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Fundy Model Forest Year-end Report 2006

Apparent survival and population viability of a forest bird indicator species in relation to landscape-scale forest management

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Executive Summary

We have spent the last six years determining habitat relationships for forest birds in an effort to predict which species are most seriously affected by forest management ('indicator species') in the Fundy Model Forest (Young 2003, Betts 2005). Our preliminary results suggest that the apparent survival (heretofore 'survival') and reproductive success of indicator species vary according to the intensity of forest harvesting that has occurred at the landscape scale. However, small sample sizes make our results inconclusive.

Large-scale ecological experiments are necessary to test theories on habitat use of forest birds, particularly in cooperation with forest managers (Diamond 1999b). Birds may be influenced more by the context of the landscape surrounding a patch than by the content (individual stand characteristics) of a patch (Diamond 1999a). One of our focal species (Black-throated Green Warbler, BTNW, *Dendroica virens*) is a habitat generalist which uses a variety of forest types and ages (Morse 1993); the other (Blackburnian Warbler, BLBW, *D. fusca*) is a specialist on mature mixed-wood forest (Morse 1994, Girard et al. 2004, Young 2005). Both are dependent on mature forest to some extent (Morse 1993, 1994). We use banded birds to extrapolate survival rates to determine the effect of a reduction of mature forest on the landscape-scale on their demographics.

We will use our survival rates to construct population viability analysis (PVA) models, which allow researchers to: (1) assess the status of a current population of a species, (2) project the population growth of a species under current conditions based on species-specific data, (3) explore species response to different management scenarios, and (4) assess any risks to a species in regard to reproductive success, mortality, and survival (Akçakaya and Sjögren-Gulve 2000, Lindenmayer et al. 2001, Reed et al. 2002). PVA is most useful when addressing questions involving one or two focal species (Akçakaya and Sjögren-Gulve 2000). In order to develop PVAs we require detailed knowledge of the life histories (survival, reproductive output, and dispersal distances) of the animals of interest (Akçakaya and Atwood 1997). Migratory songbird demographics and life histories, including reproductive output and dispersal, have been studied often and some estimates of reproductive success and dispersal distances exist for *Dendroica* warblers (Holmes et al. 1996, Cilimburg et al. 2002, Jones et al. 2004), but the major gap

in data is survival. For the indicator species we have identified in earlier work such information does not exist. In this project we will collect the survival component necessary to build PVAs. **This information on survival will also be useful to forest managers in the development of forest policy on appropriate amounts of habitat to be conserved.**

The project will contribute to the "integrated megaproject" by including the Pollett River and adjacent watersheds, with the potential to integrate vegetation sampling with other projects, and by focussing on the group's priority of determining thresholds for the amount of mixedwood forest needed for wildlife.

Objectives and Goals

We will make use of birds already colour-banded (from 2000-2005) and relate survival to the loss of suitable habitat (here I define 'suitable habitat' as all mature forest in the study area). In 2006 we will incorporate a component to study breeding dispersal and movement of individuals outside of the bounds of our resight radii. This will help us gather more accurate survival estimates. Betts et al. (*In Press*) presented evidence of post-timber harvest breeding dispersal so we know that some marked individuals are moving due to this event. Birds also seem to shift territories slightly from year-to-year in some occasions.

We will use our estimates of survival, along with productivity and dispersal estimates from the literature, to input into PVA models that will assess a range of simulated forest management scenarios on forest bird populations (Lindenmayer et al. 2001). These computer-simulation models will provide important information on relationships between population status (from the survival estimates) and potential population-limiting factors (decreasing amounts of mature forest) (Anders and Marshall 2005).

Determining whether there is a difference in survival between habitat with a high degree of loss and more connected, continuous habitat is critical. The question asked by forest managers is: *How much* habitat needs to be maintained? Answering this question at a large scale will allow forest managers to develop forest policy on appropriate amounts of habitat to be conserved.

I will use morphometric measurements (age, weight, and wing length) obtained by capturing and colour-banding the two focal species (Pyle 1997) to examine the relationships between body condition and survival, and age and survival. Heavier birds are thought to have higher survival rates (Green 2001); likewise, older birds are thought to be more prevalent in landscapes (2 km radii) with high amounts of suitable habitat and have higher survival rates in these landscapes (Holmes et al. 1996, Burke and Nol 2001, Bayne and Hobson 2002).

By relating these factors to survival of the focal species, new knowledge will be gained that will contribute to our understanding of forest management influences (causing habitat reduction) on Blackburnian and Black-throated Green Warbler habitat requirements and demographic parameters.

The specific objectives of this project are:

(1) To determine the influence of a decrease of mature forest at the landscape-scale on the apparent annual survival of a forest indicator species with narrow habitat tolerance (BLBW) and a congener with wider habitat tolerance (BTNW).

(2) To determine the influence of a decrease of mature forest at the landscape-scale on the within-season survival of the two focal species.

(3) To determine if there are any age or size relationships of individuals banded along the habitat reduction gradient.

(4) To use these data to develop PVAs that will assess a range of forest management scenarios on forest bird populations.

Study area and research design

The field work for this project commenced in the summer of 2004, continued in the summer of 2005, and will continue in the summer of 2006. Research is conducted in southeastern New Brunswick in the Greater Fundy Ecosystem and Fundy Model Forest, and includes Fundy National Park. My overall strategy is to measure apparent annual survival of the two study species along the habitat reduction gradient within the 4,000 km^2 study area. Fundy National Park is a relatively small protected area ($206km^2$) within the study area with >80% mature forest, surrounded by a matrix of managed forests of ~12-50% mature forest, making it a useful study location for this project.

Field work will be conducted by first identifying all mature forest stands in study area using Geographical Information Systems (GIS) coverages. Both focal species are dependent on mature forest to some extent (Morse 1993, 1994) and we chose to include all mature forest to maximize our probability of encountering, and subsequently banding each species.

Patches were not randomly selected among all possible mature forest patches, but were chosen to represent a range of amount of mature forest in small patches and in large, more continuous patches. Samples were collected in mature forest patches according to a stratified randomized design within the study area (Fig. 1 & 2). The samples are spread across a wide spatial range such that any differences we detect will not be confounded spatially. The amount of mature forest contained within a 2000 m radius circle (1200 ha landscape) surrounding the banding location was calculated and converted to a percentage of the total area using ArcView GIS.

Building on comparatively smaller sample sizes from a previous related study (Betts 2005), we banded (with a Canadian Wildlife Service aluminum band and a unique combination of colour bands on the legs of captured birds) as many individual birds as possible (Table 1) in 2004 and 2005, while simultaneously resighting all previously banded individuals to obtain a 'return rate.' The return rates are then converted to survival rates using program MARK (White and Burnham 1999). MARK is a flexible capture-mark-recapture/resight (CMR) program which provides parameter estimates from banded individuals re-encountered, or resighted, at a later time (White and Burnham 1999).

A related issue is whether habitat loss affects survival directly (within the breeding season) or indirectly (affects survival during migration or wintering season). Within-season survival allows us to look at resight probabilities independent of survival. We would expect within-season survival to be different between landscapes with low and high habitat amounts, respectively. However, habitat loss might also just reduce body condition which may have a lagged effect on survival (lower weight birds might not be able to survive as well on migration). The power to detect a difference between annual and within-season survival is increased dramatically by looking at the resight probability within-season. To test survival directly, we resighted a subset (Table 2) of known banded individuals every 10 to 14 days in 2005. The resighting, as opposed to recapturing, of banded individuals offers a means of avoiding the often stressful, and more time consuming, repeated capture of individuals (Brownie and Robson 1983).

Table 1. Number of banded individuals of both focal species (BLBW=Blackburnian Warbler, BTNW=Black-throated Green Warbler) from 2000-2005.

SPECIES	2000	2001	2002	2003	2004	2005	Total
BLBW	15	16	16	17	101	48	213
BTNW	10	62	45	19	149	74	359
TOTAL	25	78	61	36	250	122	572

Table 2. Subset (N) of individuals resighted a minimum of three times to test for within-season survival in 2005. Survival estimate derived from MARK (%).

SPECIES	N	Survival estimate
BLBW	34	0.7690
BTNW	72	0.9241

Methods

Banding is performed using audio playback (of species-specific territorial male songs) and mist-nets with 30mm mesh size. Adult forest songbirds are site-faithful, returning to the same places to breed from year-to-year (Holmes et al. 1996), thus allowing survival studies to be performed.

In following years (or 10-14 day periods for within-season subset), we attempt to resight each banded individual a minimum of two times throughout the season. Resighting is achieved by audio playback in the exact location (using Geographic Positioning System (GPS) coordinates) that the bird was banded in originally. We first use a Black-capped Chickadee mobbing tape for 5 minutes and scan the immediate area for banded individuals. If the bird is not resighted a species-specific tape is played for 5 minutes at banding site and repeated at 50 m radii in each cardinal (N, E, S, W) direction for 5 minutes. A minimum of 30 minutes and a maximum of 60 minutes are spent on each bird unless it is successfully resighted before.

Three years of data -- one of marking and two of resighting -- are necessary to produce a reliable survival estimate using CMR methods (Anders and Marshall 2005). Brownie and Robson (1983) suggest that a minimum of two sighting periods (in this study, months [for within-season survival] and years [for apparent annual survival]) are required.

Analysis

Objectives 1 &2: MARK gives estimates for survival using marked individuals at different encounter intervals. These will be quantified as within-season and annually, respectively, and both focal species will be analyzed individually and compared to each other. MARK is particularly beneficial because it allows testing of differences between survival and resight probabilities between and within any groups of our choosing (White and Burnham 1999). By comparing different models with co-variates (e.g. habitat amount, age, condition index, species, sex, etc...) of our selection we can use AIC (Akaike's Information Criterion) to sort the most parsimonious models (Burnham and Anderson 2002). $QAIC_c$ corrects for an 'overdispersion' (under-estimated variances and over-confidence in survival estimates) of data and small sample sizes. $\Delta QAIC_c$ is the $QAIC_c$ difference between the top ranked model with the smallest $QAIC_c$ value and competing models. Burnham and Anderson (2002) specify that a $\Delta QAIC_c$ of 0-2 shows strong support for both models; $\Delta QAIC_c$ of 4-7 shows 'considerable' support for the top model; and $\Delta QAIC_c > 10$ shows 'essentially' no support for the competing model.

Objective 3: I will perform Chi-square tests to determine any relationship between the ages of individuals of the two focal species banded along the habitat reduction gradient. Ages of banded birds are determined using criteria set forth by Pyle (1997). 'AHY' ('After Hatch Year') means that an individual is in 'at least its second calendar year' and essentially means that it is of unknown age. 'ASY' ('After Second Year') means that an individual is in at least its third calendar year, while 'SY' ('Second Year') means that a bird is in its second calendar year.

I will perform two-sample t-tests to determine any relationship between condition index (measured as body mass/wing length) of individuals of the two focal species banded at the extremes of the habitat amount gradient because if we do not detect a difference at the extremes, we will not detect it in between.

Objective 4: Reed et al. (2002) state that PVAs developed for populations that are potentially affected by the spatial distribution of habitat must explicitly address the changes in habitat quality and quantity. Survival rates collected in this study address differences in habitat quantity and will be used to develop PVAs.

I will use RAMAS GIS (Anders and Marshall 2005) population software to develop my PVA models after the 2006 field season. RAMAS GIS allows the linkage of spatial data (available in Geographic Information Systems) with population and habitat dynamics models. Habitat models to be used in PVA were developed in previous Fundy forest bird research (Betts et al. 2006).

Preliminary Results

Tables 3 to 6 show AIC tables for both focal species in relation to within-season survival. For both species the best model (A) showed constant survival and resight probabilities, indicating that time was not a factor in these models. Model A was highly favoured for both BLBW and BTNW, so we can be certain that of all of our models, this is the best available (Burnham and Anderson 2002).

Tables 7 to 10 show AIC tables for apparent annual survival of both species. For BLBW the best model (A) showed constant survival and resight probabilities (Table 7) while the best model for BTNW showed survival probability as a function of time with constant resight probability. Both models are strongly supported.

Figures 3 & 4 show box plots for condition indices of all birds banded from 2000-2005 against habitat amount. There is no significant difference of condition indices at the extremes of the habitat amount gradient (Fig. 3, $p=0.28$; Fig. 4, $p=0.22$) for either species. These results are obtained by two-tailed t-tests.

Figures 5 & 6 show Chi-square tests of proportions of ages of both focal species banded in the three habitat amount categories. There is no significant difference for either species (Fig. 5, $0.05<p<0.10$; Fig. 6, $p>0.25$).

General Discussion

We must stress that these results are preliminary and caution should be taken with inference to the general population of our focal species. For within-season survival, these are the first rates reported to our knowledge and as such, there is no reference point for comparison. Interestingly, for both species, the resight probabilities (Tables 4 & 6) were quite low, indicating that detection was difficult, possibly resulting in under-estimated survival rates. This may have been particularly true for BLBW which forage in the uppermost section of the canopy (Morse 1994) and are difficult to detect under ideal circumstances. However, the resight probability for BTNW was lower than BLBW (66.83% [Table 6] vs. 78.28% [Table 4]). It is our belief that there is a great deal more movement of individuals within-season than was previously thought. Individuals appear to be 'off territory' fairly often. By incorporating a dispersal component this summer and continuing the within-season survival study, we will increase the accuracy of our estimates.

Model A for BLBW apparent annual survival had a low resight probability of 73.44% (Table 8) again indicating the difficulty of resighting BLBW. The high standard error of 13.87% is suggestive of uncertainty in our survival estimate of 33.41%.

Model A for BTNW shows time-dependent survival with an extremely high survival rate of 93.19% over the first year (Table 10). In 2000, a total of ten individuals were banded and all were subsequently resighted in 2001. This is an incredible feat; one that we believe is highly uncharacteristic of the 'true' survival of this species, hence the term 'apparent survival.' It is likely that the time-dependent survival model was selected as the best model for BTNW solely because of the events from 2000-2001. Thus, we believe that exclusion of this year in future survival models will result in a more accurate survival estimate for this species.

There is no significant difference for condition indices (Fig. 3 & 4) by habitat amount for either of our focal species. There are also no significant age differences by habitat amount for either species (Fig. 5 & 6). Our study does not support the hypothesis that larger, older birds are disproportionately present in landscapes with higher amounts of mature forest. We have not tested the prediction that larger and/or older birds have higher survival rates. This will be done after the 2006 field season.

Our project is the first of its kind testing theories of survival at such a large spatial scale with substantial sample sizes. We will also provide the first estimates of survival for either of our focal species. After the completion of the field season in 2006 we will re-analyze our survival rates using resight data gathered this year. We will use these survival estimates to input into PVA models to determine the influence of a range of forest management scenarios on our focal species. These models will contribute to our overall understanding of the basic biology of two species of forest songbirds as well as provide information useful for managers to decide how much mature forest these species require.

Costs of the project

The project was expected to cost $44,400. Total costs of the project were actually $40,553.70. The difference was made up from spending less on food and saving on truck rental costs. NBDNRE supplied us with two field vehicles that were cheaper than renting through a car rental agency. Costs are expected to be higher in 2006 due to rising gasoline prices this summer. Fundy National Park has granted us $10,000 and the NB Wildlife Trust Fund has granted us $12,900. In kind support from NBDNRE is again being provided in the use of two trucks.

Time frame of the project

Training began the 25th of May, banding commenced on the 30th of May and ended on July 27th of 2005. Similar timing will likely take place for the 2006 field season.

Promotion

In 2005, Brad Zitske presented this project at the Fundy National Park amphitheatre (July 5), to the Moncton Field Naturalists club (Oct. 18), at the Society of Canadian Ornithologists annual meeting in Halifax, NS (Oct. 20-22), at the ACWERN annual workshop (Nov. 5), and at the Faculty of Forestry and Environmental Management (UNB) seminar (Mar. 3, 2006). Further presentations will be given until completion of project in 2007. Acknowledgements to the FMF have been and will continue to be made in presentations and publications.

Table 3. Competing models of BLBW within-season resight rates in 2005 ranked by ascending $QAIC_c$, including model selection criteria.

Model	$QAIC_c$	Δ $QAIC_c$	Akaike weight	Model likelihood	K	Model deviance
A {Φ(.) p(.)}	102.618	0.00	0.77094	1.0000	2	12.797
B {Φ(t) p(.)}	106.706	4.09	0.09984	0.1295	4	12.369
C {Φ(.) p(t)}	106.730	4.11	0.09869	0.1280	4	12.392
D {Φ(t)p(t)}	109.076	6.46	0.03053	0.0396	5	12.354

Parameter definitions: Φ = survival, p = resight probability, (.) parameter constant, (t) parameter as a function of time, K = number of parameters.

Table 4. BLBW within-season survival and resight probabilities in 2005 as a maximum-likelihood estimate (MLE) generated in MARK (White and Burnham 1999) from model A {Φ(.) p(.)}, with survival and resight probabilities both constant. Survival rates bolded.

Parameter	MLE	SE	95 % Confidence Limit	
			Lower	Upper
Φ: 2005	**0.7690**	0.0730	0.5981	0.8817
p: 2005	0.7828	0.0931	0.5521	0.9133

Parameter definitions: Φ = survival, p = resight probability

Table 5. Competing models of BTNW within-season resight rates in 2005 ranked by ascending $QAIC_c$, including model selection criteria.

Model	$QAIC_c$	Δ $QAIC_c$	Akaike weight	Model likelihood	K	Model deviance
A {Φ(.) p(.)}	214.422	0.00	0.65583	1.0000	2	9.730
B {Φ(t) p(.)}	217.379	2.96	0.14952	0.2280	4	8.456
C {Φ(.) p(t)}	217.460	3.04	0.14351	0.2188	4	8.538
D {Φ(t)p(t)}	219.524	5.10	0.05115	0.0780	5	8.433

Parameter definitions: Φ = survival, p = resight probability, (.) parameter constant, (t) parameter as a function of time, K = number of parameters.

Table 6. BTNW within-season survival and resight probabilities in 2005 as a maximum-likelihood estimate (MLE) generated in MARK (White and Burnham 1999) from model A {Φ(.) p(.)}, with survival and resight probabilities both constant. Survival rates bolded.

Parameter	MLE	SE	95 % Confidence Limit	
			Lower	Upper
Φ: 2005	**0.9241**	0.0539	0.7299	0.9821
p: 2005	0.6683	0.0656	0.5300	0.7826

Parameter definitions: Φ = survival, p = resight probability

Table 7. Competing models of BLBW resight rates from 2000-2005 ranked by ascending $QAIC_c$, including model selection criteria.

Model	$QAIC_c$	Δ $QAIC_c$	Akaike weight	Model likelihood	K	Model deviance
A {Φ(.)p(.)}	231.153	0.00	0.83537	1.0000	2	16.258
B {Φ(t)p(.)}	235.633	4.48	0.08894	0.1065	6	12.339
C {Φ(t)p(t)}	236.433	5.28	0.05962	0.0714	9	6.592
D {Φ(.)p(t)}	239.055	7.90	0.01607	0.0192	6	15.760

Parameter definitions: Φ = survival, p = resight probability, (.) parameter constant, (t) parameter as a function of time, K = number of parameters.

Table 8. BLBW and resight probabilities from 2000-2005 as a maximum-likelihood estimate (MLE) generated in MARK (White and Burnham 1999) from model A {Φ(t) p(.)}, with survival and resight probabilities both constant. Survival rates bolded.

Parameter	MLE	SE	95 % Confidence Limit	
			Lower	Upper
Φ: 2005	**0.3341**	0.0608	0.2269	0.4616
p: 2005	0.7344	0.1387	0.4068	0.9177

Parameter definitions: Φ = survival, p = resight probability

Table 9. Competing models of BTNW resight rates from 2000-2005 ranked by ascending $QAIC_c$, including model selection criteria.

Model	$QAIC_c$	Δ $QAIC_c$	Akaike weight	Model likelihood	K	Model deviance
A {Φ(t) p(.)}	405.800	0.00	0.89324	1.0000	6	8.620
B {Φ(t) p(t)}	410.105	4.30	0.10381	0.1162	9	6.631
C {Φ(.) p(.)}	417.762	11.96	0.00226	0.0025	2	28.798
D {Φ(.) p(t)}	420.121	14.32	0.00069	0.0008	6	22.941

Parameter definitions: Φ = survival, p = resight probability, (.) parameter constant, (t) parameter as a function of time, K = number of parameters.

Table 10. BTNW and resight probabilities from 2000-2005 as a maximum-likelihood estimate (MLE) generated in MARK (White and Burnham 1999) from model A {Φ(.) p(.)}, with survival and resight probabilities both constant. Survival rates bolded.

Parameter	MLE	SE	95 % Confidence Limit	
			Lower	Upper
Φ: 2005	**0.9319**	0.1259	0.2187	0.9985
Φ: 2005	**0.3078**	0.0615	0.2015	0.4392
Φ: 2005	**0.2454**	0.0571	0.1509	0.3731
Φ: 2005	**0.3218**	0.0873	0.1775	0.5091
Φ: 2005	**0.2703**	0.0452	0.1912	0.3673
p: 2005	0.8727	0.0811	0.621	0.9663

Parameter definitions: Φ = survival, *p* = resight probability

Fig. 1. Spatial distribution of all Black-throated Green Warblers banded from 2000 to 2005. Habitat amount is converted to a percentage of mature forest at 2000 m scale.

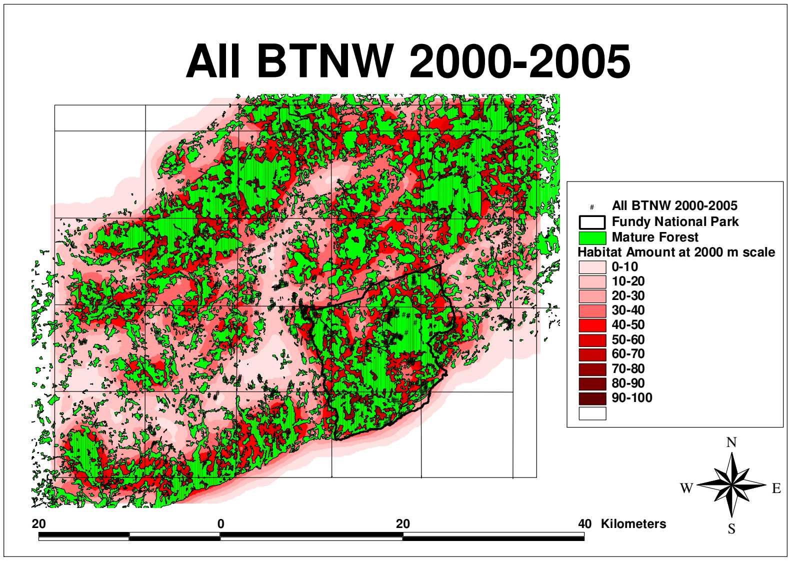


Fig. 2. Spatial distribution of all Blackburnian Warblers banded from 2000 to 2005. Habitat amount is converted to a percentage of mature forest at 2000 m scale.

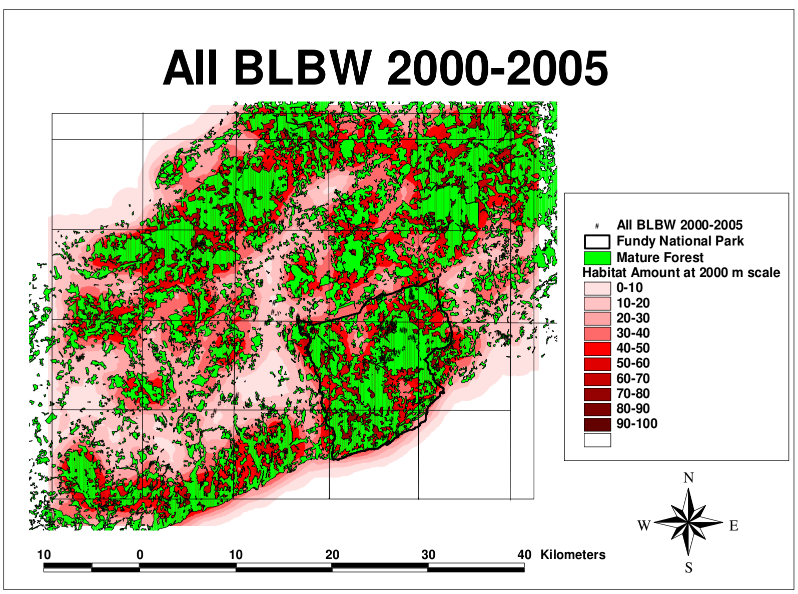
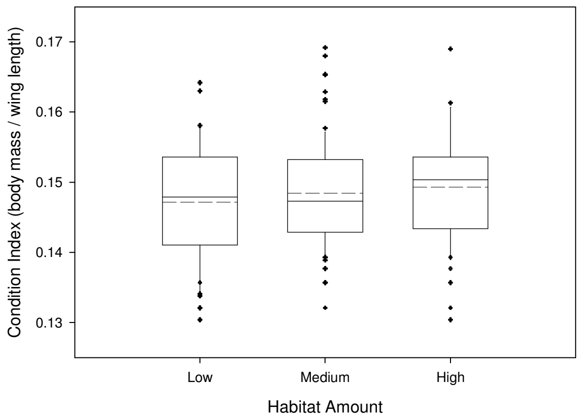
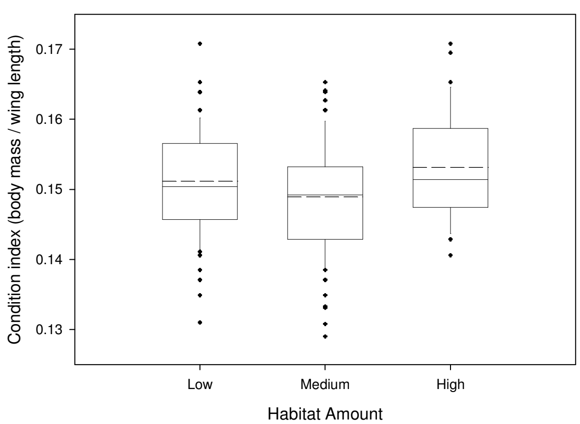


Fig. 3. Box plots comparing condition indices (body mass / wing length) between habitat amount groupings (Low = < 30%, Medium = 30-70%, High = > 70%) for Blackburnian Warblers (N = 163) banded from 2000-2005. Medians (horizontal line within each box), means (dashed line within each box), quartiles (top and bottom of box), 0.05 and 0.95 quantiles (tips of vertical whiskers), and outliers (crosshairs) are shown for each habitat amount. Results below from two-tailed t-test of Low vs. High mean condition indices.



T value -1.0830
P value 0.2820
Degrees of Freedom 79

Fig. 4. Box plots comparing condition indices (body mass / wing length) between habitat amount groupings (Low = < 30%, Medium = 30-70%, High = > 70%) for Black-throated Green Warblers (N = 233) banded from 2000-2005. Medians (horizontal line within each box), means (dashed line within each box), quartiles (top and bottom of box), 0.05 and 0.95 quantiles (tips of vertical whiskers), and outliers (crosshairs) are shown for each habitat amount. Results below from two-tailed t-test of Low vs. High mean condition indices.



T value -1.1980
P value 0.2332
Degrees of Freedom 126

Fig. 5. Chi-square test in 3 X 3 contingency table showing ages (AHY = After Hatch Year, ASY = After Second Year, SY = Second Year) of Blackburnian Warblers banded from 2000-2005 (N) by Habitat Amount (Low = < 30%, Medium = 30-70%, High = > 70%). Results of chi-square test are below.

BLBW Age by Habitat Amount

	Low	Medium	High	Total
AHY	3	3	5	11
ASY	45	73	20	138
SY	24	25	15	64
Total	72	101	40	213

Degrees of freedom: 4
Chi-square = 9.47142527601945
For significance at the .05 level, chi-square should be greater than or equal to 9.49.
The distribution is not significant.
p is less than or equal to 0.10.

Fig. 6. Chi-square test in 3 X 3 contingency table showing ages (AHY = After Hatch Year, ASY = After Second Year, SY = Second Year) of Black-throated Green Warblers banded from 2000-2005 (N) by Habitat Amount (Low = < 30%, Medium = 30-70%, High = > 70%). Results of chi-square test are below.

BTNW Age by Habitat Amount

	Low	Medium	High	Total
AHY	19	16	7	42
ASY	76	78	29	183
SY	54	63	17	134
Total	149	157	53	359

Degrees of freedom: 4
Chi-square = 1.51499146011294
For significance at the .05 level, chi-square should be greater than or equal to 9.49.
The distribution is not significant.
p is less than or equal to 1.

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