THE INFLUENCE OF NEST BOX AND HABITAT CHARACTERISTICS ON WOOD DUCK NEST BOX USE AND SUCCESS IN DELAWARE

by

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ABSTRACT

Wood Ducks (*Aix sponsa*) choose natural nesting cavities based on surrounding habitat, cavity height, and entrance dimensions. Assuming the criteria influencing the hens' choice of nest boxes are similar, efforts to optimize nest box placement based on those specifications can have a considerable impact on the efficiency of wood duck management. Volunteers and workers at Delaware Wildlands Betts and Armstrong farms, Augustine Creek Estuarine Marsh Complex, Delaware have collected nest box use of 126 wood duck boxes 2004–2009 and 2011–2015. In April-August 2017, I monitored wood duck use of 128 functioning boxes located on this property. I checked each box for use and potential success at least twice throughout the breeding season. I further collected nest box and habitat characteristics including horizontal diameter of entrance (cm), orientation of entrance (degrees), height of entrance (cm), post placement (on land or water), distance to the nearest box (m), distance to open water (m), and average visual obstruction in the four cardinal directions (cm). All boxes had the same mean dimensions of 31x31x61, same PVC pipe predator guard, and minimal age difference. I tested a series of apriori model using General Linear Modeling and Akaike Information Criteria to assess how nest box and habitat characteristics might affect long term use of the boxes Nest box use was positively influenced by nearness to open water, lower visual obstruction, and further distance to neighboring nest. I further tested a series of apriori models that assessed the impact of nest box and habitat characteristics on use of both boxes on one poll. I determined higher double box use occurred with lower height and lower visual obstruction. Last, I estimated nest success in 2017. In 2017, of the 128 boxes available, 45 nests were initiated and of those, 10 (22%) were identified as dump nests with no nesting materials or incubation attempted. Of the remaining 35 active nests, 7 showed signs of nest parasitism with >15 eggs incubated. Dump nests occurred more frequently over land and further away from water and parasitized nests occurred more frequently further from water. Ultimately only 2 nests were successful thus having a low apparent nest success of 2/35 = 5.7%.

Chapter 1

INTRODUCTION

The wood duck (*Aix sponsa*) is North America's most successful cavity nesting duck (Hepp and Bellrose 1995). The species is endemic to North America and is a year-round resident throughout the East and West Coasts of the United States with additional breeding in Southern Canada and wintering in Mexico (Dugger 1992, Hepp and Bellrose 1995). At the turn of the 19th century, their numbers became critically low due to overexploitation and habitat loss (Hepp and Bellrose 2013). However, upon enactment of the Migratory Bird Treaty Act of 1918, as well as decades of an active wood duck nest box program, their numbers have recovered and their status has steadily increased since 1966 (Sauer et al. 2017). For example, the Atlantic Flyway wood duck index has increased 1.1% annually over the entire time series (1966–2016) and 2.0% over the past 20 years (1997–2016).

The wood duck is popular with hunters and consistently ranks high among species in Atlantic and Mississippi flyway duck harvests (Dugger and Fredrickson 1992). Additionally, because the wood duck has a specialist need for cavities, increasing species productivity through well-implemented nest box programs is a priority. This is true especially now, in the face of increasing agricultural and commercial development, and the progressive loss of North America's forest resources (Dugger and Fredickson 1992).

Wood ducks are one of a few species of waterfowl that can grip bark with their strong claws and roost on branches (Hepp and Bellrose 1995). They nest in tree cavities left behind by pileated woodpeckers (*Dryocopus pileatus*), or created by fallen branches (Conner 2001, Baldessare 2014). Wood ducks base their choice of natural cavities on surrounding habitat, cavity height (2–15m above ground), and entrance dimensions (9.9–11.1 horizontally) (Baldessare 2014). Unfortunately, natural cavity availability is decreasing as old growth forests are cleared around marshlands for agricultural purposes (Bellrose and Holm 1994, Baldessare 2014).

The lack of nesting cavity availability can be amended by construction and maintenance of artificial wood duck nest boxes. This management strategy has been widely successful at escalating the growth of local populations (Dugger and Fredrickson 1992, Baldessare 2014). Nest boxes can be placed in a variety of freshwater and low salinity habitats where herbaceous cover and food are available. Open swamps and open marshes are confirmed to be the ideal habitat for nest box placement because of high resource availability and low natural cavity availability (Heitmeyer and Fredrickson 1990, Bellrose and Holm 1994).

Precise placement strategies, however, are still in development. This is complicated by the fact that many variables potentially influence wood duck box construction and placement including distance to open water, distance to the nearest nest box, surrounding vegetation density, orientation of the entrance, whether the boxes were placed over land or water, box entrance dimensions, and entrance height (Baldessare 2014, Bellrose and Holm 1994). Thus, better understanding of the best possible placement and design of artificial cavities can optimize wood duck management efforts. The South Carolina Waterfowl Association (2015) estimated the price of purchase and installation for a single wood duck box with a predator guard can be as much as $195, with yearly maintenance costing $25.00/unit. Therefore, with the right strategies in place, thousands of dollars can be saved and utilized for further management or more frequent box replacement, which increases use and success.

Optimizing wood duck box use is useful for organizations as well as private citizens to promote local wood duck population growth and occupancy rates as natural cavities become scarcer. This is why my goal was to assess nest box and habitat characteristics' effect on historic wood duck box use (2004–2009, 2011–2015, and 2017) in northeastern Delaware as well as quantify nest success in 2017.

Chapter 2

STUDY AREA

Delaware, USA, is primarily made up of the Coastal Plain physiographic region except for the northern tip of the state, which is a rolling piedmont (Tinner and Hardin 1985). Its climate is temperate humid continental, with average monthly temperatures ranging 0–24.3° C, with average precipitation of 114.3 cm, and a growing period lasting 170–200 days (Office of the Delaware State Climatologist 2011). All five wetland and deep-water systems can be found in Delaware (Riverine, Estuarine, Marine, Lacustrine and Palustrine). Palustrine and Estuarine wetlands are the predominant systems in the state, and the differences in native vegetation are due to natural events, human activities, salinity, and soil type. Most of the land in Delaware's wetlands is made up of mixed alluvial soils (Tinner and Hardin 1985).

I collected data on Delaware Wild Lands' Betts and Armstrong Farms (39°29'41.5"N, 75°36'28.2"W) which are part of the Augustine Creek wetland system. The total acreage of the study area property was 672. According the National Wetlands Inventory, Augustine Creek's Wetlands are classified as estuarine with a mix of unconsolidated bottom and emergent vegetation and which are flooded both regularly and irregularly (E1UBL, E2EM1P, and E2EM1N) (Tinner and Hardin 1985, Bertness 1999, U.S. Fish and Wildlife Service 2017).

I was given access to 126 usable wood duck boxes installed on the Betts/Armstrong properties between 1989 and 1992 (with an exception of two boxes being installed in 2017 [totaling 128]). Boxes were constructed of cedar, mounted on wooden poles in pairs (with the exception of two boxes that were mounted as a single), had the same mean dimensions of 31x31x61, and same PVC pipe predator guard. Boxes were generally spread evenly across all habitat types on the open marsh or along its' edge. None of the boxes were placed in wooded areas around the site.

Chapter 3

METHODS

In 2001, Delaware Wild Lands' volunteers and staff monitored wood duck nest box use on the property during annual maintenance efforts 2004–2009 and 2011–2015. In April of 2017, I begun monitoring wood duck use of 128 undamaged and accessible boxes. I checked each box for use at least twice throughout the breeding season. When coming across a live nest, I noted the number of eggs, their age via floating the eggs and presence of down. I monitored live nests at 2-week intervals to document depredation or hatching, while attempting to minimize disturbance. When coming across a depredated nest, I estimated the number of eggs laid in the particular box by counting eggshell pieces and recorded the presence of down to determine if the nest was active before depredation or was an inactive dump nest site.

In August of 2017, I assessed the boxes and noted the following parameters manually: stand placed on land or water, horizontal diameter of entrance (cm), orientation of entrance (degrees from magnetic north), height of entrance (cm), and average visual obstruction in the four cardinal directions (cm) as observed via a decimeter marked poll 3 m away. Using Google Earth's linear distance measuring tool, I assessed and recorded the distance to the nearest poll with a pair of boxes (m), and distance to open water (m). The satellite images used for this task were taken at the beginning of Delaware's Wood Duck breeding season in April of 2017.

I first assessed how long-term nest box use might be influenced by box and environmental characteristics between 2004–2017. Because 2 new boxes were added in 2017, they were not included in this long-term analysis and thus n = 126. For example, if a box was used 3 out of 12 years, the value for that box would be 25%. I carefully examined 12 historic aerial photos published in Google Earth between 2002–2017 at the nest box sites and did not discern any noticeable differences in the emergent vegetation over that time; therefore, I made the assumption covariates were a constant during that time. I built 19 apriori explanatory models using a generalized linear model structure and compared all models using Akaike Information Criterion corrected for small sample size (AICc, Burnham and Anderson 2002). If ΔAIC value were < 2, we conducted weighted model averaging to determine the beta values for the best-predicted covariates. I further built 15 apriori explanatory models assessing whether nest box or habitat characteristics affected the likelihood that both boxes were used on one pole. Nest box hole orientation was removed from this analysis since the two nest box openings were facing away from each other. For the top weighted model(s), I estimated beta values and significance via a Chi-squared Wald test ($P \leq 0.05$) of all predictive parameters. Last, I compared the seven habitat characteristics between dump nests and undumped nests, parasitized nests and unparasitized nests, and successful and unsuccessful nests using independent sample t-tests potentially corrected by Levene's test for equality of variances ($\alpha \leq 0.05$).

Chapter 4

RESULTS

Between 2004–2017, simple nest checks were conducted on 126 nest boxes to identify if they were being used by wood ducks. Nest box use was relatively consistent across years (2004:54%, 2005:34%, 2006:56%, 2007:32%, 2008:37%, 2009:41%, 2011:37%, 2012:35%, 2013:37%, 2014:33%, 2015:30%, and 2017:35%) supporting the likelihood that nest box characteristic or habitat variables did not change over time. I built 19 apriori models to explain nest box use as a function of nest box and environmental covariates (Table 1). Of those models, the single predictive model was: *% Nest box use = 0.408 - 0.001*(average visual obstruction) + 0.001*(distance to nearest nest box) - 0.001*(distance to open water).* Percent nest box use significantly increased with decreasing distance to open water (χ^2_1= 11.29, P = 0.001), lower visual obstruction of the habitat surrounding the nest box (χ^2_1= 7.90, P = 0.005) and increased distance between neighboring nest boxes (χ^2_1= 5.21, P = 0.023). Single linear regression of distance to water indicated nest boxes that were next to or over water (distance = 0m) were used 43% of the time between 2001–2017 (Figure 1). However, for example, if a nest box was 250 m away from water, it would only be used 16% of the time. Single linear regression of visual obstruction readings indicated nest boxes with no obstruction were used 47% of the time (Figure 2). However, for example, if nest boxes were surrounded by 250 cm of vegetation height they would only be used 27% of the time. Single linear regression of distance to nearest neighbor indicated nest box poles with no distance between neighboring poles would be used

27% of the time (Figure 3). However, for example, if nest box poles were separated by 125 m they would be used 57% of the time.

Most nest boxes were installed with two boxes per pole (however over time some boxes broke and were unusable). Of the 128 nest boxes I surveyed, 100 on 50 poles were consistently used 2004–2017. I evaluated if any habitat characteristics (minus orientation) affected percent use of both boxes in any given year over the length of the study. There was great variability on double box use ranging from 0% to 75% of the time. Two top models best predicted double box use including height of box as well as height of box + visual obstruction reading (Table 2). Thus, the average model was: *% double nest box use = 0.5248 - 0.164*(height of box) - 0.041*(visual obstruction reading.* Percent double nest box use increased with lower height (χ_1^2= 6.747, P = 0.009) and lower visual obstruction (χ_1^2= 3.897, P = 0.048). Single linear regression of height of nest box entrance predicted the lowest double nest box entrances (92 cm) had a 33% chance that both nest boxes were used in the same year (Figure 4). However, for example, if nest box hole entrance was 250 cm high, the odds of both nest boxes being used in a given year declined to 6%. Single linear regression of visual obstruction readings predicted no obstruction would promote double nest box use 27% in any given year (Figure 5). However, for example, if visual obstruction increased to 250 cm high, the odds of both nest boxes being used in a given year declined to 12%.

In 2017, I conducted intense nest monitoring to assess nest success. Two additional nest boxes were added in 2017 thus 128 boxes were available for analysis. Forty-five nests were initiated and of those, 18 had nests in both boxes on one pole (ie 9 poles). Ten nests (22%) were identified as dump nests with no nesting materials or incubation attempted, with 5 of those dump nests occurring in poles where both boxes were used. Comparing habitat characteristics of dump vs undamped nests, I found dump nests occurred more frequently over land rather than water ($t_{34.00} = 4.48$, $P <$ 0.01) and further distance from water ($t_{37.69} = 2.197$, $P = 0.03$) (Table 3). Of the remaining 35 active nests, 7 showed signs of nest parasitism with >15 eggs incubated, with 3 of those parasitized nests occurring in poles where both boxes were used. Comparing habitat characteristics of parasitized vs. unparasitized nests, I found parasitized nests occurred more frequently further from water ($t_{42.09} = 2.55$, $P = 0.01$) (Table 4). Ultimately only 2 nests were successful thus having a low apparent nest success of 2/35 = 5.7%. While there was not enough power for me to compare nest box and environmental characteristics between successful and unsuccessful nests, anecdotally the two successful nests were more easterly facing, higher off the ground/water, and closer to water (Table 5). Interestingly the two successful nests seemed to occurred in areas with higher vegetation structure beneath the box contradicting the nest box use results.

Table 1 General Linear Modeling with AIC model selection of 19 apriori models predicting how nest box characteristics and environmental variables affects nest box use between 2004–2017, Betts Farm, Delaware, USA.

Model	**k**	**AICc**	**ΔAIC**	**w**
Null	1	-60.44	-23.16	0.00
Habitat (land 1/water 0) HABITAT	2	-58.66	-24.94	0.00
Diameter of Entrance (cm) HOLE	2	-59.07	-24.53	0.00
Orientation of Entrance (degrees) ORIENT	2	-60.68	-22.92	0.00
Height of entrance (from water or land in cm) HEIGHT	2	-62.77	-20.83	0.00
Distance to nearest neighboring box (m) DISTB	2	-66.62	-16.98	0.00
Distance to open water (m) DISTW	2	-74.33	-9.27	0.01
Visual obstruction reading average (cm) VOR	2	-70.24	-13.37	0.00
HOLE + ORIENT	3	-58.99	-24.61	0.00
DISTW + VOR	3	-80.67	-2.93	0.15
HABITAT + ORIENT	3	-58.93	-24.67	0.00
HABITAT + DISTB	3	-64.61	-18.99	0.00
HEIGHT + DISTW	3	-74.38	-9.22	0.01
HEIGHT + VOR	3	-71.50	-12.10	0.00
HABITAT + HEIGHT	4	-60.71	-22.89	0.00
VOR + DISTW + DISTB	**4**	**-83.60**	**0.00**	**0.67**
HOLE + ORIENT + HEIGHT	4	-60.93	-22.67	0.00
HEIGHT + DISTW + VOR	4	-80.24	-3.36	0.12
Global	8	-77.66	-5.94	0.03

Table 2 General Linear Modeling with AIC model selection of 15 apriori models predicting how nest box characteristics and environmental variables affects double next box on a single pole between 2004–2017, Betts Farm, Delaware, USA.

Model	**k**	**AICc**	**ΔAIC**	**w**
Null	1	425.56	-5.45	0.02
Habitat (land 1/water 0) HABITAT	2	427.80	-7.69	0.01
Diameter of Entrance (cm) HOLE	2	427.74	-7.63	0.01
Height of entrance (from water or land in cm) HEIGHT	**2**	**421.50**	**-1.39**	**0.17**
Distance to nearest neighboring box (m) DISTB	2	426.47	-6.35	0.01
Distance to open water (m) DISTW	2	425.65	-5.54	0.02
Visual obstruction reading average (cm) VOR	2	424.15	-4.04	0.05
DISTW + VOR	3	425.05	-4.94	0.03
HABITAT + DISTB	3	428.66	-8.55	0.00
HEIGHT + DISTW	3	423.64	-3.53	0.06
HEIGHT + VOR	**3**	**420.11**	**0.00**	**0.35**
HABITAT + HEIGHT	4	422.18	-2.07	0.12
VOR + DISTW + DISTB	4	427.21	-7.10	0.01
HEIGHT + DISTW + VOR	4	422.20	-2.08	0.12
Global	7	429.11	-9.00	0.00

Table 3 Mean (SE) of nest box and environmental covariates that affected dump boxes (N=10) and nests (N=35) at Betts Farm, Delaware, USA, 2017.

	Dump nest		Undumped Nests	
Variable	Mean	SE	Mean	SE
Over land (1) or water (0)	0.0	0.0	0.4	0.1
Diameter of entrance (cm)	12.4	0.4	11.8	0.3
Orientation of entrance (degrees)	175.0	35.7	155.6	17.3
Height of entrance (from water or land in cm)	159.4	9.8	176.7	6.0
Distance to nearest box (m)	70.7	10.2	55.9	3.7
Distance to open water (m)	8.7	3.2	38.5	13.1
Visual Obstruction average (cm)	91.8	18.0	71.9	10.2

Table 4 Mean (SE) of nest box and environmental covariates that affected nest parasitized nests (N=7) and unparasitized nests (N=38) at Betts Farm, Delaware, USA, 2017.

	Parasitized nest		Unparasatized nest	
Variable	Mean	SE	Mean	SE
Over land (1) or water (0)	0.4	0.2	0.3	0.1
Diameter of entrance (cm)	12.5	0.6	11.8	0.2
Orientation of entrance (degrees)	196.4	39.6	153.2	16.8
Height of entrance (from water or land in cm)	166.3	14.1	174.1	5.7
Distance to nearest box (m)	49.4	6.9	61.0	4.2
Distance to open water (m)	4.5	3.8	36.9	12.1
Visual Obstruction average (cm)	43.9	15.6	82.3	9.9

Table 5 Mean (SE) of nest box and environmental covariates that affected unsuccessful (N=33) and successful (N=2) wood duck nests at Betts Farm, Delaware, USA, 2017. Ninety-four nest boxes were unused in 2017.

	Unsuccessful nests		Successful nests	
Variable	Mean	SE	Mean	SE
Over land (1) or water (0)	0.3	0.1	0.5	0.5
Diameter of entrance (cm)	11.9	0.2	12.4	4.0
Orientation of entrance (degrees)	162.4	16.1	105.0	5.0
Height of entrance (from water or land in cm)	171.2	5.3	209.5	7.5
Distance to nearest box (m)	50.8	3.6	67.5	44.8
Distance to open water (m)	33.0	10.8	7.5	7.5
Visual Obstruction average (cm)	74.9	9.2	107.5	22.5

Figure 1 The effect of distance to open water on % nest box use by wood ducks on Betts Farm, Delaware, USA, 2004–2017.

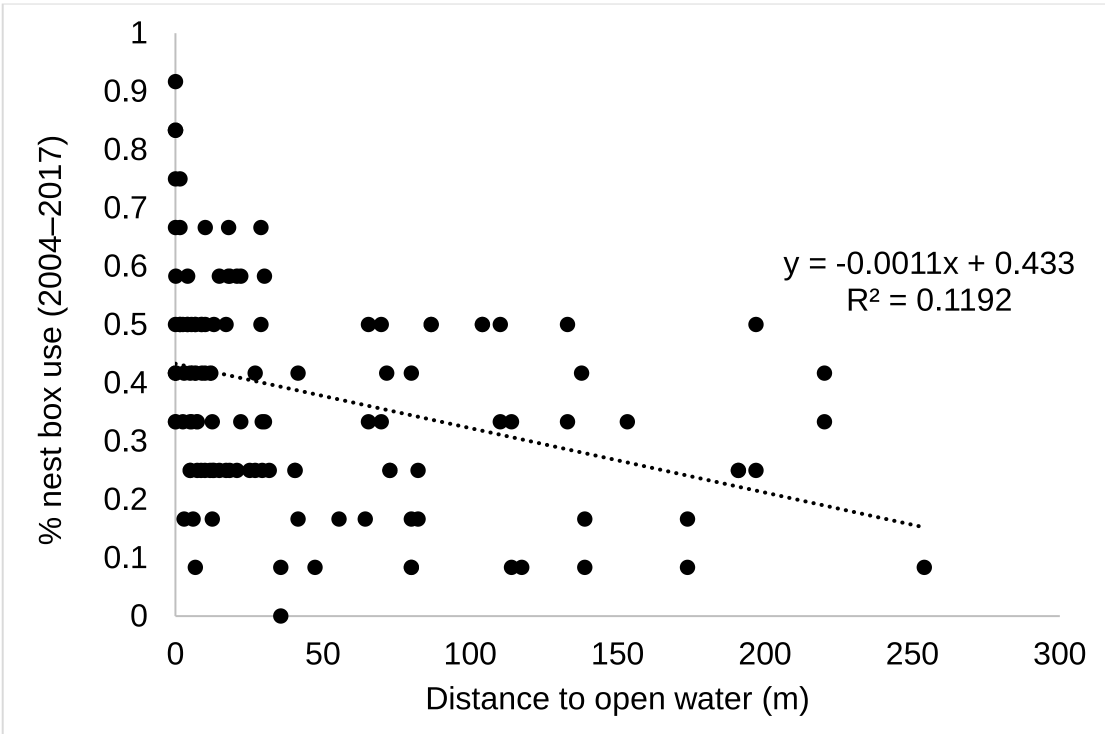


Figure 2 The effect of visual obstruction height (cm) surrounding nest box on % nest box use by wood ducks on Betts Farm, Delaware, USA, 2004–2017.

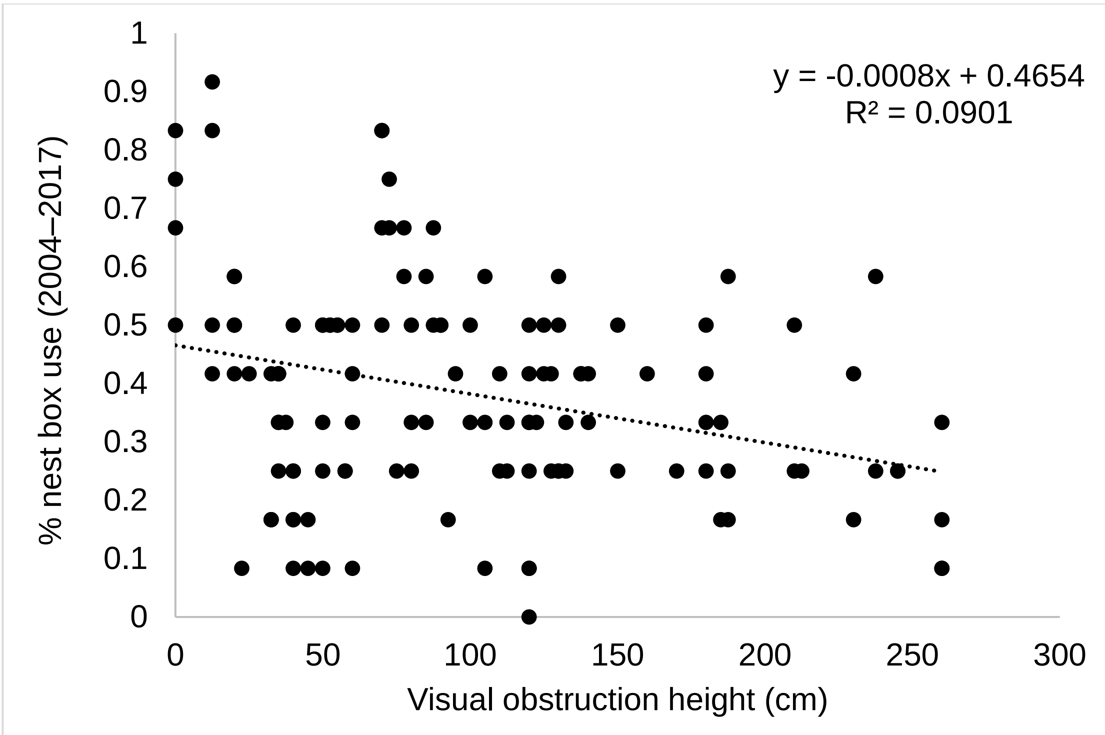


Figure 3 The effect of distance to nearest best box (m) on % nest box use by wood ducks on Betts Farm, Delaware, USA, 2004–2017.

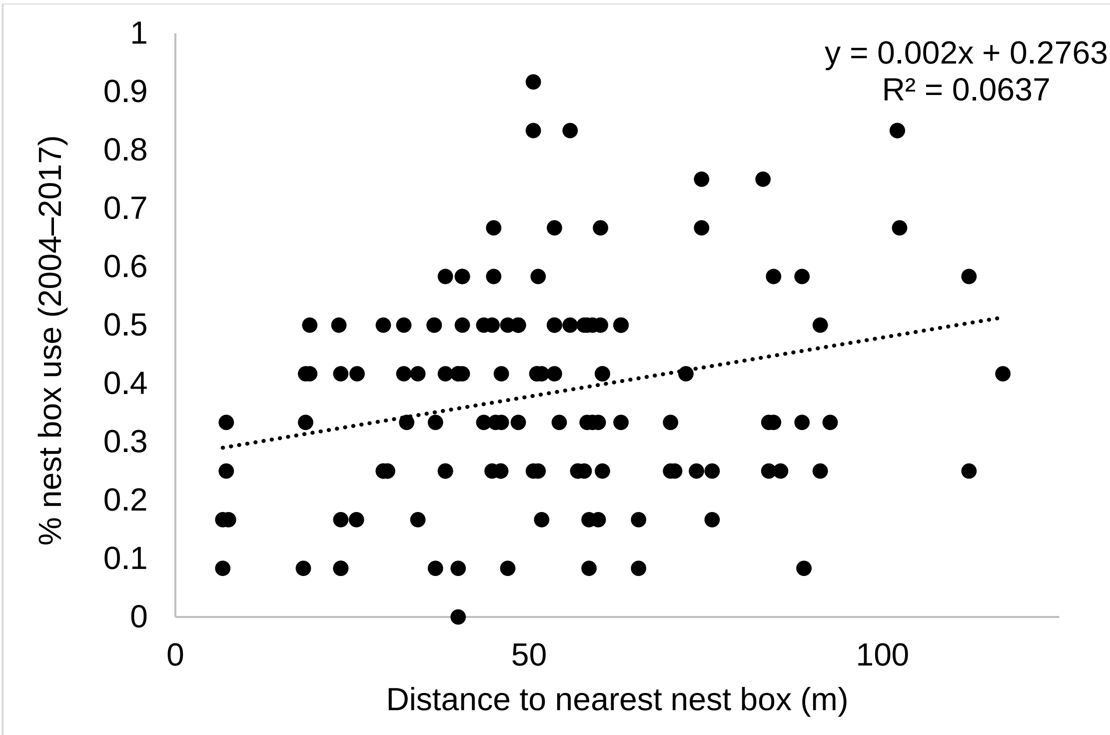


Figure 4 The effect of nest box entrance height (cm) on percent double nest box use by wood ducks on Betts Farm, Delaware, USA, 2004–2017.

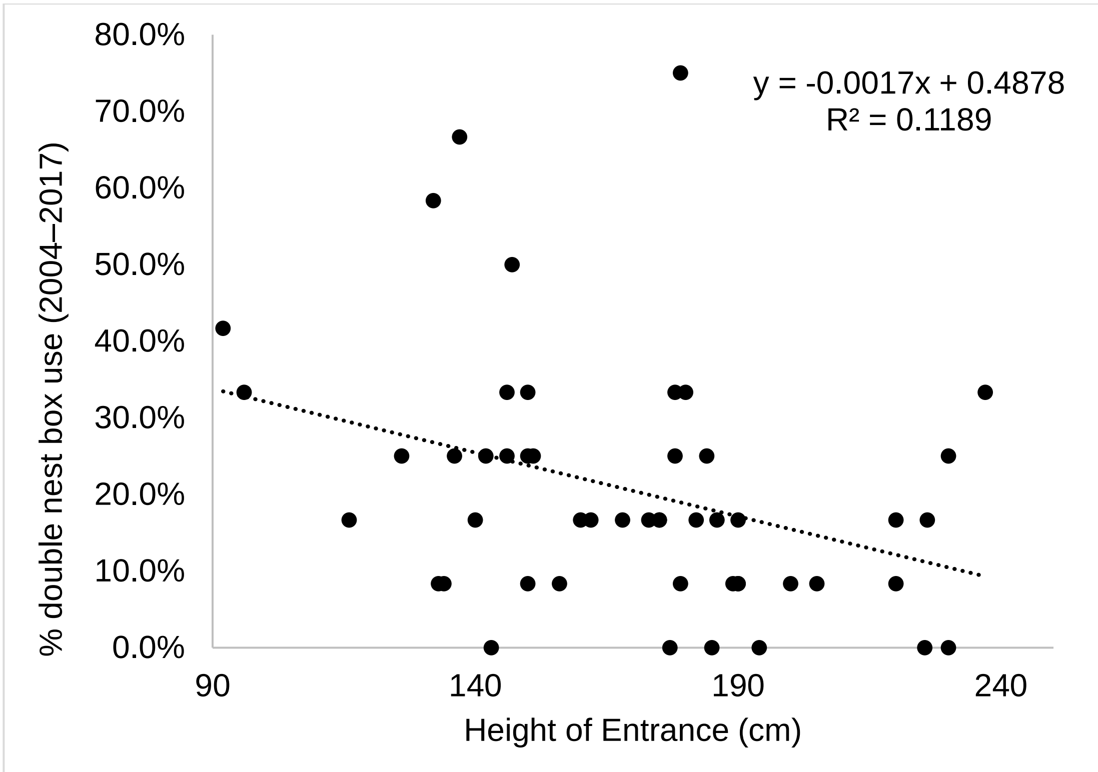
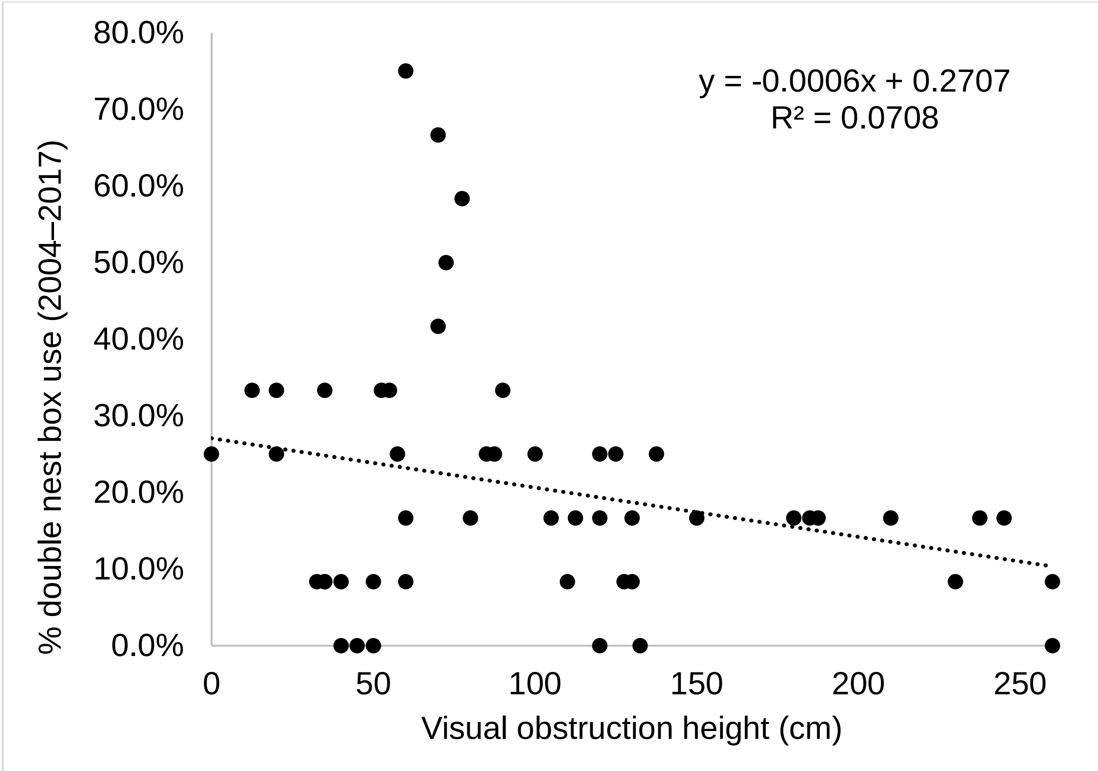


Figure 5 The effect of visual obstruction height (cm) on percent double nest box use by wood ducks on Betts Farm, Delaware, USA, 2004–2017.



Chapter 5

DISCUSSION

I determined that nest box use increases with proximity to open water, with lower visual obstruction, and with increased distance to neighboring boxes. Supporting my findings, previous research has found that nest boxes are used more often when placed in open swamps and open marshes (Heitmeyer and Fredrickson 1990, Bellrose 1994); partially because of dynamics between resources and natural nesting cavity availability. Distance to open water is the most significant factor influencing nest box choice in my study. Bellrose and Holm (1994) determined that use of boxes erected over land increases with proximity to water (up to 0.8 km). Additionally, lower distance to open water optimizes not only use, but also success of nests affected by brood parasitism, even though parasitism is higher in more visible boxes (Semel et al. 1988, Barry 1992). Many of the most frequently used boxes are placed right on open water (distance of 0 m); however, it is important to note that dense protective cover is essential to brood survival after hatching (Bellrose and Holm 1994).

Studies have shown that "habitat richness" is a significant variable affecting wood duck nest box choice. Boxes erected in areas with simpler vegetation are more likely to be chosen as nesting sites (Lacki 1987). Visual obstruction is also an interesting variable that ties in closely with distance to water. Although proximity to open water does not necessarily correlate with vegetative visual obstruction (e.g. *Phragmites* might grow on the edge of a pond), boxes placed directly on open water are often less visually obstructed in at least one direction, or have no vegetation near it at all. If emergent vegetation covers a large area, and placing a box on open water is not an option, choosing a patch that is less visually obstructed is optimal.

I found female wood ducks prefer pairs of boxes (that are on one pole) that are isolated from others poles. Very close clustering of nest boxes, such as putting several boxes on one pole, increases rates of intraspecific brood parasitism in wood ducks (Semel and Sherman 1986). However, a study by Jansen and Bollinger indicates that more isolated boxes (51–75m away from others) have higher rates of brood parasitism than boxes that are 26–50m away from any neighboring boxes (Jansen and Bollinger 1998). These contradictory aspects of intraspecific brood parasitism in wood ducks should be taken into consideration when developing box placement strategies with this variable in mind. Further examining what influences both nest boxes being used on one in any given year found some contradictory information. Double use decreases with increased height of entrance and more vegetation. This is counterintuitive, but we can make a supposition that wood ducks break natural patterns when adjusting to different nesting conditions. The difference in double use may be because it is easier for the wood ducks to see the entrance when it is lower off the ground with little vegetation.

Comparing habitat characteristics of dumped vs. undumped nests along with parasitized vs unparasitized nests, I found distance away from water increased dumping and parasitism. Double nesting on one pole in 2017 did not seem to influence nest dumping or nest parasitism rates. Further, while I did not have enough statistical power to make conclusions about factors affecting wood duck nest success, I anecdotally found easterly hole orientation, box height, nearness to water, and higher surrounding vegetation improved nest success. Wood ducks tend to nest in natural cavities higher off the ground (2–15m), probably to decrease predator access (Bellrose and Holm 1994, Baldessare 2014). They also choose cavities that are smaller, and less visible to predators and other wood ducks, which increases success by decreasing predation and brood parasitism (Semel and Sherman 1988, Soulliere 1990).

Even though the status of the wood duck is stable and increasing since 1966, we must be proactive in finding management solutions in the face of rapidly changing landscapes, and we should continue searching for most accurately efficient ways to manage their nesting habits (Sauer 2017). Based on my findings, I recommend that the optimal placement of wood duck nest boxes is on or very near open water, surrounded by minimal to no vegetation (while giving thought to cover needs of the newly hatched broods). The boxes should be spaced apart as much as possible to maximize use, with consideration for existing patterns of intraspecific brood parasitism in female wood ducks. However, I further recommend that future researchers investigate the interaction of nest parasitism with nest box placement in relation to their use and success. For example, it may be that use increases with decreased visual obstruction, but when a box is visible, brood parasitism occurs at higher rates (Soulliere 1990). Additionally, boxes placed on open water often have minimal vegetation around it, but even if they are parasitized, their success rates are higher than the success rates of parasitized boxes placed far away from open water (Semel et al. 1988, Barry 1992).

REFERENCES

Agami, M., and Y. Waisel. 1986. The role of mallard ducks (*Anas platyrhynchos*) in distribution and germination of seeds of the submerged hydrophyte *Najas marina* L. Oecologia 68:473–475.

Baldassarre, G. A., and F. H. Kortright. 2014. Ducks, geese, and swans of North America. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Barry, S. C. 1994. Evaluation of a wood duck nest box program at Yazoo National Wildlife Refuge, Mississippi, 1987-1991. Thesis, Mississippi State University, Starkville, USA.

Bellrose, F. C., and D. J. Holm. 1994. Ecology and management of the wood duck. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Bertness, M. D. 1999. The ecology of Atlantic shorelines. Sinauer Associates, Sunderland, Massachusetts, USA.

Conner, R. N., C. E. Shackelford, D. Saenz, and R. R. Schaefer. 2001. Interactions between nesting pileated woodpeckers and wood ducks. The Wilson Bulletin 113:250–253.

Dugger, K. M., and L. H. Fredrickson. 1992. Life history and habitat needs of the Wood Duck. Waterfowl management handbook. 13.1.6.:1–8.

Gersib, D. 1977. Wood Duck Nesting Boxes. Nebraska Game and Parks Commission--White Papers, Conference Presentations, and Manuscripts. 21.

Hartke, K. M., and G. R. Hepp. 2004 Habitat use and preferences of breeding female wood ducks. Journal of Wildlife Management 68:84–93.

Heitmeyer, M. E., and L. H. Fredrickson. 1990. Abundance and habitat use of wood ducks in the Mingo Swamp of southeastern Missouri. Proceedings of the 1988 North American Wood Duck Symposium, St. Louis, Missouri, USA. 141–151.

Hepp, G. R. and F. C. Bellrose. 2013. Wood duck (*Aix sponsa*), version 2.0. *In* Rodewald, P. G. (ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.169. Last accessed 3/28/2018

Hepp, G.R. and F. C. Bellrose. 1995. Wood duck: *Aix sponsa*. American Ornithologists' Union.

Jansen, R. W., and E. K. Bollinger. 1998. Effects of nest-box visibility and clustering on wood duck brood parasitism in Illinois. Transactions of the Illinois State Academy of Science 91:161–166.

Lacki, M. J., S. P. George, and P. J. Viscosi. 1987. Evaluation of site variables affecting nest box use by wood ducks. Wildlife Society Bulletin 15:196–200. by Wood Ducks. Wildl. Soc. Bull. 15:19

North American Bird Conservation Initiative. 2016. The State of North America's Birds 2016. Environment and Climate Change Canada, Ottawa, Ontario.

Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr, K. L. Pardieck, J. E. Fallon, and W. A. Link. 2017. The North American Breeding Bird Survey, Results and Analysis 1966–2015. Version 2.07.2017 USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Semel, B., and P. W. Sherman. 1986. Dynamics of nest parasitism in wood ducks. The Auk 103:813–816.

Semel, B., P. W. Sherman, and S. M. Byers. 1988. Effects of brood parasitism and nest-box placement on wood duck breeding ecology. Condor 90:920–930.

Soulliere, G. J. 1990. Review of wood duck nest-cavity characteristics. Proceedings of 1988 North America Wood Duck Symposium, 153-162.

South Carolina Waterfowl Association. 2015. Pricing for SCWA Wood Duck Projects. Retrieved from https://scwaterfowlassociation.wordpress.com/2015/05/08/pricing-for-scwa-wood-duck-projects/ Accessed 4/15/2018.

State of Delaware. 2011. Delaware Climate Information. http://climate.udel.edu/delawares-climate. Last accessed 4/25/2018

Tiner, R. W., and D. L. Hardin. 1985. Wetlands of Delaware. Dover, Delaware, USA

U. S. Fish and Wildlife Service. 2017. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/ Accessed 3/19/2018

Wilkinson, J. 1999. Protecting Delaware's natural heritage: Tools for Biodiversity Conservation. Environmental Law Institute.