Vegetation Response and Use of Wooded Edges by Northern Bobwhites After Edge-Feathering Treatment in Southwestern Ohio

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

By

Coree A. Brooks, B.S.

Graduate Program in Environment and Natural Resources

The Ohio State University

2015

Master's Examination Committee:

Robert J. Gates, Advisor

Jeremy T. Bruskotter

Thomas E. McConnell

ABSTRACT

Clean farming practices and forest succession have contributed to population decline of northern bobwhites (*Colinus virginianus*) across northern portions of their range. Intensively farmed landscapes lack early successional vegetation that provides protective cover near food sources. Earlier research indicated that population growth of northern bobwhites in southwestern Ohio is limited by lack of preferred early successional woody cover during the non-breeding season. I studied vegetation response to removal of large trees from wooded edges (here after edge-feathering) on private owned farmlands in Highland County Ohio. Ninety-nine areas ranging in length from 15 m to 91 m were treated during spring in 2012 and 2013. Vegetation structure and composition of feathered edges was measured before treatment and after 2 growing seasons and in late winter during 2012 – 2014. I used repeated measures analysis of variance to test for differences in vegetation structure and composition among study sites, edge aspects, feathered edge size classes, edge types, and basal area reduction. Basal area reduction differed between years, with a light reduction (29%) in 2012 and a heavy reduction (81%) in 2013. Horizontal, vertical, and ground cover differed among sample periods with the second fall having more vertical and horizontal cover than the first fall, and the first fall having more cover than the first winter. Basal area reduction, size, and sample periods were important predictors of cover measurements. Basal area reduction within woodlot edges or along linear features like fencerows was the most important

variable that affected vegetation response to edge-feathering. Basal area reductions between 37 – 50% resulted in positive changes in protective cover for bobwhites after 1 growing season. Large edge treatments with heavy reduction in basal area resulted in net gains in protective cover between seasons, and provided the highest overall change in cover.

I used radio-telemetry to determine bobwhite use of feathered edges, measured vegetation composition and structure at used points, and estimated home-ranges using the Fixed k LoCoH method. Locations from 24 unique coveys across 4 sites during the 2013 – 14 non-breeding season were used to compare vegetation structure and composition between feathered edges and covey use sites. Seven coveys were used to estimate home-ranges and to analyze use of feathered edges in relation to their placement within study sites. Mean home-range size was 4.6 ha and 5 total feathered edges fell within 95% local convex hull isopleths. Original placements of feathered edges were informed by previous research. Woodlots, mature fencerows, ditches, and other uncultivated areas were considered for treatment if they had previously experienced little to no use by bobwhite coveys. Edge-feathering is a technique that can convert hard edges into soft edges by felling trees, stimulating new vegetation growth gradient where vegetation slowly increases from young new growth containing grasses, forbs, and shrubs, into saplings and trees. Edge-feathering successfully converted edges that were not previously used by bobwhites, into habitat that was used by radio-marked coveys during the non-breeding season. Future management of woodlots by edge-feathering should be considered by managers, because they produce habitat similar to what bobwhites use. Other cover types such as early successional herbaceous (nesting/brood rearing), and row crop (food) need to be considered and close to feathered edges to maximize use and benefit bobwhites.

ACKNOWLEDGMENTS

Funding for this project was provided by the Federal Aid in Wildlife Restoration Program (W-134-P, Wildlife Management in Ohio), and administered jointly by the U.S. Fish & Wildlife Service (USFWS) and the Ohio Division of Wildlife (ODW), Ohio Agricultural Research and Development Center (OARDC) and the School of Environment and Natural Resources at the Ohio State University. Additional funding for the project was provided by the Highland County Pheasants Forever Chapter.

I would like to thank individuals from all agencies listed above. Specifically, I would like to thank Barb Bauer and Charlie Payne from Pheasants Forever, Heidi Devine, Nathan Striker, Ken Duren, Mark Wiley, John Kaiser, Jeff Burris, and Dave Kohler from ODW, Lee Crocker from National Wild Turkey Federation, and Donald Knight from USFWS. Heidi and Barb were an essential part to the success of this project due to their knowledge of both bobwhites and landowners.

I am grateful to the more than 50 landowners that allowed access to their properties, and eternally grateful for the 15 landowners that allowed for treatment on their property. I have developed numerous friendships and kinship with them, and their patience and interest in this project has remained pivotal. Without their cooperation, this project would not have been possible. George Fee receives a special acknowledgment for his generosity in establishing my initial knowledge and foundation of Ohio bobwhites.

His memory, knowledge, and assistance were necessary components early on in my research.

I would like to thank all the field assistants and others involved with the project. Adam Janke, Mark Wiley, and Mauri Liberati made significant contributions to the development and direction of the project. I thank Randy Knapik, Justin Valentine, Cody Grasser, Sarah Vanderhorst, Anthony Mosinski, and Taylere Bernett who all assisted in the collection of field data. I especially value my friendship with Randy Knapik and Justin Valentine, and due to the dedication and work ethic of these two, the success of this project was made possible.

I would like to thank Amy Schmidt, Olivia Ameredes, Pat Patterson, Mary Capoccia, and other office staff with the School of Environment and Natural Resources for their help. Dennis Hull was extremely vital to the daily functioning of the project for which I am thankful. I would also like to thank current and former students within the Terrestrial Wildlife Ecology Laboratory (TWEL) and staff for their help and friendships; Bryant Dossman, Lauren Blyth, Jenn Malpass, Evan Wilson, Gabe Karns, Jason Tucker, and Keith Norris.

I would like to thank Eric McConnell and Jeremy Bruskotter for agreeing to be on my committee and appreciate their comments and edits. I offer sincere thanks to Dr. Robert Gates for all of his advice and guidance during my time as a graduate student. I am very thankful I was given the opportunity to be a graduate student and show my capabilities.

I am grateful to my friends, family (Brandyn, Terrie, Rene M., Betty, Gerald, Rene C., Anna), and girlfriend (Alison) for all their love and support during this time.

They all have had a role of instilling me with hard work ethic, dedication, determination, and most importantly the passion I have in wildlife which made it possible for me to pursue my interest as a career.

Vita

May – July 2009………………………………Forest Management Intern, Michigan DNR

May – August 2010…………………………...Non-Career Wildlife Assistant, Michigan DNR

May 2011……………………………………....B.S. Wildlife Biology and Management, Michigan State University

March 2012 – August 2012 …………………...Research Technician, Terrestrial Wildlife Ecology Laboratory, Ohio State University

August 2012 to present………………………...Graduate Associate, School of Environment and Natural Resources, Ohio State University

Field of Study

Major Field: Environment and Natural Resources

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

The geographic range of Northern bobwhites (*Colinus virginianus*; hereafter bobwhite) spans almost the entire eastern half of the United States, where the species inhabits farm fields and grasslands, grass-brush rangelands, fallow fields, clear-cuts, open forests and pine-plantations. Despite their use of such diverse habitats, there is a range-wide decline of bobwhites (Guthery et al. 2000, Williams et al 2004, Veech 2006) despite a long history of research and management. Declines in other farmland bird populations including bobwhites have typically been associated with the loss or degradation of these habitats, which, in part, has been a result of modern agricultural intensification that incorporates both habitat change and various farmland management strategies (Klimstra 1982, Brennan 1991, Askins 1993, Chamberlain and Vickery 2002, Hunter et al. 2001). Habitat change such as enlarged field sizes by elimination of fencerows, field borders, and other odd areas of perennial vegetation along with commercial fertilizers, herbicides, and pesticides for maximized returns (Buttel 1990), have left large areas void of early successional habitat which is preferred by bobwhites.

Successional habitat occurs where plants colonize treeless areas created by river action, glaciation, or abandonment of cleared land (Askins 2001). Disruption or destruction of forest canopy by fire, wind storms, logging, or other management (i.e., edge-feathering) can also produce early successional habitat. Early successional herbaceous habitat is also provided through federal government programs such as the

Conservation Reserve Program (CRP), which provides wildlife habitat but also controls commodity production and soil erosion (USDA 2015). While enrolled in CRP programs, participants are required to maintain these areas by some form of disturbance (i.e., mowing, disking, and burning). These different forms of disruption stimulate new growth of succulent grasses, forbs, and young forest dominated by short sprouts and seedlings of mature forest trees, along with surviving shrubs and herbs from the original forest understory (Askins 2001, Thompson and DeGraaf 2001). Suppression of natural disturbances like wildfires and floods, along with intensification of agriculture (listed above) has left early successional habitat patchily distributed across the Midwest. Prior to European settlement, wildfires and other natural disturbances enabled maintenance of early successional forests (Lorimer 2001). The absence of these natural disturbances along with limited management on private lands will likely allow declines in early successional habitat to continue within many eastern areas (Trani et al. 2001).

Without frequent disturbances to create early successional habitat, many of these areas have now matured, become forested, and are distributed patchily around the landscape in the Midwestern U.S. Due to the irregularity in which early successional vegetation is created and the intermittent distribution on most landscapes, many early successional dependent species have been negatively affected. Old fields that are left undisturbed are an example of early successional habitat. They are also an example of what can happen when left undisturbed; they rapidly progress via secondary succession, from excellent to marginal bobwhite habitat. As noted by Ellis et al.'s (1969) successful upland game management must stress the manipulation of natural succession rather than merely the creation and subsequent abandonment of habitat.

Bobwhites started to appear in Ohio in the nineteenth century (Wheaton 1882, Peterjohn 2001) with the creation of early successional habitat because of the removal of forests. Manipulation of habitat led to expansions north into the Great Lakes region during the 1840 – 50's (Peterjohn 2001). Bobwhites were considered an abundant resident in Ohio by the late eighteen hundreds, and populations peaked around 1900 (Wheaton 1882, Peterjohn 2001). Noticeable cyclic fluctuations were observed (Hicks 1935) in the early 20th century and the severe winter of 1935 – 36 severely diminished bobwhite populations and previously recorded population highs were never attained again (Baird 1936, Trautman 1940). Bobwhites became locally distributed and abundant throughout Ohio by the mid 1970's; however, the severe winters of 1976 – 77 and 1977 – 78 reduced bobwhite populations by more than 90% (Peterjohn 2001). Bobwhites have remained on the landscape in the southwestern portion of Ohio in relatively low densities, but the continued trend in low survival and decreasing densities continues to threaten bobwhite persistence in Ohio.

Woody vegetation bordering farmland edges has generally had a positive effect on species diversity for birds that nest on edges (Best et al. 1990). Cultivated fields are the principle source of food, a finding reported in many parts of the bobwhite's range (Hanson and Miller 1961). Previous research on my study sites showed preference for row crop and early successional vegetation in close juxtaposition. Roseberry and Sudkamp (1998) suggested bobwhites were primarily associated with diverse, patchy landscapes that contained moderate amounts of grassland and row crops and abundant woody edge. Management strategies aimed to increase the availability of non-breeding season habitat on agricultural lands in Ohio have been directed at providing early successional woody cover adjacent to food sources, such as row crop or grass fields (Janke 2011). Food abundance for bobwhites on cultivated land is still higher than for birds on uncultivated lands (Errington and Hamerstrom 1936). Janke (2011) suggested that use within the home-range focused on areas where woody cover (early successional woody or forests) and food (early successional herbaceous or row crops) were in close proximity. Because woody cover is the primary escape cover for bobwhites, the amount and distribution of woody cover available within a landscape could alter fall-winter survival and the population dynamics of bobwhites (Brennan 1991, Janke 2011, Williams et al. 2000).

Habitat conversion within the context of a highly agricultural landscape remains a challenging task because removing productive crop ground and planting fencerows or ditches is not a viable option. A practical option left available within our study sites was to convert woodlot edges from closed canopy forests to early successional vegetation. Seckinger (2008) performed similar habitat manipulation and found that it clearly increased usable space consistent with Guthery's (1997) habitat management philosophy. Converting closed canopy forests to early successional habitat simultaneously eliminated bobwhite predator habitat while increasing usable space for bobwhites in this landscape (Seckinger 2008). Early successional habitats created by timber harvest are dominated by tree reproduction and differ from other woody, early successional habitats, but nevertheless provide habitat for many of the same species (Thompson and Degraaf 2001). Major disturbances typically kill most large trees but do not destroy forest floor herbaceous vegetation, shrubs, seed banks, and all respond rapidly to the increased availability of light and nutrients (Trani et al. 2001, Thompson and Degraaf 2001).

STUDY DESIGN

Study Area

I worked within the core region of bobwhite density in Ohio (Spinola and Gates 2008, Peterjohn and Rice 1991) on four study sites comprised entirely of private property (Figure 1.1). The sites were located within the till plains, more specifically the Southern Ohio Loamy Till Plain and Illinoian Till Plain (Ohio Department of Natural Resources). Study sites ranged in size from 398 to 1336 ha. Permission was achieved originally from private landowners when asked if they were willing to participate and allow access for a bobwhite project on their land. Landowners became really friendly when they understood that bobwhites would not be trapped and transferred. Most landowners had a real passion for bobwhites and no longer allowed hunting because of their affection, and cannot stand the thought of not seeing bobwhites. Landowners were also very prideful knowing that they were actively taking part in research to understand problems that were affecting bobwhites.

Row crops were the dominant cover type and though the proportion of lands in row crops varied between sites, it was the primary land use (37 – 71%) and consisted of annual rotations of corn (*Zea mays*) and soybeans (*Glycine max*) but included some double cropping with winter wheat (*Triticum* spp.). Pasture and hay cover ranged from 3 to 21% and was dominated by various cool season grass species with moderate grazing pressure or high frequency (≥ once per year) of disturbance (i.e., mowing). Forest cover ranged from 9 to 28% and was dominated by oak (*Quercus* spp.), hickory (*Carya* spp.), ash (*Fraxinus* spp.) and black walnut (*Juglans nigra*). Early successional herbaceous cover ranged from 8 to 21% and included fields enrolled in CRP, and old fields. Most

Figure 1.1 Location of 4 study sites where northern bobwhite research was conducted during the breeding and non-breeding season in Highland and Brown Counties, Ohio, USA during 2012 – 2014.

CRP fields were dominated by fescue (*Festuca* spp.) and goldenrod (*Solidago* spp.), while some fields were dominated by indiangrass (*Sorghastrum nutans*) and partridge pea (*Chamaecrista fasciculate*). Old fields were dominated by herbaceous vegetation like broom sedge (*Andropogon virginicus*), queen anne's lace (*Daucus carota*), fescue, and goldenrod. Early successional woody cover occurred predominantly in fencerows, ditches, woody CRP (CP-3A), old fields-woody, and ranged from 3 – 7%. They were characterized by blackberry (*Rubus allegheniensis*), black raspberry (*R. occidentalis*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), poison ivy (*Toxicodendron radicans*), and red cedar (*Juniperus virginiana*).

The mean temperature for breeding (April – September) and non-breeding (October – March) seasons during my research was 20.4°C and 3.7°C compared to the long-term (30 year) mean annual temperature of 11.2°C and mean winter temperature of -0.7°C. The mean precipitation for breeding (April – September) and non-breeding (October – March) season was 10.2 cm and 8.5 cm compared to the mean annual precipitation of 108.1 cm (NCDC 2015).

THESIS CONTENT

The goal of my study was to identify factors influencing vegetation response at multiple temporal and treatments scales, and also compare vegetation used by radio-marked bobwhite coveys to vegetation created by private contractors within 2 of my 4 study sites. Specifically, I attempted to identify what factors most influence vegetation response after treatment, compare cover characteristics and structure between feathered edges and locations used by bobwhites, and determine home-ranges and movements of coveys relative to feathered edges on treated sites documenting use of feathered edges by bobwhites. To do this, I examined; 1) change in vegetation composition and structure before and after treatment; 2) key structural and compositional measurements of used habitat and treated areas; and 3) home-ranges of coveys within study sites that had treatments. I first quantified vegetation composition and structure using a range of different vegetation procedures. I reduced my ground cover variables using a data reduction technique to interpret several linear combinations which I then used for comparing ground cover composition. I also compared cover measurements to different treatment intensities for edges experiencing equal seasons. I then investigated the relative importance of these vegetation dimensions to numerous covey locations and habitat used using the same sampling design for treated edges. Finally, I concentrated on the influence of treated habitat and the factors that lead to use of areas by coveys during winter by building home-ranges. Together, these two research chapters provide a multi-scaled assessment of habitat use by northern bobwhites on private land in southwestern Ohio. My final chapter summarizes the management implications of my research.

LITERATURE CITED

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Askins, A. 2001. Sustaining Biological Diversity in Early Successional Communities: The Challenge of Managing Unpopular Habitats. Wildlife Society Bulletin 29:407-412.

Baird, R. L. 1936. Oberlin (Ohio) region. Bird Lore 38:468-470.

Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of Cornfields by Birds during the Breeding Season: The Importance of Edge Habitat. American Midland Naturalist 123 1:84-99.

Buttel, F. H. 1990. Social relations and the growth of modern agriculture. Pages 113-145 *in* C. R. Carrol, J. H. Vandermeer, and P. M. Rosset, editors. Agroecology. McGraw-Hill, New York.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Chamberlain, D., and J. Vickery. 2002. Declining farmland birds: Evidence from large-scale monitoring studies in the UK. British Birds 95:300-310.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Responses of bobwhites to management in Illinois. Journal of Wildlife Management. 33:749-762.

Errington, P. L., and F. Hamerstrom. 1936. The northern bob-white's winter territory. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhite. Journal of Wildlife Management 61:291-301.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Visibility of northern bobwhite populations. Journal of Wildlife Management 64:646-662.

Hicks, L. E. 1935. Distribution of the breeding birds of Ohio. Ohio Biological Survey Bulletin No. 32, 6:125-190.

Hanson, W. R., and R. J. Miller. 1961. Edge Types and Abundance of Bobwhites in Southern Illinois. The Journal of Wildlife Management 25:71-76.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440-455.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. The Ohio State University.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Bobwhite Quail Symposium 2:1-5.

Lorimer, C. G. 2001. Historical and ecological roles of disturbance in eastern North American forests: 9000 years of change. Wildlife Society Bulletin 29:425-439.

National Climate Data Center [NCDC]. 2015. Quality Controlled Local Climatological Data. <http://www.ncdc.noaa.gov/oa/ncdc.html>.

Peterjohn, B. G. 2001. The birds of Ohio. Second edition. The Wooster Publishing

Company, Wooster, Ohio, USA.

Peterjohn, B. G., and D. L. Rice. 1991. The Ohio breeding bird atlas. Ohio department of Natural Resources, Columbus, Ohio, USA.

Physiographic Regions Of Ohio. 2013. Division of Geological Survey. Department of Natural Resources. Columbus, Ohio, USA. <http://www.dnr.state.oh.us/Portals/10/pdf/physio.pdf>

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895-902.

Seckinger, E. M., L. W. Burger, R. Whittington, A. Houston, and R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959-969.

Spinola, R. M. and R. Gates. 2008. Population Status and Trends of Northern Bobwhite (*Colinus virginianus*) in Ohio: 1984-2004. Ohio Journal of Science 108:26-30.

Thompson, F. R., and R. M. DeGraaf. 2001. Conservation Approaches for Woody, Early Successional Communities in the Eastern United States. Wildlife Society Bulletin 29:483-494.

Trani, M. K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C. M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29 2:413-424.

Trautman, M. B. 1940. The Birds of Buckeye Lake, Ohio. University of Michigan Museum of Zoology Miscellaneous Publication. No. 44:1-466.

U.S. Department of Agriculture (USDA). 2015. Washington, D. C.: United States Department of Agriculture, Farm Service Agency. Retrieved March 28, 2015 from

<http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp>

Veech, J. A. 2006. Increasing and declining populations on northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922-930.

Wheaton, J. M. 1882. Report on the birds of Ohio. Ohio Geological Survey Bulletin 4:187-628.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology-Revue Canadienne De Zoologie 78:1562-1566.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861-869.

CHAPTER 2: Vegetation Response After Treatment of Wooded Edges by Edge-Feathering to Enhance Habitat for Northern Bobwhite (*Colinus virginianus*) in Southwest Ohio

ABSTRACT

Clean farming practices and forest succession have contributed to population decline of northern bobwhites (*Colinus virginianus*) across northern portions of their range. Intensively farmed landscapes lack early successional vegetation that provides protective cover near food sources. Earlier research showed that population growth of northern bobwhites in southwestern Ohio is limited by lack of preferred early successional woody cover during the non-breeding season. I studied vegetation response to removal of large trees from wooded edges (here after edge-feathering) on private owned farmlands in Highland County Ohio. I hypothesized that edge-feathering would provide suitable habitat for bobwhites during the non-breeding season. Ninety-nine areas ranging in length from 15 m to 91 m were treated during spring in 2012 and 2013. Vegetation structure and composition of feathered edges was measured before treatment and after 2 growing seasons and in late winter during 2012 – 2014. I used repeated measures analysis of variance to test for differences in vegetation structure and composition among study sites, edge aspects, feathered edge size classes, edge types, and basal area reduction. Basal area reduction differed between years, with a light reduction (29%) in 2012 and a heavy reduction (81%) in 2013. Horizontal, vertical, and ground

cover differed among sample periods with the second fall having more vertical and horizontal cover than the first fall, and the first fall having more cover than the first winter. Basal area reduction, size, and sample periods were important predictors of cover measurements. Basal area reduction within woodlot edges or along linear features like fencerows was the most important variable that affected vegetation response to edge-feathering. Basal area reductions between 37 - 50% resulted in positive changes in protective cover for bobwhites after 1 growing season. Large edge treatments with heavy reduction in basal area resulted in net gains in protective cover between seasons, and provided the highest overall change in cover. Edge-feathering is a technique that can convert hard edges into soft edges by felling trees, stimulating new vegetation growth gradient where vegetation slowly increases from young new growth containing grasses, forbs, and shrubs, into saplings and trees. Creating suitable habitat on agriculture lands by providing early successional woody cover has the potential to increase usable space and improve annual survival rates reversing population declines.

INTRODUCTION

Farming practices have changed across the Midwest, becoming more intensive and resulted in a loss of early successional habitat. Practices such as clean farming have led to the eradication of weeds and the removal of woody debris, fencerows, waterways and old fields (Matson et al. 1997). Field sizes have increased by an order of magnitude to accommodate new equipment and cropping methods for farming (O'Connor and Shrubb 1986). Clean farming has caused remaining habitat that has not been manipulated for farming practices to change in cover quality, which affects carrying capacity. Intensive farming practices have reduced suitable habitat (Burger et al. 2006, Dailey

2002) for Northern Bobwhites (*Colinus virginianus*; hereafter bobwhite) which in the Midwest, have historically depended on agriculture landscapes (Leopold 1931).

Trani et al. (2001) projected that current declines in areas of early successional forest will continue and absence of disturbance or proactive management on private woodlands will promote continued losses of early successional forest. Maturation of woodlots (Thompson and DeGraaf 2001, Litvaitis 1993) creates hard edges between woodlots and agriculture fields as woodlots are increasingly dominated by large diameter trees, contain little understory, and provide no ecotone between different habitat types. Early successional woody vegetation is facilitated by farming practices such as fencerows and drainage ditches, which were once distributed in higher quantities throughout the Midwestern landscape than today (Brennan 1991, Hunter et al. 2001). These areas can have thick shrubby vegetation in the understory which provide suitable habitat for bobwhites and other songbirds (Best 1983, Best et al. 1990) but have been largely eliminated from modern agricultural landscapes (Demers et al. 1995).

Early successional woody cover provides more persistent cover than herbaceous cover and remains useable through the fall and winter (non-breeding season). Many studies have established the importance of woody cover for bobwhites during the non-breeding season (Yoho and Dimmick 1972, Roseberry and Klimstra 1984, Williams et al. 2000, Hiller et al. 2007, Janke 2011, Gates et al. 2012, Janke and Gates 2013, Wiley 2012). Woody cover is particularly important for bobwhites exposed to severe winter weather in the northern portion of their range (Errington and Hamerstrom 1936, Roseberry 1964, Janke 2011, Janke and Gates 2013) because it provides thermal cover (Guthery et al. 2005) and provides overhead protection from avian predators during periods of snow cover. Management strategies aimed at increasing availability of non-breeding season habitat on agricultural lands in Ohio were recommended to focus on providing early successional woody cover adjacent to food sources, such as row crop or grass fields (Hanson and Miller 1961, Janke 2011).

Edge-feathering is a relatively new practice of turning a hard edge into a soft edge, where the vegetation progresses from young new growth containing grasses, forbs, shrubs, into saplings and larger trees. Feathered edges provide early successional habitat by removing overstory trees and allowing sunlight to reach the understory to produce new growth like grasses, sedges, forbs, and shrubs which are typically absent. Feathered edges also provide an immediate woody structural component because in most cases, the trees are left in edges after they were cut. Edge-feathering can be conducted by felling trees into fields or by felling trees back into woodlots or along the edges (Chapman 2012, MDC/NRCS/UMC 2011). Unmanaged woodlots potentially provide the only remaining manageable habitat that is within highly agricultural landscapes.

The goal of my study was to evaluate changes in vegetation cover and structure on woodlot edges treated by edge-feathering to create early successional habitat within highly agricultural landscapes in southwest Ohio. Specifically, my objectives were to: 1) quantify vegetation composition and structure within feathered edges; 2) compare different intensities of edge-feathering on vegetation composition and structure; and 3) compare the directions in which treated edges were facing (aspect), the size of edge treated, and the type of habitat treated (linear wooded vs. woodlot). This allowed me to assess the utility of edge-feathering, the optimal treatment level for vegetation composition and structure, and identify factors influencing response, such that future bobwhite management utilizing this approach in this region and in other areas can be effective and successful.

STUDY AREA

This study was conducted on two sites in Highland County, Ohio (Figure 2.1). Response of vegetation composition and structure to woodlot edge treatment was conducted on Fee and Peach Orchard (Figure 2.1). The mean temperature during breeding (April – September) and non-breeding (October – March) seasons during 2012 - 2014 was 20.4°C and 3.7°C with mean precipitation of 10.2 cm and 8.5 cm (NCDC 2015). The study area was within the core range of northern bobwhites in Ohio (Spinola and Gates 2008, Peterjohn and Rice 1991). Winter cover was previously shown to limit population growth, and bobwhite densities were declining (Janke 2011) on some sites in response to lack of early successional vegetation (woody and herbaceous).

Figure 2.1 Location of 2 study sites where habitat manipulation for northern bobwhites occurred during the breeding and non-breeding seasons in Highland County, Ohio, USA (2012 – 2014).

Row crop fields were dominated by rotations of corn (*Zea mays*) and soybeans (*Glycine max*) but included some double cropping with winter wheat (*Triticum* spp.). Pasture and hay fields were dominated by various cool season grass species with moderate grazing pressure or high frequency (≥ once per year) of disturbance (i.e., mowing). Oak (*Quercus* spp.) and hickory (*Carya* spp.) dominated the upland forested areas whereas ash (*Fraxinus* spp.) and black walnut (*Juglans nigra*) dominated the bottomland forested areas (Wiley 2012). Early successional herbaceous cover included fields enrolled in the Conservation Reserve Program (CRP), and old fields. Most CRP fields were dominated by fescue (*Festuca* spp.) and goldenrod (*Solidago* spp.), while some fields were dominated by indiangrass (*Sorghastrum nutans*) and partridge pea (*Chamaecrista fasciculate*). Old field-herbaceous were dominated by broom sedge (*Andropogon virginicus*), queen anne's lace (*Daucus carota*), fescue, and goldenrod. Early successional woody cover occurred predominantly in fencerows, ditches, woody CRP (CP-3A), and old fields-woody. They were characterized by blackberry (*Rubus allegheniensis*), black raspberry (*R. occidentalis*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), and red cedar (*Juniperus virginiana*).

Woodlots, mature fencerows, ditches, and other odd areas were considered for treatment if they had previously been determined to have had little to no use by bobwhite coveys (Janke 2011, Wiley 2012). These areas were then assessed by private land biologists from Pheasants Forever and Ohio Division of Wildlife to avoid waterways, woodlots with valued timber, or other potential factors that might affect and limit treatment of these areas. Permission by the participating private landowners was obtained and potential spots were delineated for treatment. Placement of feathered edges was guided by previous research (Janke 2011, Wiley 2012) and were distributed throughout the study sites. We attempted to balance the number of feathered edges adjacent to row crop (*n*=67) and herbaceous (*n*=32) vegetation, (Conservation Reserve Program; Cp-1, Cp-2) but due to available cover types, we were not able to achieve this (Table 2.1). By design, we were able to evenly allocate feathered edges by aspect, North (*n*=25), East (*n*=28), South (*n*=23), and West (*n*=23).

Edge-feathering was conducted on Fee and Peach Orchard sites over two years. Fifty-three edge sections were treated on Fee and 16 edge sections were treated on Peach Orchard during 13 April – 9 May, 2012. These 69 edge sections all experienced 2 complete growing seasons and 2 complete winter seasons. Thirty edge sections were treated on Peach Orchard during 1 March – 21 March, 2013. These 30 edge sections experienced 2 complete growing seasons but only 1 winter season during the duration of the study. Vegetation measurements were recorded at seasonal intervals and were aimed to measure the response of vegetation following two growing seasons for those completed in spring 2012 and 2013.

Treatments were performed by two different contractors and with two different prescriptions. Contractor 1 treated period 1 and tended to cut small diameter trees leaving larger diameter trees within treated edges. Contractor 1 also used a wand to spray herbicide (i.e., Glyphosate) from a quad-mounted sprayer to treat herbaceous vegetation within edges. This treatment period will be referred to as 2012 treatment. Contractor 2 treated period 2 and was advised to cut all trees within feathered edges and treat cut-stumps with Triclopyr to avoid stump-spout. This treatment period will be referred to as 2013 treatment.

Site	Edge characteristics					
	Feathered edge length (m)	Size category	Feathered edges	Feathered edge type	Row crop edge	Herbaceous edge
Fee	15	Small	7	Woodlot	7	0
	30	Medium	41	Woodlot	41	0
	61	Large	1	Woodlot	1	0
	91	Large	4	Linear woody	3	1
Peach	-	Small	0	-	0	0
	30	Medium	27	Woodlot	5	22
	30	Medium	8	Linear woody	1	7
	91	Large	10	Woodlot	8	2
	91	Large	1	Linear woody	1	0
Total	-	-	99	-	67	32

Table 2.1 Summary of feathered edge sections by site, length, size, type, and adjacent cover type in Highland County, Ohio (2012 – 2014).

METHODS

Vegetation Sampling— Vegetation composition and structural characteristics were measured at 99 feathered edges with one to two sampling points within each edge section to compare vegetation change after the first and second growing seasons; and at the end of the first and second winter seasons. One sampling point was established if the edge section was equal to 15 m, and 2 points were established if the edge section was ≥ 30 m (Table 2.1) with aid of handheld GPS units (Garmin GPSmap 76, Garmin Oregon 450, Garmin International Incorporated, Olathe, KS). Measurements at sample points (n=191) focused on vegetation composition and structure with emphasis on ground, horizontal, and vertical cover. Specific measurements included tree basal area (DBH), shrub density (Cottam and Curtis 1956), horizontal visual obstruction (Nudds 1977), overhead cover (Kopp et al. 1998), and ground cover (Daubenmire 1959). Four transects extended in 4 directions from each sampling point at 90° intervals, delineating 4 quadrants (Figure 2.2). Transect 1 was always perpendicular to the feathered edge section and transects 2 - 4 were numbered clock-wise from the first transect. The quadrants were numbered similarly (Figure 2.3).

Vegetation cover of 69 edge sections was sampled before treatment during April – May 2012. The remaining 30 sections were measured before treatment during February – March, 2013. Subsequent measurements were recorded in fall (September – October) to quantify changes in vegetation structure and composition in early autumn when coveys were forming (Janke and Gates 2013). Fall sampling was concluded before leaf–off to quantify vegetation cover after the summer growing season representing peak cover. Ensuing measurements were recorded after winter (March – April) in 2013 – 14. Winter sampling was concluded before leaf emergence to quantify vegetation cover at the end of winter to reflect lowest cover.

The point-centered quarter (PCQ) method (Cottam and Curtis 1956) was used to measure sapling and shrub density and taxonomic composition. Distances from sampling points to the nearest woody stem 1 - 2 m high were measured out to 10 m from plot-center in each quadrant. The PCQ method provides reliable estimates of density when total plant density within a community is the only concern (Higgins et al. 2005). Three taxa were of primary interest because of abundance and importance to bobwhite, multiflora rose, *Rubus* spp., and Amur honeysuckle (*Lonicera maackii*). A fourth category, "other-woody" included tree saplings and other shrub species, most commonly poison ivy, maple, sassafras (*Sassafras albidum*), and hickory 1 – 2 m height. I measured the distance to the nearest stem to estimate overall density which sometimes included other-woody stems in each quadrant, and then I measured the other three taxa to estimate

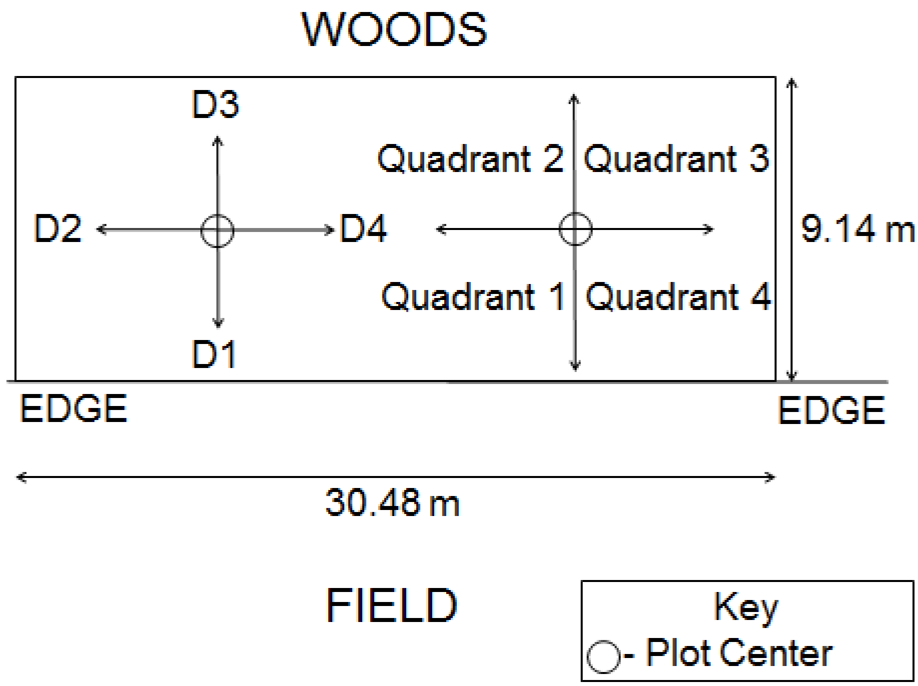


Figure 2.2 Plot design used to measure vegetation composition and structure of feathered edges before and after treatment in Highland County, Ohio (2012 – 2014).

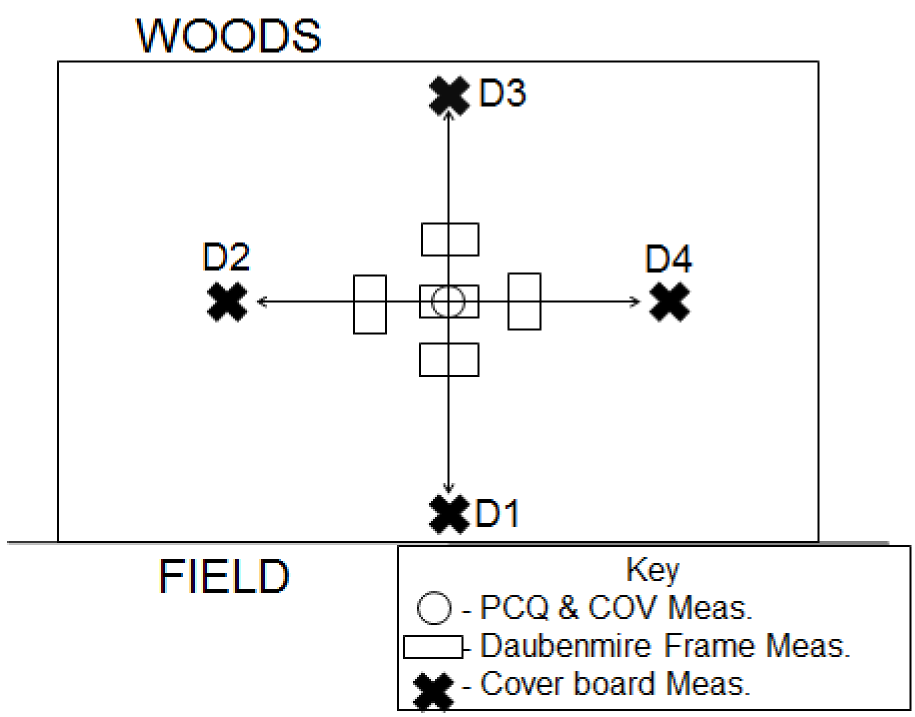


Figure 2.3 Vegetation sampling design used to measure vegetation composition and structure at feathered edges in Highland County, Ohio 2012 – 2014.

overall shrub density for multiflora rose, *Rubus* spp., and Amur honeysuckle. Shrub density was recorded as zero if no woody stem occurred within 10 m of the plot center in each quadrant. Pre-treatment shrub density was not recorded for 2013 feathered edges because of time constraints and contractor start date.

Daubenmire (1959) frames (0.2 m X 0.5 m) were used to measure ground cover (any live or dead vegetation ≤ 1m height) at plot-center and in 4 plot directions (2 m from center). The 5 measurements of ground cover were averaged for each plot. Daubenmire (1959) recommended using 0.2 m X 0.5 m quadrants for shrubs and herbaceous vegetation because cover is more easily estimated in small quadrants. Rectangular frames have advantages over square and circular plots in aggregated shrub communities because they have the greatest chance of overlapping individual clusters of shrubs (Higgins et al. 2005). Cover types included bare ground, litter, grass/sedges, forbs, shrubs, brush, and other. Litter included any dead herbaceous material no longer attached to a plant, while brush was defined as non-standing dead woody material. The percent of each cover type was recorded in one of seven intervals; (0%), >0-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95% (Schmutz et al. 1989) to calculate total ground cover. Cover types could sum to > 100% to quantify amounts of each cover type separately within the Daubenmire frame, accounting for overlapping layers in vegetation ≤ 1 above ground.

Vertical cover was measured at each plot-center in all four directions to estimate the volume of unobstructed space based on angle to obstruction ≤ 2 m away from a bobwhite on the ground (Kopp et al. 1998). I used a 2 m pole with an angle gauge affixed. The pole was tilted in the four cardinal directions until it contacted any physical obstruction (i.e., vegetation, barbed wire, trees, etc…) above 0.15 m on the pole (height of a bobwhite). The angle of tilt was recorded from 0° (upright) to 90° (prostrate). I used the arithmetic mean of the angle readings for each plot-center to calculate the mean angle of a cone above a bobwhites head.

I used a modified Nudds (1977) vegetation profile board to measure horizontal visual obstruction (horizontal cover) of vegetation in 7, 0.15 m vertical segments (0.15 m x 1.05 m) above-ground. Visual obstruction quantifies hiding, escape, and thermal cover (Higgins et al. 2005). The profile board was placed at plot-center and was read from all 4 directions by viewing the board from 7 m away at a height of 1 m (Lusk et al. 2006). The percent of visual obstruction for each segment was recorded in seven intervals; (0%), >0-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95% (Schmutz et al. 1989). Each segment was separated into one of seven vertical classes (hereafter cover classes) and the mean cover class was calculated. The mean cover class score for each vertical section was calculated as the arithmetic mean of cover for each of the 4 directional readings within each plot. The 4 directional readings within each plot-center were calculated as the arithmetic mean of the 7 mean cover class scores in each plot. Photos of each feathered edge at each sampling period in combination with profile board readings were used to visually document changes in vegetation structure (Marlow and Clary 1996, Dudley et al. 1998) before and after treatment .

I used a DBH tape and measured all trees ≥ 5 cm 1.4 m above ground level (Spurr 1964), recording basal diameter of each tree species in the entire feathered edge section. Basal area measurements were used as a measure of treatment intensity. Post-treatment basal area measurements were subtracted from pre-treatment basal area measurements and divided by pre-treatment basal area giving a basal area reduction percentage for each feathered edge section.

Feathered edges— Treated edges, whether a linear feature such as a fencerow or a woodlot edge, were assigned into three different size classes (Table 2.1). Small feathered edges were treated areas that had treatment edges equal to 15 m length. Medium feathered edges were treated areas with a treatment edge equal to 30 m length. Large feathered edges were treated areas with a treatment edge > 30 m length. A subset of medium and large feathered edges had the same total area treated but their length along the edge type differed (Table 2.1).

Data Analysis— I used analysis of variance function aov in Program R (Version 3.1.2; R Development Core Team 2014) to compare feathered edges treated by sites, size classes, aspects, and different contractors. I used split-plot analysis because my experiment had different treatments applied to plots of varying sizes (mostly fixed effects; Crawley 2012). I limited my models to only two-way interactions. I used horizontal, vertical, and ground cover to compare changes in vegetation structure and composition associated with size classes and aspect following intensity of treatment (basal area reduction). The split-plot design also accounted for the repeated sample of the same plots in different seasons. Each plot size class had its own error variance, instead of a single error variance pooled across size classes. Thus there were as many error terms as plot size classes. The analyses are presented as a series of component ANOVA tables, one for each plot size, from the largest plot size with the lowest replication at the top, to the smallest plot size with the greatest replication at the bottom (Crawley 2012).

For example, the following refers to my cover measurements with six treatments: sample time (Fall1, Fall2, Winter1, and Winter2), aspect (North [N], South [S], East [E], West [W]), size classes (large [L], medium [M], small [S]), type (woodlot [W], fence [F]), percent basal area reduction (%), and starting basal area for each plot (Figure 2.4). The largest plots were the individual feathered edge sections (referred to as plots), each of which was assigned into a sample period (sample). My model statement was:

Model <- aov (Horizontal cover change ~ Sample Time * Aspect * Size class * Type + Basal Area Reduction + Starting Basal Area + Error (Plot/Sample Time), data = data)

Split-plot experiments are inherently pseudoreplicated (Crawley 2012). The complex breakdown was due in part because sites and sections were not all treated during the same year and we did not record all measurements between years due to time constraints (Figure 2.4). The dependent variable was change in the vegetation measurement from the pre-treatment value and all sample periods were compared with pre-treatment vegetation (before treatment) measurements to compare overall change in composition and structure.

A saturated model was used initially with all predictors to test the significance of the response variables using $\alpha < 0.05$. I removed predictors that were not biologically or statistically significant to save degrees of freedom. The new models containing significant predictors were my reduced models. I also used ANOVA to examine the significant interaction between basal area reduction and sample period on the change of horizontal cover and vertical cover comparing all treatments through Fall2.

I used the function princomp in Program R (Version 3.1.2; R Development Core Team 2014) for principal components analysis (PCA) to identify linear combinations of ground cover

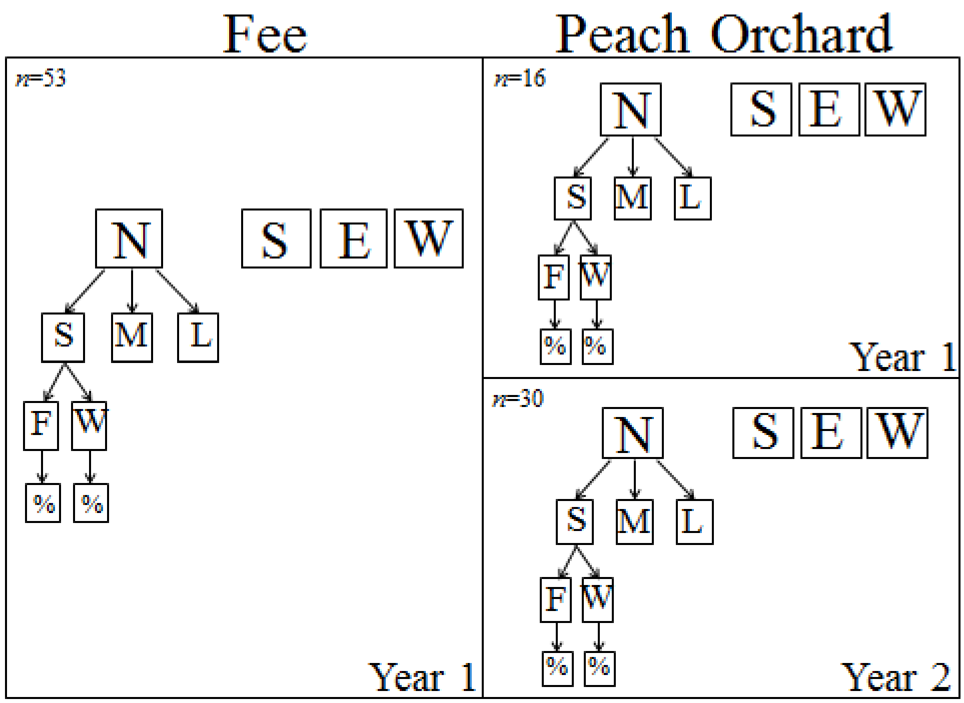


Figure 2.4 Split-plot model design for measuring vegetation composition and structure at all feathered edge sections in southwest Ohio, 2012 – 2014. All branches of comparisons for aspect are not shown for clarity.

variables that captured most of the variation by reducing dimensionally and using the PCA scores on each axis as predictor values. After running a PCA with all 7 ground cover variables, the linear combinations produced were not interpretable and variance explained was low. I proceeded to separate the variables into categories representing living (forbs, grass/sedge, and shrubs) and non-living (bare ground, litter, brush, and other) vegetation. I used the top two principle linear combinations from both living and non-living PCA's after these axes were interpreted. I then used the split-plot models similar to above but only reused my covariates (basal area reduction, starting basal area). I inserted the top two linear combinations from both PCA's (4 principle linear combinations total) to test the effect on horizontal and vertical cover. I proceeded to use them in my split-plot experimental design as covariates along with basal area reduction and starting basal area.

RESULTS

Treatment Effects-- Basal area reduction differed between contractors amid 2012 (*n*=69, mean=29.4%, min=0, max=100) and 2013 (*n*=30, mean=80.5%, min=39, max=100) treatments and basal area reduction was significantly higher in 2013 than in 2012 (t = 10.094, $P < 0.001$ (2-tailed), d.f. = 69.4) which resulted in more woody debris and sunlight penetrating the ground (Table 2.2). There was very little overlap in treatment effect and comparisons between 2012 (light) and 2013 (heavy) treatment were confounded with year and site because Fee was only treated in 2012, while Peach Orchard was mostly treated in 2013.

Shrub density increased overall for *Rubus* spp*.,* Amur honeysuckle, and other woody stems from pre-treatment to the second fall on Fee and the first round of edge-feathering on Peach Orchard (16 feathered edges). *Rubus* density increased on both sites between (121 – 452%), Amur honeysuckle density increased between (75 – 186%), and other-woody density increased between (73 – 126%) from initial measurements (Table 2.3). Multiflora rose density decreased by 12% on Fee and increased by 214% on Peach Orchard. The second round of edge-feathering on Peach Orchard (30 feathered edges) had similar responses. *Rubus* spp. density increased by 59% and Amur honeysuckle increased 67% (Table 2.3). Other-woody density decreased by 3% and Multiflora rose density decreased by 67% (Table 2.3).

Amur honeysuckle was found within 49 (92%) of Fee feathered edges before treatment. Amur honeysuckle was found within 51 (96%) of Fee feathered edges during

Site	Scientific Name	Pre-treatment basal area			Post-treatment basal area		
		Basal Area		Density	Basal Area		Density
		m^2	%[b]		m^2	%[b]	
Fee	*Acer* spp.	5.74	22.5	5.96	4.78	12.1	2.09
	Ailanthus altisima	0.11	0.4	0.23	0.31	0.8	0.08
	Carya spp.	3.05	12.0	0.62	7.90	20.1	1.74
	Celtis occidentalis	2.88	11.3	2.38	2.02	5.1	0.89
	Fraxinus spp.	8.35	32.7	1.30	13.92	35.4	3.30
	Gleditsia triacanthos Robinia pseudoacacia	0.43	1.7	0.70	0.14	0.4	0.19
	Juglans nigra	0.00	0.0	0.00	1.99	5.1	0.58
	Juniperus virginiana	0.08	0.3	0.02	0.06	0.2	0.02
	Prunus serotina	2.83	11.1	1.38	3.02	7.7	1.43
	Quercus spp.	0.00	0.0	0.00	0.65	1.7	0.09
	Ulmus spp.	0.00	0.0	0.00	1.79	4.5	1.04
	Snag	2.05	8.0	1.25	2.31	5.9	1.23
	Unknown[a]	25.30	-	16.75	1.30	-	0.45
	Total (All)[c]	50.82	-	30.66	40.65	-	13.53
Peach	*Acer* spp.	12.20	23.5	11.72	2.77	14.8	1.11
	Ailanthus altisima	0.00	0.0	0.00	0.00	0.0	0.00
	Carya spp.	4.27	8.2	3.20	2.85	15.2	0.76
	Celtis occidentalis	1.01	1.9	0.67	0.25	1.3	0.15
	Fraxinus spp.	10.66	20.6	7.13	2.08	11.1	0.70
	Gleditsia triacanthos Robinia pseudoacacia	0.74	1.4	0.76	0.11	0.6	0.04
	Juglans nigra	2.41	4.6	1.39	1.38	7.4	0.35
	Juniperus virginiana	1.09	2.0	2.11	0.03	0.2	0.02
	Prunus serotina	5.41	10.4	4.33	1.70	9.1	0.65
	Quercus spp.	6.40	12.3	4.70	5.56	29.7	0.96
	Ulmus spp.	1.88	3.6	3.78	0.05	0.3	0.11
	Snag	2.81	5.4	3.37	1.66	8.9	0.67
	Unknown[a]	3.66	-	4.09	0.02	-	0.02
	Total (All)[c]	55.52	-	53.59	18.77	-	6.00

[a] Unknown = Trees that were not identified because of limited time before treatment
[b] % = Basal area of select tree species divided by known total
[c] Total (All) = Includes tree species that are not listed within table

Table 2.2 Basal area and stem density per sections and sites for all 99 treated edges. The top 13 tree species were listed before and during the first fall in Highland County, Ohio (2012 – 2013).

the second fall sampling period, an increase in 4%. Amur honeysuckle was found within 5 of 16 (31%) feathered edges that were completed in the first year on Peach Orchard. Nine (56%) feathered edges had Amur honeysuckle during the second fall sampling period, a 24% increase. Fourteen of 30 (46%) second round feathered edges had Amur honeysuckle both sampling periods (Fall1 and Fall2) on Peach Orchard.

			Shrub Density							
Sampling Period	Site	Sample size (n)	M.[b] rose	C.I.	*Rubus* spp.	C.I.	A.[c] honey	C.I.	O.[d] woody	C.I.
Pre-treatment[a]										
	Fee	53	0.69	1.26	0.87	1.43	0.65	1.13	2.41	3.15
	Peach	16	0.14	0.18	0.25	0.46	0.08	0.18	0.88	1.31
Fall1										
	Fee	53	0.37	0.66	1.03	1.70	0.44	0.69	1.88	2.49
	Peach	16	0.32	0.56	0.36	0.71	0.04	N/A	2.59	4.87
	Peach	30	1.43	3.43	0.59	1.05	0.36	0.92	2.75	4.75
Fall2										
	Fee	53	0.61	1.06	1.92	3.01	1.14	1.92	4.17	5.65
	Peach	16	0.44	0.82	1.38	2.67	0.23	0.61	1.99	3.14
	Peach	30	0.47	0.76	0.94	1.84	0.60	1.64	2.68	3.69

[a] Pre-treatment = Shrub density was not recorded pre-treatment for the 30 Peach Orchard feathered edges due to time constraints
[b] M. rose = Multiflora rose
[c] A. honey = Amur honeysuckle
[d] O. Woody = Other-woody

Table 2.3 Density of shrub species before and after treatment in Highland County, Ohio (2012 – 2014).

Ground Cover

Fall1 through Fall2

Principal component analysis (PCA) did not seem to describe meaningful features with the seven ground cover types combined. Therefore I split the seven ground cover types into 2 groups, live cover (3-variable) and non-living cover (4-variable [Table 2.4]). Splitting the cover types into two distinct groups with a PCA provided more meaningful principal linear combinations based on proportion of variance explained and factor loadings (Table 2.4).

The first 2 components described meaningful variation in the 3-dimensional live cover responses, explaining 79% of the variance. Component 1 (interpreted as live herbaceous) had almost identical negative loadings for grass/sedge and forbs. Component 2 (interpreted as live woody) had a very high positive loading for shrubs and a very low positive loading for forbs (Table 2.4).

			Principal Components Analysis			
Time			Component 1.		Component 2.	
Fall1 - Fall2		Variable names	Factor Loadings	Eigenvectors	Factor Loadings	Eigenvectors
	Live cover	Grass/sedge	-0.708	-0.829		-0.032
		Forbs	-0.705	-0.825	0.101	0.098
		Shrub		0.064	0.994	0.995
		Proportion of variance	46%		33%	
	Non-living cover	Soil	-0.604	-0.682		-0.065
		Litter	-0.427	-0.481	-0.207	-0.217
		Brush	-0.183	-0.212	-0.872	-0.904
		Other	-0.647	-0.732	0.440	0.455
		Proportion of variance	32%		27%	

Table 2.4 Principal components analysis results for ground cover types for two growing seasons in southwest Ohio, 2012 – 2014.

The first 2 principal components described meaningful variation in the 4-dimensional non-living cover responses, explaining 59% of the variance. Principal components 3 through 4 were harder to interpret and therefore less meaningful. Component 1 (interpreted as open ground) had almost identical negative loadings for soil and other. Brush and litter also had negative loadings but they were not nearly as low. Component 2 (interpreted as woody debris) had negative loadings for brush and litter and a positive loading for other. Once these combinations were interpreted, I proceeded to use them in my split-plot experimental design as covariates along with basal area reduction and starting basal area. These were used as predictors for horizontal and vertical cover.

Winter2

Similar to Fall1 through Fall2, PCA did not seem to meaningfully describe variation of the seven ground cover types during the second winter. Therefore I split the seven ground cover types into 2 groups, live cover (3-variable) and non-living cover (4-variable [Table 2.5]). Splitting the cover types into two distinct groups with a PCA provided more meaningful interpretations of combinations based on proportion of variance explained and factor loadings (Table 2.5).

Only the first 2 principal linear components were needed to describe meaningful features of 3-dimensional live cover responses explaining almost 70% of the variance. Component 1 (interpreted as live woody) had negative loadings for grass/sedge and forbs and a higher positive loading for shrub (Table 2.5). Component 2 (interpreted as live herbaceous) had a very high positive loading for grass/sedge and a negative loading for forbs (Table 2.5). The interpretation of these components changed slightly in their explanation from Fall1 through Fall2 analyses. Component 1 is now a predictor of live woody vegetation and not live herbaceous vegetation as in the first PCA. Component 2 is now a predictor of live herbaceous vegetation and not live woody vegetation as in the first PCA.

Time			Principal Components Analysis			
			Component 1.		Component 2.	
Pre-treatment - 2nd winter		Variable names	Factor Loadings	Eigenvectors	Factor Loadings	Eigenvectors
	Live cover	Grass/sedge	-0.365	-0.510	0.868	0.935
		Forbs	-0.612	-0.540	-0.497	-0.069
		Shrub	0.702	0.784		0.019
		Proportion of variance	36%		33%	
	Non-living cover	Soil	0.458	0.705	-0.461	-0.401
		Litter	-0.596	-0.571	0.218	0.392
		Brush	-0.571	-0.525	-0.107	-0.023
		Other	-0.328	-0.332	-0.854	-0.906
		Proportion of variance	40%		24%	

Table 2.5 Principal components analysis results for ground cover types for pre-treatment measurements and after the second winter in southwest Ohio, 2012 – 2014.

The first 2 principal linear components described meaningful variation in the 4-dimensional non-living cover responses. Sixty-four percent of the variance was explained with the first 2 linear combinations, later components became harder to explain and therefore less meaningful. Component 1 (interpreted as woody debris) had almost identical negative loadings for litter and brush, a low negative loading for other, and a positive loading for soil. Component 2 (interpreted as open ground) had negative loadings for soil and other, a low negative loading for brush, and a positive loading for litter. The interpretation of these components changed slightly from the Fall1 through Fall2 analyses. Component 1 is now a predictor of woody debris and not open ground as in the first principal components analyses and vice versa for component 2.

Horizontal cover

Pre-treatment through Fall2

Aspect and the interaction of aspect with sample time, size class, and type was not a significant predictor of horizontal cover change ($F_{3,78}$ =0.8, P=0.5) so I excluded it from the remainder of the models and analyses but retained significant predictors (sample time, size, type). Change in horizontal cover after the first and second growing season was positively associated ($F_{2,186}$=500.2, P<0.001) with basal area reduction ($F_{1,91}$=60.7, P<0.001) although the relationship was somewhat weaker after the second growing seasons (Figure 2.5a). Change in horizontal cover was highest during Fall2 across all levels of basal area reduction, whereas Winter1 had less cover than Fall1. Basal area reduction < 50% resulted in no change or a loss in cover during Winter1 (Figure 2.5a), but basal area reduction of $\geq$ 50% resulted in positive horizontal cover change for all sampling periods. Basal area reduction of ~100% resulted in the highest change in horizontal cover for all sampling periods and over 50% (Figure 2.5a) increase in horizontal cover. The greatest amount of overall change in horizontal cover occurred at low levels of basal area reduction during Fall2 compared to Fall1, when higher levels of basal area reduction resulted in the greatest amount of overall change (Figure 2.5a). Removing the interaction between basal area reduction and sample period affected the fit of the model (F=3.6, P=0.030) so it was retained.

Large feathered edges had more change in horizontal cover ($F_{2,91}$=7.6, P<0.001) than medium and small feathered edges and were also positively associated with the interaction of the first and second growing seasons ($F_{4,186}$=3.0, P<0.001). Horizontal

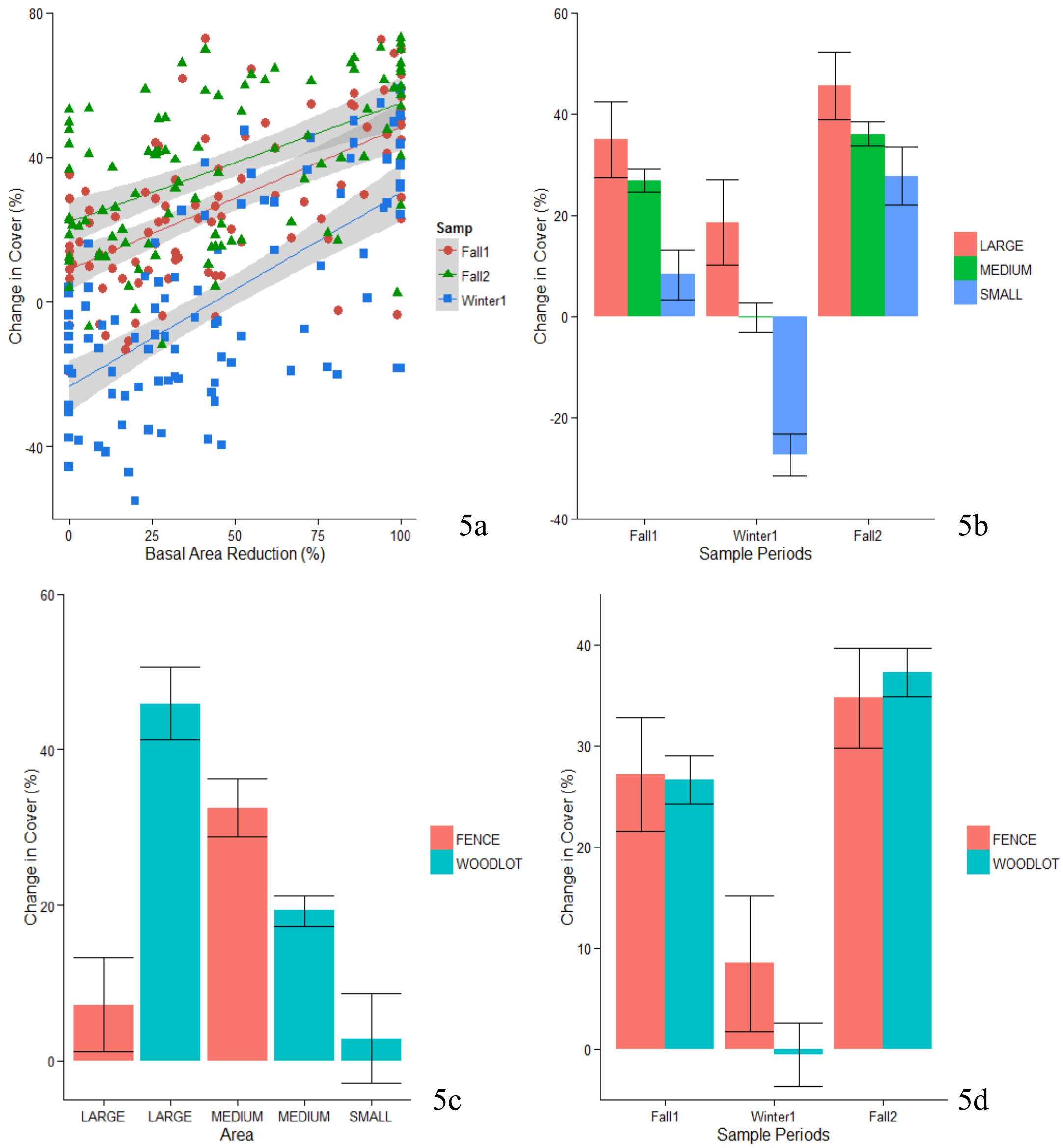


Figure 2.5 Influence of basal area reduction, sample periods, size, and type on horizontal cover measurements for all feathered edges (*n*=99) experiencing two growing seasons and one winter season post-treatment in Highland County, Ohio (2012 – 2014). Grey shading (a) and black whiskers (b - d) indicate 95% confidence intervals.

cover change in large feathered edges increased most between seasons and had a positive cover change between sampling periods (Figure 2.5b). Large feathered edges had more cover change compared to medium and small feathered edges during Winter1 and Fall2.

The interaction of large feathered edges and woodlots had the strongest relationship between horizontal cover change with respect to size ($F_{1,91}$=4.5, *P*=0.040 [Figure 2.5c]). Woodlots and fencerows had similar horizontal cover change measurements between sample periods, including Winter1, where both edge types had less cover change than Fall1 and Fall2 ($F_{2,186}$=2.1, *P*=0.05 [Figure 2.5d]).

<u>Fall2 through Winter2</u>

Aspect and the interactions of aspect with sample time, size class, and type was not a significant predictor of change in horizontal cover, ($F_{3,51}$=0.6, *P*=0.630) so I excluded it from the remainder of the models and analyses but retained significant predictors (sample time, size, type). The change in horizontal cover after the 2^{nd} growing season was positively associated with sample period ($F_{1,63}$=433.5, *P*<0.001 [Figure 2.6a]). Fall2 resulted in more change in horizontal cover than Winter2. Most treated edges (*n*=60) received < 50% basal area reduction and there was no longer a positive effect of basal area reduction (Figure 2.6a).

Large treated edges no longer had an influence on change of cover (Figure 2.6b) as medium and small edges had a moderate change in horizontal cover ($F_{2,61}$=2.5, *P*=0.09) compared to large feathered edges (Figure 2.6b). This may be because the majority of treated edges (*n*=64) were either small or medium in size (Figure 2.6b) and had lower basal reduction (Figure 2.6a). All edges lost cover compared to initial measurements during Winter2 but medium feathered edges experienced less change (x < 5% [Figure 2.6b]) in horizontal cover. Woodlots had a moderate change in horizontal cover compared to fencerows during Fall2 ($F_{1,61}$=3.4, *P*=0.07 [Figure 2.6c]) but fencerows had a small positive cover change during Winter2. Fencerows also had more

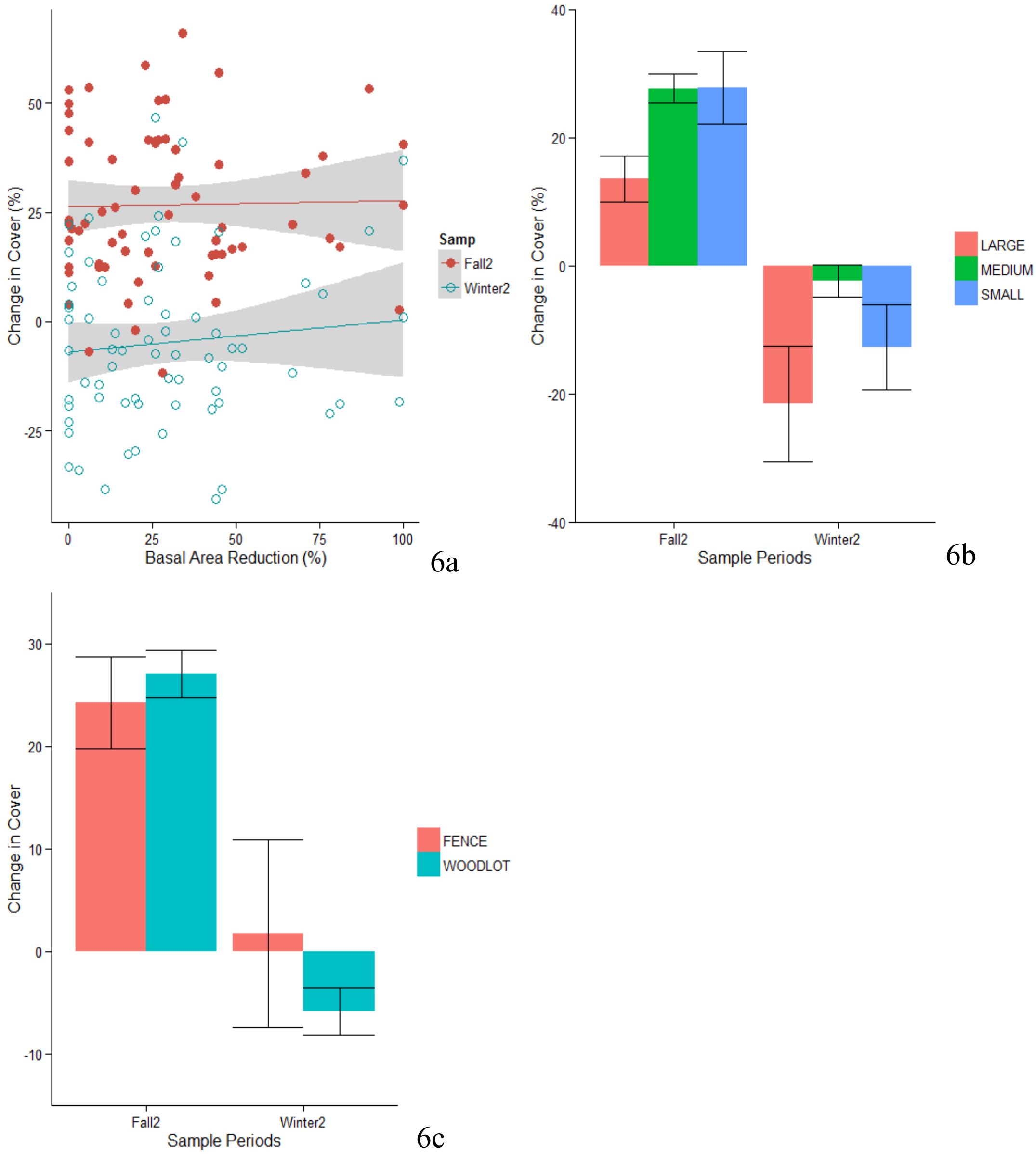


Figure 2.6 Influence of basal area reduction, sample periods, and type on horizontal cover measurements for feathered edges (*n*=69) experiencing a second growing season and a second winter season post-treatment in Highland County, Ohio (2012 – 2014). Grey shading and black whiskers indicate 95% confidence intervals.

variability compared to woodlots when compared to initial measurements. The interaction of sample and type of edge treated had similar horizontal cover change for both sample periods but compared to initial measurements resulted in less cover during Winter2 ($F_{1,63}$=9.3, P=0.003 [Figure 2.6c]).

Winter2

No covariates were significantly associated ($F_{1,61}$=0.9, P=0.4) with horizontal cover change during winter2.

Vertical cover

Pre-treatment through Fall2

Aspect and the interaction of aspect with other variables were not significant predictors of vertical cover change ($F_{3,78}$ =0.7, P=0.540) so I excluded aspect from the remainder of the models and analyses retaining only significant predictors (sample time, size). The change in vertical cover after the first and second growing season was positively associated ($F_{2,186}$=62.5, P<0.001) with basal area reduction ($F_{1,91}$=20.8, P<0.001) although the relationship was weaker during the first and second growing seasons (Figure 2.7a). Basal area reduction < 37% resulted in no change or a loss in vertical cover during Winter1 (Figure 2.7a), but basal area reduction of $\geq$ 37% resulted in positive cover change measurements for all sampling periods. Basal area reduction of ~100% resulted in the highest change in vertical cover for all sampling periods and over 15° increase in vertical cover from initial measurements (Figure 2.7a). Fall2 had higher changes in vertical cover measurements for all levels of basal area reduction, whereas Winter1 had less cover than Fall1. Edges with lower levels of basal reduction had more change in vertical cover during Fall2 compared to Fall1 measurements. Even though they had higher levels, they did not reach overall vertical cover changes compared with higher levels of basal reduction (Figure 2.7a). Removing the interaction between basal

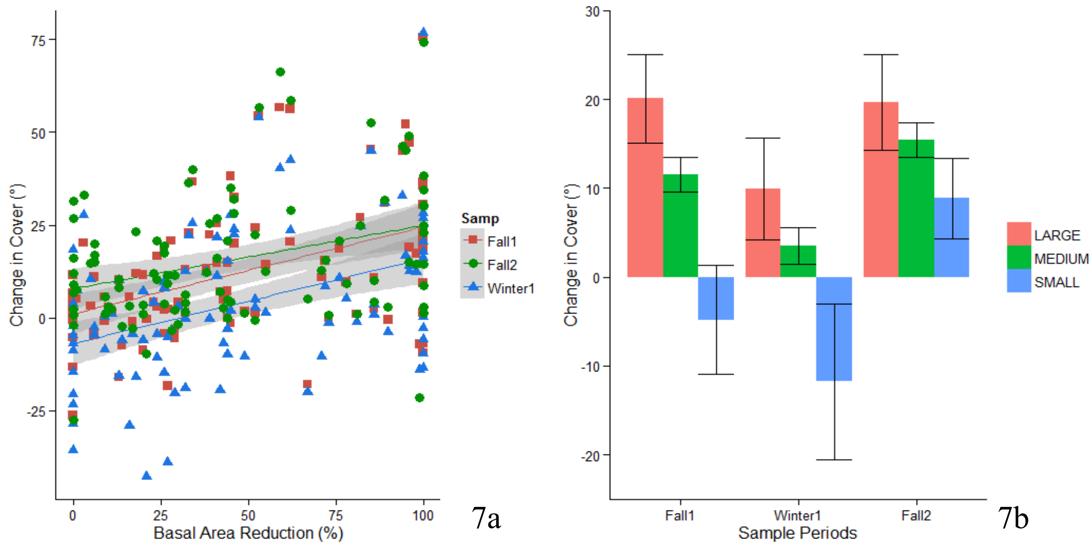


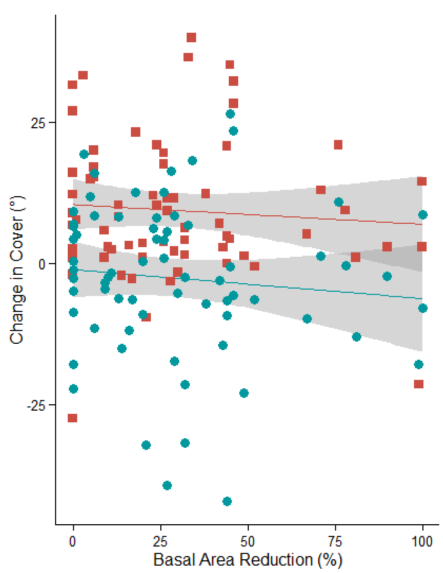
Figure 2.7 Influence of basal area reduction, sample periods, and size on vertical cover measurements for all feathered edges (*n*=99) experiencing two growing seasons and one winter season post-treatment in Highland County, Ohio (2012 – 2014). Grey shading and black whiskers indicate 95% confidence intervals.

area reduction and sample period did not affect the fit of the model (F=0.5, *P*=0.6).

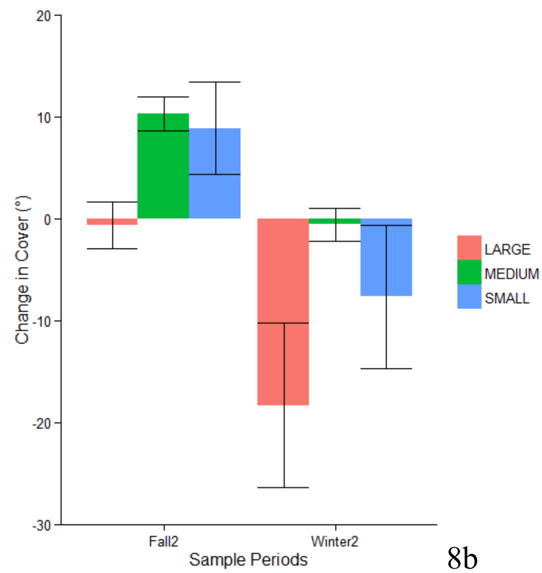
Large feathered edges had more change in vertical cover ($F_{2,91}$=3.8, *P*=0.026) than medium and small feathered edges (Figure 2.7b). They also had a moderate change in cover during both growing seasons ($F_{4,186}$=2.2, *P*=0.067 [Figure 2.7b]). Change in vertical cover in large feathered edges increased most during Fall1, whereas small feathered edges increased most during Fall2 (Figure 2.7b). Large and medium feathered edges had a positive cover change between all sampling periods (Figure 2.7b).

<u>Fall2 through Winter2</u>

Aspect, type, and their interactions were not significant predictors of vertical cover change ($F_{3,51}$<0.2, *P*>0.84) so I excluded these variables from the remainder of the models and analyses but retained significant predictors (sample time, size). Most treated edges (*n*=60) received < 50% basal area reduction (Figure 2.8a) so change in vertical cover after the 2nd growing season became positively associated with sample period ($F_{1,67}$=74.1, P<0.001 [Figure 2.8a]). Large feathered edges no longer had an influence on change in cover (Figure 2.8b). Medium and small feathered edges had more change in vertical cover during the Fall2 sample period, ($F_{2,63}$=4.0, P=0.023) and also had less vertical cover change when compared to Winter2 (Figure 2.8b). All edges lost cover compared to initial measurements but medium feathered edges experienced roughly little change in vertical cover (mean < 3° [Figure 2.8b]).



8a



8b

Figure 2.8 Influence of basal area reduction, sample periods, and size on vertical cover measurements for feathered edges (n=69) experiencing a second growing season and a second winter season post-treatment in Highland County, Ohio (2012 – 2014). Grey shading and black whiskers indicate 95% confidence intervals.

Vegetation Response

<u>Fall1 through Fall2</u>

The response of vegetation after the first and second growing seasons was positively associated with basal area reduction ($F_{1,91}$>3.2, P<0.08 [Figures 2.9a – 2.9c]), horizontal cover ($F_{1,91}$=69.5, P<0.001), and vertical cover ($F_{1,91}$=9.9, P=0.002). The only negative relationship with basal area reduction was with bare ground (Figure 2.9d). The largest response from vegetation between sample periods occurred in edges that received ~100% basal area reduction. Edges with ~100% basal area reduction had higher response from vegetation during Fall2 compared to Fall1. Edges with lower basal area reduction had higher response from vegetation after Fall2 compared to Fall1, but did not reach response levels of higher basal area reductions.

PCA axis 1, a predictor of live herbaceous plants (i.e., grass/sedges, or forbs) had more response at higher levels of basal area reduction (Figure 2.9a) and had more horizontal ($F_{1,91}$=9.6, P=0.002) cover. High levels of basal area reduction along with a second growing season displayed the same relationship with horizontal ($F_{1,91}$=49.1, P<0.001) and vertical ($F_{1,91}$=13.1, P<0.001) cover. PCA axis 2, a predictor of live woody vegetation (i.e., shrubs and saplings) had more response at higher levels of basal area reduction (Figure 2.9b) and had more vertical ($F_{1,91}$=19.8, P<0.001) cover. High levels of basal area reduction along with a second growing season displayed the same relationship with horizontal ($F_{1,91}$=15.0, P<0.001) and vertical ($F_{1,91}$=5.4, P=0.02) cover. Higher levels of basal area reduction appear to positively influence response from vegetation.

Non-living cover axis 1, a predictor of open ground, had higher loadings of open ground at low levels of basal area reduction (Figure 2.9c), and had less horizontal ($F_{1,91}$=12.1, P<0.001) cover. At higher levels of basal area reduction, non-living cover axis 1 had lower loadings of open ground during the second fall with more vertical ($F_{1,91}$=6.8, P=0.01) cover. Non-living cover axis 2, a predictor of woody debris, had

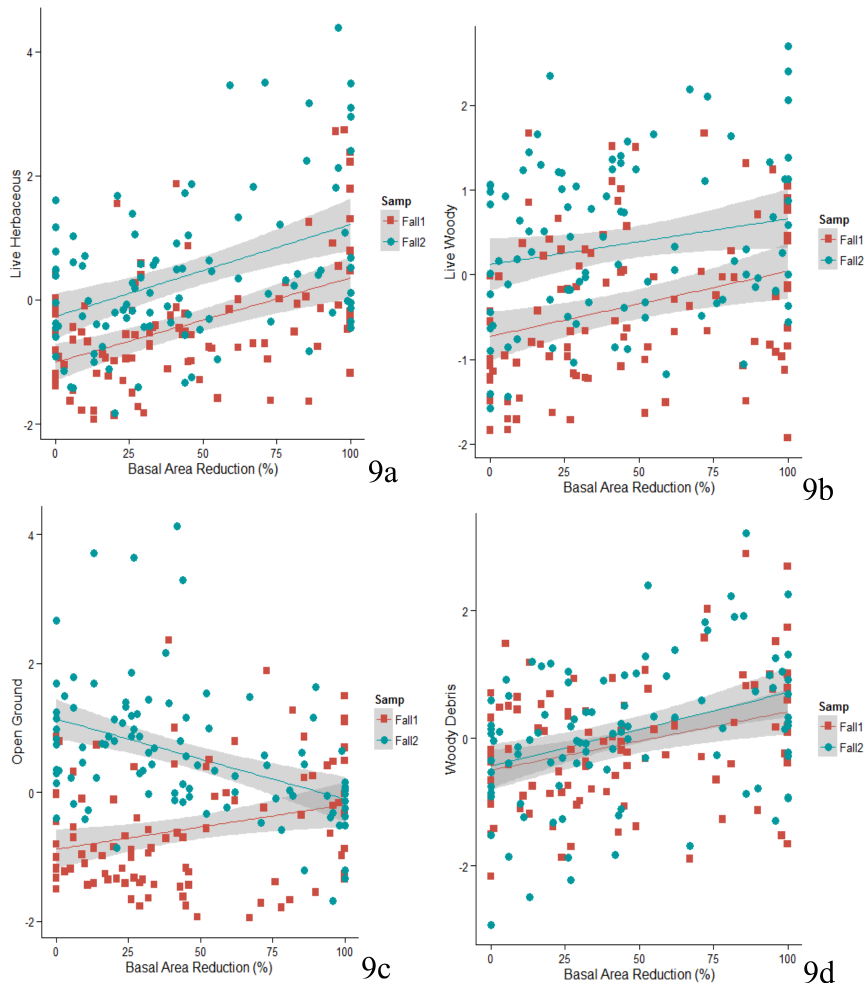


Figure 2.9 Influence of basal area reduction on vegetation response and cover measurements with PCA scores for all feathered edges (*n*=99) experiencing two growing seasons post-treatment in Highland County, Ohio (2012 – 2014). Grey shading indicates 95% confidence intervals.

negative loadings of woody debris at low levels of basal area reduction, and higher loadings at higher levels of basal area reduction (Figure 2.9d). Non-living cover axis 2 had more horizontal ($F_{1,91}$=10.0, P=0.002) cover and vertical ($F_{1,91}$=9.9, P=0.002) cover at higher levels of basal area reduction. Edges with little to no basal area reduction had negative loadings indicating low levels of woody debris, and edges with high basal area reduction had positive loadings, indicating high levels of ground cover or woody debris.

Winter2

Non-living cover axis 1, a predictor of woody debris, had negative loadings of woody debris at low levels of basal area reduction, and higher loadings at higher levels of basal area reduction (Figure 2.10a). Non-living cover axis 1 had more vertical cover ($F_{1,61}$=13.0, P<0.001 [Figure 2.10a]) at higher basal area reduction levels. Non-living cover axis 2, a predictor of open ground, had positive loadings indicating open ground at low levels of basal reduction, and negative loadings at higher levels of basal area reduction (Figure 2.10b) with less vertical cover ($F_{1,61}$=4.6, P=0.036) at low levels of basal area reduction.

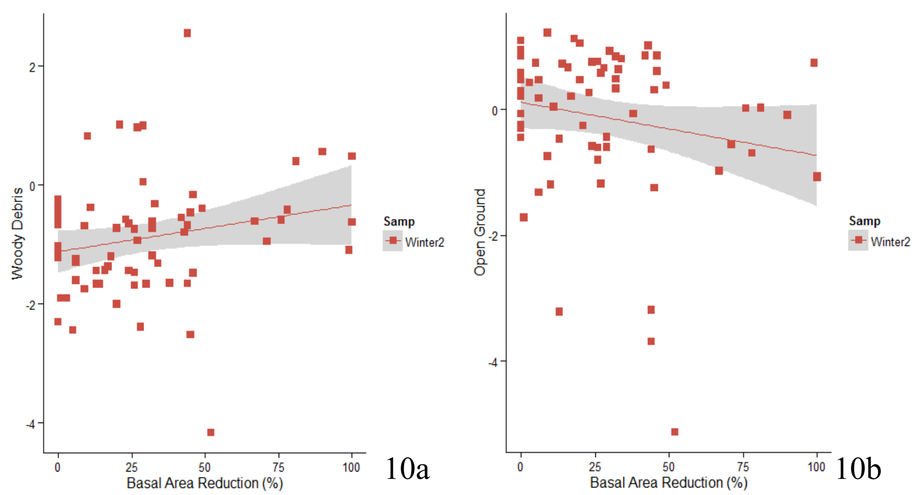


Figure 2.10 Influence of basal area reduction on vegetation response and vertical cover measurements with PCA scores for feathered edges (n=69) experiencing a second winter season post-treatment in Highland County, Ohio (2012 – 2014). Grey shading indicates 95% confidence intervals.

Discussion

Horizontal and Vertical Cover

Pre-treatment through Fall2

The amount of basal area removed from initial measurements within treated edges was the most significant predictor for cover change measurements, and the same relationships were present for both horizontal and vertical cover. Vegetation within treated edges seemed to respond to the increase in sunlight along with nutrients provided by removing overstory trees. Higher levels of basal area reduction also increased the amount of woody debris on the ground, which provides immediate cover. Basal area reduction was positively associated with live herbaceous vegetation (Figure 2.9a), live woody vegetation (Figure 2.9b), and woody debris (Figure 2.9d). Basal area reduction was negatively associated with open ground (Figure 2.9c) during the second fall. This indicates the importance of disturbance and the impact these disturbances have on the vegetation within these treated edges.

High positive loadings of open ground indicated a lack of vegetation emerging from the ground, and also a lack of woody debris or litter, allowing for the observations of other things (i.e., trash, rocks, scat), but also indicated that there was nothing there to provide obstruction, resulting in lower cover measurements (Figure 2.9c). Principal component scores around 0 were observed at complete basal area removal, indicating a relationship between basal area reduction, brush, sunlight, vegetation response, and therefore the lack of open ground.

Fall2 sampling period had more cover than the other sampling periods and showed a clear separation from Fall1 which indicates the vegetation is still responding from the treatment preformed within edges (Figure 2.5a, 2.7a) two years after harvest. Large treatment areas had more cover than smaller treatments which might be because the larger disturbance allows for more sunlight to penetrate the ground, increasing vegetation response. These larger areas may also be less susceptible to other adjacent vegetation or vegetation left within treated edges. Large areas may also have the potential to provide more structure depending on if there is more vegetation associated with the larger treatment area. Fencerows and other linear features are exposed to more sunlight which allows for more response by vegetation and increase cover.

Fall2 through Winter2

Treatment by contractor 1 was similar to what a private property owner might due if they were removing firewood or selectively removing trees. This treatment period resulted in little reduction of basal area. Actively managing woodlots or linear features by ways listed above may not result in high disturbances that cause large and immediate changes in cover. Because of this less intense reduction, the positive association of more basal area reduction and more change in cover is not as obvious (Figure 2.6a, 2.8a). Also, these edges resulted in less cover than before treatment. Finally, the trend between fencerows and woodlots or other linear features provide similar habitat regardless of treatment intensity remains similar (Figure 2.7c).

Another possible reason why lower basal area reductions did not produce a net increase in cover after Winter2, is that leaf emergence was extremely early in spring 2012. Most herbaceous vegetation, shrubs, and saplings were partially leafed out when these edges were sampled for initial measurements in spring 2012. This affected initial measurements, and caused these edges to have more cover than what would typically occur in an average year.

Even with the majority of treated edges receiving lower levels of treatment, the relationship between higher basal area reduction and woody debris was still evident. Basal area reduction was positively associated with woody debris (Figure 2.10a) and negatively associated with open ground (Figure 2.10b). Even though these edges received less basal area reduction, vegetation was still responding in certain areas causing this negative relationship with open ground. As explained above, another possible reason for vegetation response not as apparent at lower levels of basal area reduction may be the result of the early spring of 2012, which could slightly affect my results.

Fee had more Amur honeysuckle than Peach Orchard. Most woodlots on Fee were dominated by Amur honeysuckle. Woodlots on Fee were patchily distributed in an intensively farmed landscape, whereas Peach Orchard was situated more along the transitional line between woodlots and agriculture, and the woodlots were more continuous. There was a slight increase in overall abundance (4%) of Amur honeysuckle on Fee and a moderate increase of overall abundance on Peach Orchard (24%) after edge-feathering. The increase in Amur honeysuckle was most pronounced in edges treated by Contractor 1. Amur honeysuckle did not increase on Peach Orchard in edges treated in 2013 (14 of 30 [46%] sections with Amur honeysuckle in both sampling periods) which were treated by a different contractor. Contractor 1 was required to cut and treat Amur honeysuckle within treated edges, but the prescription was not followed based on observation of regenerating cut-stumps. Feathered edges treated in 2013 show an overall increase in Amur honeysuckle density, but this occurred because one feathered edge had a density 13 times larger than the next highest density, increasing the overall density. Proper treatment of Amur honeysuckle does not lead to increased density, which is why proper techniques should be followed to maintain woodlots shrubs and invasive species.

Maple and hickory regeneration seemed to be more common on the Fee site, which could have been because of the lower reduction in basal area, resulting in more shade. Sassafras and Japanese honeysuckle (*Lonicera japonica*) were more common on Peach Orchard and may be because of the higher reduction of basal area, resulting in more sunlight. Poison ivy was common across both sites and was very abundant within feathered edges.

I demonstrated that vegetation composition changed on all aspects, as long as basal area was reduced adequately to allow sufficient sunlight to reach the ground. Ohio bobwhites are at the northern portion of their range and due to lack of early successional habitat, their population and survival have been greatly impacted and reduced. Efforts to create bobwhite habitat should focus less on aspect and type, and more on size of the treatment edge and removing enough trees to allow sunlight to reach the understory to improve habitat quality of woodlot edges for bobwhites. Light and heavy treatment intensities both resulted in positive cover change during the growing seasons, but light treatments did not result in net gains of protective cover during Winter2. Landowners or managers wishing to create immediate habitat for bobwhites should consider reducing the initial basal area of the edges by around 50% to improve protective cover during the first winter. Landowners and managers that do not want to reduce the basal area of edges by that amount or wish to provide a slower transition can reduce initial basal area by < 50% which will still provide cover during certain times of the year.

Since bobwhites feed on seeds, invertebrates, and leafy material, and seek protective cover, they require habitat that meets these needs. Such structure and cover are found in early successional habitat at edges of ecotones, old fields, and feathered edges (White et al. 2005). If natural grasslands and shrublands were still widely available, then early successional species would not be so dependent on old fields, powerlines, clearcuts, or feathered edges. All of these types of habitat should be available in a region to sustain bobwhites and a full range of other native species. This may be the first step in converting an underutilized and undermanaged habitat into a valued resource that people are willing to create, protect, and sustain (Askins 2001).

Current ownership patterns of land in Ohio reveal 86.5% is privately owned outside of city limits. These areas will likely continue to remain under private ownership and potentially change in cover type. This trend will likely limit opportunities to provide early successional habitats across Ohio, except on industrial and public forests (Litvaitis 1993), and areas considered focus areas, with high participation by private landowners. This leaves private landowners as the vital component to sustaining and providing for bobwhites in the future on these landscapes.

Timber stand improvement (TSI) techniques were not practiced on my sites. Different forms of TSI include crop tree release where select trees are left and others are removed to benefit selected trees, or invasive species removal which targets invasive species. Both practices can result in possible revenue for landowners and can also result in bobwhite habitat. Most landowners did not take advantage of the woodlot resources they have and before they can in future management, landowners would have to consider other key factors. In order for TSI to be profitable, landowners have to consider the value of their timber, woodlot size, and location of the nearest timber mill. Finding new ways other than TSI to increase woodlot based revenue on farms, or providing landowners with additional ideas of how they can utilize woodlots (i.e., cutting, selling, and burning wood for heat) could also result in forest composition change and increase early successional vegetation.

LITERATURE CITED

Askins, A. 2001. Sustaining Biological Diversity in Early Successional Communities: The Challenge of Managing Unpopular Habitats. Wildlife Society Bulletin 29: 407-412.

Best, L. B. 1983. Bird Use of Fencerows: Implications of Contemporary Fencerow Management Practices. Wildlife Society Bulletin 11: 343-347.

Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of Cornfields by Birds during the Breeding Season: The Importance of Edge Habitat. American Midland Naturalist 123 1:84-99.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Burger, L. W., D. McKenzie, R. Thackston, and S. J. Demaso. 2006. The role of farm policy in achieving large-scale conservation: Bobwhite and buffers. Wildlife Society Bulletin 34:986-993.

Chapman, R. 2012. Woodland Edge Feathering. Indiana Woodland Steward Volume 21, No.1.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Crawley, M. J. 2012. The R Book Second Edtion. John Wiley & Sons Ltd., Imperial College London at Silwood Park, United Kingdom

Dailey, T. V. 2002. Emerging trends in Midwest bobwhite culture. National Quail Symposium Proceedings 5:8-19.

Daubenmire, R. 1959. A Canopy-Coverage Method of Vegetational Analysis. Northwest Science 50:431.

Demers, M. N., J. W. Simpson, R. E. J. Boerner, A. Silva, L. Berns, and F. Artigas. 1995. Fencerows, Edges, and Implications of Changing Connectivity Illustrated by Two Contiguous Ohio Landscapes. Conservation Biology 9:1159-1168.

Dudley, S. J., C. D. Bonham, S. R. Abt, and J. C. Fiscchenich. 1998. Comparison of methods for measuring woody riparian vegetation density. Journal of Arid Environments 38:77-86.

Errington, P. L. and F. N. Hamerstrom 1936. The Northern bob-white's winter territory. Iowa State College Agriculture Experiment Station Research Bulletin 201: 301-443.

Gates, R. J., A. K. Janke, M. R. Liberati, and M. J. Wiley. 2012. Demographic analysis of a declining northern bobwhite population in southwestern Ohio. Proceedings of the National Quail Symposium 7:184-193.

Guthery, F. S., A. R. Rybak, S. D. Fuhlendorf, T. L. Hiller, S. G. Smith, W. H. Puckett, Jr. and R. A. Barker. 2005. Aspects of the Thermal Ecology of Bobwhites in North Texas. Wildlife Monographs 159:1-36.

Hanson, W. R. and R. J. Miller. 1961. Edge Types and Abundance of Bobwhites in Southern Illinois. The Journal of Wildlife Management 25:71-76.

Higgins, F. H., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker 2005. Vegetation Sampling and Measurement. Techniques for wildlife investigations and management 524-553.

Hiller, T. L., F. S. Guthery, A. R. Rybak, S. D. Fuhlendorf, S. G. Smith, W. H. Puckett, and R. A. Baker. 2007. Management implications of cover selection data: Northern bobwhite example. Journal of Wildlife Management 71:195-201.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440-455.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. The Ohio State University.

Janke, A. K., and R. J. Gates. 2013. Temporal variability in survival of non-breeding northern bobwhites in Ohio. Pages 194-201 *in* T. V. Dailey, andC. E. Braun, editors. Quail VII: Proceedings of the Seventh National Quail Symposium. The University of Tennessee, National Bobwhite Conservation Initiative, Knoxville, Tennessee.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884-895.

Leopold, A. 1931. Report on a game survey of the north central states. Democrat Printing Company, Madison, Wisconsin, USA.

Litvaitis, J. A. 1993. Response of Early Successional Vertebrates to Historic Changes in Land Use. Conservation Biology 7:866-873.

Lusk, J. J., S. G. Smith, S. D. Fuhlendorf, and F. S. Guthery. 2006. Factors influencing northern bobwhite nest-site selection and fate. Journal of Wildlife Management 70:564-571.

Marlow, C. B. and W. P. Clary 1996. Natural resource monitoring for the Daubenmire disadvantaged. Sharing common ground on western rangelands: Proceedings of a livestock/big game symposium. K. E. Evans. Sparks, NV, USDA Forest Service Intermountain research station: 13-18.

Matson, P. A., W. J. Parton, A. G. Power, and M. J. Smith. 1997. Agricultural intensification and ecosystem properties. Science 277:504-509.

Missouri Department of Conservation, Natural Resources Conservation Service, Missouri University Extension [MDC/NRCS/UMC]. 2011. Edge Feathering-Forest Edge.

National Climate Data Center [NCDC]. 2015. Quality Controlled Local Climatological Data. <http://www.ncdc.noaa.gov/oa/ncdc.html>.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

O' Connor, R. J. and M. Shrubb. 1986. Farming and birds. Cambridge: Cambridge University Press.

Peterjohn, B. G., and D. L. Rice. 1991. The Ohio breeding bird atlas. Ohio department of Natural Resources, Columbus, Ohio, USA.

R Development Core Team. 2014. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Roseberry, J. L. 1964. Some Responses of Bobwhites to Snow Cover in Southern Illinois. The Journal of Wildlife Management 28:244-249.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Schmutz, J. A. 1989. Nest Habitat Use of Rio Grande Wild Turkeys. The Wilson Bulletin. 101:591-598

Spinola, R. M., and R. Gates. 2008. Population Status and Trends of Northern Bobwhite (*Colinus virginianus*) in Ohio: 1984-2004. Ohio Journal of Science 108: 26-30.

Spurr, S. H. 1964. Forest Ecology. Ronald Press company, New York, USA.

Thompson, F. R., and R. M. DeGraaf. 2001. Conservation Approaches for Woody, Early Successional Communities in the Eastern United States. Wildlife Society Bulletin 29:483-494.

Trani, M. K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C. M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29 2:413-424.

White, C. G., S. H. Schweitzer, C. T. Moore, I. B. Parnell III, and L. A. Lewis-Weis. 2005. Evaluation of the landscape surrounding northern bobwhite nest sites: a multiscale analysis. Journal of Wildlife Management 69:1528-1537.

Wiley, M. J. 2012. Usable Space and Microhabitat Characteristics for Bobwhites on Private Lands in Southwestern Ohio. Thesis. The Ohio State University.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562-1566.

Yoho, N. S. and R. W. Dimmick 1972. Habitat utilization by bobwhite quail during winter. National Quail Symposium Proceedings 1:90-99.

CHAPTER 3: **Seasonal Movements and Use of Feathered Edge Habitat by Northern Bobwhites (*Colinus virginianus*) in Southwest Ohio**

ABSTRACT

Land use changes have reduced the quantity and quality of habitat which affect northern bobwhites (*Colinus virginianus*) resulting in widespread population declines. Research has been conducted since 2009 on 4 privately owned study sites in southwestern Ohio. Prior results indicated bobwhites used early successional habitats (i.e., fencerows, old fields) in higher proportions than available on the study sites and survival was positively influenced by availability of protective cover in early successional wooded habitats. This suggests that focus should be directed to increase usable space provided by distributing key cover types across landscapes capable of supporting bobwhite populations. Unused woodlot edges were treated by felling trees (i.e., edge-feathering), which promoted the development of a gradient of early successional vegetation (i.e., grasses, forbs, shrubs, etc.) that provides protective cover near food sources during the non-breeding season. Ninety-nine areas received edge-feathering treatment on 2 study sites in Highland County, Ohio during 2012 and 2013. I used radio-telemetry to determine bobwhite use of treated areas, measured vegetation composition and structure at radio-marked bobwhite use points, and estimated home-ranges using the local convex hull method. Locations from 24 unique coveys across 4 sites during the 2013 – 14 non-breeding season were used to compare vegetation structure and composition between feathered edges and covey use sites. Seven coveys were used to estimate home-ranges and to analyze use of feathered edges in relation to their placement within study sites. Mean home-range size was 4.6 ha and 5 total feathered edges fell within 95% local convex hull home-range isopleths. Original placements of feathered edges were informed by previous research. Woodlots, mature fencerows, ditches, and other uncultivated areas were considered for treatment if they had previously experienced little to no use by bobwhite coveys. Edge-feathering successfully converted edges that were not previously used by bobwhites, into habitat that was used by radio-marked coveys during the non-breeding season. Future management of these areas by edge-feathering should be considered by managers, because they produce habitat similar to what bobwhites use. Other cover types such as early successional herbaceous (nesting/brood rearing), and row crop (food) need to be considered and close to treated edges to maximize use and benefit bobwhites.

INTRODUCTION

The historic range of Northern Bobwhites (*Colinus virginianus*; hereafter bobwhite) spanned Guatemala to Michigan and Colorado to Virginia (Johnsgard 1973: 413). Flora, fauna, and climate vary widely among areas within the bobwhites geographic region. Habitat features such as woody cover, seed-producing plants, with sparse ground cover are common elements of bobwhite habitat throughout the species range. Bobwhites are highly adaptable in how they meet their needs in diverse landscapes (Kopp et al. 1998).

Changing land-use practices and suppression of natural disturbance have greatly altered the landscape throughout the bobwhite's range (Farris et al. 1977, Roseberry

1993, Peterjohn 2003, Fies et al. 2002, Askins 2001). Contemporary land use and habitat changes create fragmented and isolated patches of habitat that reduce the viability of local populations (Noss et al. 1995, Litvaitis 1993). Therefore, range-wide declines in bobwhite abundance, as revealed by the Breeding Bird survey (Sauer et al. 2014), are ultimately caused by cumulative local extinctions that result from loss of suitable habitat patches that become increasingly isolated habitat (Lohr et al. 2011).

The quality of early successional wildlife habitat depends on the composition and structure of plant communities (Harper 2007). Fields dominated primarily by a few native grasses, may provide quality habitat for some wildlife species, such as eastern meadowlarks (*Sturnella magna*) and Henslow's sparrows (*Ammodramus henslowii*) (Giocomo 2005), and more diverse vegetation communities provide optimum habitat conditions for many other wildlife species (Burger et al. 1990, Millenbah et al. 1996). Some species become more abundant as regenerating forests age and provide sufficient food and cover, but their abundance ultimately declines as forests mature (Riddle et al. 2008). Many organisms face the problem that many landscapes lack favorable combinations of essential patches (Orians and Wittenberger 1991). A suitable landscape must contain a mixture of habitat patches that provide essential resources for survival and reproduction (Mysterud and Ims 1998).

The 'edge' ecotone, or transition where different plant communities blend together is known to be an important habitat component for bobwhites (Stoddard 1931, Rosene 1984). Edges can take several forms. Edges can be a hard and distinct boundary (inherent edge) between habitat types, such as envisioned by Leopold (1933) or a true ecological transition zone (induced edge) where two successional stages blend together such as described by Smith and Smith (2009). However, little information is available on the preference of bobwhites for different edge types or what constitutes an acceptable edge type and the scale of edge use (field vs. landscape).

Roseberry and Sudkamp (1998) reported that bobwhites in Illinois were associated with patchy landscapes that contained intermediate proportions of row crops, grassland, and abundant woody edge, but we do not know the scale of patch use in their study (Flock et al. 2012). Bobwhites appear to prefer habitat patches that provide protective or escape cover from predators, and accessibility to food during breeding and non-breeding seasons (Roseberry and Klimstra 1984, Rosene 1984, Flock et al. 2012).

Edge-feathering is a relatively new practice that converts inherent edges to induced edges, where the vegetation slowly succeeds from young new growth containing grasses, forbs, shrubs, into saplings and eventually trees. Feathered edges provide early successional habitat by removing overstory trees and allowing sunlight to reach the understory to stimulate new growth of grasses, sedges, forbs, and shrubs. Trees can be felled either into adjacent fields or back into or along the edge of wooded corridors such as fencerows or other linear wooded features. Areas were selected for edge-feathering based on previous work that showed little or no use of woodlots by bobwhites, and others have showed the same non-use of woods based off tracking and flushing records (Murphy and Baskett 1952). Previous research also showed bobwhites used and preferred early successional habitat, and by creating early successional habitat along these previously unused woodlots, we were increasing preferred habitat for use.

The goal of my study was to evaluate the effects of creating habitat in areas that had previously received little to no use and apparently lacked suitable habitat. This allowed me to assess the utility of edge-feathering, the ideal placement and configuration to benefit quail, such that future bobwhite management utilizing this approach in this region and in other areas can be successful. Specifically, my objectives were to: 1) compare vegetation composition and structure at locations used by radio-marked coveys to feathered edges; 2) determine home-ranges and movements of coveys relative to feathered edges on treated sites; and 3) document use of feathered edges by bobwhites.

STUDY AREA

This study was conducted on four sites in southwestern Ohio in Highland and Brown Counties (Figure 3.1). Three sites were located in Highland County and the fourth was located in the northeast corner of Brown County. Two sites (Fee and Peach Orchard) were the most northern located sites and were where wooded edges were treated. Two reference sites (Wildcat and Thurner) were located 5.7 – 15.6 km south of the Peach Orchard study site. The mean temperature for breeding (April – September) and non-breeding (October – March) seasons during my research was 20.4°C and 3.7°C with mean precipitation of 10.2 cm and 8.5 cm (NCDC 2015). The study area was within the core range of bobwhites in Ohio (Spinola and Gates 2008, Peterjohn and Rice 1991).

Average habitat composition for all study sites was primarily row crop agriculture planted in corn and soybeans and covered 53%. Forests covered 16% of the study sites followed by early successional herbaceous vegetation at 13%. Pasture/Hay covered 8% of the study sites followed by non-habitat (6%), early successional woody (5%), and feathered edges (0.1%; Table 3.1). Woody ditches and woody fencerows included similar habitat comprised of trees and small saplings of black cherry (*Prunus serotina*), box elder (*Acer negundo*), hackberry (*Celtis occidentalis*), honey locust (*Gleditsia* *triacanthos*), shrubs consisting of amur honeysuckle (*Lonicera maackii*), and poison ivy (*Toxicodendron radicans*) along with herbaceous vegetation such as ragweed (*Ambrosia trifida).* Herbaceous ditches and herbaceous fencerows were similar, consisting of low

Figure 3.1 Location of 4 study sites where northern bobwhite research was conducted during the breeding and non-breeding season in Highland and Brown Counties, Ohio, USA during 2012 – 2014.

herbaceous vegetation dominated mostly by fescue (*Festuca* spp.), foxtail (*Alopecurus* spp.), and marestail (*Conyza canadensis*). Woodlot edges-woody were characterized by oak (*Quercus* spp.), hickory (*Carya* spp.), ash (*Fraxinus* spp.), and black walnut (*Juglans nigra*). The understory composition of these woodlots included saplings such as sugar maple (*Acer saccharum*) and hackberry and shrubs such as, multiflora rose (*Rosa multiflora*), and *Rubus spp.* Early successional fields were categorized as old fields or odd areas that were not characterized by any of the other habitat types. They were dominated by broom sedge (*Andropogon virginicus*), queen anne's lace (*Daucus carota*), fescue, goldenrod (*Solidago* spp.), blackberry (*Rubus allegheniensis*), black raspberry (*R. occidentalis*), multiflora rose, autumn olive (*Elaeagnus umbellata*), and red cedar (*Juniperus virginiana*).

Site	Year	Cover type (%)						
		Row crop	Forest	ES[a] Herbaceous	ES[a] Woody	Feathered edge	Pasture/ Hay	Non-habitat
Fee	2012-13	70.5	9.2	8.3	3.6	0.1	2.5	5.8
	2013-14	70.7	8.9	7.7	3.4	0.1	3.2	6.0
Peach	2012-13	37.2	28.3	20.0	4.9	0.1	4.6	4.6
	2013-14	36.9	28.0	20.6	4.8	0.4	4.6	4.6
Wildcat	2012-13	49.7	10.4	11.1	3.8	0.0	20.8	4.1
	2013-14	49.6	10.4	11.2	3.7	0.0	21.0	4.2
Thurner	2012-13	53.9	16.0	11.3	6.7	0.0	4.5	7.6
	2013-14	54.4	16.4	10.2	6.7	0.0	4.7	7.6

[a] ES = Early Successional

Table 3.1 Cover types available to northern bobwhites on four study sites in southwest Ohio, 2012 – 2014.

Covey densities have fluctuated on Fee and Peach Orchard sites since 2009. Covey densities on Fee declined from a high of 7 (Janke 2011, Wiley 2012) in 2009 to 3 in 2014. Peach Orchard had an increase in overall coveys with a high of 4 (*personal observation*) in 2013 from 1 in 2010 (Janke 2011, Wiley 2012). Abundance of birds overall was highest on sites that had even proportions of nesting, brood rearing, food, and winter cover all within close proximity (*personal observation*). Males were observed whistling during the breeding season across both sites, but observations tended to be more frequent when adequate early successional herbaceous cover types were present. Nesting was observed on both sites and summer habitat use was centered around early successional herbaceous fields (i.e., Cp-1, Cp-2) and agriculture fields (i.e., corn, soybeans). Coveys tended to be clumped and in close proximity to one another in years and across years when these cover types were only found in certain areas of the study sites (*personal observation*). Marked bobwhites did not travel far when selecting non-breeding home-ranges and home-range selection seemed to contain all cover types listed above. Coveys tended to switch their seasonal use during winter from areas with herbaceous vegetation to areas containing more woody cover (i.e., woody fencerows, woody ditches, and old fields).

Woodlots, mature fencerows, ditches, and other uncultivated areas were considered for treatment if they had previously experienced little to no use by bobwhite coveys. These areas were surveyed by private land biologists from Pheasants Forever and Ohio Division of Wildlife to avoid areas such as waterways within wooded areas, woodlots with valued timber, requested areas by landowners, or other potential factors that might affect or limit treatment. If these areas were clear of potential factors which would limit treatment, areas were selected for edge-feathering. Feathered edges were placed adjacent to row crop (n=67) and herbaceous (n=32) vegetation, (Conservation Reserve Program; Cp-1, Cp-2) on the Fee (n=53) and Peach Orchard (n=46) sites.

Wooded edges were treated during April – May 2012 (n=69), and February – March 2013 (n=30). This allowed for edges on Peach Orchard to be in two different years of succession and treatment intensity. The first round occurred on Fee (n=53) and Peach Orchard (n=16) study sites and started on the 13 April, 2012 and were completed on the 9 May, 2012. The second round only occurred on the Peach Orchard (n=30) study site and started on 1 March, 2013 and were completed on 21 March, 2013. Feathered edge sections varied in length from 15 m to 91 m with the majority (*n*=76) equaling 30 m (Table 3.2) in length.

Site	Edge characteristics					
	Feathered edge length (m)	Size category	Feathered edges	Feathered edge type	Row crop edge	Herbaceous edge
Fee	15	Small	7	Woodlot	7	0
	30	Medium	41	Woodlot	41	0
	61	Large	1	Woodlot	1	0
	91	Large	4	Linear woody	3	1
Peach	-	Small	0	-	0	0
	30	Medium	27	Woodlot	5	22
	30	Medium	8	Linear woody	1	7
	91	Large	10	Woodlot	8	2
	91	Large	1	Linear woody	1	0
Total	-	-	99	-	67	32

Table 3.2 Number of feathered edge sections by site, length, and adjacent cover type in Highland County, Ohio (2012 – 2014) available for bobwhite coveys.

METHODS

Capture and Handling— I used covey call surveys, systematic searches with pointing dogs, and snow tracking to locate coveys during October – March 2012 – 2014. I captured bobwhites on all sites using baited funnel traps (Stoddard 1931: 442-445) and targeted mist netting (Wiley et al. 2013). Burlap was used to protect birds in funnel traps (Lehman 1946) and for concealment from predators. I leg banded all captured bobwhites and radio-marked a subset of individuals weighing ≥ 165 g with a necklace-style radio-transmitter (≤ 4.3% of body weight, 6 hour mortality sensor; Advanced Telemetry Systems, Isanti, MN). Bobwhites were released at capture sites immediately after marking. A total of 206 birds were captured and 177 were fitted with radio-collars.

Movement and Home-range— Trapping, handling, and marking protocols were reviewed and approved by the Animal Care and Use Committee at The Ohio State University (protocol number 2007A0228). Bobwhites were located ≥ 4 days/week throughout each year using homing from short distances (White and Garrott 1990). Efforts were made to maintain > 1 radio-marked bird per covey and to regularly flush coveys to determine covey sizes. I defined a covey as a group of ≥ 2 birds located together consecutively ≥ 7 times after 1 October. Cover type occupied by radio-marked bobwhites was recorded at time of location. Janke (2011) reported that investigators correctly identified cover types 93.8% of the time in tracking trials conducted during the non-breeding season.

Habitat composition and structure were measured at known covey locations for a total of 626 covey use points. I used radio-locations and covey points that had similar vegetation to those of feathered edges. For example, covey locations found within crop fields or other habitat types not similar to feathered edges were removed. I used locations from 24 coveys (*n*=484) during 4 November 2013 - 31 March 2014. Radio-marked bobwhites fitted with radio-transmitters (*n*=11) from the previous year made up 11 unique coveys during the second year. Vegetation measurements from known covey locations were used to compare habitat composition and structure to treated edges.

I used radio-locations from a total of 7 of 13 known coveys, 3 coveys (*n* = 280) during the 2012 - 2013 non-breeding season and 4 coveys (*n* = 183) during the 2013 – 2014 non-breeding season on Fee and Peach Orchard (Table 3.3). Only 7 coveys met the minimum qualifications for building home-ranges. Coveys were pooled by site due to the small number of coveys used for this analysis during the individual years. I imported bobwhite covey locations into ArcGIS and covey locations only included observations where I tracked all radio-marked members to the same location. I excluded from home-range and covey movement calculations observations where all radio-marked members of the covey were not together. I constructed 95% Fixed k Local Convex Hull (LoCoH; Getz and Wilmers 2004) utilization distributions from relocation data to estimate the home-ranges of radio-marked bobwhites. The LoCoH method is known to outperform kernel estimations in fragmented landscapes and areas with narrow habitat (Getz et al. 2007) corridors such as those on my study sites (i.e., fencerows, ditches, feathered edges). The convex hull for each point is constructed from the (k-1, where k is the nearest neighbor convex hull) nearest neighbors to that point. Hulls are merged together from smallest to largest based on the area of the hull (Calenge 2011).

		Coveys		
Site	Year	Name	Number of Radio-Locations	Home-Range Size (ha)
Fee	2012-13		No coveys on Fee site	
	2013-14	Kin	77	4.5
		Tree	22	1.2
Peach	2012-13	Church	122	2.6
		Don	82	5.1
		John	76	2.0
	2013-14	Day	25	8.1
		West	59	8.7
Total	-	7	463	

Table 3.3 Individual covey radio-locations by site used to develop Fixed k LoCoH home-ranges for bobwhites on two study sites in southwest Ohio, 2012 – 2014.

Vegetation Sampling— Vegetation composition and structural characteristics were measured at all (*n*=99) feathered edges to evaluate vegetation measurements and compare their suitability for bobwhites during the non-breeding season. Vegetation of feathered edges was measured before treatment, during the end of the first and second growing seasons, and at the end of the first and second winters after treatment. Vegetation was also measured at radio-marked bobwhite covey locations. I compared vegetation structure and composition between treated edges in fall and winter with sites used by radio-marked coveys. Treatments were performed by two different contractors with two different prescriptions. Contractor 1 treated edges by cutting smaller diameter trees, leaving larger diameter trees in edge and treated herbaceous vegetation within edges with Glyphosate. Contractor 2 treated edges by cutting all trees and treated cut-stumps with Triclopyr to prevent stump re-sprouting.

Measurements included shrub density (Cottam and Curtis 1956), horizontal visual obstruction (Nudds 1977), overhead cover (Kopp et al. 1998), and ground cover (Daubenmire 1959). One to 2 sampling points were located in each edge section with four transects extending in 4 directions at 90° intervals, delineating 4 quadrants (Figure 3.2). Transect 1 was always perpendicular to the treated edge, and transects 2 - 4 followed clock-wise (Figure 3.3b). Sampled covey use locations followed a similar protocol for vegetation measurements and the quadrants were always established the same way (Figure 3.3a). Vegetation at feathered edges was recorded in the fall (September - October) and winter (March) to measure initial measurements before the start of the non-breeding season and then at the end of winter 2013 - 14. Fall sampling of feathered edges was concluded before leaf descent to represent optimal cover, and winter sampling was concluded before leaf emergence to reflect the poorest cover during the most limiting period. Covey use points were measured continually through November to March to analyze change in cover conditions during the non-breeding season.

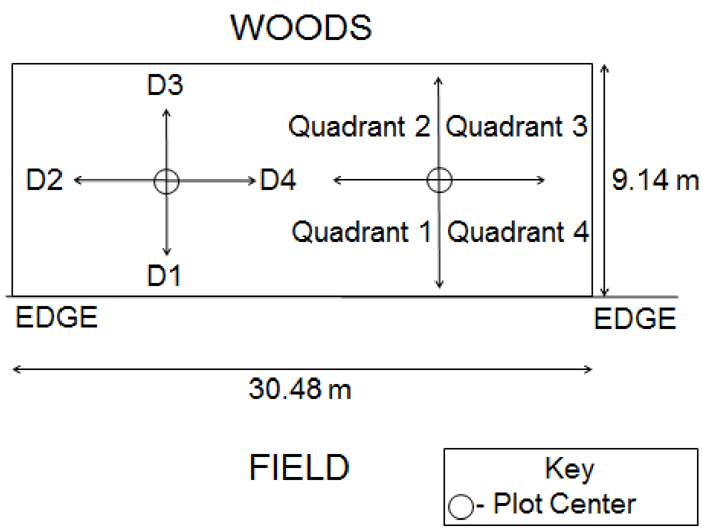


Figure 3.2 Plot design used to measure vegetation composition and structure of feathered edges before and after treatment in Highland County, Ohio (2012 – 2014).

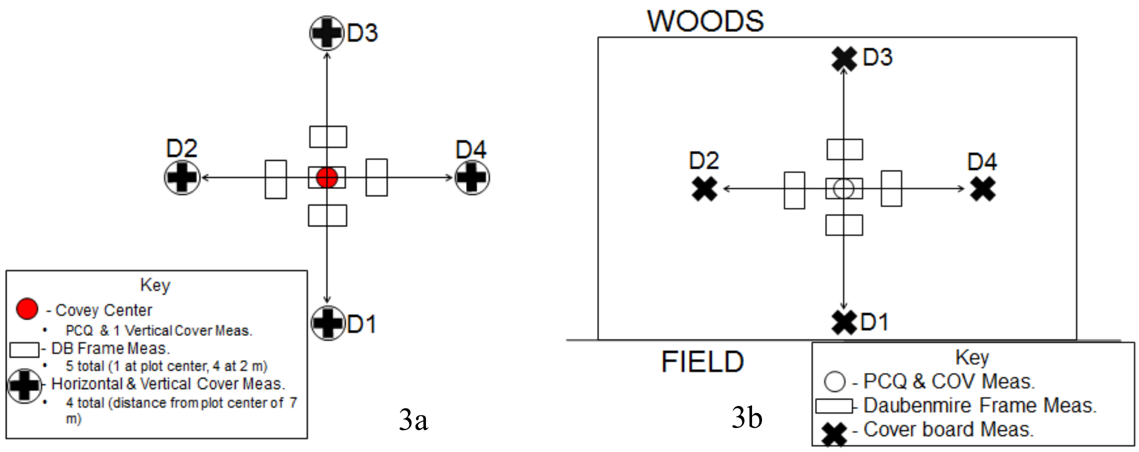


Figure 3.3 Vegetation sampling designs used to measure vegetation composition and structure at all feathered edge locations, and known covey use locations in Highland and Brown Counties, Ohio (2012 – 2014).

Daubenmire frames (0.2 m X 0.5 m) were used to measure ground cover at plot-center and covey-center in 4 directions (2 m from center) at a height of <1 m for a total of 5 measurements (Daubenmire 1959). Daubenmire (1959) recommended using 0.1 m^2

quadrant for shrubs and herbaceous vegetation because cover is more easily estimated in small quadrants. Cover types included bare ground, litter, grass/sedges, forbs, shrubs, brush, and other. Litter included any dead herbaceous material no longer attached to a plant, while brush was defined as non-standing dead woody material. The percent of each cover type was recorded in one of seven intervals; (0%), >0-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95% (Schmutz et al. 1989) to calculate total ground cover. Cover types could sum to > 100% to quantify amounts of each cover type separately within the Daubenmire frame accounting for overlapping layers.

I used a modified Nudds (1977) vegetation profile board to assess horizontal visual obstruction (horizontal cover) of vegetation in 7, 0.15 m vertical segments (0.15 m x 1.05 m) above ground (see Chapter 2). Horizontal cover quantifies hiding, escape, and thermal cover (Higgins et al. 2005). Photos of each feathered edge at each sampling period in combination with profile board readings were used to visually document changes in vegetation structure (Marlow and Clary 1996, Dudley et al. 1998) before and after treatment.

Vertical cover was measured at each plot-center and covey-center in all four directions to estimate the volume of unobstructed space using angle to obstruction < 2 m away from a bobwhite on the ground (Kopp et al. 1998). Four additional vertical cover measurements were included at covey points 7 m from covey-center at profile board locations to account for Jankes (2011) 12.9 m GPS and telemetry error. I used a 2 m pole with an angle gauge affixed and tilted the pole in the four cardinal directions until it contacted any physical obstruction (i.e., vegetation, barbed wire, trees, etc…) above 0.15

m on the pole (height of a bobwhite). The angle of tilt was recorded from 0° (upright) to 90° (prostrate; see Chapter 2).

Data Analysis— I used lm function in Program R (Version 3.1.2; R Development Core Team 2014) for regression and one-way analysis of variance (aov) that related cover at covey use sites to date, contractor treated edges to sampling period, and the comparison of treatment edges to covey habitat types through time. I used a simple plot command and scatterplot in Program R through time (November – March) to examine the temporal trend in horizontal cover measurements at known covey locations. I used all feathered edges and a simple plot command with scatterplot in Program R to compare 2012 and 2013 treatments, regardless of the unequal growing seasons each treatment experienced; and compared horizontal and vertical cover measurements for known covey locations, fall sampled edges, and winter sampled edges.

I used 7 habitat types (woody ditches, herbaceous ditches, woody fencerows, herbaceous fencerows, woodlot edges-woody, early successional fields, and feathered edges) to compare feathered edge vegetation composition and structure with areas used by radio-marked bobwhites during the non-breeding season. I used discriminant function analysis function lda in Program R (Version 3.1.2; R Development Core Team 2014), to test how the explanatory variable contributed to the correct classification of individuals. I then used 95% confidence ellipses using ggplot2 (Program R version 3.1.2; R Development Core Team 2014) to compare between my linear discriminate axis.

I used a multivariate analysis of variance function MANOVA in Program R (Version 3.1.2; R Development Core Team 2014) with a Wilk's lambda test to compare the differences in centroids among groups (bare ground, litter, grass/sedge, forbs, shrubs, brush, and other) in discriminant function analysis. I used a MANOVA with a Wilk's lambda to test my 7 ground cover responses (bare ground, litter, grass/sedge, forbs, shrubs, brush, other) to see if there was a difference between means of my identified habitat types bobwhites were observed using. The Wilk's lambda tests the difference between centroids of identified groups of subjects on a combination of dependent variables (Everitt and Dunn 1991, Polit 1996). Non-significant response variables were removed from further analysis. I combined ditches, fencerows and used feathered edges into a category I termed "linear woody". Early successional category contained points in fields or odd areas that were not cultivated. Woodlot edge-woody was comprised of woodlots with the understory made up of shrubs and saplings. Twenty-twelve feathered edges and 2013 feathered edges were treated edges in their respective years. Using the remaining ground cover types, I used a discriminant function analysis and used an lda to test how the explanatory variables contributed to the correct classification of individuals.

RESULTS

I used plots from 99 feathered edges (*n*=191) during the 2013 – 2014 fall and winter sampling seasons for measurements of horizontal cover, vertical cover, and ground cover and compared them to cover measurements from known covey use points. Feathered edges completed in March 2012 (*n*=69) experienced their second growing and winter seasons and feathered edges completed in March 2013 (*n*=30) experienced their first growing and winter seasons.

Horizontal Cover— Seven different habitat types were used with a subset of covey use locations. Covey use locations were subsetted by habitat types that resembled feathered edges. For example, covey points such as those observed in cut corn or standing bean fields were not included in analyses, so accurate attempts of comparison between treated edges and covey cover types could be made. Horizontal cover decreased at bobwhite used sites during the non-breeding season (b_{date}= 67.2 – 0.18, $P < 0.001$, n = 494 [Figure 3.4a]). Feathered edges treated in 2012 had more horizontal cover than feathered edges treated in 2013 ($b_{Treatment}$= 78.4 ± 6.42, $P = 0.016$, n = 99 [Figure 3.4c]) during the fall sample period, and both provided more cover than used bobwhite sites. Feathered edges treated in 2012 had a median fall horizontal cover of 88.2% and 2013 treated edges had median fall cover of 80.4%. During the winter sample period, 2013 feathered edges had more horizontal cover than 2012 treated edges ($b_{Treatment}$= 62.4 ± 9.1, $P = 0.001$, n = 99 [Figure 3.4d]). Feathered edges treated in 2013 had a median winter horizontal cover of 64.2% and 2012 treated edges had median winter cover of 53.4%, and both provided more cover than sites used by bobwhites during that same time.

Vertical Cover— Vertical cover decreased at bobwhite used sites during the non-breeding season (b_{date}= 79.6 – 0.10, $P < 0.001$, n = 494 [Figure 3.4b]). Feathered edges treated in 2012 had almost identical vertical cover to edges treated in 2013 ($b_{Treatment}$= 86.0 ± 0.46, $P = 0.76$, n = 99 [Figure 3.4e]) during the fall sample period, and both provided more cover than sites used by bobwhites. Feathered edges treated in 2012 had median fall vertical cover of 88.4° and 2013 treated edges had median vertical cover of 87.9°. Feathered edges treated in 2012 had almost identical vertical cover to edges treated in 2013 ($b_{Treatment}$= 76.7 ± 3.23, $P = 0.23$, n = 99 [Figure 3.4f]) during the winter sample period, and both provided more cover than sites used by bobwhite. Feathered edges treated in 2012 had a median winter vertical cover of 76.5° and 2013 treated edges had a median vertical cover of 81.8°.

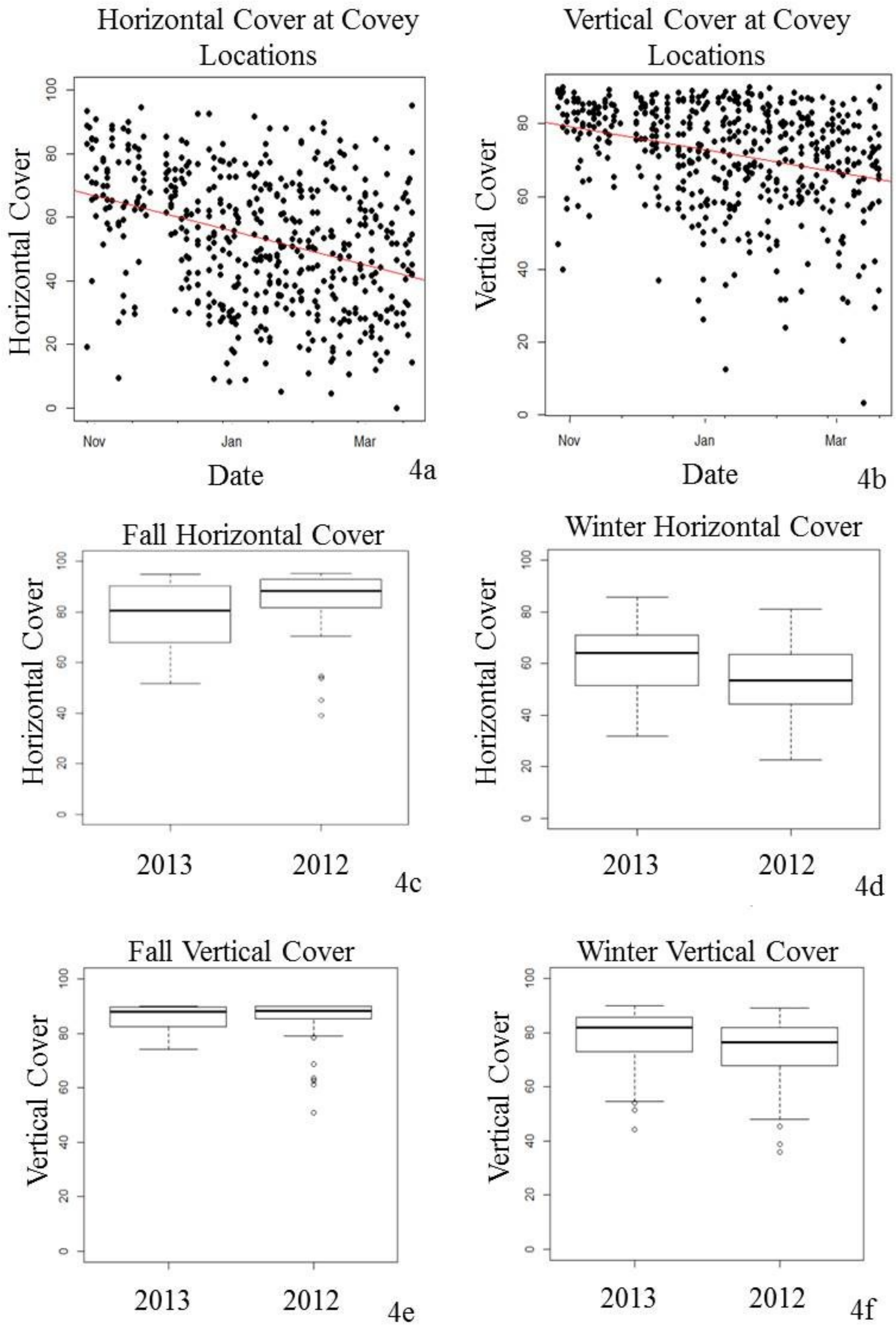


Figure 3.4 Scatterplots and box blots comparing vegetation measurements at habitat used by bobwhites throughout the non-breeding season to feathered edges during the fall and winter sampling seasons in Highland and Brown Counties, Ohio (2013 – 2014).

Ground cover— There was a significant main effect of habitat type on ground cover type (w=0.22, $F=38.5_{28,2064}$, P < 0.001, α=0.01). Each of the 7 response variables were all significant ($F_{4,578} > 7.48$, $P = 0.001$) except litter ($F_{4,578} = 0.9$, $P = 0.49$). The lda correctly classified 56% of observations into the correct a priori group (Table 3.4). The first two discriminant axis explained 93% of the variation (LD1= 77%, LD2= 16% [Table 3.5]). The first axis was interpreted to represent brush because brush had the highest loading and the second linear discriminant axis was interpreted as herbaceous vegetation, because forbs and grass/sedge had similar high loadings (Figure 3.5). The 95% confidence ellipses of early successional (ES) fields, linear woody (LW), and woodlot edge-woody (WEW) use sites all overlapped on both axes (Figure 3.5). Feathered edges-2012 (EF) overlapped LW and WEW use sites but not ES fields on the first axis. EF-2013 was clearly separated from use sites in all habitat types on the first discriminant axis. The second discriminant axis did not differ from treated and use sites, indicating that herbaceous vegetation was similar between treated and sites used in all habitats.

I tested the difference between EF-2012 and EF-2013 to see if there was a treatment effect, time effect, or both. This was because feathered edges treated in 2013 only had experienced 1 growing season, whereas 2012 edges had experienced 2 growing season. There was a significant main effect with habitat type on ground cover types (w=0.17, $F=63.1_{7,91}$, $P < 0.001$, α=0.01). Each of the 7 response variables considered separately, were all significant ($F_{1,97} > 5.8$, $P = 0.018$) except litter and other ($F_{1,97} < 0.4$, $P > 0.53$). Using the 5 univariate significant ground cover types, I used discriminant function analysis to test multivariate differences between 2012 and 2013 years. The lda

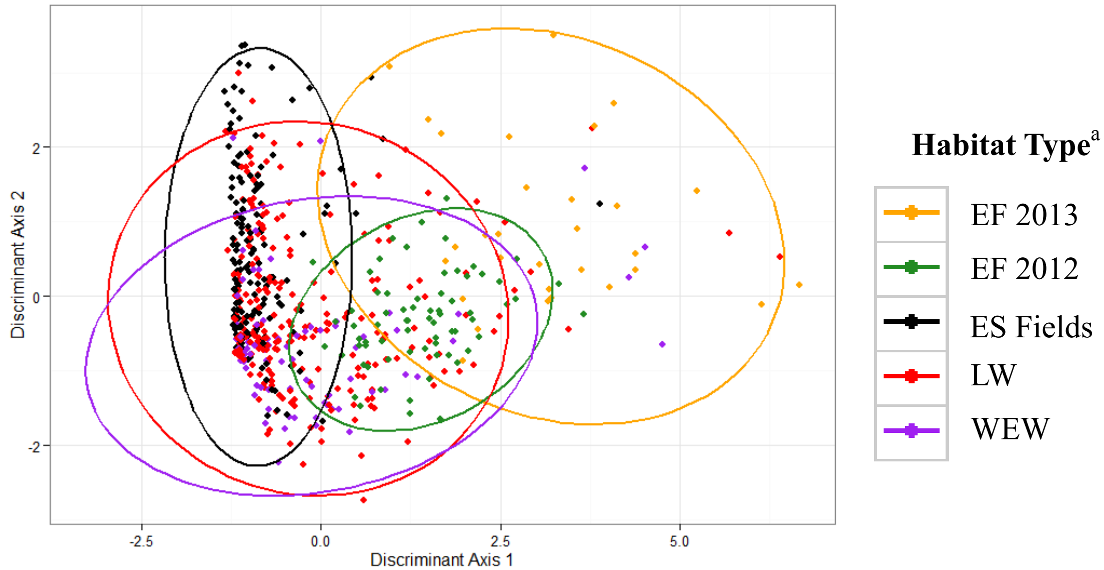
Predicted class	Reference Class						Predicted accuracy (%)
	EF 2013	EF 2012	ES Fields	LW	WEW	Total	
EF 2013	21	2	1	8	4	36	58
EF 2012	8	38	0	14	5	65	58
ES Fields	1	0	89	46	8	144	61
LW	0	29	71	178	60	338	52
WEW	0	0	0	0	0	0	0
Total	30	69	161	246	77	583	
Correctly classified accuracy (%)	70	55	55	72	0		

Table 3.4 The error matrix of the testing data set for habitat code method. The horizontal totals represent the correct classification. The vertical totals represent the number and distribution of classification error.

Variable Names	Axis 1		Axis 2	
	Eigenvectors	Factor Loadings	Eigenvectors	Factor Loadings
Bare ground	0.0155	0.3830	-0.0455	-0.0067
Grass/sedge	-0.0058	-0.1521	0.0412	0.6838
Forbs	-0.0012	-0.0080	0.0499	0.7145
Shrubs	0.0038	0.1640	-0.0008	-0.2275
Brush	0.0860	0.9906	0.0282	0.0634
Other	-0.0044	-0.3933	0.0109	-0.1518
Proportion of Variance	0.7654		0.1588	

Table 3.5 Factor loadings, Eigenvectors, and proportion of variance explained on both discriminant axes for ground cover measurements at bobwhite covey use locations and feathered edges September 2013 – March 2014.

correctly classified 93% of observations. The first axis was interpreted to represent brush because brush was assigned the highest loading. The difference between EF-2012 and EF-2013 in the above comparison is a treatment effect (Figure 3.6a - 3.6b).



[a] EF 2012 = Edge-feather 2012, EF 2013 = Edge-feather 2013, ES Fields = Early successional fields, LW = Linear woody, WEW = Woodlot edge-woody

Figure 3.5 Discriminant function analysis plot showing microhabitat use from bobwhite covey radio-locations (4 November 2013 – 31 March 2014) identified by habitat type compared to feathered edges with 95% confidence ellipses surrounding each group.

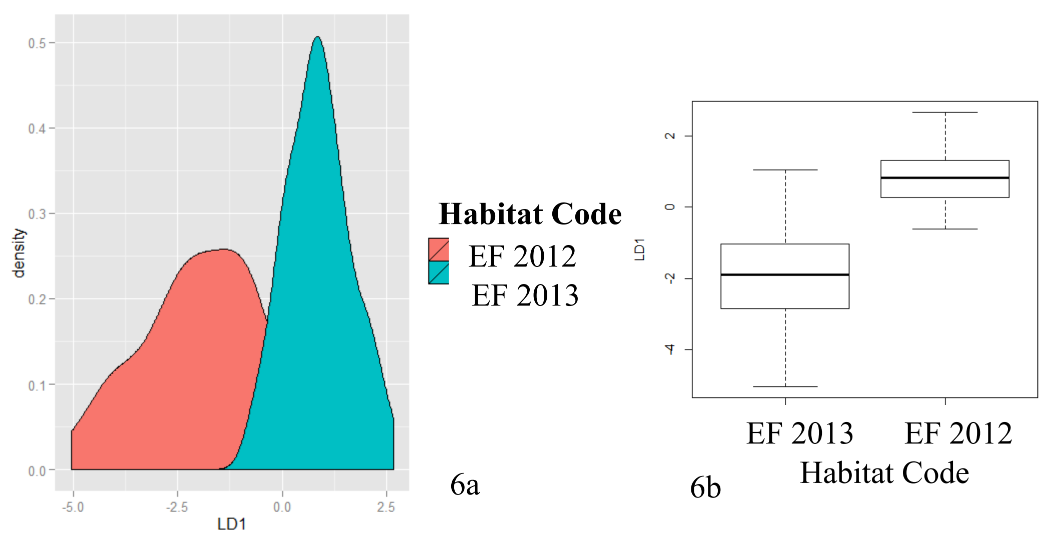


Figure 3.6 A discriminant analysis function and a basic boxplot showing the difference between brush measurements and treatment years (heavy vs. light) identified by habitat code.

Home-Range— Home-range polygons were constructed for 7 coveys on Fee and Peach Orchard study sites during the non-breeding season (1 October – 31 March 2012 – 2014). Using a 95% confidence interval with an average number of 66 relocations per covey (range = 22 – 122), the average covey home-range for both years (2013 and 2014) was 4.6 ha (range = 1.2 – 8.7 ha).

Feathered Edge Use— Four of 16 feathered edges on the Peach Orchard study site were used by radio-marked coveys during October 2012 – March 2013. Only 11 of 280 (4%) locations of radio-marked coveys were within feathered edges (Table 3.6). Only one feathered edge fell within the 95% local convex hull home-range of any covey (Table 3.6). This single feathered edge accounted for 1% of the total area of this covey home-range. Six of 99 (6%) feathered edges on Fee and Peach Orchard study sites were used by radio-marked coveys during October 2013 – March 2014. Only 11 of 183 (6%) locations were recorded within feathered edges (Table 3.6). Only one feathered edge fell within the 95% local convex hull home-range on Fee, (0.6% of covey home-range), and 3 feathered edges fell within one home-range on Peach Orchard (1% of covey home-range). Use of feathered edges was low across both sites and years totaling 5%. Only 5 treated edges occured within 95% home-ranges of coveys across both sites and years (Table 3.6).

Considering a 12.9 m buffer around each covey location, (radio-location error, Janke 2011) 18 of 280 (6%) radio-locations were associated with feathered edges in the first year and 19 of 183 (10%) radio-locations in the second year. Considering further, a 75.4 m buffer which was the calculated minimum daily movement for 7 coveys used in the home-range analysis, coveys were within and potentially used feathered edges on 122 of 463 (26%) occasions across years and sites (Table 3.6).

Site	Year	Marked Coveys	Covey Radio-locations w/in EF	w/in 12.9m	w/in 75.4m	Home-Range No. EF w/in Fixed k LoCoH Home-Range 95%
Fee	2012-13	1	0	0	0	0
	2013-14	2	5	10	30	1
Peach	2012-13	4	11	18	41	1
	2013-14	3	6	9	51	3
Total	-	10	22	37	122	5

Table 3.6 Covey radio-locations within certain criteria of feathered edges and also with a 95% Fixed k LoCoH home-range in Highland county, Ohio (2012 – 2014).

DISCUSSION

Movements and Home-ranges— The average covey home-range size over both winters in my study (4.6 ha) was similar to reports by Roseberry and Klimstra (1984) where winter covey home-ranges were typically < 10 ha in Illinois. Errington and Hamerstrom (1936) stated that cruising radii for coveys living under favorable conditions were short, and that birds could usually be flushed within 400 m of the same place at each visit. Lohr et al. (2010) observed mean daily movement of 158 m which was more than double what I observed (74.5 m). Lohr et al.'s (2010) 13 coveys in New Jersey were consistent with the 400 m range of movement reported by Errington and Hamerstrom. In all cases but one, the covey territories for Murphy and Baskett (1952) were about 400 m to 610 m in longest dimension. Coveys in small isolated patches of habitat are especially vulnerable to localized changes in availability of food resources and escape cover since their ability to move to another patch of habitat is limited. Williams et al.'s (2000) found that decreased movement was also associated with increased use of woody vegetation.

Williams et al.'s (2000) study areas contained only 3 – 4% woody cover in a Kansas cropland and rangeland landscape. My study sites in Highland County had similar amounts of woody cover (3 – 5%) and could have facilitated similar winter daily movement rates by allowing coveys to move throughout their home-range without necessitating fast movements across open areas (Williams et al. 2000).

Feathered edges— Summaries of vegetation structure and composition for habitat types used by radio-marked coveys indicated early successional areas like fencerows, ditches, old fields, woodland edges, and feathered edges all had similar cover measurements. Overall, feathered edges were more closed providing more cover than most habitat types where radio-marked coveys were located. Use of feathered edges was low, but this cannot be attributed to poor cover quality created by edge-feathering. Not all feathered edges that received use occurred within covey home-ranges, which suggests that when birds were moving or were forced to leave an area, they used feathered edges if they found them. One example of this was a covey that only moved outside of its 95% home-range for a short period of time (3-days), where this covey was observed in 3 different feathered edges before moving back to its home-range where it remained for the rest of the year. Also, coveys did not appear to be affected or select feathered edges by adjacent cover type, because comparable use of feathered edges between herbaceous fields (2 feathered edges; Cp-1, Cp-2) and row crop fields (3 feathered edges) was observed.

Ground cover measurements were also similar between use sites and feathered edges. There appeared to be very little variability in brush composition in ES-fields, but a large range of variability in herbaceous vegetation across the other 4 habitat types.

There appears to be a minimum amount of brush needed to support use of ES-fields by bobwhites. This could be due to the fact that fields used by bobwhites in our study are in advanced successional stages, containing shrubs such as autumn olive, multiflora rose, *rubus* spp., and red cedar, which tend to colonize treeless areas over time. Bobwhites found within these fields, utilized these different types of vegetation listed above. These different types of vegetation do not provide the amount (volume) of brush like a falling hickory limb or a felled tree, but nevertheless do provide brush to the ground layer. Brush was still evident, and was provided by these vegetation types. Feathered edges with higher treatment intensity had more brush because the basal area was reduced by a greater amount. All trees that were cut remained in the feathered edge sections and no landowners removed firewood even though allowed. The higher treatment also had higher discriminant function analysis scores for grass/sedge and forbs when compared to the other habitat types. The 2013 treated edges have an ellipse that is centered slightly higher, with herbaceous vegetation plotted across the entire gradient. This may be the result of the higher reduction in basal area, which allowed for more sunlight and nutrients to reach the understory, resulting in more vegetation like grasses, sedges, and forbs.

Depending on intensity of treatment, edge-feathering can create habitat that is structurally and compositionally similar to vegetation and habitat types used by bobwhite coveys. Gates (1991) recommends strips of early successional habitat (similar to my feathered edges), should be 10 to 15 m wide, the width of many shrubby edge zones. Our feathered edges were not as wide (7 m), which might also explain differences in composition.

Treated edges did not appear to attract bobwhites as originally anticipated. Use of treated edges appeared to be highly affected by juxtaposition with summer (nesting/brood rearing) habitat and agriculture fields (soybeans and corn). Feathered edges within close proximity to these other two habitat types received use compared to feathered edges that were not within close proximity. Across both years of the study, coveys (n=5) with home-ranges that contained feathered edges within home-range, were observed using feathered edges during the non-breeding season.

Edges were treated in areas where little or no use was documented during the non-breeding season in preceding years. The assumption was that useable space and covey densities would increase if suitable protective cover was provided where none existed. Consideration of other habitat types like nesting, brood rearing, and food were not considered in the initial stages of treating woodlots. Guthery (1999) postulated that beyond an unknown critical threshold, too much woody cover and too little herbaceous cover on a landscape would cause a loss of usable space. I observed this on the Fee study site. Limited use of treated edges may be explained by locations of summer (nesting/brood rearing) habitat and crop fields (soybeans and corn). Coveys formed and established home-ranges near suitable breeding habitat, although there were local scale shifts between areas used during spring-summer and later in fall-winter. Coveys seemed to establish home-ranges where there was adequate brood rearing/nesting habitat near sources of food, and early successional habitat during fall-winter. Thus edge treatments should target areas close to other key habitat types with nesting cover and food.

Edge-feathering was being conducted during the pinnacle of crop prices, and the result of these extremely high crop prices, was the removal of CRP land and conversion back to row crops. No amount of edge-feathering can replace the loss of early successional herbaceous habitat, but we were trying to stay within the constraints of working farms. Unfortunately, where we lost herbaceous vegetation on our study sites, we lost quail, even with the addition of feathered edges.

Bobwhites have been observed using cover such as agriculture wash-out holes, undercut stream banks, old tobacco barns, rolled barbed wire bundles, and were observed diving into foxtail clumps to avoid predators (*personal observation*). These somewhat rare and isolated events do not change the fact bobwhites must have effective brushy cover with access to food. This is crucial not only if bobwhites are to thrive, but exist at all (Errington and Hamerstrom 1936). Given the likely importance of habitat loss and possible fragmentation on bobwhite population trends, management efforts to increase the area of useable space should take priority over improving the quality of existing habitat patches. Lastly, such efforts should be established in proximity to remaining bobwhite source populations to improve colonization success and population viability.

LITERATURE CITED

Askins, R. A. 2001. Sustaining Biological Diversity in Early Successional Communities: The Challenge of Managing Unpopular Habitats. Wildlife Society Bulletin 29: 407-412.

Burger, L. W. Jr., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Trans. N. Am. Wildl. Nat. Resour. Conf. 55:74-83

Calenge, C. 2011. Home Range Estimation in R: the adehabitat Package. 1-67.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Daubenmire, R. 1959. A Canopy-Coverage Method of Vegetational Analysis. Northwest Science 50:431.

Dudley, S. J., C. D. Bonham, S. R. Abt, and J. C. Fiscchenich. 1998. Comparison of methods for measuring woody riparian vegetation density. Journal of Arid Environments 38:77-86.

Errington, P. L., and F. Hamerstrom. 1936. The northern bob-white's winter territory. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.

Everitt B.S., and Dunn G. 1991. Applied Multivariate Data Analysis. Edward Arnold. London. pp. 219±220.

Farris, A. L., E. D. Klonglan and R. C. Nomsen. 1977. The ring-necked pheasant in Iowa. Iowa Conserv. Comm., Des Moines. 147.

Fies, M., M. L. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium. 5:173-179.

Flock, B. E., P. S. Gipson, R. D. Applegate, and W. B. Ballard 2012. Distance-based habitat associations of northern bobwhites in a fescue-dominated landscape in Kansas. Proceeding of the National Quail Symposium 7:42-51.

Gates, J. E. 1991. Powerline Corridors, Edge Effects, and Wildlife in Forested Landscapes of the Central Appalachians. Wildlife and Habitats in managed landscapes. Island Press Washington D. C. 13-32.

Getz, W. M., and C. C. Wilmers. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography 27:489-505

Getz, W. M., S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, and C. C. Wilmers. 2007. LoCoH: nonparametric kernel methods for constructing home ranges and utilization distributions. PLoS ONE 2:e207.

Giocomo, J. J. 2005. Conservation of grassland bird populations on military installations in the eastern United States with special emphasis on Fort Campbell Army Base, Kentucky. Ph.D dissertation. Knoxville, TN: University of Tennessee. 181.

Guthery, F. S. 1999. Slack in the configuration of habitat patches for northern bobwhites. Journal of Wildlife Management 63:245-250.

Harper, C. A. 2007. Strategies for Managing Early Succession Habitat for Wildlife. Weed Technology 21:932-937.

Higgins, F. H., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker 2005. Vegetation Sampling and Measurement. Techniques for wildlife investigations and management 524-553.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. The Ohio State University.

Johnsgard, P. A. 1973. Grouse and quails of North America. Univ. of Nebraska Press, Lincoln. 413 pp.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884-895.

Lehmann, V. W. 1946. Mobility of Bobwhite Quail in Southwestern Texas. The Journal of Wildlife Management 10:124-136.

Leopold, A. 1933. Game management. Charles Scribners and Son's, New York, USA.

Litvaitis, J. A. 1993. Response of Early Successional Vertebrates to Historic Changes in Land Use. Conservation Biology 7:866-873.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the Edge: Northern Bobwhite Ecology at the Northern Periphery of Their Range. Journal of Wildlife Management 75:52-60.

Marlow, C. B. and W. P. Clary. 1996. Natural resource monitoring for the Daubenmire disadvantaged. Sharing common ground on western rangelands: Proceedings of a livestock/big game symposium. K. E. Evans. Sparks, NV, USDA Forest Service Intermountain research station: 13-18.

Millenbah, K. F., S. R. Winterstein, H. Campa III, L. T. Furrow, and R. B. Minnis. 1996. Effects of Conservation Reserve Program field age on avian relative abundance, diversity, and productivity. Wilson Bull. 108:760-770.

Murphy, D. A., and T. S. Baskett. 1952. Bobwhite mobility in central Missouri. Journal of Wildlife Management 16:498-510.

Mysterud, A. and R. A. Ims. 1998. Functional Responses in Habitat Use: Availability Influences Relative Use in Trade-Off Situations. Ecology 79:1435-1441.

National Climate Data Center [NCDC]. 2015. Quality Controlled Local Climatological Data. <http://www.ncdc.noaa.gov/oa/ncdc.html>.

Noss, R. F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered ecosystems of the United States: A preliminary Assessment of loss and degradation. Biological Report 28, National Biological Service, Washington, D.C., USA.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

Orians, G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. American Naturalist 137:29-49.

Peterjohn, B. G., and D. L. Rice. 1991. The Ohio breeding bird atlas. Ohio department of Natural Resources, Columbus, Ohio, USA.

Peterjohn, B. G. 2003. Agricultural landscapes: Can they support healthy bird populations as well as farm products? Auk 120:14-19.

Polit, D. F. 1996 Data Analysis and Statistics for Nursing Research. Appleton and Lange, Stamford, Connecticut. pp. 320±321.

R Development Core Team. 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Riddle, J. D., C. E. Moorman, and K. H. Pollock. 2008. The Importance of Habitat Shape and Landscape Context to Northern Bobwhite Populations. The Journal of Wildlife Management 72:1376-1382.

Roseberry, J. L. 1993. Bobwhite and the “new” biology. Proceedings of the National Quail Symposium 3:16-20.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895-902.

Rosene, W. 1984. The bobwhite quail- its life and management. The Sun Press, Hartwell, Georgia, USA

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966 - 2013. Version 01.30.2015. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schmutz, J. A. 1989. Nest Habitat Use of Rio Grande Wild Turkeys. The Wilson Bulletin. 101:591-598

Smith, T. M., and R. L. Smith. 2009. Elements of ecology. Seventh edition. Benjamin-Cummings, San Francisco, California, USA.

Spinola, R. M. and R. Gates. 2008. Population Status and Trends of Northern Bobwhite (*Colinus virginianus*) in Ohio: 1984-2004. Ohio Journal of Science 108:26-30.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Son’s, New York, USA.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, CA, USA.

Wiley, M. J. 2012. Usable Space and Microhabitat Characteristics for Bobwhites on Private Lands in Southwestern Ohio. Thesis. The Ohio State University.

Wiley, M. J., A. K. Janke, and R. J. Gates. 2013. Efficacy and effects on survival of targeted-mist netting of northern bobwhites in Ohio. Proceedings of the National Quail Symposium.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562-1566.

CHAPTER 4: Management Implications

Suggestions of minimum area for bobwhite management have been emphasized for half a century (Thompson and Mattison 1950, Murphy and Baskett 1952) and modern management (Williams et al. 2004) has considered even broader units of scale such as communities of landowners or physiographic regions which, could be larger or smaller than the previous suggestions of 6 – 10 km^2. This scale seems compatible with population viability modeling by Guthery et al. (2000), who found that larger tracts of usable space decreased vulnerability to extinction. The Fee site fell within the suggested minimum size and key bobwhite cover types such as early successional herbaceous, early successional woody, and row crops were all within the site. Also, edge-feathering has been shown to provide a viable option for converting un-used woodlots or mature linear features into preferred early successional habitat. Unfortunately, other habitat types were not considered during my research years until after edge-feathering were completed. Bobwhite densities have declined while shifts in occupied habitat have been documented on the Fee study site. As a result, a lack of breeding habitat (early successional herbaceous) along with its sporadic distribution within Fee, resulted in suboptimal placement of feathered edges and subsequent low use.

The Peach Orchard site did not fall within the suggested size ranges but was more realistic for bobwhite management. This was because of the ability to interact with fewer landowners on a more regular basis and because cover types remained the same between years. This allowed for documentation of all bobwhite interactions on the site and kept landowners informed about the newest findings. The other notable piece of information was Peach Orchard had roughly equal proportions, interspersion (Roseberry and Klimstra 1984, Burger et al. 1990, Stauffer et al. 1990), and stable cover types were associated with higher bobwhite density compared to the Fee site.

Within landscapes containing bobwhites, and where adequate habitat remains for management, I recommend landowners and managers assess areas for management consideration (the core), and also the immediate surrounding land. The viability of local bobwhite populations are affected not only by their own reproductive and survival rates, but also by connections with neighboring populations (Fies et al. 2002). Habitat assessment needs to evaluate 3 cover types, including early successional herbaceous, early successional woody, and row crop and the interspersion and juxtaposition of these cover types. If the proportions of these habitat types are comparable, less manipulation and consideration for management would occur. The final need of the assessment must also consider presence of bobwhites before further consideration, which supports the assertions that local management should be concentrated in landscapes that have high potential for a positive response by bobwhites (Roseberry and Sudkamp 1998, Cobb et al. 2002, Williams et al. 2004). This is an approach for landowners and managers to consider spatial and temporal probability distributions of habitat features, and developing comprehensive habitat management programs (Kopp et al. 1998), with high probability of positive outcomes and success. If early successional herbaceous vegetation is limited, as it is in most cases, programs that establish field borders such as provided by the Natural Resources Conservation Service (NRCS) should be considered. If early successional woody vegetation is limited, forest management such as edge-feathering, thinning, or Timber stand improvement (TSI) are effective ways for increasing early successional woody vegetation in agriculture landscapes.

Habitat (i.e., cover types, habitat change, and manipulated habitat) and bobwhite densities and survival have been adequately quantified in southwest Ohio. The dominance of forest and agriculture in this landscape has been detrimental to bobwhites and resulted in lower bobwhite densities (0.73 coveys/km^2). Southwest Ohio is a worthy reference for other Midwestern states due to the similar habitat types present on the landscape. Brennan (1991) said in general, most wildlife rarely have experiments conducted that provide a basis for scientific management (MacNab 1983), but because of the bobwhites general habitat ecology and behavior, it lends itself to experimentation that can be used as a scientific basis for management.

Riddle et al.'s (2008) found there to be nearly twice as many bobwhite on farms in agriculture-dominated landscapes after establishment of field borders, which was the limiting habitat type on the Fee site. With help from wildlife agencies, we were able to prioritize future site-level management efforts in areas where the overall landscape matrix is most suitable for bobwhites (Fies et al. 2002), and we were able to consider the juxtaposition and interspersion of key cover types. To combat loss of key habitat, actions were taken by project patterns to address this problem, and new programs with additional incentives for any participating landowner who enrolled in Conservation Reserve Programs (CRP) were compensated.

Habitat manipulation remains a difficult and challenging process while trying to manage for bobwhites within an area, and across the bobwhite's range. Researchers understand the value of herbaceous field borders around agricultural fields (Stoddard 1931, Puckett et al. 1995, Smith 2004), opening or thinning forests (Hanson and Miller 1961), and reducing the amount of mature woodland or cropland or both to raise the abundance of bobwhites on farms. In Illinois and other states, CRP contributed to bobwhite habitat but it depended on quantity, quality, and also other habitats and components (Roseberry et al. 1994, Weber et al. 2002.). These management strategies seem to be viable for reversing bobwhite declines and have been concerns we have addressed in my Ohio study. Findings indicate the potential for bobwhites to recolonize habitat patches in fragmented landscapes, assuming source populations exist to produce colonists. Observed long distance movements are encouraging (Lohr et al. 2011, *personal observations*) because they suggest potential for recolonization of unoccupied patches, but greater connectivity on the landscape is required.

Where there is habitat there are bobwhites (Guthery 1997) and when dominant land use trends are not favorable to bobwhites, they disappear. This simple concept seems impossible for some to grasp (Brennan 2002). The development of more ecologically designed agricultural systems that reintegrate features of traditional agricultural knowledge into modern intensive agricultural practices can contribute to meeting the challenges we face today (Matson et al. 1997). Broad implementation of such strategies will require the contributions and interactions of social as well as natural scientists, national and international agricultural research institutions, industry, policymakers, and farmers (Matson et al. 1997). Because the bobwhite is no longer a by-product of land-use practices in agriculture and forestry, broad scale management programs will need to be designed to maintain populations (Brennan 1991).

LITERATURE CITED

Brennan, L. A. 1991. How Can We Reverse the Northern Bobwhite Population Decline? Wildlife Society Bulletin 19:544-555.

Brennan, L. A. 2002. A decade of progress, a decade of frustration. National Quail Symposium Proceedings 5:230-232.

Burger, L. W. Jr., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Trans. North American Wildlife and Natural Resource Conference. 55:74-83.

Cobb, D. T., T. L. Sharpe, D. Sawyer, and D. O. Baumbarger. 2002. Integrating early-successional wildlife and habitats into North Carolina's 21st century landscape. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 56:124–135.

Fies, M., M. L. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium. 5:173-179

Guthery, F. S. 1997. A Philosophy of Habitat Management for Northern Bobwhites. The Journal of Wildlife Management 61:291-301.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of Northern Bobwhite Populations. The Journal of Wildlife Management 64:646-662.

Hanson, W. R. and R. J. Miller. 1961. Edge Types and Abundance of Bobwhites in Southern Illinois. The Journal of Wildlife Management 25:71-76.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884-895.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the Edge: Northern Bobwhite Ecology at the Northern Periphery of Their Range. Journal of Wildlife Management 75:52-60.

MacNab, J. 1983. Wildlife management as experimentation. Wildlife Society Bulletin. 11:397-401

Matson, P. A., W. J. Parton, A. G. Power, and M. J. Smith. 1997. Agricultural intensification and ecosystem properties. Science 277:504-509.

Murphy, A. and T. S. Baskett. 1952. Bobwhite Mobility in Central Missouri. The Journal of Wildlife Management 16:498-510.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505–515.

Riddle, J. D., C. E. Moorman, and K. H. Pollock. 2008. The Importance of Habitat Shape and Landscape Context to Northern Bobwhite Populations. The Journal of Wildlife Management 72:1376-1382.

Roseberry, J. L., B. J. Richards, and T. P. Hollenhorst. 1994. Assessing the potential impact of Conservation Reserve Program lands on bobwhite habitat using remote sensing, GIS, and habitat modeling. Photogrammetric Engineering and Remote Sensing 60:1139–1143.

Roseberry, J. L. and S. D. Sudkamp. 1998. Assessing the Suitability of Landscapes for Northern Bobwhite. The Journal of Wildlife Management 62:895-902.

Roseberry, J. L. and W. D. Klimstra. 1984. Population Ecology of the Bobwhite, Southern Illinois University Press, Carbondale, Illinois, USA.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Dissertation, Mississippi State University, Starkville, USA.

Stauffer, D. F., G. A. Cline, and M. J. Tonkovich. 1990. Evaluating potential effects of CRP on bobwhite quail in Piedmont Virginia. North American Wildlife and Natural Resource Conference. 55:57-67.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Son's, New York, USA.

Thompson, D. R., and H. Mattison. 1950. Quail need food, cover and space. Wisconsin Conservation Bulletin. 15:1-4.

Weber, W. L., J. L. Roseberry, and A. Woolf. 2002. Influence of the Conservation Reserve Program on landscape structure and potential upland wildlife habitat. Wildlife Society Bulletin 30:888–898.

Williams, C. K., F.S. Guthery, and R. D. Applegate. 2004. The Northern Bobwhite Decline: Scaling Our Management for the Twenty-First Century. Wildlife Society Bulletin 32:861-869.

BIBLIOGRAPHY

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Askins, R. A. 2001. Sustaining Biological Diversity in Early Successional Communities: The Challenge of Managing Unpopular Habitats. Wildlife Society Bulletin 29: 407-412.

Baird, R. L. 1936. Oberlin (Ohio) region. Bird Lore 38:468-470.

Best, L. B. 1983. Bird Use of Fencerows: Implications of Contemporary Fencerow Management Practices. Wildlife Society Bulletin 11:343-347.

Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of Cornfields by Birds during the Breeding Season: The Importance of Edge Habitat. American Midland Naturalist 123 1:84-99.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Brennan, L. A. 2002. A decade of progress, a decade of frustration. National Quail Symposium Proceedings 5:230-232.

Burger, L. W. Jr., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Trans. North American Wildlife and Natural Resource Conference. 55:74-83.

Burger, L. W., D. McKenzie, R. Thackston, and S. J. Demaso. 2006. The role of farm policy in achieving large-scale conservation: Bobwhite and buffers. Wildlife Society Bulletin 34:986-993.

Buttel, F. H. 1990. Social relations and the growth of modern agriculture. Pages 113-145 *in* C. R. Carrol, J. H. Vandermeer, and P. M. Rosset, editors. Agroecology. McGraw-Hill, New York.

Calenge, C. 2011. Home Range Estimation in R: the adehabitat Package. 1-67.

Chamberlain, D., and J. Vickery. 2002. Declining farmland birds: Evidence from large-scale monitoring studies in the UK. British Birds 95:300-310.

Chapman, R. 2012. Woodland Edge Feathering. Indiana Woodland Steward Volume 21, No.1.

Cobb, D. T., T. L. Sharpe, D. Sawyer, and D. O. Baumbarger. 2002. Integrating early-successional wildlife and habitats into North Carolina’s 21st century landscape. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 56:124–135.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Crawley, M. J. 2012. The R Book Second Edtion. John Wiley & Sons Ltd., Imperial College London at Silwood Park, United Kingdom.

Dailey, T. V. 2002. Emerging trends in Midwest bobwhite culture. National Quail Symposium Proceedings 5:8-19.

Daubenmire, R. 1959. A Canopy-Coverage Method of Vegetational Analysis. Northwest Science 50:431.

Demers, M. N., J. W. Simpson, R. E. J. Boerner, A. Silva, L. Berns, and F. Artigas. 1995. Fencerows, Edges, and Implications of Changing Connectivity Illustrated by Two Contiguous Ohio Landscapes. Conservation Biology 9:1159-1168.

Dudley, S. J., C. D. Bonham, S. R. Abt, and J. C. Fiscchenich. 1998. Comparison of methods for measuring woody riparian vegetation density. Journal of Arid Environments 38:77-86.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Responses of bobwhites to management in Illinois. Journal of Wildlife Management. 33:749-762.

Errington, P. L., and F. Hamerstrom. 1936. The northern bob-white's winter territory. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.

Everitt B. S., and G. Dunn. 1991 Applied Multivariate Data Analysis. Edward Arnold. London. pp. 219-220.

Farris, A. L., E. D. Klonglan and R. C. Nomsen. 1977. The ring-necked pheasant in Iowa. Iowa Conserv. Comm., Des Moines. 147 p.

Fies, M., M. L. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium. 5:173-179.

Flock, B. E., P. S. Gipson, R. D. Applegate, and W. B. Ballard. 2012. Distance-based habitat associations of northern bobwhites in a fescue-dominated landscape in Kansas. Proceeding of the National Quail Symposium 7:42-51.

Gates, J. E. 1991. Powerline Corridors, Edge Effects, and Wildlife in Forested Landscapes of the Central Appalachians. Wildlife and Habitats in managed landscapes. Island Press Washington D. C. 13-32.

Gates, R. J., A. K. Janke, M. R. Liberati, and M. J. Wiley. 2012. Demographic analysis of a declining northern bobwhite population in southwestern Ohio. Proceedings of the National Quail Symposium 7:184-193.

Getz, W. M., and C. C. Wilmers. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography 27:489-505.

Getz, W. M., S. Fortmann-Roe, P. C. Cross, A. J. Lyons, S. J. Ryan, and C. C. Wilmers. 2007. LoCoH: nonparametric kernel methods for constructing home ranges and utilization distributions. PLoS ONE 2:e207.

Giocomo, J. J. 2005. Conservation of grassland bird populations on military installations in the eastern United States with special emphasis on Fort Campbell Army Base, Kentucky. Ph.D dissertation. Knoxville, TN: University of Tennessee. 181 p.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhite. Journal of Wildlife Management 61:291-301.

Guthery, F. S. 1999. Slack in the configuration of habitat patches for northern bobwhites. Journal of Wildlife Management 63:245-250.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Visibility of northern bobwhite populations. Journal of Wildlife Management 64:646-662.

Guthery, F. S., A. R. Rybak, S. D. Fuhlendorf, T. L. Hiller, S. G. Smith, W. H. Puckett, Jr. and R. A. Barker. 2005. Aspects of the Thermal Ecology of Bobwhites in North Texas. Wildlife Monographs 159:1-36.

Hanson, W. R. and R. J. Miller. 1961. Edge Types and Abundance of Bobwhites in Southern Illinois. The Journal of Wildlife Management 25:71-76.

Harper, C. A. 2007. Strategies for Managing Early Succession Habitat for Wildlife. Weed Technology 21:932-937.

Hicks, L. E. 1935. Distribution of the breeding birds of Ohio. Ohio Biological Survey Bulletin No. 32, 6:125-190.

Higgins, F. H., K. J. Jenkins, G. K. Clambey, D. W. Uresk, D. E. Naugle, J. E. Norland, and W. T. Barker 2005. Vegetation Sampling and Measurement. Techniques for wildlife investigations and management 524-553.

Hiller, T. L., F. S. Guthery, A. R. Rybak, S. D. Fuhlendorf, S. G. Smith, W. H. Puckett, and R. A. Baker. 2007. Management implications of cover selection data: Northern bobwhite example. Journal of Wildlife Management 71:195-201.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440-455.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. The Ohio State University.

Janke, A. K., and R. J. Gates. 2013. Temporal variability in survival of non-breeding northern bobwhites in Ohio. Pages 194-201 *in* T. V. Dailey, andC. E. Braun, editors. Quail VII: Proceedings of the Seventh National Quail Symposium. The University of Tennessee, National Bobwhite Conservation Initiative, Knoxville, Tennessee.

Johnsgard, P. A. 1973. Grouse and quails of North America. Univ. of Nebraska Press, Lincoln. 413 pp.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Bobwhite Quail Symposium 2:1-5.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884-895.

Lehmann, V. W. 1946. Mobility of Bobwhite Quail in Southwestern Texas. The Journal of Wildlife Management 10:124-136.

Leopold, A. 1931. Report on a game survey of the north central states. Democrat Printing Company, Madison, Wisconsin, USA.

Leopold, A. 1933. Game management. Charles Scribners and Son's, New York, USA.

Litvaitis, J. A. 1993. Response of Early Successional Vertebrates to Historic Changes in Land Use. Conservation Biology 7:866-873.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the Edge: Northern Bobwhite Ecology at the Northern Periphery of Their Range. Journal of Wildlife Management 75:52-60.

Lorimer, C. G. 2001. Historical and ecological roles of disturbance in eastern North American forests: 9000 years of change. Wildlife Society Bulletin 29:425-439.

Lusk, J. J., F. S. Guthery, R. R. George, M. J. Peterson, and S. J. DeMaso. 2002. Relative Abundance of Bobwhites in Relation to Weather and Land Use. Journal of Wildlife Management. 66:1040-1051.

Lusk, J. J., S. G. Smith, S. D. Fuhlendorf, and F. S. Guthery. 2006. Factors influencing northern bobwhite nest-site selection and fate. Journal of Wildlife Management 70:564-571.

MacNab, J. 1983. Wildlife management as experimentation. Wildlife Society Bulletin. 11:397-401.

Marlow, C. B. and W. P. Clary 1996. Natural resource monitoring for the Daubenmire disadvantaged. Sharing common ground on western rangelands: Proceedings of a livestock/big game symposium. K. E. Evans. Sparks, NV, USDA Forest Service Intermountain research station: 13-18.

Matson, P. A., W. J. Parton, A. G. Power, and M. J. Smith. 1997. Agricultural intensification and ecosystem properties. Science 277:504-509.

Millenbah, K. F., S. R. Winterstein, H. Campa III, L. T. Furrow, and R. B. Minnis. 1996. Effects of Conservation Reserve Program field age on avian relative abundance, diversity, and productivity. Wilson Bull. 108:760-770.

Missouri Department of Conservation, Natural Resources Conservation Service, Missouri University Extension [MDC/NRCS/UMC]. 2011. Edge Feathering-Forest Edge.

Murphy, D. A., and T. S. Baskett. 1952. Bobwhite mobility in central Missouri. Journal of Wildlife Management 16:498-510.

Mysterud, A. and R. A. Ims. 1998. Functional Responses in Habitat Use: Availability Influences Relative Use in Trade-Off Situations. Ecology 79:1435-1441.

National Climate Data Center [NCDC]. 2015. Quality Controlled Local Climatological Data. <http://www.ncdc.noaa.gov/oa/ncdc.html>.

Noss, R. F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered ecosystems of the United States: A preliminary Assessment of loss and degradation. Biological Report 28, National Biological Service, Washington, D.C., USA.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

O' Connor, R. J. and M. Shrubb. 1986. Farming and birds. Cambridge: Cambridge University Press.

Orians, G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. American Naturalist 137:29-49.

Peterjohn, B. G., and D. L. Rice. 1991. The Ohio breeding bird atlas. Ohio department of Natural Resources, Columbus, Ohio, USA.

Peterjohn, B. G. 2003. Agricultural landscapes: Can they support healthy bird populations as well as farm products? Auk 120:14-19.

Physiographic Regions Of Ohio. 2013. Division of Geological Survey. Department of Natural Resources. Columbus, Ohio, USA. <http://www.dnr.state.oh.us/Portals/10/pdf/physio.pdf>

Polit, D. F. 1996. Data Analysis and Statistics for Nursing Research. Appleton and Lange, Stamford, Connecticut. pp. 320-321.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505–515.

R Development Core Team. 2014. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Riddle, J. D., C. E. Moorman, and K. H. Pollock. 2008. The Importance of Habitat Shape and Landscape Context to Northern Bobwhite Populations. The Journal of Wildlife Management 72:1376-1382.

Roseberry, J. L. 1964. Some Responses of Bobwhites to Snow Cover in Southern Illinois. The Journal of Wildlife Management 28:244-249.

Roseberry, J. L. 1993. Bobwhite and the "new" biology. Proceedings of the National Quail Symposium 3:16-20.

Roseberry, J. L., B. J. Richards, and T. P. Hollenhorst. 1994. Assessing the potential impact of Conservation Reserve Program lands on bobwhite habitat using remote sensing, GIS, and habitat modeling. Photogrammetric Engineering and Remote Sensing 60:1139–1143.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895-902.

Rosene, W. 1984. The bobwhite quail- its life and management. The Sun Press, Hartwell, Georgia, USA.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966 - 2013. Version 01.30.2015. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schmutz, J. A. 1989. Nest Habitat Use of Rio Grande Wild Turkeys. The Wilson Bulletin. 101:591-598.

Seckinger, E. M., L. W. Burger, R. Whittington, A. Houston, R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959-969.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Dissertation, Mississippi State University, Starkville, USA.

Smith, T. M., and R. L. Smith. 2009. Elements of ecology. Seventh edition. Benjamin-Cummings, San Francisco, California, USA.

Spinola, R. M. and R. Gates. 2008. Population Status and Trends of Northern Bobwhite (*Colinus virginianus*) in Ohio: 1984-2004. Ohio Journal of Science 108: 26-30.

Spurr, S. H. 1964. Forest Ecology. Ronald Press company, New York, USA.

Stauffer, D. F., G. A. Cline, and M. J. Tonkovich. 1990. Evaluating potential effects of CRP on bobwhite quail in Piedmont Virginia. North American Wildlife and Natural Resource Conference. 55:57-67.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Son's, New York, USA.

Thompson, D. R., and H. Mattison. 1950. Quail need food, cover-and space. Wisconsin Conservation Bulletin 15:1-4.

Thompson, F. R., and R. M. DeGraaf. 2001. Conservation Approaches for Woody, Early Successional Communities in the Eastern United States. Wildlife Society Bulletin 29:483-494.

Trani, M. K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, C. M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29 2:413-424.

Trautman, M. B. 1940. The Birds of Buckeye Lake, Ohio. University of Michigan Museum of Zoology Miscellaneous Publication. No. 44:1-466.

U.S. Department of Agriculture (USDA). 2015. Washington, D. C.: United States Department of Agriculture, Farm Service Agency. Retrieved March 28, 2015 from <http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp>

Veech, J. A. 2006. Increasing and declining populations on northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922-930.

Weber, W. L., J. L. Roseberry, and A. Woolf. 2002. Influence of the Conservation Reserve Program on landscape structure and potential upland wildlife habitat. Wildlife Society Bulletin 30:888–898.

Wheaton, J. M. 1882. Report on the birds of Ohio. Ohio Geological Survey Bulletin 4:187-628.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, CA, USA.

White, C. G., S. H. Schweitzer, C. T. Moore, I. B. Parnell III, and L. A. Lewis-Weis. 2005. Evaluation of the landscape surrounding northern bobwhite nest sites: a multiscale analysis. Journal of Wildlife Management 69:1528-1537.

Wiley, M. J. 2012. Usable Space and Microhabitat Characteristics for Bobwhites on Private Lands in Southwestern Ohio. Thesis. The Ohio State University.

Wiley, M. J., A. K. Janke, and R. J. Gates. 2013. Efficacy and effects on survival of targeted-mist netting of northern bobwhites in Ohio. Proceedings of the National Quail Symposium.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562-1566.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861-869.

Yoho, N. S. and R. W. Dimmick. 1972. Habitat utilization by bobwhite quail during winter. National Quail Symposium Proceedings 1:90-99.

APPENDIX A: Covey Home-Ranges Using Fixed k LoCoH with a 95% Utilization Distribution During Non-Breeding Seasons 2012 – 2014.

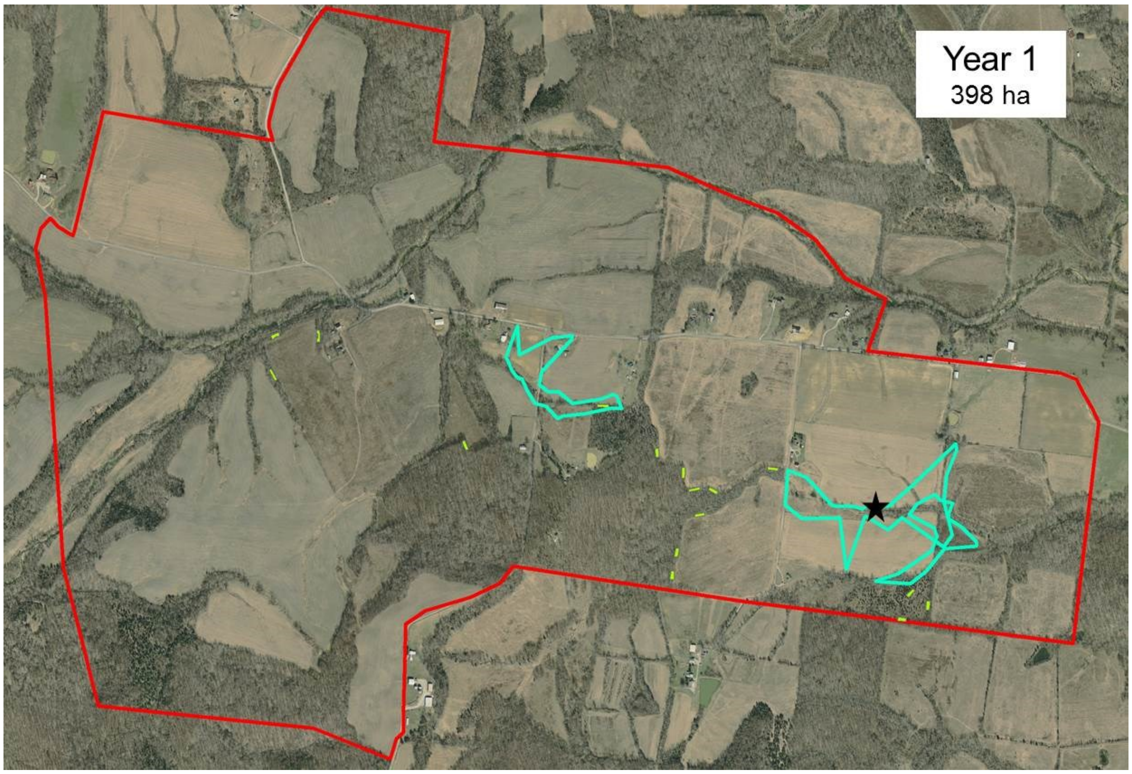


Figure A.1 Locations of radio-marked bobwhite coveys home-range across Peach Orchard during 2012 – 2013 non-breeding season bounded by 95% isopleth of utilization distribution. The black star is the location of an additional covey that did meet the minimum requirements for building home-ranges.

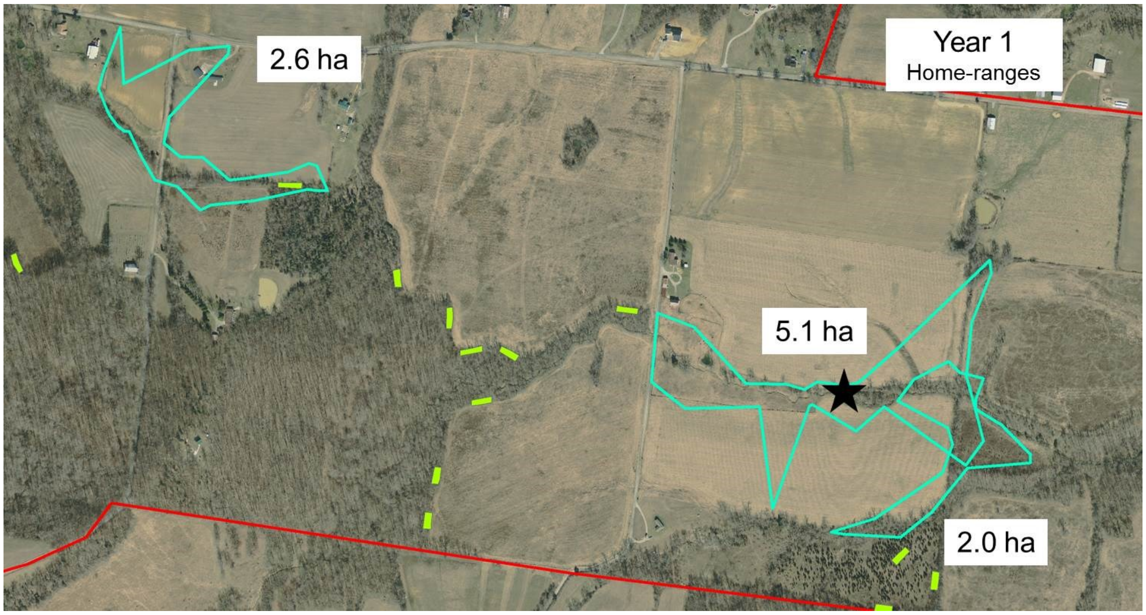


Figure A.2 Locations of radio-marked bobwhite coveys home-range on Peach Orchard during 2012 – 2013 non-breeding seasons bounded by a 95% isopleth of utilization distribution in relation to locations of feathered edges (green rectangles).

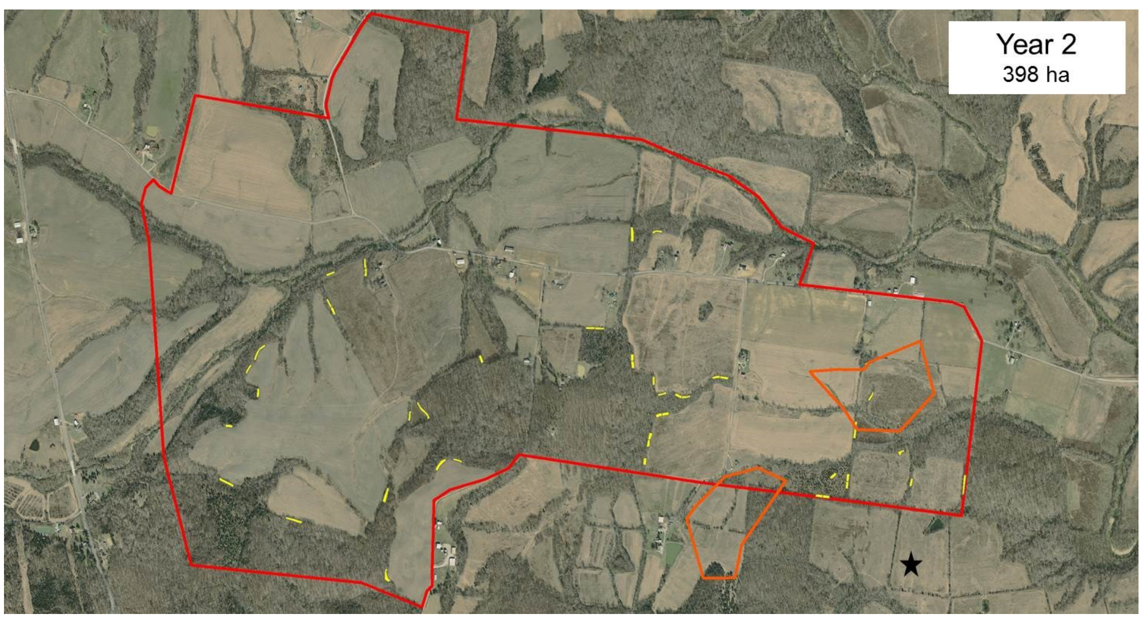


Figure A.3 Locations of radio-marked bobwhite coveys home-range across Peach Orchard during 2013 – 2014 non-breeding season bounded by 95% isopleth of utilization distribution. The black star is the location of an additional covey that did meet the minimum requirements for building home-ranges.

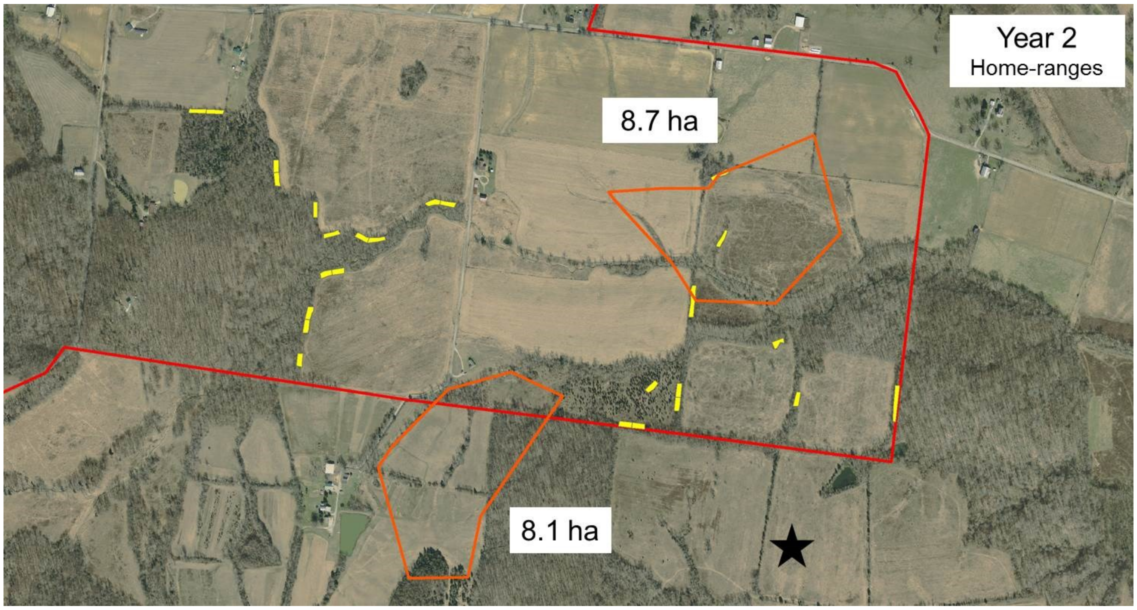


Figure A.4 Locations of radio-marked bobwhite coveys home-range on Peach Orchard during 2013 – 2014 non-breeding season bounded by a 95% isopleth of utilization distribution in relation to locations of feathered edges (yellow rectangles).

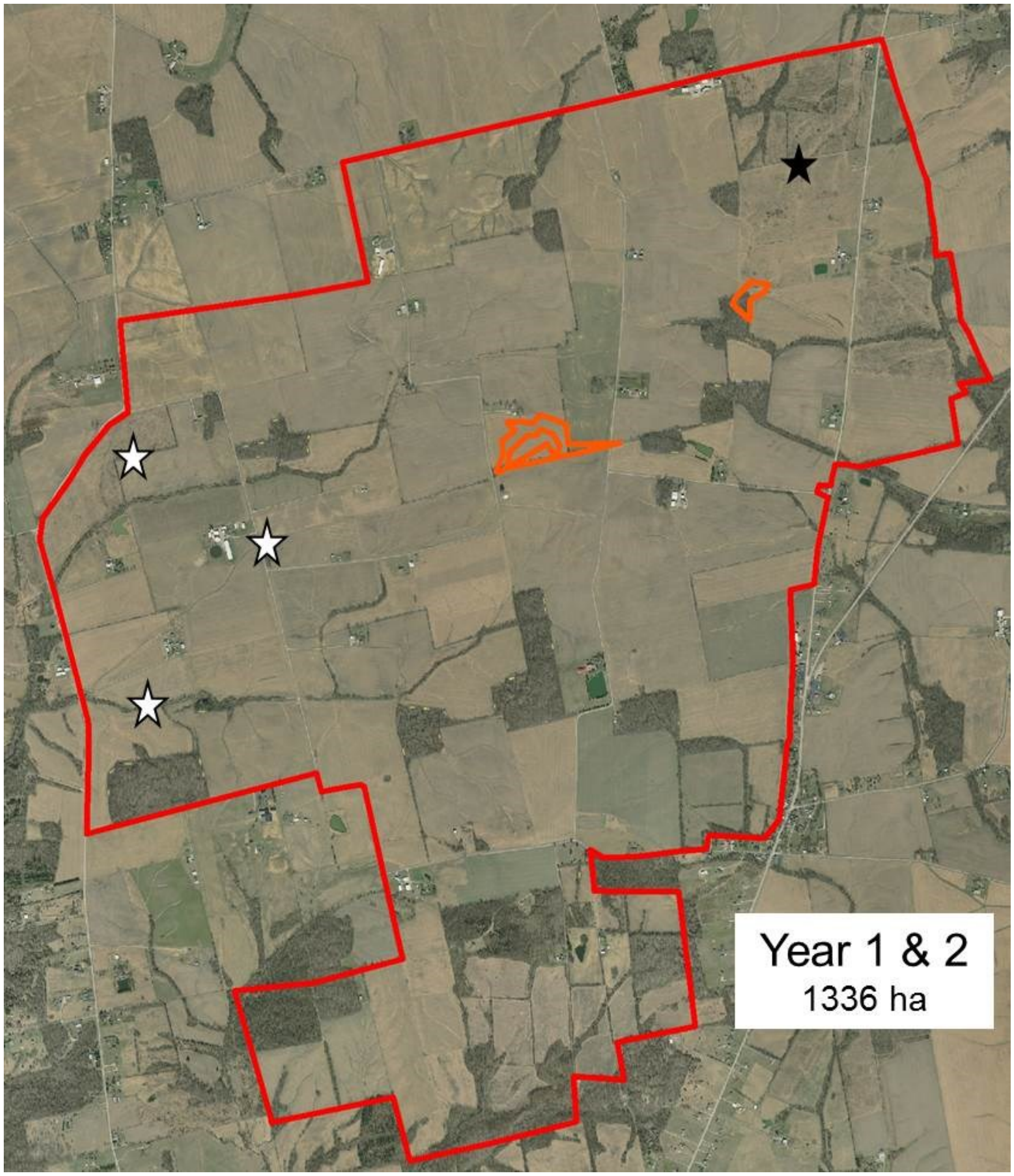


Figure A.5 Locations of radio-marked bobwhite coveys home-range across Fee 2012 – 2014 non-breeding seasons bounded by 95% isopleth of utilization distribution. The white stars are the location of coveys during 2012 – 2013 non-breeding season, and the black star is the location of an additional covey during 2013 – 2014 non-breeding season that did meet the minimum requirements for building home-ranges.

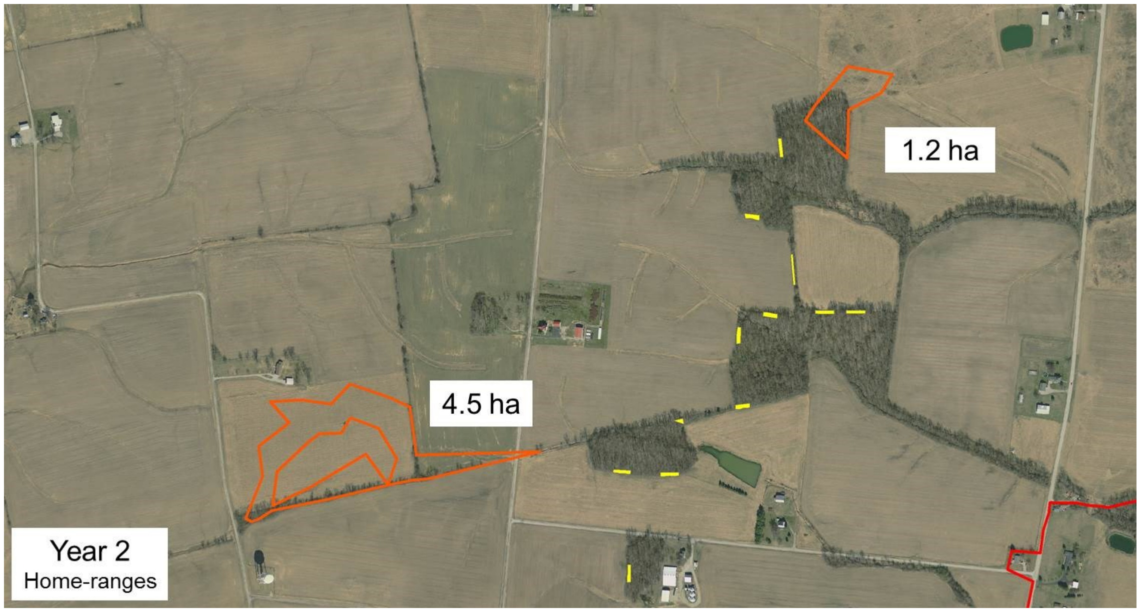


Figure A.6 Locations of radio-marked bobwhite coveys home-range on Fee during 2013 – 2014 non-breeding season bounded by a 95% isopleth of utilization distribution in relation to locations of feathered edges (yellow rectangles).