	70.00	5	350	0.10	0.13	0.45, 0.40, 0.35, 0.30, 0.25
0.89	75.00	5	375	0.10	0.11	0.45, 0.40, 0.35, 0.30, 0.25
0.90	80.00	5	400	0.10	0.10	0.45, 0.40, 0.35, 0.30, 0.25
0.92	85.00	5	425	0.10	0.08	0.45, 0.40, 0.35, 0.30, 0.25
0.93	90.00	5	450	0.10	0.07	0.45, 0.40, 0.35, 0.30, 0.25

Table 20. Power to detect a 0.16 decrease (from 0.45 to 0.29) in the proportion of sites occupied in low suitability habitat over a 5 year period using the Cochran-Armitage Test for Linear Trend

Power	Sample size per year: n	years	Total sample size over 5 years: N	Alpha	Beta	Proportions over years
0.72	75	5	375	0.10	0.28	0.45, 0.41, 0.37, 0.33, 0.29
0.75	80	5	400	0.10	0.25	0.45, 0.41, 0.37, 0.33, 0.29
0.77	85	5	425	0.10	0.23	0.45, 0.41, 0.37, 0.33, 0.29
0.79	90	5	450	0.10	0.21	0.45, 0.41, 0.37, 0.33, 0.29
0.81	95	5	475	0.10	0.19	0.45, 0.41, 0.37, 0.33, 0.29
0.83	100	5	500	0.10	0.17	0.45, 0.41, 0.37, 0.33, 0.29

Interpretation:

- Sample at least 60 sites from low suitability habitat to detect a five year occupancy decrease from 0.45 to 0.25 with 80% power.

Table 21. Power to detect a 0.20 decrease (from 0.65 to 0.45) in the proportion of sites occupied in moderate suitability habitat over a 5 year period using the Cochran-Armitage Test for Linear Trend

Power	Sample size per year: n	years	Total sample size over 5 years: N	Alpha	Beta	Proportions over years
0.71	50.00	5	250	0.10	0.28	0.65, 0.60, 0.55, 0.50, 0.45
0.75	55.00	5	275	0.10	0.25	0.65, 0.60, 0.55, 0.50, 0.45
0.79	60.00	5	300	0.10	0.21	0.65, 0.60, 0.55, 0.50, 0.45
0.81	65.00	5	325	0.10	0.18	0.65, 0.60, 0.55, 0.50, 0.45
0.84	70.00	5	350	0.10	0.16	0.65, 0.60, 0.55, 0.50, 0.45
0.86	75.00	5	375	0.10	0.14	0.65, 0.60, 0.55, 0.50, 0.45
0.88	80.00	5	400	0.10	0.12	0.65, 0.60, 0.55, 0.50, 0.45
0.90	85.00	5	425	0.10	0.10	0.65, 0.60, 0.55, 0.50, 0.45
0.91	90.00	5	450	0.10	0.09	0.65, 0.60, 0.55, 0.50, 0.45

Table 22. Power to detect a 0.16 decrease (from 0.65 to 0.49) in the proportion of sites occupied in moderate suitability habitat over a 5 year period using the Cochran-Armitage Test for Linear Trend

Power	Sample size per year: n	years	Total sample size over 5 years: N	Alpha	Beta	Proportions over years
0.70	75.00	5	375	0.10	0.29	0.65, 0.61, 0.57, 0.53, 0.49
0.73	80.00	5	400	0.10	0.27	0.65, 0.61, 0.57, 0.53, 0.49
0.75	85.00	5	425	0.10	0.24	0.65, 0.61, 0.57, 0.53, 0.49
0.77	90.00	5	450	0.10	0.22	0.65, 0.61, 0.57, 0.53, 0.49
0.79	95.00	5	475	0.10	0.20	0.65, 0.61, 0.57, 0.53, 0.49
0.81	100.00	5	500	0.10	0.19	0.65, 0.61, 0.57, 0.53, 0.49

Interpretation:

- Sample at least 65 sites todetect a five year occupancy decrease of from 0.65 to 0.49 with 80% power.