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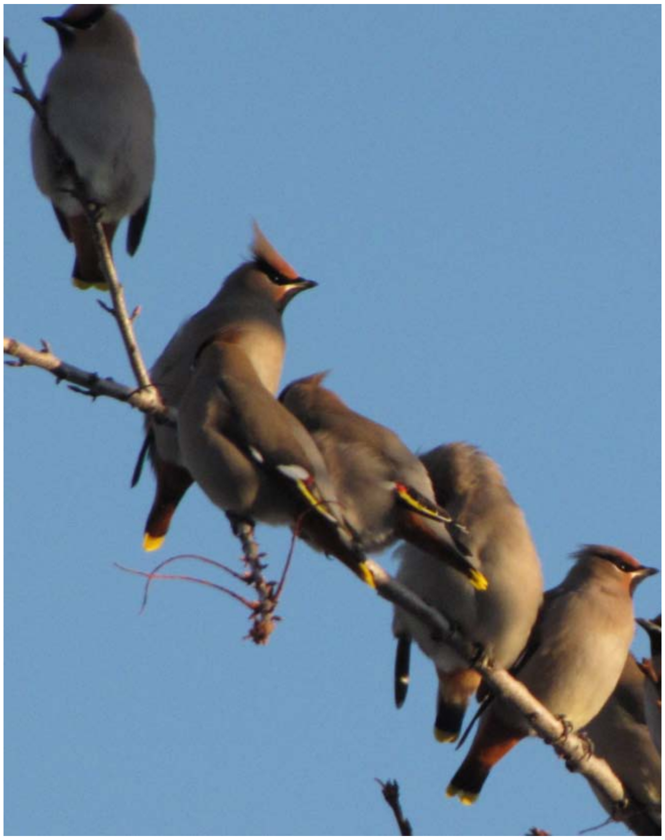
Summary of Songbird Trends in Banff National Park: 2007 to 2011



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2014

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Clark's nutcracker, J. Whittington

Abstract

Many songbird species are declining throughout North America. We analysed 5 years of songbird recording data from 135 sites in Banff National Park. Twenty of 61 species analysed significantly declined from 2007 through 2011 and 8 species increased. Similarly, 2 species declined from 1995 through 2009 at the Vermilion Lakes Wetlands. The olive-sided flycatcher, which is federally listed as *Threatened*, requires recently burned forests. It along with 2 other aerial insectivores declined. Our results are consistent with declines of many species in Revelstoke-Glacier National Park. Time-to-event modelling with survival analysis is a promising approach for analysing songbird data. A comprehensive analysis of all Mountain Park songbird data will help differentiate mechanisms of population change.

Introduction

Songbirds are monitored throughout the world because they are susceptible to changing climatic conditions, habitat loss, and habitat fragmentation (Sillett et al. 2000, Ballard et al. 2003, Nebel et al. 2010). In 2007, the Mountain National Parks, including Banff National Park (BNP), developed a bird monitoring program to track changes in bird abundance both within parks and across a large latitudinal gradient from Waterton through to Jasper. The program used the point count approach for monitoring multiple species of birds (Gillies and Franken 2006). Researchers recorded 10 minutes of birdsongs at specific sites during the breeding season. Bird specialists then identified individuals and recorded the minimum number of individuals at each site. Objectives of this report are to:

1. Summarise trends in relative bird abundance in Banff National Park.
    a. Songbird diversity trends.
    b. Species specific trends in relative abundance from 2007 through 2011.
    c. Species specific trends at Vermilion Lakes 1995 through 2009.
    d. Species specific shifts in elevation.
2. Compare the results of 3 statistical approaches for analysing song bird data.

Methods

Study Design and Field Methods

All Mountain National Parks implemented songbird monitoring programs in 2007. All parks followed the same protocols (Gillies and Franken 2006) and uploaded data into a shared database to enable large scale analyses. Power analysis suggested 100 point counts spread across 10 transects would be required to detect annual 3% declines in species diversity over 10 years and annual 5% declines in species abundance over 20 years (Gillies and Franken 2006). Transects were located on randomly selected trails. Point count locations were set up at 300 m intervals so that individual birds would not be detected at multiple sites (Hobson et al. 2002). Sites were selected to increase sampling effort at rare but productive areas including aspen stands, shrub lands, and grasslands. Although not as productive, alpine sites were also sampled because they could be highly influenced by changing climatic conditions. Sites were selected to avoid noise associated with rivers and highways because the background noise masked bird songs and reduced detection rates. Sites were visited once per year between 4:00 am and 8:30 am during breeding season (primarily June).

In 2007, BNP piloted 156 sites spread between Carrot Creek and Saskatchewan Crossing (Figure 1). Some sites were dropped or moved because of river noise (e.g. Paradise Valley and Mosquito Creek). We later learned that Mike and Diane McIvor sampled 50 sites in the lower Bow Valley from 1995 through 1999 (Figure 2) and then a subset (8) of those sites from 2001 through 2005 at Vermilion Lakes (McIvor and McIvor 1999, 2005). Therefore, in 2009 we re-sampled the Vermilion Lakes sites and in 2012 and 2013 we re-sampled highly productive McIvor sites near Mule Shoe and Moose Meadows, but that bird recording data was not ready at the time analysis. BNP currently has 148 active bird monitoring sites, including 17 that were sampled by McIvors (Figure 3).

One difference between the McIvor and Parks data was that McIvor's identified birds at the sites and did not record bird songs. Further, McIvor visited sites 2 times in June whereas Parks visited sites once. Thus, less vocal birds could have had lower detection rates with the Parks sampling method. However, other studies have shown that acoustic recordings, which can be replayed, identify slightly more bird species than real-time observations (Hobson et al. 2002).

Songbird specialists analysed the 2007 - 2011 recordings and for each point count determined the time to first detection for each species and the minimum number of songbirds observed for each 3.33 minute interval within the 10 minute recording session. Songs and bird calls that were difficult to identify were sent to other specialists for verification.

Northern hawk owl, J. Whittington

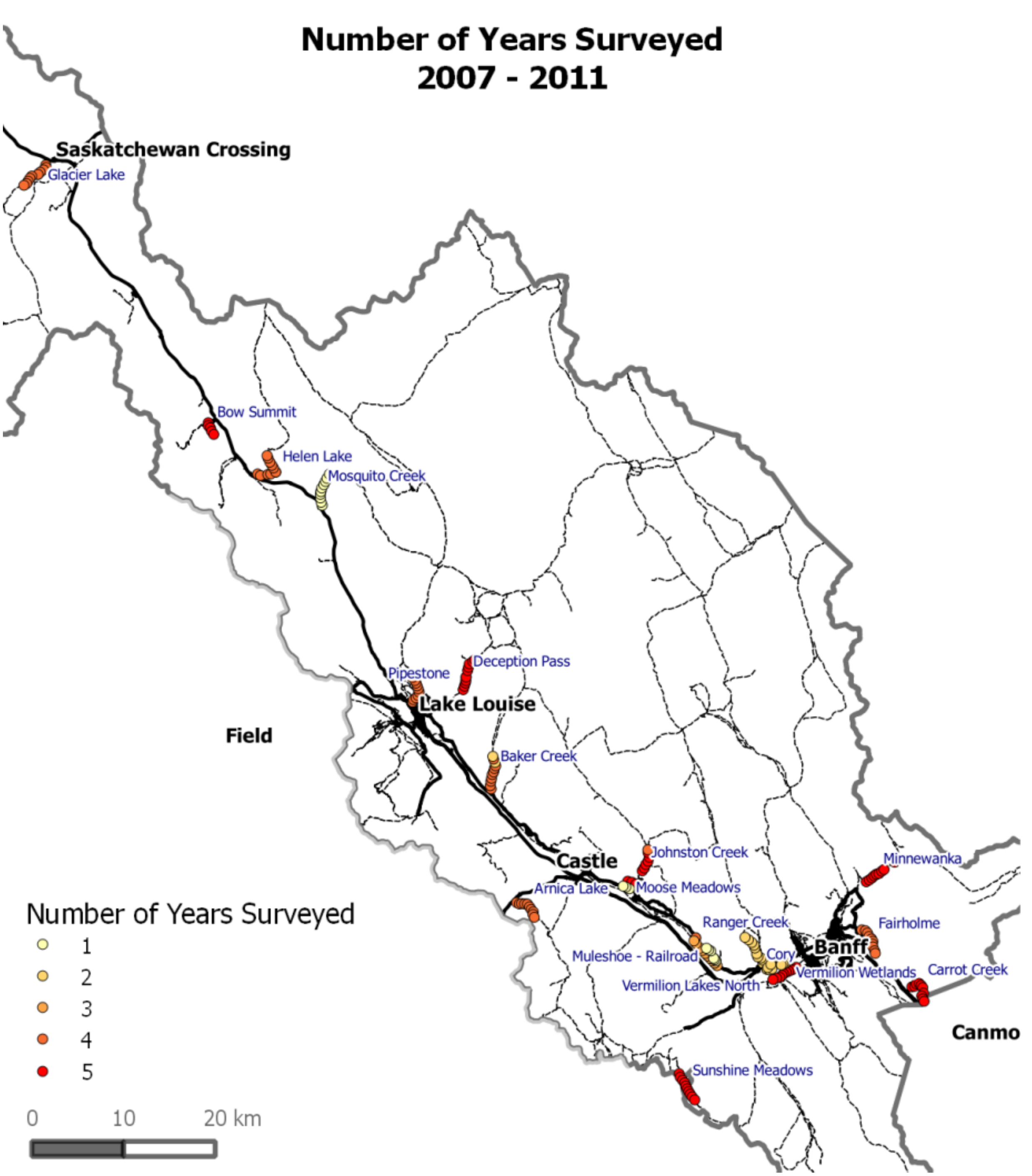

Figure 1. Number of years surveyed using acoustic recordings from 2007 through 2011.

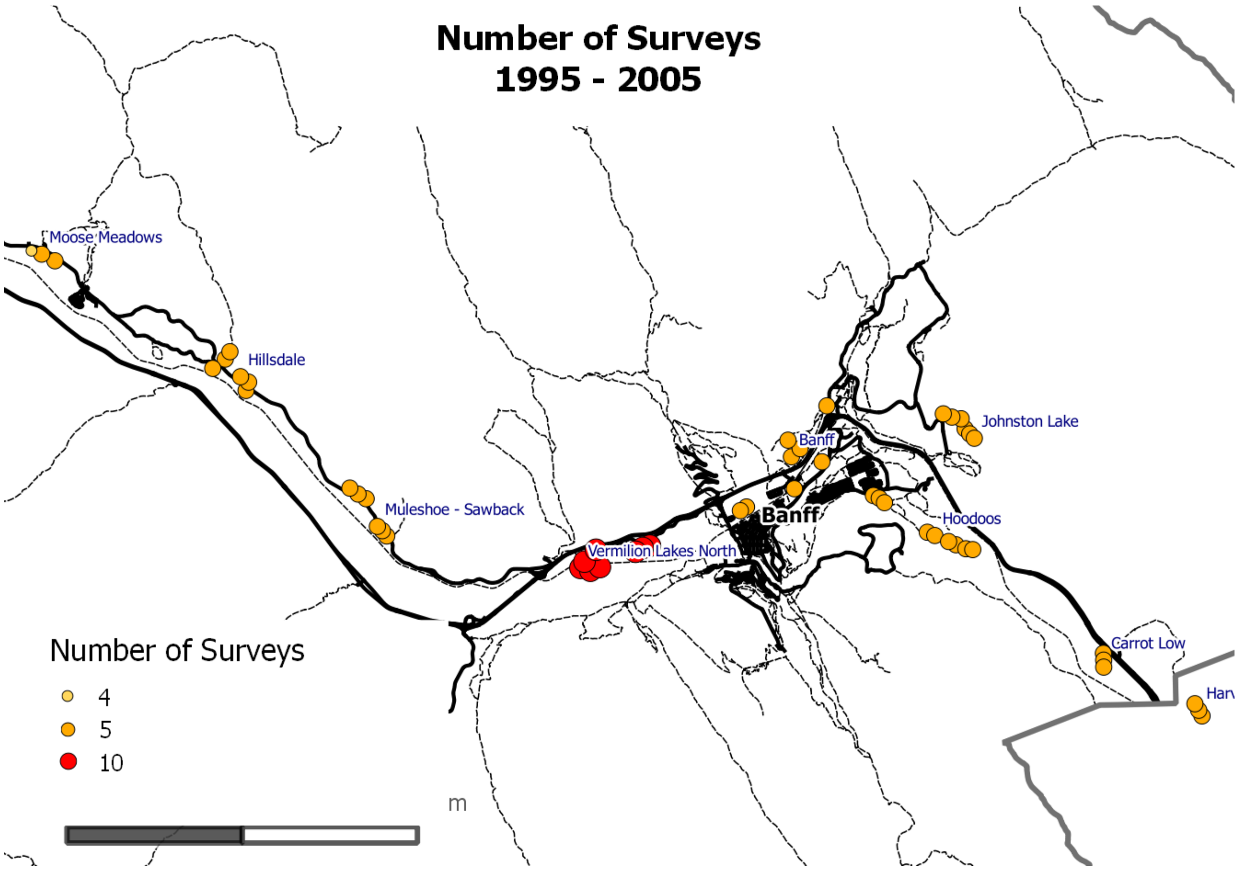

Figure 2. Number of years surveyed using real-time identification between 1995 and 2005 (McIvor and McIvor 1999, 2005). Three sites at Yamnuska are not shows on this map.

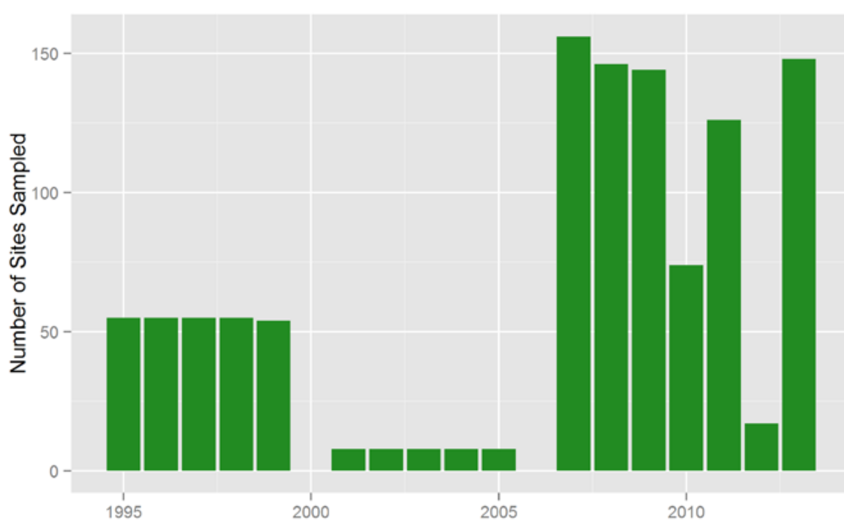

Figure 3. Number of sites sampled by McIvor's (1995- 2005) and Parks Canada (2007 – 2013).

Statistical Analysis

Biodiversity

We selected 135 sites that were sampled for at least 3 years between 2007 and 2011. For each site we calculated the number of species observed. We then used generalized linear mixed effects models (glmm) with a negative binomial link to determine if the number of species detected per transect (i.e. biodiversity) changed over time. We used number of species detected as our response variable and a random effect for site so that the models essentially tracked changes over time at a site level in a repeated measures format. We used likelihood ratio-tests and forward stepwise selection to develop our final model (Hosmer and Lemeshow 2000). Explanatory variables were tested in the following order: calendar day, hour of the day, and then year. Thus, variables influencing detection probability were assessed before assessing the effects of year. We predicted detection rates and thus the number of species detected would decrease later in the breeding season and decrease later in the morning. We used a Type I error of 0.05.

Relative Abundance in BNP: 2007 - 2011

A common challenge facing monitoring programs is that a species may be present but undetected on surveys. Occupancy (MacKenzie et al. 2006) and distance sampling (Buckland et al. 2005) are frequently used to estimate detection probability either through multiple surveys or estimating detection rates as a function of distances between animals and the observers. Those detection probabilities are then used to estimate probability of occupancy for the study area (or proportion of area occupied) or abundance for distance sampling. Distance sampling can be used with in-situ point counts but not with songbird recordings because bird distances cannot be estimated. Therefore, acoustic recordings provide indices of abundance and occupancy modelling with repeated surveys would be the preferred sampling methodology. However, given high detection rates the costs associated with multiple surveys outweigh the statistical benefits (Carlson and Schmiegelow 2002). That leaves 4 potential methods for monitoring trends in relative abundance.

i. **Occupancy** models using species detection history for the three 3.33 minute time intervals. While this approach has potential, we did not pursue it because the 3 intervals within the 10 minute sampling period are not repeat visits and are likely highly correlated.

ii. **Survival analysis** using time-to-first detection. Detection rates have recently been found to be positively correlated with abundance (McCarthy et al. 2013). Consequently, survival analysis is a promising approach for analysing changes in abundance. Another benefit of survival analysis is that it considers undetected species right censored. Species that are not detected during the 10 minute sampling interval could conceivably be detected in the future depending on the baseline hazard. We used an exponential parametric survival model with a random effect for site where the likelihood of detection was constant across the 10 minute period. The likelihood of detection or instantaneous hazard at time *t* for a full model was $Hazard\ (t) = \frac{1}{exp^{(Intercept+\beta_{day}\cdot Day+\beta_{hour}\cdot Hour+\beta_{Elevation}\cdot Elevation+\beta_{year}\cdot Year)}}$ where *Day* was calendar day, *Hour* was hour of the day, *Elevation* (m), and β indicates estimated coefficients. Note that a positive coefficient for *Year* indicates that time to detection increases with year and is thus negatively correlated with abundance.

iii. **Negative binomial glmm's** examine the effects of year on the minimum number of birds heard at a site and use a random effect for site so that the models assess changes in relative abundance at a site level. These models do not incorporate detection probability. A glmm with a poisson link is a special case of the negative binomial where the variance equals the mean. Negative binomial links are commonly used for ecological count data when variance does not equal the mean. Predicted abundance was $\lambda = exp^{(Intercept + \beta_{day} \cdot Day + \beta_{hour} \cdot Hour + \beta_{year} \cdot Year)}$. Coefficients for Year were positively correlated with probability of occurrence.

iv. **Logistic regression glmm's** examine the effects of year on species presence – absence rather than relative abundance with a random effect for site. Predicted probability of occurrence was $p = \frac{exp^{(Intercept + \beta_{day} \cdot Day + \beta_{hour} \cdot Hour + \beta_{year} \cdot Year)}}{1 + exp^{(Intercept + \beta_{day} \cdot Day + \beta_{hour} \cdot Hour + \beta_{year} \cdot Year)}}$. Coefficients for Year were positively correlated with probability of occurrence.

We ran survival, negative binomial, and logistic regression models for 61 species that were detected at $\geq$ 5 sites. We limited the analysis to 135 sites with at least 3 years of data. For each species we restricted the analysis to sites where the species had been present at least once during the 5 years. We excluded sites where the species was never present because the lack of trend at those sites (all 0 detection history) could mask trends where the species was present. We include all sites in another analysis below examining shifts in elevation over time (i.e. changes in resource selection). As with the biodiversity analysis we used forward stepwise selection to select our final model. We considered covariates in the following order: calendar day, hour, elevation, and year. We used a Type I error of 0.05 for the likelihood ratio tests and further constrained the addition of variables by only including them if p-values for the β coefficients were < 0.05.

Species Occurrence at Vermilion Lakes: 1995 - 2009

In 2009, we re-sampled 8 sites in the Vermilion Lakes Wetlands that had been surveyed for 10 years: 1995 – 1999 and 2001 – 2005 (McIvor and McIvor 1999, 2005). Given the low number of sites, we expected low power to detect trends. We ran logistic regression glmm's for 37 species that were detected at $\geq$ 5 sites. We used the same modeling approach and explanatory variables as above except we tested for a significant quadratic term for year for species with both increases and decreases over the 15 years.

Range Shifts: Elevation

Changing climatic conditions could lead to changes in elevation preferences of songbirds. We used logistic regression glmm's and presence/absence data from all 135 sites to determine if changes in probability of occurrence over time depended on elevation. We ran the analysis on all 61 species as above. We used forward stepwise selection with the same explanatory variables as above except we also considered a quadratic term for elevation because we expected some species would select mid-range elevations. We also tested for an interaction between elevation and year.

We ran our analysis in R 3.02 (R Development Core Team 2013) using the following packages: sp, maptools, rgdal, plyr, lubridate, and ggplot2 (Bivand et al. 2008, Wickham 2009, Grolemund and Wickham 2011, Wickham 2011, Keitt et al. 2012). We used freely available, open source software QGIS 2.01 (www.qgis.org) for mapping.

Results

Biodiversity

From 2007 – 2011 we recorded the presence of 104 bird species with up to 54 species per site. Vermilion Lakes Wetlands had the highest songbird diversity. Other areas of high songbird diversity included low elevation areas with aspen stands, shrubs, and grasslands. The average number of species per site declined by almost 1 species over 5 years (Figure 6).

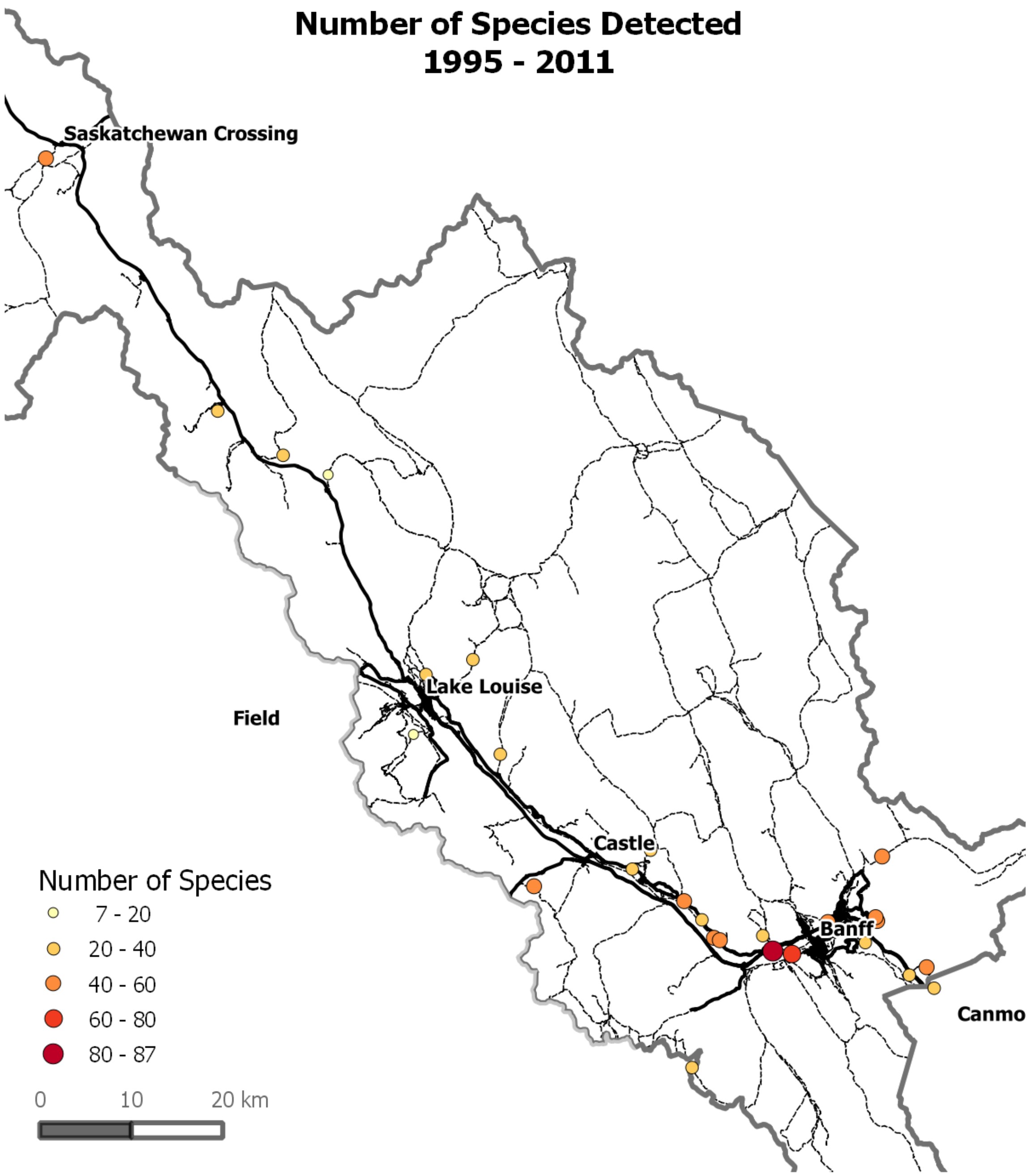

Figure 4. Number of species detected per transect (usually 10 sites) in BNP from 1995 – 2011.

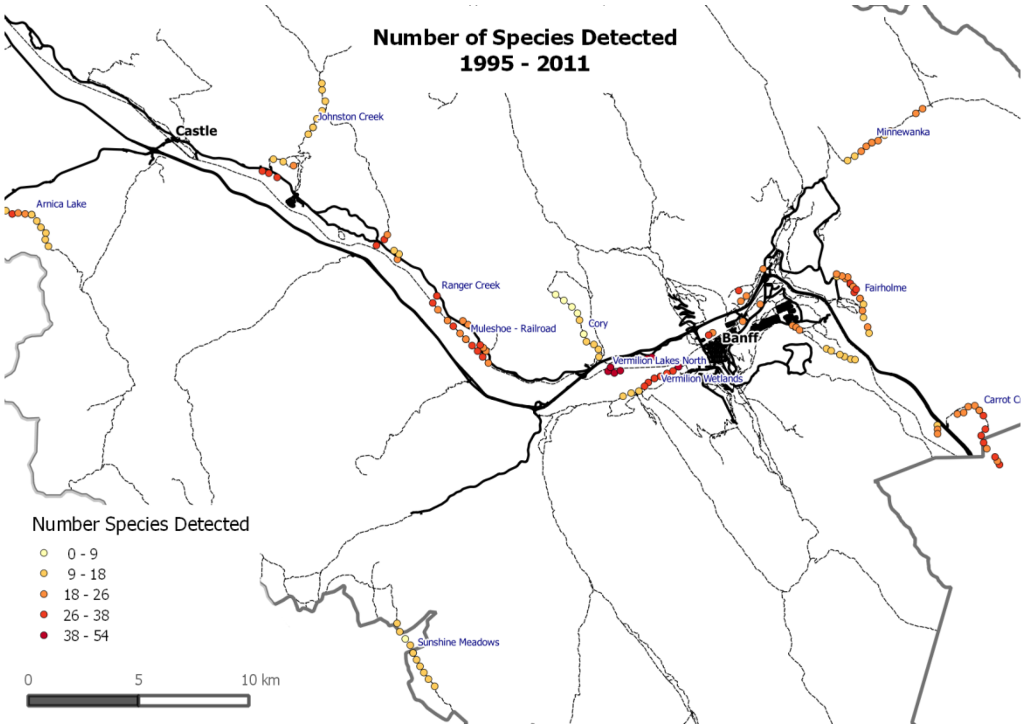

Figure 5. Number of species detected per site in the lower Bow Valley, BNP from 1995 – 2011.

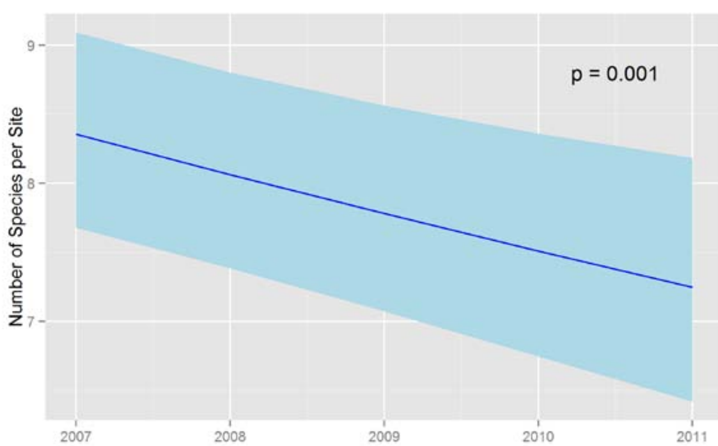

Figure 6. Predicted average number of species per site and 95% CI's from 2007 – 2011.

Relative Abundance in BNP: 2007 – 2011

We analyzed data from 61 species that were present at $\geq$ 5 sites. We detected significant changes in relative abundance for 28, 18, and 26 species from the survival, negative binomial, and logistic regression models respectively. Species with significant changes in the negative binomial and logistic regression were included in the list of significant species in the survival models. Relative abundance of 20 species declined and 8 species increased (Figure 7, Figure 8, Figure 9).

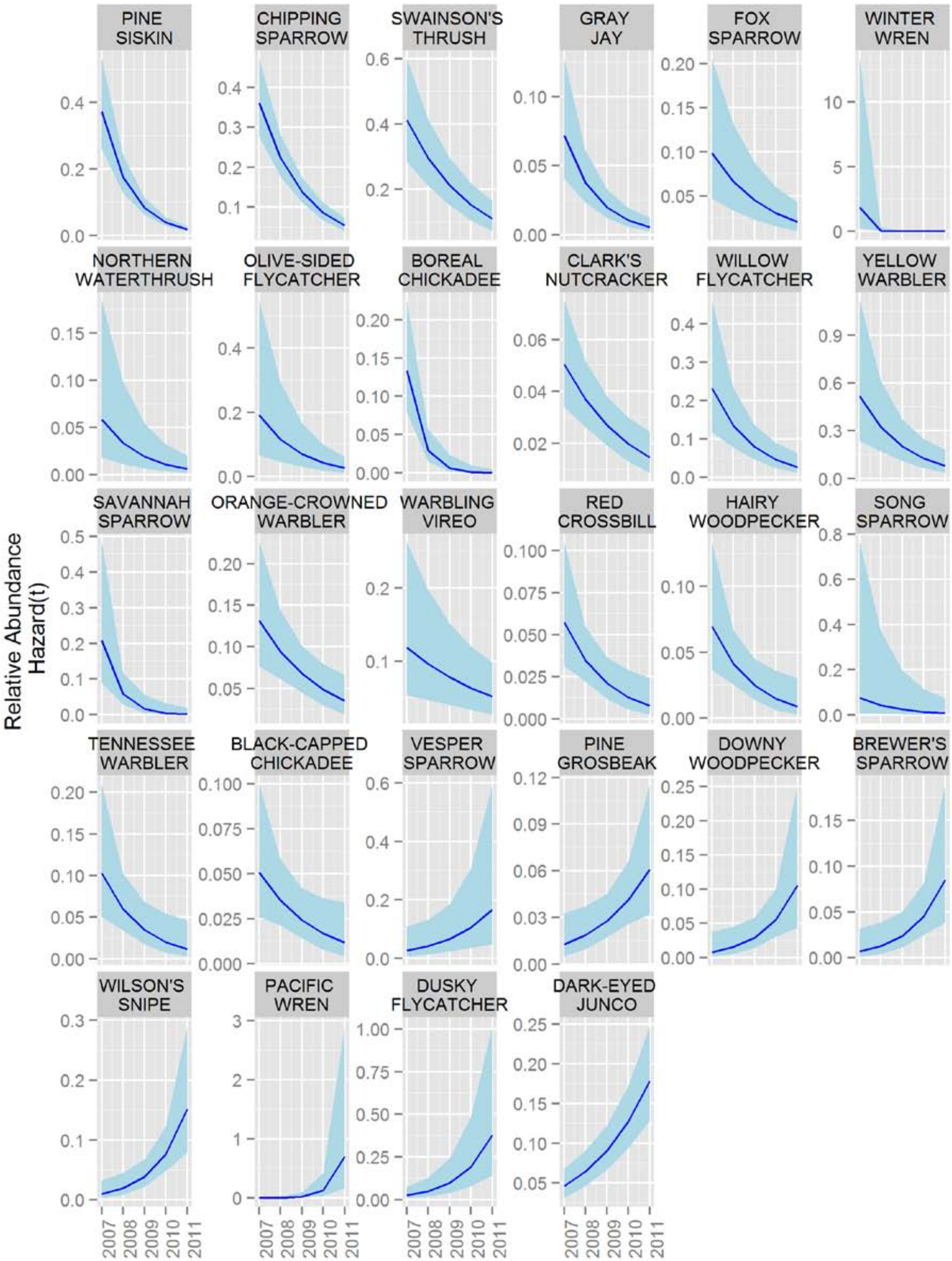

Figure 7. Predicted likelihood of detection (instantaneous hazard at time *t*) and 95% CI's from 2007 - 2011 for each species with a significant trend (Type I error < 0.05) from the survival analysis. Species are ordered from decreasing to increasing by the strength of their p-value.

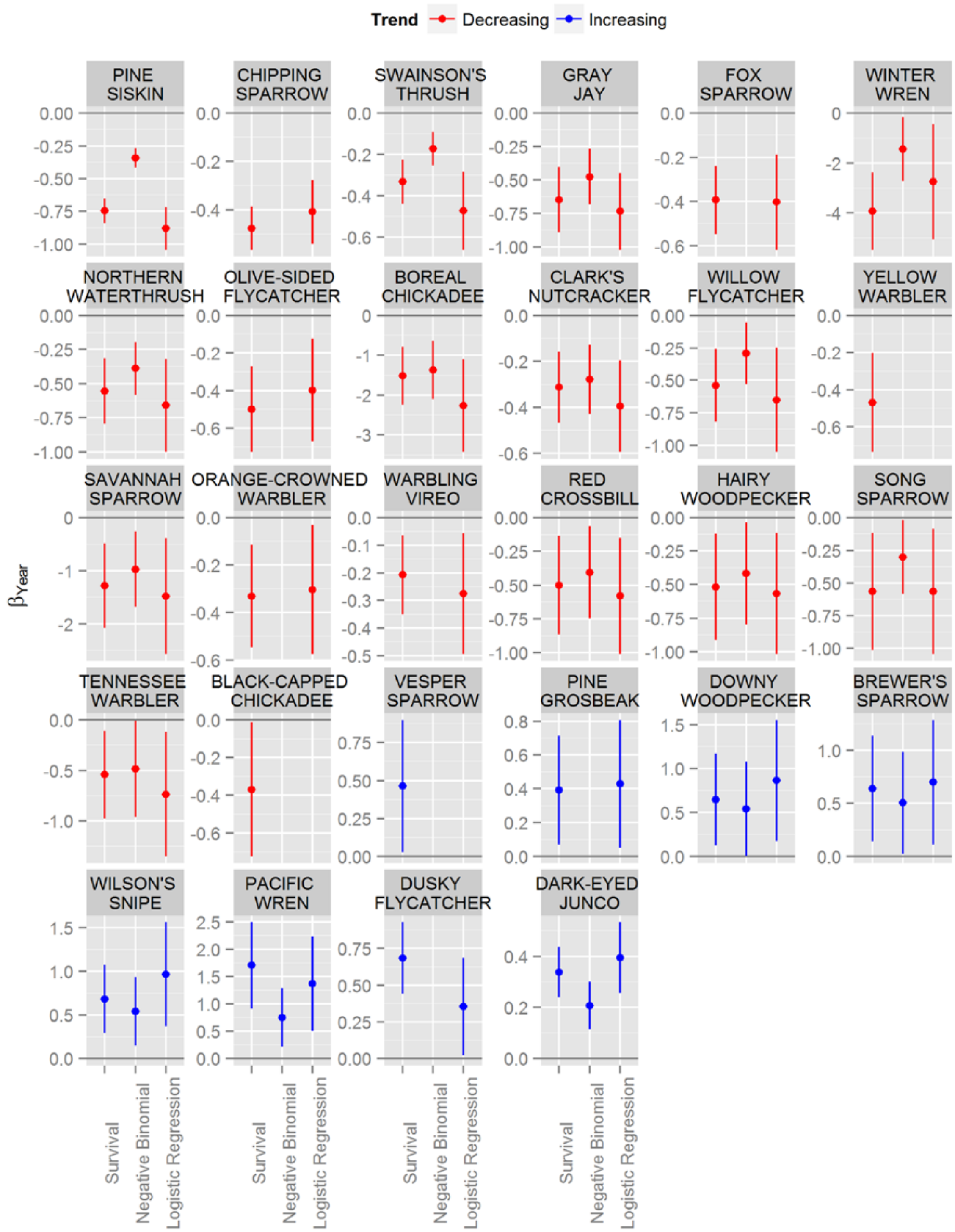

Figure 8. β coefficients and 95% CI's for the Year explanatory variable from the survival, negative binomial, and logistic regression models. Note that survival β coefficients are multiplied by -1 to make them comparable with the other methods.

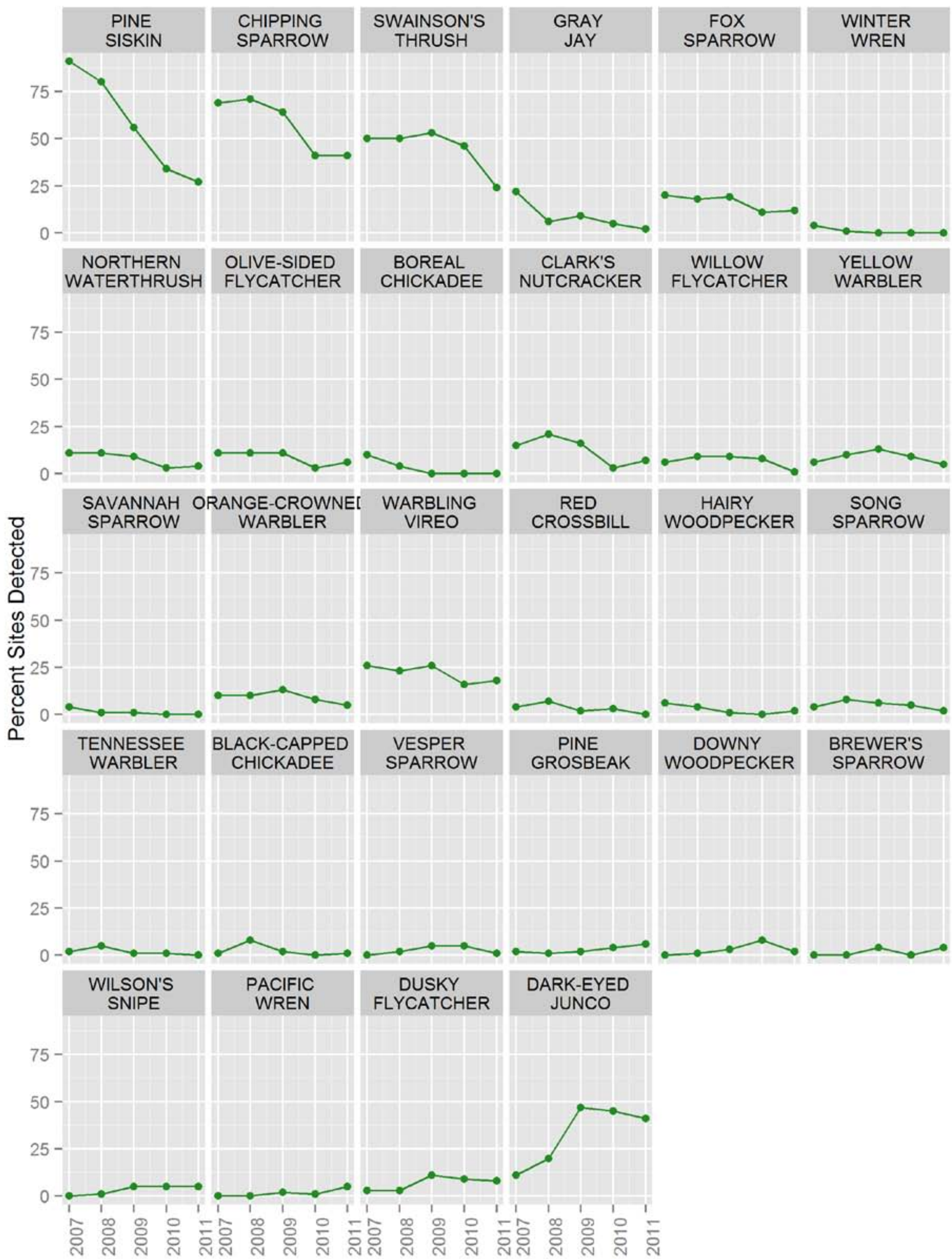

Figure 9. Percent of the 135 sites that each species was detected from 2007 – 2011. Species listed are those that had significant changes in relative abundance from the survival models.

Species Occurrence at Vermilion Lakes: 1995 – 2009

Probability of occurrence declined for 2 of 37 species analyzed from the Vermilion Lakes Wetlands (8 sites). Those two species were the Alder Flycatcher and the American Bittern (Figure 10). Note that birds were identified real-time from 1995 – 2005 and from recordings in 2009.

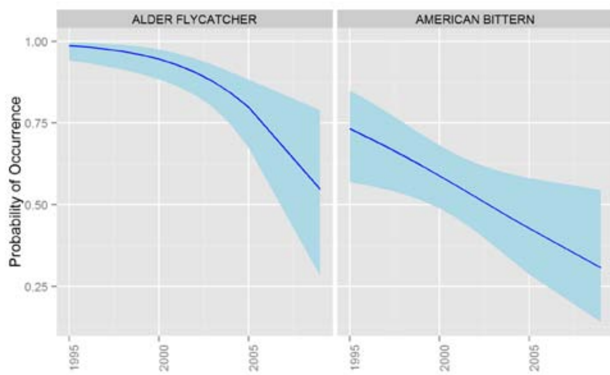

Figure 10. Relative probability of occurrence and 95% CI's for two species with significant decreases in occurrence at the Vermilion Lakes Wetlands from 1995 – 2009.

Range Shifts: Elevation

Two species showed shifts in their selection of elevations between 2007 and 2011 (Figure 11). Logistic regression glmm's for dark-eyed juncos and fox sparrows had a significant interaction between year and elevation. In 2007, dark-eyed juncos preferred elevations around 1800 m. By 2011, dark-eyed junco range increased at lower elevations and showed stronger preference for elevations around 1550 m. Conversely, fox sparrows were highly abundant at high elevations in 2007 and were not found low elevation habitat. The relative abundance of fox sparrows then declined, especially at high elevations.

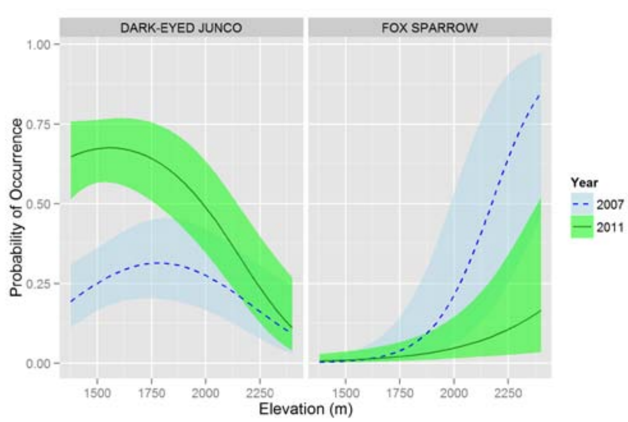

Figure 11. Probability of occurrence versus elevation for 2 species that had a significant interaction between year and elevation from logistic regression glmm analysis.

Table 1. Trends in relative abundance for species detected at ≥ 5 sites in BNP or with significant trends from Revelstoke – Glacier National Park 2007 – 2012 (Gillies 2013). The table also shows the number of sites where each species was detected within BNP from 1995 – 2011, the status recommended by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the status assigned by the Canadian Species at Risk Act[1]. Residents live year round in BNP or winter in adjacent areas.

Species	Resident	Number of Sites Detected BNP	BNP Trend 135 Sites 2007 - 2011	Vermilion Trend 8 Sites 1995- 2009	Revelstoke Glacier Trend 2007 - 2012	COSEWIC Status	Species at Risk Act Status
ALDER FLYCATCHER		12		Decline			
AMERICAN BITTERN		5		Decline			
AMERICAN PIPIT		13					
AMERICAN REDSTART		24					
BANK SWALLOW		1				Threatened	No Status
BARN SWALLOW		1				Threatened	No Status
BLACK-CAPPED CHICKADEE	R	43	Decline		Decline		
BLACKPOLL WARBLER		15					
BOREAL CHICKADEE		28	Decline				
BREWER'S SPARROW		13	Increase				
BROWN-HEADED COWBIRD		84					
BROWN CREEPER	R	26					
CASSIN'S VIREO		9					
CEDAR WAXWING	R	37			Decline		
CHIPPING SPARROW		190	Decline		Decline		
CLARK'S NUTCRACKER	R	71	Decline				
COMMON LOON		24					
COMMON NIGHTHAWK		1				Threatened	Threatened
COMMON YELLOWTHROAT		31					
DARK-EYED JUNCO		164	Increase		Increase		
DOWNY WOODPECKER	R	12	Increase				
DUSKY FLYCATCHER		30	Increase				
FOX SPARROW		47	Decline				
GOLDEN-CROWNED KINGLET	R	86					
GRAY-CROWNED ROSY-FINCH		11					
GRAY JAY	R	78	Decline		Decline		
HAIRY WOODPECKER	R	25	Decline				
HERMIT THRUSH		74			Decline		
LAZULI BUNTING		1			Increase		
LEAST FLYCATCHER		42					
LINCOLN'S SPARROW		48					
MACGILLIVRAY'S WARBLER		17					
MALLARD	R	15					

Species	Resident	Number of Sites Detected BNP	BNP Trend 135 Sites 2007 - 2011	Vermilion Trend 8 Sites 1995- 2009	Revelstoke Glacier Trend 2007 - 2012	COSEWIC Status	Species at Risk Act Status
MOUNTAIN CHICKADEE	R	117					
NORTHERN FLICKER	R	47					
NORTHERN WATERTHRUSH		36	Decline				
OLIVE-SIDED FLYCATCHER		34	Decline			Threatened	Threatened
ORANGE-CROWNED WARBLER		62	Decline				
PACIFIC WREN		8	Increase				
PILEATED WOODPECKER	R	36					
PINE GROSBEAK	R	19	Increase				
PINE SISKIN	R	216	Decline				
RED-BREASTED NUTHATCH	R	117			Decline		
RED-NAPED SAPSUCKER		13			Decline		
RED CROSSBILL		28	Decline		Decline		
RUBY-CROWNED KINGLET		157			Decline		
RUFFED GROUSE	R	20					
SAVANNAH SPARROW		18	Decline				
SONG SPARROW		24	Decline		Decline		
SPOTTED SANDPIPER		21					
STELLER'S JAY	R	4			Increase		
SWAINSON'S THRUSH		156	Decline				
TENNESSEE WARBLER		20	Decline				
TOWNSEND'S SOLITAIRE		19					
TOWNSEND'S WARBLER		119			Increase		
TREE SWALLOW		16					
VARIED THRUSH		80			Decline		
VESPER SPARROW		10	Increase				
WARBLING VIREO		93	Decline				
WESTERN WOOD-PEWEE		16					
WHITE-CROWNED SPARROW		74					
WHITE-THROATED SPARROW		15					
WHITE-WINGED CROSSBILL		58					
WILLOW FLYCATCHER		37	Decline				
WILSON'S SNIPE		35	Increase				
WILSON'S WARBLER		54			Decline		
WINTER WREN		9	Decline				
YELLOW-RUMPED WARBLER		197					
YELLOW WARBLER		32	Decline				

1. http://www.sararegistry.gc.ca/sar/index/default_e.cfm

Discussion

Red-breasted nuthatch. Benoit Audet
www.natureinstruct.org/dendroica/

We found declines in overall biodiversity and relative abundance for 20 of 61 species (15%) and increases in relative abundance for 8 of 61 species (6%). These results were somewhat surprising given the relatively short time interval (5 years) and because the power analysis suggested that 10 years would be required to have over 80% power to detect annual declines of 3% (Gillies and Franken 2006). However, our results were consistent with analyses of 2007 - 2012 songbird data from Revelstoke-Glacier National Park (Table 1). Over 6 years, 12 of 55 species (22%) declined and 4 species (7%) increased in relative abundance (Gillies 2013). That study analysed data using glmm's with a poisson link and a Type I error of 0.10. Eleven species declined in both BNP and Revelstoke-Glacier: the black-capped chickadee, cedar waxwing, chipping sparrow, gray jay, hermit thrush, red-breasted nuthatch, red crossbill, ruby-crowned kinglet, song sparrow, varied thrush, and Wilson's warbler. Two species increased in both BNP and Revelstoke-Glacier: the dark-eyed junco and Townsend's warbler. Species with consistent trends in both parks suggest common mechanisms of decline.

One of the challenges associated with identifying threats to migratory songbirds is that population changes can be driven mechanisms occurring in their southern wintering areas, migratory routes, and northern breeding grounds (Sillett et al. 2000). Moreover, changing climatic conditions can interact with timing of food emergence (Both et al. 2006, Nebel et al. 2010), optimal temperatures for population growth (Jiguet et al. 2010), and evolutionary history (Lavergne et al. 2013) to affect survival and recruitment rates. Similarly, songbird trends can be driven trophic cascades where human activity (Hebblewhite et al. 2005) or climatic factors (Martin and Maron 2012, Newson et al. 2012) affect ungulate density that in turn affect resources available to songbirds. Given that migratory song bird abundance can be driven by so many factors, it is important to monitor all stages of their life cycle across broad geographic ranges to identify mechanisms behind population change (Sillett et al. 2000). Thus, Mountain Park bird monitoring data should contribute to international analyses of migratory songbird trends. Further, changes in habitat condition, resources, and climate in the Mountain Parks can have direct effects on songbird populations and those effects can be best identified through combined analyses of all Mountain Park data.

Changes in abundance of resident species are likely driven by local climatic, habitat, and predator-prey interactions. Resident species that declined in our study area were the black-capped chickadee, Clark's nutcracker, gray jay, hairy woodpecker, and pine siskin. Resident species that increased were the downy woodpecker and pine grosbeak. None of these species are SARA listed and further investigation is required to determine why these populations are changing and how those changes fit within their natural range of variability.

Aerial insectivores have been susceptible to declines across North America (Nebel et al. 2010). Guilds especially vulnerable to declines are the long distance migrants. The aerial insectivore populations are strongly affected by aerial insect abundance, which in turn are affected by climatic conditions, habitat, and pesticides. Insectivores within our study area that declined were the: alder flycatcher, olive-sided flycatcher, and willow flycatcher. Not all insectivores declined in our study area. The dusky flycatcher increased in relative abundance and the least flycatcher did not change. Interestingly, the declining flycatchers are all long-distance migrants, whereas the dusky flycatcher is a short distance migrant. Large scale weather systems affect the fecundity of insectivorous birds (Sillett et al. 2000) and those effects are often most pronounced at high latitudes (Nebel et al. 2010) and potentially high elevation areas such as the Rocky Mountains. Further analysis could examine the relationship between the North Pacific Oscillation and bird trends. Such analysis would help differentiate how factors at local breeding areas (e.g. BNP), large scale breeding grounds (e.g. Mountain National Parks), and wintering areas affect changes in songbird trends.

Olive-sided flycatcher, Maggie Smith
www.natureinstruct.org/dendroica/

The olive-sided flycatcher was the only declining species that was also listed as *Threatened* under the Canadian Federal Species at Risk Act (COSEWIC 2007). Olive-sided flycatchers migrate over 8000 km from northern Canada to the Andes Mountains in South America. Factors affecting population declines are unclear, but are thought to be driven by changing habitat quality in their wintering areas. In North America, olive-sided flycatchers strongly select burned and logged forests, (Morissette et al. 2002, Robertson and Hutto 2007), however they have much lower nesting success in logged forests potentially because of higher predation risk (Robertson and Hutto 2007). Continued implementation of prescribed burns in Banff National Park should improve conditions for olive-sided flycatchers.

We compared 3 methods of analysing songbird point count data: survival (time-to-event) analysis and glmm's with either a negative binomial or logistic regression link. The survival analysis appears to be the best method and most promising approach. Survival models detected trends for some species that were not detected by the other 2 approaches. Our analysis further supported the positive relationship between detection rate and abundance (McCarthy et al. 2013) because β coefficients for our three types of analysis were very similar and did not diverge for any of the species. The survival approach is also appealing because like occupancy modelling it allows for imperfect detection. Species not detected during the 10 minutes sampling interval could have been detected with further sampling with cumulative probability of detection versus time determined by the baseline hazard. Inferences about trends from glmm's that assume baseline hazards can be confounded if detection probability changes among years or is affected by habitat type (MacKenzie et al. 2002, MacKenzie et al. 2006, Bailey et al. 2013, Kéry et al. 2013). Occupancy modelling assesses trends by estimating detection probability and probability of occupancy in two stages. Survival analysis estimates the effects of year and factors affecting detection probability at once. Future analysis could explore the merits and biases of occupancy and survival methods.

Next Steps
BNP and Revelstoke-Glacier both found many species of declining songbird populations after only a relatively short time period of monitoring. A comprehensive analysis of all Mountain Park songbird data from Waterton through Jasper would help identify local versus broad scale trends and mechanisms affecting songbird populations. Continued monitoring of active point counts will be important track future changes to the songbird community. Updated power analyses would help determine the frequency at which sites should be monitored.

Most song bird monitoring across North America has occured at low elevations. The strength of the Mountain Parks monitoring program is that it monitors high elevation areas that might respond more quickly to changing climatic conditions. However, the current songbird study design has few high elevation grassland sites. Thus, the addition of sites at high elevation grasslands in the Red Deer and Panther Valley area would strengthen the BNP study design.

Acknowledgements
Numerous people helped collect the songbird data including: Mike McIvor, Diane McIvor, Andrea Kortello, Simon Ham, Steve Bertollo, Julie Timmins, Helene Galt, Karsten Heuer, Art Laurenson, and Brian Chruszcz. Cam Gillies provided excellent advice for the project study design and analysis.

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