PROJECT REPORT 2020

LONG-TERM MONITORING OF THE BARN SWALLOW (*HIRUNDO RUSTICA*) IN THE LITTLE CAMPBELL RIVER WATERSHED, 2014-2020

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Abstract

Barn Swallow (*Hirundo rustica*) populations are decreasing on a national and global level. In Canada, Barn Swallows are listed as threatened by the Species at Risk Act. In 2014, A Rocha Canada initiated a Barn Swallow monitoring program to examine the current status and long-term trends of Barn Swallow populations within the Little Campbell River watershed (LCRW) in southwestern British Columbia. Between 2 and 18 buildings containing active Barn Swallow nests were monitored during the breeding season each year from 2014-2020 (5-42 nests per year). Nest checks were conducted weekly between May-September. Eight landowners monitored their own nests and contributed data. We analyzed the effects of environmental predictor variables, including landcover within 400 m of nest sites, on measures of nest success. A noticeable decline in nest activity was evident in four sites. 2017 had colder May temperatures than other years and also had low clutch survival and fledgling numbers. There was a slight trend toward earlier clutch initiation throughout the study period, which may have been driven by one particularly late year. In a year with early average clutch initiation, nests with earliest first egg-laying were less likely to be successful. No environmental variables significantly affected nest success consistently across years, but higher nests had more first-brood fledglings in 2017. Buildings containing active Barn Swallow nests had less surrounding forest than buildings with only inactive (historic) nests. The future of A Rocha Canada's Barn Swallow monitoring program should include greater engagement with landowners, including education and communication, and practical steps to protect Barn Swallows such as construction of artificial nest structures. Most Barn Swallow breeding occurs on private land in the LCRW, so building and maintaining partnerships with landowners will be a crucial step in the conservation of this species.

Introduction

Barn Swallows (*Hirundo rustica*) are medium-sized, migratory passerines that forage on flying insects over open fields. They are identifiable by their metallic blue-black back, rust-colored throat and forehead, and deeply forked tail that extends beyond the wingtips. Barn Swallows are present on every continent except Antarctica and are in every province within Canada, often in rural areas used for agriculture. They typically nest in or on artificial structures such as barns, sheds, houses, bridges, and road culverts. Because of this, populations have historically increased alongside human settlement. Prior to human settlement, Barn Swallows nested in caves, on cliff face ledges and in other holes (COSEWIC 2011). North American Barn Swallows (*Hirundo rustica erythrogaster*) breed in the northern hemisphere and overwinter in Central and South America.

Barn Swallows are considered socially monogamous, although polygamy is common (COSEWIC 2011). They nest in small colonies that usually contain no more than 10 pairs and often fewer. Nests are constructed on flat, horizontal surfaces using mud pellets and lined with soft material such as hair, feathers, or grass. Clutch size typically ranges from 2-7 eggs (Brown and Brown 1999). Incubation is shared between the male and female and lasts from 12-17 days, after which the parent will continue to care for the chicks for around 20 days until they fledge from the nest. Pairs usually lay one or two clutches within one breeding season, and may lay as many as three.

Despite their status as the most widespread swallow species in the world, Barn Swallow populations are declining on both a national and global scale. Breeding Bird Survey (BBS) data show a decline of 3.6% per year in Canada, or 76% over the 40-year period from 1970-2009, with most of the decline occurring in the mid-1980s (ECCC 2019). In British Columbia, Barn Swallows have declined by 4.69 percent per year from 1970 to 2017. In 2011, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed Barn Swallows as threatened. They were federally listed as threatened in Canada by the Species at Risk Act (SARA) in 2017. Although the cause of decline is not fully understood, loss of foraging and nesting habitat is speculated to be the primary threat facing Barn Swallows (ECCC 2019). Pasture and farmland are becoming increasingly developed for industry and housing in Canada, resulting in loss of optimal Barn Swallow foraging habitat. Other threats facing Barn Swallows include decreased insect prey populations, direct and indirect mortality due to increased climate perturbations on breeding grounds, competition for nest sites with non-native species such as House Sparrows, and ectoparasitism, primarily from blowflies and mites (ECCC 2019).

In an effort to better understand the causes of swallow decline and their status locally, A Rocha Canada began monitoring Barn Swallow nests at 10 sites within the Little Campbell River watershed (LCRW) in 2014. This monitoring continued each year from 2014-2020. A citizen science component was added in 2019 that encouraged landowners to monitor their nests and contribute data. The purpose of this study was to increase knowledge of Barn Swallow nest site distribution within the LCRW and to document timing of nesting and nest success in relation to habitat variables such as surrounding landcover. We report seven years of Barn Swallow nest success data with the objectives of refining project priorities and survey methods, evaluating land use and habitat variables potentially affecting Barn Swallows, and assessing potential threats to Barn Swallows in the LCRW.

Methods

Study area

The Little Campbell River watershed (LCRW) covers a total area of 75 km^2 in southwest British Columbia. The LCRW spans the City of Surrey as well as the southern edge of the Township of Langley (City of Surrey 2020). It also includes regions of the Semiahmoo First Nations Reserve No. 1, the U.S. state of Washington, and the city of White Rock (City of Surrey 2020). Although it faces continuous pressure from development, the LCRW is chiefly characterized by agricultural land use and rural residential use (City of Surrey 2020), making it largely suitable for Barn Swallows relative to the greater Metro Vancouver region.

Site selection

A Rocha Canada began monitoring Barn Swallow nest sites in 2014 by selecting 10 sites known to contain either active or historic nests. Seven of these sites contained active nests. In 2015, only 2 sites with active nests were monitored, both at A Rocha’s Brooksdale Environmental Centre. In 2016, new sites were located by flagging 206 potential sites (buildings that appeared suitable for Barn Swallow nesting) on Google Earth aerial imagery. Addresses for each property containing the flagged buildings were extracted from the City of Surrey (COSMOS;

http://www.surrey.ca/city- services/665.aspx) or the Township of Langley (Geosource; http://www.tol.ca/geosplash/). A Rocha then mailed letters to 100 addresses that were randomly selected from the original 260. The letters described A Rocha's swallow monitoring efforts and asked landowners if they would be open to allowing nest monitoring on their property. Fourteen sites with active Barn Swallow nests were monitored in 2016, followed by 11 in 2017 and 12 in 2018.

In 2019, another 100 letters were mailed to landowners randomly selected from the original 260 properties that did not receive letters in 2016. Eighteen active sites were monitored during 2019, followed by 16 in 2020. A citizen science program was initiated in 2019 that encouraged landowners to monitor their own nests and contribute their data. Landowners were given mirrors attached to a telescoping pole that could be used for nest checks, along with datasheets and instructions. Eight landowners monitored their own nests in 2019, and seven of these continued the project in 2020.

Nest monitoring

Once a nest was determined to be active, weekly nest checks were conducted for the duration of the breeding season. The timing of nest checks varied across years, but were typically conducted from early May through late August. Due to the timing of A Rocha's internship program, nest checks in some years ended before all nestlings had fledged and some nest checks started after the beginning of egg-laying. Nests were checked using a wireless cavity inspection camera attached to an extendable pole (for nests > 10 ft from the ground) or a mirror attached to an extendable pole (for nests < 10 ft from the ground). The number of eggs, live young, and dead young were recorded, along with the presence of fresh mud or feathers. If there was uncertainty about the number of live young in the nest, the smallest number of clearly distinguishable chicks was recorded until more chicks could be confirmed at later checks.

Building and nest variables

At each site, we recorded environmental variables specific to the building and the nest. Building-level variables recorded in the field included level of human presence, structure type (enclosed or open), presence of livestock within 100 m of the building (usually this implied present on the same property as the nest building), number of active nests, and total number of intact nests (Table 1). We also measured the amount and type of surrounding landcover categories around each building (Table 1, Fig. 1). Buildings were mapped on a 2012 land cover map of the Little Campbell Watershed using ArcGIS. This land cover map was created using data from the City of Surrey and the Township of Langley and updated based on 2012 aerial imagery in 2013 (Reed 2013). This map was further updated in 2015 and 2017 to account for land cover changes. All aerial photos were acquired from the National Agriculture Inventory (NAIP) program (USDA 2017).

Land cover was originally classified into 17 categories (Reed, 2013) that were further grouped into four distinct categories as follows:

1. *Field:* Agricultural Herb and Grass, Agricultural Row Crops, Turf Grass, Unmanaged Herb and Grass, Unmanaged Shrub
2. *Forest:* Mature Forest, Urban Trees, Young Deciduous Forest, Young Evergreen Forest, Young Mixed Forest
3. *Freshwater:* Estuarine Marsh, Freshwater Lake, Freshwater River, Marsh
4. *Urban:* Urban Suburban/Low Density, Urban Suburban/Moderate Density, Urban Suburban/High Density

The percent cover of each landcover category was extracted within 400-m buffers surrounding each nest building (Fig. 1). We chose 400 m as a buffer size to reflect the lower estimate of Barn Swallow foraging distance as reported by Ambrosini et al. (2002) and Lenske (2018).

Table 1. Building- and nest-level variables

Variable	Description	Summary
Building variables (N=34 active buildings)		
Human presence	Presence of people within or around the nest site	Minimal = 12, Moderate = 20, Constant = 2
Structure type	Type of building or structure	Enclosed = 22, Open = 12
Livestock presence	Presence of livestock within 100 m of nest site	Yes = 24, No = 12
Active nests	Number of active nests in the building	Mean = 2.1 (range 1-15)
Intact nests	Number of in-tact, including active, nests in the building	Mean = 4.2 (range 1-26)
% Field	Percent of 400-m buffer around nest site containing field	Mean = 45.9% (range 1.0 – 72.0%)
% Forest	Percent of 400-m buffer around nest site containing forest	Mean = 25.9% (range 1.0 – 62.7%)
% Water	Percent of 400-m buffer around nest site containing water	Mean = 1.1% (range 0 – 25.0%)
% Urban	Percent of 400-m buffer around nest site containing urban	Mean = 28.1% (range 4.8 – 81.0%)
Nest variables (N=101 active nests)		
Nest height	Height of nest (m)	Mean = 3.0 (range 2.1 – 7.6)
Opening	Distance between the top of the nest and the structure ceiling (cm)	Mean = 7.4 (range 3.0 – 23.0)
Location	Location of nest within building	Exterior = 9, Interior = 92

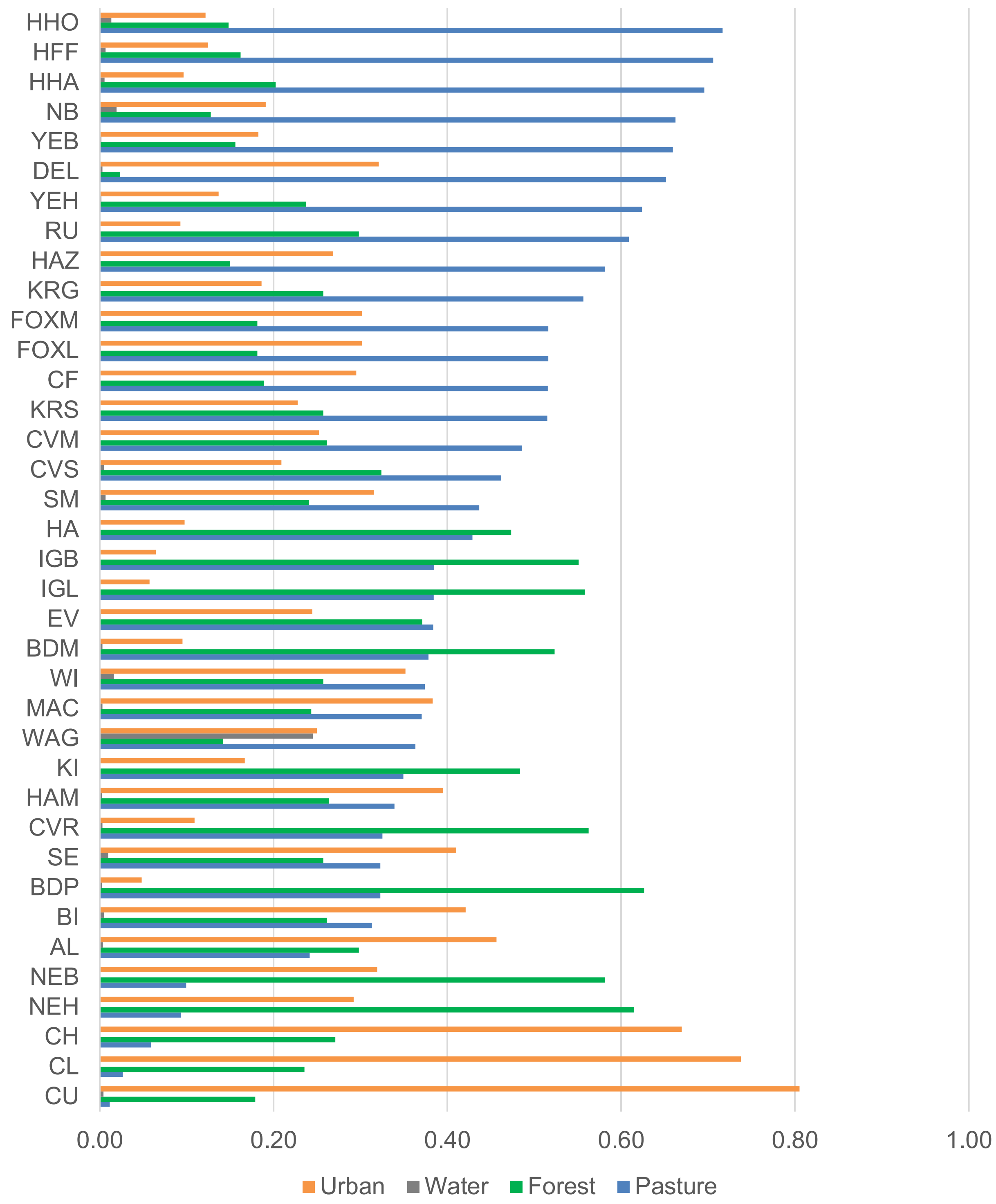

Figure 1. Percentage of four landcover types surrounding each nest building within 400 m

Estimating Dates

Incubation time for Barn Swallows is generally 12-17 days in British Columbia and chicks are usually in the nest prior to fledging for 19-24 days (Campbell et al. 1997 cited in COSWIC 2011). Therefore, if eggs were laid before the first check, we estimated laying date by subtracting 14 days from the estimated hatching date. If nestlings had hatched prior to the first check or hatch date was unknown, we estimated hatching date as 21 days before the fledging date. If the nest was empty during one check and all eggs were present during the subsequent check, laying date was estimated as the midpoint between the two checks. If egg-laying was still in process during a check, we estimate laying date based on the fact that Barn Swallows typically lay one egg per day. Hatching date was estimated as the midpoint between a check with eggs and a check with nestlings, unless hatching was in process during a check. Fledging date was estimated as the midpoint between checks with nestlings and an empty nest.

Measures of Nest Success

Clutch size (number of eggs laid), number of fledglings (chicks that successfully fledged), and overall clutch survival (number of fledglings / clutch size) were calculated as measures of nest success. Ultimately, a nest was considered successful if it fledged at least one chick.
Because nest checks were conducted weekly, number of fledglings was less accurate than clutch size. We estimated fledgling numbers by subtracting the number of dead chicks found on or around the nest at any time during the rearing period from the number of nestlings that were recorded in the last nest check prior to fledging. If no dead chicks were observed, all nestlings were assumed to have fledged.

Statistical Analysis

We examined differences across years for clutch size, number of fledglings, and clutch survival using Kruskal-Wallis tests and for probability of second broods and nest success using chi-square tests.

We analyzed the effects of environmental variables on measures of nest success using generalized linear mixed models with Poisson distribution for clutch size and number of fledglings and with binomial distribution for nest success. Year was included as an interaction term in order to detect relationships between response and predictor variables that varied by year. Building was included as a random effect since some buildings contained multiple nests. All statistical analyses were conducted using R version 3.5.1.

Temperature data for each year was obtained from Environment and Climate Change Canada (https://climate.weather.gc.ca/historical_data/search_historic_data_e.html) using information from the closest weather station to all nest locations (White Rock Campbell Scientific).

Results

Survey effort and nest activity

Number of active Barn Swallow nests monitored ranged from 25 (2014) to 42 (2019), excluding 2015 in which only 5 nests were monitored at 2 buildings (Table 2). Number of active buildings monitored ranged from 7 (2014) to 18 (2019), also excluding 2015.

Second broods were observed in 20 – 64% of nests (Table 2). Third broods were observed in one nest in 2017 and two nests in 2020. No measures of nest success differed significantly across years. However, 2017 had the lowest clutch survival (0.53) and average number of fledglings (2.3 in 2017 and 2020; Table 2). The lowest average minimum temperature for May (9.1°C), when most first-broods were in the nestling stage, was also observed in 2017 (Fig. 2), which may have been associated with low fledgling numbers and nest success.

Survey effort varied considerably over the seven-year study period with a large turnover in the composition of buildings monitored (Table 3). In total, 34 buildings were monitored over seven years (Fig. 3). Two pulses in effort occurred in 2016 and 2019, when letters were mailed to landowners in order to locate more sites. This resulted in an increase in the number of sites monitored during those years. Site turnover across years also occurred due to loss of building access (e.g., when properties were sold or made unsuitable for nesting swallows) and the occasional addition of new sites via word-of-mouth. The loss of one building (NB), which contained 6-15 active nests per year, to a fire in November 2019 resulted in a large drop in number of active nests monitored.

Table 2. Measures of survey effort and nest success across years.

	2014	2015	2016	2017	2018	2019	2020
Number of active buildings surveyed	7	2	14	11	12	18	16
Number of active nests surveyed	25	5	27	28	30	42	33
First brood							
Average clutch size	4.3	4.5	4.5	4.4	4.1	4.3	3.9
Average number of fledglings	2.7	3.4	3.3	2.3	2.7	2.8	2.3
Nest success (%)	89%	100%	87%	75%	68%	73%	71%
Average clutch survival	0.76	0.75	0.77	0.53	0.67	0.62	0.54
Rate of second broods	64%	20%	48%	57%	47%	43%	58%
Second brood							
Average clutch size	4.0	--	4.2	4.1	3.9	4.2	4.1
Average number of fledglings	3.1	--	2.4	3.5	--	3.3	3.4
Nest success (%)	75%	--	70%	80%	--	83%	94%
Average clutch survival	0.66	--	0.57	0.78	--	0.77	0.83
Third brood	0%	0%	0%	3.6%	0%	0%	6.1%

-- second brood nest fate could not be reliably determined because a large proportion of nests were not monitored to completion (or in the case of 2015, there was only one second brood)

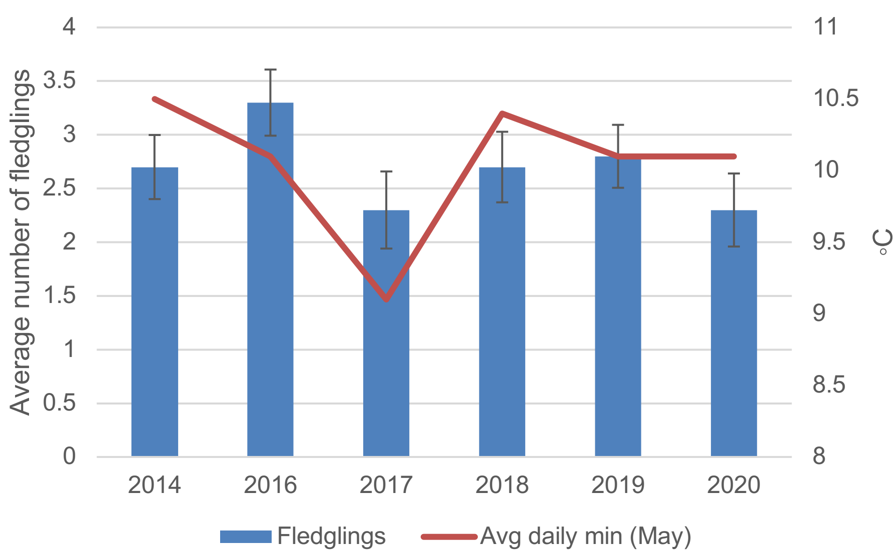

Figure 2. Average number of first-brood fledglings and average daily minimum temperature for May across all years. Error bars indicate standard error.

Table 3. Number of active first brood (top), second brood (middle) and third brood (bottom) Barn Swallow nests, total number of fledglings, and average fledglings per year monitored at each building. Number of successful nests are in parentheses. Superscript numbers indicate number of nests with unknown fate. Dashes indicate the building was not monitored in a given year.

Building code	Number of nests 2014	2015	2016	2017	2018	2019	2020	Total fledglings	Average fledglings/years monitored
AL*	--	--	--	--	--	1(1)	1(1)	12	6
						0	1(1)		
BDM	0	1(1)	1(1)	0	1(1)	1(0)	0	12	2
	0	0	0	0	0	0	0		
BDP	$3(1)^2$	4(4)	4(3)	4(3)	4(4)	1(1)	2(0)	71	10.1
	3(3)	1(1)	1(1)	1(1)	2^2	0	0		
BDS	0	--	1(1)	--	--	--	--	3	1.5
	0		0						
BI*	--	--	1(1)	1(0)	1(1)	1(1)	1(1)	21	4.2
			1(1)	1(1)	1^1	0	1(1)		
CF	6(5)	--	1(1)	--	--	--	--	17	8.5
	3^3		0						
CL	--	--	0	1(1)	1(1)	2(2)	--	12	3.0
				0	1^1	0			
CU	--	--	1(1)	0	0	0	--	2	0.5
			0	0	0	0			
CVM	0	--	0	0	0	1(1)	$1^{(1)}$	9	1.5
	2(0)		0	0	0	1(0)	1(1)		
DEB	--	--	0	0	1(0)	--	--	0	0
			0	0	0				
DEL	--	--	1(1)	0	0	--	--	3	1.0
			1^1	0	0				
EV*	--	--	--	--	--	1(1)	1(1)	12	6.0
						1(1)	1(1)		
FOXL	--	--	--	1(0)	--	--	--	0	0
				0					

FOXM	--	--	--	3(3)	--	--	--	12	12.0
				1(0)					
HA*	--	--	--	--	--	1(1)	1(1)	8	4.0
						0	1(1)		
							1(1)		
HAM*	--	--	--	--	--	--	1(0)	7	7.0
							1(1)		
							1(1)		
HAZ	--	--	--	--	--	2(1)	3(1)	18	9.0
						1(1)	1(1)		
HFF	2(2)	--	2(1)	2(0)	2(1)	1(0)	0	36	6.0
	2(2)		2(1)	2(2)	0	0	0		
HGAZ	0	0	0	0	0	0	0	0	0.0
	1(0)	0	0	0	0	0	0		
HHA	1(1)	--	1(1)	0	1(1)	0	0	15	2.5
	1(1)		0	0	0	0	0		
HHO	0	--	1(1)	1(1)	1(0)	0	0	11	1.8
	0		0	1(1)	1[1]	0	0		
KI	--	--	--	--	1(0)	0	0	3	1.0
					1(1)	0	0		
KRG	--	--	1(1)	1(1)	1(1)	0	1(0)	18	3.6
			1(1)	1(1)	1[1]	0	0		
MAC	--	--	1(0)	0	0	0	1(1)	6	1.2
			0	0	0	0	1(1)		
NB	8(7)	--	6(6)	8(8)	10(6)	15(9)	--	194	38.8
	4(3)[1]		6(3)[2]	8(5)[1]	6[6]	7(6)			
NEB	--	--	--	--	--	1(1)	1(1)	17	8.5
						1(1)	1(1)		
RU	--	--	--	--	--	1(1)	1(1)	15	7.5
						1(1)	1(1)		
SE*	--	--	--	--	--	1(1)	3(2)	16	8.0
						1(1)	2(2)		
SM	--	--	--	--	--	4(4)	6(5)[1]	47	23.5
						2(2)	4(4)		

WAG	--	--	--	1(0) 1(1)	--	--	--	3	3.0
WI*	--	--	1(1) 1(0)	1(1) 0	1(1) 1[1]	1(1) 1(1)	1(1) 0	22	4.4
YEB*	--	--	--	--	--	1(1) 1(1)	--	9	9.0
YEH*	--	--	--	--	--	1(1) 1(0)	--	5	5.0
YOE	--	--	--	--	--	--	4(1)[3] 3(2)	13	13.0

*landowner-monitored

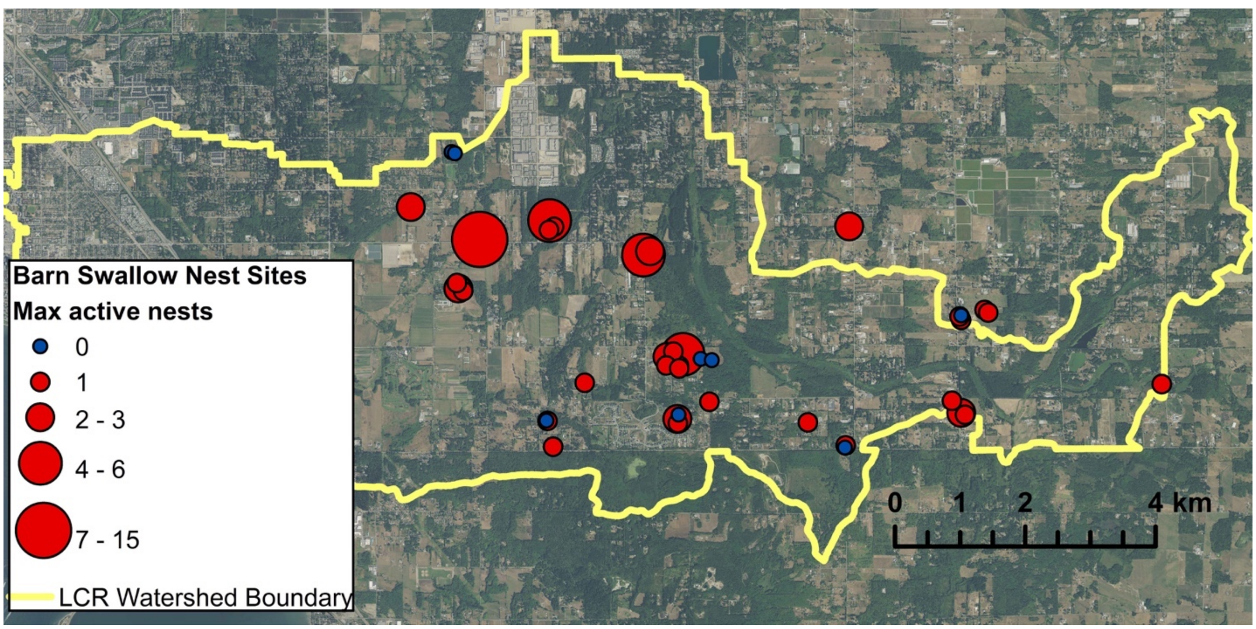

Figure 3. Map of study area showing all buildings monitored for Barn Swallow nest activity in the Little Campbell River watershed from 2014-2020 and maximum number of active nests per building.

Over the study period, eight landowners monitored their own nests and contributed their data to the project. This data was mainly collected in the later years of the study (2019-2020) after we made a concerted effort to encourage more landowner participation in the study. Landowners generally held positive attitudes toward Barn Swallows and expressed a desire to help in their conservation.

Site turnover over the seven years prevents a detailed analysis of trends over time, but a noticeable decline in nest activity was evident in some sites. For example, BDP contained 3-4 active nests each year until 2019, when it declined to 1, followed by 2 in 2020 (but with 0 nest success; Table 3). HFF gradually declined from 2 active nests to 0, with gradual declines in nest success as well. KI and KRG also showed a loss of nest activity over time (Table 3). Reasons for loss of nest activity in these sites are unclear and were not due to human removal. Nests were removed by humans at two other sites resulting in loss of nest activity.

Timing of nesting

Timing of first egg-laying varied across the study period (Fig. 4). Earliest egg laying occurred in 2019, with an average first lay date of May 24 (range = May 4-July 5). The latest start of egg laying occurred in 2014, with an average first lay date of June 4 (range = May 19-June 29).

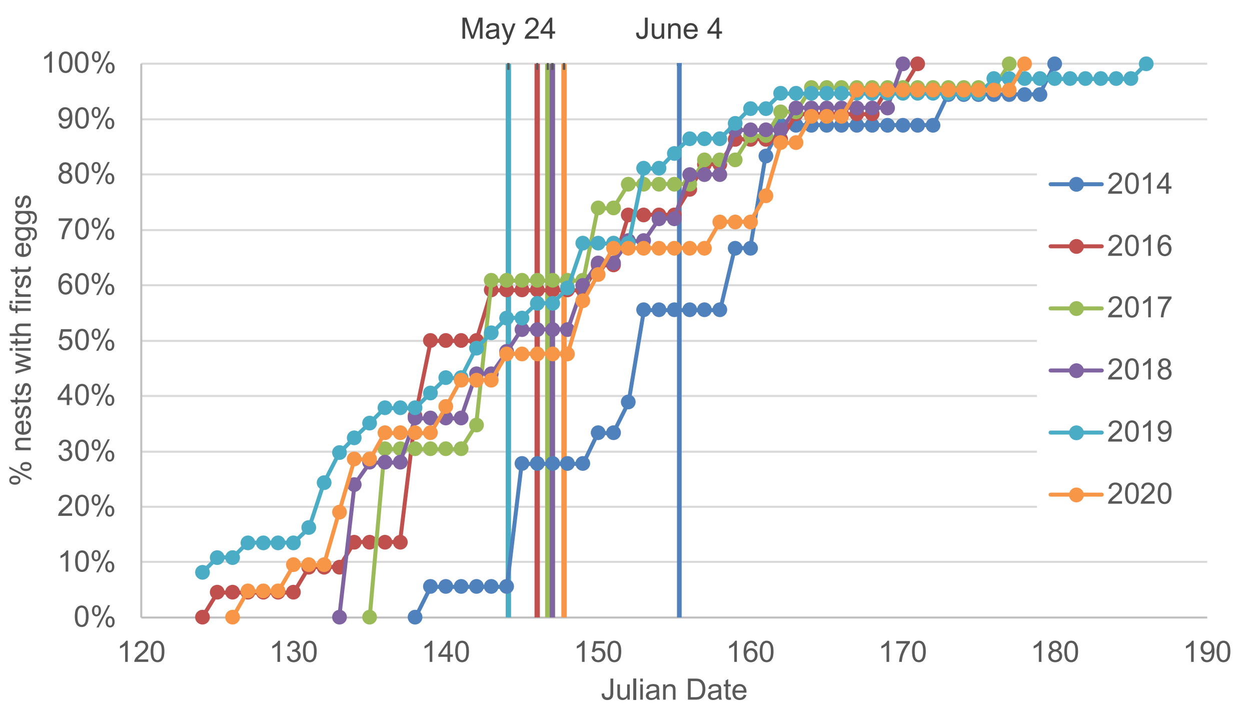

Figure 4. Cumulative frequency distribution of first egg-laying over all sites from 2014-2020. 2015 is omitted since only two buildings were monitored. Vertical bars indicate average first laying date.

Linear regression analysis showed a slight, though significant, trend toward earlier clutch initiation throughout the study period (Fig. 5) (adjusted $R^2 = 0.02$, $p = 0.03$). However, when data from 2014 was omitted, this trend was not significant. Exploratory analyses showed no consistent relationship between first laying date and spring temperature.

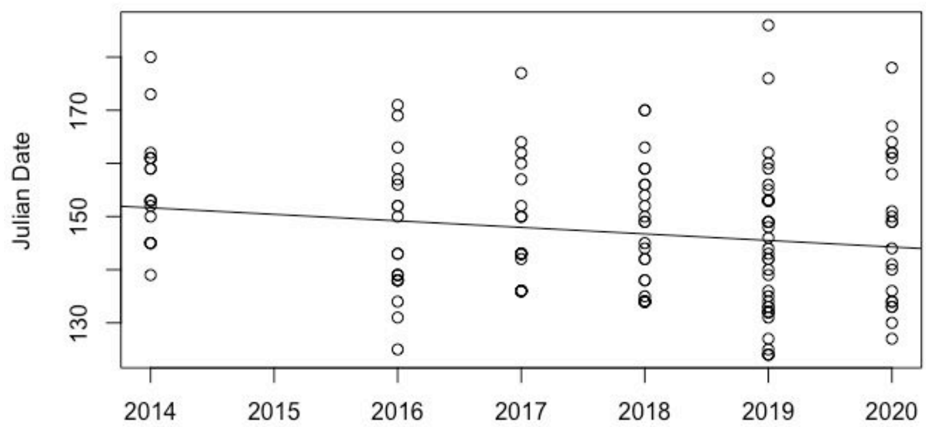

Figure 5. Date of first egg laying from 2014-2020 with trend line showing linear regression analysis.

There was no significant effect of first laying date on any measures of nest success across all years. However, there was a marginally significant interaction between year and first laying date in the generalized linear mixed model for predicting nest success. In 2019, first clutches that were started later in the year were more likely to be successful (p=0.07). 2019 also had the earliest average first laying date. Although marginally significant, this indicates that in years when egg-laying begins early, the earliest first clutches may have lower success.

Predictors of nest success

No predictor variables significantly affected any measures of nest success consistently across all years. Year was marginally significant as an interaction term with nest height in the model for number of fledglings. In 2017, higher nests tended to have more first-brood fledglings (marginally significant interaction between nest height and year 2017; p=0.09; Fig. 6).

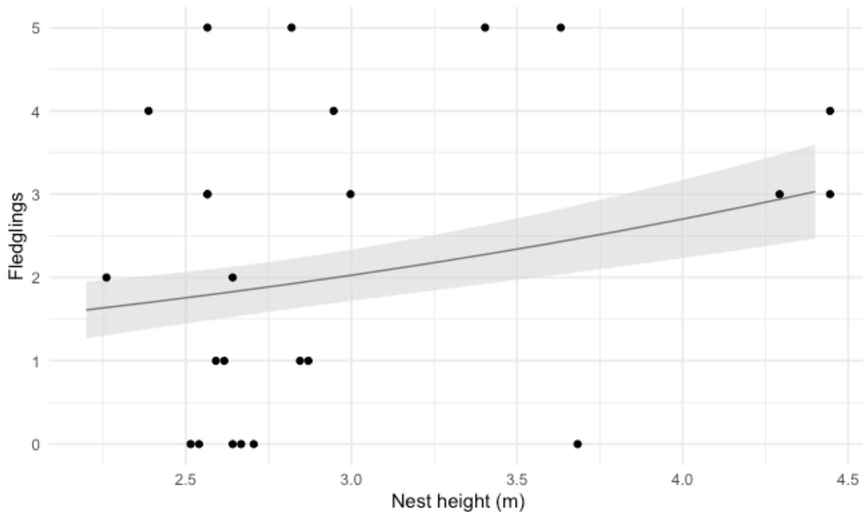

Figure 6. Effect of nest height on number of first-brood fledglings in 2017. The trend line shows predictions from a generalized linear mixed effects model for 2017 with standard error shaded.

Predictors of nest activity within buildings

According to a generalized linear model, active buildings (those containing at least one active nest during the study period) were surrounded by less forest within 400 m than inactive buildings ($p = 0.05$). No other land cover variables significantly affected building activity. However, it is worth nothing that some amount of freshwater was present within 400 m of 15 active buildings (48%) compared to only one inactive building (13%; Fig. 7). No significant relationships were found between average number of fledglings per building and any predictor variables.

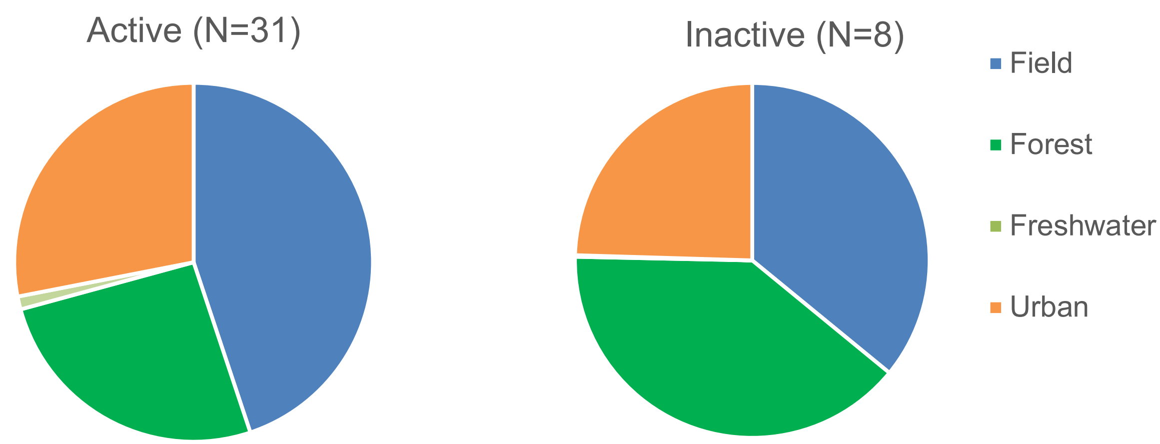

Figure 7. Average percent landcover surrounding active and inactive nest buildings.

Discussion

Barn Swallows are federally listed as a threatened species in Canada and are designated a species of special concern (blue list) in British Columbia. This study presents seven years of Barn Swallow nest monitoring data. Because sample sizes and site composition varied considerably over the study period, it is difficult to quantitatively assess changes in nest success over time in this region. Declines in nest activity were noticeable at four sites, and anecdotal evidence from landowners suggests that over a longer time period (~20 years), there have been substantial declines in number of active Barn Swallow nests within the LCRW.

There appears to be a slight shift toward earlier initiation of egg laying, but this may be a false trend driven by one late year (2014) and one early year (2019). We found no relationship between May temperatures (when most first broods are in the nestling stage) and date of first egg-laying or nest success. However, other temperature variables may be stronger predictors of egg-laying. For instance, Imlay et al. (2018) found that less winter precipitation on the breeding grounds was associated with earlier breeding for Barn Swallows in eastern Canada, likely caused by earlier emergence of insects. They also found that clutch initiation dates for Barn Swallows advanced by 9.9 days between the time periods 1962-1972 and 2006-2016. Similarly, Dunn and Winkler found that clutch initiation in Tree Swallows advanced by up to 9 days between 1959-1991 (Dunn and Winkler 1999). Climate change may be causing a shift toward earlier breeding in Barn Swallows in this region, but this would be evident over a much longer time scale than our seven-year study.

In our study, the year with the lowest clutch survival rate and number of fledglings (2017) coincided with the coldest minimum temperatures for the month of May, suggesting that cold snaps during the nestling stage may have negatively affected survival. Others have found that cold snaps during pre-breeding or migratory periods can lead to mass adult mortality events for Barn Swallows (Newton 2007, Winkler et al. 2013, Imlay and Leonard 2019). A detailed analysis of the effects of temperature on Barn Swallow nest success was beyond the scope of this study, but should be considered in future research.

Nest height was the only predictor variable that showed any association with nest success, and was only significant during one year (2017). Higher nests may protect against predation by mammals (e.g., cats, rats, raccoons), but not against avian predators such as American Crows. Nest height may have affected ambient temperature within nests, especially during the year with particularly cold May temperatures. We were not able to monitor nest temperature, but it may be that higher nests were warmer and protected nestlings from cold snaps.

Surrounding land cover within 400 m showed no relationship to nest success. Boynton (2017) similarly found Barn Swallow reproductive success to be independent of habitat in British Columbia’s lower mainland. In Ontario, Lenske (2018) found a positive association between mean number of Barn Swallow fledglings and wetland area at 200 and 1000 m scales and a negative association between mean number of fledglings and area of open water. At a 2000 m scale they found a positive association between mean number of fledglings and surrounding field cover (grass or pasture). We only analyzed landcover within 400 m of nest sites, and larger scale habitat features might influence Barn Swallow nest success in our area. However, others have found negative effects of urban habitat at smaller scales (Osawa 2015, Györkös Teglhøj 2017). Swallow declines have also been attributed to pesticide use (Nocera et al. 2012; Hallmann et al. 2014), which we were not able to quantify in this study.

The presence of livestock has also been shown to positively affect Barn Swallow breeding success due to a greater and more profitable insect community (Gruebler et al. 2010; Orlowski and Karg 2013), but we found no influence of livestock on nest success. Similarly, Imlay et al. (2017) found no association between insect abundance and nestling success in three species of swallows and McClenaghan et al. (2019) found Barn Swallow reproductive success to be unaffected by insect availability.

Buildings were more likely to contain active Barn Swallow nests when surrounded by less forest cover within 400 m. Since Barn Swallow are aerial foragers, they rely on open areas for finding food and a large amount of surrounding forest may deter nesting at a site. The likelihood of a building containing active nests was not influenced by other landcover categories (such as urban or field). It may be that some areas classified as “urban” according to our landcover map (such as green spaces around suburban houses and small farms) may not be substantially different in quality for Barn Swallows than those classified as “field”. The landcover map used in this study was created for the purpose of analyzing broad-scale changes in landcover over time. Therefore fine-scale landcover features, such as small ponds and wetlands, that are important for swallows (Lewis-Phillips et al. 2020) may not have been captured by our landcover map. Although not significant, active buildings were surrounded by more freshwater than inactive buildings, but this primarily included rivers and marshes rather than farmland ponds. Some smaller farmland ponds may have not been captured in our landcover map, and future research should examine the effects of ponds and wetlands on Barn Swallow nest success. Osawa (2015) found that Barn Swallow nest occurrence was positively influenced by river density in Japan, and it is likely that the Little Campbell River and its tributaries attract Barn Swallows to nearby nest sites in our area.

This study engaged eight landowners in monitoring Barn Swallow nests on their properties, and alerted many more to the status of Barn Swallows through letter mailouts in 2016 and 2019. Citizen science is recognized as a powerful tool for involving the public in conservation and collecting valuable scientific data, especially on private land (Dickinson et al. 2010, McKinley et al. 2017). Evidence also suggests that participants in citizen science monitoring programs may be more likely to engage in practical conservation actions (such as controlling for invasive species) that are affecting the species being monitored (Larson et al. 2016). With limited staff capacity for conducting nest surveys and the fact that most Barn Swallow nests are on private land in the LCRW, A Rocha greatly benefits from the efforts of volunteer landowners in our conservation and research. The citizen science component of this project is limited, however, by the ability of landowners to monitor nests that are higher than can be reached by an extendable mirror pole and by the physical ability and comfort levels of landowners. Citizen science data is often of more variable quality; for instance, some participants check nests daily and report highly accurate dates for egg-laying, hatching, and fledging (even more accurate than our weekly checks) while others provide less accurate data due to longer gaps in nest monitoring. Despite the challenges, citizen science provides an opportunity to collect more long-term data across a broader geographic range. The citizen science component of this project also educates the public and empowers citizens to protect threatened species on their land.

The importance of long-term data collection on threatened species makes continuing our Barn Swallow work in the LCRW a priority. Challenges in this study have included limitations in our ability to monitor nests more than once per week, difficulties in finding sites with active Barn Swallow nests, and challenges with classifying surrounding land cover at fine scales. In the future, efforts could be made to increase and improve the citizen science monitoring component. More advertising (such as posters in public spaces) could secure greater numbers of landowners willing to take an active role in monitoring nests. More intensive training and regular communication (including follow-up in the off season) with participants may improve the quality and frequency of data collected. Additional nest sites may be found through observing swallows foraging in fields and tracking them to nest sites. Online citizen science platforms such as eBird and iNaturalist may also be utilized. However, the tradeoffs between adding more professionally monitored sites and increasing the frequency of monitoring should be considered.

A Rocha's priority is to improve the ecological health of the Little Campbell River watershed using applied conservation science. The future of our Barn Swallow programme should move beyond monitoring toward practical steps to protect this threatened species. Artificial nest structures have been tested in Ontario (Ontario Ministry of Natural Resources and Forestry 2016) and could be tested at sites in the LCRW. Such structures could also provide educational opportunities if constructed in public spaces. At some sites, nest activity declined because of loss of swallow access (e.g., windows and doors kept closed or buildings being demolished) or nests being removed by people. Artificial nest structures would provide alternative nesting spaces for swallows when current nest spaces are deemed unsuitable. Educational materials should also be developed highlighting ways in which landowners could maintain or improve nesting habitat for Barn Swallows, such as installing wooden nest cups, leaving barn doors or windows open for swallows, and preserving or improving natural habitat. Building ponds and wetlands on private property could be an important next step in this project to improve habitat for swallows as well as bolster overall biodiversity. Recent studies have found that aquatic emergent insects from ponds and wetlands have higher nutritional value for swallows than terrestrial insects (Twining et al., 2018). Furthermore, ponds and wetlands provide sources of water, which is critical in the hot summer months, and mud, an important component in Barn Swallow nests. Finally, landowners should be encouraged to leave old nests in place rather than removing them, which can increase reproductive success and allow for earlier breeding (COSEWIC 2011). Since most Barn Swallow breeding occurs on private land in the LCRW, engaging and involving landowners will be a crucial step in the conservation of this species.

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