The Journal of Wildlife Management 76(3):528–533; 2012; DOI: 10.1002/jwmg.254

Habitat Relations

Effects of Crop Field Characteristics on Nocturnal Winter Use by American Woodcock

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ABSTRACT Since the late 1960s, American woodcock (*Scolopax minor*) have undergone population declines because of habitat loss. Previous research suggested ridge and furrow topography in conventionally tilled soybean fields provided critical nocturnal cover as birds foraged on earthworms. However, the use of no-till technology has increased and many fields now lack ridge and furrow topography. We assessed woodcock winter nocturnal foraging habitat use given recent changes in agricultural technology, and investigated how field treatment, earthworm abundance, and environmental variables affect the selection of nocturnal foraging sites. We counted woodcock along transects in 5 field treatments twice in each of 67 fields during December–March 2008–2009 and 72 fields during December–March 2009–2010. During both seasons, we collected earthworm and soil samples from a subset of fields of each field treatment. Woodcock densities were at least twice as high in no-till soybean fields planted after corn and in undisked corn fields with mowed stalks than in other field treatments. No-till soybean planted after corn and undisked corn fields contained ridge and furrow topography, whereas other crops did not, and earthworms were at least 1.5 times more abundant in no-till soybean fields than other field treatments. Ridges and furrows in no-till soybean fields planted after corn and undisked corn fields may provide wintering woodcock with thermal protection and concealment from predators. No-till soybean fields planted after corn offered the additional benefit of relatively high food availability. The presence of ridge and furrow topography can be used to predict woodcock field use on the wintering grounds in agricultural areas. Farmers can provide nocturnal winter foraging sites for woodcock by delaying field disking and leaving ridge and furrow topography in crop fields. © 2011 The Wildlife Society.

KEY WORDS American woodcock, foraging habitat, no-till agriculture, North Carolina, *Scolopax minor*, wintering habitat.

American woodcock (*Scolopax minor*; hereafter referred to as woodcock) is a species of conservation concern because of range-wide population declines, associated with a decrease in early-successional forest habitat (Dessecker and McAuley 2001, Cooper and Parker 2010). The loss of early-successional habitat has been documented in northeastern North America, where most woodcock breeding occurs, and in the Southeast where woodcock migrate for the winter (Thompson and DeGraaf 2001, Trani et al. 2001). Hence, woodcock is listed as a Species of High Concern by the United States Shorebird Conservation Plan (U.S. Fish and Wildlife Service, unpublished report), and a Game Bird Below Desired Condition by the United States Fish and Wildlife Service (U.S. Fish and Wildlife Service 2004).

Woodcock habitat use changes seasonally and from night to day, and varies depending on geographic region. Across their range, woodcock use different nocturnal habitat types for roosting and foraging, including lightly grazed pastures (Glasgow 1958), bottomland hardwoods, young pine plantations, seed-tree harvests and fallow-old fields (Krementz et al. 1995, Berdeen and Krementz 1998), forest openings (Horton and Causey 1979), and fallow soybean and abandoned grass fields (Krementz et al. 1995). Most research has not evaluated winter woodcock use of crop fields because

Received: 28 March 2011; Accepted: 26 July 2011;
Published: 7 November 2011

Additional Supporting Information may be found in the online version of this article.

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none were present in the study areas. However, during the 1970s and early 1980s, researchers in eastern North Carolina documented woodcock use of crop fields at night (Stamps and Doerr 1976, Connors and Doerr 1982, Stribling and Doerr 1985).

Results of the North Carolina studies indicated woodcock used conventionally tilled soybean fields with ridge and furrow topography more than disked corn or winter wheat fields (Stribling and Doerr 1985). Soybean fields were richer in organic matter and nitrogen than other field types and provided higher quality habitat for earthworms, the primary food item for woodcock across their range (Stribling and Doerr 1985). Soil between rows in soybean fields was warmer and easier to probe for earthworms than in other field types. Additionally, woodcock likely used the crop furrows for protection from winter weather and predators (Connors and Doerr 1982, Stribling and Doerr 1985). However, recent changes in agricultural practices associated with the adoption of no-till technology, including lack of bedding and narrower row spacing, may have altered nocturnal foraging habitat structure and changed woodcock behavior (Heiniger et al. 2000).

No-till, or conservation tillage, has become a popular alternative to conventional tillage because no-till technology reduces soil erosion, surface water runoff, and wind erosion, and increases carbon sequestration (Uri et al. 1999). Additionally, multiple studies have reported benefits to wildlife from no-till agriculture, especially increased crop residue on the soil surface that provides better cover and food resources than conventional agriculture field treatments (Flickinger and Pendleton 1994, Lokemoen and Beiser 1997). Warburton and Klimstra (1984) recorded greater bird abundance and invertebrate diversity and abundance in no-till corn fields compared to conventionally tilled corn fields. Small mammals were more abundant in no-till compared to tilled fields, because of quality cover from predators and increased food supply (Warburton and Klimstra 1984). Also, evidence exists that no-till agriculture provides better avian nesting habitat than conventional tillage because of reduced soil disturbance and chemical use (Lokemoen and Beiser 1997, Martin and Forsyth 2003). Stribling and Doerr (1985) hypothesized that woodcock would use no-till soybean fields if they provided abundant earthworm prey and protection from winter weather.

To determine woodcock winter nocturnal foraging habitat use given recent changes in agricultural technology, we assessed differences in woodcock and earthworm abundance and environmental variables among field treatments. We hypothesized that no-till fields would have greater earthworm abundance than tilled fields because of reduced soil disturbance (Smith et al. 2008). However, in addition to tillage, other environmental variables (e.g., crop history, soil type, percent organic matter, temperature, moisture, and pH) can affect earthworm communities (Owen and Galbraith 1989, Kladivko et al. 1997). For example, Reynolds et al. (1977) reported soil moisture and temperature as 2 of the most critical factors, and Owen and Galbraith (1989) reported soil pH as the best predictor of earthworm biomass. In combination, these environmental factors and their effects on earthworm abundance could influence woodcock use of field treatments.

STUDY AREA

We studied wintering woodcock from 2008 to 2010 in the same area woodcock were studied during the late 1970s and early 1980s near New Holland and Lake Mattamuskeet National Wildlife Refuge in Hyde County, North Carolina (Stamps and Doerr 1976, Connors and Doerr 1982, Stribling and Doerr 1985). In the mid-1980s, farmers in the area began gradually adopting no-till technology for soybean crops (Stribling and Doerr 1985). The crop fields we surveyed occurred within a contiguous mosaic of different field treatments bordered by bottomland forest to the north and south. All crop fields bordered US Highway 264 to the south; all fields were equidistant from adjacent bottomland forest, which provided diurnal habitat for woodcock (Blackman 2011). Field size varied from 0.6 ha to 90.5 ha, with an average of 9.6 ha. In 2008–2009, field treatments included no-till soybean planted after corn ($n = 19$), no-till soybean planted after wheat ($n = 19$), winter wheat ($n = 14$), disked corn ($n = 9$), and undisked corn with mowed stalks ($n = 6$). In 2009–2010, field treatments included no-till soybean planted after wheat ($n = 23$), disked corn ($n = 21$), undisked corn with mowed stalks ($n = 13$), no-till soybean planted after corn ($n = 8$), and winter wheat ($n = 7$). Farmers rotated crops between years, and alternated between soybeans and corn, or among soybeans, corn, and winter wheat. Also, corn stalks were mowed after harvest and wheat was planted into corn fields that were disked flat in the fall. No-till soybean fields planted after corn had ridges and furrows from the previous corn crop, whereas no-till soybean fields planted after wheat lacked ridge and furrow topography because of disking when wheat was planted. Some farmers tilled ridges and furrows into fields to improve crop drainage and soil warming (Lilly 1981); the beds were then used for multiple seasons and fields were considered no-till after the first season. The local soil type was mainly a combination of Scuppernong muck, Hydeland silt loam, Gullrock muck, Engelhard loamy very fine sand, Fortesque silt loam, and Belhaven muck, and all soils were poorly drained (Soil Survey Staff, Natural Resources Conservation Service 2009).

METHODS

Woodcock Surveys

We surveyed 67 fields twice from December–March 2008–2009 and 72 fields twice from December–March 2009–2010 by looking for woodcock eye shine using halogen bulb headlamps (Stribling and Doerr 1985). We conducted all surveys between dusk and midnight to coincide with peak nocturnal woodcock activity (Glasgow 1958, Stribling and Doerr 1985). During each season, 2 observers each walked a randomly selected 400-m transect in every field to maintain consistent effort among field sizes, and recorded the number of woodcock seen and the distance from observer to bird

(Anderson et al. 1979). Because transects were randomly selected, the distance between observers varied from 15 m to 150 m. We conducted surveys perpendicular to crop rows (Connors and Doerr 1982). If woodcock flushed during the survey, we tracked them using eye shine to avoid double-counting individuals that landed ahead on our transect line. We used distance sampling to account for detection probability and surveyed in multiple field treatments each night to control for variation in weather and moon phase (Glasgow 1958, Royle and Dorazio 2008).

Environmental Variables

During February–March 2009 and January–March 2010, we collected soil and earthworm samples from all field treatments: no-till soybean fields planted after corn ($n = 11$ fields for soil; $n = 10$ fields for worms), no-till soybean planted after wheat ($n = 28$; $n = 30$), disked corn ($n = 8$; $n = 27$), undisked corn with mowed stalks ($n = 18$; $n = 19$), and winter wheat ($n = 8$; $n = 12$). We collected earthworms and soil with hand-held shovels from 6 0.5-m^2 plots in each field (Duriez et al. 2006). We spaced sample plots 15 m apart and oriented plots on a diagonal to ensure that we conducted sampling across rows. We collected samples between rows when present, because we observed woodcock roosting and feeding between rows. We sampled to a depth of 7.5 cm, the depth that earthworms are available to probing woodcock (Stribling and Doerr 1985), and collected samples from dusk until midnight to mimic woodcock feeding hours (Glasgow 1958). We preserved earthworms in 70% ethanol and identified them to species (Blackman et al. 2010).

Because soil characteristics are a good indicator of quality earthworm habitat and quality woodcock foraging grounds, we gathered data on soil moisture content and temperature using a moisture probe and a soil thermometer, respectively (Owen and Galbraith 1989). The probe reported soil water content as a percentage by volume. Soil samples were tested for pH level, percent organic matter, and nitrate content (Waters Agricultural Laboratory, Camilla, GA). During both seasons, we collected 6 row width and ridge height (when present) measurements per field.

Statistical Analyses

We used JAGS statistical software to run a Bayesian complete data likelihood density model with data augmentation to account for non-detected, but present individuals in our woodcock surveys and compare woodcock density among field treatments (Tanner and Wong 1987, Royle and Dorazio 2008, Plummer 2010). The complete data likelihood model used a half-normal distance function and the distribution of the observed data to create the augmented data, and we used quartiles for mean comparison (Tanner and Wong 1987). We used 2 models: 1 allowed each field treatment to have a unique distance function, and the other assumed a single distance function across field treatments (see Appendix for a full explanation of the model and Table S1 available online at www.onlinelibrary.wiley.com for the JAGS code used in this analysis). We used the Deviance Information Criterion (DIC) to select the best detection probability model (Spiegelhalter et al. 2002). We used analysis of variance with Tukey's post hoc analysis ($P < 0.05$) to test for differences in earthworm abundance and environmental variables among field treatments.

RESULTS

The relationship between woodcock detections and field treatment was similar between the 2 years ($F_1 = 0.61$, $P = 0.44$), so we combined all data across years. The density model with constant detection probability was favored by DIC over the model with detection probability varying by field treatment (Table 1). We detected 2–17 and 2–9 times greater mean densities of woodcock in no-till soybean fields planted after corn and in undisked corn fields with mowed stalks than in other field treatments, respectively (Table 2).

Earthworm abundance differed among field treatments ($F_4 = 8.52$, $P < 0.001$), with 1.5–2.5 times more earthworms in no-till soybean planted after corn and no-till soybean planted after wheat than in other field treatments (Fig. 1). Ridge height ($F_3 = 107.82$, $P < 0.001$), row width ($F_3 = 569.11$, $P < 0.001$), soil nitrate content ($F_4 = 15.73$, $P < 0.001$), soil moisture ($F_4 = 18.93$, $P < 0.001$), and soil temperature ($F_4 = 12.67$, $P < 0.001$) all varied among field treatments (Table 3). No-till soybean after corn and undisked corn with mowed stalks had 11.5–32 times greater ridge height (range 7.62–14.00 cm and 2.00–19.05 cm, respectively) and 3.5–5.5 times greater row width (range 91.40–104.10 cm and 76.20–99.06 cm, respectively) than other field treatments. No-till soybean and undisked corn fields had 1.3 times lower soil temperature and 1.5 times higher soil moisture than disked corn and winter wheat fields. Disked corn and winter wheat fields had the highest nitrate content by 2.5 times. Soil organic matter content ($F_4 = 0.21$, $P = 0.93$) and pH ($F_4 = 2.26$, $P = 0.06$) were similar among field treatments (Table 3).

DISCUSSION

The presence of ridge and furrow topography appeared to have the greatest influence on woodcock use of crop fields. At the same study area, Stribling and Doerr (1985) reported woodcock foraging in conventionally tilled soybean fields. In both studies, woodcock used field treatments with ridge and furrow topography. Ridges and furrows likely offer woodcock thermal advantages by acting as a wind break and reducing wind chill and velocity (Stribling and Doerr 1985). Also, the ridges and furrows likely provide conceal-

Table 1. Bayesian complete likelihood density model comparison of constant detection probability ($\{P_{\text{single}}\}$) versus variable detection probability based on field treatment ($\{P_{\text{variable}}\}$) from American woodcock surveys in Hyde County, North Carolina, USA, 2008–2010.

Model	DIC[a]	ΔDIC[b]	pD[c]
$\{P_{\text{single}}\}$	−593.0	0.0	378.5
$\{P_{\text{variable}}\}$	−580.7	12.3	405.4

[a] Deviance Information Criterion (DIC; Spiegelhalter et al. 2002).

[b] Difference in DIC relative to minimum DIC.

[c] pD = variance(deviance)/2.

Table 2. American woodcock per ha by field treatment from Bayesian complete likelihood density model, Hyde County, North Carolina, USA, 2008–2010. We show standard deviation and 2.5% (Q.025) and 97.5% (Q.975) quartiles. Field treatments with different letters (superscript) had different woodcock densities based on quartile separation.

Field treatment	Mean	SD	Q.025	Q.975
No-till soybean after corn^{A}	0.86	0.00089	0.70	1.05
Undisked corn w/mowed stalks^{B}	0.46	0.00074	0.34	0.62
No-till soybean after wheat^{C}	0.23	0.00035	0.17	0.30
Disked corn^{C}	0.18	0.00036	0.12	0.26
Winter wheat^{D}	0.05	0.00022	0.02	0.10

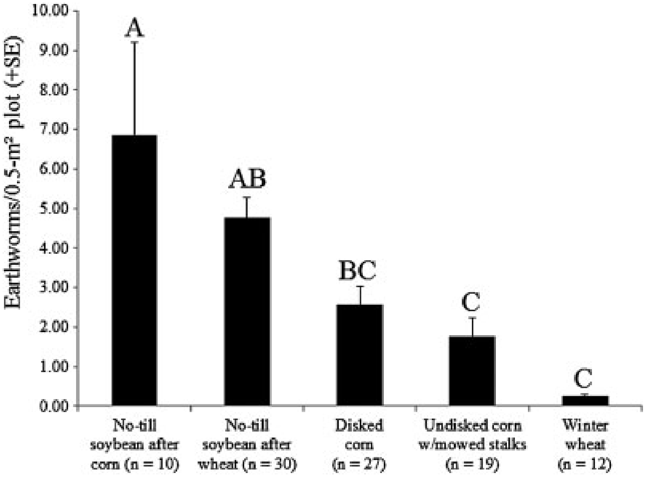

Figure 1. Average number of earthworms collected per 0.5-m^2 plot by field treatment (+SE) in Hyde County, North Carolina, USA, 2009–2010. Field treatments with different letters had different numbers of earthworms.

ment from predators (Connors and Doerr 1982). Woodcock use of no-till soybean fields planted after corn rather than those planted after wheat demonstrates the importance of ridges and furrows because the 2 types of no-till fields only differed in their topography. Similarly, Krementz et al. (1995) reported that woodcock likely did not use crop fields in Virginia because residual crop materials were removed and fields were tilled flat. Gutzwiller et al. (1983) suggested habitat structural variables (e.g., tree density and edge height) were useful to identify important woodcock habitat on the breeding grounds. Similarly, the presence of ridge and furrow topography in crop fields could help predict woodcock habitat use on the wintering grounds in agricultural areas.

The adoption of no-till technology likely has increased earthworm availability for woodcock because tillage negatively affects earthworm communities by exposing individuals to predation, and altering soil moisture and organic matter content (Edwards et al. 1995). Also, others have documented greater earthworm abundance in no-till fields compared to conventional tillage, primarily due to no-till technology's minimal soil disturbance (Edwards and Lofty 1982, Kladivko et al. 1997, Smith et al. 2008). Stribling and Doerr (1985) reported no difference in earthworm abundance among conventionally tilled soybean, disked corn, and winter wheat fields. However, earthworms collected from conventionally tilled fields had higher protein levels than worms from disked corn and winter wheat fields because duff accumulation in furrows increased food availability for earthworms (Stribling and Doerr 1985). Therefore, no-till fields with ridges and furrows offer woodcock an abundant earthworm supply that may provide greater nutritional benefits than no-till fields that lack topography.

Although we recorded differences in soil moisture, temperature, and nitrate content among field treatments, soil disturbance (i.e., tillage) was the main factor that affected earthworm communities, and woodcock foraging success. Field treatments that were most recently tilled (i.e., disked corn and winter wheat) had lower soil moisture, higher soil temperature, and lesser earthworm abundance than other field treatments. Greater soil moisture values in no-till fields likely improved habitat quality for earthworms (Reynolds et al. 1977). Soil temperature and pH likely did not affect earthworm abundance because temperatures were relatively low in all field treatments because of cold winter weather, below the 10–18° C ideal range for earthworms, and pH measurements were close to neutral, which supports most earthworm populations (Edwards and Lofty 1972, Reynolds et al. 1977). Soil organic matter and nitrogen content are important factors regulating earthworm distribution (Reynolds et al. 1977). However, we did not record greater earthworm abundance in field treatments with high soil organic matter or nitrate content because organic matter and nitrate were not limiting factors in the soil types at our study area. The soils were rich in organic matter, regardless of field treatment, because historic water saturation caused anaerobic slowing of organic matter decomposition (Lilly 1981). Similarly, Clapperton et al. (1997) reported that high earthworm abundance in no-till fields compared to conventional-tillage was due to a lack of soil disturbance, and not differences in soil organic carbon, moisture, or temperature.

Table 3. Mean soil pH, percent organic matter (OM), nitrate content (NO_3; kg/ha), percent moisture (M), and temperature (T; °C) per 0.5-m^2 sample plot, and row width (RW; cm) and ridge height (RH; cm) with standard errors (SE) by field treatment, Hyde County, North Carolina, USA, 2008–2010. Different superscript letters within columns indicate differences ($P < 0.05$) among field treatments.

Field treatment	pH	SE	OM (%)	SE	NO_3 (kg/ha)	SE	M (%)	SE	T (°C)	SE	RW (cm)	SE	RH (cm)	SE
No-till soybean after corn	7.36	0.03	5.15	0.33	13.84^{BC}	1.34	36.10^{AB}	1.46	6.17^{B}	0.48	97.98^{A}	0.76	9.88^{A}	0.45
No-till soybean after wheat	7.33	0.01	6.98	1.96	10.30^{C}	0.71	38.99^{A}	0.80	6.44^{B}	0.26	28.39^{B}	2.09	0.90^{B}	0.26
Undisked corn w/mowed stalks	7.31	0.02	7.48	2.21	12.67^{C}	0.97	39.56^{A}	1.24	6.38^{B}	0.28	92.91^{A}	1.13	10.53^{A}	1.19
Disked corn	7.35	0.04	6.30	0.50	27.26^{A}	4.59	22.27^{C}	1.54	8.00^{A}	0.72	0.00	0.00	0.00	0.00
Winter wheat	7.42	0.03	4.65	0.40	20.47^{AB}	2.37	30.30^{BC}	1.50	8.37^{A}	0.62	17.16^{C}	1.16	0.33^{B}	0.16

MANAGEMENT IMPLICATIONS

Woodcock conservation efforts in agricultural areas should focus on educating farmers about agricultural practices that benefit woodcock. To create nocturnal habitat for woodcock following conventional corn production, farmers can leave ridges and furrows intact over winter. If field disking is necessary, it should be delayed until spring. By not disking, farmers save time, fuel, and labor costs (Sahota 2008). Farmers can mow corn stalks for the winter instead of disking. Mowed stalks may benefit woodcock because dense cover in unmowed corn fields can impede woodcock flight (Glasgow 1958). In the next planting season, soybeans can be drilled into the existing corn ridge and furrow system, and the topography will be retained into the next winter. In fields not in corn production, farmers can till in the spring to create ridges and furrows to improve crop drainage and soil warming. The beds can be used for multiple seasons and crops can be rotated with no further tillage required until the beds need to be re-created. Crop row width and ridge height are important considerations for woodcock management. Rows must be wide enough to allow woodcock movement and foraging, and ridges tall enough to provide protection from predators and winter weather. Because woodcock use of crops was correlated with field structure, and not a single crop type, woodcock in agricultural areas across the wintering range should benefit from access to ridge and furrow topography in fields, regardless of the crop type. Future research should assess the impact of ridges and furrows on field use by other wildlife species.

ACKNOWLEDGMENTS

C. Shake, C. Diggins, and J. Stocking provided assistance with field research. J. Connors, K. and B. Davis, B. Desjardins, P. Doerr, J. Gerwin, M. Gibbs, J. Heitman, D. Krementz, R. Lancia, D. McAuley, T. Simons, and C. Sorenson provided technical assistance on various aspects of the project. J. Connors, D. McAuley, and T. Cooper reviewed an earlier version of the manuscript. We thank J. A. Royle for freely providing OpenBUGS code that we customized for this analysis. We thank all landowners who allowed access to their property. Funding for this project was provided by the United States Fish and Wildlife Service Webless Migratory Game Bird Research Program, and the Fisheries, Wildlife, and Conservation Biology Program at North Carolina State University.

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APPENDIX. Model Explanation

Royle and Dorazio (2008) contributed the major components of this hierarchical distance sampling model. The data augmentation method for a distance sampling model works by generating "virtual" individuals, that is, we allow for there to be the possibility of many more animals than were observed. Let n be the number of individuals detected, N be the actual number of animals in the unit, and M be the total number of animals (virtual and observed) considered for the unit ($n \leq N \ll M$). Let $x_i = 1$ if animal i is observed, 0 otherwise. Let $y_i = 1$ if animal i is present (exists), 0 otherwise, with the constraint that $P(y_i = 1|x_i = 1) = 1$.

The hierarchical Bayesian formulation allows for the posterior probability function to be conditionally decomposed into components often referred to as the process, data and parameter component. Here, the process component refers to the data augmentation,

$$[N|M,\psi] \sim \mathrm{Bin}(M,\psi);\ [y_i|M,\psi] \sim \mathrm{Bin}(1,\psi),$$

where ψ is a binomial parameter for abundance, $N = \sum_{i=1}^{M} I(y_i = 1)$, and $I()$ is an indicator function.

The data component of the posterior takes 2 pieces, detection probability and the detection process. We assumed a double exponential distance model,

$$\begin{gathered} p(z_i,\theta) \propto \exp(-(z_i/\theta)^2), \\ [z_i] \sim U(0{,}50\,\mathrm{m}). \end{gathered}$$

Note above that distance sampling carries the assumption that the distances are uniformly distributed. The second component of the data model is the detection process,

$$[x_i|z_i,\theta,y=1] \sim \mathrm{Bin}(1,p(z_i,\theta))$$

Thus, the total likelihood for this model is,

$$\begin{aligned} &[N,\psi,\sigma|X,Y,Z,M] \\ &\quad \propto \underbrace{\left\{\prod_{i=1}^{M}[x_i|z_i,\theta,y_i=1][z_i|y_i=1]\right\}}_{\text{Data}} \underbrace{[y_i|M,\psi]}_{\text{Process}} \underbrace{[\psi,\theta]}_{\text{Priors}}, \end{aligned}$$

with priors,

$$[\psi] \sim \mathrm{beta}(0.5,0.5), [\theta] \sim \mathrm{Unif}(0{,}50)$$

To adapt this model for the density problem, distance data were aggregated by field treatment. ψ and θ were allowed to vary by field treatment, though 1 model had θ constant across field treatments. M for each field treatment was ten times the number of observed individuals in the given field treatment. Density was then estimated as the abundance/(transect dimension × number of transects).

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