

Distribution, Relative Abundance and Population Size of Williamson's Sapsucker in South-central British Columbia

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Abstract: The Extent of Occurrence (EO) of Williamson's Sapsucker in British Columbia has not changed since last spatially defined in 2007 despite intensive survey efforts including the B.C. Breeding Bird Atlas from 2008-2012. The Area of Occupancy (AO) has now been spatially defined for the Merritt-Princeton area in addition to that already defined in 2007 for the Okanagan-Boundary. Relative abundance in terms of numbers of detections per call- and drum-playback (CPB) declined significantly as the breeding season progressed, being highest in April as territories are established. Nest or breeding territory population size was estimated independently by three methods for the Merritt-Princeton and Okanagan-Boundary AOs combined. In 2008, a nest population of 399 (SE 155) was estimated using a simple random sample of 174 225-m radius plots each searched intensively for nests. Only using data collected prior to 2008, breeding territory population size was estimated to be 381 (no SE available) by extrapolating from the sum of assumed areas sampled by CPB and follow-up nest searches over a number of years. In 2012, breeding territory population size of 526 (SE 107) was predicted from the linear regression of breeding territory density with average habitat suitability ratings in 30 census areas. In 2007 a nest population estimate was attempted in the remainder of the EO west of Okanagan Lake using 3038 variable-radius CPB plots but no reliable statistical estimate could be made as only one nest was discovered. Mean nest density was estimated to be 0.28/km² within the combined Merritt-Princeton and Okanagan-Boundary AOs. Within the remainder of the EO west of Okanagan Lake, densities were too low to reliably estimate.

Keywords: Williamson's Sapsucker, *Sphyrapicus thyroideus*, distribution, relative abundance, breeding population size, breeding density

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Introduction

Williamson's Sapsucker, *Sphyrapicus thyroideus*, is a medium-sized woodpecker specialized for feeding on sap. It has been designated as Endangered in Canada (COSEWIC 2005), and is listed under Schedule 1 of the Species at Risk Act. The Canadian breeding population of Williamson's Sapsucker occurs entirely in British Columbia (Gyug *et al.* 2007). Very little information existed on breeding occurrences in B.C. until very recently (Cannings *et al.* 1987; Campbell *et al.* 1990; Cooper 1995). Even by 2006 (Gyug *et al.* 2007), the locations occupied in B.C. were not entirely known, especially in the regions west of Okanagan Lake and in the East Kootenay. The Extent of Occurrence (EO; a minimum convex polygon covering all known breeding locations) had been defined by Gyug *et al.* (2007) but there was only enough detailed survey information up to and including 2006 to spa-

tially define the Area of Occupancy (AO; the area currently occupied for breeding) for the Okanagan-Boundary population at that time.

Distribution, breeding population size, and trends in those two parameters, are some of the most important criteria used to assess conservation status. However, these are often difficult to determine for rare species. Williamson's Sapsucker males respond readily to call and drum playbacks (CPB) in the breeding season (Gyug *et al.* 2007), and nests are relatively easy to find when in the mid to late nestling phase compared to most passerine birds that tend to be secretive around their nests. These factors make widespread inventories relatively efficient for estimating occurrence, relative abundance and/or population size.

Based on data available up to and including 2004, the

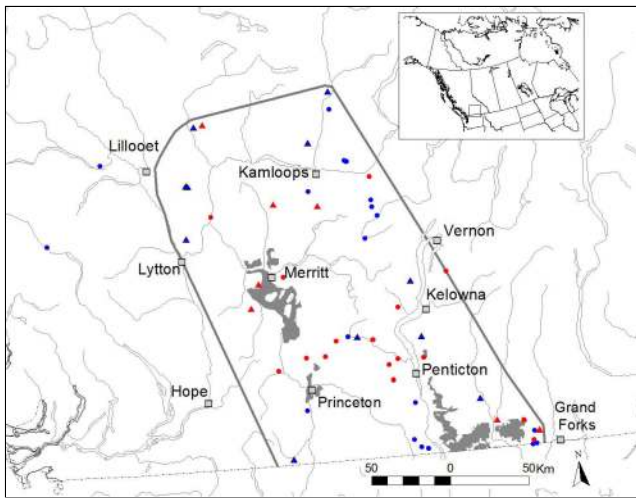


Figure 1. Williamson's Sapsucker Extent of Occurrence (EO; heavy line) as defined in Gyug *et al.* (2007), and Areas of Occupancy (AO; grey shaded areas) in south-central B.C. as refined since 2006. All known Williamson's Sapsucker observations outside the spatially defined AOs are shown: prior to 2007 in blue; more recent in red. Nests are triangles; other observations are dots.

size of the Canadian breeding population was estimated to be 215 breeding pairs (COSEWIC 2005). This was based on an estimated 182 pairs in the Okanagan-Boundary AO given average breeding pair density in 3 census areas in older mixed western larch – Douglas-fir forest, and then extrapolating to the total amount of older forest in the AO. The estimate of 33 pairs in the remainder of B.C. was based on anecdotal information. Blancher *et al.* (2007) estimated a breeding population of 1300 Williamson's Sapsuckers in B.C. using Breeding Bird Survey (BBS) data but considered that data to be insufficient to provide any estimate of variance. That estimate was based on detections on only 1 of the 20 BBS routes in B.C. that intersect the Williamson's Sapsucker EO.

The goal of this study was to update the known distribution of Williamson's Sapsucker populations in the Okanagan-Boundary and west of Okanagan Lake since last reported by Gyug *et al.* (2007), to estimate relative abundance in terms of response to call- and drum-playbacks and some of the factors which may affect relative abundance measures, and to estimate the nest or breeding territory population size by three independent methods. Abundance estimates of Williamson's Sapsucker in the East Kootenay were the subjects of other studies not reported here.

Methods

Study Area

The study area encompassed the EO of Williamson's Sapsucker in south-central B.C. (Gyug *et al.* 2007) not in-

cluding the East Kootenay region. Based on general forest types, the study area is divided into two regions (Figure 1): the region west of the Okanagan valley in the Merritt and Princeton areas; the Okanagan-Boundary region on the east side of the Okanagan valley, extending approximately from Pentiction to Grand Forks. The region west of the Okanagan valley is primarily mixed forests of ponderosa pine, Douglas-fir, and trembling aspen while the Okanagan-Boundary is primarily mixed western larch and Douglas-fir forests.

The AO for long-term purposes of habitat management and defining critical habitat was defined as areas occupied for breeding that were relatively contiguous and occurring in blocks of $\geq 5 \text{ km}^2$. AO boundaries were drawn first to contain all known groups of nests, secondly to contain all areas where relative abundance was >1 per 100 CPB when averaged over 100 km^2 moving windows, and thirdly to contain contiguous areas that had yet to be sampled but where we assumed Williamson's Sapsucker would be present based on habitat similarities.

Only single isolated nest locations have been found outside the AO boundaries as mapped (Figure 1). Typically, these nest locations would be used for 1–3 years and then not used again or, after a number of years, the site might be re-occupied. For our purposes, isolated nest locations outside contiguous AOs have been considered to be part of the EO but not part of the AO. Areas west of Okanagan Lake within the EO but outside the AOs were termed the West EO. The AO west of Okanagan Lake is referred to here as the Merritt-Princeton AO, and east of Okanagan Lake as Okanagan-Boundary AO.

Sampling Methods

CPB methodology employed at survey points was detailed in Gyug *et al.* (2007). CPB surveys were conducted only when winds were $< \text{Beaufort } 4$, not during rain, and throughout the breeding season from late March to late June. Normally CPB were attempted as early as practicable so that the majority of surveys would be conducted early in the breeding season when responsiveness was thought to be highest (e.g., Rushmore 1973 for Yellow-bellied Sapsuckers, *Sphyrapicus varius*). At the elevations where Williamson's Sapsucker occur in B.C. (800–1500 m, Gyug *et al.* 2007) most resource roads were snowbound and inaccessible until late April or early May. Where nest locations were required to confirm breeding for conservation purposes, or to estimate nest populations, follow-up nest searches were conducted in mid to late June wherever Williamson's Sapsuckers had been detected on CPB surveys. In this period, most nests would be in the mid-to-late nestling phase, the nestlings call out loudly from the nest cavity, adults are engaged in carrying food back to the nest on average 15–20 times per hour (Crockett 1975), and nests are therefore relatively easy to locate.

In addition to those CPB up to and including 2006 already reported by Gyug *et al.* (2007), CPB surveys were

done within a variety of projects, some large and extensive with robust study designs, others based on surveyor choice of sample areas, and some sampling only limited areas over a short period. Large projects completed after 2006 included 3038 CPB points in the West EO in 2007 to determine distribution, relative density and population size (see West EO section below for sampling design); 416 CPB points in 2007 to determine AO location in the Okanagan-Boundary; and 547 CPB points in 2007 in the Merritt area to determine local distribution. Inter-point survey distance was 400 m or more for most of these surveys. Except where surveys were part of pre-determined study designs, most other points were surveyor-choice but attempts were made to only sample where no previous sampling had been done. In 2008, 174 plots were surveyed in a simple random design within the Merritt-Princeton and Okanagan-Boundary AOs in 2008 (see AO nest population estimate section below). Long-term monitoring within the AOs began in 2010 and has continued annually to 2013 using CPB surveys (without follow-up nest searches) under stratified random or systematic sampling designs. These included 165 CPB points sampled once and 55 sampled three times each in 2010; 126 points sampled five times each in 2011; 224 points sampled up to four times each in 2012; and 213 points sampled twice each in 2013. In 2012, to find nests for conservation and management purposes, areas of Low or better suitability habitat were identified that had yet to be sampled by CPB surveys. These were sampled by 1037 CPB points in total including 30 census areas >1 km² in size (see Other AO Breeding Territory Estimates section).

Distribution and Relative Abundance

Relative abundance was estimated as the number of Williamson's Sapsuckers detected per 100 CPB survey points to be consistent with Gyug *et al.* (2007). Where sites were surveyed multiple times between years, or sometimes within years, all data were included as any such surveys were part of pre-determined study designs.

The distribution of Williamson's Sapsucker within B.C. was also verified using data from the B.C. Breeding Bird Atlas (British Columbia Breeding Bird Atlas 2012). Over the five-year period from 2008–2012, 53215 hours of observation by 700 observers contributed >300,000 breeding records of 333 species. Observations were tallied by 10 km squares over the whole province with records returned from 4489 of a total possible 10392 squares. In the southern interior of B.C., i.e., in all areas where there was even a remote chance of a Williamson's Sapsucker occurring, there were 18 regions with records returned from 1675 squares of a total possible 3036 squares. We also examined Williamson's Sapsucker detections on point counts. In these 18 regions, 15333 point counts were done from late May through early July where all birds detected during a 5 minute period were tallied at each point.

Factors potentially affecting relative abundance and examined here using ANOVA included the two AOs, time pe-

riod of sampling, and habitat suitability. Time periods were defined broadly as the breeding season progressed from territorial establishment in April, nest excavation in early May, incubation in late May, and rearing of the nestlings through June or into early July. Most Williamson's Sapsuckers in B.C. fit this general schedule during the breeding season.

Habitat suitability modeling and mapping had been completed for each AO in B.C. by 2010 (Gyug, unpublished data). This modeling was based on nest locations relative to physical data (e.g., slope, aspect and elevation), to forest inventory data, and included stereo aerial photo interpretation of presence of possible nest trees. We post-hoc stratified all CPB survey points by the maximum habitat suitability within 300 m of each point. Habitat suitability mapping was scaled relative to the benchmark in B.C. of 3.1 Williamson's Sapsucker nests/km² (Gyug *et al.* 2007). Using the standards in place for habitat suitability modeling in B.C. (RISC 1999), High suitability was 76–100% of the benchmark (midpoint 88%), Moderately High was 51–75% of benchmark (midpoint 63%), Moderate was 26–50% of benchmark (midpoint 38%), Low was 6–25% of benchmark (midpoint 16%), Very Low was 1–5% of benchmark (midpoint 3%) and Nil was <1% of benchmark. When used for averaging and in regressions, suitability was scored between 0 and 1 by dividing the classes and midpoints referred to in the previous sentence by 100.

Gyug *et al.* (2007) found that relative abundance was lower in afternoon samples compared to morning samples, so time of day was another factor examined for effect upon relative abundance. Controlling for habitat suitability and time-of-breeding season, we developed early morning (dawn to 10:59 AM) and afternoon (11:00 AM to dusk) pairs of relative abundance estimates for Low and Moderate suitability class habitats. These pairs were compared using a paired two-tailed t-test to detect any significant differences in relative abundance that may be due to time of day.

Nest or Breeding Territory Abundance Estimates

We used three independent methods to estimate population size. Determination of population size was not the primary goal of any of these projects, but each was conducted in a way which would allow us to use the data to determine population size. The simplest and most direct method was applied in 2008. The AOs were randomly sampled by 0.16 km² plots (225 m radius) which were intensively searched for nests. This allowed us to estimate nest density and therefore nest population size of the AOs. Two other less direct methods were also applied. First, summing the assumed total area sampled by CPB up to and including 2006 for the Okanagan-Boundary and to 2007 for Merritt-Princeton, and then summing the total number of known breeding territories, allowed us to estimate breeding territory density and then total breeding territories in each AO. Secondly, in 2012, we determined breeding territory density and average habitat suitability of 30 census areas, and used the regression of density on habitat suitability to predict the number of terri-

tories in the entire AO. The specifics of these study designs and methods are detailed below.

We also assessed whether CPB detection data alone might be sufficient to estimate population size. We were not relying on detection data to estimate population size because we had previously suspected Williamson's Sapsucker frequently approached the observer before being detected. This would bias any population estimate high if relied upon, and would violate an essential assumption of distance sampling methods (Buckland *et al.* 1993). The distance of each first CPB detection was compared to each nest location to determine if this was the case, or whether detections alone might be used to determine population size without bias.

For the 2008 sampling, we defined population size as the nest population because we were sampling relatively small (0.16 km²) plots where we applied sufficient effort to count every active Williamson's Sapsucker nest within a plot. For larger census areas in 2012, or for the broad-based surveys up to 2007, where nest searches may not have been intensive enough to detect every nest, we included probable breeding territories. These included territories where a pair was present and we suspected breeding, but we could not find a nest whether because any nest may have already failed, or because we had insufficient time to conduct a complete search.

Using the number of nests or breeding territories as the population estimate, the breeding population size would be this number multiplied by two, assuming a pair of adult sapsuckers at each nest or in each territory. This does not allow for any floater or non-breeding adults, or adults that may have abandoned breeding attempts and territories before being detected on our surveys. Crockett (1975) estimated about 10% of the adult population in his study area in Colorado consisted of non-breeding males and the proportion of non-breeding males is probably similar in B.C. (Table 3 of Gyug *et al.* 2007).

AO Nest Estimate 2008

In 2008, we sampled 225 m radius plots selected at random within the spatially defined AOs at Merritt-Princeton and Okanagan-Boundary primarily to provide an unbiased sample of Williamson's Sapsucker bird and nest locations for habitat modeling (L. Gyug, unpublished data). These same data were used to estimate nest population size. Each plot centre was at least 400 m from the AO boundaries, and at least 800 m from any other plot centre. The two AOs were treated as separate strata and sampled at different intensities: 124 plots were sampled in the Okanagan-Boundary AO (698 km²), and 50 in the Merritt-Princeton AO (743 km²). Plots were sampled initially by CPB between May 2 and June 3, 2008. About 45 minutes were spent searching within a 225 m radius (16 ha) of the randomly selected plot centre. The search included at least five CPB survey points within the plot so that CPB surveys would have been completed within 100 m of every part of the plot. Plots with very simple habitats that

lacked many trees were sometimes completed in as little as 25 minutes. All observations or detections of Williamson's Sapsucker were recorded on a GPS unit, or the distance and direction estimated from a marked GPS point so that the location could be plotted.

Nest searches at 53 plots where Williamson's Sapsucker had been detected took place between June 11 and 28. At least 1 hour was spent searching each plot unless a nest was found before then, or detections of Williamson's Sapsucker led the investigators outside the plots to search for nests. Attempts were made to approach every part of the plot to within at least 100 m to provide a complete nest search. Locations of nests were marked on GPS units.

A total nest population was estimated extrapolating from the mean number of nests per sample plot within each stratum. To assist in comparison of relative variation of different methods, coefficient of variation (CV) was considered to be the standard error (SE) divided by the mean.

AO Breeding Territory Estimate 2006-2007

The total number of confirmed (active nest known) and probable (pair present, or male present for >1 week during breeding season) nest territories was extrapolated to the entire AO based on the proportion of the AO sampled. The area sampled by each CPB and follow-up nest searches was totaled based on an assumed sample radius of 300 m at each CPB point. For the Okanagan-Boundary AO this included all CPB up to and including 2006, and for the Merritt-Princeton AO up to and including 2007. Since the CPB were done for a variety of purposes, and chosen by surveyor choice without a sample design, any biases associated with the method would be unknown. However, since thousands of CPB had been completed, the area covered was large and may have simulated an unbiased sample. Given those assumptions, the total area of each AO sampled by CPB and nest searches was estimated. No variance on the population estimate was available using these methods and possible biases were not quantifiable.

Since not every nest territory is occupied each year, and we were summing a multi-year sample, to estimate population size the number of territories occupied in any given year had to be adjusted downwards from the total number of territories. The fraction of occupied territories in a given year was estimated by checking known nest territories for re-occupancy in 2007 and 2008 and averaging annual re-occupancy rates. For the Okanagan-Boundary AO, these were also averaged with the 2006 territory re-occupancy data reported by Gyug *et al.* (2007).

AO Breeding Territory Estimate 2012

Breeding territory populations were predicted from the regression of census area densities on average habitat suitability ratings. Nest habitat suitability modeling had been completed for each AO in 2009 and 2010 (Gyug, unpublished data). Results from two breeding territory census areas had

been reported by Gyug *et al.* (2007) and 18 other census areas had been completed prior to the habitat suitability modeling. The results from these 20 census areas were used to calibrate densities for the habitat suitability modeling. In 2012, 30 new census areas, averaging 2.3 km² and ranging in size from 1.0 to 6.7 km², were selected within the AOs where no previous CPB sampling had been completed but where habitat suitability modeling was available. These census areas were sampled by CPB at 400 m grid spacing in May, with follow-up nest searches in June wherever Williamson's Sapsuckers were detected. Breeding territory density included confirmed active nests plus probable breeding activity where pairs were found but no nest could be located.

The average habitat suitability of each of the 30 census areas was the weighted average of the midpoint suitability rating of each class (on a 0 to 1 scale) times the area of each habitat suitability class. The breeding territory density found in each census area was regressed against average suitability. No census areas were sampled where average habitat suitability was < 0.07 as sampling concentrated on Low or better habitats where nests were expected. The relative abundance sampling done over many years had given us confidence that Very Low habitats contained almost no Williamson's Sapsuckers and our efforts would not be well spent there. Therefore the regression line was constrained to go through the origin, i.e., where suitability = 0, nest density was expected to = 0, to compensate for this lack of samples in Very Low or Nil habitats. The linear regression equation was applied to the average suitability of the entire AOs to predict average density, and then multiplied by the area of the AOs to predict breeding territory population size. Confidence limits on the prediction were estimated using the standard error of the regression equation.

West EO Distribution and Abundance

The primary purpose of CPB sampling west of Okanagan Lake in 2007 was to determine if there were any previously unknown breeding concentrations of Williamson's Sapsucker, and secondarily to provide relative abundance and nest population estimates. Inventories in 2006 in particular (Gyug *et al.* 2007) had found concentrations of nests in both the Merritt and Princeton areas but it was not known if other concentrations existed elsewhere within the EO.

In 2007, the sampling frame in the EO west of Okanagan Lake consisted of the BEC variants PPxh1, IDFxh1, IDFxh2, IDFdK1, and IDFdK2 (see Gyug *et al.* 2007) outside the Merritt-Princeton AO that could be potentially occupied by Williamson's Sapsucker (Figure 2). Two-stage sampling (Thompson 2002) was used to subsample the large area (10158 km²). The area was divided into 199 primary sampling units (10 x 10 km squares of the UTM grid). Primary units predominantly on private land without public road access, and areas dominated by steep slopes >60% were excluded from the sampling frame. 72 of the 199 primary units were randomly selected for sampling using a spatially

balanced design (Generalized Random Tessellation Stratified; Stevens and Olden 2004) to assure relatively even coverage across the entire area.

Secondary sub-sampling within selected primary units was by variable-radius CPB survey points followed by nest searches wherever there were detections. CPB points were placed along roads at approximate 400 m intervals, either by observer choice in what looked to be suitable habitat, or at 400 m intervals along roads without respect to habitat. Two sampling days (about 80 CPB points) were put in selected primary units that were entirely covered (100 km²) by the sampling frame, and scaled down proportionately for primary units containing lesser amounts of the sampling frame. A total of 3038 CPB points were sampled between 2 May and 5 June, for an average 42.2 CPB points per primary sampling unit. Nest searches at 5 sites where Williamson's Sapsucker were detected took place between May 26 and June 17.

Nest abundance within each sampled primary unit was to have been estimated from the nests discovered during the sampling and then nest population mean and variance estimated using conventional two-stage statistical methods (Thompson 2002). However, with only one nest discovered during sampling, no reliable estimate of nest population size could be made, so this analysis was not ultimately undertaken, and this data was used only to determine distribution and relative abundance.

Results

Distribution

There have been 49 widely dispersed locations reported in the EO including 19 individual nest trees west of Okanagan Lake outside of the Merritt-Princeton AO and 3 nest trees outside the Okanagan Boundary AO east of Okanagan Lake (Figure 1). This included all the recent records known to the authors, as well as other records available from 1953–2006 (see Gyug *et al.* 2007). There were only 3 new nest locations discovered since 2006 near the EO boundaries. One, discovered during the 2007 West EO sampling, was about 200 m north of Scotty Creek, 9.5 km upstream from the confluence with the Bonaparte River (shown 46 km northeast of Lillooet on Figure 1). The other two were within 125 m of each other and used successively in 2007 and 2008. These were 1 km east of the abandoned open pit mine on Phoenix Mt., or as shown on Figure 1, 12.5 km northwest of the city of Grand Forks. The EO of Williamson's Sapsucker in this part of B.C. does not appear to have enlarged since reported in Gyug *et al.* (2007).

The small population at Hat Creek 47 km north of Lytton was estimated at a total of 6 nests prior to 2004 based on 3 known nests (see Gyug *et al.* 2007) and an estimate of 3 other nests (COSEWIC 2005). Our CPB sampling in 2007 resulted in no detections in that area even at previously known nest

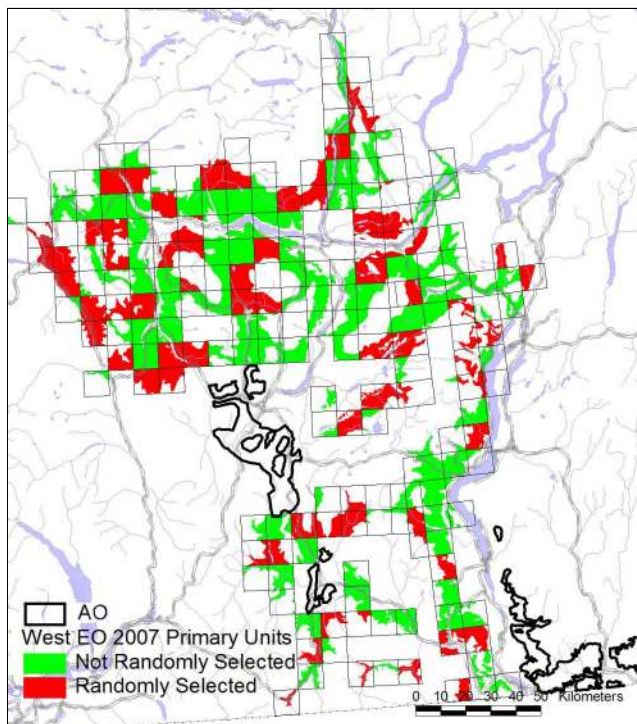


Figure 2. Primary sampling units (10 km Breeding Bird Atlas UTM grid squares) showing the areas within BEC variants PPxh1, IDFxh1, IDFdk1 and IDFdk2 available for sampling within the 199 primary units in the Williamson's Sapsucker Extent of Occurrence west of Okanagan Lake.

sites which appeared to be unoccupied. Several other visits to Hat Creek over several years did not result in any Williamson's Sapsucker detections (Ken Wright, pers. comm.

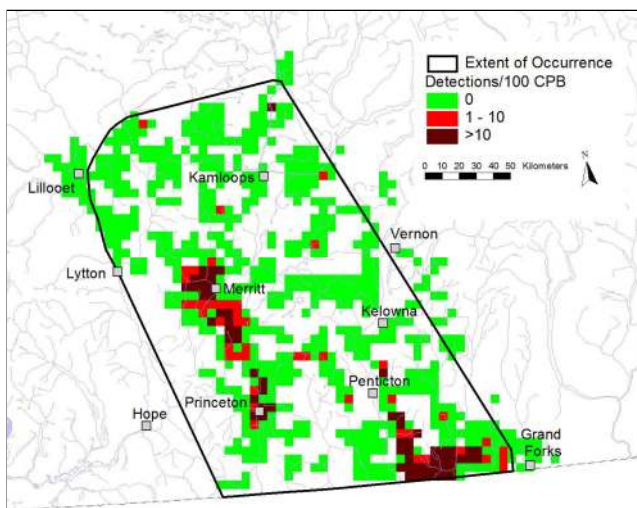


Figure 3. Williamson's Sapsucker relative abundance based on 11596 call- and drum-playback (CPB) survey points in the Okanagan-Boundary and west of Okanagan Lake in B.C. from 1996–2012. Relative abundance shown averaged for 5 km cells. Blank areas have not been surveyed by CPB sampling.

to L. Gyug, 2012). The status of the small population at Hat Creek is uncertain but Williamson's Sapsuckers may no longer be present there.

The Merritt-Princeton AO (Figure 1) was mapped based on known breeding locations and on relative abundance (Figure 3). It totaled 742 km² consisting of 5 blocks of habitat ranging in size from 14 to 554 km². The Okanagan-Boundary AO totaled 698 km² consisting of 5 blocks of habitat ranging in size from 5 to 501 km². The only significant change in the Okanagan-Boundary AO since reported in Gyug *et al.* (2007) was a block of habitat on Phoenix Mt. (between Greenwood and Grand Forks) that was considerably reduced in size to 5 km².

During the B.C. Breeding Bird Atlas from 2008–2012, Williamson's Sapsuckers were detected in 65, 10 km atlas squares in only 5 regions (Figure 4) out of a total 1675 squares with records in the 18 regions where there was any likely possibility of occurring. Williamson's Sapsuckers were only detected on 6, 5 min point counts of 2435 point counts conducted in these 5 regions, for a detection rate of only 0.2% on point counts. Red-naped Sapsuckers (*Sphyrapicus nuchalis*) were detected in 783 squares, i.e., from about every second square that had any breeding records, in the same 18 regions and in only 10 other squares in other regions (Figure 4). Red-naped Sapsuckers were detected on 793 of the 15333, 5 min point counts in these 18 regions, for a detection rate of 5.2%. Considering only those same 5 regions where Williamson's Sapsucker were detected, Red-naped Sapsuckers were detected on 370 of the 2435 point counts, for a detection rate of 15.2%. Given that Red-naped Sapsuckers, a species of similar size and habits, were found to be distributed much more widely and commonly, if there were concentrations of breeding Williamson's Sapsuckers in B.C. outside of the known AOs, these would probably have been detected during the atlassing project.

Relative Abundance

There were no significant differences between the two AOs in relative abundance ($F_{1,5592} = 0.010$; $P = 0.92$). However there were significant differences by sampling time period ($F_{3,5592} = 66.95$; $P < 0.001$), and by maximum habitat suitability within 300 m of sampling points ($F_{1,5592} = 45.45$; $P < 0.001$) (Figure 5). The Very Low habitat was not included in the ANOVA because of a missing cell in the design as no such points had been sampled in April. Very Low suitability habitats had relative abundance much lower than either Moderate or Low in those time periods where samples were available. Very few Williamson's Sapsuckers were detected where there was only Very Low suitability habitat within 300 m of the sampling point (Figure 5) with only 4 ever detected on 259 CPBs, or an average of 1.54 detected /100 CPB.

Relative abundance in the EO outside the AO was even lower than for Very Low habitats within the AO (Figure 5). In total, 26 were detected on 5784 CPBs outside the AOs for an average of 0.45 detected /100 CPB. Comparing relative abun-

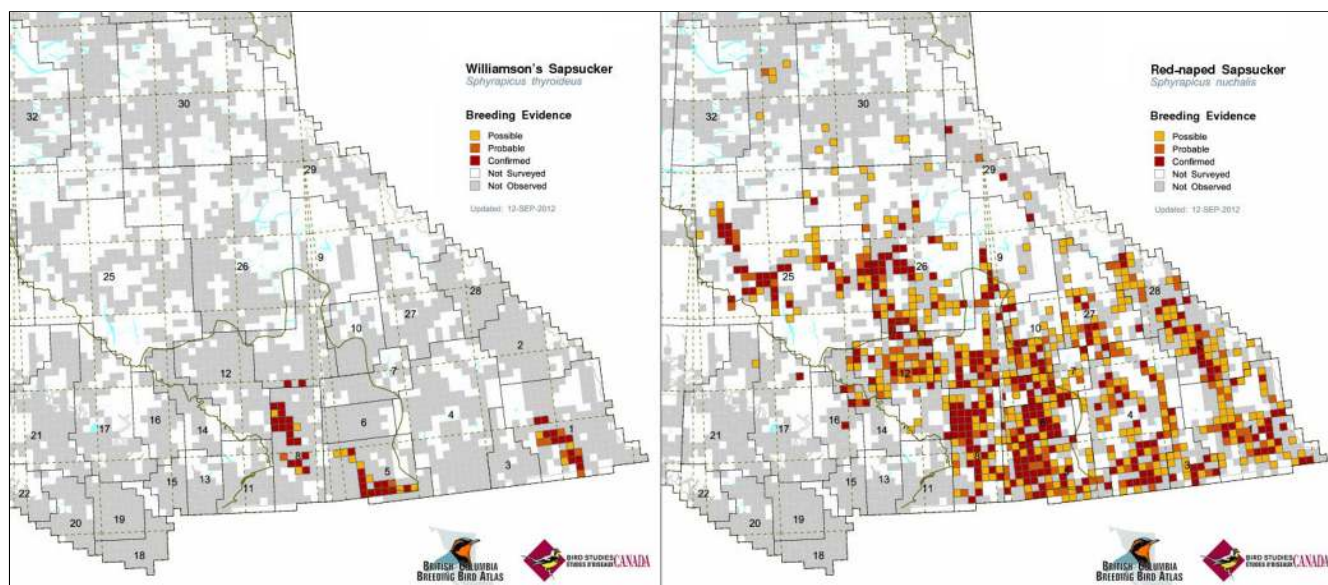


Figure 4. B.C. Breeding Bird Atlas 2008–2012 breeding evidence by 10 km atlas square for Williamson's Sapsucker (left) and for Red-naped Sapsucker (right). Maps reproduced from B.C Breeding Bird Atlas website <http://www.birdatlas.bc.ca/bcdata/maps.jsp>.

dances in the same time period, relative abundance in the EO outside of the AO was 0.6 to 4% (mean 1.9%) of that in Moderate suitability habitat within the AO, and 0.7 to 7.2% (mean 3.2%) of that in Low suitability habitat within the AO.

Relative abundance did not differ significantly ($t = 1.51$, 7 d.f., $p = 0.18$) between morning (mean 0.28 detections/100 CPB; SE 0.05) and afternoon (mean 0.24 detections/100 CPB; SE 0.05). This was based on 8 paired samples of morning and afternoon from 2 habitats (Low and Moderate suitability) and 4 breeding season stages (April, early May, late May, June). An average of 350 CPB (range 140-932) were included in each of the 16 samples.

Nest or Breeding Territory Estimates

The mean distance of Williamson's Sapsucker first detections (136 m, SE 7, $n = 187$) was significantly lower than the mean distances of nests found after searches (260 m, SE 12, $n = 187$) from the same CPB points (paired t -test: $t = 10.7$, 186 d.f., $P < 0.001$). The mean nest distance was 1.8 times greater than the mean first detection distance. Therefore if population estimates were to be calculated based only on first detection distance after CPBs, these would be biased high by a factor of 3.2 since the area sampled varies with the square of the radius. We therefore could not use detections from CPB alone to estimate population size without significant upward bias because the detections alone would appear to be sampling a much smaller area than was actually being sampled. Only by combining detections with later nest or breeding territory searches could we estimate an unbiased population size.

In the Merritt-Princeton AO, the 2008 nest population estimate from simple random sampling of 0.16 km² plots was 187 (SE 130) nests; in the Okanagan-Boundary AO it was 212

(SE 84) nests (Table 1). 1.1% of the West AO was sampled by 50 plots, and 2.8% of the Okanagan-Boundary AO was sampled by 124 plots. Considering both AOs as one sample of two separate geographic strata, and based on the 8 nests found inside plots during sampling, the nest population estimate of both together was 399 (SE 155) with a 95% CI from 96–702 (Table 1). No adjustment for detectability was used because all Williamson's Sapsuckers and nests within the plots were assumed to be detected given our intensive search

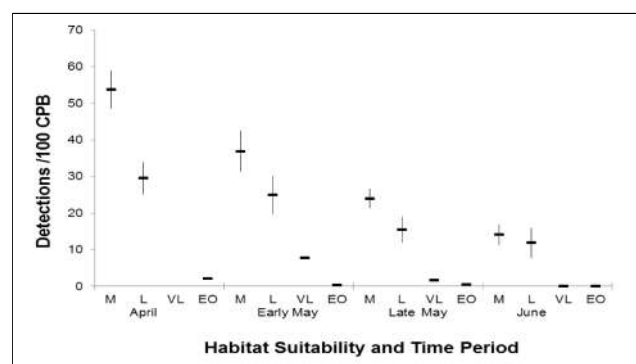


Figure 5. Williamson's Sapsucker relative abundance (detections / 100 call- and drum-playbacks (CPB)) within the combined Merritt-Princeton and Okanagan-Boundary Areas of Occupancy and in the remainder of the Extent of Occurrence (EO) in B.C. Observations were grouped by time period and by maximum habitat suitability (M = Moderate or higher; L = Low; VL = Very Low) within 300 m of the CPB point. 95% confidence intervals shown for Moderate and Low groups only; there were too few observations within the Very Low and EO to estimate confidence intervals (see text). No CPB were available in Very Low in April.

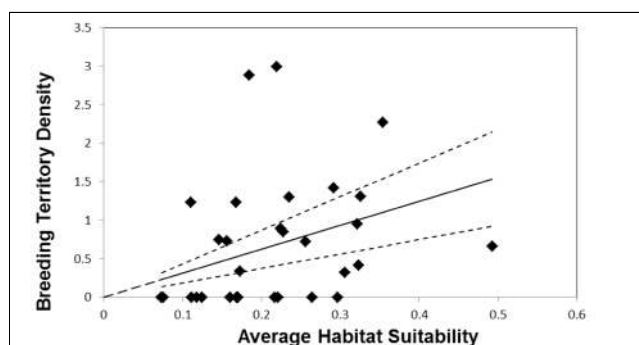


Figure 6. Regression of Williamson's Sapsucker breeding territory density including confirmed and probable breeding territories in 30 nest census areas vs. average habitat suitability within each census area on a scale of 0 to 1, 2012. Regression line shown as solid line extended with dashes to origin. 95% prediction limits for mean breeding territory density given mean habitat suitability shown as dashed lines.

effort of each 0.16 km² plot using 45, -60 min upon initial CPB and 60 min or more upon later nest searching.

For areas sampled by CPB and follow up nest searches prior to 2008, estimated number of occupied breeding territories in any given year totaled 381 (Table 2). Mean annual re-occupancy of nest territories in the Okanagan-Boundary AO (50.2%) was the mean of annual re-occupancy rates from 2006 (50.6%, Gyug *et al.* 2007), from 2007 (53.2%; 58 of 109 territories that were checked were re-occupied), and from 2008 (46.8%; 37 of 79 territories that were checked were re-occupied). Mean annual re-occupancy of nest territories in the Merritt-Princeton AO (64.1%) was the mean of the 2007 re-occupancy rate (72.4%; 21 of 29 known territories were re-occupied), and from 2008 (55.8%; 24 of 43 known territories that were checked were re-occupied).

In 2012, breeding territory density was significantly correlated with average habitat suitability when the linear regression was constrained to have a Y-intercept of 0 ($Y = 3.111 \cdot X$; $F_{1,29} = 24.1$, $P < 0.001$; SE of slope = 0.634; SE of regression = 0.820; Figure 6). The predicted breeding territory population estimate in the AOs was 526 (SE 107, CV 21%; Table 3).

Since each of the three population estimates for the AOs were independently derived, we can estimate the nest

population size as the mean of the three (399, 381, 526) if we assume the population did not change during the survey period. The mean would be 435 nests and/or breeding territories (SE 79; CV 18%) with a 95% Confidence Interval of 95–775.

In 2007 in the West EO, only 5 Williamson's Sapsuckers were detected on 3038 CPB points, and only 1 nest was discovered during nest searches. With only 1 nest in the sample, no reliable nest estimate was judged to be possible, and the attempted study design, which would rely on normal distribution of observations, would not be applicable. One other nest was found during the surveys but was discovered incidentally between survey points and was not part of the sample.

Discussion

The distribution of Williamson's Sapsucker in south-central B.C. appears to be well known now. Lack of any detections of groups of Williamson's Sapsucker nests outside the AOs, both on our targeted surveys and the Breeding Bird Atlas surveys, leads us to conclude that there are likely no such groups of nests outside the known AOs. Outside of the AOs, there are likely only single isolated nests at very low densities.

Relative abundance based on response to CPB was sensitive to stage of the breeding season assuming that true abundance did not change between different sampling periods within the breeding season. This will be true for the most part, but some breeding territories will fail and be abandoned during the breeding season. However, the decline in relative abundance from April to June was far higher than could be explained by a few nest failures alone. Therefore, to compare relative abundance between regions, sites or habitats, the time of the breeding season must be adjusted for or entered as a variable in any analysis. Relative abundance also differed between habitat suitability classes. However, since we controlled for time of breeding season in that comparison, the difference in relative abundance is assumed to reflect a difference in true abundance between habitat suitability classes.

Table 1. Williamson's Sapsucker nest population estimate from searches of 225 m radius plots, Merritt-Princeton and Okanagan-Boundary Areas of Occupancy, 2008.

AO	Area km ²	Area sampled per Pt km ²	Total Possible Pts N	Sampled Pts n	Nests found x	Nest estimate x/n * N	Variance s ²	SE s	CV %	95% Conf. Int. ^a
Merritt-Princeton	743	0.16	4668	50	2	187	16894	130	70	-
Okanagan-Boundary	698	0.16	4382	124	6	212	6985	84	39	48-376
Total	1440					399	23879	155	39	96-702

^a Confidence interval not shown for Merritt-Princeton as lower bound would be below 0.

Table 2. Williamson's Sapsucker breeding territory estimates prior to 2008 based on extrapolation from area sampled during CPB (without specific sample design), and follow-up nest searches, Merritt-Princeton and Okanagan-Boundary Areas of Occupancy.

AO	Survey Years	Area ^a (km ²)	Sampled Area (km ²)	Fraction of AO Sampled	Known Breeding Territories	Mean Re-occupancy of Nesting Territories ^b	Occupied Breeding Territories per Year
		A	a	a/A	n	R	$n * A/a * R$
Merritt-Princeton	1998–2007	770	189	0.245	64	0.641	167
Okanagan-Boundary	1996–2006	743	245	0.330	141	0.502	214
Total							381

^a Note that the AO sizes reported here in 2006–2007 were slightly larger than reported in Table 1 for 2008. For 2008 areas were deleted from the AO where additional information showed no nests or where no nests would be expected based on a better understanding of habitat requirements.

^b See text for estimate of mean re-occupancy (for purposes of this table to show calculation method, arbitrarily named R).

In 2007 and prior, we assumed a 300 m radius was sampled by our CPB but this was a simplification substituting a single number for the gradual decrease of detectability with distance from the observer. This decrease in detectability can be quantified with distance-sampling methods (Buckland *et al.* 1993) but is a source of error in our estimate of breeding territories for which we did not have an estimate. We could not apply detections of adults on CPB surveys to determine absolute abundance as the result would be biased high since Williamson's Sapsucker frequently approached the observer in response to CPB before being detected. The area sampled by the CPB would then appear to be fairly small, when, in fact, based on the locations of nests found, the area sampled would be quite large. This would bias the apparent density of birds upwards compared to the actual density of nests, violating an essential assumption of distance sampling that animals not approach the observer before being detected (Buckland *et al.* 1993). Only if nest locations or locations or the center of territories for pairs were used could absolute abundance be determined using distance sampling or variable-radius plot methods. In this study, we used fixed-size plots in 2008 and 2012 so that we did not have to account for the decrease in detectability as the distance from the sample point increased.

In addition, males respond to CPB readily but females may also sometimes respond, and if not seen they cannot be reli-

ably separated from males based only on call or drum. Therefore the fraction of the population that is detectable is unknown. Using nests as the basis for a population estimate does not require us to make any assumption about differences in detectability of male and female Williamson's Sapsucker, and to simply assign a value of two adults per nest if we wish to determine breeding population size. This would not take into account unmated males, which Crockett (1975) estimated to be about 10% of his study population in Colorado, and was estimated at 9% in the Okanagan Boundary, and 25% in Merritt-Princeton (Gyug *et al.* 2007). Our estimates of breeding territories would take these males into account since they would have been on territory and counted as a probable territory. So, a factor of 1.75 to 1.91 would be used to convert our estimate of breeding territories to adult population size.

Using the three independent methods to estimate population size, the estimates were in the same range (399 nests, 381 breeding territories and 526 breeding territories), even given the very different methods used for each estimate. While these estimates appeared to be increasing over time (381 prior to 2008; 399 in 2008; 526 in 2012), they were calculated with such widely different methods, each with such wide confidence intervals (where they could be estimated) that these data should not be used to infer population trends.

The only previous population estimate for Williamson's Sapsucker in B.C. was the estimate of 182

Table 3. Williamson's Sapsucker breeding territory estimates predicted from regression of territory densities against average habitat suitability in 30 census areas in the Merritt-Princeton and Okanagan-Boundary Areas of Occupancy, 2012.

AO	Area (km ²)	Average Habitat Suitability	Predicted Density ^a	SE	Predicted Territories	95% Confidence Interval
Merritt-Princeton	743	0.096	0.300	0.061	223	134–312
Okanagan-Boundary	698	0.140	0.435	0.089	303	182–424
Total	1439	0.117	0.365	0.075	526	316–736

^a See text for regression equation used for prediction.

breeding pairs in the Okanagan-Boundary based on observed densities and habitat extent (COSEWIC 2005). This estimate was within the 95% confidence intervals of the estimates produced for the Okanagan-Boundary in this study. The anecdotal estimate of 33 pairs in the remainder of B.C. (COSEWIC 2005) was greatly underestimated, which can now be corrected with reliable data upon which to base revised estimates.

The 2008 nest population estimates were based on sampling that was not planned to produce a robust population estimate, so it was not surprising that there was a relatively high CV of 39%. In the future, variance of nest population estimates could be reduced by increasing sample size or sample effort, but this would also increase costs. Using the same effort as in 2008, variance might be reduced by 1) using variable-radius plots and distance sampling methods rather than fixed radius plots to include more nests in the estimate than by fixed-radius plots, 2) stratifying by habitat suitability, 3) proportional allocation of effort among strata according to strata size and expected variance, and 4) using a dual-frame design where known nests are sampled on a list frame independently of stratified random area sampling (e.g., as used for Bald Eagle nest population estimates, Haines and Pollock 1998).

The 2012 population size was predicted from sampling conducted for other purposes, so, again, it was not surprising that there were very wide confidence intervals on the population estimate. If census areas had been sampled specifically to predict population size, the design would have been different. The habitat strata would have been pre-defined, rather than applied post-hoc as in this case, sample size apportioned according to strata size and expected variance, and samples selected randomly from within strata. The regression would not have been necessary, and a stratified random design could be used to predict population size. However, even if the regression of density on habitat was used again, the design could have been better balanced with more samples selected from each end of the habitat suitability ratings. More Very Low or Nil habitats would have been sampled so that regression would not have to be constrained to go through origin, which makes Pearson's r irrelevant, and usually highly skews F values compared to unconstrained regression. Also, more High suitability habitats would have been sampled than were selected in 2012. In 2012, only previously unsampled areas were selected, and virtually all known High suitability habitats had already been sampled prior to 2012.

Relatively little confidence could be put in any West EO population estimate that would have been calculated because just one nest was found within the sampling. Unless methods can be found to increase efficiency of sampling, i.e. increase the numbers of nests found during area frame sampling without substantially increasing effort, no reliable population estimates are ever likely to be possible for this area where densities appear to be very low.

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