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Nesting Ecology of Wild Turkeys in a Bottomland Hardwood Forest

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Abstract.—Although extensively studied in upland landscapes, little has been published regarding Eastern Wild Turkey (*Meleagris gallopavo silvestris*) nest site selection and reproductive ecology in bottomland systems. Wild Turkeys in these systems face unique conditions, such as persistent flooding, so facets of nesting ecology observed in primarily upland landscapes may not apply directly to Wild Turkeys in bottomland systems. We studied nesting ecology of radio-marked female Wild Turkeys during six nesting seasons (2002–2004, 2008–2010) in a bottomland hardwood system in south-central Louisiana. We studied landscape level nest site selection at three spatial scales (200 m, 400 m, and 800 m) and found Wild Turkeys selected nesting locations in areas that offered greater proportions of nonflooded bottomland forests and higher forest edge density than generally available across the study site at all scales. At smaller spatial scales, forest openings were also important to nest site selection, while at large scales, nest location was negatively related to landscape diversity. All nests were located in dry higher elevation forests (n = 35) or forest openings (n = 6). These habitats were likely selected because they offered protection from flood-related nest mortality and access to brood-rearing habitat. At the micro habitat scale, ground level cover was important to nest site selection, and likely provided protection from ground predators. Nests were often associated with small recent breaks in the canopy, presumably as a response to the resulting growth in understory cover. Wild Turkeys avoided nesting in managed forest stands with large areas of open canopy, likely because rapid successional growth in these areas made understory growth too dense. Nest predation was the greatest cause of nest failure (55%). Nesting rates (60%) and female success rates (24%) were among the lowest reported for the species, whereas nest success (39%) was near the range wide average. Reproductive performance may have been hampered by a scarcity of quality nesting habitat due to flooding and generally sparse understory vegetation, which left nests vulnerable to predation. Despite low nesting rates and female success, there was no evidence of a declining population on our study area. We suspect this may be a result of either high poult survival due to high quality brood-rearing habitat or because high female survival rates allow individual birds multiple chances to successfully reproduce.

Introduction

Reproductive success is an important parameter influencing Eastern Wild Turkey (*Meleagris gallopavo silvestris*) population dynamics (Vangilder, 1992; Roberts and Porter, 1996). Wild Turkey reproduction has been widely studied in a variety of upland landscapes (Lazarus and Porter, 1985; Ransom *et al.*, 1987; Day *et al.*, 1991; Paisley *et al.*, 1998; Thogmartin, 1999; Nguyen *et al.*, 2003). However, except for the study by Wilson *et al.* (2005), information regarding reproduction and nest site selection in bottomland

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hardwood forest systems is noticeably lacking. Bottomland systems are recognized as high quality turkey habitats (Dickson, 2001) and the lack of information available on nesting ecology in these systems represents a substantial gap in our understanding of Wild Turkey ecology. Wild Turkeys nesting in bottomland systems face unique conditions, such as persistent flooding. Consequently, nesting ecology in upland landscapes may not translate directly to these systems.

Reproductive output for a given area may be a function of the availability of quality nesting habitat. For example, as a ground nester, Wild Turkey nests are particularly susceptible to predation, as evidenced by the large number of studies identifying predation as the primary cause of nest failure (Vander Haegen *et al.*, 1988; Still and Baumann, 1990; Palmer *et al.*, 1993; Miller *et al.*, 1998; Paisley *et al.*, 1998; Thogmartin and Johnson, 1999). Habitat characteristics may influence predation risk and this likely plays a large role in wild turkey nest site selection. For example, a characteristic commonly associated with turkey nests across the species range is the presence of well developed, ground level vegetation, providing visual cover in the immediate vicinity of the nest (Porter, 1992). Dense vegetation may reduce visual clues to terrestrial predators (Bowman and Harris, 1980) and dense screening cover has been associated with reduced mammalian predation (Lehman *et al.*, 2008). Turkeys may choose to place their nests in such areas as a means of predator defense and a lack of such protective habitat may translate into increased nest predation and low nest success.

Animals are known to respond to habitat characteristics at a range of spatial scales (Wiens, 1989; Orians and Wittenberger, 1991) and landscape factors at larger scales may also influence nest site selection. For example, Thogmartin (1999) found that turkeys selected large habitat patches and avoided areas with a high degree of edge density in a highly fragmented landscape, whereas Lazurus and Porter (1985) suggested that nest site selection may be partially influenced by proximity to suitable brood rearing habitat. An understanding of nest site selection is important because it identifies the habitat and landscape characteristics important to wild turkey nesting and can guide land management decisions aimed at increasing wild turkey production.

Previous work on our study area indicated low nesting rates (Wilson *et al.*, 2005) and suggested that a large portion of the population may have had their clutch destroyed prior to initiating incubation. Understory vegetation is generally sparse due to annual flooding in low-lying areas and general over story shading. These factors may reduce the availability of suitable nesting cover, thus exposing nests to increased predation risk. Flooding presents an additional threat to nest success on our study area. Our objectives were to identify the landscape and habitat characteristics associated with nest site selection at a variety of spatial scales and to describe reproductive parameters and identify causes of nest failure in a bottomland hardwood forest system in Louisiana. We hypothesized that turkeys would choose to place nests in patches of denser ground level vegetation relative to what was generally available and in areas of relatively higher elevation less prone to flooding.

STUDY AREA

We conducted research on a 17,243 ha tract (hereafter Sherburne) of bottomland hardwood forest in Iberville, St. Martin, and Point Coupee Parishes, Louisiana, located in the Atchafalaya floodway system. Sherburne included Sherburne Wildlife Management Area owned by the Louisiana Department of Wildlife and Fisheries, Bayou des Ourses owned by the United States Army Corps of Engineers, and the Atchafalaya National Wildlife Refuge owned by the United States Fish and Wildlife Service. The coordinates for the headquarters of Sherburne WMA are 30°31′59″, 91°42′54″W. Additionally, there were approximately 770 ha of private lands interspersed among the state and federal lands. Sherburne was bordered on the south by Interstate 10, on the north by Highway 190, on the west by the Atchafalaya River, and the east by the East Protection Guide Levee.

Sherburne was comprised of 96% forest, 2% forest openings, and 2% open water based on our delineation of habitat types (see methods). The most common overstory species included eastern cottonwood (*Populus deltoids*), nuttall oak (*Quercus texana*), water oak (*Q. nigra*), overcup oak (*Q. lyrata*), sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanicus*), black willow (*Salix nigra*), and baldcypress (*Taxodium distichum*). Understory vegetation was relatively sparse because of overstory shading and was particularly sparse in areas that experienced annual persistent flooding. Forest openings consisted of wildlife food plots, right-of-ways (electric and natural gas) maintained through mowing and herbicide application, levees, and natural regeneration from forest harvesting.

Due to logging practices of previous landowners (*i.e.*, high-grading) relatively few hard mast producing species were present away from riparian zones or sites where persistent flooding made logging difficult. Although Sherburne was logged extensively during the 1950s, many areas have remained virtually undisturbed since. Forest management practices including group selection cuts, individual selection cuts, clear cuts, and shelterwood cuts designed to promote regeneration of dominant canopy species and increase stand diversity have been applied to portions of Sherburne with varying intensity since 1986 and encompassed approximately 7% of the total study area. Due to construction of levees and water control structures, Sherburne did not experience direct flooding from the Atchafalaya River, instead river induced flooding was manifested in the form of back water flooding moving north from southern areas of the Atchafalaya Basin and varied in severity from year to year. Most seasonal flooding on Sherburne could be attributed to local precipitation during the rainy season (Feb.–Apr.) as poorly drained alluvial soils allow surface water to persist for extended periods of time, often into early Jun. in most years. Mean annual high and low temperatures for the region are 27.8 C and 8.9 C respectively, and average annual rainfall is 155.4 cm.

METHODS

Nest site location.—We captured female Wild Turkeys using cannon nets at bait sites distributed throughout the study area during summer (Jun.–Aug.) of 2007 and 2008. We trapped during summer because bait site use and capture opportunities were practically nonexistent during winter. Each captured female was fitted with a standard serially numbered aluminum leg band and a 75 g (≤3% body weight) mortality sensitive radio transmitter (Advanced Telemetry Systems, Isanti, Minnesota) attached backpack style. Battery life of radio transmitters was approximately 2 y. We released all birds at the capture site immediately following processing. Previous researchers captured females during summers of 2001–2003; they were similarly handled, marked, and released (Wilson *et al.*, 2005). All capture and handling procedures were covered under Louisiana State University Agricultural Center Institutional Animal Care and Use Protocol number AE2010-09.

We tracked birds throughout the year via radio telemetry using a 3-element Yagi antenna and an ATS R4000 receiver (Advanced Telemetry Systems, Isanti, Minnesota). To insure that all nesting related activity was detected, we triangulated ≥1 location daily for each turkey beginning on 15 Feb. and continued through the end of the nesting season in each year. We studied nesting ecology during the 2008–2010 nesting seasons; whereas previous researchers collected data during the 2002–2004 nesting seasons using the same methods described below (*see* Wilson *et al.*, 2005).

We assumed a bird to have initiated incubation when it was found in the same location for two consecutive days. Once we determined a turkey to be incubating, we approached the nest to within a distance of ~15 m and placed flagging tape on the vegetation surrounding the nest site. On each piece of flagging, we recorded a compass bearing toward the incubating bird and used this information to later help locate the nest. Since incubation often triggered the mortality sensor in the VHF transmitters, we treated any consistent mortality signals discovered from 1 Apr.–15 May as an incubating bird and did not attempt to recover the radio for 30 d to avoid accidentally flushing turkeys that may have been incubating. In addition to the nests of radio marked birds, several nests were located incidentally by Sherburne staff and other researchers working on the study area who accidentally flushed incubating birds.

Once incubation had been terminated and the female had left the nest site (due to successful hatching or nest failure), or after 32 d had passed since the first known date of incubation, we located the nest and recorded its location with a hand held Global Position System (GPS) unit. We considered a nest successful if ≥1 egg hatched and unsuccessful otherwise. We used clues at the nest site to determine the cause of nest failure. We considered a nest abandoned if the nest was undisturbed and a full clutch of eggs was found intact and considered a nest to have been destroyed by floods in cases where the nest site was inundated by water. We considered a nest to have been destroyed by predators if the nest site was trampled, eggs were destroyed at the nest site, eggs were found carried away from the nest site and destroyed, or if the nest was devoid of eggs, incubation lasted <27 d and the female was not observed to be tending a brood. We considered a female to have been killed by a predator during incubation if the carcass of the female was found within the immediate vicinity of the nest. We considered nests abandoned due to observer interference if an observer flushed an incubating bird that subsequently did not return to incubate.

Reproductive parameters.—We calculated reproductive parameters based on those identified by Vangilder (1992). Specifically, we defined nesting rate as the percentage of females alive on 23 Mar. that were known to incubate a nest. We chose 23 Mar. because that was the earliest incubation start date recorded on Sherburne. We defined the renesting rate as the percentage of females that renested following the failure of their first nesting attempt, excluding those females who were killed while incubating their initial nest. Since Wild Turkeys do not begin incubation until the entire clutch has been laid (Eaton, 1992), and we were not able to detect nests until incubation began, it is probable that estimates of nesting rates are biased low as some nests were likely destroyed prior to incubation. Nest and renest success was defined as the percentage of initial and renests that successfully hatched ≥1 egg, respectively. Nests that were suspected of observer induced abandonment were excluded from these estimates. We calculated female success as the percentage of females alive on 23 Mar. that successfully hatched ≥1 egg. Because all females were captured during summer (Jun.–Aug.), we did not separate age classes because all individuals were >1 year of age at the time of capture and adults by the first nesting season in which they were studied.

Landscape-scale habitat selection.—To investigate nest site selection at the landscape level, we generated an equal number of random locations within the study area using Hawth's Analysis Tools (http://www.spatialecology.com/htools) in ArcGIS 9 (ESRI, Redlands, California). Because turkeys may respond to different landscape characteristics at varying scales (Johnson, 1980; Wiens, 1989), we created circular plots with radii of 200 m, 400 m, and 800 m centered on each nest and random point to investigate how relationships between landscape characteristics and nest site selection varied along a spatial gradient. We intersected these plots with a digital landcover of Sherburne which we created in ArcGIS 9 using 2004 digital orthophoto quarter quadrangles (DOQQs) and digital elevation models (DEM, 5 m^2 resolution) derived from 2003 LIDAR data (available at http://atlas.lsu.edu). Because stand specific information was not readily available for Sherburne, we delineated habitat types into three broad categories based on the combination of visual characteristics of the landscape visible on the DOQQs, elevation data from the DEMs, and ground truthing in the field. Habitat types included water influenced forests (bottomland hardwood forests that experienced seasonal flooding and held standing water for a considerable portion of the year, including cypress-tupelo swamps and riparian areas immediately adjacent to waterways), non flooded forests (bottomland hardwood forests of relatively high elevation not associated with flooding in most years, including ridges, natural levees, terraces, and higher flats), and openings (including right-of-ways, levees, foot plots, and roads). To delineate non flooded and water influenced bottomland forests we first generated 0.25 m contour lines from DEMs using ArcGIS 9. Because the average elevation of Sherburne varied along a north-south gradient, we separated large contour datasets into sufficiently small parcels such that a specific elevation value would be hydrologically consistent across the whole parcel. For instance, an elevation of 19 m may flood regularly in the north; whereas, 19 m may represent the highest point of land in the southern part of the study area. In each parcel, we considered the area below the specific elevation contour that represented the highest elevation to regularly flood on average each year as water influenced. We determined the cut off elevation based on personal experience during flood periods and from cross referencing contour datasets to DOQQs. At each spatial scale, we calculated the percentage of each habitat type within each plot and then calculated the Shannon-diversity index to provide a measure of habitat diversity for each plot. Because Wild Turkeys have been reported to nest close to edges between forest habitats and openings (Speake *et al.*, 1975; Everett *et al.*, 1985; Campo *et al.*, 1989; Seiss *et al.*, 1990), we calculated edge density within each plot as the total length (m) of all edge between forest habitats and openings divided by the total area (ha) of each plot.

Using these variables, we developed a suite of 19 *a priori* biologically relevant logistic regression models to differentiate between nest sites and random locations at each spatial scale. Because the percentage of non flooded and water influenced bottomland forest were highly correlated at all scales ($r^2 = -0.86$, -0.92, and -0.97, respectively), we used only the percentage of non flooded forest when constructing models. For all models, we used the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow, 1980) to assess model fit. We calculated Akaike's information criterion adjusted for small sample sizes (AIC_c), and used ΔAIC_c and Akaike weights (w_i) to evaluate model performance (Burnham and Anderson, 2002). We used model averaging (Burnham and Anderson, 2002) based on the top performing models (cumulative $w_i = 0.95$) to calculate parameter estimates and odds ratios at each spatial scale. We used 85% confidence intervals for model averaged parameter estimates to distinguish between informative and uninformative parameters at each scale and considered a parameter informative if the 85% confidence interval did not include zero (Arnold, 2010).

Micro-habitat nest site selection.—To investigate selection at the level of the nest site, we measured habitat characteristics within 10 m of each nest discovered during the 2003–2004 and 2008–2010 seasons. We estimated canopy cover using a spherical densiometer (Lemmon, 1956) directly over the nest and 10 m from the nest in each of the four cardinal directions. We then averaged each canopy cover reading to provide one value for the nest site. We estimated lateral visual obstruction for each nest by taking minimum (VOmin), average (VOavg), and maximum (VOmax) readings of a Robel pole (Robel *et al.*, 1970) placed at the nest center from a distance of 10 m in each of the four cardinal directions and averaged the four readings of each measurement to provide one value for the nest site. We used a 1 m^2 Daubenmire frame (Daubenmire, 1959) to quantify ground cover composition as the percentage of water, bare ground, grasses, forbs, ferns, vines, debris, and woody vegetation present within each frame. Ground cover measurements were taken at the nest and at a distance of 10 m in each of the four cardinal directions and averaged to provide a single value for each nest. We recorded the habitat type (non flooded forest, water influenced forest, or opening) each nest was located in and the distance from the nest to the nearest forest edge. For each nest site, a random site was chosen within 100–500 m of the nest by randomly selecting a distance and bearing from the nest site and the same characteristics were measured as described above. This allowed comparison of the habitat within the immediate area of nest placement to that of other locations that each nesting female could have sampled prior to nesting. Habitat characteristics of each nest site and its associated random site were recorded on the same day, ≤5 d following the day in which we determined the nest was no longer active.

We developed a suite of 28 *a priori* biologically relevant logistic regression models designed to discriminate between nest and random sites relative to microhabitat characteristics. Because visual obstruction measurements were highly correlated ($r^2 <$ 0.70) we used only estimates of average obstruction (VOavg) when constructing models. For all models, we used the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow, 1980) to assess model fit, calculated AIC_c values, and ranked candidate models based on ΔAIC_c and w_i (Burnham and Anderson, 2002). We used model averaging (Burnham and Anderson, 2002) based on the top performing models (cumulative w_i = 0.95) to calculate parameter estimates and odds ratios. We used 85% confidence intervals for model averaged parameter estimates to distinguish between informative and uninformative parameters, and considered a parameter informative if the 85% confidence interval did not include zero (Arnold, 2010).

For all analyses, we pooled data across years due to wide variation in the number of turkeys radio marked at the start of each nesting season and small sample sizes in some years. Habitat characteristics were not recorded and nest locations were not available from the 2002 season. As such these nests were excluded from all habitat selection analyses.

RESULTS

We captured and radio marked 65 female turkeys over the course of five summer trapping seasons. The number of individuals actively being tracked at the start of any given nesting season ranged from 4–17 (Table 1). We discovered 47 nests across six nesting seasons, 35 nests belonged to radio marked birds and 12 nests were found opportunistically. Three nests were likely abandoned due to observer disturbance and were censored when estimating nest success. Additionally, nests belonging to birds that were not radio marked were censored when estimating nest success because fates of these nests could not be confidently determined. Of the remaining 32 nests whose fates were known, 12 (37.5%) were successful in hatching ≥1 egg, 11 (34.4%) were destroyed by predators, 4 (12.5%) failed due to predation of the incubating female, 4 (12.5%) were destroyed by flooding, and 1 (3.1%) was abandoned. All flood related nest loss occurred during the 2002 nesting season which was characterized by above average spring flooding during which many areas that remain dry in normal years were inundated. Nest predation accounted for most (55%) nest

TABLE 1.—Reproductive parameters of Eastern Wild Turkeys nesting on Sherburne WMA, Louisiana, during the 2002–2004 and 2008–2010 nesting seasons. Numbers in parentheses correspond to the number of nesting attempts or successful nesting attempts

Year	n[1]	Nesting rate[2]	First nest success[3]	Renest rate[4]	Renest success[5]	Female success[6]
2002	6	83.3% (5)	20% (1)	0%	N/A	20% (1)
2003	8	2.5% (1)	0%	0%	N/A	0%
2004	5	60% (3)	66.7% (2)	100% (1)	0%	40% (2)
2008	4	100% (4)	25% (1)	50% (1)	0%	25% (1)
2009	17	70.6% (12)	60% (6)	50% (2)	50% (1)	41.2% (7)
2010	10	50% (5)	20% (1)	0%	N/A	10% (1)
All years	50	60% (30)	39.3% (11)	26.7% (4)	25% (1)	24% (12)

[1] Number of radio marked females alive on 23 Mar.

[2] Number of females to successfully reach incubation

[3] Number of first nesting attempts to hatch ≥1 egg. Nests suspected of observer-induced abandonment were censored from estimates

[4] Number of surviving females to renest after failure of their first nesting attempt

[5] Number of successful renest attempts. One female renested twice in 2009

[6] Successful females (*i.e.*, number of radio marked females alive on 23 Mar. to successfully hatch ≥1 egg)

failures. The nesting rate (proportion of females initiating incubation) was 60%, the nest success rate for initial nesting attempts was 39.3%, the renesting rate was 26.7% and the renest success rate was 25%. One female renested twice in 2009 and was successful on her second renesting attempt; this was the only recorded successful renest attempt. Overall female success was 24%.

We measured landscape characteristics at 41 nests and their associated random locations (Table 2). One nest from 2003 was excluded because its location was not recorded properly. All models had adequate goodness-of-fit based on the Hosmer-Lemeshow statistic ($P > 0.05$). Edge density and percentage of non flooded forest were consistently included in top ranked models (Table 3) and were identified as informative parameters at all spatial scales (Table 4). At all scales, Wild Turkeys selected nesting areas that offered greater edge density and proportion of non flooded forest compared to availability in the study area (Table 2). At 200 m only one model was considered plausible ($\Delta AIC_c < 2$), containing edge density, non flooded forest, and percent forest openings (Table 3). All three parameters were identified as informative and had an equal model averaged odds ratio of 1.04 (Table 4), indicating all parameters equally influenced nesting suitability. At the 400 m scale, four models were considered plausible ($\Delta AIC_c < 2$, Table 3); however, only edge density and non flooded forest were identified as informative parameters (Table 4). At the largest spatial scale (800 m), six models were considered plausible ($\Delta AIC_c < 2$, Table 3); however, only edge density, proportion of non flooded forest, and habitat diversity were identified as important parameters (Table 4). Based on the calculated odds ratios for each variable, nest site suitability increased as edge density and the proportion of non flooded forest increased, but decreased slightly as landscape diversity increased (Table 4).

We measured microhabitat characteristics for 40 nests and random locations (Table 5). Two nests were censored because they were discovered during mowing of a field, which altered the habitat around the nests. All models we evaluated had adequate goodness-of-fit based on the Hosmer-Lemeshow statistic ($P > 0.05$). The top ranked model included visual obstruction of the nest, the proportions of bare ground and woody vegetation within 10 m

TABLE 2.—Mean ± standard error for landscape characteristics measured within 200 m, 400 m, and 800 m buffered areas around Eastern Wild Turkey nest locations (n = 41) and random locations (n = 41) from the 2003–2004 and 2008–2010 nesting seasons on Sherburne WMA, Louisiana

Variable	Nests	Random
200 m buffer		
Edge density[1]	55.87 ± 4.21	16.54 ± 4.48
%Water	3.45 ± 0.99	1.07 ± 0.38
%Water-based forest	8.94 ± 2.42	50.07 ± 5.74
%Non-flooded forest	76.35 ± 3.95	44.62 ± 5.33
%Open	11.26 ± 3.32	4.25 ± 2.16
Diversity index	0.49 ± 0.04	0.47 ± 0.05
400 m buffer		
Edge density	46.76 ± 1.91	15.82 ± 3.72
%Water	3.35 ± 0.65	0.99 ± 0.26
%Water-based forest	13.51 ± 2.50	49.33 ± 4.94
%Non-flooded forest	74.50 ± 3.14	46.31 ± 4.51
%Open	8.64 ± 2.07	3.37 ± 1.39
Diversity index	0.62 ± 0.04	0.58 ± 0.04
800 m buffer		
Edge density	38.08 ± 1.33	15.64 ± 2.48
%Water	2.84 ± 0.35	1.28 ± 0.21
%Water-based forest	17.71 ± 2.21	47.62 ± 3.96
%Non-flooded forest	73.45 ± 2.29	48.43 ± 3.61
%Open	6.00 ± 1.03	2.67 ± 0.63
Diversity index	0.70 ± 0.03	0.69 ± 0.04

[1] Length (m) of all edges between forest habitats and openings divided by area (ha)

of the nest, and distance to the nearest forest edge (Table 6); all of which were identified as informative parameters (Table 7). Turkeys placed their nests in locations that offered more visual cover, less bare ground, more woody vegetation, and were in closer proximity to forest edges compared to random sites located within 500 m of known nests (Table 5). Visual obstruction had the greatest influence on nest site selection, with a location being 2.32 times more likely to be suitable to for nest placement with each unit increase in visual obstruction (Table 7).

DISCUSSION

As expected Wild Turkeys on Sherburne selected topographically higher areas for nesting. All nests were located in non flooded forests (n = 35) or openings (n = 6). Water influenced forests were avoided, which corresponded to habitat selection observed during the pre incubation period (Byrne *et al.*, 2011). Several advantages may come from nesting in drier areas. For example flooding can seriously impact turkey nesting (Kimmel and Zwank, 1985), and given the flood prone nature of bottomland forests, nesting in non flooded sites offers the best chance of avoiding flood related nest loss. Additionally, proximity to quality brood rearing habitat may play an important role in nest site selection (Porter, 1992). Non flooded forests on Sherburne appear to provide the qualities associated with good brood rearing habitat – herbaceous ground cover that provides food resources and cover for developing poults, yet sparse enough to allow for ease of movement and predator detection

TABLE 3.—Highest ranking logistic regression models (cumulative w_i = 0.95) differentiating between Eastern Wild Turkey nests (n = 41) and random points (n = 41) based on landscape characteristics at three spatial scales during the 2003–2004 and 2008–2010 nesting seasons, Sherburne WMA, Louisiana

Model[1]	K[2]	AICc[3]	ΔAICc[4]	w_i[5]
200 m scale[6]				
Edge + %NF + %Open	4	75.94	0.00	0.51
Edge + %NF + %Open + Diversity	5	78.07	2.14	0.18
Edge + %NF	3	79.18	3.25	0.10
Edge + %NF + %Open + %Water + Diversity	6	79.41	3.47	0.09
Edge + %NF + Diversity	4	80.93	5.00	0.04
Edge + %NF + %Water	4	80.94	5.00	0.04
400 m scale				
Edge + %NF + %Water	4	73.02	0.00	0.27
Edge + %NF	3	73.04	0.03	0.27
Edge + %NF + %Water + Diversity	5	74.77	1.75	0.11
Edge + %NF + %Open	4	74.82	1.80	0.11
Edge + %NF + Diversity	4	75.14	2.13	0.09
Edge + %NF + %Open + %Water + Diversity	6	76.21	3.20	0.06
Edge + %NF + %Open + Diversity	5	76.82	3.80	0.04
800 m scale				
Edge + %NF	3	68.94	0.00	0.25
Edge + Diversity	3	69.90	0.96	0.15
Edge + %NF + %Water	4	70.24	1.30	0.13
Edge + %NF + Diversity	4	70.48	1.54	0.11
Edge + %NF + %Open	4	70.80	1.84	0.10
Edge + %NF + %Water + Diversity	5	70.81	1.86	0.10
Edge + %NF + %Open + %Water + Diversity	6	71.34	2.40	0.07
Edge + %NF + %Open + Diversity	5	71.79	2.84	0.06

[1] Edge = forest edge density, %NF = % of plot containing non-flooded forest, %Open = % of plot containing forest openings, %Water = % of plot containing open water, and Diversity = landscape diversity

[2] Number of parameters

[3] Akaike's Information Criterion adjusted for small sample size

[4] Difference in AIC_c relative to smallest value

[5] AIC_c weight

[6] AIC_c value for intercept-only model at all scales = 115.73

(Porter, 1992; Godfrey and Norman, 1999). Non flooded forests represented the preferred habitat type of female turkeys during the brood rearing season (Byrne *et al.*, 2011); thus, the proximity to brood rearing habitat may be an additional benefit of nesting in non flooded forests.

Dry areas on Sherburne also provided more ground level vegetative cover than those that experienced regular inundation. The presence of ground level cover is important to nesting turkeys (Hon *et al.*, 1978; Everett *et al.*, 1985; Campo *et al.*, 1989; Still and Baumann, 1990; Day *et al.*, 1991; Chamberlain and Leopold, 1998) and the concealment such cover provides likely serves as a predator defense mechanism (Lehman *et al.*, 2008). Despite the fact that understory vegetation is rather sparse on Sherburne, turkeys consistently chose to nest in patches that offered ground level vegetative cover within the immediate vicinity of the nest

TABLE 4.—Model averaged estimates, standard errors, 85% confidence intervals, and odds ratios for parameters occurring in the highest ranking logistic regression models (cumulative w_i = 0.95) differentiating between Eastern Wild Turkey nests (n = 41) and random points (n = 41) based on landscape characteristics at three spatial scales during the 2003–2004 and 2008–2010 nesting seasons, Sherburne WMA, Louisiana Parameter[1]

	Estimate	SE	85% CI	Odds ratio
200 m scale				
Edge*	0.04	0.01	0.02–0.05	1.04
%NF*	0.04	0.01	0.02–0.06	1.04
%Open*	0.04	0.02	0.01–0.07	1.04
%Water	0.07	0.09	−0.05–0.20	1.07
%Diversity	−0.68	1.37	−2.65–1.29	0.51
400 m scale				
Edge*	0.07	0.02	0.04–0.09	1.07
%NF*	0.03	0.01	0.01–0.05	1.03
%Open	0.02	0.03	−0.02–0.07	1.02
%Water	0.17	0.12	−0.01–0.34	1.19
Diversity	−1.07	1.75	−3.59–1.45	0.34
800 m scale				
Edge*	0.12	0.04	0.07–0.18	1.13
%NF*	0.04	0.03	0.001–0.08	1.04
%Open	0.05	0.06	−0.04–0.14	1.05
%Water	0.25	0.22	−0.06–0.56	1.28
Diversity*	−3.54	2.42	−7.03–0.05	0.03

[1] Edge = forest edge density, %NF = % of plot containing non-flooded forest, %Open = % of plot containing forest openings, %Water = % of plot containing open water, and Diversity = landscape diversity

* Informative parameter (*i.e.*, 85% CI does not include zero)

and avoided nesting in areas consisting largely of bare ground. Nests in openings were located along rights-of-ways, levees, and fields that had not been recently mowed and were dominated by dense cover, primarily consisting of Johnson grass (*Sorghum halepense*). Nests in forests were placed within a range of understory vegetative cover types, including southern shield fern (*Thelypteris kunthii*), vines such as green brier (*Smilax* spp.) and blackberry (*Rubus* spp.), various woody shrubs, and within the debris of fallen trees.

Nests in forests were commonly associated with small canopy breaks caused by fallen trees. These isolated openings allowed understory vegetation to flourish and also provided cover in the form of debris from the fallen trees themselves. These areas allowed small tree saplings as well as other small woody shrubs to grow in the immediate vicinity of the canopy break and likely accounts for the observed connection between woody vegetation and nest sites. Hurricane Gustav impacted Sherburne in the fall of 2008, causing an estimated 30% reduction in canopy cover across the area (Louisiana Department of Wildlife and Fisheries, unpublished data). The following nesting season (2009) was characterized by a higher than average nesting rate (71%) and female success rate (41%). Interestingly, there is little evidence that applied forest management techniques designed to reduce canopy cover served to provide nesting habitat on a long term basis. Only two nests were found within forest stands that had been managed with these harvests; both nests were found during the 2004 nesting season in a shelterwood treatment that had been cut the previous fall.

TABLE 5.—Means ± SE of habitat characteristics measured at Eastern Wild Turkey nests (n = 40) and random points (n = 40) during the 2003–2004 and 2008–2010 nesting seasons, Sherburne WMA, Louisiana

Variable	Nests	Random points
	Mean ± SE	Mean ± SE
% Canopy cover	77.8 ± 5.43	85.2 ± 4.27
Visual obstruction[1] (m)-min	0.79 ± 0.06	0.51 ± 0.07
Visual obstruction (m)-avg	0.95 ± 0.04	0.73 ± 0.06
Visual obstruction (m)-max	1.2 ± 0.044	1.03 ± 0.06
Ground cover[2]		
% Grass	15.5 ± 5.0	7.7 ± 3.35
% Woody	5.6 ± 0.91	3.1 ± 0.71
% Forb	15.3 ± 2.00	15.8 ± 2.37
% Vine	19.9 ± 3.00	17.7 ± 2.74
% Fern	23.8 ± 3.90	18.6 ± 3.60
% Bare ground	4.2 ± 0.92	22.2 ± 4.10
% Debris	15.1 ± 2.49	12.29 ± 2.31
%Water	0.0 ± 0.0	2.08 ± 0.92
Distance to edge (m)	55.8 ± 8.59	86.6 ± 12.80

[1] Visual obstruction measured using a Robel pole

[2] Ground cover composition estimates obtained by use of a 1 m^2 Daubenmire frame

TABLE 6.—Highest ranking logistic regression models (cumulative w_i = 0.96) differentiating between Eastern Wild Turkey nests (n = 40) and random points (n = 40) based on microhabitat characteristics during the 2003–2004 and 2008–2010 nesting seasons, Sherburne WMA, Louisiana

Model[1]	K[2]	AICc[3,4]	ΔAICc[5]	w_i[6]
VOavg + BG + EDGE + WOOD	5	86.93	0.00	0.53
VOavg + BG + EDGE	4	89.81	2.88	0.12
BG + EDGE	3	90.73	3.81	0.08
BG + WOOD	3	91.33	4.41	0.06
VOavg + BG + EDGE + CC	5	91.72	4.80	0.05
VOavg + BG + EDGE + DEB	5	91.94	5.01	0.04
VOavg + BG + EDGE + GRASS	5	92.09	5.16	0.04
BG x EDGE	4	92.95	6.02	0.03
VOavg + BG	3	93.74	6.81	0.02

[1] VOavg = average visual obstruction, BG = % ground cover consisting of bare ground, WOOD = % ground cover consisting of woody vegetation, EDGE = distance to nearest forest/opening edge, DEB = % ground cover consisting of debris, GRASS = % ground cover consisting of grass, CC = canopy cover, BGXEDGE = the interaction between % ground cover consisting of bare ground and distance to nearest forsest/opening edge

[2] Number of parameters

[3] Akaike's Information Criterion adjusted for small sample size

[4] AICc value for intercept-only model = 110.13

[5] Difference in AIC_c relative to smallest value

[6] AIC_c weight

TABLE 7.—Model averaged estimates, standard errors, 85% confidence intervals, and odds ratios for parameters occurring in the highest ranking logistic regression models (cumulative w_i = 0.95) differentiating between Eastern Wild Turkey nests (n = 40) and random points (n = 40) based on microhabitat characteristics during the 2003–2004 and 2008–2010 nesting seasons, Sherburne WMA, Louisiana

Parameter[1]	Estimate	SE	85% CI	Odds ratio
VOavg*	1.30	0.84	0.08–2.51	2.32
WOOD*	0.12	0.06	0.04–0.20	1.13
BG*	−0.08	0.03	−0.13–0.04	1.03
EDGE*	−0.01	0.001	−0.02–0.001	0.99
DEB	0.01	0.02	−0.02–0.03	1.01
CC	0.01	0.01	−0.01–0.02	1.01
GRASS	<0.01	0.01	−0.02–0.02	1.00

[1] VOavg = average visual obstruction, BG = % ground cover consisting of bare ground, WOOD = % ground cover consisting of woody vegetation, EDGE = distance to nearest forest/opening edge, DEB = % ground cover consisting of debris, GRASS = % ground cover consisting of grass, CC = canopy cover

* Informative parameter (*i.e.*, 85% CI does not include zero)

Succession occurs rapidly in these stands (LeGrand, 2005), and after two growing seasons understory vegetation appeared to be too dense to be of use for turkeys and turkeys avoided these areas during all seasons (Byrne *et al.*, 2011). Given the rapid rate of succession, suitable nesting habitat likely only exists within a single growing season of canopy disturbance. Thus, we offer that natural periodic disturbances create an abundance of ephemeral, high quality nesting habitat over a broad area, and that temporary increases in reproductive output likely follow such events. Further investigation into the effects of major natural disturbances on turkey reproduction in southern bottomland hardwood forests may prove valuable for predicting pulses in female success and recruitment.

Openings where an important aspect of nest site selection at small spatial scales (200 m). The majority of open habitats on Sherburne consisted of narrow linear features and only comprised approximately 2% of the total study area. These aspects of forest openings explains why openings were important at small scales but were less important at larger scales; as plot size increased the total percentage of openings decreased for both actual nests and random locations (Table 2). It should be noted five of the six nests in openings were discovered opportunistically. Considering nests in openings are potentially more likely to be encountered incidentally compared to nests in forested habitats, the proportional use of openings for nesting may be inflated. It is likely that the percentage of the total population nesting in openings was to some extent smaller than the 17% we report here.

A proclivity for nesting close to edges has been widely reported for Wild Turkeys (Hillestad, 1970; Speake *et al.*, 1975; Everett *et al.*, 1985; Campo *et al.*, 1989; Seiss *et al.*, 1990; Still and Baumann, 1990). Likewise, turkeys on Sherburne chose to nest in areas with high edge densities at all landscape scales. The mean distance of nest placement from the nearest edge was 55.8 m, with 80% of nests located within 100 m of a forest edge and 8 nests located ≤10 m from a forest edge. Forest patches in which turkeys nested were relatively large (mean patch size = 424 ha) and provided ample nesting availability further from edge areas. Turkeys may choose to nest near edges because the associated openings can function as travel lanes and offer incubating females increased foraging opportunities near the nest.

Potential nest predators, such as raccoons and coyotes are known to concentrate in areas with high landscape heterogeneity and to make use of edge areas (Byrne and Chamberlain, 2011; Dijak and Thompson, 2000; Kays *et al.*, 2008) which may expose nests near edges to increased predation risk. Landscape structure and degree of forest fragmentation can influence the severity of edge effects on nest predation (Paton, 1994; Donovan *et al.*, 1997; Keyser *et al.*, 1998; Stephens *et al.*, 2003). For instance turkeys in a highly fragmented forest in Arkansas avoided nesting in edge habitats, presumably as a response to high predator densities (Thogmartin, 1999). Conversely, the relatively unfragmented forest composition of Sherburne may serve to reduce potential edge related predation risks, as the success of initial nesting attempts (39.3%) was well within the range of that reported for adult Eastern Wild Turkeys in the literature [range: 16% (Paisley *et al.*, 1998) – 66.7% (Swanson *et al.*, 1995)].

The overall nesting rate of 60% in this study is among the lowest reported for adult Eastern Wild Turkeys [reported range: 63.4% (Miller *et al.*, 1998) – 100% (Vander Haegen *et al.*, 1988)]. This number is likely biased low because nests that were destroyed prior to incubation could not be detected; however, this bias is present in all VHF-based Wild Turkey studies. Because the overall success rate of initial nesting attempts on Sherburne falls well within the normal range for adult Eastern Wild Turkeys, it is the low nesting rate that must account for the overall low rate of female success. Female success is probably the most directly comparable metric of total reproductive output among studies, and at 24%, this is among the lowest reported [range: 19.5% (Thogmartin and Johnson, 1999) – 82.8% (Vangilder, 1992)] for adult Eastern Wild Turkeys.

We contend that the low reproductive output observed on Sherburne results from a scarcity of quality nesting cover which likely results in some females being forced to place nests in suboptimal habitat that increases the risk of nest predation. This would account for the low nesting rates observed, as many individuals likely lost clutches prior to incubation and observer detection. A number of individuals for which a nesting attempt was never discovered exhibited behaviors associated with nesting; namely, concentrated activity in a small area over a narrow time frame. Turkeys on Sherburne exhibited significant increases in home range size during the pre- incubation period relative to other times of the year (Byrne *et al.*, 2011) suggesting that females may be forced to sample a large area while searching for a suitable nesting location. While an increase in space use at this time may have been a result of increased foraging range in response to a lack of foraging resources during an energetically demanding time of year, the general productivity of Sherburne and significantly smaller home ranges observed during all other seasons (Byrne *et al.*, 2011) makes this alternative hypothesis unlikely. Additionally, turkeys on our study area would not respond to bait during the winter and pre- incubation periods as would be expected if forage availability was a limiting factor.

Despite female success rates similar to those in areas with declining turkey populations (Miller *et al.*, 1998; Thogmartin and Johnson, 1999), harvest rates of males on Sherburne do not indicate any negative population trends (Louisiana Department of Wildlife and Fisheries, 2010). A habitat mediated trade off may exist, in which low reproduction as a result of poor nesting habitat is compensated for by high poult survival due to quality brood rearing habitat. In this scenario, the number of poults produced may be low, but a substantial percentage of poults that do hatch are recruited into the adult population. Adult female survival rates on Sherburne were relatively high compared to the reported range wide average and survival rates for females that did not incubate a nest in a given year were higher than for individuals that did (Byrne, 2011). Therefore, it is possible that high survival rates offset low reproductive output by providing females multiple opportunities to successfully reproduce. Clearly, a better understanding of the relationship between habitat, reproduction, and recruitment in bottomland hardwood systems is needed and presents an interesting avenue of future ecological research.

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