ANNUAL PROJECT REPORT

STATUS OF THE BARN SWALLOW (*Hirundo rustica erythrogaster*) IN THE LITTLE CAMPBELL RIVER WATERSHED – HABITAT AND PREDATION

A ROCHA CANADA CONSERVATION SERIES

August 2016

AUTHORS:

Caitlin Russell

Michelle Jackson

Andrew Baylis, A Rocha Canada

Christy Juteau, A Rocha Canada

CONTACT:

conservation@arocha.ca

CANADA A ROCHA Environmental Stewardship

Abstract

The North American Barn Swallow, *Hirundo rustica erythrogaster,* migrates from Central and South America to breeding grounds in the United States and Canada. In Canada, Barn Swallows are in decline and listed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). A Rocha Canada began a monitoring program in 2014 to investigate the status of the Barn Swallow in the Little Campbell River Watershed (LCRW), British Columbia. The purpose of this study was to continue the Barn Swallow monitoring program by analyzing nest success, associations with land cover, and instances of predation in the LCRW. During the 2016 breeding season (May-August), 15 buildings containing active and historical Barn Swallow nests were visited weekly. Additionally, 14 motion sensor trail cameras were deployed at 6 sites in order to detect any instances of nest predation. We analyzed the effects of surrounding land cover on Barn Swallow clutch size and number of fledglings within different buffer sizes (100, 200, 400, 500, and 800 m) around nest buildings. Twelve buildings contained active nests and hosted one to nine Barn Swallow pairs throughout the breeding season. We found a significant association between clutch size and amount of pasture up to 100 m from nest buildings. No instances of predation were captured using the trail cameras. Further research will be needed to assess population stability and limiting factors on Barn Swallow reproductive success in the LCRW.

Acknowledgements

We would like to thank all the land owners who allowed us to monitor Barn Swallow nests on their properties. We would also like to thank Campbell Valley Park and the Semiahmoo Fish and Game Club for allowing us to access their properties throughout the season.

Thank you also to Andrew, Laney and Sarah for aiding in fieldwork and to Christy and Andrew for their assistance with project planning.

Recommended Citation:

Russell, C., Jackson, M. Juteau, C., and Baylis, A. 2016. STATUS OF THE BARN SWALLOW *(Hirundo rustica erythrogaster)* in THE LITTLE CAMPBELL WATERSHED - HABITAT AND PREDATION. A Rocha Canada Conservation Science Series. A Rocha Canada, Surrey, B.C., Canada.

Cover illustrations:

From left to right: Barn Swallow nestlings begging for food, Barn Swallow parent incubating eggs.

Table of Contents

Introduction

Land use changes have been emphasized as the biggest threat to terrestrial biodiversity in the last few decades (Jetz et al., 2007). One species that has traditionally benefited from human modification to the natural environment is the Barn Swallow (*Hirundo rustica*). Originally nesting in caves, by the 1800's Barn Swallows started nesting on human-made structures in North America, Europe and Asia (Zink et al., 2006). Barn Swallows' association with rural human settlement has allowed them to expand their range and become the most widespread and abundant swallow species in the world (Zink et al., 2006). Several agricultural activities support Barn Swallow populations; for instance, barns and sheds provide nesting sites (Zink et al., 2006), cleared land for pasture promotes foraging (Evans et al., 2007) and the presence of livestock attracts swallow insect prey (Ambrosini et al., 2012).

Barn Swallows are small passerine, aerial insectivores, separated into 6-14 subspecies (Dor et al., 2010). The North American subspecies *(Hirundo rustica erythrogaster)* breeds from Canada to Mexico. They annually migrate from Central and South America in May and stay on their breeding grounds until early September (Stotz et al., 1992). The International Union for the Conservation of Nature (IUCN) notes that worldwide, Barn Swallow populations are decreasing. In Canada, the rate of population decline is significant enough for conservation concern and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has listed Barn Swallows as threatened (COSEWIC, 2011).

Barn Swallow declines in Canada began in the 1980's and the Canadian Breeding Bird Survey (BBS) revealed a 76% population decline between 1970 and 2009. Although the reasons for this decline are not well understood, COSEWIC identifies the main causes to be loss of nesting and foraging habitats, large scale insect population declines, and direct and indirect mortality due to an increase in climate perturbations (COSEWIC, 2011). Additional threats include competition for nest sites with invasive species (e.g., House Sparrows) and factors associated with Barn Swallow migration or wintering grounds (COSEWIC, 2011).

The Little Campbell watershed (LCRW) is located on the southern edge of the Township of Langley and the City of Surrey (City of Surrey, 2016). This area has experienced heightened development pressure over the past several years, and there is concern about how new developments will affect the health of the Little Campbell River and the watershed's ability to provide habitat for species at risk. Recently, a 77-acre semi-truck park and warehouse was proposed in the LCRW. The Little Campbell River runs through the northwest side of the proposed development. This proposal would involve rezoning the development site from Agricultural Land Reserve to light industrial land and would pose threats to species at risk, forests, and water quality (Madrone Environmental Services, 2015). Madrone Environmental

Services (2015) recognizes Barn Swallows as one of 26 species that would be negatively affected if the development proposal is accepted due to loss of old-field grass habitat.

Rezoning agricultural land to industrial land could decrease the amount of foraging habitat for Barn Swallows. In recent decades, the amount of swallow foraging habitat in Canada has declined due to the loss of dairy farms (and their associated pastures and hayfields) and wetlands owing to economic forces (COSEWIC, 2011). In Quebec, the number of dairy farms decreased by half as a result of farm abandonment, industrialization, and urbanization (Jobin et al., 1996). This change coincided with the beginning of steep declines in Barn Swallow populations (1970-1988).

Across Canada, there has been a trend towards the conversion of dairy farms to intensive agriculture such as row crops (COSEWIC, 2011). One reason for this conversion is that policies now favor grain production for livestock over dairy farming (Jobin et al., 1996). Although Barn Swallows will forage over row crops, pasture is preferred in Denmark, Italy, and England (Evans et al., 2007). There is a well-established positive association between Barn Swallows and the presence of livestock (Ambrosini et al., 2012; Grüebler et al., 2010; Henderson et al., 2007). In Italy, Barn Swallow distributions can be predicted by livestock farming within the past 3-5 years (Ambrosini et al., 2002).

The amount of high-quality foraging habitat around Barn Swallow nest sites is important for Barn Swallow reproductive success because nestling feeding rate depends on the distance parents have to go to forage (Turner, 2006). Turner (2006) suggests that distance from the nest site is more important than insect abundance for determining where swallows forage because of energetic costs (Turner, 2006). In the LCRW, Barn Swallow foraging distance is not well known. Hereward et al. (2014) found that amount of pasture within 400 meters of the nest site was positively correlated with number of Barn Swallow fledglings at a site. Hereward et al. (2014) chose 400 m buffer sizes as a midpoint between 170 m (Barn Swallow foraging distance observed in Scotland; Bryant and Turner, 1982) and 805 m (foraging distance observed in West Virginia; Samuel, 1971). Ambrosini et al (2002) found Barn Swallows to forage 400 m from nest sites in Italy and Turner (2006) reports that North American Barn Swallows mostly forage up to 400 m. However, Møller (2001) found that slightly less than 50% of the European Barn Swallows that he observed foraged within 100 m. COSEWIC (2011) reports that most Barn Swallows in Canada forage within a few hundred metres and the Ontario Ministry of Natural Resources (MNR) reported the average distance traveled by Barn Swallows during the breeding season to be 148 m when the temperature was above 20 but increased to 203 when it was 16 or less.

Predators may also limit the abundance of Barn Swallows in the LCRW. Crows, Common Ravens, Black-Billed Magpies, House Wrens, European Starlings, owls, cats, rats, mice and squirrels are all possible predators of Barn Swallow nestlings and eggs (Turner, 2006; cited in

Ferguson, 2016). Even if predators do not physically disturb eggs or nestlings, their presence may still impact Barn Swallow reproductive success. Vitousek et al (2014) found a consistent and strong relationship between corticosterone levels (secreted in response to predators), nest abandonment, and reproductive success. Barn Swallows with a high corticosterone response to the presence of predators had more nest failure and offspring mortality due to a reduced provisioning rate at those nests (Vitousek et al., 2014).

The purpose of this study was to contribute to a long-term Barn Swallow monitoring program in the Little Campbell River watershed that was started in 2014. We asked whether clutch size or number of fledglings was associated with surrounding habitat within a series of different buffer sizes (100, 200, 400, 500, and 800 m) in order to assess the importance of foraging habitat at different scales and to better understand Barn Swallow foraging distance in the LCRW. Specifically, we tested the hypothesis that the importance of surrounding habitat on reproductive success differs at a smaller scale (e.g., 100 m) than a larger scale (e.g., 800 m). We also investigated how the presence of predators at nest sites affects nest success using motion sensor cameras placed near active nests.

Methods

Study area

Our study took place in the Little Campbell River watershed (LCRW). The LCRW encompasses 75 km^2, including the main stem of the Little Campbell River, its tributaries and the surrounding riparian area. The LCRW is located on the southern edge of the Township of Langley and the City of Surrey with portions in the United States, the Semiahmoo First Nations Reserve No. 1, and the City of White Rock (City of Surrey, 2016). Within the LCRW there has been low intensity urban development and the watershed is primarily characterized by rural residential and agricultural land uses (City of Surrey, 2016). The LCRW is situated within the larger context of the Fraser River estuary and delta, a threatened, important bird and biodiversity area (IBM) (Bird Life International, 2016).

Site Selection

Fifteen building structures containing active or historic Barn Swallow nests were selected for monitoring on both private and public land (Fig. 1). Five of these sites were also monitored in 2014. To locate new nest sites, we first selected 206 potential sites within areas designated as pasture according to a 2012 land cover map used by Hereward et al. (2014) overlaid onto Google Earth aerial imagery. Buildings that appeared to be suitable for Barn Swallow nests (i.e., barns and sheds) were flagged on Google Earth. Addresses for each property containing the flagged buildings were extracted from the city of Surrey (COSMOS; http://www.surrey.ca/city-services/665.aspx) and the township of Langley (Geosource; http://www.tol.ca/geosplash/) websites. A Rocha then mailed letters to 100 of these landowners that were randomly selected from the original 260. The letters described A Rocha's recent swallow monitoring efforts and asked landowners to contact us if they noticed Barn Swallow nesting activity and would be open to allowing us to access their property to monitor the nests. Four landowners replied and their properties were included in our monitoring. The remaining additional new sites were located through friends and partners of A Rocha and neighbours of the original letter recipients.

Figure 1. Buildings containing Barn Swallow nests that were monitored in the Little Campbell River watershed (LCRW) from May to August, 2016. Inset shows the location of the LCRW (yellow) in southwestern British Columbia.

Site Assessment

At each site, we recorded the number of active and inactive Barn Swallow nests. For new sites (not monitored in 2014) we drew a map of the building structure and labelled each nest with a number. For sites that were included in the 2014 study we used the existing nest labels, adding numbers for new nests since 2014. Sites were then classified as either human sites or grassland/shrubland following a modified version of the protocol outlined by Bird Studies Canada's Nestwatch programme (http://www.birdscanada.org/volunteer/pnw/?targetpg=bars). We followed this protocol for site assessments in order to upload our data to Bird Studies Canada's long-term Barn Swallow monitoring database at the end of our study. All human sites were subcategorized as rural and all grassland sites were subcategorized as overgrown field or planted grass (including pastures and grassy hayfields). The height of each nest was measured using an extendable pole.

Weekly Nest Checks

Nest checks were conducted weekly during the morning and afternoon using a camera attached to an extendable pole that allowed us to see into the nest while minimizing disturbance. The number of eggs, live young and dead young were recorded. At certain development stages, it was difficult to distinguish the number of live young because some nestlings were obscured from view by other nestlings. Distinct nestlings were usually identified by their yellow beaks. If there was any uncertainty about the number of live young in the nest, the smallest number of clearly distinguishable beaks was recorded until more individual nestlings could be confirmed at a later check. Nest checks began on May 20, 2016 and continued until August 5, 2016. We began monitoring some sites later in the season but we did not miss any first broods. Inactive nests were visited once a month to confirm the nests remained inactive.

Camera Monitoring

Motion-sensor Bushnell HD trail cameras were set up to focus on 14 active nests at six sites. We mounted cameras at all nests that were near an accessible platform or beam for ease of attachment and that had suitable light conditions for generating images. Duct tape was placed on the LED camera lights on most cameras to minimize overexposure. After detecting motion, the cameras were set to take a series of three photos at 1-second intervals, then to delay taking more photos for 10 minutes. We looked through the photos once per week and recorded any potential Barn Swallow predators or competitors that entered the camera frame.

Analysis

Estimating dates

We estimated laying date, hatching date, and fledging as the midpoint between the last days that we observed eggs or chicks (for hatching date and fledgling date, respectively). In cases where eggs had been laid before the first check, we estimated laying date by subtracting two weeks from the estimated hatching date. When nestlings hatched before the first check, we estimated hatching date as 3 weeks before the estimated fledging date. Bird Studies Canada (2016) lists incubation time as 12-17 days and nestling period as 17-24 days.

We used clutch size and number of fledglings as measures of nest success. Because we were only able to monitor nests weekly, fledgling counts were less reliable than clutch size. When the chicks were close to fledging (eyes open, downy feathers, eggs hatched for more than a week), we did not use the extendable camera pole to avoid causing the chicks to prematurely fledge. Therefore, it was difficult to obtain accurate counts of the number of chicks that successfully left the nest. For the purposes of this study we estimated the number of fledglings as the greatest number of chicks seen in the nest at the same time minus any dead nestlings found in or near the nest.

Habitat

We mapped building structures on a 2012 land cover layer of the LCRW (see Hereward et al., 2014 for details) using ArcGIS. We created 5 buffers around each building structure (100m, 200m, 400m, 500m, and 800m; Fig. 2). We then extracted land cover percentages within each buffer. Land cover was classified as grass/pasture/shrub (hereafter referred to as pasture), forest, fresh water marsh, or urban. We used visual assessment to confirm that the 2012 land cover map reflected current land use in the watershed.

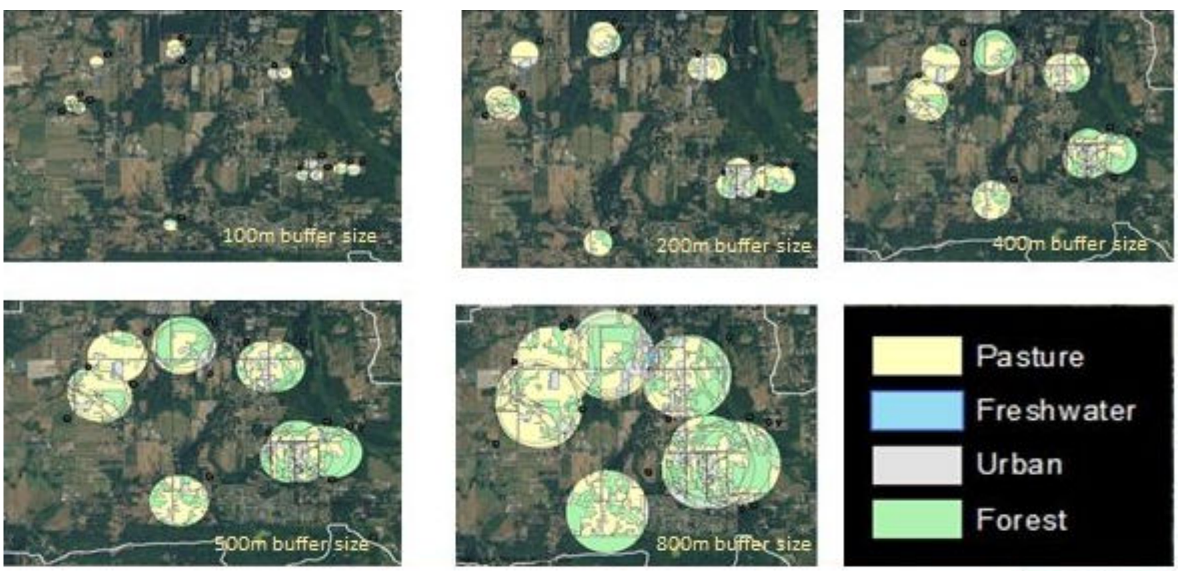

Figure 2. Land cover types (pasture, freshwater, urban, and forest) surrounding each building structure within 100m, 200m, 400m, 500m, and 800m buffers.

Statistical Analysis

We used linear mixed effects models to examine the association between two independent variables related to nest success (clutch size and number of fledglings from the first brood) and land cover percentages within each buffer size separately. We also analyzed the effect of laying date on clutch size and number of fledglings using linear mixed effects models. We included building as a random effect in all of the models to account for the fact that some buildings contained several nests. One nest site was not included in the analysis because it fell outside the watershed boundary and we did not have land cover data for areas outside the LCRW. We also eliminated a second site because buffers of 400 m or larger contained area outside the LCRW; this site contained no active nests this year or in 2014.

Results

Nest Sites

Twelve nest sites contained active nests (Fig. 3). NB had the most active nests (9), followed by BP (5). HFF had two active nests, and HHA and HHO each had one active nest. All other sites contained only one active nest, but many had several inactive nests. CVM had the most inactive nests (7), two of which were active in 2014. One nest at CVM contained two eggs during the first check on May 31. We set up a camera at that nest but no birds were ever observed. The eggs in the nest never hatched, and may have been left over from a previous year.

Five sites monitored this year were also monitored in 2014 (Fig. 4). HATCH (which includes 3 buildings) and NB had the same number of active nests in both years. BROOK had more active nests this year than in 2014. CF had fewer active nests this year than in 2014. The two nests at CVM that were active in 2014 were not active this year.

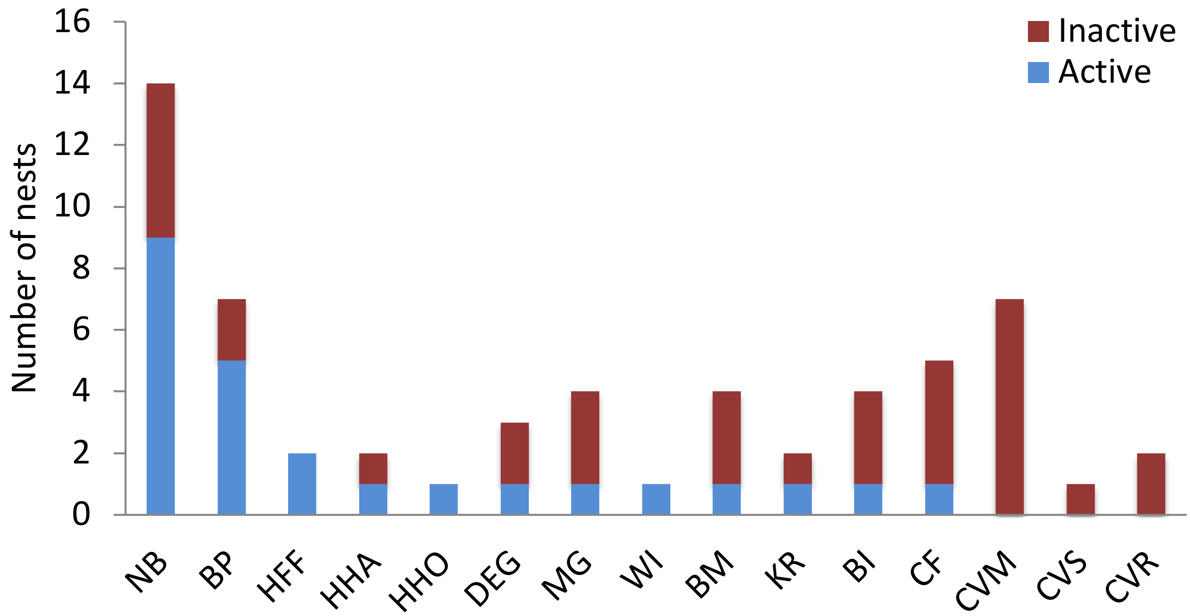

Figure 3. Number of nests (active and inactive) at each site.

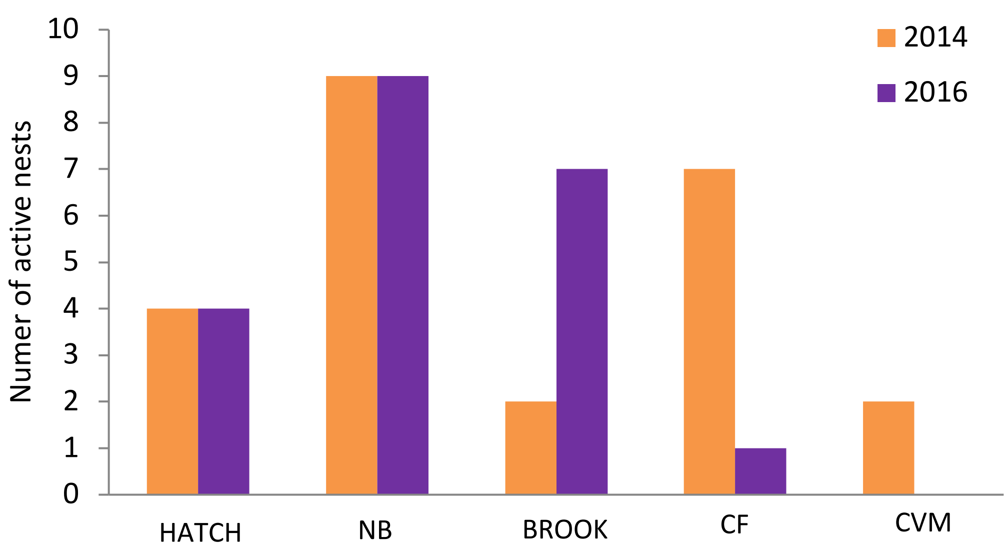

Figure 4. Number of active Barn Swallow nests in 2014 and 2016. Only the sites monitored in both years are shown. For comparison, all buildings at HATCH (includes HFF, HHO and HHA) and BROOK (includes BP and BM) are combined.

Timing of nesting

We observed the first Barn Swallow eggs at DEG on May 4, 2016, and the first chicks on the same property on May 18 (Fig. 6). The greatest number of active nests being monitored simultaneously during the season was 19 in the second and third week of June (June 8 - June 15). Pairs began laying second broods on June 29, and second broods peaked in terms of number of nests with chicks on July 27. By August 12 (the date of the last nest checks), four nests were still active. Two of these nests contained eggs (one from a first brood and one from a second) that we assumed would not hatch because they remained in the nest longer than 3 weeks. The other two active nests contained chicks that were close to fledging, and we assumed these chicks would fledge for the purpose of the analysis. Three Barn Swallow pairs at NB had late first broods, laying eggs on July 16, July 31, and July 27. The first brood chicks in these nests were either not hatched or were still young and naked after second clutches had started in other nests. Several nests already contained chicks by the time of our first nest checks (at sites MG, KR, CF, DEG, BI, and BP).

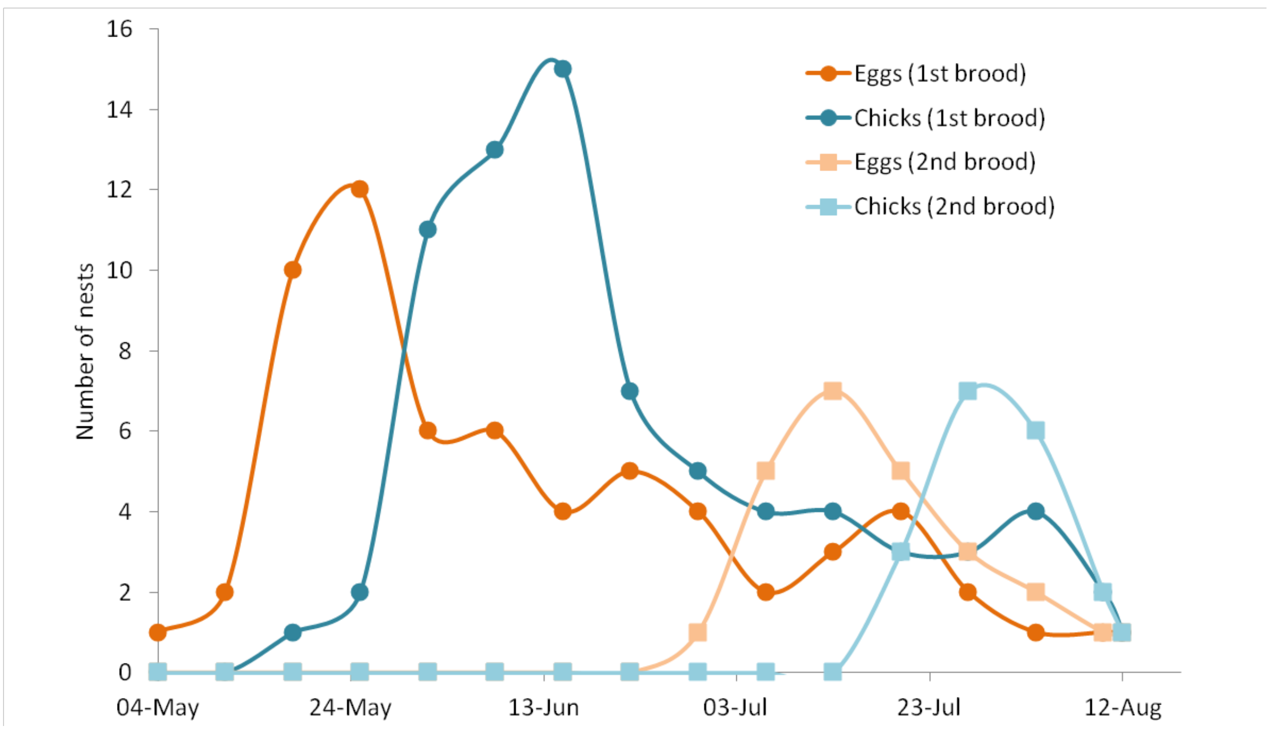

Figure 5. Number of nests containing eggs and chicks for first and second broods across the breeding season.

Clutch Size and Second Broods

Eight Barn Swallow pairs laid second broods (Fig. 6). Clutch size varied from 3 to 7 eggs for the first clutch and 3 to 5 eggs for the second clutch. Average clutch size was 4.1 for first broods and 4.3 for second broods.

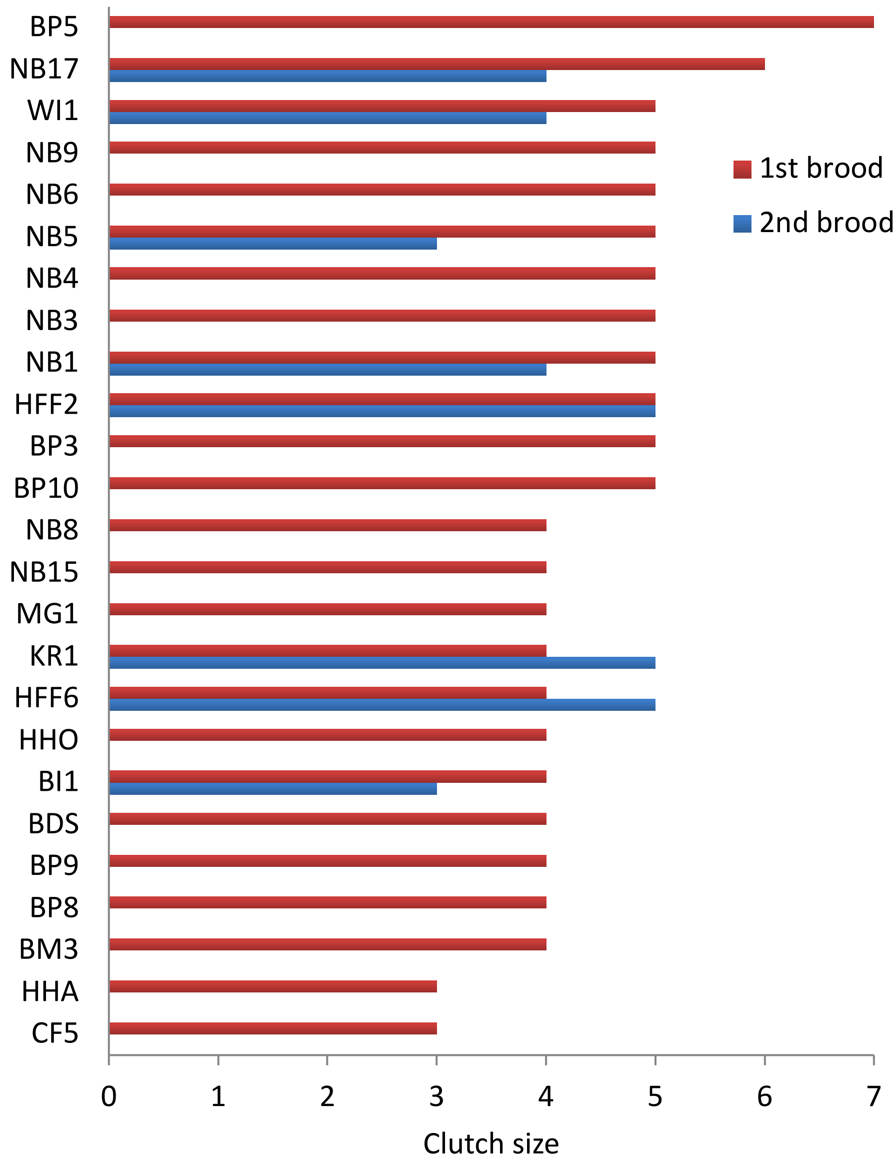

Figure 6. Clutch size for first and second broods in each active nest.

Fledging Success and Chick Survival

Thirteen nests had complete success for first broods (all chicks fledged) and four experienced complete failure (all chicks died or eggs failed to hatch; Fig. 7). At HHO, an observer noticed one chick dead near the nest building. One of the nests at HFF completely failed for each of two broods (each clutch contained 5 eggs). All nestlings from both clutches were found dead when they were close to fledging. The first brood was found dead by an observer underneath the nest and we found the second brood dead in the nest. We found two dead nestlings from separate nests at NB. Each was found dead below the nest, and had downy feathers. One was found on June 14 and the other was found on August 8. Two first-brood nestlings from WI died on June 15. These chicks were found below the nest and had downy feathers. The second brood from this nest (3 eggs) did not hatch after three weeks and were presumed dead. The owner of the property dissected two of the eggs. One egg had no embryo development and the other had very limited development. The nest at MG (containing 5 eggs) had complete nest failure. All chicks died after hatching. Following this nest failure the nest was taken down by the owner.

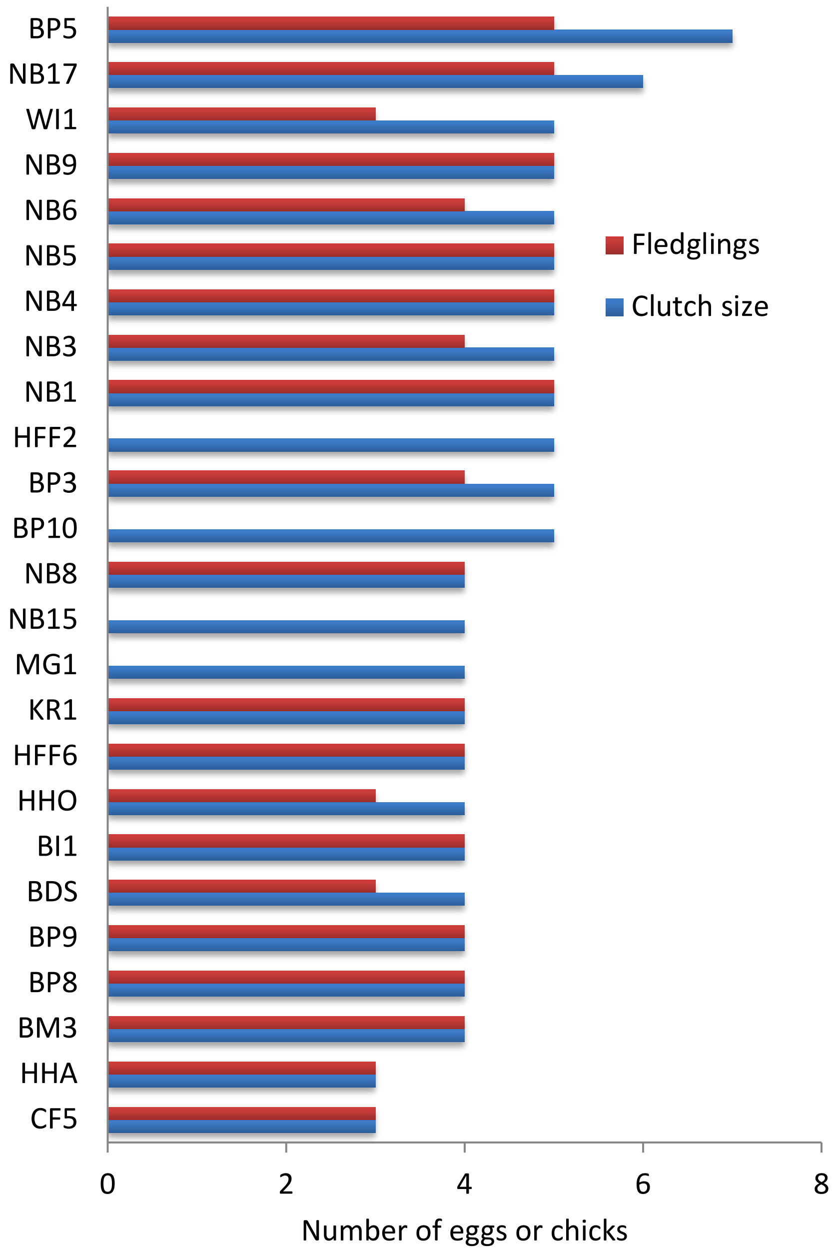

Figure 7. Number of fledglings and clutch size (number of eggs) for first broods.

Predators and Competitors

The trail cameras did not capture any incidence of nest predation but they did capture some images of potential predators or competitors near nests. Images of House Sparrows approaching Barn Swallow nests were captured on camera at HFF, and a rat was captured on camera at NB (but not close to a nest).

At BP, we saw juvenile European Starlings which could compete with Barn Swallows. At two private properties there were cats that roomed freely in the barns with Barn Swallow nestlings, and two properties also had dogs. At one of these properties we witnessed a juvenile Barn Swallow leave the nest prematurely and be chased by a dog (it was unable to fly). We were able to capture the chick and return it to the nest.

Land Cover Surrounding Nest Sites

Within 100 m surrounding nest buildings, average pasture cover was 57% (± 24.5; Fig. 8). BP had the highest pasture cover within 100 m (97%) and WI had the lowest pasture cover (16%). Average forest cover within 100 m was 18% (± 16.1). BS had the highest percentage of forest (44%), while NB and CVM contained no forest within 100 m.

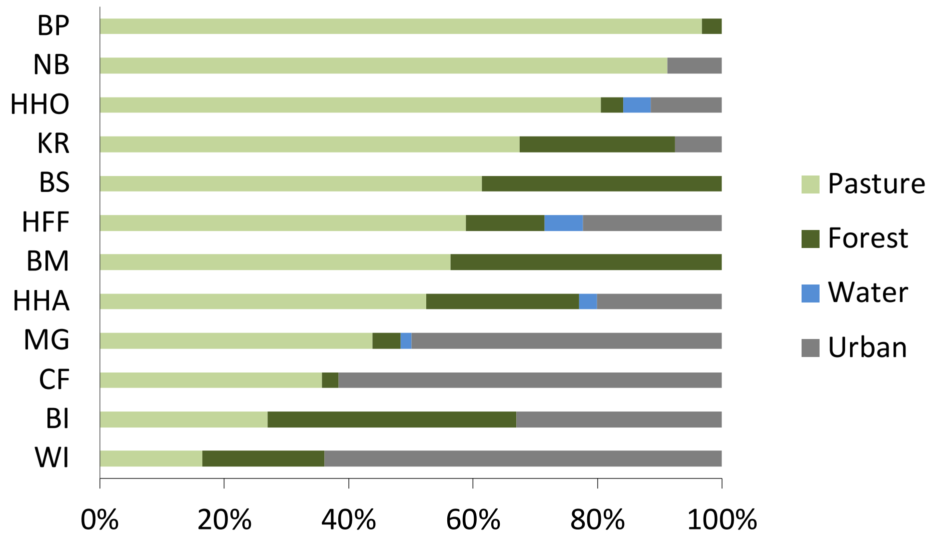

Figure 8. Land cover percentages for each site within a 100-m buffer.

Habitat Associations

Clutch size was positively associated with percent pasture ($p = 0.03$) within a 100-m buffer (Fig. 9). This relationship was marginally significant within a 200-m buffer ($p = 0.08$), but was not significant within larger buffers. Clutch size was negatively associated with percent forest (marginally significant; $p = 0.08$) within a 100-m buffer but not within larger buffers.

Number of fledglings was positively associated with percent pasture within a 100-m buffer (marginally significant; $p = 0.09$; Fig. 10), but was not associated with any other habitat types within other buffer sizes.

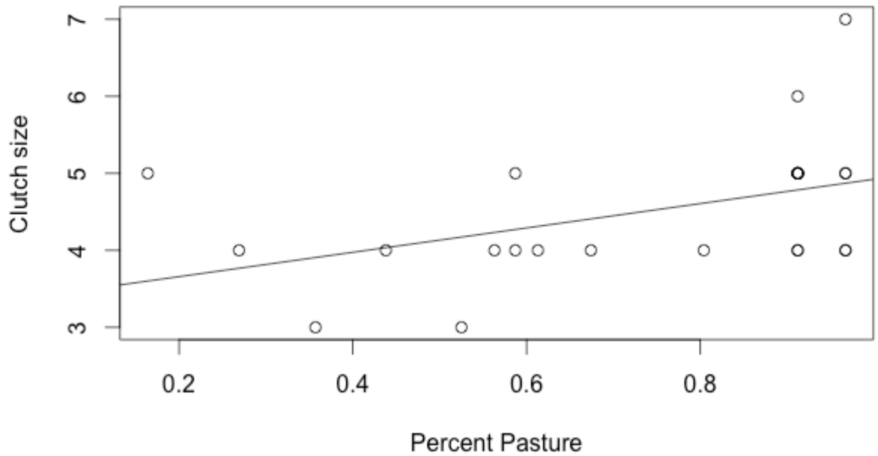

Figure 9. Relationship between clutch size and percent pasture within a 100-m buffer surrounding nest buildings (p = 0.03).

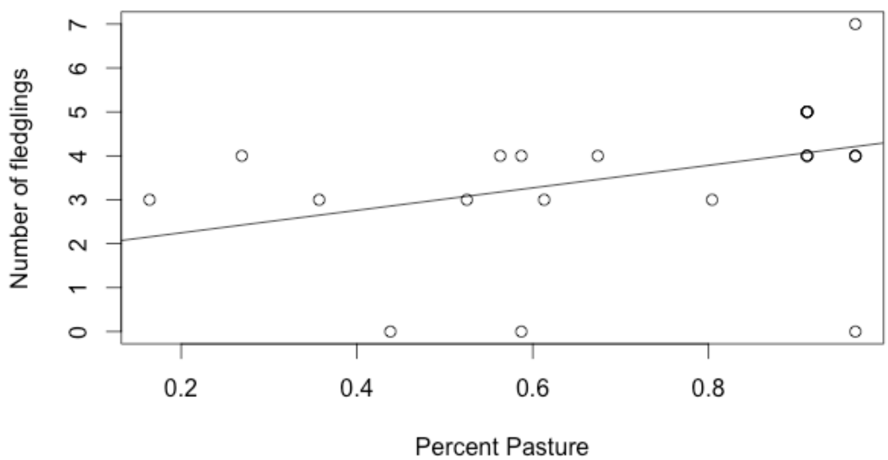

Figure 10. Relationship between number of fledglings and percent pasture within a 100-m buffer surrounding nest buildings (p = 0.09).

Discussion

Distribution of sites across the LCRW

We added five new sites to our Barn Swallow monitoring program in 2016. These included MG, WI, KR, BI, and DEG. A Rocha also made several new contacts late in the season who had properties with Barn Swallow nests. We were unable to monitor these properties this season due to time constraints but they may be included in next year's monitoring.

Although the majority of the Barn Swallow monitoring sites in 2016 were concentrated near the center of the watershed, the addition of KR expanded our monitoring to the south. In 2014, the feedlot was the site furthest to the east and the White Rock footbridge was the furthest west, but neither of these sites had active nests in 2014 and they were not monitored this year since it was confirmed in 2014 that these sites had not contained active Barn Swallow nests for several years prior (Hereward et al. 2014). Excluding DEG, which fell outside the boundary of the LCRW, MG was the easternmost site with an active nest.

Land Cover Associations with Nest Success

Hereward et al. (2014) found a positive association between surrounding pasture and number of Barn Swallow fledglings within a 400 m buffer, while we found a positive association between percent pasture and clutch size at 100 m but not at larger buffer sizes. We also found a marginally significant association between pasture and number of fledglings at 100 m but not at larger scales. These different results could be due to differences in methods and analyses. We used linear mixed effects models to analyze the effect of surrounding land cover on both clutch size and number of fledglings for each nest individually, with building included as a random effect (since some buildings contained multiple nests). We chose to conduct our analysis at the level of the building rather than site (as in Hereward et al., 2014) because at our smallest buffer size (100 m), some buildings on the same properties differed substantially in surrounding land cover. Hereward et al. (2014) used a Spearman Rank test to determine the effect of surrounding land cover on the total number of fledglings at each site, with some sites containing multiple buildings (such as HATCH) with multiple nests in each building. These different results could have also been influenced by the non-overlapping sites sampled in 2014 and 2016 (only 5 sites overlapped between years).

It may be possible to reanalyze the 2014 data using the site groupings and analysis methods used in this report. However, since only 5 sites were consistent between the two years, the sample size would be small. The discrepancies between methods across years have important implications for maintaining a long-term Barn Swallow monitoring program in the LCRW. In subsequent years, it will be useful to detail and apply standard methodology to improve consistency and allow A Rocha to combine and compare data collected across years.

The positive effect of surrounding pasture on Barn Swallow reproductive success within 100 m found in this study may be indicative of the distance that adult Barn Swallows travel to forage for nestlings. An extensive study of Barn Swallow foraging distances in Europe revealed that more than 98% of all foraging took place within a distance of 500 m and slightly less than 50% within 100 m (Møller, 1985). Samuel (1971) studied North American Barn Swallow foraging distances in West Virginia and estimated a foraging distance of 805 m. European and North American Barn Swallows belong to different clades and although these clades are less differentiated then most avian species they may correspond to phylogenetic or evolutionary species (Zink et al., 2006); thus potentially exhibiting markedly different foraging behaviour.

It is possible that increasingly fragmented foraging land is restricting Barn Swallows to a smaller foraging area than they would naturally use in the LCRW. We used the same aerial imagery and land cover categories in 2016 as were used in Hereward et al. (2014); therefore, any changes in amount of pasture would not have been accounted for. However, although there is development pressure in the LCRW, there does not appear to have been substantial changes in amount of pasture in the last two years that would restrict Barn Swallow foraging distances to 100 m. We overlaid the 2012 land cover categories used in Hereward et al. (2014) onto current Google Earth imagery and did not notice substantial changes in pasture cover, nor did any of the land surrounding our Barn Swallow nest sites appear to have been modified in the past two years.

It may be that environmental conditions affecting aerial insect abundance differed between 2014 and 2016, causing Barn Swallows to forage closer to nest sites in 2016. Insect abundance is known to be affected by annual weather changes such as ENSO events (Swetnam and Belancourt, 1998). If foraging Barn Swallows are able to find insects closer to their nesting site, this should increase reproductive success since studies show that Barn Swallows prefer to forage closer to their nesting site to minimize energy costs (Turner, 2006).

Finally, our different results compared to 2014 could have been influenced by changes in the amount and presence of livestock at Barn Swallow nesting sites. Ambrosini et al. (2002) found that livestock presence in the past 3-5 years predicts Barn Swallow abundance. Although we did not quantify current and historical livestock presence, we did notice changes in the presence and abundance of livestock at some nest sites. For example, there were fewer chickens at CF than in 2014, and six Barn Swallow nests that were active at that site in 2014 were no longer active in 2016. Additionally, there were pigs at NB in 2014 but not in 2016. The presence of animals in close proximity to nest sites would likely attract more insects to the sites, meaning Barn Swallows would not need to travel as far to find food.

Number of active nests across years

There was a decrease in the number of active nests at both CVM and CF since 2014. In 2014 there were two active nests at CVM, but one of these nests completely failed and the other had one nestling death (Hereward et al. 2014). Hereward et al. (2014) suggest that the chicks from the nest that had complete nest failure probably prematurely fledged, as they were found hanging from and surrounding the nest on the ground as if they had been disturbed. It is unclear what might have disturbed the Barn Swallow nestlings or have caused them to prematurely fledge. At the beginning of the 2016 nesting season we set up a camera near one of the nests at CVM to detect possible disturbances. No disturbances were recorded, and the camera was taken down when it was decided that the nest was not active. We did, however, notice Barn Owls using the upper level of the barn. It is unknown whether owls were present at the site in 2014; if so, their presence may have caused the nests to be unsuccessful and prevented Barn Swallows from returning. Owls are known to be a Barn Swallow predator and usually remove nestlings directly from the nest (Turner 2006; cited in Ferguson, 2016). It is possible that the owls did not directly predate the nestlings in this case, but the stress caused by the presence of predators may have been enough to cause the parents to abandon their young. Since 2014, blackberry shrubs have grown over the windows at CVM, limiting swallow access to the nests. If the blackberry bushes were cut down, Barn Swallows may return to the site in future years.

At CF, many of the old nests had fallen down. However, we are uncertain why there was no swallow activity in the remaining nests or why there was no new nest building activity. Although Barn Swallows will reuse old nests we did see nests at other sites that were in the process of being built or were newly built since 2014. For example, at WI we observed new nest building activity as late as August. There were fewer chickens at CF this year which may have attracted fewer swallows because of less manure and associated insects. Additionally, the barn doors remained closed most of the time during the 2016 study, and we were told that they were left open more often in 2014. Therefore, the Barn Swallow nests may have been harder to access by adult birds. However, there was still one active nest at CF, so at least one mating pair was able to access the barn.

BP contained more active nests this year compared to 2014. This site also contained the most pasture within 100 m, but the amount of pasture remained unchanged across years. BP (located at A Rocha’s Brooksdale Environmental Centre; BROOK) appears to contain high quality

Barn Swallow nesting and foraging habitat. However, there are plans to remove or alter all three buildings with active nests at Brooksdale in a way that will destroy the nests over the next several years. A Rocha staff have discussed ways to preserve Barn Swallow nesting locations when this happens, including building nesting platforms on other buildings (Christy Juteau, personal communication, 2016). However, since Barn Swallows tend to return to their previous nesting sites at a high rate (Iverson, 1988), creating new nesting opportunities may be less beneficial than improving existing nesting sites.

Nestling deaths

We are uncertain what caused the observed Barn Swallow nestling deaths during our study. Although Barn Swallows typically have a high rate of nestling success, nest failures can occur for a variety of reasons such as predation, nest destruction by other species, ectoparasites, and human causes (Turner 2006; cited in Ferguson, 2016). Although House Sparrows sometimes take over nests and kill eggs and young in the process, we consider this unlikely. We did not observe House Sparrows using Barn Swallow nests after nest failures. In the instances where a House Sparrow was captured in camera images, it appeared one of the Barn Swallow adults successfully chased it away.

The two nests at HFF were located only 2 m apart, yet one nest completely failed twice while the other nest had two successful broods. Since there was such a difference in nest success between two closely spaced nests, we consider it likely that the nestlings in the failed nest died due to ectoparasites rather than predation or other disturbance (which would have likely affected both nests). COSEWIC (2011) lists blowfly parasites as the most common reason for Barn Swallow nestling death in British Colombia, leading to complete or partial nest failure. However, mites may be more common in Barn Swallow nests than blowflies in British Columbia's lower mainland (C. Boynton, personal communication). Additionally, Barn Swallow nests in colonies are more likely than single nests to experience failure because of ectoparasites (Shields et al., 1987).

Predation was considered unlikely because rats and mice are more likely to predate on nests with eggs (rather than nestlings), and cats, owls, and raptors usually take all the young from a nest leaving no trace (Turner 2006; cited in Ferguson, 2016). The only possible indicator of predation that we observed was egg shells found below the nest at some sites. Because songbirds generally eat their egg shells or carry them away, this is often an indicator of predation (Turner, 2006). At sites with only one active nest (WI and MG), ectoparasites are still a possible cause of nestling death but this is less likely than at sites with multiple nests. Both WI and MG had low amounts of surrounding pasture so it is possible that adult Barn Swallows were unable to find enough insects to feed their young. We preserved the deceased nestlings from the failed MG nest for further analysis.

At some sites we observed eggs that never hatched; for example, at CVM there was one egg in a nest that was either left from the previous season or was laid this year and abandoned before our first nest check. Since we never observed any swallow activity at that site, and blackberries had grown over the window, we are inclined to think the egg was left from the last breeding season. Unhatched eggs were also observed at WI and BP. The incubation period for Barn Swallows is 12-17 days so after 3 weeks we assumed eggs were not going to hatch (Bird Studies Canada, 2016). There are a variety of reasons why eggs do not complete develop such as lack of incubation, excessively high or low temperatures, lack of fertilization, and genetic defects. At WI both parents were attentive and incubated the eggs even up to 3 weeks. The property owner reported that the parents who laid the unhatched eggs exhibited very different behaviour than the pair who had fledged juveniles earlier in the season from the same nest. If the second brood was laid by different parents than the first, it is possible that one of the parents was unfertile.

Population Trends

We did not conduct Barn Swallow population counts, but anecdotal evidence suggests that there are fewer Barn Swallows returning to breed in the LCRW than in previous years. There were many more inactive nests than active nests in the sites that we monitored. Although all of the inactive nests were not necessarily active at one time, the number of inactive nests is an indicator of each building's nesting habitat capacity in the form of beams and light fixtures. The small ratio of active to inactive nests is surprising because adult Barn Swallows often return to the same nest year after year (Iverson, 1988). During our nest site visits, several landowners reported fewer active nests this year than they had observed in the past. One property was selected for monitoring at the beginning of the season because the owner reported having several active nests (~10) in previous years. That property contained several horse barns and pasture for foraging. However, despite the appearance of high-quality nesting and foraging habitat, no Barn Swallows returned to that site this year.

Future Research

In order to add to the exiting body of research and improve the value of our results, it would be helpful to create a detailed, standardized Barn Swallow monitoring template that could be followed in the same way each year. This would make data more comparable across years. Secondly, it may also be useful to group land cover categories differently for analysis. For example, pastures of differing quality were grouped together along with grass and shrubland, which may have influenced our results. Alternatively, categorizing land cover by hand only within buffers around each site using current aerial imagery would provide more detailed categories for use in analysis than the categories used in this study, which were developed for use in larger scale studies of watershed change over time. This method would also allow for current land cover data to be used each year. Thirdly, it would be helpful to obtain more data on the presence of livestock at each site, such as livestock species, frequency of grazing, and proximity to Barn Swallow nests. Finally, we would like to obtain more accurate counts of nestlings and fledglings in the future. We were limited by our capacity to perform fieldwork only once per week, but more frequent nest checks would have likely resulted in more accurate counts of nestlings and fledglings.

Because this was the first year we had access to trail cameras, we used this year as a pilot study to determine how the cameras might be best utilized in the future. One of us (C.R.) conducted a test at BP to determine how sensitive the cameras were to capturing adult Barn Swallows provisioning nestlings. At one nest with a camera, C.R. watched Barn Swallow parents fly to and from the nest for 30 minutes and recorded each time a parent was seen returning to the nest. These visual observations were compared to the images taken from the camera, and it was found that the camera adequately captured each return to the nest. However, it appeared that at some sites, cameras were not recording all instances of adults returning to the nests (e.g., long time periods would elapse between images of birds returning to nests with healthy young, whereas the parents must have been feeding the young at more frequent intervals than were recorded). This may have been due to inadequate light conditions or problems associated with individual cameras. Replace the camera memory cards and repositioning the cameras during each nest visit was time and labour intensive. However, if we could guarantee that all images of birds provisioning nests were recorded, valuable data on Barn Swallow feeding rates could be obtained from the cameras in subsequent years.

A mark recapture study involving banding Barn Swallows in the LCRW would provide valuable estimates of rates of return to breeding sites. Standardized counts of foraging Barn Swallows would also provide an estimate of population numbers and trends over time. These methods were beyond the scope of our study but would be useful for tracking long-term trends in Barn Swallow abundance and reproductive success in the LCRW.

Conclusion

We found that amount of pasture within 100 m of nest sites positively influenced Barn Swallow clutch size and number of fledglings. Given that Barn Swallows are declining across North America and are listed as threatened in Canada, we recommend preserving pastureland as one conservation measure to boost swallow population numbers and reproductive success. In the LCRW, much pasture remains undeveloped. However, this land is not valued for its conservation significance and is vulnerable to the widespread urban development occurring throughout British Columbia's lower mainland. As shown here and in Hereward et al. (2014), Barn Swallows are a threatened species dependent on pasture for foraging, and may be considered an umbrella species for conservation of other field and pasture-dependent species. Our study provides additional information on Barn Swallow nest success within the LCRW, ultimately contributing to further knowledge about the status and conservation of this threatened species.

References

Ambrosini, R., Bolzern, A. M., Canova, L., and Saino, N. 2002. Latency in response of Barn Swallow *Hirundo rustica* populations to changes in breeding habitat conditions. *Ecology Letters 5*(5): 640–647.

Ambrosini, R., Rubolini, D., Trovo, P., Liberini, G., Bandini, M., Romano, A., et al. 2012. Maintenance of livestock farming may buffer population decline of the Barn Swallow *Hirundo rustica*. *Bird Conservation International*, *22*(04): 411–428.

Bird Studies Canada. Barn Swallow (*Hirundo rustica*) Identification & Life History. Retrieved September 20, 2016, from Bird Studies Canada, http://www.birdscanada.org/volunteer/pnw/index.jsp?targetpg=barsfact

Bryant, D. M., and Turner, A. K. 1982. Central place foraging by swallows (Hirundinidae): The question of load size. *Animal Behaviour*, *30*(3): 845–856.

City of Surrey. Campbell River Floodplain. Retrieved September 20, 2016, from http://www.surrey.ca/city-services/3658.aspx

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2011. COSEWIC assessment and status report on the Barn Swallow *Hirundo rustica* in Canada. (www.sararegistry.gc.ca/status/status_e.cfm).

Dor, R., Safran, R. J., Sheldon, F. H., Winkler, D. W., and Lovette, I. J. 2010. Phylogeny of the genus Hirundo and the Barn Swallow subspecies complex. *Molecular Phylogenetics and Evolution*, *56*(1): 409–418.

Evans, K. L., Wilson, J. D., and Bradbury, R. B. 2007. Effects of crop type and aerial invertebrate abundance on foraging Barn Swallows *Hirundo rustica*. *Agriculture, Ecosystems and Environment*, *122*(2): 267–273.

Ferguson, G. British Columbia Swallow Conservation Project. Retrieved September 20, 2016 from https://bcswallowconservationproject.wordpress.com/swallow-best-management-practices/.

Grüebler, M. U., Korner-Nievergelt, F., and Von Hirschheydt, J. 2010. The reproductive benefits of livestock farming in Barn Swallows *Hirundo rustica*: Quality of nest site or foraging habitat? *Journal of Applied Ecology*, *47*(6): 1340–1347.

Henderson, I., Holt, C., and Vickery, J. 2007. National and regional patterns of habitat association with foraging Barn Swallows *Hirundo rustica* in the UK. *Bird Study*, *54*(3): 371–377.

Hereward, H., Juteau, C., and Baylis, A. 2014. Status of Barn Swallows (*Hirundo rustica erythrogaster*) and Cliff

Swallows (*Petrochelidon pyrrhonota*) in the Little Campbell River Watershed. A Rocha Canada Conservation Science Series. A Rocha Canada, Surrey, B.C.

Jetz, W., Wilcove D. S., and Dobson A.P. 2007. Projected impacts of climate and land-use change on the global diversity of birds. PLoS Biol 5(6): e157. doi:10.1371/journal.pbio.0050157

Jobin, B., DesGranges, J. L., and Boutin, C. 1996. Population trends in selected species of farmland birds in relation to recent developments in agriculture in the St. Lawrence Valley. *Agriculture, Ecosystems and Environment 57*(2-3): 103–116.

Madrone Environmental Services Ltd. Summary Notes from "South Campbell Heights Environmental Study." Retrieved September 20, 2016, from http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwj32cG8p53PAhXHHB4KHTAtDxcQFggjMAE&url=http%3A%2F%2Fwww.grandviewstewardship.org%2Fwpcontent%2Fuploads%2F2015%2F09%2FEnvironmental_Study_Summary_Notes_CBC_Briefing.docx&usg=AFQjCNGOnwdNDQTrVCLRszYmmG78H7il4g

Moller, A. P. 2001. The effect of dairy farming on Barn Swallow *Hirundo rustica* abundance, distribution and reproduction. *Journal of Applied Ecology 38*(2): 378–389.

Samuel, D. 1971. The Breeding biology of Barn and Cliff Swallows in West Virginia. *The Wilson Bulletin 83*(3): 284-301.

Iverson, S. S. 1988. Site tenacity in culvert-nesting Barn Swallows in Oklahoma. *Journal of Field Ornithology 59*(4): 337-344.

Stotz, D. F., Bierregaard, R. O., Cohn-Haft, M., Petermann, P., Smith, J., Whittaker, A., and Wilson, S. V. 1992. The status of North American migrants in Central Amazonian Brazil. *The Condor 94*(3): 608–621.

Swetnam, T. W. and Betancourt, J. L. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American southwest. *Journal of Climate 11*(12): 3128–3147.

Turner, A. 2006. *The Barn Swallow*. T & A D Poyser, London. 256 pp.

Vitousek, M. N., Jenkins, B. R., and Safran, R. J. 2014. Stress and success: Individual differences in the glucocorticoid stress response predict behavior and reproductive success under high predation risk. *Hormones and Behavior 66*(5): 812-819.

Zink, R. M., Pavlova, A., Rohwer, S., and Drovetski, S. V. 2006. Barn Swallows before barns: Population histories and intercontinental colonization. *Proc Biol Sci 273*(1591): 1245–1251.