

## ABSTRACT

KLIMSTRA, RYAN LAW. Wildlife Use of Native Warm-season and Non-native Cool-season Grass Forage Fields. (Under the direction of Christopher E. Moorman).

Concurrently, several small mammal and bird species associated with native early successional plant communities have declined. Establishment of native warm-season grass (nwsg) fields has been proposed as a strategy to provide wildlife habitat and diversify forage production, yet monocultures of nwsg may offer poor-quality habitat for birds and small mammals. Changes in small mammal and avian populations associated with changes in forage production systems could alter the ecological services they provide (e.g., seed dispersal and prey).

We measured territory density and reproductive effort for eastern meadowlark (*Sturnella magna*), grasshopper sparrow (*Ammodramus savannarum*), field sparrow (*Spizella pusilla*), and indigo bunting (*Passerina cyanea*) in 7 nwsg forage fields (4 hayed and 3 grazed), 7 non-native cool season (csg) forage fields (4 hayed and 3 grazed), and 3 nwsg-forb fields managed for wildlife (“wildlife” fields) during May-August 2009 and 2010. We developed a hierarchical spatially-explicit capture-recapture (HSCR) model to compare abundance of hispid cotton rats (*Sigmodon hispidus*), white-footed mice (*Peromyscus leucopus*), and house mice (*Mus musculus*) among 4 hayed csg fields, 4 hayed nwsg fields, and 4 nwsg-forb fields managed for wildlife during 2 summer trapping periods in 2009 and 2010.

Eastern meadowlark territory density was at least 2 times greater in csg grazed fields than other field types and increased with field size. Grasshopper sparrow territory density did not differ among field types but increased with field size. Field sparrow territory density was at least 2.5 times greater in wildlife fields than in all other field types, and indigo bunting territory density was greater in nwsg hayed and wildlife fields than in other field types and increased with field size. Cotton rat abundance estimates were greater in wildlife fields than in nwsg hayed and csg hayed fields. Abundance of white-footed mouse and house mouse did not differ among field types. Also, we radio-collared 12 cotton rats, of which 1 was killed by haying equipment and 2 died of predation following dispersal out of recently hayed fields. Visual obstruction near ground ( $<0.5$  m) generally was greater in wildlife fields and nwsg fields than in csg fields. Forb coverage was greater in csg grazed and wildlife fields than in nwsg and csg hayed fields and leaf litter and thatch coverage were greater in csg hayed and wildlife fields than in nwsg fields.

Our results suggest monocultures of tall nwsg provide low quality habitat for several grassland/shrubland songbirds and small mammals. Using moderate grazing strategies instead of high-intensity grazing and haying may increase suitability of nwsg forage fields for grassland birds while maintaining forage quality. Furthermore, a lack of cover following haying likely is the key factor limiting small mammal abundance in forage fields.

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Wildlife Use of Native Warm-season and Non-native Cool-season Grass Forage Fields

by  
Ryan Law Klimstra

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APPROVED BY:

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Christopher E. Moorman  
Committee Chair

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Craig Harper

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Clyde Sorenson

## **DEDICATION**

I would like to dedicate this thesis to my Mom and Dad. I will forever be grateful of their everlasting support and encouragement. To my Grandmother, who helped fund the start of my graduate school career. She loved that another grandson was following the footsteps of his grandfather, Willard Klimstra. Keep “working hard at staying alive,” Grandmother. Her love and humor will always live on in my heart.

## **BIOGRAPHY**

Ryan Klimstra was born in Asheville, North Carolina, and grew up in Hendersonville, NC. Ryan received a Bachelor of Science degree in Biology from the College of Charleston in 2006. He worked for a remote salmon hatchery in Kodiak, Alaska for two consecutive summers following college. Ryan dreamed of returning to Alaska as a wildlife biologist. He moved to Raleigh, North Carolina in 2008, where he began working on his Master's degree in Fisheries, Wildlife, and Conservation Biology at North Carolina State University. When time permits, Ryan enjoys traveling, hunting, fishing, and camping with his family and friends, or by himself.

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## **BREEDING SONGBIRD USE OF NATIVE WARM-SEASON AND NON-NATIVE COOL-SEASON GRASS FORAGE FIELDS**

### **Abstract**

Establishment of native warm-season grass (nwsg) fields has been proposed as a strategy to provide avian habitat and diversify forage production, yet monocultures of nwsg may offer poor-quality food and cover for some bird species. We measured territory density and reproductive effort for eastern meadowlark (*Sturnella magna*), grasshopper sparrow (*Ammodramus savannarum*), field sparrow (*Spizella pusilla*), and indigo bunting (*Passerina cyanea*) in 7 nwsg forage fields (4 hayed and 3 grazed), 7 non-native cool-season grass (csg) forage fields (4 hayed and 3 grazed), and 3 nwsg-forb fields managed for wildlife (“wildlife” fields) during May-August 2009 and 2010. Eastern meadowlark territory density was at least 2 times greater in csg grazed fields than other field types and increased with field size. Grasshopper sparrow territory density did not differ among field types but increased with field size. Field sparrow territory density was at least 2.5 times greater in wildlife fields than in all other field types, and indigo bunting territory density was greater in nwsg hayed and wildlife fields than in other field types and increased with field size. Monocultures of tall nwsg do not appear to be a better alternative than csg pastures for grassland songbirds, especially eastern meadowlarks; additionally, shrubland songbirds selected nwsg-forb fields managed with less frequent disturbance than nwsg and csg forage fields. We suggest moderate grazing strategies instead of high-intensity grazing and haying may increase suitability of csg and nwsg forage fields for grassland birds while maintaining forage quality.

## **Introduction**

Since the mid-1900s, native grasslands have declined as a result of fire suppression and conversion to other land-uses (Heard et al. 2000). Farming transitioned from ubiquitous small family-owned farms to fewer large, commercially operated farms (Lobao and Meyer 2001). As small family farms disappeared, so did the early successional vegetative cover provided by fallow fields; modern commercial farm operations generally double or triple-crop fields, providing substantially less early successional cover (Harper and Moorman 2006). Non-native, cool-season grasses (csg), especially tall fescue (*Schedonorus phoenix*), were widely established for livestock grazing and hay production through the mid-1900s (Ball et al. 1996). Additionally, recent afforestation in the eastern United States has led to a reduction in grasslands (Brennan and Kuvlesky 2005). As a result of the decline in native grasslands, grassland-associated wildlife populations have declined throughout North America (Brennan 1991, Hunter et al. 2001). Concomitantly, grassland birds have experienced broad-scale and rapid population declines, in part a result of the practices used to establish and maintain pastures and hayfields (Knopf 1994, Giuliano and Daves 2002).

Tall fescue is a popular livestock forage because it is established and managed easily, and tolerates heavy grazing pressure (Siegel et al. 1985). However, nwsg are C4 grasses and produce more forage than tall fescue during summer months (Harper et al. 2007). Cool-season grasses produce the majority of their biomass during April and May and should be harvested before seedheads are produced (Ball et al. 1996). However, csg usually are grazed, hayed, or mowed after seedheads are produced, which typically is in May and June, during peak songbird nesting (Wiens 1969). Additionally, csg such as tall fescue and orchardgrass

(*Dactylis glomerata*) offer poor quality habitat for wildlife species dependent on overhead cover and an open structure at ground-level (Barnes et al. 1995, Washburn et al. 2000, Harper and Gruchy 2009a, Harper and Gruchy 2009b). These grasses produce a dense thatch layer with little bare ground, limiting access for some wildlife (e.g., foraging northern bobwhite (*Colinus virginianus*) broods); however, dense thatch and shorter grass heights are favorable to some grassland songbirds [e.g., eastern meadowlark (*Sturnella magna*)]. Conversely, some varieties of nwsg [e.g., bluestems (*Andropogon gerardii* or *Schizachyrium scoparium*) and indiagrass (*Sorghastrum nutans*)] produce the majority of their biomass in June and can be optimally harvested after most birds have nested (Harper et al. 2007). Therefore, nwsg may provide habitat for some bird species, but may exclude species better adapted to the vegetation structure and thatch in csg pastures.

Recent emphasis to increase nwsg across the landscape, especially for cattle forage production, may provide breeding space for some songbirds, but food and cover is influenced by grass species composition and management. Conversion of csg pastures to nwsg could provide breeding habitat for grassland birds if the appropriate composition and structure were maintained for focal bird species. For example, haying and grazing bluestems or indiagrass could occur later than for csg and could potentially reduce destruction of grassland songbird nests (Harper et al. 2007). However, when managed intensively for forage production, dense monocultures of tall nwsg may not provide suitable plant structure and composition for grassland birds and other wildlife (Barnes et al. 1995, Harper et al. 2007). Conversely, a nwsg field managed for conditions beneficial to early succession wildlife may not produce quality forage for livestock because vegetation composition may include undesirable species

and grass density may be much less than desirable (Harper et al. 2007). Therefore, research is needed to compare breeding songbird use among csg forage fields, nwsg forage fields, and fields managed less for forage production and more for wildlife habitat.

We compared breeding songbird use among nwsg forage fields, csg forage fields, and nwsg-forb fields managed for early succession wildlife (hereafter, “wildlife fields”). We surveyed birds in hayed and grazed forage fields, and compared songbird territory density and an index of reproductive success among the field type and forage management combinations. We hypothesized grassland songbirds would have greater territory density in csg forage fields with lower vegetation height than in nwsg fields and wildlife fields, and shrubland songbirds would have greater territory density in nwsg forage fields and wildlife fields than in csg forage fields that lack tall vegetation.

## **Methods**

### *Study Area*

We studied breeding songbird use of forage fields during 2009 and 2010 in the western Piedmont of North Carolina on privately owned land in Iredell, Davie, Rowan, and Lincoln counties. We surveyed songbirds in 4 hayed nwsg fields (1.89-9.06 ha,  $\bar{x}$ =5.97 ha), 3 grazed nwsg fields (2.12-3.43 ha,  $\bar{x}$ =2.69 ha), 4 hayed csg fields (1.54-7.85 ha,  $\bar{x}$ =5.1 ha), 3 grazed csg fields (3.23-12.58 ha,  $\bar{x}$ =9.05 ha), and 3 wildlife fields (2.91-3.32 ha,  $\bar{x}$ =3.07 ha). Of the 7 csg fields, 3 hayed and 3 grazed fields were dominated by tall fescue and 1 hayed field was dominated by orchardgrass. Of the 3 csg grazed fields, 2 were moderately grazed both years and 1 was intensively grazed both years. Prior use of planted csg fields was unknown. Six nwsg fields were converted from tall fescue to single species forage production

stands; 1 hayed big bluestem, 1 grazed big bluestem, 3 hayed switchgrass (*Panicum virgatum*), and 1 grazed eastern gamagrass (*Tripsacum dactyloides*). One nwsg grazed field was planted as a forage production stand with a mix of little bluestem, big bluestem, and indiangrass. Grazed nwsg fields were grazed moderately until average grass height was ~25cm, then rested until average grass height returned to ~76cm. Wildlife fields were managed to maintain a mix of native grasses and forbs and to provide food and cover resources for a variety of wildlife. However, landowners were most interested in the benefits these fields provided to white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), and northern bobwhite. Two of the wildlife fields were planted to indiangrass, little bluestem, sideoats grama (*Bouteloua curtipendula*), and partridge pea (*Chamaecrista* spp.), and 1 was planted to switchgrass and eastern gamagrass. The switchgrass and eastern gamagrass field was mowed in alternating thirds every year and the other 2 were burned approximately every 3 years. All nwsg fields (forage and wildlife) were planted between 2002 and 2008; thus, fields varied from 1 to 8 years since planting. The csg fields were planted between 1999 and 2007.

#### *Bird Survey Methods*

We used spot mapping (Robbins 1970, Engstrom 1988, and Ralph et al. 1993) to determine territory densities of 4 focal bird species: eastern meadowlark, grasshopper sparrow (*Ammodramus savannarum*), field sparrow (*Spizella pusilla*), and indigo bunting (*Passerina cyanea*). We also recorded observations of loggerhead shrike (*Lanius ludovicianus*), American kestrel (*Falco sparverius*), northern bobwhite, blue grosbeak (*Passerina caerulea*), and eastern kingbird (*Tyrannus tyrannus*), but did not have sufficient

sample sizes for analysis. Eastern meadowlark, grasshopper sparrow, and field sparrow are listed in the North Carolina Wildlife Action Plan (NC WAP) (NCWRC 2005) as species of concern. We conducted spot mapping from 15 April – 1 August 2009 and 2010. Simultaneous locations of all target species were recorded on a single grid map (1:2500) during each of 8 visits, and later transcribed to individual species territory maps. We assigned territories that extended beyond the boundary of the field a fraction of a territory proportional to the amount of the territory contained in the field. Also, we recorded behaviors indicating stage of the breeding cycle and calculated an index of reproductive effort (Vickery et al. 1992). We ranked breeding cycle stage according to the reproductive index described by Vickery et al. (1992) as follows: 1) establishing a territory; 2) attracting a mate; 3) building a nest and (or) laying/incubating eggs; 4) feeding nestlings; 5) feeding fledglings; 6) one successful brood and a second nest; and 7) 2 successful broods. We surveyed the entire field during each visit, and all visits on a given day were completed before 11AM (Bibby et al. 1992). Walking routes of each field came within 50 m of all points within the field (Bibby et al. 1992). We walked each field at a slow pace and varied our routes and start and finish locations to diversify the direction and timing of site visits (Bibby et al. 1992).

### *Vegetation Sampling*

We sampled vegetation during July and August 2010. Both csg and nwsg hayed fields were cut after seedheads were produced. We were unable to record exact management dates because management occurred without notice when weather and the schedule of the farmer permitted. Therefore, vegetation sampling sometimes occurred after a recent management event. We measured vegetation structure and composition along 3, 30-m transects in each of

the 17 fields. Each field was stratified into 3 equal-area units, and a single transect was randomly positioned in each unit. If a transect extended outside the field, it was discarded and a new transect position was generated. We used a vegetation profile board (2.0-m tall by 30.5-cm wide with alternating colors every 25-cm the length of the board) to measure visual obstruction from 2 positions (i.e., 0-m and 15-m mark) at each transect (Nudds 1977). An observer remained at each position while the board was placed 15 m away in each cardinal direction. The observer estimated and recorded the percentage (i.e., 1= 0-25%, 2= 26-50%, 3= 51-75%, 4= 76-100%) of vegetation obscuring their view of the profile board for all eight of the 25-cm sections. We recorded centimeters of vegetation coverage by species and presence of bare ground and leaf litter directly beneath the first 5 m of each transect. This approach resulted in multiple observations of vertical plant coverage in a fixed distance within each transect and produced values greater than 5 m that we treated as an index of cover. Density scores for each 25-cm section of the vegetation profile board, an index of cover by plant species, bare ground, and leaf litter cover were averaged for each field. We grouped plant species into 4 categories (i.e., native grass, non-native grass, forb, and woody).

### *Statistical Analysis*

We conducted a generalized linear mixed model analysis of variance to test for differences in territory density among field types (SAS Institute Inc. Cary, NC). The model for territory density included year and field type as fixed effects and field size as a random effect. In the model, we indicated a poisson distribution and used the link=log function for analysis. Overall, Vickery indices were concentrated at the lower levels of the index, which did not allow for analysis as ordinal data because maximum likelihood estimates cannot be

calculated with excessive zero values for higher index levels. To correct for low sample size at higher Vickery index levels, we combined grasshopper sparrow and eastern meadowlark as grassland birds, and field sparrow and indigo bunting as shrubland birds. We removed wildlife fields from the grassland bird Vickery index analysis because there were no observations in this treatment type. We collapsed Vickery index levels into 2 categories (i.e., 1,2=0 and 3,4,5,6,7=1; 0 represents a male establishing a territory and attracting a mate and 1 represents nest building or egg laying and any further advanced reproductive behavior) and used a binomial logistic regression model to test the differences in probabilities of the dichotomous Vickery index among field types. For vegetation variables, we conducted a generalized linear mixed model analysis of variance to test for differences among field types (SAS Institute Inc. Cary, NC). Models for the vegetation data included field type as a fixed effect. Vegetation profile board data were log transformed and percent cover data were square root transformed. However, we report all values for vegetation variables in their original form. We considered statistical significance at  $P < 0.05$ .

## **Results**

Eastern meadowlark territory density was more than 2 times greater in csg grazed fields than in all other field types and greater in nwsg hayed and csg hayed than in nwsg grazed and wildlife fields (Figure 1). Grasshopper sparrow territory density did not vary among field types (Table 1; Figure 1). Field sparrow territory density was at least 2.5 times greater in wildlife fields than in all other field types and greater in nwsg hayed fields than in nwsg grazed or csg fields (Figure 1). Indigo bunting territory density was greater in wildlife and nwsg hayed fields than in nwsg grazed or csg fields (Figure 1). Eastern meadowlark,

grasshopper sparrow, and indigo bunting territory density increased with field size, but field sparrow territory densities did not vary with field size (Table 1).

Modified Vickery levels for grassland birds and shrubland birds did not differ among field types or between years, and were not correlated to field size (Table 2).

Visual obstruction varied among field types (Table 3). In general, visual obstruction was greatest in wildlife fields and least in grazed csg fields, especially at the lower heights on the vegetation profile board.

Forbs were more prevalent in csg grazed, nwsg grazed, and wildlife fields than in nwsg and csg hayed fields (Table 3). There was less bare ground in wildlife fields than in all other field types (Table 3). There was more leaf litter and thatch in csg hayed and wildlife fields than in all other field types, and nwsg and csg grazed fields had more leaf litter and thatch than hayed nwsg (Table 3). There were few woody species present and coverage did not differ among field types (Table 3).

## **Discussion**

Native warm-season grass forage production fields did not provide the vegetation structure selected by eastern meadowlark, but grasshopper sparrows did not appear to use forage fields based on vegetation composition or structure. Eastern meadowlarks used csg grazed fields that had shorter grass heights than nwsg fields, a moderately dense thatch layer, no woody vegetation, and high percent coverage of forbs. Native warm-season grass species in hayed and grazed fields encouraged tall, dense vegetative structure less suitable for meadowlark use. Similarly meadowlarks did not use wildlife fields that had greater density of tall vegetation than in csg fields.

The vegetation structure in wildlife fields favored field sparrows and indigo buntings, but not eastern meadowlarks or grasshopper sparrows. Wildlife fields had tall, dense native grasses, greater forb coverage, and dense thatch layers, and were relatively small patches located close to woody edges. In previous studies, eastern meadowlarks did not select fields with woody vegetation and avoided fields with woody edges (Larkin et al. 2001, Coppedge et al. 2008). Indigo bunting territory densities were greatest in wildlife fields and nwsgr forage fields, where perches required for singing and territory defense and field-perimeter shrubs for nesting were present (Payne 1992). Similarly, field sparrows likely used the vegetation in wildlife fields and shrubs and trees adjacent to fields for nesting (Best 1978, 1979).

Eastern meadowlark and grasshopper sparrow territory densities increased with field size, indicating some level of area sensitivity. Grazed csg forage fields (3.23-12.58 ha,  $\bar{x}$ =9.05 ha) were larger on average than other field types, which could explain why meadowlarks were most abundant in these fields. Conversely, wildlife fields (2.91-3.32 ha,  $\bar{x}$ =3.07 ha) and nwsgr grazed fields (2.12-3.43 ha,  $\bar{x}$ =2.69 ha) were small and likely not suitable for area-sensitive birds such as meadowlarks and grasshopper sparrows. Helzer and Jelinski (1999) reported the effect of edges on area-sensitive birds was reduced in fields > 50ha and that fields this large increased interior area and maximized species richness. Although total grassland area with the inclusion of grassland surrounding our study fields rarely was >50ha, Ribic et al. (2009) reported eastern meadowlark density increased with an increased proportion of grassland within 200m of a field. Therefore, cool-season grass fields bordering our study fields (exception was wildlife fields) may have increased the effective size of study fields.

The vegetation types surrounding wildlife fields provided nesting and perching substrates required by field sparrows and indigo buntings. Although we observed these species feeding in wildlife fields, we detected the core of their territories in adjacent cover, where they likely nested. We located one field sparrow nest in a clump of big bluestem within the perimeter of a wildlife field. However, specific grass type and structure within forage fields likely was less important to field sparrow abundance in fields than the brushy structure adjacent to fields (Best 1979).

Haying and mowing removes the vegetative structure necessary for grassland songbird reproduction (Dale et al. 1997). Conversely, moderate full-season grazing by cattle encourages plant species diversity, allows some litter accumulation, promotes open structure at ground level, and maintains diverse vegetative structure for nesting cover throughout the grassland songbird breeding season (Walk and Warner 2000, Birckhead 2012). Although plant species diversity and structure created by grazing appeared better for meadowlarks, they also used hayed fields but to a lesser degree (Herkert 1994, Horn et al. 2002). Other studies indicate grasshopper sparrow presence and abundance is influenced more by structure and bare ground than by plant species composition (Walk and Warner 2000, Fletcher and Koford 2002). Grasshopper sparrow territory densities were greater in all field types than in wildlife fields, which contained the least bare ground; however, grasshopper sparrow territory densities were not greater in fields where grazing facilitated diverse structure or diverse plant species composition.

## **Management Implications**

To conserve avian habitat within forage production systems, producers must integrate focal bird species habitat requirements and forage production objectives. If forage production is the main objective of the producer and there is a secondary interest in wildlife, bluestems and indiangrass mature later and could be planted as nwsg hay forage to allow songbirds to successfully fledge young before haying. Additionally, moderate grazing of nwsg species in forage fields will allow a diverse structure and prevent removal of all nesting cover at once, facilitating nesting success for breeding birds. If early succession wildlife is the primary management objective of the landowner, management should be determined by identifying focal species first, and then the appropriate field size, vegetative composition, and grazing or fire regimen necessary to maintain composition and structure required by focal species. Small fields of native grasses and forbs, especially those surrounded by shrubs and young trees, will provide breeding habitat for shrubland bird species (e.g., field sparrow and indigo bunting), but not for area-sensitive grassland bird species (e.g., eastern meadowlark and grasshopper sparrow). Nwsg field management (e.g., grazing or burning) activities should be conducted outside of the peak nesting season of focal bird species (mid-April to mid-July) to prevent nest destruction or disruption. Cool-season grasses also are used by grassland birds, and management (e.g., haying or grazing) of these fields often occurs when songbirds are nesting. For better forage quality, cool-season grasses should be hayed or grazed before seedheads are produced (late April/early May in the Mid-South region; Ball et al. 1996), which is before the peak nesting period for some grassland birds. Moderate grazing of cool-season grass fields may benefit eastern meadowlarks more than haying or intense grazing.

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Table 1. Model results from a generalized linear mixed model analysis of variance comparing songbird territory density among native warm-season grass hayed, native warm-season grass grazed, cool-season grass hayed, cool-season grass grazed, and wildlife fields (NC, 2009-2010).

Territory Density Model Results				
Species	Variable	Den_df	F-value	P-value
Eastern meadowlark	Field Type	27	8.99	<0.001
	Year	27	0.08	0.78
	Field size	27	10.26	0.004
Grasshopper sparrow	Field Type	27	1.41	0.26
	Year	27	2.53	0.12
	Field size	27	17.69	<0.001
Field sparrow	Field Type	27	47.69	<0.001
	Year	27	3.88	0.06
	Field size	27	2.37	0.14
Indigo bunting	Field Type	27	44.42	<0.001
	Year	27	21.56	<0.001

Table 1 Continued

Field size	27	42.77	<0.001
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Table 2. Model results from binomial logistic regression comparing modified Vickery index levels among native warm-season grass hayed, native warm-season grass grazed, cool-season grass hayed, cool-season grass grazed, and wildlife fields (NC, 2009-2010).

Vickery Index Model Results				
Species	Variable	df	Wald Chi-Square	P-value
Grassland birds	Field Type	3	0.84	0.84
	Year	1	2.06	0.15
	Field size	1	0.11	0.10
Shrubland birds	Field Type	4	0.90	0.92
	Year	1	0.64	0.42
	Field size	1	0.18	0.67

Table 3. Mean profile board (Nudds) vegetation density estimates (i.e., 1= 0-25%, 2= 26-50%, 3= 51-75%, 4= 76-100%) and an index of cover for native warm-season grass (nwsg), cool-season grass (csg), and wildlife fields (NC, 2009-2010). Means in the same row followed by the same letter were not different ( $p \geq 0.05$ ). Standard errors are in parentheses.

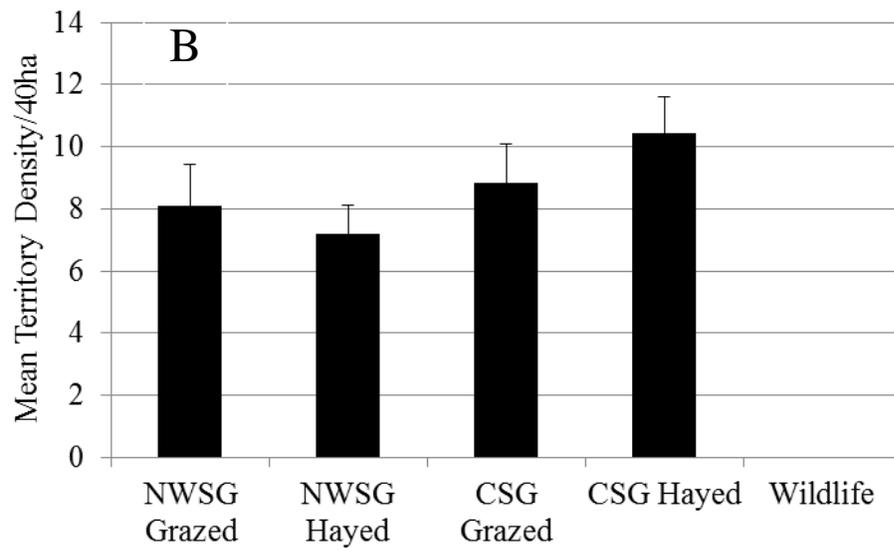
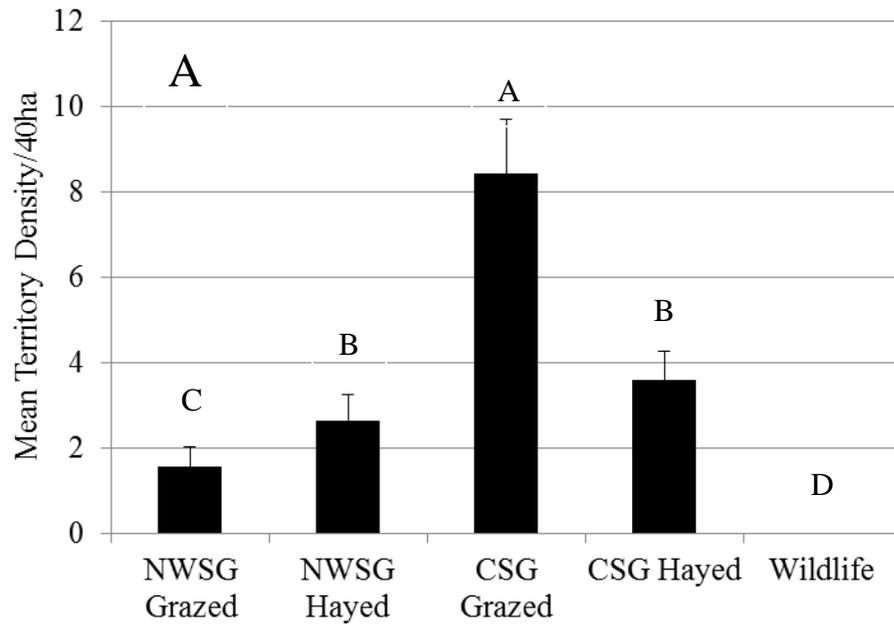
Variable	Treatment				wildlife
	nwsg		csg		
	<u>Grazed</u>	<u>Hayed</u>	<u>Grazed</u>	<u>Hayed</u>	
Nudds					
25cm	4.00 <sup>A</sup> (0.00)	4.00 <sup>A</sup> (0.00)	3.64 <sup>B</sup> (0.18)	3.50 <sup>C</sup> (0.10)	4.00 <sup>A</sup> (0.00)
50cm	3.69 <sup>A</sup> (0.16)	3.94 <sup>A</sup> (0.06)	2.5 <sup>B</sup> (0.40)	1.00 <sup>C</sup> (0.00)	4.00 <sup>A</sup> (0.00)
75cm	2.92 <sup>B</sup> (0.33)	3.71 <sup>A</sup> (0.11)	1.53 <sup>C</sup> (0.22)	1.00 <sup>D</sup> (0.00)	3.97 <sup>A</sup> (0.03)
100cm	2.17 <sup>B</sup> (0.37)	2.54 <sup>B</sup> (0.33)	1.04 <sup>C</sup> (0.06)	1.00 <sup>C</sup> (0.00)	3.53 <sup>A</sup> (0.19)
125cm	1.39 <sup>B</sup> (0.17)	1.58 <sup>B</sup> (0.24)	1.00 <sup>C</sup> (0.00)	1.00 <sup>C</sup> (0.00)	2.61 <sup>A</sup> (0.30)
150cm	1.03 <sup>B</sup> (0.03)	1.04 <sup>B</sup> (0.03)	1.00 <sup>B</sup> (0.00)	1.00 <sup>B</sup> (0.00)	1.61 <sup>A</sup> (0.34)
175cm	1.00 (0.08)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.14 (0.09)
200cm	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
% Grass Cover					
Native	75.49 <sup>A</sup> (7.19)	102.87 <sup>A</sup> (9.94)	1.18 <sup>B</sup> (1.18)	0.00 <sup>B</sup> (0.00)	84.96 <sup>A</sup> (14.67)
Non-native	6.96 <sup>B</sup>	5.28 <sup>B</sup>	78.56 <sup>A</sup>	79.33 <sup>A</sup>	0.98 <sup>B</sup>

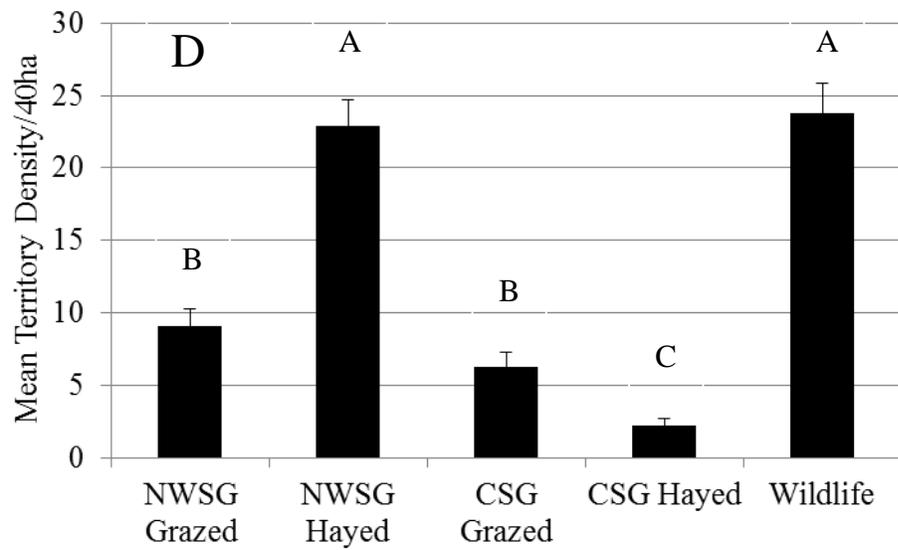
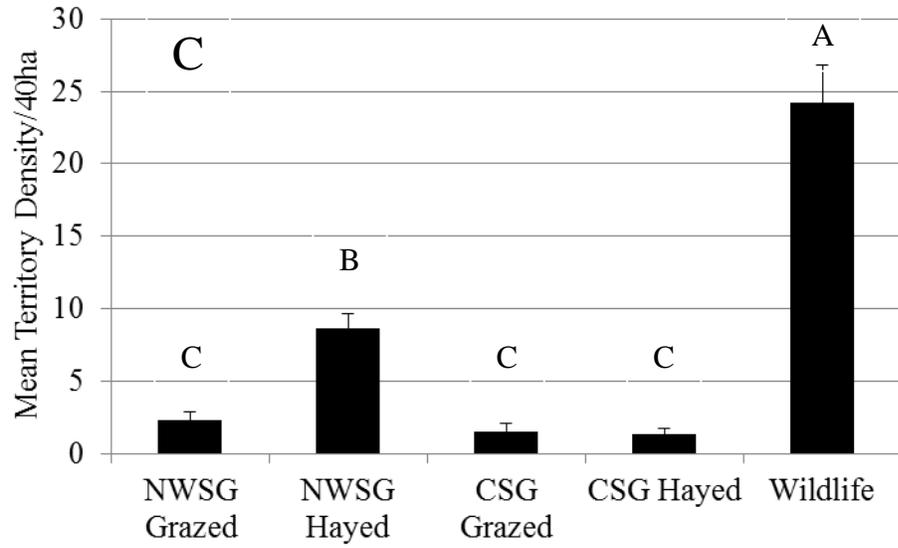
Table 3 Continued

	(2.64)	(3.54)	(10.94)	(7.39)	(0.98)
Forb Cover	45.20 <sup>A</sup>	16.95 <sup>B</sup>	49.49 <sup>A</sup>	9.98 <sup>B</sup>	54.40 <sup>A</sup>
	(15.87)	(10.64)	(11.78)	(6.25)	(12.10)
Woody Cover	0.00	2.17	0.00	0.00	0.25
	(0.0)	(2.00)	(0.00)	(0.00)	(0.61)
Bareground Cover	8.82 <sup>A</sup>	16.72 <sup>A</sup>	12.78 <sup>A</sup>	7.07 <sup>A</sup>	0.00 <sup>B</sup>
	(2.63)	(7.14)	(7.03)	(3.26)	(0.00)
Leaf litter/ Thatch					
Cover	23.04 <sup>B</sup>	1.30 <sup>C</sup>	32.49 <sup>B</sup>	68.67 <sup>A</sup>	78.84 <sup>A</sup>
	(7.00)	(0.94)	(16.20)	(7.10)	(11.10)

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Figure 1. Mean territory density ( $\pm$  SE) for eastern meadowlark (A), grasshopper sparrow (B), field sparrow (C), and indigo bunting (D) in native warm-season grass (nwsg), cool-season grass (csg), and wildlife fields based on a minimum of 8 visits per individual field (NC, 2009-2010). Means followed by the same letter were not different ( $p \geq 0.05$ ).





## **SMALL MAMMAL USE OF HAYED NATIVE WARM-SEASON AND NON-NATIVE COOL-SEASON FORAGE FIELDS**

### **Abstract**

A recent emphasis to establish native warm-season grasses (nwsg) for forage production may provide resources no better for small mammals than currently is available in non-native cool-season grass (csg) forage production fields. Additionally, changes in small mammal populations associated with changes in forage production systems could alter the ecological services they provide (e.g., seed dispersal and prey). We developed a hierarchical spatially-explicit capture-recapture model to compare abundance of hispid cotton rats (*Sigmodon hispidus*), white-footed mice (*Peromyscus leucopus*), and house mice (*Mus musculus*) among 4 hayed csg fields, 4 hayed nwsg fields, and 4 nwsg-forb (“wildlife”) fields managed for wildlife during 2 summer trapping periods in 2009 and 2010. Cotton rat abundance estimates were greater in wildlife fields than in nwsg and csg fields and greater in nwsg fields than in csg fields. Abundance of white-footed mouse and house mouse populations was lower in wildlife fields than in nwsg and csg fields, but the nwsg and csg field types did not differ in effects on abundance of these 2 species. Lack of cover following haying in csg and nwsg fields likely was the key factor limiting small mammal abundance, especially cotton rats, in forage fields. Retention of vegetation structure in managed forage production systems, either by including cool-season and warm-season grass fields, or by leaving unharvested field borders, should provide refugia for small mammals during haying events.

## Introduction

Widespread establishment of non-native, cool-season grasses (csg) as cattle forage, conversion of native grasslands to row-crops, and the recent intensifying of agricultural practices likely has reduced habitat quality for small mammals (Bowles 1981, Kaufman and Kaufman 1989). Non-native, grass forage fields planted as dense monocultures have low plant species diversity and limited structural diversity, which limits resource availability (Collins and Gibson 1990, Sietman et al. 1994). Furthermore, haying csg forage fields dramatically changes groundcover structure and temporarily can displace individual small mammals and potentially reduce long-term population densities (Lemen and Clausen 1984, Sietman et al. 1994, Kaufman and Kaufman 2008).

Conventional wisdom that native, warm-season grasses (nwsg) are of better quality for various wildlife species than csg has contributed to the recent emphasis to establish these grasses for forage production throughout the Southeast. However, similar to csg, nwsg management likely influences resource availability and small mammal use. Densely stocked native grass monocultures intensively managed as hay forage may lack the same critical food (i.e., diversity of grasses and forbs) and cover resources that are absent from intensively managed csg forage fields. Specifically, hispid cotton rats (*Sigmodon hispidus*) avoid hayed forage systems and select grasslands with persistent overhead cover, and access to nwsg and forbs (Kincaid and Cameron 1982, Kaufman and Kaufman 2008). Although white-footed mice (*Peromyscus leucopus*) are considered a woodland species, a study by Kaufman and Kaufman (2008) positively associated them with native grasslands that were not hayed. House mice (*Mus musculus*) are an introduced habitat generalist species commonly found in

woodlands, croplands, and grasslands and likely are less sensitive to variation in structure and composition connected to forage field management (Kaufman et al. 2000).

Consideration of small mammal populations in forage production systems is warranted as they play a key role as predators and prey. Small mammals fulfill important ecological services such as seed predation and serve as a prey source for larger carnivores (Korpimäki 1984, Hulme 1994). Declines in small mammal populations could lead to reduced numbers of avian and mammalian predators and alterations in seed dispersal (French et al. 1976, Korpimäki et al. 2005). Korschgen and Stuart (1972) suggested that abundant small mammal populations provide a prey source to predators, thereby reducing alternative predation of desirable game species [e.g., eastern cottontail (*Sylvilagus floridanus*) and northern bobwhite (*Colinus virginianus*)]. Although small mammals are a key component of trophic dynamics, there is limited research on the effects of forage grassland management on these species. Specific management actions associated with forage systems could differentially affect small mammal populations and negatively affect grassland ecosystems.

To determine small mammal population response to cattle forage production systems, we developed a hierarchical spatial capture-recapture (HSCR) model that allowed integrated estimation and modeling of abundance among distinct sample groups. We used the model to compare abundance of 3 rodent species, hispid cotton rat, white-footed mouse, and house mouse, as a function of field type, including hayed csg fields, hayed nwsg fields, and nwsg-forb fields managed for wildlife (hereafter “wildlife fields”). We hypothesized: 1) small mammal abundance would be greater in wildlife fields where cover and food resources were available more continuously than in nwsg and csg forage fields hayed during spring and

summer months; and 2) small mammal abundance would be greater in nwsg hayed fields than in csg hayed fields because of the structure produced by nwsgs, especially at ground level.

## **Methods**

### *Study Area*

During the summers of 2009 and 2010, we documented small mammal use of forage fields in the western piedmont of North Carolina on privately owned land in Iredell and Davie counties. In 2009, we captured small mammals in 4 hayed nwsg fields (1.89-9.06 ha,  $\bar{x}$ =6.18 ha), 4 hayed csg fields (1.54-9.51 ha,  $\bar{x}$ =6.16 ha), and 4 wildlife fields (1.62-3.32 ha,  $\bar{x}$ =2.71). In 2010, we captured small mammals in 4 hayed nwsg fields (1.89-9.06 ha,  $\bar{x}$ =5.43 ha), 4 hayed csg fields (1.54-7.85 ha,  $\bar{x}$ =5.10 ha), and 4 wildlife fields (1.62-3.32 ha,  $\bar{x}$ =2.71). One nwsg field and 1 csg field from 2009 were not available to trap in 2010 and were replaced; therefore, we trapped in a total of 14 fields. Of the 5 hayed csg fields, 4 were dominated by tall fescue (*Festuca arundinacea*), and 1 was dominated by orchardgrass (*Dactylis glomerata*). Of the 5 hayed nwsg fields, 2 were converted from tall fescue to single species forage production stands of big bluestem (*Andropogon gerardii*), and 3 were planted as a forage production stand with a mix of little bluestem (*Schizachyrium scoparium*), big bluestem, and indiagrass (*Sorghastrum nutans*). Of the 4 wildlife fields, 2 were planted in a mix of indiagrass, little bluestem, sideoats grama (*Bouteloua curtipendula*), and partridge pea (*Chamaecrista* spp.), and 2 were planted in a mix of switchgrass and eastern gamagrass (*Tripsacum dactyloides*). Wildlife fields were managed to maintain a mix of native grasses and forbs and to provide food and cover resources for a variety of wildlife. However,

landowners were most interested in the benefits these fields provided to white-tailed deer (*Odocoileus virginianus*), eastern cottontail, and northern bobwhite. The nwsg fields and wildlife fields were planted between 2002 and 2008, so fields varied from 1 to 8 years since planting. The csg fields were planted between 1999 and 2007, so fields varied from 2 to 11 years since planting. One wildlife field was mowed in alternating thirds every year and the other 3 were burned in 2007 and then approximately every 3 years.

### *Small Mammal Trapping*

We captured small mammals using 50 Sherman live traps (7.6 X 8.9 X 22.9 cm) spaced 15 m apart in a 5X10 rectangular grid (11,250 m<sup>2</sup>) at each of the 14 sites. The short side of the rectangular trapping grid was placed along the edge in all fields with the longer side extending towards the field interior. If field shape did not permit this configuration, traps were spaced evenly throughout. During both 2009 and 2010, we trapped 6 of 12 fields at a time in each of 2 trapping sessions, with ~1 week between sessions and ~3 weeks before trapping the same fields a second time. All fields, with the exception of 1 nwsg and 1 csg fields not available for trapping during 2010 and the 2 fields used as their replacements, were trapped twice May-July in 2009 and 2010. We used a combination of peanut butter and oatmeal to bait traps for 5 consecutive nights. Traps were set each afternoon and checked before 10:00 am the following morning to limit trap mortality. All captured individuals were ear tagged, weighed, and sexed. Recaptures only were identified and weighed. After processing, we released individuals as quickly as possible. We closed traps until late afternoon to avoid having animals in traps during the heat of the day. All trapping, handling,

and marking of small mammals were conducted in accordance with the North Carolina State University Institutional Animal Care and Use Committee (protocol #09-071-0)

### *Telemetry*

We placed radio-transmitters on 12 adult cotton rats during June and July, 2010. Individuals were trapped during the aforementioned capture-recapture portion of the study. We placed radio-transmitters on 4 cotton rats in 2 hayed nwsg fields 5-10 days before they were hayed, and on 8 cotton rats in 2 wildlife fields. We fitted cotton rats with a MINI CABLE-TY COLLAR TRANSMITTER (SERIES M1500), manufactured by Advanced Telemetry Systems. Animals were not anesthetized during the attachment procedure; instead, rats were restrained by holding the “scruff” of skin behind the head. This method of restraint reduced handling time. We secured each collar transmitter using a standard cable-ty with a soft plastic coating surrounding the more rigid plastic of the cable-ty itself to ensure minimal discomfort to the animal. The 2.4-gram transmitter was not placed on cotton rats weighing less than 80 grams to prevent any animals from carrying more than an additional 3% of their body weight. We allowed transmitted rats to acclimate for 24 hours before collecting radio telemetry locations. Using a hand-held 3 element Yagi antenna, we tracked each cotton rat to a distance of 5 m twice daily. If individual cotton rats did not allow a close approach, they were not forced to travel large distances. Rather, we collected the GPS coordinates as close to the original detection location as possible. Collars were recovered after death related events (e.g., predation and haying equipment). All animal care and use procedures were approved by the Institutional Animal Care and Use Committee (IACUC) at North Carolina State University (IACUC ID# 09-071-0).

### *Vegetation Sampling*

We sampled vegetation during July and August 2010. All csg and nwsg fields were hayed after seedheads were produced. We were unable to record exact haying dates because management occurred without notice when weather and the schedule of the farmer permitted. Therefore, vegetation sampling sometimes occurred after a recent haying event. We measured vegetation structure and composition along 3 30-m transects in each of the 12 fields. Each field was stratified into 3 equal-area units, and a single transect was randomly positioned in each unit. If a transect extended outside the field, it was discarded and a new transect position was generated. We used a vegetation profile board (2.0-m tall by 30.5-cm wide with alternating colors every 25-cm the length of the board) to measure visual obstruction from 2 positions (i.e., 0-m and 15-m mark) at each transect (Nudds 1977). An observer remained at each position while the board was placed 15-m away in each cardinal direction. The observer estimated and recorded the percentage (i.e., 1= 0-25%, 2= 26-50%, 3= 51-75%, 4= 76-100%) of vegetation obscuring their view of the profile board for all eight of the 25-cm sections. We recorded centimeters of vegetation coverage by species and presence of bare ground and leaf litter directly beneath the first 5m of each transect. This approach resulted in multiple observations in a fixed distance within each transect and produced values greater than 5m that we treated as an index of cover. Density scores for each 25-cm section of the vegetation profile board, an index of cover by plant species, bare ground, and leaf litter cover were averaged for each field. We grouped plant species into 4 categories (i.e., native grass, non-native grass, forb, and woody).

## *Statistical Analysis*

We developed a hierarchical spatial capture-recapture (HSCR) model that allowed integrated estimation and modeling of abundance. Spatial capture-recapture models (Efford 2004, Borchers and Efford 2008, Royle and Young 2008) were developed to formally account for the problem – common to many capture-recapture experiments – that the area to which abundance estimates apply is unknown. Royle and Converse (In Review) developed a formulation of SCR models to account for replicated capture-recapture experiments, in which the purpose is to model variability in abundance over space and/or time. The state-space model includes both an observation component (probability of detection) and a process component (abundance). More details can be found in Royle and Converse (In Review; see also Converse and Royle 2012).

The HSCR model includes a component that describes variation in abundance across  $g$  groups, in which  $N(g)$ , the population size for group  $g$ , has a Poisson distribution with mean  $\lambda(g)$ . Then a log-linear model of the  $\lambda(g)$  can be developed, such as:

$$\log(\lambda(g)) = \beta_0 + \beta_1 * X(g)$$

where  $X(g)$  is some group-specific covariate (e.g., treatment). In addition, the HSCR model includes a model for encounter observations, with  $y(i,j,k) = 1$  if individual  $i$  is encountered in sample occasion  $j$  in trap  $k$ . The observation model is a Bernoulli model in which  $\Pr(y(i,j,k) = 1) = p(i,j,k)$  with:

$$\text{Mlogit}(p(i,j,k)) = \alpha_0 + \alpha_1 * d[i,k]$$

Where  $\text{Mlogit}()$  is the multinomial logit transform which forces  $p(i,j,k)$  to sum to one across traps and  $d(i,k)$  is the distance between the individual's latent activity center, say  $s(i)$ , and the trap location. The activity centers are assumed to have a uniform distribution over the state-space enclosing the trap array. Additional individual and/or time-specific covariate that may influence detection may also be included.

Our abundance model included fixed effects of trapping period (i.e., season) and field type. Our detection model included only the distance portion of the HSCR model (such that probability of capture in a trap is a function of distance between the trap and the individual's latent activity center).

The implementation of the HSCR model requires specification of a region around each trapping grid which defines where individual activity centers may be located (the "state-space"). We fit the model via Markov chain Monte Carlo methods in JAGS (Plummer 2009; use of trade or product names does not imply endorsement by the US government) using the R2Jags library in the R programming environment (R Core Team 2012) using standard vague priors for parameters. We assessed convergence based on  $\hat{R} < 1.05$  as recommended by Gelman et al. (2004).

For vegetation variables, we conducted a generalized linear mixed model analysis of variance to test for differences among field types (SAS Institute Inc. Cary, NC). Models for the vegetation data included field type as a fixed effect. Vegetation profile board data were log transformed and percent cover data were square root transformed. However, we report

all values for vegetation variables in their original form. We considered statistical significance at  $P < 0.05$ .

## **Results**

### *Variation in Abundance*

A total of 6,000 trap-nights of sampling during 2009-2010 yielded 379 individual captures representing 3 small mammal species. More individuals were captured in 2009 than in 2010 (Table 1). Hispid cotton rats were the most captured species during 2009, and white-footed mice were the most captured species during 2010. House mice had the least captures in both years.

Field type had an effect on cotton rat abundance, which was greater in wildlife fields than in nwsg and csg fields and greater in nwsg fields than csg fields (based on 95% credible intervals for the 2 treatment effects not overlapping 0, and on non-overlapping 95% CIs between the 2 treatment effects; Table 2). Also, cotton rat abundance was markedly greater during trapping period 2 in 2009 (Table 2 and Figure 1A). Overall density of cotton rats was approximately 4.2 individuals  $\text{ha}^{-1}$ .

White-footed mouse abundance was lower in wildlife fields than in both nwsg and csg (Table 3, Figure 1B). Abundance estimates in nwsg and csg fields were not different from each other. Overall density of white-footed mice was 1.2 individuals  $\text{ha}^{-1}$ .

House mouse abundance was lower in wildlife fields than in nwsg and csg fields, but abundance estimates in nwsg and csg fields were not different (Table 4 and Figure 1C). Overall density of house mice was 1.23 individuals  $\text{ha}^{-1}$ .

## *Telemetry*

Because of management activities or predation events, we were unable to collect enough location data for individual cotton rats to determine home range or territory size. However, we suggest or determined the fate of 9 of the 12 individuals (Table 5). Of the 12 collared individuals, 6 presumed mortalities occurred. One individual (Table 5, ID 322) in a nwsg field was tracked to the belly of a black rat snake (*Elaphe obsoleta obloleta*) 2 days after haying (Table 5). The black rat snake was located and observed in the canopy surrounding the field for 10 consecutive days until the transmitter was passed. Another individual (Table 5, ID 460) in a nwsg field traveled to the edge of the field the same day it was hayed, and then traveled 818 m over 5 days to a drainage ditch within a 12-ha corn field where it remained for 27 days (Table 5). The transmitter was recovered 274 m away from the drainage ditch beneath a snag, which suggested avian predation. Remains from another individual (Table 5, ID 458) in a nwsg field were found torn apart by a discbine or hay tedder (Table 5). The remaining 3 confirmed mortalities occurred in a wildlife field. One individual (Table 5, ID 442) was found 14 days after transmitter attachment with roundworms (Nematoda) in the gut, and the other 2 individuals (Table 5, ID 495 and 430) were found 15 and 18 days after attachment, partially eaten next to coyote (*Canis latrans*) scat.

Two transmitters (ID 391 and 392) were recovered 1 and 14 days after attachment in wildlife fields with no apparent mortality (Table 5). An individual (ID 451) in a nwsg field traveled to, and remained in, a nearby brushy area for 10 days, where the transmitter was recovered with no apparent mortality (Table 5). One individual's (ID 456) transmitter was

found 8 days after attachment in a wildlife field, presumably chewed off (Table 5). The remaining 2 individuals (ID 150 and 171) survived for 22 days in a wildlife field (Table 5). Their fate is unknown because the field season ended.

### *Vegetation*

Visual obstruction was greater in nwsg and wildlife fields than in csg fields (Table 6). Native warm-season grass and wildlife fields had less visibility from 25 cm to 125 cm than csg fields, and wildlife fields had less visibility from 75 cm to 175 cm than all other fields (Table 6). Vegetation at 150 cm and 175 cm was not different in nwsg and csg fields and there was no difference in vegetation among field types above 175 cm (Table 6). Coverage of native grass was greater in nwsg and wildlife fields than in csg fields, and coverage of non-native grass was greater in csg fields than in nwsg and wildlife fields (Table 6). Coverage of forbs was 2.5 times greater in wildlife fields than in nwsg and 4 times greater than in csg fields (Table 6). Amount of bare ground was greater in nwsg and csg fields than in wildlife fields (Table 6). Coverage of leaf litter and thatch was greater in csg and wildlife fields than in nwsg fields (Table 6). Very little woody vegetation was present and coverage did not differ among field types (Table 6).

### **Discussion**

Cotton rat abundance estimates were greatest in wildlife fields because they provided consistent sources of cover and food, especially later in the spring when perennial vegetation had matured, whereas vegetation structure was reduced greatly in nwsg and csg forage fields following haying. Additionally, wildlife fields likely served as refugia for individuals dispersing following haying of nearby forage fields or harvesting of other agricultural crops.

Similar to wildlife fields, native warm-season grasses in forage fields provided tall, dense vegetative cover and a food source commonly selected by cotton rats; however, vegetation was never hayed in wildlife fields, so food and cover remained more continuously.

Similarly, Moorman et al. (2013) reported large numbers of cotton rat captures in field borders planted with nwsg and wildflowers that retained food and cover throughout the growing season and no captures in mowed borders where resources were removed.

House mice and white-footed mice are omnivorous and largely considered habitat generalists; therefore, plant community composition likely is of less importance to these species than it is to herbivorous cotton rats (Whitaker 1966, Randolph et al. 1991). After vegetation was hayed and little overhead cover remained in csg and nwsg fields, house and white-footed mice continued to be captured along woody field edges where they likely fed on insects and various seed-bearing plants and used the adjacent shrubs and trees for cover and travel corridors (Whitaker 1966, Baker 1968, Wegner and Merriam 1979). Moreover, nearby anthropogenic features (e.g., row crops, barns, or houses) likely supplemented both species' diets and cover requirements and may help explain a lack of difference in abundance estimates between forage field types. Unlike cotton rats, mice were not directly dependent on the species of grasses or forbs present in forage fields and were able to use other food and cover resources before and after fields were hayed (Whitaker 1966, Wegner and Merriam 1979, Kaufman and Kaufman 2008).

Haying during our study likely reduced overhead protection from avian predators, displaced individuals, and resulted in direct mortality. Kaufman and Kaufman (2008) reported several grassland small mammal species avoided hayed fields, which is consistent

with our lack of captures of other grassland-associated small mammals that we expected to be present [e.g., meadow jumping mouse (*Zapus hudsonius*) and meadow vole (*Microtus pennsylvanicus*)]. Kaufman and Kaufman (2008) reported low or no cotton rat captures in nwsg (e.g., big bluestem, indiagrass, and little bluestem) fields before and after haying. Similarly, we estimated low cotton rat abundance in nwsg and csg hayed fields compared to wildlife fields that never were hayed. Moreover, we located the shredded remains (i.e., by mechanical means) of 1 cotton rat that we had radio-collared in a recently hayed nwsg field, which suggests direct mortality from forage harvest (Klimstra 2013). Additionally, 2 predation events on cotton rats were observed after forage harvest in nwsg fields, indicating an increased mortality risk for individual small mammals that disperse from hayed fields (Klimstra 2013). Because of the ecological value of small mammals in grassland systems, more studies are needed to directly address changes in their population dynamics caused by haying.

Although haying removed food and cover from all forage fields (Kincaid and Cameron 1982, Kaufman and Kaufman 2008), there was a slightly greater abundance of cotton rats in nwsg fields than in csg fields. Similarly, greater point estimates for white-footed mice and house mice in nwsg fields suggests csg fields in this study may have been less beneficial for both species. Greater edge to area ratios in nwsg fields allowed immediate access to cover following haying and likely contributed to greater point estimates for all small mammal species in the field type. Additionally, open ground structure in nwsg fields allowed easier small mammal movement than the dense thatch layers formed in csg fields

One important caveat to our results is that low initial capture and recapture rates made it impossible for us to model variation in detection probability across fields. In particular, our models do not account for the possibility that field type may affect the catchability of animals, rather than or in addition to their abundance. Future research in these systems should focus on extending trap density and/or trapping period length to produce larger sample sizes of captured individuals.

### **Management Implications**

Although it is impractical to expect producers to alter forage production systems to accommodate small mammals, a majority of the forage producers we worked with had an interest in wildlife, especially game animals, such as cottontails and northern bobwhite. Wildlife managers working with forage producers can explain the ecological role of small mammals and encourage producers to manage fields with consideration of the small mammal community. Moderately grazing forage fields as an alternative to haying can increase forb diversity and provide structure selected by some grassland songbirds, and similarly may benefit grassland small mammals (Birkhead 2012, Klimstra 2013). Incorporating both native warm-season and cool-season forage as separate but adjacent units or fields in the same forage production system will provide a continual high-quality forage resource and provide small mammals with nearby escape cover as the 2 field types should be hayed at different times. Additionally, leaving small fields or field borders unharvested will create refugia for small mammals after cover is removed from forage fields (Moorman et al. 2013).

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Table 1. Total captures of individual cotton rat, white-footed mouse, and house mouse in native warm-season grass forage fields, non-native cool-season grass forage fields, and wildlife fields in NC, 2009 and 2010. Capture totals do not include re-captures.

Year	Total Captures		
	Cotton Rat	White-footed mouse	House Mouse
2009	202	59	46
2010	23	35	14
Total	225	94	60

Table 2. Cotton rat model results where D=mean density of individuals ha<sup>-1</sup> across all fields, N.tot=abundance estimate of individuals across all fields, b.dist=distribution, b.seas[1-3]=year and trapping period, b.treatment[1]=warm-season grass, and b.treatment[2]=cool-season grass.

Model Results				
Model Effects	Mode	Mean	C.I.	
			Lower	Upper
D	4.17	4.22	3.43	5.15
N.tot	646.85	654.68	533.00	800.00
b.dist	-1.32	-1.32	-1.56	-1.08
b.seas [1] <sup>a</sup>	-0.17	-0.18	-0.59	0.21
b.seas [2] <sup>a</sup>	2.04	2.07	1.82	2.34
b.seas [3] <sup>a</sup>	-0.79	-0.81	-1.29	-0.36
b.treatment [1]	-1.79	-1.79	-2.16	-1.44
b.treatment [2]	-3.48	-3.54	-4.38	-2.83

<sup>a</sup>The 3 seasonal effects represent the divergence of these seasons from the mean. Although there are 4 seasons, our model has an intercept and only the first 3 seasonal effects are estimable.

Table 3. White-footed mouse model results where D=mean density of individuals ha<sup>-1</sup> across all fields, N.tot=abundance estimate of individuals across all fields, b.dist=distribution, b.seas[1-3]=year and trapping period, b.treatment[1]=warm-season grass, and b.treatment[2]=cool-season grass.

Model Results				
Model Effects	Mode	Mean	C.I.	
			Lower	Upper
D	1.19	1.20	1.04	1.39
N.tot	128.03	128.92	112.00	150.00
b.dist	-1.76	-1.79	-2.10	-1.51
b.seas [1] <sup>a</sup>	0.35	0.34	0.01	0.67
b.seas [2] <sup>a</sup>	0.21	0.20	-0.15	0.54
b.seas [3] <sup>a</sup>	-0.09	-0.12	-0.51	0.24
b.treatment [1]	2.05	2.17	1.34	3.13
b.treatment [2]	1.42	1.51	0.66	2.50

<sup>a</sup>The 3 seasonal effects represent the divergence of these seasons from the mean. Although there are 4 seasons, our model has an intercept and only the first 3 seasonal effects are estimable.

Table 4. House mouse model results where D=mean density of individuals ha<sup>-1</sup> across all fields, N.tot= abundance estimate of individuals across all fields, b.dist=distribution, b.seas[1-3]=year and trapping period, b.treatment[1]=warm-season grass, and b.treatment[2]=cool-season grass.

Model Results				
Model Effects	Mode	Mean	C.I.	
			Lower	Upper
D	0.00	1.23	-0.73	2.02
N.tot	235.24	259.12	153.00	427.00
b.dist	-1.05	-1.03	-1.52	-0.57
b.seas [1] <sup>a</sup>	-0.08	-0.09	-0.55	0.73
b.seas [2] <sup>a</sup>	1.36	1.40	0.92	1.96
b.seas [3] <sup>a</sup>	0.22	0.27	-0.32	0.88
b.treatment [1]	3.84	4.32	2.31	7.21
b.treatment [2]	2.26	2.56	0.42	5.51

<sup>a</sup>The 3 seasonal effects represent the divergence of these seasons from the mean. Although there are 4 seasons, our model has an intercept and only the first 3 seasonal effects are estimable.

Table 5. Radio-collar transmitter tracking histories for 12 hispid cotton rats captured in hayed native warm-season grass (nwsg) and wildlife fields during summer of 2010 in the western piedmont of North Carolina, USA.

Tracking History					
Individual ID	Sex	Field Type	Dates Collared	Date Hayed	Fate
322	F	nwsg	6/16-7/6	6/23	predation by black rat snake
460	M	nwsg	6/19-7/26	6/20	avian predation
458	M	nwsg	6/18-6/22	6/20	mortality by harvest equipment
451	M	nwsg	6/18-7/1	6/20	collar found in nearby brush
430	F	wildlife	7/1-7/15	n/a	found 1 m from coyote scat
495	F	wildlife	7/2-7/13	n/a	predation/half eaten
391	F	wildlife	6/28	n/a	collar not attached securely
392	F	wildlife	7/2-7/15	n/a	unknown
442	F	wildlife	6/29-7/12	n/a	gut filled with round worms
456	F	wildlife	7/1-7/3	n/a	collar chewed off
150	M	wildlife	7/29-8/6	n/a	unknown/field season ended
171	F	wildlife	7/30-8/6	n/a	unknown/field season ended

Table 6. Mean profile board (Nudds) vegetation cover estimates (i.e., 1= 0-25%, 2= 26-50%, 3= 51-75%, 4= 76-100%) and percent cover indices for native warm-season grass (nwsg), non-native cool-season grass (csg), and wildlife fields. Means in the same row followed by the same letter were not different ( $p \geq 0.05$ ). Standard errors are in parentheses.

Variable	Treatment		
	nwsg	csg	wildlife
<b>Nudds</b>			
25cm	4.00 <sup>A</sup> (0.00)	3.50 <sup>B</sup> (0.10)	4.00 <sup>A</sup> (0.00)
50cm	3.94 <sup>A</sup> (0.06)	1.00 <sup>B</sup> (0.00)	4.00 <sup>A</sup> (0.00)
75cm	3.71 <sup>B</sup> (0.11)	1.00 <sup>C</sup> (0.00)	3.98 <sup>A</sup> (0.02)
100cm	2.54 <sup>B</sup> (0.33)	1.00 <sup>C</sup> (0.00)	3.56 <sup>A</sup> (0.16)
125cm	1.58 <sup>B</sup> (0.24)	1.00 <sup>C</sup> (0.00)	2.85 <sup>A</sup> (0.27)
150cm	1.04 <sup>B</sup> (0.03)	1.00 <sup>B</sup> (0.00)	2.02 <sup>A</sup> (0.33)
175cm	1.00 <sup>B</sup> (0.00)	1.00 <sup>B</sup> (0.00)	1.33 <sup>A</sup> (0.14)
200cm	1.00 (0.00)	1.00 (0.00)	1.08 (0.06)
<b>% Cover Grass</b>			
Native	102.87 <sup>A</sup> (9.94)	0.00 <sup>B</sup> (0.00)	103.45 <sup>A</sup> (15.13)
Non-native	5.28 <sup>B</sup> (3.54)	79.33 <sup>A</sup> (7.39)	2.80 <sup>B</sup> (1.68)
<b>% Cover Forbs</b>			
	16.95 <sup>B</sup> (10.64)	9.98 <sup>B</sup> (6.25)	42.55 <sup>A</sup> (10.93)
<b>% Cover Woody</b>			
	2.17 (2.00)	0.00 (0.00)	0.43 (0.43)

Table 6 Continued

% Cover

Bare ground	16.72 <sup>A</sup> (7.14)	7.07 <sup>A</sup> (3.26)	0.00 <sup>B</sup> (0.00)
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% Cover

Leaf litter/ Thatch	1.30 <sup>B</sup> (0.94)	68.67 <sup>A</sup> (7.10)	84.13 <sup>A</sup> (8.65)
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Figure 1. Point estimates (Mode) and credible intervals for cotton rat (A), white-footed mouse (B), and house mouse (C) in native warm-season grass (WSG), non-native cool-season grass (CSG), and wildlife fields (Wild) based on two trapping period in NC, 2009 and 2010. Point estimates with overlapping credible intervals were not different.

