THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

SCHOOL OF FOREST RESOURCES

THE EFFECTS OF TEMPORAL AND HABITAT PARTITIONING IN NESTBOX SELECTION OF THREE SECONDARY CAVITY NESTING BIRDS ON THE PENN STATE UNIVERSITY CAMPUS

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ABSTRACT

Three secondary cavity nesters on the Penn State Campus that often nest in artificial nestboxes are the eastern bluebird (*Sialia sialis*), the tree swallow (*Tachycineta bicolor*), and the house wren (*Troglodytes aedon*). The objective of my study was to examine artificial nestboxes as a limiting resource within the three species and to determine the method of niche partitioning used to reduce competition. To test this, I examined 59 established nestboxes during the summer of 2009. Species nestbox selection was analyzed to determine significant differences in the time of box choice and habitat type. Timing of nestbox selection differed significantly among the three species ($F = 20.94$, $p < 0.001$). Eastern bluebird mean nest date was May 29 (+/- 3.00 days S. E.), for tree swallows: May 15 (+/- 1.27 days S. E.), and for house wrens: June 14 (+/- 3.62 days S. E.). I plotted box occupancy over time to examine the breeding techniques of the three species and found that eastern bluebirds occupy nestboxes throughout the season, tree swallows occupy during early season, and house wrens occupy during late season. Tree stem count within 11.3 m, shrub stem count within 5 m, percent forb, brush, and grass cover within 5 m, and percent coverage of entrance hole were analyzed for each nestbox. It was determined that only tree stem count had a significant difference in the boxes chosen by house wrens when compared to tree swallows and eastern bluebirds ($F = 5.60$, $p = 0.008$). It was determined that temporal separation between the three species was used to reduce direct competition while habitat separation was somewhat secondary.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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SECTION 1

INTRODUCTION

Interspecific competition is a complex area of study that is unified by the principal of competitive exclusion. This principal states two species cannot occupy similar niches, one species will always displace the other and either drive the second species to extinction, or force the second species to shift its niche. This principal also proposes that species can coexist if they adapt to effectively partition resources (Gause 1934). Cohabitating species have developed adaptations such as the exploitation of: different microhabitats, prey at different life stages, or the same habitat at different time periods. The methods by which species partition resources are classified in four separate categories: food, space, time, and habitat type (Keddy 2001). It should be emphasized, however, that these categories are not independent of one another but inherently linked (Pontin 1982). This principal does, however, have underlying flaws. Though it is possible to prove that the niches of two species may not be identical, the theory cannot be disproven as it is impossible to measure all variables in question (Sinclair et al. 2006). Despite the apparent flaw within the principal, it remains an integral component of nearly all studies concerning habitat partitioning of coexisting species.

An important component of competitive exclusion is the theory of habitat selection. The theory states that limiting resources in the presence of interspecific competitors will cause a species to contract its niche to avoid overlap (Rosenwig 1981).

Though the theory relates specifically to habitat characteristics, temporal partitioning can also apply to the theory; coexisting species avoid direct interference by using the same resource at different times of day or during different seasons (Carothers and Jaksic 1984).

Three passerines native to Central Pennsylvania depend on cavities for nest sites: eastern bluebirds (*Sialia sialis*), tree swallows (*Tachycineta bicolor*), and house wrens (*Troglodytes aedon*). Since the agricultural revolution, forest and farm management practices in North America have led to an overall decline in standing dead trees, which provide secondary cavity nesters with breeding habitat (Zeleny 1976, Munro and Rounds 1985). Artificial nestboxes, placed in the landscape for eastern bluebirds, gained popularity in the 1960s and have compensated for the reduction in natural cavities (Parren 1991). Amateur ornithologists have worked to increase bluebird populations with the addition of nestboxes: however, the boxes attract sympatric species which compete with bluebirds for nesting space (Gowaty and Plissner 1998). If nest sites are a relatively finite resource, the three species may use different methods to exploit artificial nestboxes to coexist.

OBJECTIVE AND HYPOTHESIS

The objective of this study was to determine how the three sympatric cavity-nesting species partition the resource of nestboxes on the northern edge of the Penn State University, University Park campus. The goal was to determine what methods of niche partitioning were employed by the three passerine species to share nesting sites by examining temporal use of the boxes and habitat type. I hypothesized that the three coexisting species reduce niche overlap by either nesting at different times in the season or selecting nestboxes associated with different habitat characteristics.

To test this hypothesis, I monitored 59 artificial nestboxes during the summer of 2009. I recorded habitat characteristics and nestbox occupancy and tested whether use differed by habitat type or temporal separation.

SECTION 2

METHODS

LIFE HISTORIES

Understanding the breeding biology of each study species was an important component of the study. Nesting materials, time of nest construction, time needed to lay a full clutch, incubation period, and time from hatch to fledging were well understood before monitoring commenced.

EASTERN BLUEBIRD

Eastern bluebirds are of the order Passeriformes and family Turdidae. Their distribution is throughout the Eastern United States and South Eastern Canada and extends into areas of Mexico and Nicaragua (Gowaty and Plissner 1998). They are partial migrants that breed throughout most of their range, but are less common in the northern expanses during the winter (Gowaty and Plissner 1998, Haas and Haas 2005). They are secondary cavity nesters that breed in open and edge habitats. As a result of nestbox campaigns and increasingly milder winters, population trends have shown a 97.4% increase in populations from 1966 to 1993 (Gowaty and Plissner 1998).

They begin first nest construction in late February to early March and inhabit nestboxes until early August; most breeding pairs lay between two and three successful broods per season (Gowaty 1980, Gowaty and Plissner 1998). Time between nest completion and egg laying is between 6-8 days, females lay 1 egg / day until the clutch reaches full size (3-7 eggs). Incubation begins when the nest reaches full clutch size and typically two weeks are required until eggs hatch; the period between hatching and fledging is also two weeks (Gowaty and Plissner 1998).

Eastern bluebird nests are identified as loosely constructed cup nests made entirely of grasses or pine needles; paper, plastic, and feathers were rarely used as nesting materials (Gowaty and Plissner 1998). Bluebirds tend to select nest sites that are relatively open with occasional scattered trees or shrubs and have no discernable preference for water (Pinkowski 1979, Haas and Haas 2005).

HOUSE WREN

House wrens are of the order Passeriformes and family Troglodytidae. They breed across the United States with a North South distribution from Texas to North central Canada, and are partial migrants in central Pennsylvania (Johnson 1998, Haas and Haas 2005). House wrens begin nest construction in late April to mid-May, the first eggs of the season are usually layed in mid-May and second clutches are usually layed late June to early July (Drilling and Thompson 1991). Females lay almost as soon as nests are built, they lay one egg / day until a full clutch size is reached (between 4-7 eggs). Eggs hatch thirteen days after first egg is layed and fledge two weeks later (Johnson 1998).

House wren nests are constructed of hundreds of small sticks; the nest cups are lined with grass, bark, hair, and feathers (Johnson 1998). The breeding habitat of house wrens is largely associated with denser overstory and understory within 30m of the nest site, but areas with extremely dense understory tend to have a higher probability of nest failure. Little information is available concerning a more detailed description of the breeding habitat of house wrens (Johnson 1998).

TREE SWALLOW

Tree Swallows are of the order Passeriformes and family Hirundinidae. They are migrants in central Pennsylvania and their breeding range extends from southern Alaska into the northern portions of the U. S. (Robertson et al. 1992, Haas and Haas 2005). Nest construction begins on the last week of April to the early May (Stutchbury and Robertson 1987). Eggs are laid in early May immediately after nest completion and females lay one egg / day until full clutch size is reached (5-7 eggs) (Robertson et al. 1987). Eggs hatch two weeks after being layed and young fledge three weeks later (Robertson et al. 1992).

Tree swallow nests are made mostly of grass or pine needles; parents add feathers to nests that are usually from species of waterfowl (Robertson et al. 1992). Swallows prefer large tracts of open land with sparse trees, often near water and avoid nesting near forest edges (Stutchbury and Robertson 1987).

STUDY SITE

I monitored 59 established nestboxes of similar design. The boxes were in and around agricultural fields associated with sheep, horses, beef and dairy cattle on the northern most edge of University Park, Pennsylvania (Figure 2-1). Initially, 102 nestboxes were placed there in March of 1996 (Dunmore 1999). Of the original 102 boxes, 45 were present in 2009 and 14 nestboxes of a slightly different design were placed in one of the agricultural fields by an unknown third party after 2002. The unknown boxes were absorbed into this study and referred to as “I” boxes.

The original nestboxes were constructed of unpainted 2 cm exterior plywood and constructed with dimensions from Stokes and Stokes (1991). They were top opening with a hinged lid. The floor of the box was 10 x 14 cm and the entrance hole was 14 cm from the top of the floor and 4 cm wide. The “I” boxes were of similar construction, but opened from the side. Most of the original boxes were attached to pre-existing wooden fence posts that supported electrified wire fences. The bottoms the entrance holes to the ground were, on average, 1.0 m. The 14 “I” boxes were located at the northern most edge of the study area. They were attached to sign posts and many had predator guards, the bottoms of their entrance holes were 1.6 m above the ground. The geographic location of each nestbox was found using a handheld GPS and plotted using ArcGIS 9.3 (Table A-1)

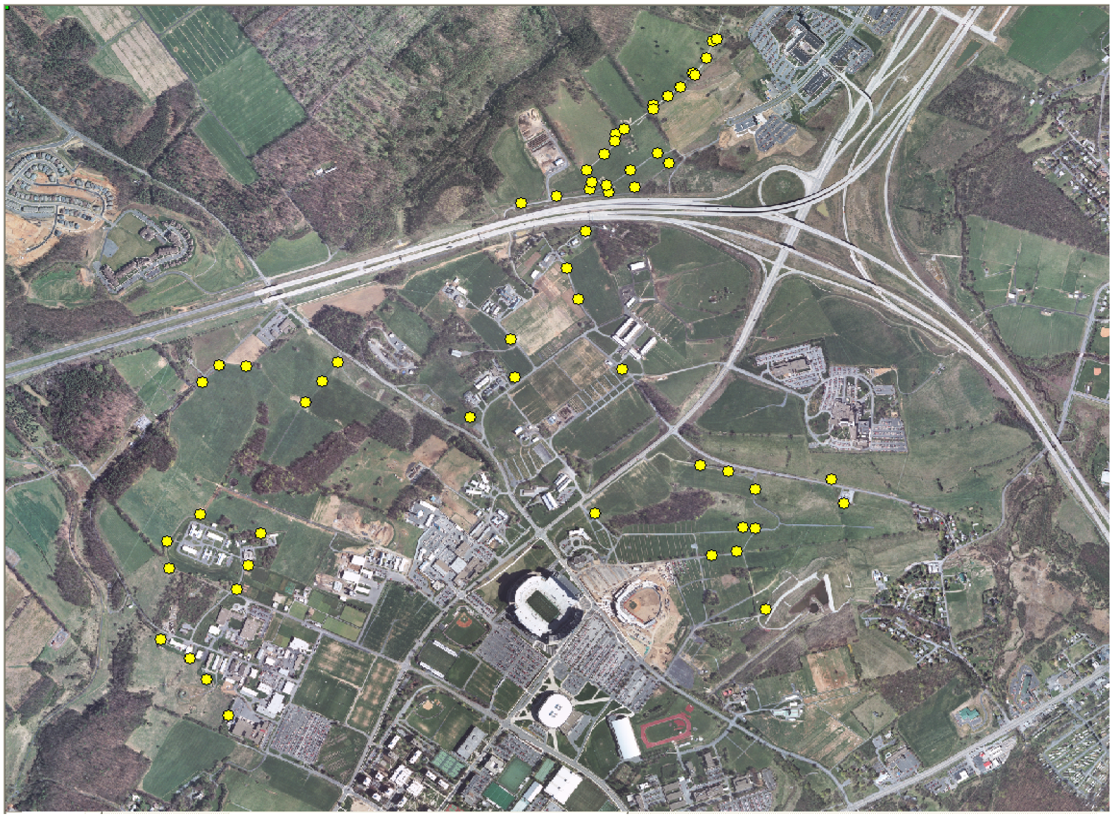

Figure 2-1 Aerial map of the study site University Park, Pennsylvania. 59 artificial nestboxes marked. Photograph from USGS.

NESTBOX MONITORING

These 59 boxes were monitored to determine species selection from May 3 through July 31, 2009. The boxes were monitored every three to seven days and checked for nesting material, eggs, young, and adult presence. To monitor each box, I approached quietly, opened, and recorded what I saw inside. Species identity was determined by nest construction. Eastern bluebird nests were cup-shaped and neatly constructed of grass or pine needles (Gowaty and Plissner 1998). Tree swallow nests were also made of grass or pine needles, but were lined with feathers (Robertson et al. 1992). House wren nests were messy and constructed with hundreds of sticks and twigs (Johnson 1998).

Boxes with nests but not a full clutch of eggs were monitored weekly, and boxes with full clutches were checked once every three days until the young were approximately seven days old; at that point the boxes were checked once every four to five days until fledging. Species presence was recorded from the week nesting material was found, to the week of nest removal.

Nests were removed and discarded for five reasons. (1) Adults were not seen or heard near the nest within the period of a week; (2) full clutches were cool to touch for repeated visits, (3) there was full mortality of all the nestlings; (4) there was a sudden absence of young, be it by predation or by fledging; or (5) the nests were constructed by house sparrows (*Passer domesticus*) or by small mammals, as they were not a part of the study.

TEMPORAL PARTITIONING

Active nestboxes were monitored for the duration of their use, a nestbox was occupied from the time nesting material first appeared in the box to the time of fledging of young or nest failure. The appearance of nesting material was recorded as a nestbox selection event. The success of each nesting attempt was recorded along with the time of occupancy for each box (Table A-13, A-14, and A-15).

The week of nestbox selection by species was plotted against time to examine the distribution of nestbox selection events throughout the season. To determine differences in the timing of nestbox use the date of nestbox selection was analyzed for each species with one-way ANOVA and Tukey error test. The proportion of boxes occupied by each species was plotted against time to examine the general use of boxes over the course of the summer.

HABITAT SELECTION

Over the course of this study, the methods of testing the hypothesis changed as the study took place. The initial collected habitat variables were more elaborate and generally based on similar studies (Munro and Rounds 1985, Radunzel et al. 1997). Orientation, percent cover of entrance hole, and percent canopy cover were collected at each box. Average litter depth, estimated percent ground cover of grass, brush, forbs, green, and bare, and stem count and species data of shrubs and saplings <8 cm DBH were collected within a 5 m radius. The stem count of trees >8 cm DBH was collected within 11.3 m (Tables A-3, A-4, A-5, A-6, A-7, A-8, A-9, A-10, A-11, A-12 and A-13). Orientation was not analyzed because many studies have found it to yield inconsistent results (Rendell and Robertson 1994). Percentages were corrected via arcsine transformation (Ahrens et al. 1990). It should be noted that during the course of the study, the habitat data for boxes 63 and 106 were lost and were not included in any habitat analysis.

To eliminate redundancies in the data, all habitat variables were regressed against one another (Table A-13). Variable pairs that had correlation coefficients > 0.5 or < -0.5 were eliminated based on biological significance. Habitat variables were reduced to six categories based on habitat importance. The remaining variables were shrub stem counts, tree stem counts, percent cover of entrance hole, percent grass, percent forb, and percent brush.

To determine whether each species selected boxes associated with different habitat variables, I used a one-way ANOVA and Tukey test to compare habitat variables associated with boxes used only by a single species. Nestboxes used by multiple species over the course of the season were not included in this analysis. In addition to the comparison of boxes used by a single species, I also compared the use and non-use of the boxes for each species for the six habitat variables.

SECTION 3

RESULTS

GENERAL RESULTS

Over the course of the study, there were 101 nesting attempts, 54 attempts by eastern bluebirds, 21 attempts by tree swallows, and 26 attempts by house wrens. Of the 59 boxes, one box remained unoccupied, 23 boxes housed only eastern bluebirds, 8 boxes housed only tree swallows, and 7 boxes housed only house wrens. Of the boxes that housed more than one species over the course of the season, 6 boxes housed both eastern bluebirds and tree swallows, 6 boxes housed both eastern bluebirds and house wrens, 7 boxes housed both tree swallows and house wrens, and 1 box housed eastern bluebirds, tree swallows, and house wrens. 25 out of 54 nest attempts by eastern bluebirds failed, 7 out of 24 nest attempts by house wrens failed, and 3 out of 21 nest attempts by tree swallows failed (Tables A-14, A-15, and A-16).

TEMPORAL PARTITIONING

Nestbox selection events had similar trends to seasonal occupancy. Eastern bluebirds select throughout the entire season and decline steadily as the season progresses, Tree swallows select early in the season then drop off rapidly, House wrens select throughout the season but gradually increase selection events towards late June and early July (Figure 3-1). The mean date of nestbox selection for eastern bluebirds was May 29 (+/- 3.00 days S. E.), the mean date for tree swallows was May 15 (+/- 1.27 days S. E.), and the mean date for house wrens was June 14 (+/- 3.62 days S. E.) (Figure 3-2). Timing of nestbox selection differed among the three species ($F = 20.94$, $p < 0.001$) with all comparisons significantly different (Tukey, $p < 0.05$).

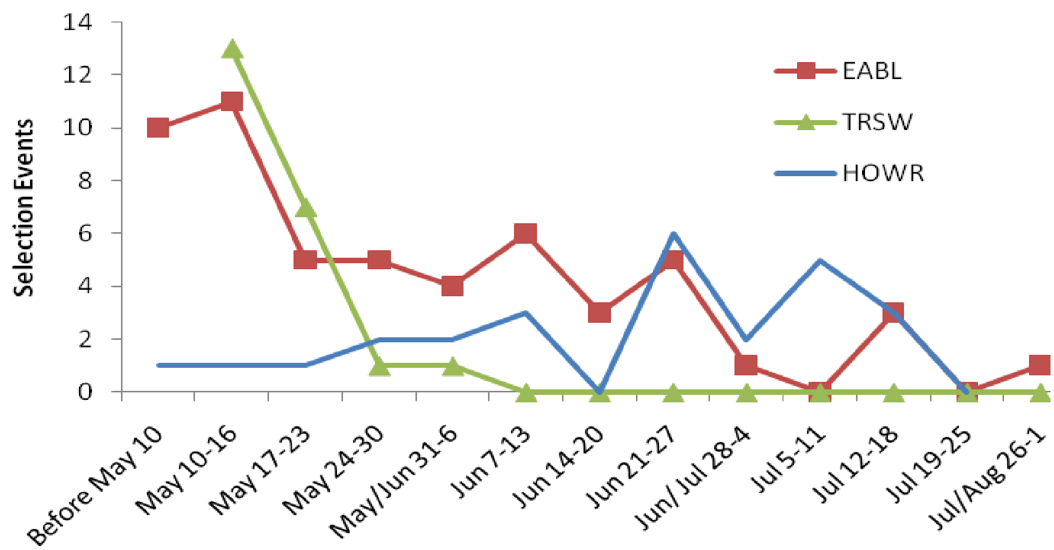

Figure 3-1. Number of nestbox selection events per week for the summer of 2009 in University Park, Pennsylvania.

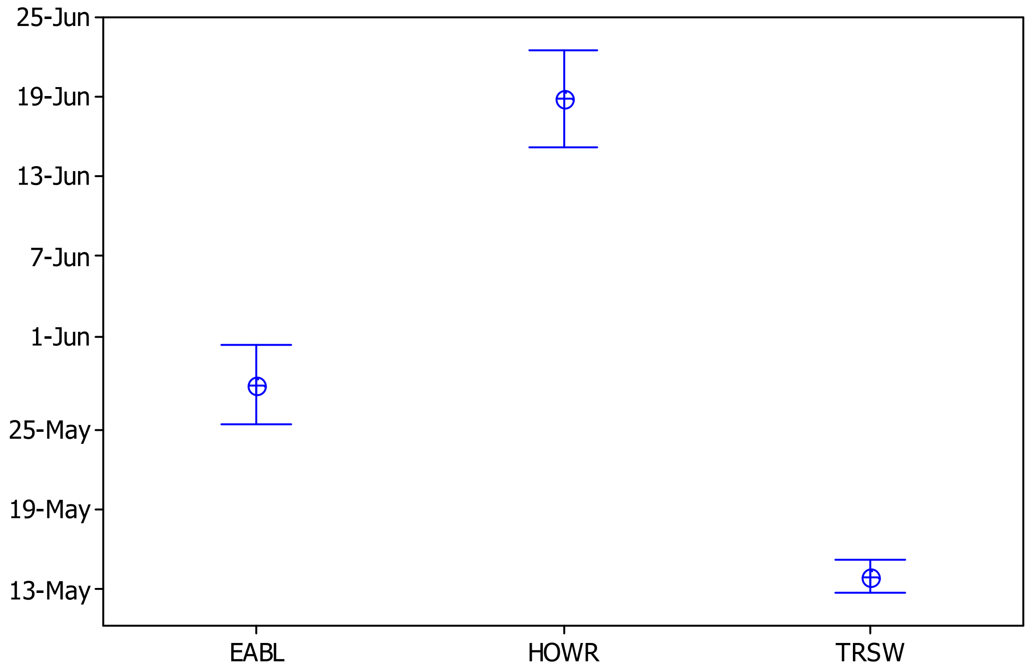

Figure 3-2. Mean nestbox selection date +/- SE throughout the 2009 breeding season in University Park, Pennsylvania.

The highest number of boxes were occupied during the week of June 7-13 at 79%. At that time most of the boxes in use were occupied by eastern bluebirds, followed by tree swallows, then house wrens. Eastern bluebirds had the highest occupancy of nestboxes throughout the season, Tree swallows occupied many boxes at the start of the season, then gradually declined to zero by July 12. House wrens peaked on July 15 and occupied a low percentage of the boxes during the early season (Figure 3-3).

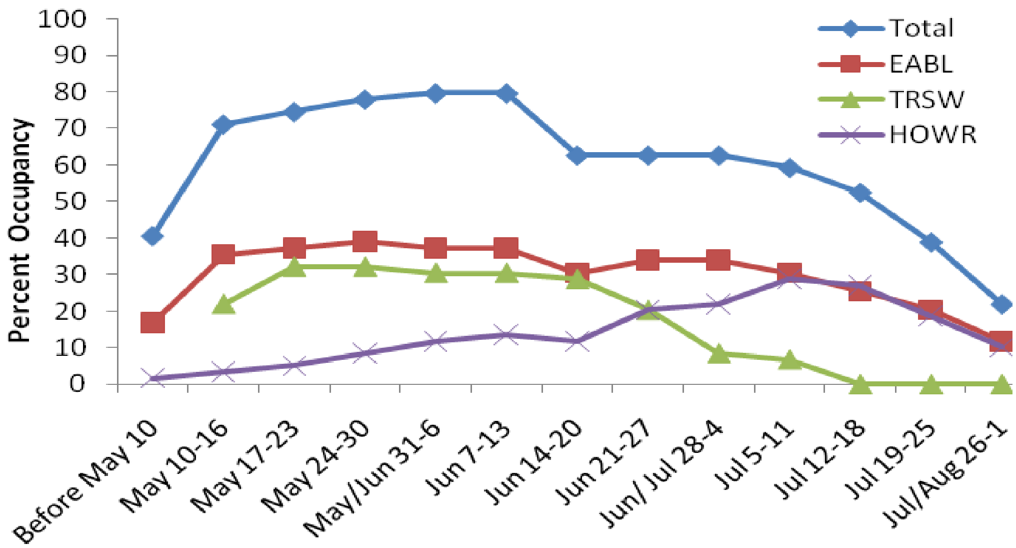

Figure 3-3. Percentage of boxes occupied by week for the summer of 2009 in University Park, Pennsylvania.

HABITAT PARTITIONING

After eliminating nestboxes that housed multiple speceis over the course of the season, one –way ANOVAs of the habitat data revealed tree stem count was significantly different ($F = 5.60$, $p = 0.008$) between the three species. Tukey error tests revealed a difference in the mean tree stem counts surrounding boxes occupied by only house wrens when compared to boxes occupied by only tree swallows and only eastern bluebirds (Table 3-1).

Table 3-1. One –way ANOVA of habitat data for eastern bluebirds, tree swallows, and house wrens (N=38) in Central Pennsylvania in 2009.

Variable	F	P	Significant Differences in Tukey Comparison
Shrub/Sapling Stem Count	1.51	0.235	None
Tree Stem Count	5.60	0.008	HOWR
% Door Cover	0.62	0.542	None
% Grass	0.01	0.993	None
% Forb	1.30	0.286	None
% Brush	1.82	0.177	None

Presence and absence of house wrens with respect to tree stem count was run on a one- way ANOVA for 57 of the 59 boxes (as the data sets for two nestboxes were lost). Of the 20 nestboxes used by house wrens the mean tree stem count was significantly higher than the 37 that were not used by house wrens ($p = 0.008$). No other habitat variables revealed significant relationships with nestbox selection (Table 3-2).

Table 3-2. The geographic location and number of all nestboxes monitored for the summer of 2009 on the Penn State Campus

Eastern Bluebirds

	Used (N=35)		Not Used (N=22)			
	Mean	SD	Mean	SD	F	P
Shrub	1.571	5.782	2.545	6.631	0.340	0.561
Trees	0.257	0.852	0.500	1.336	0.700	0.405
Door	0.142	0.314	0.149	0.391	0.010	0.941
Grass	0.979	0.264	0.956	0.206	0.120	0.731
Forb	0.312	0.317	0.212	0.159	1.870	0.177
Brush	0.066	0.117	0.054	0.100	0.450	0.505

House Wrens

	Used (N=20)		Not Used (N=37)			
	Mean	SD	Mean	SD	F	P
Shrub	3.800	8.895	0.946	3.590	2.960	0.091
Trees	0.850	1.663	0.081	0.227	7.630	0.008
Door	0.137	0.347	0.149	0.344	0.020	0.898
Grass	0.955	0.218	0.978	0.256	0.120	0.730
Forb	0.230	0.209	0.297	0.296	0.790	0.379
Brush	0.073	0.115	0.050	0.109	0.540	0.467

Tree Swallows

	Used (N=21)		Not Used (N=36)			
	Mean	SD	Mean	SD	F	P
Shrub	2.476	6.772	1.639	5.723	0.250	0.621
Trees	0.048	0.218	0.528	1.298	2.810	0.100
Door	0.150	0.357	0.141	0.338	0.010	0.925
Grass	0.951	0.249	0.981	0.240	0.210	0.652
Forb	0.226	0.265	0.301	0.271	1.030	0.316
Brush	0.022	0.068	0.079	0.125	3.780	0.057

SECTION 4

DISCUSSION

Eastern bluebirds, tree swallows, and house wrens reduced direct competition through temporal separation. Tree swallows nested early in the season, house wrens nested later in the season, and eastern bluebirds nested throughout the season. Habitat partitioning was also a factor in nestbox selection. House wrens chose boxes with higher tree densities than boxes chosen by the other two species, but all other habitat variables tested were not significant factors in nestbox choice.

In this region, the three sympatric passerines have three distinct methods of nestbox use. The data reveal there is a distinct nesting style for eastern bluebirds as compared to the other two. Bluebirds nest continuously and often. Though a large portion of their broods were not successful, there was a good chance that at least one of their broods would fledge. With this method, bluebirds did not need to be as aggressive to possible intruders (personal observations).

Tree swallows used a different method; they nested early in the season with large clutches. This, combined with their high level of aggression towards conspecifics, allows them to occupy a large number of boxes in a season for a short period of time (Stutchbury and Robertson 1987). This temporal separation in concert with their avoidance of trees works to eliminate encounters with house wrens (Rendell and Robertson 1990).

House wrens exhibited partitioning temporally and by habitat type. They were more likely to nest in areas with high tree stem counts late in the season. They are not as outwardly aggressive as tree swallows and eastern bluebirds, they have been known to sabotage conspecifics nests by adding nesting material (Rendell and Robertson 1990).

Temporal partitioning is not widely studied as a method of niche separation, and few, if any, studies exist concerning temporal partitioning in secondary cavity nesters. However, some species of tern reduce nest site competition by nesting at different times in the same geographic location (Burger and Gochfeld 1990). Temporal partitioning of nest sites must be examined further to better understand its role to reduce interspecific competition.

With regard to habitat characteristics and species choice, the data in this study generally was in agreement with previous studies. Munro and Rounds (1985) found a positive relationship between woody pastures and the presence of house wrens. Rendell and Robertson (1990) found a negative relationship between tree density and tree swallows, though my data do not reveal a significant relationship between the two, the means suggest a larger sample size would reveal significant data.

The relationship between habitat type and species choice was relatively weak, but there may have been a variable that this study did not examine that could strengthen the relationship. To examine habitat variables more intensely, the number of nestboxes should be increased and placed in areas with more varied habitat characteristics (e.g. more heavily wooded areas).

One interesting component of this study was that the "I" boxes had more tree swallow nesting attempts than eastern bluebird and house wren attempts combined; 12, 3, and 7 respectively. Because the "I" boxes differed from the original boxes in height, placement, predator guards, and altered construction, it is impossible to determine exactly what characteristic drew in the tree swallows without further experimentation.

While this study examined only two of the four variables that influence niche partitioning (timing and habitat type), future experimentation should examine differences in food availability and relative location of the boxes. Additionally, observing the nestbox selection over the course of several years would be beneficial in expanding current knowledge.

APPENDIX

Table A-1. The geographic location and number of all nestboxes monitored for the summer of 2009 on the Penn State Campus

Box Number	Latitude	Longitude	Box Number	Latitude	Longitude
5	40.8122	-77.8463	83	40.8199	-77.8709
5A	40.8121	-77.8465	100	40.8154	-77.8538
12	40.8140	-77.8488	106	40.8204	-77.8690
15	40.8149	-77.8475	109	40.8204	-77.8702
16	40.8141	-77.8477	110	40.8206	-77.8650
18	40.8162	-77.8469	111	40.8187	-77.8593
19	40.8158	-77.8431	112	40.8201	-77.8573
20	40.8166	-77.8436	113	40.8214	-77.8575
21	40.8169	-77.8481	114	40.8203	-77.8527
22	40.8171	-77.8493	115	40.8199	-77.8657
51	40.8284	-77.8530	116	40.8192	-77.8664
52	40.8294	-77.8514	117	40.8238	-77.8551
53	40.8305	-77.8496	118	40.8227	-77.8546
54	40.8316	-77.8488	119	40.8251	-77.8543
56	40.8274	-77.8507	121	40.8149	-77.8469
57	40.8266	-77.8521	I-11	40.8277	-77.8512
58	40.8264	-77.8533	I-12	40.8272	-77.8523
59	40.8265	-77.8541	I-13	40.8267	-77.8534
60	40.8263	-77.8556	I-14	40.8272	-77.8542
61	40.8260	-77.8571	I-15	40.8277	-77.8535
62	40.8111	-77.8727	I-16	40.8282	-77.8530
63	40.8104	-77.8714	I-17	40.8286	-77.8526
64	40.8097	-77.8707	I-18	40.8293	-77.8513
65	40.8085	-77.8697	I-19	40.8297	-77.8507
67	40.8128	-77.8694	I-20	40.8300	-77.8502
68	40.8136	-77.8689	I-21	40.8304	-77.8495
69	40.8147	-77.8684	I-22	40.8310	-77.8491
72	40.8135	-77.8723	I-23	40.8317	-77.8486
73	40.8144	-77.8724	I-24	40.8267	-77.8540
74	40.8154	-77.8710			

Table A-2 Total nestbox use by single species or multiple species during the summer of 2009 in University Park, Pennsylvania

	Code	N
None	0	1
EABL	1	23
TRSW	2	8
HOWR	3	7
EABL+TRSW	4	6
EABL+HOWR	5	6
TRSW+HOWR	6	7
E+T+H	7	1

Table A-3. Habitat data collected for nestboxes 5, 5A, 12, 15, 16, and 18 in University Park, Pennsylvania in the summer of 2009

Box number	5	5A	12	15	16	18
code	4	1	3	4	5	6
orientation	137.5	151	177	260	179	278
height m	1.01	0.91	0.85	0.98	1.16	1.13
hole width cm	3.99	4.08	3.96	3.99	3.96	3.81
shrub stem count	5	5	6	0	9	24
tree stem count	0	0	6	0	0	0
% canopy cover	0.00	0.00	45.05	0.00	0.00	0.00
% door cover	20	50	75	20	80	0
avg litter mm	24.44	37.33	19.22	20.56	22.22	2.89
%green	90	80	65	100	70	45
%brush	0	0	0	0	5	0
%moss	0	0	0	0	0	0
%rock	5	10	0	0	0	0
%grass	20	10	40	100	60	40
%forb	85	80	25	5	25	10
%litter	90	80	65	100	70	45
%bare	10	20	35	0	30	55
%shrub	5	5	20	0	5	5

Table A-4. Habitat data collected for nestboxes 19, 20, 21, 22, 51, and 52 in University Park, Pennsylvania in the summer of 2009

Box number	19	20	21	22	51	52
code	5	1	1	3	1	1
orientation	282	206	30	20	124	129
height m	1.01	1.16	1.07	1.07	0.98	0.98
hole width cm	3.87	3.84	3.78	3.84	3.81	3.66
shrub stem count	0	0	0	0	1	0
tree stem count	0	0	0	2	0	0
% canopy cover	0.00	0.00	2.08	0.78	3.39	0.78
% door cover	0	0	0	0	0	0
avg litter mm	11.78	11.67	7.67	16.67	19.50	17.22
%green	100	95	50	55	60	55
%brush	0	0	5	5	0	0
%moss	0	0	0	0	0	0
%rock	0	0	0	0	0	0
%grass	100	90	45	50	60	55
%forb	5	10	10	20	0	5
%litter	100	95	55	60	60	55
%bare	0	0	45	45	40	0
%shrub	0	0	0	0	0	0

Table A-5. Habitat data collected for nestboxes 53, 54, 56, 57, 58, and 59 in University Park, Pennsylvania in the summer of 2009

Box number	53	54	56	57	58	59
code	5	5	0	3	1	1
orientation	148	123	144	151	182	86
height m	1.01	0.98	0.94	1.01	1.16	1.04
hole width cm	3.96	3.96	3.81	3.69	3.90	3.90
shrub stem count	1	0	0	0	1	0
tree stem count	0	0	0	1	0	0
% canopy cover	0.00	0.00	2.08	16.67	0.00	0.00
% door cover	0	0	0	0	20	0
avg litter mm	8.56	15.44	21.22	12.89	15.00	27.22
%green	60	65	95	100	100	50
%brush	0	0	0	0	0	0
%moss	0	0	0	10	0	0
%rock	0	0	0	0	0	0
%grass	60	65	95	95	95	50
%forb	0	0	5	10	10	0
%litter	75	65	95	100	100	85
%bare	25	35	5	0	0	15
%shrub	0	0	0	0	0	0

Table A-6. Habitat data collected for nestboxes 60, 61, 62, 63, 64, and 65 in University Park, Pennsylvania in the summer of 2009. "*" indicates missing data.

Box number	60	61	62	63	64	65
code	1	2	3	1	1	5
orientation	174	153	124	21	32	119
height m	0.90	0.88	1.01	1.01	1.13	1.49
hole width cm	3.96	3.90	3.84	3.84	3.96	3.90
shrub stem count	0	0	3	0	*	0
tree stem count	1	1	0	0	*	3
% canopy cover	0.00	42.45	8.07	0.00	*	34.11
% door cover	0	95	0	0	*	0
avg litter mm	36.22	28.00	7.44	10.56	*	18.17
%green	70	50	95	95	*	95
%brush	0	0	5	0	*	0
%moss	0	0	0	0	*	5
%rock	0	0	0	5	*	0
%grass	70	35	75	80	*	80
%forb	0	0	20	30	*	0
%litter	100	90	85	95	*	95
%bare	0	10	5	5	*	0
%shrub	0	0	10	0	*	0

Table A-7. Habitat data collected for nestboxes 67, 68, 69, 72, 73, and 74 in University Park, Pennsylvania in the summer of 2009.

Box number	67	68	69	72	73	74
code	6	1	5	3	1	1
orientation	309	192	263	61	124	163
height m	1.04	1.07	0.94	0.91	0.94	1.13
hole width cm	3.84	3.93	3.90	3.96	3.81	3.96
shrub stem count	0	0	33	0	0	0
tree stem count	0	0	4	0	0	0
% canopy cover	0.00	0.00	12.24	0.00	0.00	0.00
% door cover	0	0	30	0	0	0
avg litter mm	1.56	8.83	13.22	24.44	6.11	17.50
%green	75	75	95	90	75	80
%brush	0	0	5	10	10	5
%moss	0	0	0	0	0	0
%rock	0	0	0	0	0	0
%grass	75	70	65	85	60	75
%forb	0	5	35	5	10	15
%litter	25	90	95	100	80	85
%bare	0	10	5	0	20	15
%shrub	0	0	5	0	0	0

Table A-8. Habitat data collected for nestboxes 83, 100, 106, 109, 110, and 111 in University Park, Pennsylvania in the summer of 2009. "*" indicates missing values

Box number	83	100	106	109	110	111
code	1	1	5	2	2	1
orientation	324	249	17	321	320	145
height m	1.01	1.14	1.10	1.04	1.04	0.98
hole width cm	3.93	3.84	3.66	3.78	3.81	3.96
shrub stem count	0	0	*	0	2	0
tree stem count	0	0	*	0	0	0
% canopy cover	0.00	0.00	*	0.00	0.00	0.00
% door cover	80	0	*	0	0	0
avg litter mm	25.00	20.11	*	15.00	11.22	27.78
%green	100	90	*	80	90	100
%brush	15	5	*	0	0	0
%moss	0	0	*	0	10	0
%rock	0	0	*	0	0	0
%grass	55	85	*	75	85	60
%forb	45	30	*	10	5	45
%litter	100	100	*	80	100	100
%bare	0	0	*	20	0	0
%shrub	0	0	*	0	0	0

Table A-9. Habitat data collected for nestboxes 112, 113, 114, 115, 116, and 117 in University Park, Pennsylvania in the summer of 2009.

Box number	112	113	114	115	116	117
code	1	1	1	4	1	1
orientation	234	59	49	312	325	246
height m	1.01	1.05	1.07	1.04	1.01	0.94
hole width cm	3.99	3.93	3.96	3.96	3.81	3.96
shrub stem count	0	0	0	0	0	0
tree stem count	1	0	0	0	0	0
% canopy cover	60.94	0.00	0.00	0.00	0.00	0.00
% door cover	0	0	0	0	0	0
avg litter mm	11.44	6.11	3.11	11.33	24.33	11.89
%green	95	55	65	95	80	55
%brush	0	5	0	5	0	0
%moss	0	0	0	0	0	0
%rock	0	0	0	0	0	0
%grass	90	55	65	95	50	55
%forb	10	5	0	0	30	0
%litter	100	55	65	100	100	55
%bare	0	45	35	0	0	45
%shrub	0	0	0	0	0	0

Table A-10. Habitat data collected for nestboxes 118, 119, 121, I-11, I-12, and I-13 in University Park, Pennsylvania in the summer of 2009.

Box number	118	119	121	I-11	I-12	I-13
code	1	1	4	4	2	2
orientation	261	343	278	327	338	357
height m	0.93	0.98	1.13	1.62	1.55	1.58
hole width cm	3.99	3.93	3.81	3.87	3.81	3.90
shrub stem count	0	0	0	0	21	0
tree stem count	0	0	0	0	0	0
% canopy cover	0.00	0.00	0.00	0.00	0.00	0.00
% door cover	0	0	0	0	60	0
avg litter mm	11.89	12.44	10.89	5.33	14.25	14.67
%green	60	95	80	85	60	60
%brush	0	0	0	0	0	0
%moss	0	0	0	0	0	0
%rock	0	0	0	0	0	0
%grass	60	95	50	75	60	60
%forb	0	0	30	10	5	5
%litter	70	100	80	85	60	60
%bare	30	0	20	15	40	40
%shrub	0	0	0	0	5	0

Table A-11. Habitat data collected for nestboxes I-14, I-15, I-16, I-17, I-18, and I-19 in University Park, Pennsylvania in the summer of 2009.

Box number	I-14	I-15	I-16	I-17	I-18	I-19
code	6	2	6	2	7	3
orientation	334	5	289	336	38	311
height m	1.46	1.65	1.65	1.58	1.65	1.58
hole width cm	3.72	3.81	3.81	3.66	3.72	3.99
shrub stem count	0	0	0	0	0	0
tree stem count	0	0	0	0	0	0
% canopy cover	0.00	0.00	7.03	5.99	0.78	0.00
% door cover	0	0	0	0	0	0
avg litter mm	6.78	12.67	22.42	55.33	21.75	9.92
%green	50	55	55	70	50	55
%brush	5	0	0	0	0	0
%moss	0	0	0	0	0	0
%rock	0	0	0	0	0	0
%grass	50	55	55	70	50	55
%forb	5	0	0	5	0	0
%litter	55	60	60	70	55	60
%bare	45	40	40	30	45	40
%shrub	0	0	0	0	0	0

Table A-12. Habitat data collected for nestboxes I-20, I-21, I-22, I-23, and I-24 in University Park, Pennsylvania in the summer of 2009.

Box number	I-20	I-21	I-22	I-23	I-24
code	4	2	3	6	6
orientation	315	313	262	300	246
height m	1.49	1.65	1.55	1.52	1.52
hole width cm	3.81	3.96	3.81	3.72	3.72
shrub stem count	0	0	0	0	0
tree stem count	0	0	1	0	0
% canopy cover	0.52	2.60	25.00	1.56	0.00
% door cover	0	0	0	0	0
avg litter mm	30.17	33.33	13.92	39.17	14.78
%green	70	90	55	70	70
%brush	0	0	0	0	0
%moss	0	0	0	0	0
%rock	0	0	0	0	0
%grass	70	90	55	70	65
%forb	5	0	5	5	5
%litter	75	95	55	75	70
%bare	25	5	45	25	30
%shrub	0	0	0	0	0

Table A-13. Correlation coefficients of habitat variables for the summer of 2009 in University Park, Pennsylvania. Variable pairs with r values > 0.5 or < - 0.5 are highlighted.

	Shrub count	Tree count	Door cover	Canopy Cover	%Green	%Brush	%Grass	%Forb	%Litter	%Bare	%Shrub
Shrub count	1.000	0.357	0.383	0.073	-0.049	0.099	-0.208	0.267	-0.118	0.158	0.639
Tree count	0.357	1.000	0.347	0.658	0.029	0.030	-0.111	0.125	0.023	-0.008	0.501
Door cover	0.383	0.347	1.000	0.256	0.072	0.163	-0.298	0.373	0.071	-0.010	0.550
Canopy cover	0.073	0.658	0.256	1.000	0.029	-0.121	-0.013	-0.050	0.055	-0.054	0.242
%Green	-0.049	0.029	0.072	0.029	1.000	0.106	0.665	0.367	0.825	-0.805	-0.029
%Brush	0.099	0.030	0.163	-0.121	0.106	1.000	-0.029	0.260	0.105	-0.045	0.083
%Grass	-0.208	-0.111	-0.298	-0.013	0.665	-0.029	1.000	-0.319	0.582	-0.603	-0.358
%Forb	0.267	0.125	0.373	-0.050	0.367	0.260	-0.319	1.000	0.242	-0.162	0.476
%Litter	-0.118	0.023	0.071	0.055	0.825	0.105	0.582	0.242	1.000	-0.825	-0.153
%Bare	0.158	-0.008	-0.010	-0.054	-0.805	-0.045	-0.603	-0.162	-0.825	1.000	0.173
%Shrub	0.639	0.501	0.550	0.242	-0.029	0.083	-0.358	0.476	-0.153	0.173	1.000

Table A-14. Nestbox occupancy of eastern bluebirds by week over the course of the summer of 2009 in University Park, Pennsylvania. The number indicates nesting attempt per box. Highlighted values indicate failed nest. Of the 54 nesting attempts, there were 25 failures.

Box Number	Before May 10	May 10-16	May 17-23	May 24-30	May/ Jun 31-6	Jun 7-13	Jun 14-20	Jun 21-27	Jun/ Jul 28-4	Jul 5-11	Jul 12-18	Jul 19-25	July/ Aug 26-1
5				1	1	1							
5A	1	1	1										
15	1	1	1					2	2	2			
16	1	1	1	1	1								
19												1	1
20				1	1	1	1	1	1	1			
21	1	1	1	1	1	1			2	2	2	2	2
51		1	1	1	1	1			2	2	2	2	2
52		1	1	1	1	1	1	1		2	2	2	2
53				1	1	1							
54		1	1	1	1	1							
58		1	1	1	1	1							
59		1	1	1									
60							1	1	1	1	1	1	
63	1	1	1		2	2							
64						1	1	1	1	1	1	1	
65	1		2	2	2								
68	1	1	1	2	2	2	2	2	2				
69					1	1	1	1	1	2	2	2	2
73		1	1	1	1	1	1	1	1		2		
74	1				2	2	2	2	2	2			
83				1	1								
100	1	1	1	1	2	2	2	2	2	2	2		
106		1	1	2	2	2	2	2	2		3	3	3
111	1	1	1	1				2	2	2	2		
112		1	1	1	1	1	2	2	2	2			
113		1	1	1				1	1	1			
114			1	1	1	1	1						
115								1	1	1	1	1	1
116		1	1	1		2	2	2	2	2	2	2	
117		1	1	1	1	1	1						
118		1	1	1	1	1	1	1					
119						1	1	1	1	1			
121											1	1	
I-11							1	1	1	1	1		
I-18		1											
I-20							1	1	1	1	1	1	

Eastern bluebirds did not nest in boxes 12, 18, 22, 56, 57, 61, 62, 67, 72, 109, 110, I-12, I-13, I-14, I-15, I-16, I-17, I-19, I-21, I-22, I-23, an I-24

Table A-15. Nestbox occupancy of house wrens by week over the course of the summer of 2009 in University Park, Pennsylvania. The number indicates nesting attempt per box. Highlighted values indicate failed nest. Of the 24 nesting attempts, there were 7 failures.

Box Number	Before May 10	May 10-16	May 17-23	May 24-30	May/ Jun 31-6	Jun 7-13	Jun 14-20	Jun 21-27	Jun/ Jul 28-4	Jul 5-11	Jul 12-18	Jul 19-25	July/ Aug 26-1
12								1	1	1			
16											1	1	1
18								1	1	1	1	1	
19									1	1			
22					1	1		2	2	2	2	2	2
53			1	1	1	1	1	1	2	2	2	2	2
54						1	1	1	1	1	1	1	
57		1	1	1	1	1	1	1			2	2	
65	1	1	1	1	1					2	2	2	2
67										1	1	1	
69						1	1	1	1	1	1	1	1
72											1	1	1
106					1	1	1	1	1	1			
I-14								1	1	1	1		
I-16								1	1	1	1		
I-18									1	1	1	1	
I-19				1	1	1	1	1	1	1	1		
I-22										1	1		
I-23										1	1		
I-24				1	1	1	1	1	1	1			
House wrens did not occupy boxes 5, 5 A, 15, 20, 21, 51, 52, 56, 58, 59, 60, 61, 62, 63, 68, 73, 74, 83, 100, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 121, I-11, I-12, I-13, I-15, I-17, I-20, and I-21													

Table A-16. Nestbox occupancy for Tree Swallows by week over the course of the summer of 2009 in University Park, Pennsylvania. Highlighted values indicate failed nest. Of the 21 nesting attempts, there were three failures.

Box Number	Before May 10	May 10-16	May 17-23	May 24-30	May/ Jun 31-6	Jun 7-13	Jun 14-20	Jun 21-27	Jun/ Jul 28-4	Jul 5-11	Jul 12-18	Jul 19-25	July/ Aug 26-1
5		1	1	1									
15			1	1									
18			1	1	1	1	1	1	1	1			
61			1	1	1	1	1	1					
67			1	1	1	1	1	1					
109			1	1	1	1	1	1	1				
110			1	1	1	1	1	1					
115		1	1	1	1	1	1						
121					1	1	1	1	1	1			
I-11		1	1										
I-12		1	1	1	1	1	1	1					
I-13		1	1	1	1	1	1	1					
I-14		1	1	1	1	1	1	1					
I-15		1	1	1	1	1	1						
I-16		1	1	1	1	1	1	1					
I-17		1	1	1	1	1	1						
I-18				1	1	1	1	1	1	1			
I-20		1	1	1	1	1							
I-21		1	1	1	1	1	1	1	1	1			
I-23		1	1	1	1	1	1						
I-24		1	1	1	1	1	1						

Tree swallows did not nest in boxes 5 A, 12, 16, 19, 20, 21, 22, 51, 52, 53, 54, 56, 57, 58, 59, 60, 62, 63, 65, 68, 69, 72, 73, 74, 83, 100, 111, 112, 113, 114, 116, 117, 118, 119, I-19, and I-22

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The Pennsylvania State University, University Park, PA
The Schreyer Honors College
Bachelor of Science in Wildlife and Fisheries Science, Wildlife Option, May 2010
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RESEARCH AND WORK EXPERIENCE:

Teaching Assistant: Penn State University, University Park, PA 2009- 2010
Supervisor: Dianne Burpee
Classes: Introductory Molecular Biology and Ecology and Evolutionary Biology
Promoted from Assistant TA to Full TA in the spring of 2010

- Oversaw a weekly two-hour laboratory section with 23 students
- Wrote and graded weekly quizzes and assignments
- Helped answer students' questions during laboratory exercises
- Held office hours weekly
- Prepared laboratory classrooms for instruction

Field Assistant: Penn State University, University Park, PA 2009
Supervisor: Margaret Brittingham, Ph. D
Project Goal: Monitor and track the eastern bluebird population on the Penn State campus

- Performed daily nestbox checks on 59 boxes
- Collected vegetation data and monitored nest use
- Compiled and analyzed habitat data using Minitab

Research Assistant: Penn State University, University Park, PA 2008
Supervisor: Claude dePamphilis, Ph. D
Project Goal: Trace the evolutionary history of several species of liverwort

- Cloned chloroplast DNA using PCR
- Reviewed primary literature concerning the evolutionary history of plants
- Formatted citations using Endnote

Grower's Assistant for Quality Gardens Inc., Valencia, PA 2006- 2007

- Gained extensive knowledge of native and exotic plant species
- Answered customer's questions
- Received instruction in Integrated Pest Management and pesticide safety

PUBLICATIONS:

Junior Bird Guide to Blackwater National Wildlife Refuge 2009
Wrote, illustrated, and designed a children's birding pamphlet detailing eleven common birds of the Chesapeake Bay

Biography for William D. Boyce 2007
A brief essay concerning Boyce's life and accomplishments for the Pennsylvania Center for the Book

HONORS AND AWARDS:

Oswald Scholarship 2009
Outstanding student in the agricultural sciences

Ferguson-Cope Scholarship 2009
Excellent academic achievement, character, and professional promise in the field of forestry

Eagle Scout 2006
Established bluebird trails to educate community children about bluebird conservation

RELEVANT COURSEWORK:

Tropical Field Ecology

- Spent two weeks in Costa Rica for field-intensive, research-oriented coursework
- Studied species diversity in costal lowland and high altitude rainforests
- Designed and carried out experiments involving avian behavior and species diversity

Vertebrate Zoology

- Studied vertebrate diversity in the Northeastern U. S.
- Emphasis on vertebrate physiology, systematics, and ecology

Ecotoxicology

- Studied the effects of chemical pollutants on ecosystems
- Emphasis on effects of pollutants on vertebrates