DEAN'S OFFICE, FACULTY OF FORESTRY

Undergraduate Thesis

Evaluating nest box addition as a population augmentation strategy for tree swallows, *Hirondelle bicolore*, in interior British Columbia, Canada

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ABSTRACT

Tree swallow populations across North America are exhibiting negative annual trends. An exception to the broader trend is interior BC, Canada where tree swallow populations are growing. Augmentation of successful populations by the addition of nest boxes to cavity poor landscapes may be an appropriate strategy to mitigate or reverse the national decline. This was evaluated through an analytical comparison of the reproductive performance (clutch size and hatchlings) of tree swallow breeding pairs nesting in natural cavities and nest boxes in the William's Lake region of BC, Canada. For the 2001-2003 breeding seasons mean clutch size (means ± SE, nest boxes: 5.94 ± 0.199 eggs (n=83), cavities: 4.2 ± 0.204 eggs (n=74)) and number of living hatchlings (means ± SE, nest boxes: 4.51 ± 0.265 chicks(n=83), cavities: 2.51 ± 0.27 chicks(n=74)) detected were significantly higher (clutch size: p-value=0.0001, hatchlings: p-value 0.0001, alpha=0.05) for pairs using nest boxes. Nest boxes provide tree swallow breeding pairs with additional nesting territories and result in higher reproductive rates. Nest box addition has the potential to be a long term population augmentation mechanism but further studies on long term impacts at the community level are necessary before it can be implemented as a management plan.

INTRODUCTION

Species of the aerial insectivore guild utilize a broad range of habitats for nest site selection and foraging areas, which has allowed them to successfully colonize the majority of North America (McCracken 2008). Despite this variation in acceptable habitat, long term and recent guild-wide declines in aerial insectivores have been detected by Regional Breeding Bird Surveys across the continent (McCracken 2008). Typical limiting factors such as suitable nest site availability, competition from exotic species or large scale land use changes can be shown to be at least partly responsible for individual species' declines (Aitken & Martin 2007, Carrascal & Alonso 2006, Cornelius et al. 2008, Gains et al. 2010, Kath & Dunn 2009, Koch et al. 2011, Miller 2010, McCracken 2008, Shustack & Rodewald 2010, Zhu et al. 2010) but are less explanatory at the guild level. The life history trait that unites this otherwise diverse guild is a reliance on insect populations as a primary food source (McCracken 2008). Accordingly, changes in insect populations arising from light sensitivity, deleterious aquatic conditions and climatic variation are being investigated as an alternate cause of this decline (McCracken 2008). Although interesting and likely relevant, very little is known about broad scale insect population trends or demographics and even less is known about management (McCracken 2008). Until the mechanism behind the decline is better understood, mitigation or reversal of this trend must rely on management strategies that have been proven to be effective in the past, namely habitat conservation and addition of critical limited resources such as suitable nest sites (Aitken & Martin 2011, Brandies et al. 2002, Holt & Martin 1997, Wesolowski 2007).

The overall population trend for Canada and the US is negative but there is notable temporal and geographical variation (McCracken, 2008). In the William's Lake area of British Columbia several members of the guild experiencing continental declines, tree swallows (*Hirondelle bicolor*), fly catchers (*Empidonax* spp.) and wood pewees (*Contopus sordiulus*) , were shown to have linear increases in abundance and detection over the last 13 years (Adamson et al. 2010). Despite deforestation from forestry practices, massive habitat and food supply fluctuation from the MPB outbreak and competition from exotics such as the European Starling, *Sturnus vulgaris,* interior BC still acts as an aerial insectivore refuge (Adamson et al. 2010). Augmentation of healthy growing populations may be an appropriate strategy to counteract the large scale decline, at least locally.

Secondary cavity nesters (SCNs) such as the tree swallow are reliant on excavated or naturally occurring cavities for nesting sites (Aitken and Martin 2007, Aitken and Martin 2008, Cornelius et al. 2008, Gains et al. 2010, Holt and Martin 1997, Kath & Dunn 2009, Koch et al. 2011, Martin et al. 2004, Miller 2010, Robertson and Rendell 1990, Saab et al 2009). Density, diversity and abundance of SCN species are correlated with the abundance, nature (excavated or naturally formed), diversity (height on tree, cavity dimensions) and spatial distribution of cavities (Wiebe et al. 2006, Zhu et al. 2010). Stable populations of woodpeckers, in the capacity of cavity excavators, play an important role in maintaining SCN populations and allowing for growth (Aitken and Martin 2007). Nest box addition studies have conclusively shown that distributing appropriate nesting sites throughout cavity-poor areas can significantly increase abundance and diversity of mammalian and avian SCN species (Holt and Martin 1997). Significant increases in abundance and breeding capacity have also been reported in SCN bird populations housed in grid arrangements of nest boxes when compared to adjacent populations in natural cavities (Robertson and Rendell 1990). It should be noted that these results are limited in their representation of natural population performance and behavior as the nest grids limit the variation of cavity dimensions and alter the impacts of predation and parasitism while forcing breeding pairs to coexist at unnatural densities (Robertson and Rendell 1990).

Tree swallows are experiencing a -2.7% annual trend across Canada(McCracken, J. 2008) but have been shown to have increasing populations in the Williams Lake region of BC (Adamson et al. 2010). Adding nest boxes as surrogates in cavity-poor areas has the potential to allow for further growth in these populations (Aitken and Martin 2008, 2011). However, the demographics associated with nest box populations in otherwise suitable habitat are poorly understood in comparison to populations in natural cavities. Fecundity and associated cavity data were collected for tree swallows in the same area of the William's Lake Region of BC for breeding pairs housed in cavities and in nest boxes. By comparing fecundity rates, specifically clutch size and max number of observed hatchlings, between the two nest site types I hope to evaluate whether nest box addition is an appropriate management strategy for augmentation of growing tree swallow populations, where cavity limitation may be an issue. If average clutch size and hatchlings from nest boxes are greater than or equal to values obtained from natural cavities, then it can be concluded that application of this strategy is appropriate, at least in the area of study.

Study Area

All data used for analysis was collected between 2001-2003 from adjacent study areas in the Cariboo-Chilcotin Region of central interior British Columbia (51°52'N, 122°21'W) southwest of the city of William's Lake. A map of the area is shown in Figure 1. Located in the warm dry Interior Douglas-fir biogeoclimatic zone, the landscape is composed of mixed coniferous and deciduous forest surrounded by a grassland matrix. Prevalent tree species include Douglas-fir, lodge pole pine, white and hybrid spruce and quaking aspen. Cavity data specifically came from the Riske Creek study area where long term cavity monitoring has lead to multiple published articles. Nest box data came from study sites on Becher's Prairie where nest site limitation theory was being examined by the experimental addition of nest boxes to cavity poor areas. For additional details describing the sites, experimental design and data collection techniques of the original studies see Martin et al. (2004) and Aitken and Martin (2011).

METHODS

The first step in comparing the data from the two studies was extracting the specific data I needed from the two Microsoft Excel spreadsheets supplied by K. Aitken (Boxes) and K. Martin (Natural cavity nests). The cavity data were already in a usable format with one entry per cavity per year that included occupant fecundity measurements as well as cavity dimensions, height on tree, tree decay class and aspect. Data covered all cavities shown to contain active tree swallow nests for years 2001-2003.

The nest box data were recorded in a different format but they contained observations for tree swallow nests in boxes for 2001-2003. The main difference between the spreadsheets was that, in the nest-box dataset, each visit to a box was recorded as its own entry resulting in 3-4 rows of data per box per breeding season. As the original study was focused on changes in abundance and diversity of nest box occupants, general fecundity data was recorded in a comments section in the final column of each entry. The parameters noted with consistency were clutch size and number of living or dead hatchlings seen on a given visit. These two parameters were also recorded in the cavity data and so became the factors examined in the comparison. The nest box data were made compatible for statistical comparison with the natural cavities data by combining observations from multiple visits into a single entry per box per year with an associated clutch size and number of hatchlings.

The extracted data for clutch size and max observed living hatchlings, included as an appendix, were analyzed with GLM procedures using the SAS 9.2 statistics package, 2002-2008, SAS Institute Inc, Cary, NC, USA, to test the significance of the nest site origin as a treatment and to assure the residuals met the assumptions of normality and equal variance. The GLM procedures used 2 treatment classes (box and nat) over 3 breeding seasons (2001, 02 and 03) with maximum of 43 replicates per treatment per year and an alpha level of 0.05. The number of replicates varied by nest type and year. For natural cavities n=22 in 2001, n=23 in 2002 and n=29 in 2003. For nest boxes n=19 in 2001, n=43 in 2002 and n=21 in 2003. Blank entries indicate the lack of an accurate observation and were excluded in the analysis. Concurrence with assumptions was judged using normality test p-values (p-value>0.05= residuals normally distributed), visual examination of normality plots and histograms as well as the Bartlett's test. Assistance in writing the SAS programming was supplied by Dr. Tony Kozack.

RESULTS

Results of the GLM procedures for clutch size and hatchlings (Table 3) yielded significant findings. However, using untransformed data, neither output met the normality assumption (all test p-values<0.01). The clutch size output also failed to meet the equal variance assumption (Bartlett's test p-value=0.002) while the hatchling output met the assumption (Bartlett's test p-value= 0.0346). By applying a power transformation of X^1.8 both outputs were able to meet the equal variance assumption (clutch size^1.8 p-value=0.0124, hatchlings^1.8=0.0172) but had no effect on the normality test values.

Tree swallow pairs breeding in natural cavities laid significantly smaller clutches size (p-value<0.0001) than those using nest boxes (Table 2). Mean clutch sizes for cavities were smaller in each individual year (Figure 2) and when annual data was pooled cavities on average contained 1.742 fewer eggs than nest boxes (2001, 2002 and 2003 combined, means ± SE, nest boxes: 5.94 ± 0.199 eggs (n=83), cavities: 4.2 ± 0.204 eggs (n=74)). Figure 2 illustrates that clutch sizes increased similarly in 2003 for both nest types (nest boxes: +0.62, cavities: +0.68) in comparison to the 2001 and 2002 seasons. This difference was significant between 2001 and 2003(p-value 0.011, alpha 0.017) and nearly so between 2002 and 2003(p-value 0.032, alpha 0.017).

Similar results were obtained for number of maximum observed living hatchlings with significantly fewer chicks detected in cavities (p-value<0.0001) (Table 3). Mean number of hatchlings observed was lower in each individual year for nests in cavities (Figure 3) and when annual data was pooled cavities on average contained 1.9994 fewer hatchlings than nest boxes (2001, 2002 and 2003 combined, means ± SE, nest boxes: 4.51 ± 0.265 chicks(n=83), cavities: 2.51 ± 0.27 chicks(n=74)). Figure 3 shows separate trends for each nest type. Cavities hit a low point in 2002 (1.9 hatchlings) and rebounded in 2003(3.4 hatchlings), an 81% increase. Nest boxes exhibited a slight negative trend -7.1% between 2001(4.68 hatchlings) and 2003 (4.35 hatchlings). No other significant interactions were detected.

I calculated the number of hatched chicks/egg laid for the three year period and for each year by combining the mean clutch size and hatchling values (Table 4). For nest boxes an overall average of 5.94 eggs led to 4.506 hatchlings, a 75.85% hatching rate or 0.76 chicks per egg. For cavities an average of 4.2 eggs led to an average of 2.5 hatchlings, a 59.52% hatching rate or 0.60 chicks per egg (Figure 4). The cavities data set also contained information on the number of hatchlings that reached the fledgling stage. Of the cavities used for the GLM procedure 29 had reliable fledgling counts. The mean for these 29 cavities was 1.433 fledglings and was incorporated into Figure 4. With this new data point, Figure 4 now shows the survival trend , estimated by a best fit line(y=-1.385x+5.48), for tree swallow offspring in cavities through three life stages. A trend line fitted to the nest box data had a similar slope (y=-1.43x+7.37), indicating a similar rates of loss in offspring across live stages for the two nest types. Extending the nest box best fit line to the fledgling interval results in an estimated average of 3.08 fledglings per nest box for 2001-2003.

DISCUSSION

The purpose of the project is to evaluate whether the addition of nest boxes to cavity poor landscapes can be a population augmentation mechanism for tree swallows in interior BC, Canada as part of a proactive effort to mitigate nationwide declines. It is established that adding nest boxes to cavity poor areas can increase the local abundance of tree swallow breeding pairs and other SCN species (Aitken & Martin 2011, Holt & Martin 1997). Less examined but equally important to evaluation of nest box addition as a management strategy is the reproductive performance of breeding pairs in nest boxes and the survivability of their offspring. The studies that have analyzed these properties used data collected from nest box grids and rarely compared results to data from adjacent natural populations (Robertson & Rendell 1990). I used data from a population where nest boxes were distributed throughout otherwise unaltered cavity poor habitat and compared them to another component of the population breeding in natural cavities. Analysis of this comparison reported that mean clutch size and number of hatchlings found in nest boxes significantly exceeded those found in natural cavities for 2001-2003. More eggs were laid in nest boxes and a higher percentage hatched. Further, based on trends observed in the data, nest boxes may result in two times the number of hatchlings surviving to the fledgling stage. Based on these results, long term next box addition is an appropriate strategy for tree swallow population augmentation.

While the results are significant and provide evidence in favor of nest box addition, this analysis is notably limited by the number of breeding seasons with data available for comparison and in the number of species considered. After the 2003 breeding season, the nest boxes were removed and the abundance of occupant species returned to pre-addition levels (Aitken & Martin 2011). This highlighted nest site availability as the limiting factor on population density but precluded a longer term dataset. Additional years of data would allow for better interpretation of the trends detected in Figures 3 and 4. Clutch sizes increased for nest boxes in 2003 while number of hatchlings decreased slightly. Timing of breeding initiation, influenced by annual stochastic variation in temperature and cavity availability can alter the date of first egg which has been shown to impact subsequent clutch sizes and chick survival (Koch et al 2011). Alternately the reduced number of hatchlings may have been due to increased targeting of nest boxes by parasites and predators, which has been documented in other nest box studies (Robertson & Rendell 1990). Identification of the causal factors of trends based on data from three breeding seasons is purely speculation.

Only a single species was examined in this analysis. While nest boxes function as high quality nesting sites tree swallows they may have deleterious or negligible effects on other species. The datasets used in this project contain nest box and cavity data for multiple species. It is possible to compare clutch size and hatchlings across nest types for these species as well. The mountain bluebird, *Sialia currucoides*, for example is a conspecific of the tree swallow with similar data available. Mountain bluebirds are dominated by European starlings when competing for nest sites and may also benefit from the addition of nesting territories (Aitken & Martin 2008, Koch et al 2011). The use of nest boxes as a bluebird population augmentation strategy could be evaluated using similar methods. Analysis of reproductive performance at the community level in this type of nest box arrangement is necessary to accurately model the effects of long term nest box addition.

In conclusion, the regional tree swallow population of interior BC breeding in natural cavities is growing and will potentially be limited by the number of available nest sites (Adamson et al 2010). Long term nest box addition to otherwise suitable sites with limited natural or excavated cavities is an inexpensive and direct way to increase the number of nesting territories available to breeding pairs (Aitken & Martin 2011). Other methods of increasing nest site availability, such as inoculating trees with fungi to hasten decay and promote excavation by woodpeckers, are indirect, operate on long time scales, may be economically unfeasible at the landscape scale and have had only limited success (Brandies et al 2002, Filip et al 2004). Additional territories would also be available to other SCN species, possibly reducing competition for quality nest sites with conspecifics such as the mountain bluebird and invasive species such as the European starling. The results this analysis indicate that pairs breeding in these boxes will have increased reproductive output compared to neighbors in cavities. The scope and applicability of the results are limited. Future studies will need to expand the time frame of data collection and number of species considered to better understand the impacts of nest box addition before long term nest box addition can be implemented as a management strategy at broad scales.

TABLES

Table 1: Summary of statistical parameters, mean and standard error, calculated for tree swallow clutch size data (number of eggs).

Year	Natural		Nest Box	
	Mean	SE	Mean	SE
2001	3.89	0.360	5.63	0.337
2002	4.01	0.360	5.79	0.177
2003	4.69	0.273	6.41	0.312
Total	4.20	0.204	5.94	0.199

Table 2: Summary of statistical parameters, mean and standard error (SE), calculated for tree swallow maximum observed living hatchling data (number of chicks).

Year	Natural		Nest Box	
	Mean	SE	Mean	SE
2001	2.26	0.593	4.68	0.589
2002	1.86	0.575	4.48	0.296
2003	3.40	0.516	4.35	0.514
Total	2.51	0.270	4.51	0.265

Table 3: GLM procedure results for the clutch size and living hatchlings of tree swallow breeding pairs housed in nest boxes or natural cavities in interior BC, Canada for years 2001-2003.

Clutch Size

Source of Variation	Degrees Of Freedom	Sum of Squares	Mean Square	F- value	P- Value
Model	74	214.59	2.8998	2.14	0.0014
Error	59	79.81	1.3526		
Corrected Total	133	294.40			

Hatchlings

Source of Variation	Degrees Of Freedom	Sum of Squares	Mean Square	F- value	P- Value
Model	72	307.23	4.2671	1.18	0.2643
Error	55	199.24	3.6224		
Corrected Total	127	56.47			

Table 4: Annual hatched chicks/egg laid values for of tree swallow breeding pairs housed in nest boxes or natural cavities in interior BC, Canada for years 2001-2003.

Year	Natural Cavities	Nest boxes
2001	0.58	0.83
2002	0.46	0.77
2003	0.72	0.68
Total	0.60	0.76

FIGURES

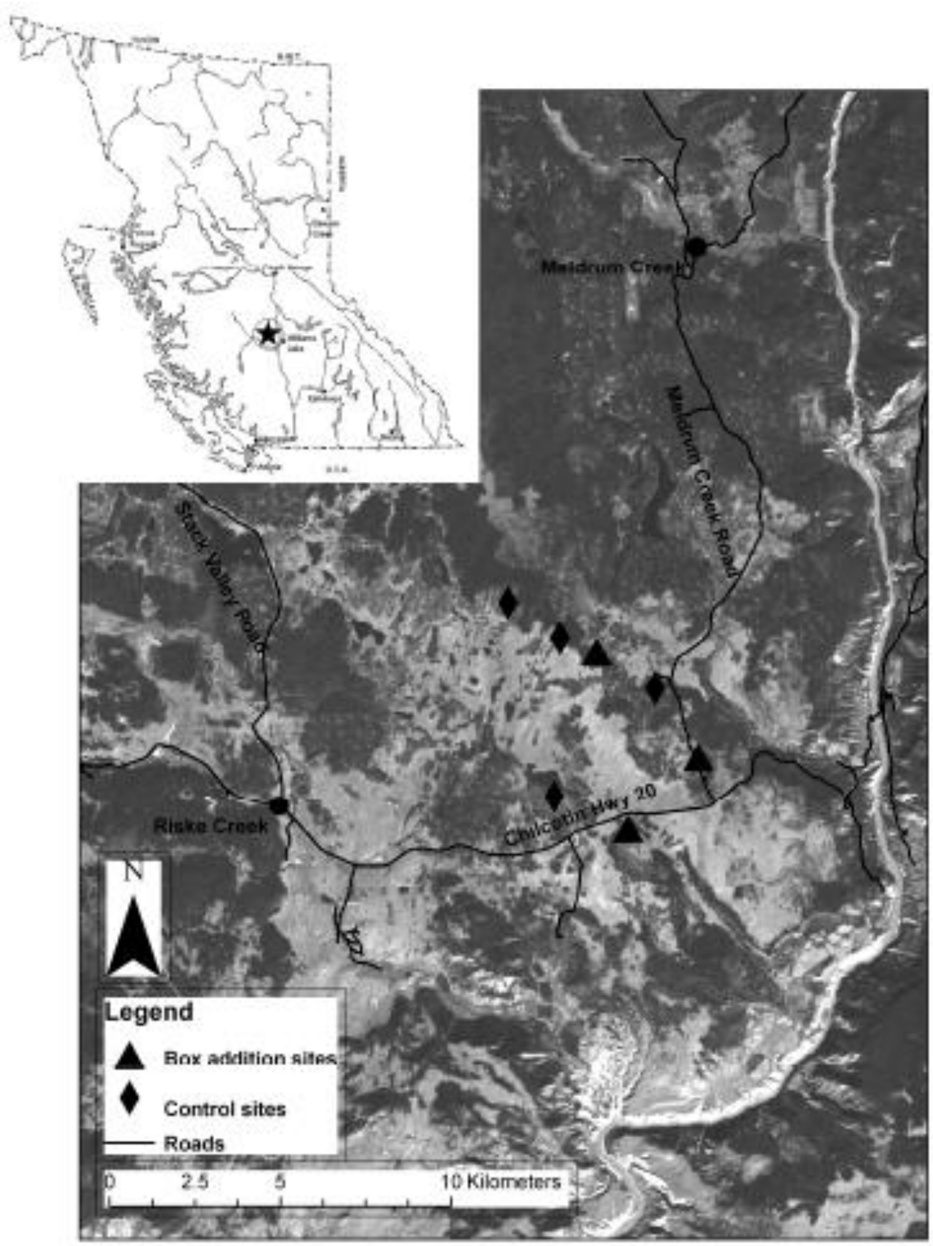

Figure 1: Map of interior British Columbia, Canada with nest box addition sites indicated (Aitken and Martin 2011).

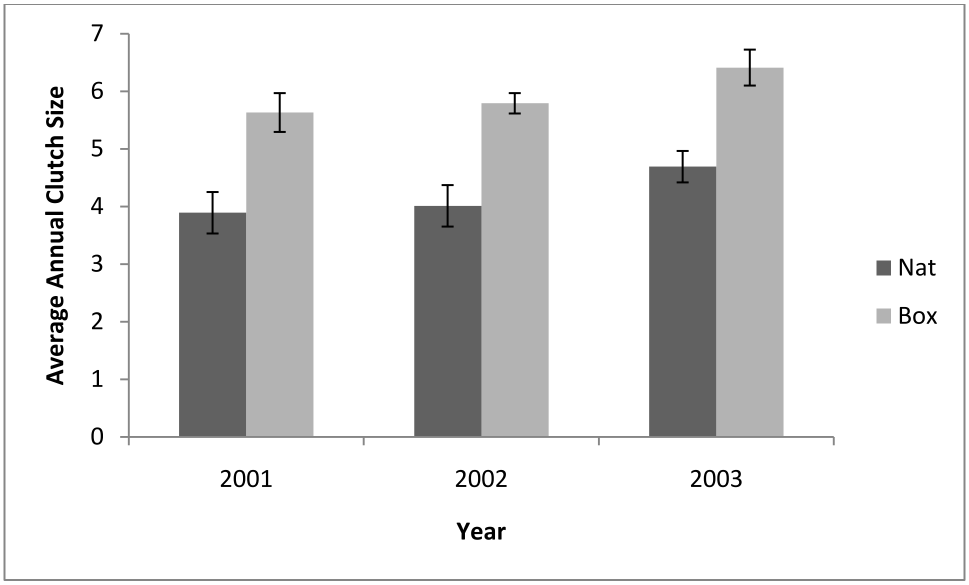

Figure 2: Histogram of average annual clutch size for tree swallow breeding pairs in cavities and nest boxes in years 2001 (boxes:n=19, cavities:n=22), 2002(boxes:n=43, cavities:n=23), and 2003(boxes:n=21, cavities:n=29) in interior British Columbia Canada.

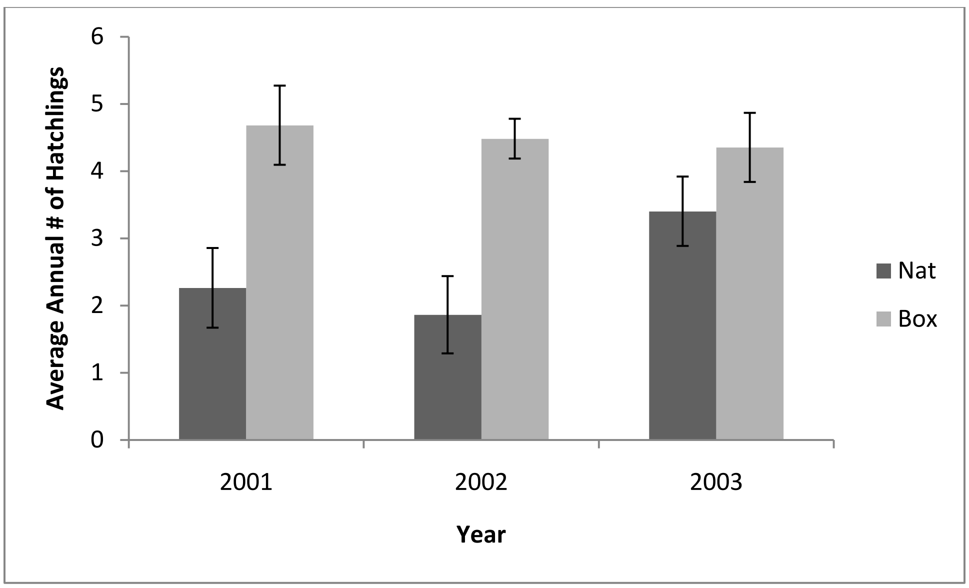

Figure 3: Histogram of average annual number of hatchlings for tree swallow breeding pairs in cavities and nest boxes for years 2001(boxes:n=19, cavities:n=22), 2002(boxes:n=43, cavities:n=23) and 2003(boxes:n=21, cavities:n=29) in interior British Columbia, Canada.

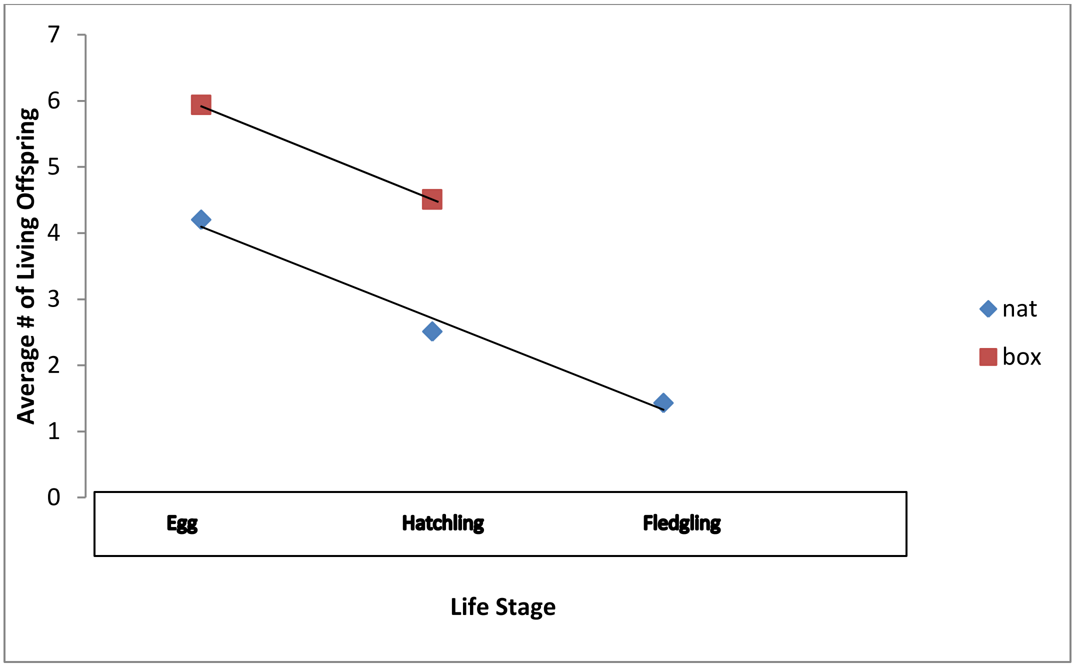

Figure 4: Plot with trend line of average number of offspring for tree swallow breeding pairs housed in nest boxes (n=83) and natural cavities (n=74) (n=29 for hatchlings) for years 2001-2003 in interior British Columbia, Canada as offspring pass through progressive life stages. Fledgling detection not recorded in nest box dataset.

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APPENDIX

Raw extracted data of clutch size and max observed living hatchlings for Tree Swallows in nest-boxes (box)and natural cavities (nat) for years 2001, 2002 and 2003.

Treatment	Year	Replicate	Clutch size	Hatchlings
Box	2001	1	5	
Box	2001	2	6	5
Box	2001	3	6	6
Box	2001	4		
Box	2001	5	6	6
Box	2001	6	6	5
Box	2001	7	6	6
Box	2001	8	6	6
Box	2001	9	4	0
Box	2001	10	6	5
Box	2001	11	5	
Box	2001	12	6	4
Box	2001	13	4	4
Box	2001	14	6	6
Box	2001	15	4	3
Box	2001	16	7	3
Box	2001	17	4	4
Box	2001	18	3	3
Box	2001	19	4	3
Box	2002	1	6	6
Box	2002	2	4	4
Box	2002	3	6	0
Box	2002	4	6	6
Box	2002	5	6	6
Box	2002	6	5	4
Box	2002	7	5	2
Box	2002	8	4	4
Box	2002	9	5	5
Box	2002	10	5	3
Box	2002	11	6	4
Box	2002	12	6	3
Box	2002	13	6	6
Box	2002	14	5	1
Box	2002	15	4	4
Box	2002	16	8	8
Box	2002	17	5	5
Box	2002	18	6	5
Box	2002	19	5	
Box	2002	20	5	3
Box	2002	21	5	4
Box	2002	22	7	5
Box	2002	23	7	6
Box	2002	24	6	6
Box	2002	25	6	6
Box	2002	26	6	5
Box	2002	27	6	6
Box	2002	28	6	4
Box	2002	29	6	6

Box	2002	30	7	7
Box	2002	31	5	5
Box	2002	32	7	5
Box	2002	33	7	4
Box	2002	34	6	1
Box	2002	35	6	4
Box	2002	36	6	0
Box	2002	37	5	4
Box	2002	38	7	6
Box	2002	39	6	5
Box	2002	40	6	6
Box	2002	41	6	4
Box	2002	42	7	7
Box	2002	43	5	4
Box	2003	1	6	3
Box	2003	2	4	4
Box	2003	3	5	4
Box	2003	4	5	3
Box	2003	5	6	5
Box	2003	6	5	3
Box	2003	7	6	4
Box	2003	8	6	4
Box	2003	9	6	5
Box	2003	10	6	3
Box	2003	11	5	3
Box	2003	12	6	4
Box	2003	13	6	4
Box	2003	14	8	7
Box	2003	15	6	2
Box	2003	16	7	4
Box	2003	17	7	4
Box	2003	18	7	5
Box	2003	19	6	4
Box	2003	20	7	5
Box	2003	21	6	4
Nat	2001	1	3	3
Nat	2001	2	4	2
Nat	2001	3		
Nat	2001	4	2	
Nat	2001	5	4	3
Nat	2001	6	2	0
Nat	2001	7	2	0
Nat	2001	8		0
Nat	2001	9		
Nat	2001	10		
Nat	2001	11	7	7
Nat	2001	12	3	3
Nat	2001	13	2	2
Nat	2001	14	1	0
Nat	2001	15	6	5
Nat	2001	16	6	5
Nat	2001	17		
Nat	2001	18		
Nat	2001	19	5	4
Nat	2001	20	5	0
Nat	2001	21		
Nat	2001	22	2	0

Nat	2002	1		
Nat	2002	2		4
Nat	2002	3	3	3
Nat	2002	4	5	
Nat	2002	5	3	0
Nat	2002	6	4	0
Nat	2002	7	1	
Nat	2002	8	5	5
Nat	2002	9		
Nat	2002	10	5	
Nat	2002	11		0
Nat	2002	12		0
Nat	2002	13	3	3
Nat	2002	14	4	3
Nat	2002	15	4	0
Nat	2002	16		3
Nat	2002	17		
Nat	2002	18		0
Nat	2002	19	4	4
Nat	2002	20	4	3
Nat	2002	21	3	
Nat	2002	22	3	0
Nat	2002	23	5	0
Nat	2003	1		
Nat	2003	2	4	
Nat	2003	3	5	
Nat	2003	4	2	0
Nat	2003	5	7	4
Nat	2003	6	3	0
Nat	2003	7	5	4
Nat	2003	8	7	5
Nat	2003	9	6	4
Nat	2003	10		
Nat	2003	11		
Nat	2003	12	6	
Nat	2003	13	2	2
Nat	2003	14		
Nat	2003	15	3	3
Nat	2003	16	4	4
Nat	2003	17	6	6
Nat	2003	18	3	3
Nat	2003	19		
Nat	2003	20	4	0
Nat	2003	21	5	4
Nat	2003	22	4	4
Nat	2003	23		
Nat	2003	24		
Nat	2003	25	3	3
Nat	2003	26	7	
Nat	2003	27	3	3
Nat	2003	28	6	6
Nat	2003	29	5	3