

ARTHROPOD CONSUMPTION BY NORTHERN BOBWHITE CHICKS IN MANAGED TALL FESCUE MONOCULTURES

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ABSTRACT

An extensive amount of Conservation Reserve Program (CRP) habitat for northern bobwhite (*Colinus virginianus*) has been lost to planting of tall fescue (*Schedonorus phoenix*). We conducted foraging trials using human-imprinted bobwhite chicks ($n = 288$) and collected terrestrial arthropods using a customized yard vacuum to assess the effects of 3 USDA mid-contract management (MCM) cost-share practices on chick foraging rates and arthropod prey selection in 36 tall fescue-dominated CRP fields in Illinois during 2008. We applied fall strip disking, fall glyphosate spraying, and fall glyphosate spraying followed by spring legume interseeding in alternating strips to 33% of each treatment field on a 3-year rotation. Glyphosate and glyphosate-interseeding treatments provided greater brood habitat benefits for bobwhite chicks than disking and control fields. Chicks consumed a greater abundance ($P < 0.0001$) and biomass ($P = 0.0017$) of arthropods in managed fields than in unmanaged fields. Abundance and biomass of arthropods consumed by chicks were higher in glyphosate and glyphosate-interseeded strips with 1-, 2-, and 3-growing seasons post-treatment, but disking only provided this benefit for 1 growing season. Vacuum sampling provided a poor index of the availability of arthropods to bobwhite chicks, as measured by foraging of imprinted chicks. Vacuum sampling indicated arthropod abundance was greater in unmanaged than in managed fields ($P = 0.170$). Custom vacuums are not an appropriate tool for measuring the abundance of arthropods important to bobwhite chicks in tall fescue CRP. Fall strip disking is an inferior MCM practice to glyphosate-based treatments in tall fescue-dominated CRP.

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Key words: arthropod selection, brood habitat, *Colinus virginianus*, Conservation Reserve Program, disking, glyphosate, Illinois, mid-contract management, northern bobwhite, tall fescue, vacuum sampling

INTRODUCTION

Efforts are underway to restore northern bobwhite population densities to levels similar to those of the 1980s (NBTC 2011). The northern bobwhite is a culturally and economically important game bird species experiencing severe long-term population declines across most of its breeding range (Brennan 1991, Burger et al. 1999, Brennan 2002, Williams et al. 2004, Brennan and Kuvlesky 2005, NBTC 2011). Researchers suggest that availability of suitable nesting and brood-rearing habitat is limiting recovery of bobwhite populations range-wide (NBTC 2011). An extensive amount of

Conservation Reserve Program (CRP) habitat for bobwhite has been lost in the Midwest and portions of the Southeast to the planting of tall fescue (*Schedonorus phoenix*). Tall fescue was popular among soil conservationists as a cover crop for CRP plantings during the early years of enrollment because of its ability to stabilize soil quickly, effectively control soil erosion, and relatively low cost (Burger et al. 2006). Tall fescue is a non-native, sod-forming, perennial grass with a dense and relatively short growth form (Barnes et al. 1995, Washburn et al. 2000). The percentage of bare ground rapidly decreases as the thatch layer density increases as tall fescue plantings age, and desirable seed-producing annual plants are out-competed (Ellis et al. 1969, Burger et al. 1990, David et al. 1995). This growth structure results in a monotypic stand of dominant grass that is impenetrable by bobwhite broods in search of arthropod prey (Fettingner et al. 2002).

Restoration efforts for northern bobwhite focus on improving nesting and brood-rearing habitat conditions

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within existing grassland-shrub communities (NBTC 2011). Emphasis in the Midwestern United States is on converting stands of introduced sod-forming pasture grasses, such as tall fescue, to mixed stands of native warm-season grasses and forbs (Ruffner and Barnes 2010). Tall fescue conversion is often limited by resource availability and is not a practice that private landowners will adopt without technical and financial assistance. Federally sponsored mid-contract management (MCM) provides CRP participants with technical and financial assistance to implement common farm practices (i.e., herbicide spraying, disking, and drill-seeding) to restore early successional plant communities in aging CRP fields for bobwhite and grassland-obligate birds. Limited information is available on the effects of specific MCM practices to improve foraging conditions for bobwhite chicks in tall fescue CRP fields.

Field experiments using human-imprinted gallinaceous chicks have been used with great success to assess habitat quality (Palmer et al 2001), wildlife-habitat interactions (Burke et al. 2008, Huwer et al. 2008), and nutrition (e.g., foraging rates, food availability, and selection of arthropod prey) (Smith and Burger 2005, Doxon and Carroll 2010). Researchers suggest that human imprinting techniques for evaluating foraging habitat quality and food availability may be superior to other standard sampling methods because imprinted chicks are more likely to sample and select arthropods that are truly available to wild chicks and will interact with environmental factors (e.g., vegetation structure) in ways similar to wild birds (Kimmel and Healy 1987, Palmer et al. 2001).

The objectives of our research were to compare the effects of 3 U.S. Department of Agriculture-approved MCM practices including: (1) fall strip disking, (2) fall glyphosate spraying, and (3) fall glyphosate spraying in combination with spring legume drill-seeding on foraging rates and arthropod prey selection of imprinted bobwhite chicks in tall fescue CRP fields in south-central Illinois.

STUDY AREA

We conducted our study in tall fescue-dominated CRP fields within Wayne, White, and Jefferson counties in south-central Illinois, USA (centered at 38° 22' 49" N, 88° 21' 57" W). The landscape was composed of 63.5% row-crop agriculture (i.e., corn, soybeans, sorghum, and winter wheat), 15.4% forested land (i.e., savanna uplands and coniferous), 12.6% agricultural grasslands (i.e., CRP grasses, hayfields, and pastures), and 8.5% wetlands, open water, and residential and commercial developments (USDA 2007a). Collectively, these counties encompassed nearly 9% (39,027 ha) of Illinois' total CRP enrollments with 5% (21,591 ha) in Wayne County alone (USDA 2007b). The majority of the CRP parcels enrolled in grassland-specific conservation practices in this region were planted to CP1 (non-native, cool-season grasses), and re-enrolled in CP10 (existing grasses and legumes) as contracts began to expire.

METHODS

Mid-contract Management

We selected 36 tall fescue-dominated CRP fields as paired plots ($n = 18$) based on similarities in vegetation structure, disturbance histories based on landowner records, and spatial proximity. We randomly assigned fields within paired plots as either treatment or control. Treatment fields were randomly assigned 1 of 3 MCM regimes. All MCM regimes were applied following USDA, Natural Resources Conservation Service (NRCS) Early Succession Habitat Development and Management Standards-647 (NRCS Standards-647; USDA 2000).

We managed 6 CRP fields with strip disking during October–November, 2005–2007 using multiple passes with an Athens 3-m wide wheel disk (Athens Plow Company, Athens, TN, USA) until 30–50% residual vegetation remained on the soil surface as required by NRCS Standards-647 (USDA 2000). We applied alternating disked strips to 33% of each treatment field annually for 3 consecutive years, and no portion of a field was managed more than once. Disked strips were 10-m wide and we left 20 m unmanaged between managed strips during the first treatment year. We disked 10-m wide strips adjacent to the managed strips during the second and third treatment years (i.e., 2007 and 2008).

We managed 12 fields with glyphosate during October–November, 2005–2007. Glyphosate was applied by 2 local agricultural service providers at a rate of 526.5 ml of Roundup Original® Max (Monsanto Company, St. Louis, MO, USA) and 476 g of ammonium sulfate/ha. We applied glyphosate in 17-m wide alternating strips and left 34 m unmanaged between managed strips. We used a 3-m wide no-till box drill (Great Plains, Salina, KS, USA) to interseed the glyphosate sprayed strips in 6 of the 12 fields annually for 3 consecutive years. We planted a legume seed mixture (Wyatt Seed Company Inc., Petersburg, IN, USA) consisting of 87.5% Korean lespedeza (*Lespedeza stipulacea maxim*) and 12.5% partridge pea (*Cassia fasciculata*) at a rate of 3.4 kg/ha.

Chick Care and Imprinting

We cared for and imprinted bobwhite chicks to humans following techniques described by Kimmel and Healy (1987), Palmer et al. (2001), and Smith and Burger (2005). All chick care, handling, imprinting, foraging trials, and crop dissection procedures followed the Southern Illinois University, Carbondale, Institutional Animal Care and Use Committee protocol (IACUC, protocol #06-011). We acquired bobwhite chicks from a licensed, commercial game bird breeder (Keith Deal Farms, Galatia, IL, USA) within hours of hatching and housed them in a 9-m² indoor brood-pen (1 m high). We maintained the temperature in the indoor brood-pen between 36 and 38° C using infra-red heat lamps positioned 30–60 cm above the floor of the pen. We minimized heat loss by covering the top of the pen with black roofing paper attached to a wood-framed panel. Collectively, 2 trainers spent at least 12 hrs/day in the

indoor brood-pen with the chicks, handling and hand-feeding them live arthropods following Kimmel and Healy (1987), Palmer et al. (2001), and Smith and Burger (2005). We collected arthropods from nearby grasslands using sweep nets 2–3 times daily. We maintained a constant supply of water and commercial poultry food containing 28% crude protein in the indoor pen for optimum growth (Peoples et al. 1994).

We moved the chicks to a 21-m² outdoor brood-pen during daylight hours from 3 to 10 days of age and allowed them to forage in an area with mixed grasses and forbs. Trainers periodically walked through the outdoor brood-pen with the chicks, sounding a whistle call to expose the chicks to habitats and foraging conditions similar to the experimental foraging trials (Smith and Burger 2005). We returned the chicks to the indoor brood-pen overnight and provided them with supplemental poultry food and water. We removed all food items (i.e., live arthropods and commercial poultry food) from the indoor brood-pen 12 hrs prior to start of the experimental foraging trial to ensure passage of all undigested food items prior to the start of the trials.

Chick Foraging Trials

We conducted foraging trials during 5–8 June 2008 with chicks at 10–13 days of age in 6 fields per treatment and their paired control fields ($n = 18$ paired fields, 36 fields in total). We conducted foraging trials once per strip condition in managed fields (i.e., 1-yr, 2-yr, and 3-yr strips) and once in each paired control field. We conducted foraging trials between 0800 and 1200 hrs CST to avoid wet vegetation and cool ambient temperatures. Trainers released broods of 4 imprinted bobwhite chicks in a predetermined strip location and allowed chicks to forage for 30 min. The lead trainer traveled in front of the chicks when possible, sounding a whistle call periodically to encourage chicks to move through the vegetation patch as would an adult bobwhite with a young brood. The remaining trainers observed from 2–3 m behind or beside the chicks to minimize vegetation and arthropod disturbances and to prevent lateral movements into adjacent strips. The chicks were gathered after 30 min and euthanized by CO₂ asphyxiation, placed in zip tight freezer bags, and immediately placed on ice.

The esophagi and crops were removed from the base of the skull to the proventriculus in the laboratory, and stored in a 70% ethanol solution. Intact arthropods and body fragments were removed from these organs and identified to family taxa following Triplehorn and Johnson (2005; insects) and Kaston (1979; spiders). The individuals within a family were counted, dried at 19° C for 24 hrs, and weighed to the nearest 0.0001 g using a digital analytical balance (Thermo Fisher Scientific, Hampton, NH, USA).

Arthropod Vacuum Sampling

We used a modified, gasoline-powered yard vacuum (Echo model ES230 vacuum, Lake Zurich, IL, USA) to sample arthropods during 9–11 June 2008 at the same

locations where the foraging trials were previously conducted on 5–8 June 2008. We altered 1,200 μ m nylon mesh collection bags (WARD'S Natural Science, Rochester, NY, USA) to ensure a tight fit inside the intake tube of the yard vacuum (Steward and Wright 1995). We removed the manufacturer-installed shredder blade of the vacuum to prevent holes in the collection bag and subsequent loss of biological samples.

The vacuum operator walked a slow, constant pace along 2 consecutive, 5–m long linear transects at each sampling point. The operator ran the vacuum on full-power during sampling, and probed it repeatedly through the vegetation at < 60 cm above the ground surface. The contents of the nylon mesh collection bag (e.g., arthropods and grass debris) were stored in a zip tight freezer bag and frozen. We separated the arthropods from the grass debris in the laboratory, (1–4 weeks after sampling) and stored them in 70% ethanol. We identified arthropods to family, counted, dried at 19° C for 24 hrs, and weighed them to the nearest 0.0001 g.

Statistical Analyses

We used general linear mixed models (GLM) with block and nested effects to test for treatment and strip condition differences in relative abundance, dry-weight biomass, family richness, and diversity of arthropods consumed by imprinted chicks (PROC MIXED; SAS Institute, Cary, NC, USA). We included treatment and strip condition as fixed effects, and block and strip condition nested within treatment as random effects. We included the main effects and interaction terms in the model. Each brood of imprinted chicks was an experimental unit and dependent variables were averaged within broods. We tested dependent variables for normality and homogeneity of variances and applied logarithmic transformations to meet the assumptions of analysis of variance when appropriate. Significance level was set at $\alpha < 0.05$ for all analyses. *Post-hoc* pairwise comparisons with Tukey-Kramer adjustments were made among significantly different treatments and strip conditions.

We used the GLM to test for treatment and strip condition differences in relative abundance, dry-weight biomass, family richness, and diversity of arthropods collected using the vacuum sampling technique. We used a *post-hoc* Tukey-Kramer comparison when treatment differences were detected. We used compositional analysis (Aebischer et al. 1993) to test for differences between the proportion of arthropods consumed by imprinted chicks and the proportion of arthropods collected using vacuum sampling. We used BYCOMP.-SAS (Version 1.0; Ott and Hovey 1997) to perform compositional analysis. This program is designed to repeat 999 random simulations of the data, followed by a multivariate analysis of variance to calculate the significance of Wilks' lambda (Λ) from a ranked matrix of *t*-tests (Ott and Hovey 1997). We replaced missing values with 0.0001 for arthropods that were collected but not consumed by chicks.

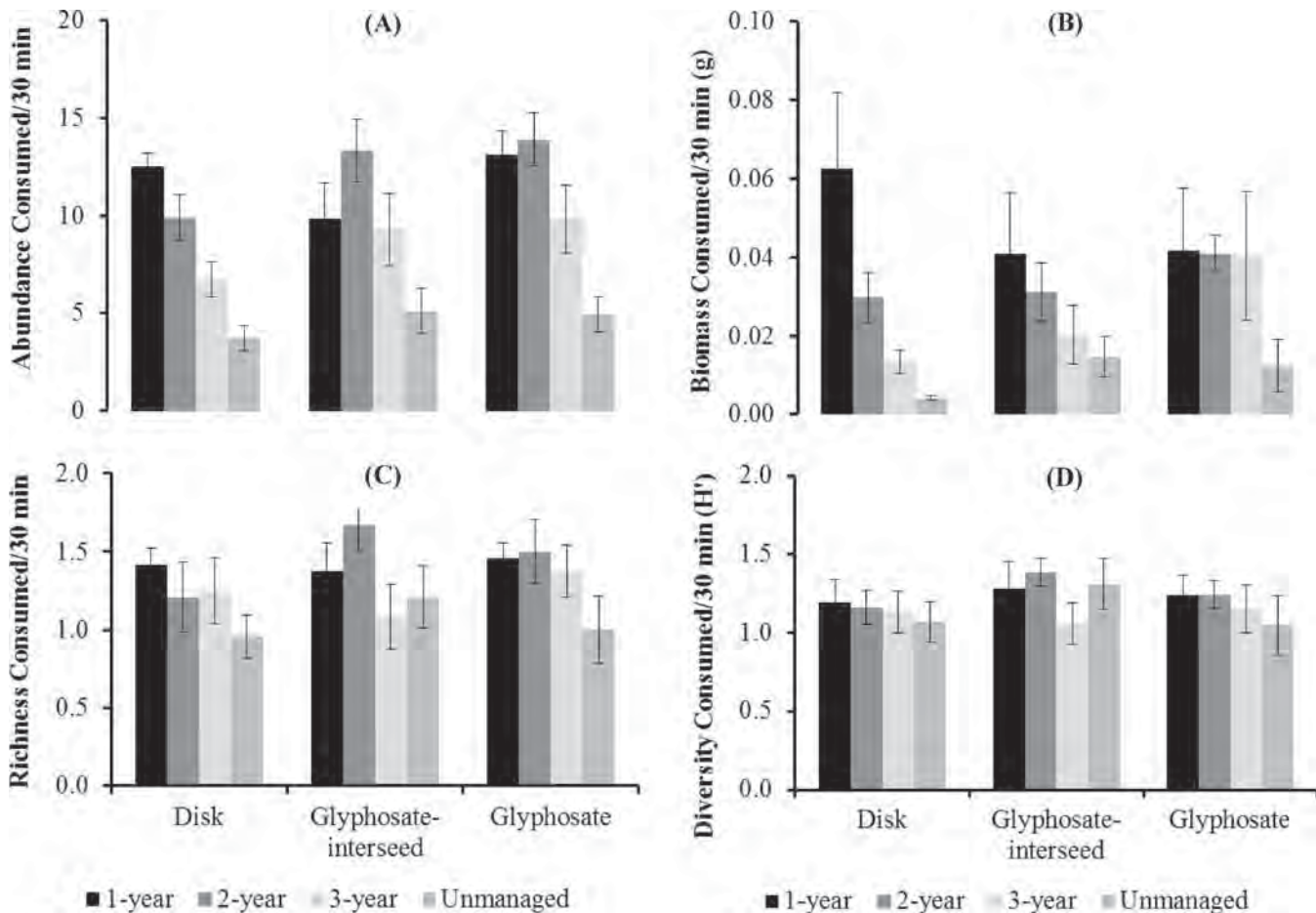


Fig. 1. Abundance, biomass, family richness, and diversity (mean \pm SE) of arthropods consumed/30 min by northern bobwhite chicks during foraging trials in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

RESULTS

We conducted 72 foraging trials using 288 imprinted bobwhite chicks. Bobwhite chicks consumed 19 arthropod families. The 2 most common family taxa consumed were Formicidae (ants) and Armadillidiidae (pill bugs), followed by Oxyopidae (lynx spiders), Gnaphosidae (ground spiders), Chrysomelidae (leaf beetles), and Cicadellidae (leafhoppers).

Bobwhite chicks consumed more arthropods in managed than in unmanaged fields ($F_{3,14} = 16.02$, $P < 0.0001$). Chicks in disked fields consumed the greatest abundance of arthropods in 1-year strips, but abundance progressively decreased as the number of years post-treatment increased (Fig. 1A). Abundance of arthropods consumed by chicks in 3-year disked strips did not differ from unmanaged strips ($P = 0.4118$). Abundance of arthropods consumed in glyphosate and glyphosate-interseeded fields was greatest in 2-year strips compared to other years. Glyphosate-based treatments provided benefits for > 3 years, whereas disking provided benefits for only 2 years at most.

Biomass of arthropods consumed was greater in managed than in unmanaged fields ($F_{3,27} = 8.18$, $P = 0.0017$). Biomass did not differ among strip conditions

($F_{6,39} = 1.68$, $P = 0.1524$), but general trends indicate biomass decreased as the number of years post-treatment increased (Fig. 1B). Thus, biomass among 1-, 2-, and 3-yr glyphosate strips remained constant, and was greater compared to unmanaged strips. Family richness of arthropods consumed was greater in glyphosate and glyphosate-interseeded fields than in disked and unmanaged fields ($F_{3,14} = 3.22$, $P = 0.0286$; Fig. 1C). There were no differences in diversity of arthropods consumed among treatments ($F_{3,14} = 0.34$, $P = 0.7934$) or strip conditions ($F_{6,42} = 0.73$, $P = 0.6305$; Fig. 1D), indicating bobwhite chicks may obtain a search image or selected particular arthropod prey that are easier to capture. These data indicate chicks consumed more Formicidae than Armadillidiidae in glyphosate and glyphosate-interseeded fields, and more Armadillidiidae than Formicidae in disked fields (Fig. 2).

We collected 13,020 arthropods representing 13 Orders and 69 families from 144 vacuum samples. There was a greater abundance of arthropods in unmanaged strips than in managed strips ($F_{3,20} = 8.26$, $P = 0.0002$). Abundance of arthropods collected were marginally greater in unmanaged and disked strips than in glyphosate-based treatment strips ($F_{6,43} = 2.00$, $P = 0.0860$; Fig. 3A). Biomass was generally greater in unmanaged fields

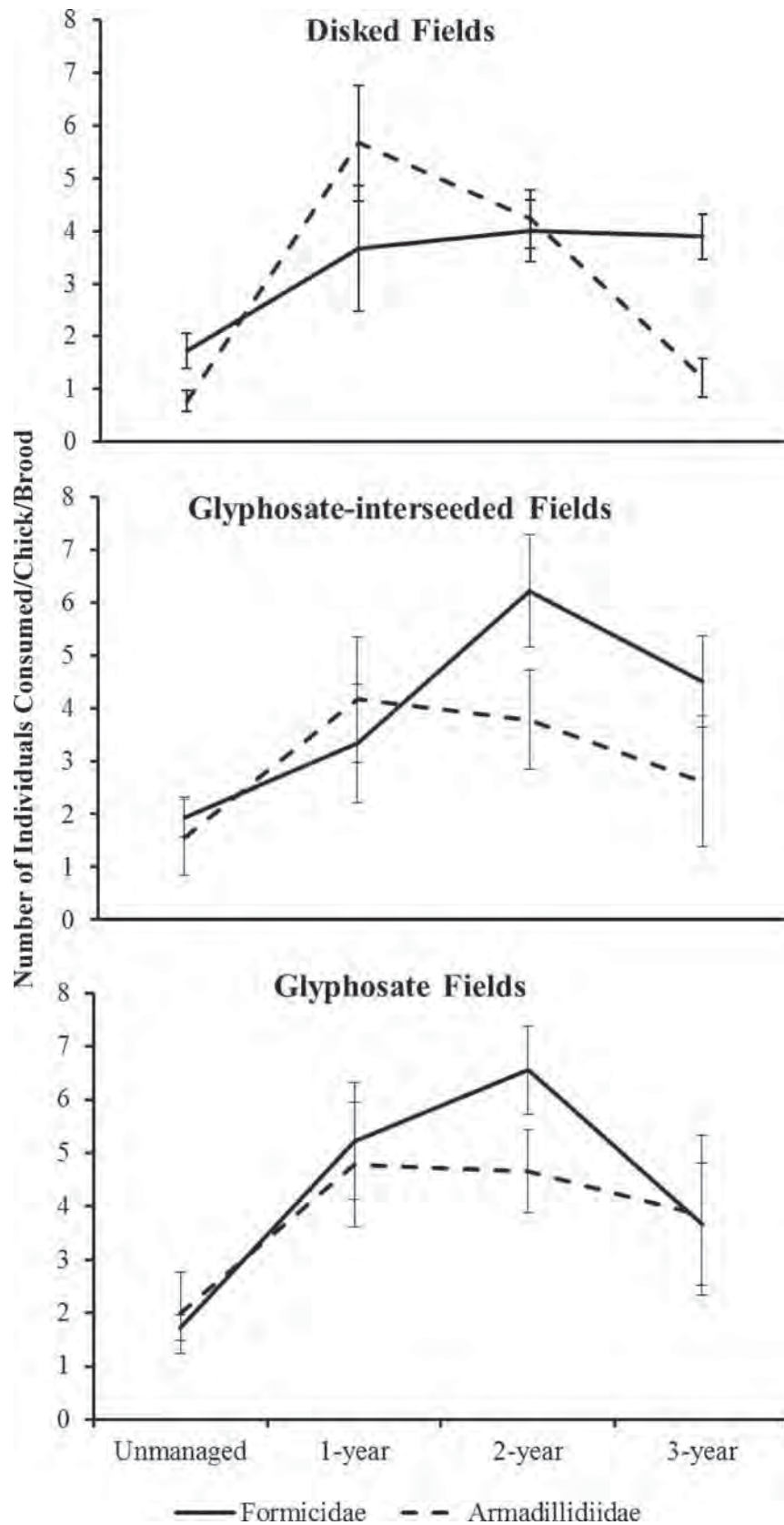


Fig. 2. Mean (\pm SE) abundance of Formicidae and Armadillidiidae consumed by northern bobwhite chicks by treatment and years since treatment in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

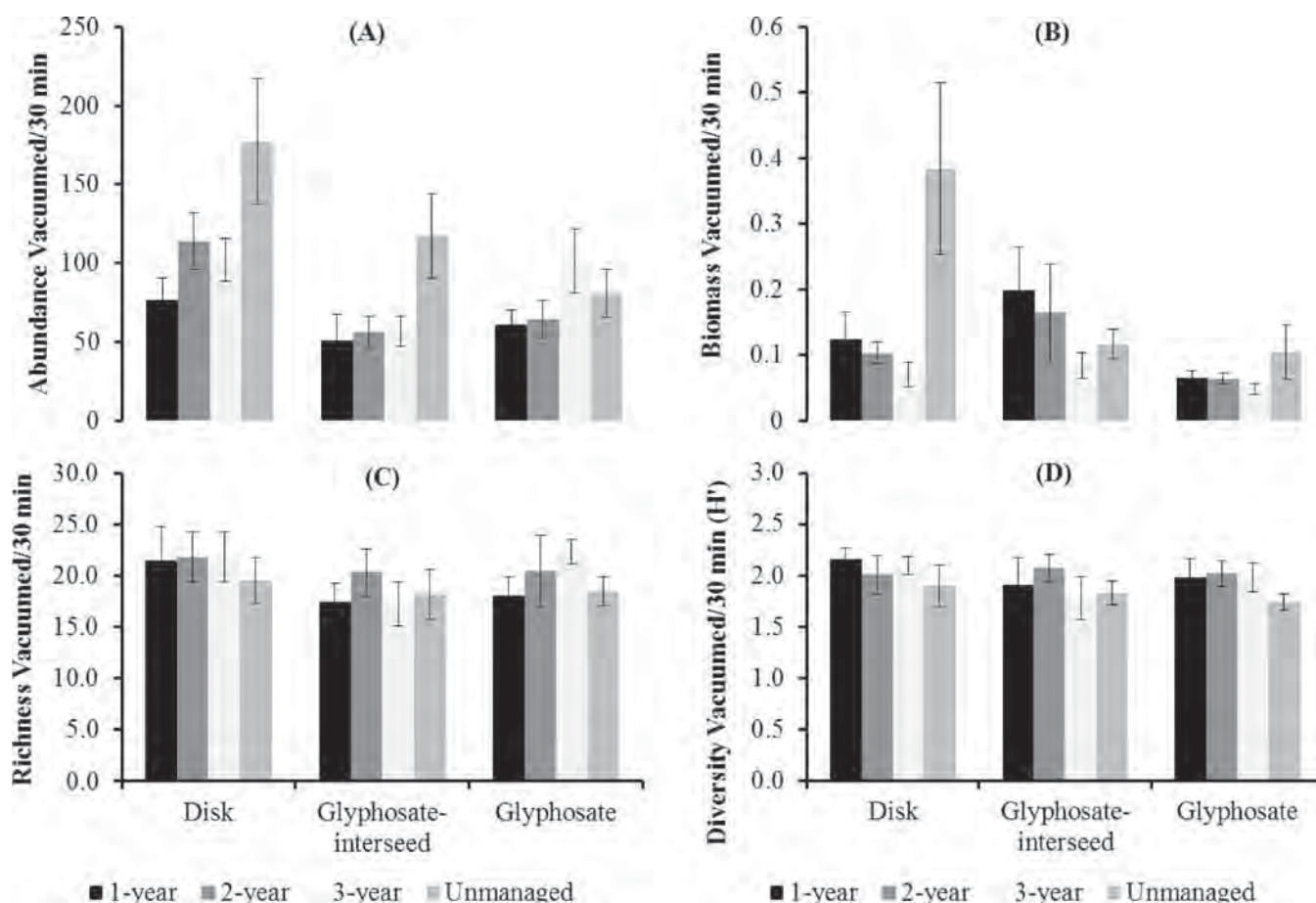


Fig. 3. Abundance, biomass, family richness, and diversity (mean \pm SE) of arthropods collected/5-m transect by vacuum sampling in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

($F_{3,20} = 3.16$, $P = 0.0538$), but did not differ among strip conditions ($F_{6,43} = 1.68$, $P = 0.1729$; Fig. 3B). We found no treatment or strip condition effects on family richness or diversity of arthropods collected using vacuum sampling (Fig. 3).

Chicks consumed arthropods disproportionately to what was expected because vacuum sampling showed that arthropod abundance was greater in unmanaged fields compared to managed fields. Consequently, arthropod prey selection by bobwhite chicks foraging in tall fescue CRP fields occurred nonrandomly (Wilks' lambda $\Lambda = 0.13$, $F_{6,66} = 68.16$, Randomized $P < 0.0001$). Compositional analysis indicated chicks consumed a greater proportion of Hymenoptera, Isopoda, and Lepidoptera than were collected using vacuum sampling (Table 1).

DISCUSSION

Arthropods are the primary component of bobwhite chick diets during the first 2 weeks post-hatch (Handley 1931, Nestler 1940, Hurst 1972, Burger et al. 1993); thus, this essential food resource is a major factor influencing chick survival rates, recruitment, and population abundance (Rosene 1969, Hurst 1972). Lusk et al. (2005) noted the first 4 weeks post-hatch were the most critical

for bobwhite chick survival, and that management of less suitable habitat could result in increased survival by increasing arthropod availability to chicks. Our study demonstrated bobwhite chicks consumed more arthropods in managed fields than in unmanaged fields, suggesting that MCM can be an effective tool for enhancing foraging

Table 1. Proportion and rank of used (consumed) arthropods by imprinted northern bobwhite chicks and arthropod availability in Conservation Reserve Program fields in south-central Illinois, USA, during 2008.

Order	Proportion consumed	Proportion collected	Rank
Hymenoptera	0.42	0.28	1 ^a
Isopoda	0.33	0.08	2 ^a
Lepidoptera ^b	0.03	0.01	3 ^a
Araneae	0.07	0.11	4
Coleoptera	0.05	0.14	5
Other ^c	0.03	0.12	6
Hemiptera	0.07	0.26	7

^a Rank numbers represent preferred food items that were consumed in larger proportion than were available.

^b All Lepidoptera were larvae.

^c Other includes Diptera, Orthoptera, and Opilione.

habitat quality for bobwhite broods in tall fescue-dominated CRP fields. The observed differences between managed and unmanaged CRP fields reinforce the importance to bobwhites of effective management of natural plant succession, vegetation structure, and plant species composition (Osborne 2010).

The foraging efficacy of bobwhite chicks in fields managed with fall strip disking, fall glyphosate spraying, and fall glyphosate-interseeding differed in regards to the MCM practice and time since disturbance. Benefits for foraging bobwhite chicks in glyphosate and glyphosate-interseeded fields persisted for at least 3 growing seasons post-treatment. Arthropod consumption rates in disked fields in contrast were greatest during the first growing season post-treatment with benefits diminishing as time since disturbance increased. We demonstrated benefits for foraging bobwhite chicks persist longer in glyphosate-based treatment strips than in disked and unmanaged strips.

Formicidae (ants) are an important arthropod prey for bobwhite chicks (Landers and Johnson 1976), and were the most abundant taxa consumed by imprinted chicks in our study. However, chicks in disked fields consumed less ants and more Armadillidiidae than in glyphosate-based treatment fields. Benson et al. (2007) noted that disking of the soil layer as a vegetation management tool alters the arthropod community composition due to an increased amount of decaying organic matter. We infer the observed differences in the diet of chicks likely resulted from differences in the physical properties of the soil and composition of the arthropod communities as described by Benson et al. (2007). We found little evidence in the literature of Armadillidiidae in the diet of bobwhite chicks (Landers and Johnson 1976). Additional research is needed to assess the nutritional value of this prey item compared to common arthropod prey. This information may have negative consequences on chick survival and population recruitment if Armadillidiidae are less digestible and do not provide adequate nutritional value for bobwhite chicks.

Barnes et al. (1995) suggested arthropod availability in tall fescue-dominated fields may be similar among grassland habitat types including native grasses, and foraging habitat quality for bobwhite chicks is limited by the vegetative structure. We demonstrated that bobwhite chicks consumed more arthropods in managed fields although arthropod availability was greater in unmanaged fields. We suggest that an increase in the percentage of bare ground and lower stem density in managed fields (Sparling and Osborne 2009, Osborne et al. 2012) allowed chicks to search more effectively for arthropod prey. We believe the observed differences in arthropod availability and composition among treatments may have resulted from differences in the vegetation structure and percentage of bare ground (Siemann et al. 1998, Symstad et al. 2000). Glyphosate and glyphosate-interseed treatments are more effective at suppressing tall fescue cover, and increasing the percentage of bare ground and annual forbs than disking (Barnes et al. 1995, Washburn et al. 2000, Greenfield et al. 2002, Ruffner and Barnes 2010, Osborne et al. 2012). We suspect the observed differences in

arthropod consumption in these fields resulted from observed differences in the structure and compositional of the grassland habitat as demonstrated by Osborne et al. (2012).

Chicks foraging in managed fields were able to access bare ground and scratch and search for prey under the litter duff layer (Stoddard 1931, Rosene 1969, Roseberry and Klimistra 1984). The litter layer was mostly absent in glyphosate-interseeded fields during the first growing season post-treatment as the box-drill buried the dead and dying vegetation beneath the soil surface during planting. Thus, presence of the litter layer apparently provided a refuge for particular arthropod prey that were important for bobwhite chicks in our study. Mobility of chicks was not directly measured in our study, but our inferences support the conclusions of other researchers (Taylor et al. 1999, Doxon and Carroll 2010) and suggest insect prey consumption by chicks may be related to the percentage of bare ground cover and the chicks' ability to maneuver through the habitat. Chick movements and their ability to capture arthropod prey in unmanaged fields were highly restricted by dense stands of tall fescue.

Kimmel and Healy (1987) suggested human-imprinted chicks may be a superior technique to evaluate foraging habitat quality and food availability than other standard arthropod sampling methods including sweep nets and pitfall traps. Researchers suggest that imprinted chicks are more likely to sample and select arthropods that truly are available to wild chicks and would interact with environmental factors (e.g., vegetation structure) in ways similar to wild birds (Palmer et al. 2001). The vacuum samples in our study contained 23 arthropod families that were not present in the diet of bobwhite chicks. Many of the families unique to the vacuum samples were leaf-dwelling insects that inhabit the middle to upper strata of the vegetation column and are generally out of the reach of most bobwhite chicks. Similar to other researchers (Utz et al. 2001, Doxon and Carroll 2007), our study demonstrated that imprinted bobwhite chicks selected slow moving, ground-dwelling arthropods, primarily Formicidae, and that arthropod prey selection was nonrandom. Vacuum sampling provided a poor index of the availability of arthropods to bobwhite chicks, as measured by foraging by imprinted chicks. We conclude that vacuums are not an appropriate tool for measuring the abundance of arthropods important to bobwhite chicks in tall fescue CRP.

MANAGEMENT IMPLICATIONS

Our observation of differences between managed and unmanaged CRP fields reinforced the importance to bobwhite of effective management of natural plant succession, vegetation structure, and plant species composition (Osborne 2010).

Increased suitability of CRP for bobwhites could have a profound positive effect on abundance of the species with 14 million ha of tall fescue plantings in the Midwest and southeastern U.S. (Ball et al. 1993) and the

predominate grass planted in CRP cool-season grass enrollments (Carmichael 1997).

We recommend that managers implement glyphosate-based MCM practices to improve brood-rearing habitat conditions for bobwhite chicks in tall fescue-dominated CRP fields. Glyphosate-based treatments suppress grass cover and create structurally diverse patches of habitat for longer periods than disking treatments. More open habitats should increase bobwhite brood foraging efficiency by facilitating chick movement through the habitat. A 3-year rotation of glyphosate-based MCM applied in alternating strips should provide a mosaic of nesting and brood-rearing habitat conditions with a diversity of early successional areas for foraging bobwhite broods.

Our study provides biologists and policy makers with information to facilitate science-based management decisions regarding management of tall fescue for bobwhite brood-rearing habitat.

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