ABSTRACT

DOUGLASS, KELLY ELAINE. The Effects of Tillage on Shot Concentrations in Publicly Managed Mourning Dove Fields in North Carolina. (Under the direction of David T. Cobb and Phillip D Doerr.)

Despite the research on lead (Pb) shot deposition and ingestion by mourning doves (*Zenaida macroura*), there has been no research to determine how management practices may be utilized to effectively reduce Pb shot concentrations and potentially reduce shot availability in fields managed for dove hunting. We conducted a 2-part study on 5 publicly managed mourning dove fields on Conoho Farms (CF), a segment of the Roanoke River Wetlands Game Land, in Martin County, North Carolina. The goals of this study were to 1) quantify hunter effort and success in the dove fields during the 2007 and 2008 dove hunting seasons and 2) measure shot concentrations in the dove fields from August 2007 to August 2009 and to determine if concentration levels were significantly affected by season, crop, hunter effort, or tillage.

To quantify hunter effort, we mailed self-administered diary surveys (N = 845) to every individual receiving a special hunt (SH) and point-of-sale (POS) permit during both dove hunting seasons on the 5 dove fields in CF. We used the modified Tailored Design method to collect hunter use, effort, and success data for each hunting season. Data were analyzed using the Kruskal-Wallis test to determine differences in hunter effort and success between seasons and permit types and among fields. The adjusted overall response rate for the survey was 74.7%. Only 141 (22.7%) respondents reported hunting doves at CF. Hunters using the 5 fields at CF expended 801.75 hours ($\bar{x}$ = 4.01, SE 0.13), fired 6,782 shots ($\bar{x}$ = 33.91, SE 2.25), and harvested 1,331 doves ($\bar{x}$ = 6.66, SE 0.36) during the 2007-2008 dove hunting seasons. When estimated to the entire

population of permitted dove hunters using CF, hunters would have expended 1,092.17 hours, fired 9,239 shots, and harvested 1,813 doves. Hunters reported firing a mean of 5.68 (SE 0.33) shots per harvested dove. Hunter effort and success per hunting event did not differ between seasons, but were significantly greater for the SH permittees than the POS permittees. SH permittees harvested more doves than POS permittees, and hunter success differed among fields. The number of hours hunted, but not shots fired, differed among fields.

To measure shot concentrations, we collected soil samples from the same 5 dove fields in CF using a complete block design with 12 plots, each of which received a combination of the following planting and management treatments: 3 crops (sunflower (*Helianthus annuus*), millet (*Setaria italica* or *Brachiaria ramosa)*, or corn (*Zea mays*)) and 2 treatments (till or no-till). Soil samples (N = 4,204) were collected before, during, and after dove hunting seasons for 2 years from August 2007 to August 2009. Hunter effort data were standardized by area and categorized (high/low) by block based on the results of the hunter survey. Data were analyzed using a generalized linear mixed model, with a negative binomial distribution, to evaluate differences in shot concentrations among crops and seasons, and between treatments and areas of high and low hunter effort. Shot concentrations differed among seasons and crops and between areas of high and low hunter effort, including a significant interaction between crop and effort. We could not detect any significant effect of treatment, indicating that tillage does not reduce shot concentrations in dove fields. Managers could effectively reduce shot concentrations in dove fields and, therefore, reduce Pb exposure to doves, by limiting hunter access and/or effort or requiring nontoxic shot on managed dove fields.

The Effects of Tillage on Shot Concentrations in Publicly Managed Mourning Dove Fields in North Carolina

by
Kelly Elaine Douglass

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Fisheries, Wildlife, and Conservation Biology

Raleigh, North Carolina

2011

APPROVED BY:

David T. Cobb Co-Chair of Advisory Committee	Phillip D. Doerr Co-Chair of Advisory Committee
Kenneth B. Pollock Minor Representative	Richard A. Lancia Committee Member

DEDICATION

To my grandfathers, Charles Frank and Ross Douglass, for always encouraging me to pursue my dreams. You are dearly missed.

BIOGRAPHY

Kelly Douglass, the younger of two siblings, was born in 1980 to Charles and Rachel Douglass and grew up in Raleigh, North Carolina. She graduated from Enloe High School in 1998 and began her undergraduate studies in Zoology at North Carolina State University the same year. In her second year of college, Kelly switched curriculums and graduated from NCSU in 2002 with a B.S. in Fisheries and Wildlife Sciences and minors in English and Environmental Sciences. During her time as an undergraduate student, she worked as an Assistant Teacher Intern and an Environmental Educator at the North Carolina Museum of Natural Sciences from 2000-2006. She also obtained an internship with the North Carolina Wildlife Resources Commission in 2000, which led to her first permanent position as Captive Cervid Biologist in 2004. The following year, Kelly began her Masters degree in Fisheries, Wildlife, and Conservation Biology at NCSU, with a minor in Statistics. Kelly continued to work as a full-time employee for the duration of her M.S. degree, and obtained a new position with the NCWRC as Forest Stewardship Biologist in June 2010.

ACKNOWLEDGEMENTS

I would like to thank the North Carolina Wildlife Resources Commission (NCWRC) for funding and supporting this project and for retaining me as a full-time employee throughout the course of this study. I would also like to thank North Carolina State University for supporting this research and providing me with a location to store and sieve soil.

I am also grateful to my advisory committee: Dr. David Cobb, Dr. Phil Doerr, Dr. Ken Pollock, and Dr. Richard Lancia. My committee stuck with me, despite the temptations of retired life, international travel, and job offers over the course of 6 years. I especially appreciate the guidance and support that I received from Dr. David Cobb, my co-chair and friend. Your encouragement kept me going.

This project would not have been possible without the help and support of so many people. I tried to keep a list of everyone who helped me throughout the course of this study, so please forgive me if I forgot anyone.

Special thanks to Joe Fuller and the NCWRC Research and Survey biologists for the initial project idea. And thanks to all the guys with the NCWRC piedmont game lands who provided ideas for project design and implementation, when the project was scheduled for Butner-Falls of Neuse game land: Harlan Hall, Isaac Harrold, Chris Dawes, Chris Teague, Mark Dover, Justin McVey, Adam Johnson, Greg Hochstetler, Brian

Michaelsen, Chris Baranski, Brent Beamer, Chris Summerlin, Michael Huffman, and Brandon Minor.

My deepest gratitude to the NCWRC crew who were responsible for planting and managing the dove fields at Conoho Farms: David Turner, Craig Wolff, Shane Felts, Tony Holliday, and Stephen Dulin. I could not have asked for a better crew to work with! I will always appreciate the dedication, commitment, and fortitude you showed throughout the entire project and the friendships we have made. I look forward to many more trips to Williamston in the years to come. A special thanks to Dale Davis and Tommy Hughes, as well, for their never-ending support of their management crews, dedication to this project, hard work, and innovative ideas. You are exceptional men and leaders.

I would like to thank the folks in the NCWRC Engineering Division for their assistance with procuring and operating the high-tech GPS unit: Mark Lee, Tom Covington, David Sutton, and Erik Christofferson. Thanks to Scott Anderson and Jamie Hammermann for guidance with operating GIS software.

I would like to acknowledge the multitude of individuals who helped collect and sieve soil samples: Dale Davis, David Turner, Craig Wolff, Shane Felts, Tommy Hughes, Stephen Dulin, Tony Holliday, Paul Williams, Andrew Cole, William Ridgeway, Vic French, Jessica Homan, Richard Clark, Tad Castellow, Brent Wilson, Andrew Mynatt, Brandon Bridges, Trey Hardison, Walter James, Wynne Hughes, Jeff Jones, Kevin Daughtey, Michael Annas, Michael Huffman, Chris Turner, David Rowe, Robbie

Norville, Deanna Noble, Thomas Padgett, LeAnne Bonner, Ken Knight, George Strader, Greg Batts, Michael Juhan, Michael Carraway, Kimberly McCargo, Joe Fuller, Evin Stanford, Ryan Myers, Adrian Carper, Jim Wilson, Dain Palmer, Daron Barnes, David Cobb, Jane Dalrymple, Jamie Hammermann, Justin McVey, Jenna Begier, Chel Douglass, Ed Davis, Aimee Rockhill, Jonathan Garrow, and Susan McIntyre. Thank you so much for your hard work, despite the long hours and variable weather. And most of all, thank you for the laughs and good times! My stress level would have been much higher had it not been for you.

Thanks to Tommy Hughes, Dan Martin, Jessica Homan, Richard Clark, Tad Castellow, and Trey Hardison for your innovation and ingenuity. Our field work would have been much more difficult without your brilliant invention of the steel shovel that we used to collect soil samples and what we so fondly referred to as the "contraption."

I would like the following individuals for helping with the hunter survey, by entering survey data, running license queries, creating databases, mailing surveys, and providing information on permit hunts: Lisa Hocutt, Jamie Sosnowski, Kim Sparks, Heather Geary, Wanda Mugo, Pat Dupree, Nea Nettles, and Sheila Rand. I would like to extend special appreciation to Dain Palmer, for his help with survey design, implementation, analysis, and thesis review – my knowledge of quantitative human dimensions has greatly improved, thanks to you. I would also like to thank the hunters who obtained a permit to hunt doves on Conoho Farms, and those who responded to our survey.

My sincerest gratitude goes to Dr. Jason Osborne, for his statistical consultation and patience. Dr. Osborne dedicated numerous hours helping me analyze data, despite the complexities of my study design. I would like to thank Adrian Carper, as well, for his help with data analysis. Thanks to Jim Wilson and Erica Cutchins for editing my thesis. And thanks to my supervisors in the NCWRC for their patience and flexibility with my work schedule: Daron Barnes, Brad Gunn, David Cobb, Ken Knight, Brad Howard, and Isaac Harrold.

Finally, I thank my friends and family, who continuously gave me their love and support, not just in the last 6 years but throughout my entire life. I could not have done any of this without you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Lead (Pb) toxicity was first identified in wild birds in 1842, with the first documented cases of Pb poisoning in the United States in the late 1870s (Friend et al. 2009). Reports of Pb poisoning in birds, especially waterfowl, became increasingly common over the 20th Century and by the 1980s, scientists had confirmed that the accumulation of spent Pb shot in the environment, primarily from hunting activities, was the most common means of exposure to Pb by waterfowl and was a significant mortality factor in waterfowl species (Shillinger and Cottam 1937, Jordan and Bellrose 1950, Bellrose 1951, Jordan and Bellrose 1951, Coburn et al. 1951, Bellrose 1959, White and Stendell 1977, Longcore et al. 1982, Kendall and Driver 1982, Mudge 1983, Sanderson and Bellrose 1986, Anderson et al. 1987, Srebocan and Rattner 1988, Pain and Rattner 1988, Smit et al. 1988, Friend et al. 2009). Annual total mortality estimates attributed to Pb poisoning for North American waterfowl populations ranged from 1.5 to 3 million birds (Davidson 2006).

As a result, the U.S. Fish and Wildlife Service completed an Environmental Impact Statement (EIS) discussing the use of nontoxic alternatives to Pb shot for waterfowl hunting (USFWS 1985). The results of that EIS led the U.S. Fish and Wildlife Service to phase in a national prohibition from 1986-1991 on the use of Pb shot for waterfowl hunting (USFWS 1986). Despite the research conducted in the 1960s and 1970s on the effects of Pb shot ingestion in other birds, insufficient research existed to

justify the use of nontoxic shot for hunting non-waterfowl species (Friend et al. 2009). Shortly after the North American ban on using Pb shot for waterfowl, a surge of research occurred throughout the world on Pb exposure, ingestion, and toxicity in other avian species. Today, research has documented the ingestion of Pb ammunition – shot pellets, bullets and/or fragments, and prey contaminated with Pb ammunition – by over 120 avian species (Tranel and Kimmel 2009).

Studies on Pb shot ingestion by mourning doves (*Zenaida macroura*) have reported ingestion frequencies ranging from 0.2% to 6.5% of birds sampled and documented a range of 1-24 pellets (Table 1). These ingestion frequencies are based on manual or x-ray examination of gizzards, collected from hunter-harvested birds, for the presence of Pb shot pellets. The results of these studies may be negatively biased because: 1) both manual and x-ray examination of gizzards may fail to detect all Pb pellets in the gizzard (Sanderson and Bellrose 1986); 2) birds passing or completely grinding an ingested Pb pellet may appear to never have ingested Pb shot by sampling only the gizzards and not other soft tissues for Pb content (Sanderson and Bellrose 1986); and 3) mourning doves which ingest as few as two Pb shot pellets may die from Pb poisoning within hours of ingestion and therefore may not be sampled (Schulz et al. 2006).

Pb shot pellets ingested by doves are excreted, regurgitated, or retained in the gizzard (Franson 1996, Plautz 2009). Pellets retained in the gizzard are converted to toxic Pb salts through a combination of mechanical and chemical degradation, which may

take up to 6 weeks (Franson 1996, Pain 1996). The Pb salts are absorbed into the bloodstream, rapidly deposited in soft tissues such as the liver and kidney, and later deposited in bone. Therefore, Pb exposure and toxicity can be determined, with or without the presence of Pb shot in the body, by examining various body tissues for Pb concentrations. Ingestion frequencies based on Pb concentrations in body tissue seem to be more accurate in determining actual Pb shot ingestion than those based solely on examining the presence of Pb shot in gizzards (Kendall and Scanlon 1979, Castrale and Oster 1993, Kendall et al. 1996). Ingestion frequencies based on tissue analysis in Pb-dosed doves have ranged from 10.9% to 60.0%, much higher than those based on pellet counts in gizzards (Locke and Bagley 1967, Kendall and Scanlon 1979, George, III 1987, Castrale and Oster 1993).

The physiological effects of Pb shot ingestion on the exposed bird seem to be directly related to pellet retention time and Pb dissolution and absorption within the body, which are affected by environmental conditions at the time of ingestion and the condition, gender, age, and dietary components of the bird (Plautz 2009). Schulz et al. (2006) reported an increase in survivorship for male (2.5%) and female (3.8%) doves with each 1-g increase in body mass prior to ingesting Pb shot, indicating that a greater body mass prior to ingesting Pb shot may increase survivability. Dieter et al. (1976) and Finley and Dieter (1978) reported female birds having higher bone Pb concentrations during the breeding season, possibly due to the replacement of calcium (Ca) for eggshell production with Pb or an increase in grit ingestion, which may decrease female survivability (Trost

1981, Scheuhammer 1996). Franson et al. (2009) found hatch year mourning doves to ingest Pb shot pellets at a greater frequency (3.5%) than after hatch year birds (0.08%). Younger birds may also experience a greater effect of Pb toxicity than older birds, including increased mortality, reduced growth, severe depression of red blood cell activity, oxidative stress, and reduced liver weights (McConnell 1967, Hoffman et al. 2000*a, b*). Buerger et al. (1986) found that 91% of the mourning doves ingesting Pb pellets died on days when minimum daily temperatures were at or below freezing (≤ 0° C), whereas all doves ingesting 1 Pb pellet and housed indoors with controlled temperatures survived, indicating that colder temperatures may increase mortality in Pb-dosed birds. Kendall et al. (1981) reported 72% mortality in Pb-dosed ringed turtle doves exposed to cold temperatures (6° C ± 1° C) and 0% mortality in Pb-dosed doves not exposed to cold temperatures (21° C ± 1° C).

Although Marn et al. (1988) did not report any significant differences in Pb tissue concentrations between mourning doves held at different temperatures (5° C or 22° C), they did find that Pb-dosed doves held at the colder temperature and given mixed seed-corn (versus a commercial pelleted diet) had significantly higher Pb in kidney tissues. They suggested that diet had the most influence on retention time and erosion of Pb pellets and the amount of Pb retained in body tissues, and that susceptibility to Pb toxicosis was dependent on the degree of Pb shot exposure and the composition and nutritional content of mourning dove diets. The selection and consumption of soft seed over hard seed, and/or green, leafy foods or insects over seeds, as well as increased

consumption of Ca and protein may reduce Pb toxicity (McConnell 1967, Trost 1981, Marn et al. 1988). Schulz et al. (2007) found that doves ingesting Pb pellets with a bolus of food may increase the passing of pellets through the digestive system, where as birds ingesting Pb pellets in between feedings retained pellets longer. Schulz et al. (2006) later supported this theory by showing that shorter retention time of Pb pellets in the gizzard decreased Pb absorption and toxicity and increased survivability in doves. They reported higher survival rates for doves that retained ≤ 2 pellets at 2 days post-ingestion (57%) than doves that retained 13-19 pellets at 2 days post-ingestion (8%).

The specific level of Pb toxicity a mourning dove may experience after ingesting 1 Pb pellet, or any other specified amount of Pb, is impossible to determine because of individual variation – diet, gender, age, weight, temperature, and pellet retention time (Kendall et al. 2006). Studies have, however, documented that an increase in the ingestion of Pb pellets decreased survival in mourning doves. Schulz et al. (2006) found that mortality increased by 18% for each additional pellet ingested. Birds ingesting multiple pellets may die quickly from the acute effects of Pb poisoning, whereas birds ingesting only 1 pellet may not necessarily die from Pb toxicity, but may experience reduced body function as a result from the chronic effects of Pb toxicity. Reduced body function – anemia, weight loss, reductions in brain function, oxygen carrying capacity, and circulatory function – may lead to compromised immunity, which may cause changes in animal behavior or flight patterns or activity and may result in increased predation and increased disease susceptibility (Carrington and Mirarchi 1989, Schulz et al. 2006). As

Pb ingestion may cause direct or indirect mortality, morbidity effects should be considered, in addition to direct mortality, when determining the cumulative survival rate of birds ingesting Pb.

Another facet of mourning dove research related to Pb exposure focused on determining the amount of Pb pellets that were being deposited on fields managed for hunting. Studies have reported Pb shot concentrations in the top soil layers of managed dove fields ranging from 0 pellets/ha to 107,639 pellets/ha (Table 2). Increases in shot concentrations over time, primarily based on results from examining soil samples collected pre- and post-hunting, were documented in all of these studies. Anderson (1986) reported a 211% increase in shot concentrations after 4 months, whereas Lewis and Legler (1968) reported a 300% increase in shot concentrations after a 2-day dove hunt.

One study documented how shot concentrations changed over time and the potential effects of tillage on Pb shot concentrations in mourning dove fields by collecting soil samples pre- and post-hunt and pre- and post-tillage from 15 dove fields in Indiana (Castrale 1989). All fields were either plowed or disked, and planted in sunflowers (*Helianthus annuus*), with some fields including strips of wheat (*Triticum sp.*), corn (*Zea mays*), proso millet (*Panicum miliaceum*), or milo (*Sorghum bicolor).* Fields varied in size, from 0.8 ha to 15.7 ha, and shape, from large rectangular fields to long, narrow strips. Soil samples were collected unequally between fields and across time: pre-hunt (n = 700) from 17 fields, post-hunt (n = 750) from 15 fields, pre-tillage (n

= 500) from 5 fields, and post-tillage (n = 456) from 6 fields. Pb concentrations increased 645% in the 13 fields sampled pre- and post-hunt, and decreased 1.2% in the 5 fields sampled post-hunt and pre-tillage. He also documented a 73% decrease in Pb concentrations, on average, in the 6 fields sampled pre- and post-tillage, and indicated that the degree of tillage was directly related to a reduction in Pb shot. Despite the percent decrease he reported in shot concentrations post-tillage, the actual effects of tillage on Pb concentrations were unknown because the degree of tillage was not consistent across fields and was not uniformly applied as a treatment; nor was tillage replicated in all crop types.

When examining the cumulative research on Pb ingestion rates by mourning doves, the resulting health effects and mortality rates, and the concentrations of Pb shot to which doves may potentially be exposed, such variability in the results may lead wildlife managers to grossly over or underestimate the impacts of Pb toxicity on mourning dove populations. Plautz (2009) estimated that 0.98 million doves (range 0.34-1.66 million) may potentially die from ingesting Pb shot pellets, assuming 10% of the fall mourning dove population feeds in high risk areas, such as managed dove fields, with a 75% mortality rate (Dolton et al. 2007, Plautz 2009). Although this number may seem insignificant when compared to the annual harvest of 20-25 million doves per year (Dolton et al. 2007), the potential impact to mourning dove populations in North America may be considerable, given the possible range of Pb shot ingestion reported in the literature, the various health effects and mortality rates caused by Pb toxicity, and the

undetermined effects of indirect mortality associated with Pb ingestion. The population impacts of Pb toxicity may become even more pronounced when considering the persistence of Pb in undisturbed soils (Jorgensen and Willems 1987) and the possibility of increased Pb shot deposition over time and shot availability in dove fields with high hunter pressure and limited tillage.

From 1966-2009, mourning dove population trends in the Eastern Management Unit (EMU) have increased based on the number of doves heard and seen in the Breeding Bird Survey, or decreased based on the number of doves heard in Mourning Dove Call-count Survey (CCS), or remained stable based on the number of doves seen in the CCS (Dolton et al. 2009). Therefore, with the increased interest in Pb toxicity in doves and the conflicting results of mourning dove survey data within the EMU, it becomes increasingly important to demonstrate if management practices may be utilized by state fish and wildlife agencies to effectively reduce Pb shot concentrations in mourning dove fields, and thus potentially reduce Pb availability.

The goals of this project were to determine shot concentrations in publicly managed mourning dove fields in North Carolina (located within the EMU) and to determine if concentration levels were significantly affected by tillage. The specific objectives of this study included: 1) measuring the concentration of shot pellets in soil samples taken from 5 dove fields in eastern North Carolina from August 2007 to August 2009; 2) measuring hunter effort and success on these fields during the 2007 and 2008 dove hunting seasons; and 3) determining the effects of sampling period, tillage, crop

type, and hunter effort on the shot concentrations found in these fields. Hypotheses for this study that will be tested include:

H_{O-1}: Shot pellets will not be found in any soil samples;

H_{O-2}: Shot concentrations will not differ among sampling periods (i.e. no change over time);

H_{O-3}: Shot concentrations will not differ among crop types;

H_{O-4}: Shot concentrations will not differ among management treatments; and

H_{O-5}: Hunter effort will not differ between fields or over time.

LITERATURE CITED

Anderson, W.L. 1986. Investigations of abundance of spent shotgun pellets in soil and sediment in Illinois. Pages 43-49 *in* J. S. Feierabend and A. B. Russell, editors. Proceedings of the symposium on lead poisoning in wild waterfowl: a workshop. National Wildlife Federation, Washington, D.C., USA

Anderson, W.L., S.P. Havera, and R.A. Montgomery. 1987. Incidence of ingested shot in waterfowl in the Mississippi Flyway, 1977-1979. Wildlife Society Bulletin 15:181-188.

Bellrose, F.S. 1951 Effects of ingested lead shot upon waterfowl populations. North American Wildlife Conference Transactions 16:125-135.

Bellrose, F.C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Natural History Survey Bulletin 27:235-288.

Best, T.L., T.E. Garrison, and C.G. Schmitt. 1992. Availability and ingestion of lead shot by mourning doves (Zenaida macroura) in Southeastern New Mexico. Southwestern Naturalist 37:287-292.

Buerger, T.T., R.E. Mirarchi, and M.E. Lisano. 1986. Effects of lead shot ingestion on captive mourning dove survivability and reproduction. Journal of Wildlife Management 50:1-8.

Carrington, M.E. and R.E. Mirarchi. 1989. Effects of lead shot ingestion on free-ranging mourning doves. Bulletin of Environmental Contamination and Toxicology 43:173-179.

Castrale, J.S. 1989. Availability of spent lead shot in fields managed for mourning dove hunting. Wildlife Society Bulletin 17:184-189.

Castrale, J.S. 1991. Spent shot ingestion by mourning doves in Indiana. Proceedings of the Indiana Academy of Science 100:197-202.

Castrale, J.S. and M. Oster. 1993. Lead and δ-aminolevulinic acid dehydratase in the blood of mourning doves dosed with lead shot. Proceedings of the Indiana Academy of Science 102:265-272.

Coburn, D.R., D.W. Metzler, and R. Treichler. 1951. A study of absorption and retention of lead in wild waterfowl in relation to clinical evidence of lead poisoning. Journal of Wildlife Management 15:186-192.

Davidson, W.R. 2006. Field manual of wildlife diseases in the Southeastern United States. Third edition. Southeastern Cooperative Wildlife Disease Study, Athens, Georgia, USA.

Dieter, M.P., M.C. Perry, and B.M. Mulhern. 1976. Lead and PCB's in canvasback ducks: a relationship between enzyme levels and residues in blood. Archives of Environmental Contamination and Toxicology 4:1-3.

Dolton, D.D. T.A. Sanders, and K. Parker. 2009. Mourning dove, white-winged dove, and band-tailed pigeon population status, 2009. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Finley, M.T. and M.P. Dieter. 1978. Influence of laying on lead accumulation in bone of mallard ducks. Journal of Toxicology and Environmental Health, Part A 4:123-129.

Franson, J.C. 1996. Interpretation of tissue lead residues in birds other than waterfowl. Pages 265-279 *in* W.N. Mayer, G.H. Heinz, and A.W. Redman-Norwood, editors. Environmental contaminants in wildlife: interpreting tissue concentrations. Lewis Publishers, CRC Press, Boca Raton, Florida, USA.

Friend, M., J.C. Franson, and W.L. Anderson. 2009. Biological and societal dimensions of lead poisoning in birds in the USA. Pages 34-60 *in* R.T. Watson, M. Fuller, M. Pokras, and W.G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA.

George, III, A.L. 1987. Effects of lead shot ingestion on several blood variables and bodyweight in mourning doves. Thesis, Auburn University, Auburn, Alabama, USA.

Hoffman, D.J., G.H. Heinz, L. Sileo, D.J. Audet, J.K. Campbell, L.J. LeCaptain, and H.H. Obrecht, III. 2000. Developmental toxicity of lead-contaminated sediment in Canada geese (*Branta canadensis*). Journal of Toxicology and Environmental Health, Part A 59:235-252.

Hoffman, D.J., G.H Heinz, L. Sileo, D.J. Audet, J.K. Campbell, and L.J. LeCaptain. 2000. Developmental toxicity of lead-contaminated sediment to mallard ducklings. Archives of Environmental Contamination and Toxicology 39:221-232.

Jordan, J.S. and F.C. Bellrose. 1950. Shot alloys and lead poisoning in waterfowl. Transactions of the 15th Annual North American Wildlife Conference 155-168.

Jordan, J.S. and F.C. Bellrose. 1951. Lead poisoning in wild waterfowl. Illinois Natural History Survey Biological Notes No. 26.

Jorgensen, S.S. and M. Willems. 1987. The fate of lead in soils: the transformation of lead pellets in shooting-range soils. Ambio 16:11-15.

Kendall, R.J. and C.J. Driver. 1982. Lead poisoning in swans in Washington State. Journal of Wildlife Diseases 18:385-387.

Kendall, R.J. and P.F. Scanlon. 1979. Lead concentrations in mourning doves collected from middle Atlantic game management areas. Proceedings of the 33rd Annual Conference Southeastern Association of Fish and Wildlife Agencies 33:165-172.

Kendall, R.J., H.P. Veit, and P.F. Scanlon. 1981. Histological effects and lead concentrations in tissues of adult male ringed turtle doves that ingested lead shot. Journal of Toxicology and Environmental Health 8:649-658.

Kendall, R.J., T.E. Lacher, Jr., C. Bunck, B. Daniel, C. Driver, C.E. Grue, F. Leighton, W. Stansley, P.G. Watanabe, and M. Whitworth. 1996. An ecological risk assessment of lead shot exposure in non-waterfowl avian species: upland game birds and raptors. Environmental Toxicology and Chemistry 15:4-20.

Lewis, J.C. and E. Legler. 1968. Lead shot ingestion by mourning doves and incidence in soil. Journal of Wildlife Management 32:476-482.

Locke, L.N. and G.E. Bagley. 1967. Lead poisoning in a sample of Maryland mourning doves. Journal of Wildlife Management 31:515-518.

Longcore, J.R., P.O. Corr, and W.E. Spencer, Jr. 1982. Lead shot incidence in sediments and waterfowl gizzards from Merrymeeting Bay, Maine. Wildlife Society Buletin 10:3-10.

Marn, C.M., R.E. Mirarchi, and M.E. Lisano. 1988. Effects of diet and cold exposure on captive female mourning doves dosed with lead shot. Archives of Environmental Contamination and Toxicology 17:589-594.

McConnell, C.A. 1967. Experimental lead poisoning of bobwhite quail and mourning doves. Proceedings of the 21st Annual Conference Southeastern Association of Fish and Wildlife Commissioners 21:208-219.

Mudge, G.P. 1983. The incidence and significance of ingested lead pellet poisoning in British wildfowl. Biological Conservation 27:333-372.

Pain, D.J. 1996. Lead in waterfowl. Pages 251-264 *in* Beyer, W.N., G.H. Heinz, and A.W. Redmon-Norwood, editors. Environmental contaminants in wildlife: interpreting tissue concentrations. CRC Press, Inc. Boca Raton, Florida, USA.

Pain, D.J. and B.A. Rattner. 1988. Mortality and hematology associated with the ingestion of one number four lead shot in black ducks, *Anas rubripes*. Bulletin of Environmental Contamination and Toxicology 40:159-164.

Plautz, S.C. 2009. The voluntary lead shot ingestion rate of mourning doves (*Zenaida macroura*) on a disked field. Thesis, Southern Illinois University Carbondale, Carbondale, Illinois, USA

Sanderson, G.C. and F.C. Bellrose. 1986. A review of the problem of lead poisoning in waterfowl. Illinois Natural History Survey Special Publication 4:1-34.

Schulz, J.H., J.J. Millspaugh, B.E. Washburn, G.R. Wester, J.T. Langian III, and J.C. Franson. 2002. Spent-shot availability and ingestion on areas managed for mourning doves. Wildlife Society Bulletin 30:112-120.

Schulz, J.H. J.J. Millspaugh, A.J. Bermudez, X. Gao, T.W. Bonnot, L.G. Britt, and M. Paine. 2006b. Acute lead toxicosis in mourning doves. Journal of Wildlife Management 70:413-421.

Schulz, J.H., X. Gao, J.J. Millspaugh, and A.J. Bermudez. 2007. Experimental lead pellet ingestion in mourning doves (*Zenaida macroura*). The American Midland Naturalist 158:177-190.

Shillinger, J.E. and C.C. Cottam. 1937. The importance of lead shot in waterfowl. Transactions of the 2nd North American Wildlife Conference 398-403.

Smit, T., C.G. vanLieshout, G.J. deGraaf, H. vanBeek, and L.G. Moraal. 1988. Influence of the consumption of lead shot on the health of birds. Limosa 61:179-182.

Srebocan, E. and B.A. Rattner. 1988. Heat exposure and the toxicity of one number four lead shot in mallards, *Anas platyrhynchos*. Bulletin of Environmental Contamination and Toxicology 40:165-169.

Tranel, M.A. and R.O Kimmel. 2009. Impacts of lead ammunition on wildlife, the environment, and human health–A literature review and implications for Minnesota. Pages 318-337 *in* R.T. Watson, M. Fuller, M. Pokras, and W.G. Hunt (Eds.).

Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA.

Trost, R.E. 1981. Dynamics of grit selection and retention in captive mallards. Journal of Wildlife Management 45:64-73.

U.S. Fish and Wildlife Service. 1985. Draft supplemental environmental impact statement on the use of lead shot for hunting migratory birds in the United States. U.S. Department of the Interior, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 1986. Final supplemental environmental impact statement. Use of lead shot for hunting migratory birds in the United States. U.S. Department of the Interior, Washington, D.C., USA.

White, D.H. and R.C. Stendell. 1977. Waterfowl exposure to lead and steel shot on selected hunting areas. Journal of Wildlife Management 41: 469-475.

Table 1. Frequency of lead shot ingestion by mourning doves, based on manual or x-ray examination of dove gizzards collected from samples of hunter-harvested birds, as reported in the literature.

Study	No. of doves collected	Frequency of shot ingestion	No. of pellets ingested per dove (range)	Study area
Locke and Bagley (1967)	62	6.5%	1-3	Maryland
Lewis and Legler (1968)	1,949	1.2%	1-24	Tennessee
Kendall and Scanlon (1979)	412	2.4%	1-2	Maryland, Virginia, North Carolina, and South Carolina
Castrale (1991)	3,386	2.5%	1-16	Indiana
Best et al. (1992)	420	0.2%	1	New Mexico
Schulz et al. (2002)	884	0.3%	1	Missouri

Table 2. Lead shot concentration estimates in mourning dove fields, including the number of fields sampled, the volume of soil collected per sample, the total number of soil samples collected, and the total number of pellets found during each study, as reported in the literature.

Study	Number of fields sampled	Volume of soil collected per sample (cm^3)	Number of soil samples collected	Number of pellets found	Shot concentration estimates (pellets/ha)[a]
Lewis and Legler (1968)	1	279.08	100	81	27,132 – 107,639
Anderson (1968)	1	1,209.34	150	84	23,500 – 73,200
Castrale (1989)	15	1,209.34	2,406	Not reported[b]	0 – 83,928
Schulz et al. (2002)	2	930.25	834	19	353 – 6,342

[a]Shot concentration estimates were reported by authors in area (pellets/ha), not volume (pellets/ cm^3), units.

[b]The total number of pellets found was not reported by the author; only shot concentration estimates per sampling period were provided.

STUDY AREA

This study was conducted at Conoho Farms (CF), a segment of the Roanoke River Wetlands Game Land (RRWGL). RRWGL is publicly owned and managed by the North Carolina Wildlife Resources Commission (NCWRC) and consists of 16,985 ha in Bertie, Halifax, Martin, and Northampton counties, North Carolina (Figure 1). RRWGL was purchased jointly by the North Carolina Department of Transportation, North Carolina Wildlife Resources Commission, and the U.S. Fish and Wildlife Service in the late 1980s and early 1990s. RRWGL is a permit-only hunt area, including special opportunities for hunting white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), small game, dove, and waterfowl.

The NCWRC manages 5 fields in CF specifically for mourning dove (*Zenaida macroura*) hunting; all are located off Hwy 125 North in Williamston, North Carolina (Figure 2). These fields range in size from 1.5 ha to 13.4 ha. Before the NCWRC acquired CF, the fields were heavily grazed as part of an active cattle farm. The first year after acquisition, the NCWRC removed the farm buildings and fences from the property, applied several herbicide treatments to control the fescue (*Festuca arundinacea*), and planted buckwheat (*Fagopyrum esculentum*) in the fields. The following year, 1997, the NCWRC began managing the fields intensively for dove hunting. The fields were planted in strips of sunflowers (*Helianthus annuus*) and millet (*Setaria italica* or *Brachiaria ramosa)* using a combination of till and no-till practices and sprayed with

herbicide as needed to control other vegetation. Portions of the sunflower and millet strips were mowed, and sections of the millet strips were burned, each year < 2 weeks prior to the hunting season. Sunflower and millet strips were rotated within the fields annually to increase the efficacy of herbicide applications. In the early 2000s, strips of corn (*Zea mays*), milo (*Sorghum* sp.), and native warm season grasses were added to the fields and the management regime continued in the same way, with annual crop rotations, till and no-till planting, herbicide treatments, and mowing or burning portions of each crop strips prior to the hunting season (D. Davis, NCWRC, personal communication).

These fields were chosen for this study because they were: 1) located < 1 km from each other, minimizing environmental variation due to precipitation, topography, and soil characteristics; 2) reported as having heavy hunter use; 3) consistently managed; 4) large enough in size to meet the study design requirements; and 5) all included in the NCWRC permit hunt system.

Herbicides

Twelve plots were established within the 5 dove fields at CF for this study. Herbicides were used on the plots consistently throughout the study period to control weeds and maintain dominant crops. Although the timing of herbicide treatments and planting were weather dependent, the management activities varied only slightly from year to year.

No-till corn plots were sprayed with glyphosate (Roundup WeatherMAX®) at a rate of 1.6 L/ha around the second week in April each year to kill all vegetation and

facilitate planting. Tilled corn plots were not sprayed with herbicide prior to planting. All corn plots were planted with Roundup Ready® corn around mid-April, and sprayed post-emergent with glyphosate (Roundup WeatherMAX®) at a rate of 1.6 L/ha around mid- to late-May to control weeds.

No-till sunflower plots were sprayed with glyphosate (Roundup WeatherMAX®) at a rate of 1.6 L/ha around the second week in April each year to kill all vegetation and facilitate planting. Tilled sunflower plots were not sprayed with glyphosate prior to planting. All sunflower plots were sprayed pre-emergent with Prowl® H2O at a rate of 2.3 L/ha around the last week in April and planted with Clearfield™ sunflower seeds early- to mid-May. All sunflower plots were sprayed post-emergent with Beyond® at a rate of 0.3 L/ha in late-May to control weeds.

All millet plots were sprayed with glyphosate (Roundup WeatherMAX®) at a rate of 1.6 L/ha in mid-April each year to kill all vegetation and facilitate planting. Millet plots were not sprayed with a post-emergent herbicide when planted in mid-to late-May.

Hunting Pressure

Dove hunters were required to obtain 2 special permits from the NCWRC to hunt on CF throughout the season: a special hunt (SH) permit for 5 days during the first 2 weeks of the season and a point-of-sale (POS) permit for the remainder of the season. The NCWRC established daily hunter quotas of 50 hunters per day for the 5 SH days, but did not limit hunting during the POS days (i.e., no quota). Prior to 2005, CF was heavily

hunted on the opening weekend of each season and all SH permits were sold for the first 2 SH days (D. Davis, NCWRC, personal communication). All permits for the remaining 3 SH may or may not have been sold, and the hunting activity continued to decrease throughout the remainder of the season (D. Davis, NCWRC, personal communication). After 2005, daily quotas were met each year for all SH days, except for the last SH day in 2005 (L. Hocutt, NCWRC, unpublished data). The number of SH and POS permits sold each year since 2005 was 107-178 permits and ≥ 185 permits, respectively (L. Hocutt, NCWRC, unpublished data; Table 3).

Soils

Six different soils occurred on the study plots (U.S. Department of Agriculture 1989): Norfolk loamy fine sand (NoB, NoA), Bonneau loamy sand (BoC, BoB), Lynchburg fine sandy loam (Ly), and Goldsboro fine sandy loam (GoA) (Figure 3). The total plot area covered by these soil types ranged from 0.2% for GoA to 44.4% for NoB (Table 4).

Four of these soils are categorized within 2 soil series, NoB and NoA (in the Norfolk series) and BoC and BoB (in the Bonneau series), and thus have very similar soil characteristics (Table 5). Norfolk and Bonneau soils are the dominant soils on the study plots and represent a total of 95.5% of the total plot area. They are both well drained soils, with a moderate to rapid permeability, weak fine to fine granular structure, and

medium acidity. They have a slope range of 0% to 12%, and are light yellowish to grayish brown in color.

Climate

Climatological data for the study period, August 2007 through September 2009, were obtained on-line from the National Climatic Data Center for Williamston, North Carolina (National Oceanic and Atmospheric Administration 2011).

Daily temperatures and 24-hour precipitation totals were converted to metric units. Descriptive statistics for temperature (° C) were calculated, including daily highs, daily lows, mean daily temperatures, standard deviations for each mean, and the maximum and minimum daily temperatures for each month (Table 6). Descriptive statistics for 24-hour precipitation (cm) were also calculated, including daily maximums, mean daily precipitation, and standard deviations for each mean, monthly sums, and annual means (Table 7). The minimum daily precipitation for each month was 0 cm.

Daily temperatures throughout the study period ranged from -10.6° C to 38.3° C (Figure 4). The maximum daily temperature was recorded on 9-10 August 2007 and 9 June 2008, and the minimum daily temperature was recorded on 17-19 January 2009.

The 24-hour precipitation totals throughout the study period ranged from 0 cm to 10.5 cm (Figure 5). The maximum daily precipitation occurred on 24 July 2008. The most precipitation (20.2 cm) occurred during July 2008, whereas June 2008 received the least precipitation (0.8 cm).

LITERATURE CITED

National Oceanic and Atmospheric Administration [NOAA]. 2011. National Climatic Data Center internet services. Local climatological observations for Williamston, North Carolina. <http://www.ncdc.noaa.gov/oa/ncdc.html/> Accessed 24 January 2011.

U.S. Department of Agriculture [USDA]. 1989. Natural Resources Conservation Service soil survey staff. Soil Survey of Martin County, North Carolina. <http://websoilsurvey.nrcs.usda.gov/> Accessed 8 April 2007.

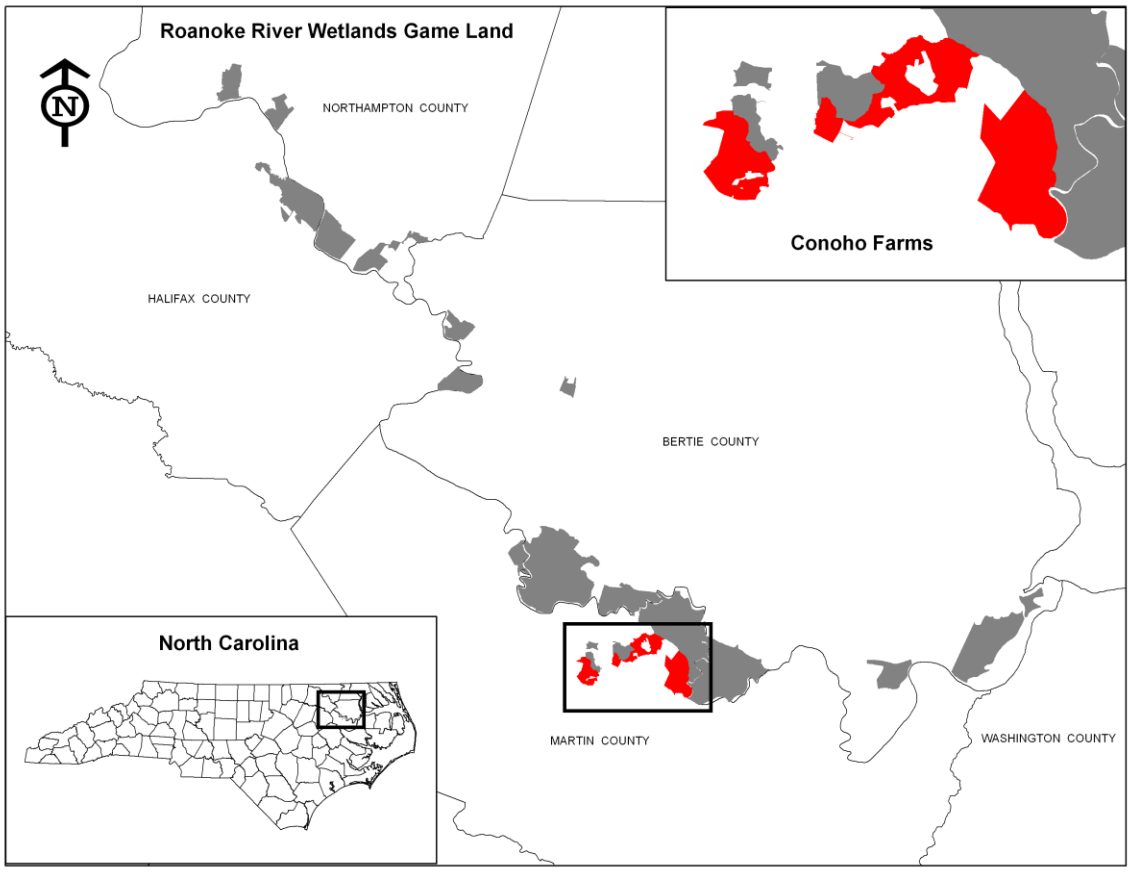


Figure 1. Conoho Farms (highlighted in red), a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

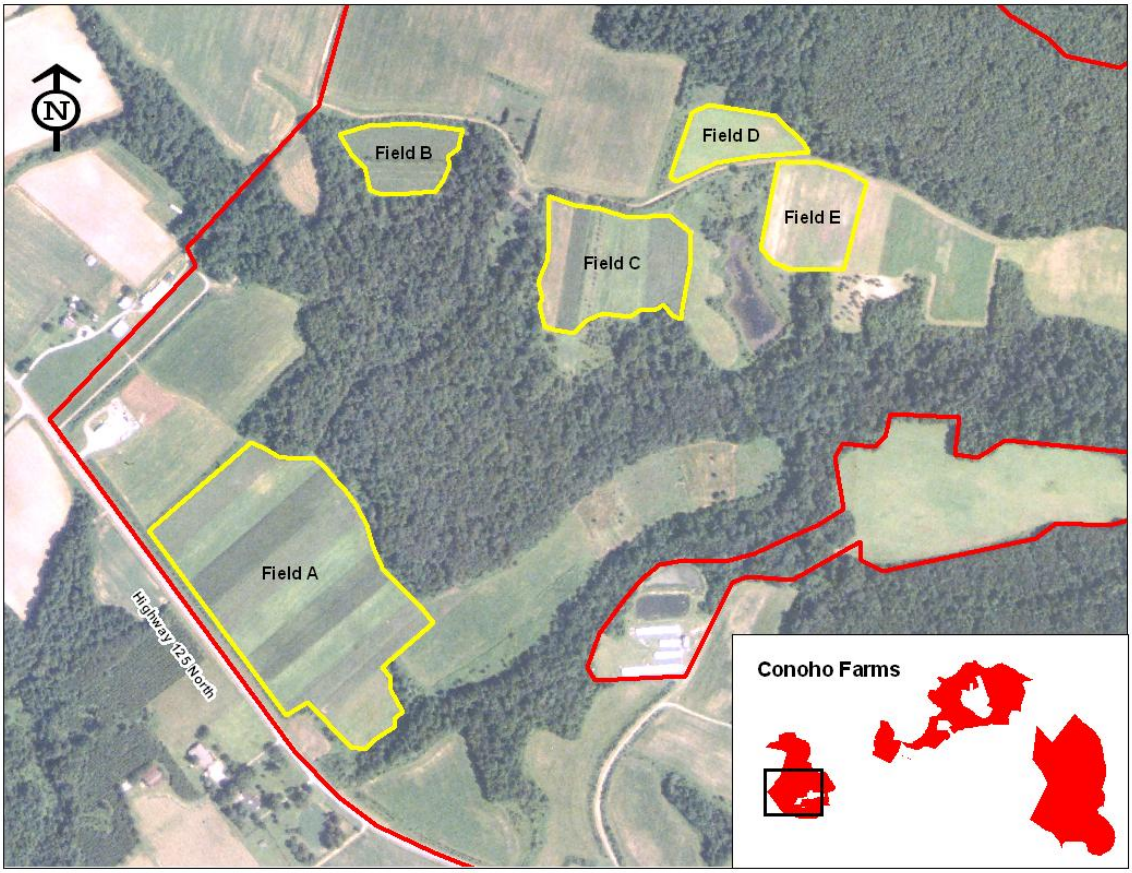


Figure 2. Five fields used to study shot concentrations in publicly managed dove fields within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

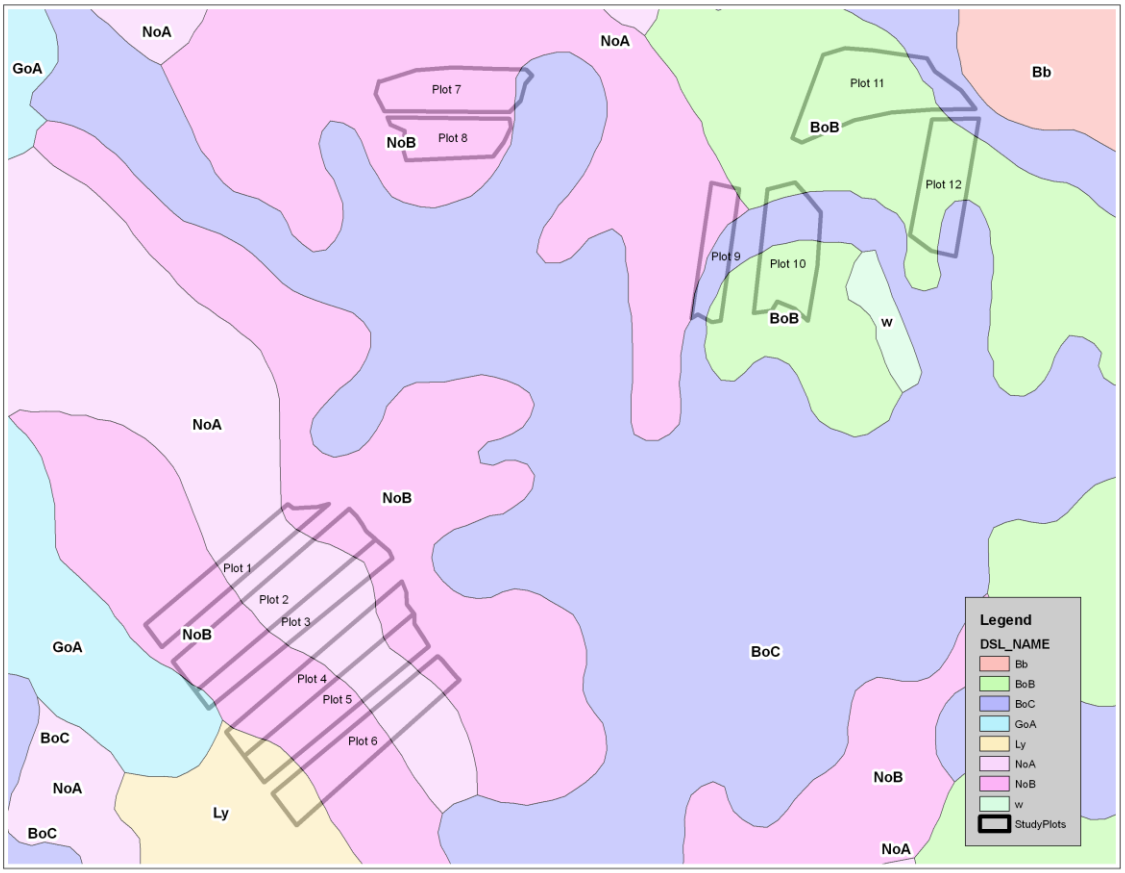


Figure 3. Distribution of soil types within 12 plots in 5 fields used in this study, located within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009, as reported in the 1989 Soil Survey of Martin County, North Carolina.

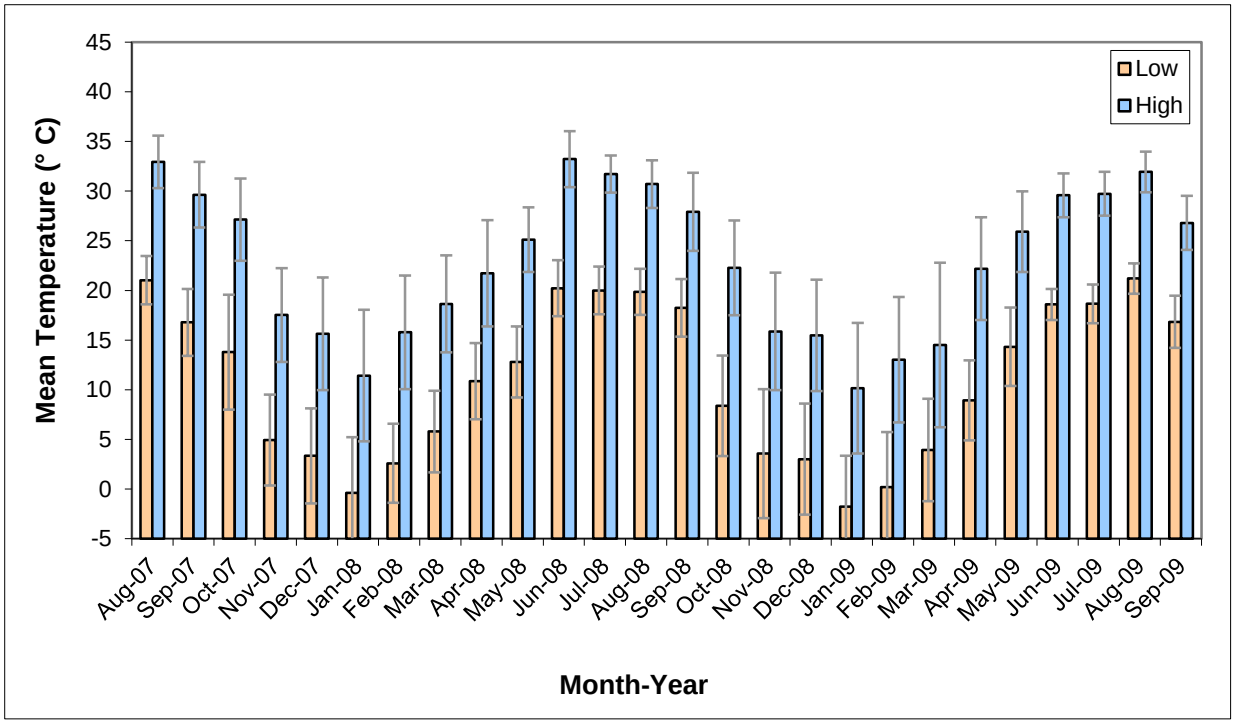


Figure 4. Mean daily temperatures (and standard deviations) for high and low daily temperatures per month at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

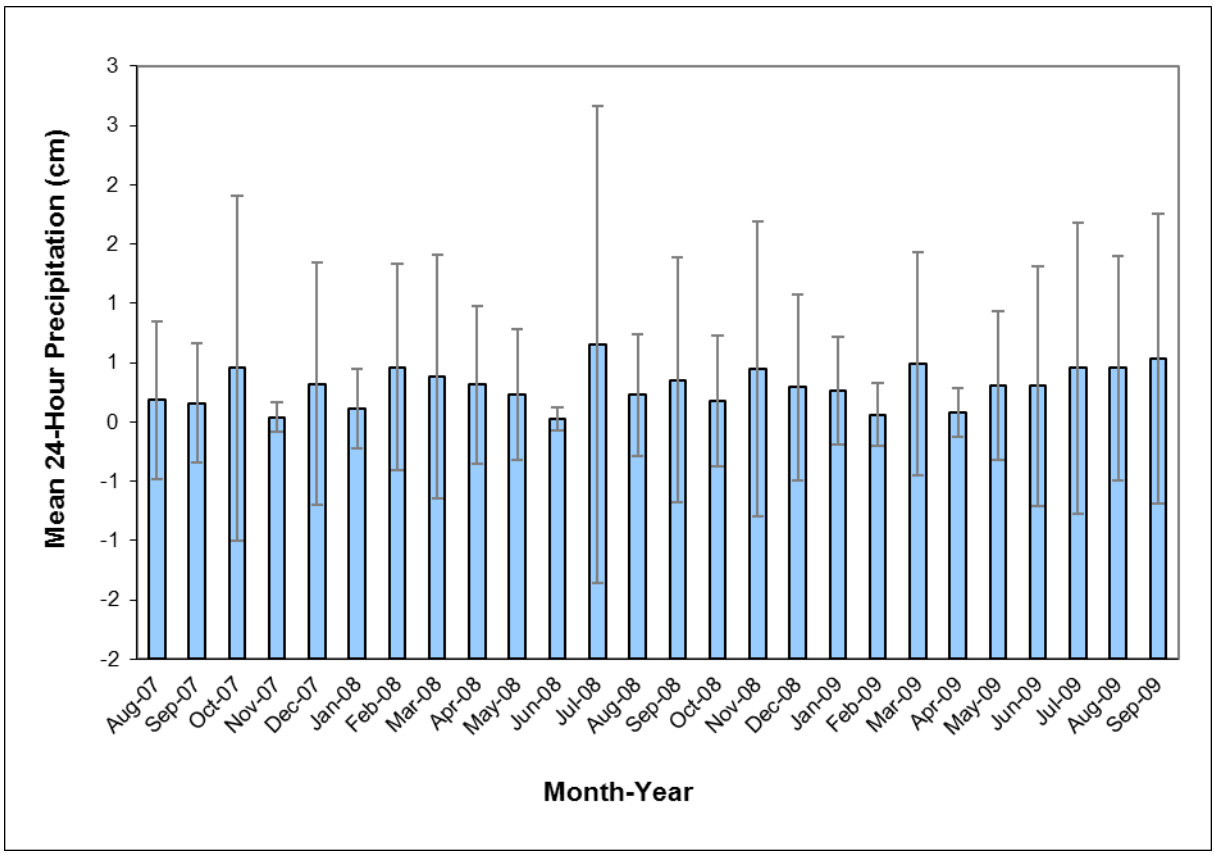


Figure 5. Mean daily precipitation (and standard deviations) per month at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

Table 3. Number of permits sold by permit type (i.e., special hunt and point-of-sale) to hunt mourning doves on Conoho Farms, a segment of Roanoke River Wetlands Game Land, in Martin County, North Carolina, 2005-2011.

	Number of permits sold	
Dove season (year)	Special hunt	Point-of-sale
2005-2006	107	185
2006-2007	162	245
2007-2008	124	394
2008-2009	119	368
2009-2010	154	204
2010-2011	178	211

Table 4. Area of soil series within plots and percentage of plot area of the soil series found within the dove fields at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009[a].

		Soil series			
Plot	Area (ha)	Norfolk (%)	Goldsboro (%)	Lynchburg (%)	Bonneau (%)
1	0.67	0.67 (100.0)	--	--	--
2	1.13	1.13 (99.7)	< 0.01 (0.3)	--	--
3	0.68	0.66 (97.1)	0.02 (2.9)	--	--
4	0.86	0.81 (93.1)	--	0.06 (6.9)	--
5	0.89	0.76 (85.1)	--	0.13 (14.9)	--
6	0.96	0.78 (81.6)	--	0.18 (18.4)	--
7	0.73	0.69 (94.8)	--	0.06 (6.9)	0.04 (5.2)
8	0.51	0.51 (100.0)	--	--	--
9	0.48	0.21 (42.8)	--	--	0.27 (57.2)
10	0.83	--	--	--	0.83 (100.0)
11	1.15	--	--	--	1.15 (100.0)
12	0.77	--	--	--	0.77 (100.0)

[a]Area (ha) and percentage of plot area were calculated from the soil distributions reported in the 1989 Soil Survey of Martin County, North Carolina.

Table 5. Soil characteristics for the top layer of each soil series present within the 12 plots in the 5 fields, located at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009[a].

	Soil Series			
Soil Characteristics	Norfolk	Bonneau	Lynchburg	Goldsboro
Soil Classification	loamy fine sand	loamy sand	fine sandy loam	fine sandy loam
Drainage	well drained	well drained	somewhat poorly drained	moderately well drained
Permeability	moderate	rapid	moderate	moderately slow
Slope Range	0-6%	0-12%	< 2%	0-2%
Typical Color	light yellowish brown	grayish brown	dark grayish brown	dark grayish brown
Granular Structure	fine	weak fine	weak fine	weak fine
Acidity Level	medium	medium	medium	medium
Top Layer	0-15.24 cm	0-25.4 cm	0-25.4 cm	0-22.86 cm

[a]Soil characteristics are summarized from information reported in the 1989 Soil Survey of Martin County, North Carolina.

Table 6. Daily temperature data, by month, at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

	High Temperatures (° C)			Low Temperatures (° C)		
Month Year	Maximum	$\bar{x}$	SD	Minimum	$\bar{x}$	SD
Aug 2007	38.3	32.9	2.63	17.2	21.0	2.43
Sep 2007	35.0	29.6	3.31	11.1	16.8	3.37
Oct 2007	35.0	27.1	4.14	2.2	13.8	5.78
Nov 2007	25.6	17.5	4.73	-2.2	4.9	4.57
Dec 2007	26.1	15.6	5.67	-5.0	3.4	4.79
Jan 2008	23.9	11.4	6.62	-7.8	-0.4	5.60
Feb 2008	26.7	15.8	5.72	-3.3	2.6	3.99
Mar 2008	27.2	18.6	4.88	-0.6	5.8	4.10
Apr 2008	30.0	21.7	5.34	2.8	10.9	3.84
May 2008	30.0	25.1	3.25	6.7	12.8	3.58
Jun 2008	38.3	33.2	2.83	14.4	20.2	2.82
Jul 2008	35.6	31.7	1.88	15.0	20.0	2.41
Aug 2008	35.0	30.7	2.39	13.9	19.9	2.32
Sep 2008	32.8	27.9	3.93	13.9	18.2	2.91
Oct 2008	30.6	22.3	4.77	-2.2	8.4	5.06

Table 6. Continued

Nov 2008	25.6	15.9	5.91	-5.0	3.6	6.50
Dec 2008	25.0	15.5	5.61	-6.1	3.0	5.60
Jan 2009	22.8	10.1	6.57	-10.6	-1.8	5.12
Feb 2009	23.3	13.0	6.32	-7.8	0.2	5.56
Mar 2009	27.2	14.5	8.28	-7.8	3.9	5.15
Apr 2009	31.1	22.2	5.18	1.1	8.9	4.03
May 2009	31.1	25.9	4.07	6.1	14.3	3.94
Jun 2009	32.8	29.6	2.20	16.1	18.6	1.56
Jul 2009	33.3	29.7	2.20	14.4	18.7	1.95
Aug 2009	35.0	31.9	2.05	18.3	21.2	1.54
Sep 2009	31.1	26.8	2.71	10.0	16.8	2.63

Table 7. 24-hour precipitation data, by month, at Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

	24-hour Precipitation (cm)				
Month Year	Maximum Daily[a]	Daily Mean	SD of Daily Mean	Monthly Sum	Annual Mean[b]
Aug 2007	3.45	0.18	0.66	5.72	7.74
Sep 2007	2.51	0.16	0.50	4.65	7.74
Oct 2007	6.35	0.45	1.45	14.05	7.74
Nov 2007	0.58	0.04	0.13	1.22	7.74
Dec 2007	5.56	0.32	1.02	9.96	7.74
Jan 2008	1.63	0.11	0.34	3.38	9.32
Feb 2008	3.07	0.46	0.87	13.36	9.32
Mar 2008	4.14	0.38	1.03	11.79	9.32
Apr 2008	3.05	0.32	0.66	9.50	9.32
May 2008	1.93	0.23	0.55	7.19	9.32
Jun 2008	0.46	0.03	0.10	0.79	9.32
Jul 2008	10.46	0.65	2.01	20.22	9.32
Aug 2008	2.06	0.23	0.52	7.09	9.32
Sep 2008	5.08	0.35	1.03	10.59	9.32

Table 7. Continued

Oct 2008	2.92	0.18	0.55	5.51	9.32
Nov 2008	5.08	0.45	1.24	13.39	9.32
Dec 2008	3.30	0.29	0.78	9.07	9.32
Jan 2009	1.57	0.27	0.45	7.95	11.17
Feb 2009	1.40	0.06	0.27	1.78	11.17
Mar 2009	4.24	0.49	0.94	15.29	11.17
Apr 2009	0.91	0.08	0.20	2.29	11.17
May 2009	2.36	0.30	0.63	8.76	11.17
Jun 2009	5.08	0.30	1.01	9.14	11.17
Jul 2009	5.59	0.46	1.23	14.17	11.17
Aug 2009	4.11	0.45	0.95	13.64	11.17
Sep 2009	5.66	0.53	1.22	15.98	11.17

[a]Minimum daily 24-hour precipitation data are not reported here because the minimum daily precipitation was 0 cm for all months.

[b]Annual means are assigned to each month, and calculated from the daily 24-hour precipitation data for all months, within a calendar year.

Hunter Effort and Success in Publicly Managed Mourning Dove Fields

KELLY E. DOUGLASS, *North Carolina Wildlife Resources Commission*, PO Box 31063, Raleigh, NC 27612, USA

DAVID T. COBB, *North Carolina Wildlife Resources Commission*, 1722 Mail Service Center, Raleigh, NC 27699-1722, USA

PHILLIP D. DOERR, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7646, Raleigh, NC 27695, USA

KENNETH H. POLLOCK, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7617, Raleigh, NC 27695, USA

RICHARD A. LANCIA, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7646, Raleigh, NC 27695, USA

ABSTRACT We attempted to quantify hunter effort and success in 5 publicly managed mourning dove (*Zenaida macroura*) fields during the 2007 and 2008 dove hunting seasons on Conoho Farms (CF) in Martin County, North Carolina. Self-administered diary surveys (N = 845) were mailed to every individual receiving a special hunt (SH) and point-of-sale (POS) permit during both dove hunting seasons on CF. We used the modified Tailored Design method to collect hunter use, effort, and success data for each hunting season. Data were analyzed using the Kruskal-Wallis test to determine differences in hunter effort and success between seasons and permit types and among fields. The adjusted overall response rate for the survey was 74.7%. Only 141 (22.7%)

respondents reported hunting doves at CF. Hunters using the 5 fields at CF expended 801.75 hours ($\bar{x}$ = 4.01, SE 0.13), fired 6,782 shots ($\bar{x}$ = 33.91, SE 2.25), and harvested 1,331 doves ($\bar{x}$ = 6.66, SE 0.36) during the 2007-2008 dove hunting seasons. When estimated to the entire population of permitted dove hunters using CF, hunters would have expended 1,092.17 hours, fired 9,239 shots, and harvested 1,813 doves. Hunters reported firing a mean of 5.68 (SE 0.33) shots per harvested dove. Hunter effort and success per hunting event did not differ between seasons, but were significantly greater for the SH permittees than the POS permittees. SH permittees harvested more doves than POS permittees, and hunter success differed among fields. The number of hours hunted, but not shots fired, differed among fields. The results of this study can be used to improve the permitting system and increase hunting opportunities for dove hunters in North Carolina, and may be used in the Atlantic Flyway to manage dove populations in the Eastern Management Unit through regulating harvest.

KEY WORDS harvested, hunter effort, hunting, North Carolina, mourning dove, success, survey, Z*enaida macroura*.

The Journal of Wildlife Management: 00(0): 000-000, 20XX

In North Carolina, mourning doves (*Zenaida macroura*) are the most heavily harvested game species, and second only to white-tailed deer (*Odocoileus virginianus*) in the number of hunters they attract (Pollock and Wen 2009). The annual mourning dove harvest in North Carolina is approximately 1,503,095 birds (Pollock and Wen 2009). The most dove hunting occurs in the coastal region of North Carolina, with approximately

51% of the hunters, 58% of the harvest, and 54% of the days hunted (Pollock and Wen 2009).

Since the 1950s, the North Carolina Wildlife Resources Commission (NCWRC) has conducted mail surveys to estimate total harvest and hunter effort (Pollock and Wen 2009). For dove hunting, this survey has only provided statewide or regional estimates for the total number of hunters, hunter effort (in hunter days), and birds harvested.

The goal of this project was to survey dove hunters to estimate their hunter effort and success in publicly managed mourning dove fields in North Carolina during the 2007 and 2008 dove hunting seasons. Our objectives included: 1) quantify the hunter effort and success, using the number of hours hunted, shots fired and doves harvest within (and around) 5 dove fields in eastern North Carolina during the 2007 and 2008 dove hunting seasons; and 2) comparing differences in hunter effort and success between permit types, hunting seasons, and among these fields.

Hunting Season Structure

The U.S. Fish and Wildlife Service determines the federal framework for all dove hunting seasons in the United States, including the maximum number of hunt days, season date range, daily bag limit, and the number of season splits. Each state wildlife agency then establishes the dove season within the federal framework. The NCWRC adopted dove hunting seasons using the maximum allowable hunting opportunity provided by the frameworks for 2007 and 2008. The season dates, daily bag limits, and

possession limits for 2007 and 2008, respectively, were: 1 September 2007 – 12 January 2008 (bag: 12; possession: 24) and 1 September 2008 – 10 January 2009 (bag: 15; possession 30). Each season had 3 splits, and allowed a maximum of 61 and 62 hunt days, respectively. The federal framework was changed in 2008 for mourning doves, which allowed states in the Atlantic Flyway to set a maximum daily bag limit of 15 doves instead of the 12-bird bag limit in previous years; the NCWRC adopted this change. Dove hunting is not allowed on Sundays in North Carolina.

The NCWRC also has the authority to limit hunting activity on publicly owned and managed lands (i.e., game lands) in North Carolina. To hunt on Roanoke River Wetlands Game Land (RRWGL), a special permit must be obtained from the NCWRC through the Permit Hunt Opportunities Program (PHOP). For mourning doves, hunting is limited to 5 days during the first 2 weeks of the first split of the season and hunters are required to obtain a special hunt (SH) permit for doves. After the first 2 weeks of the season, hunters are required to obtain a point-of-sale (POS) permit for small game and, under this permit, may hunt doves on any legal day (i.e., Monday-Saturday) during the remainder of the season. The administrative fee for each SH or POS application for the 2007 and 2008 hunting seasons was $5.00 ($USD). Daily hunter quotas of 50 hunters per day were established for the 5 SH days; hunting was not limited during the POS days (i.e., no quota).

For the 2007 mourning dove season, legal shooting hours for doves were from 1200 until sunset for the first week (1-8 September 2007) and 0.5 hr before sunrise until

sunset for the remainder of the season. For the 2008 season, legal shooting hours were from 1200 until sunset for opening day (1 September 2008) only, and 0.5 hr before sunrise until sunset for the remainder of the season.

Permitting System

Any licensed hunter in North Carolina could have applied for a SH or POS permit to hunt the 5 dove fields at CF during the 2007 and 2008 dove hunting seasons. Application deadlines for the SH permits were 10 August in both years. The POS permit did not have an application deadline; hunters could begin applying for POS permits 1 July for the upcoming season and could continue to apply until the end of that season.

Hunters applying for the SH permit were allowed up to 5 hunt choices (i.e., hunt days), which had to be listed in preferential order. Permit quotas for the 5 SH days were met both years. The NCWRC used a permit-draw system to randomly draw applicants for each of the 5 SH days. After all random draws occurred for the 5 SH days, hunters received notification of their specific SH days if they were drawn to hunt and were mailed their permits within a few days. SH permits allowed hunters to harvest only mourning doves.

There was no permit quota for POS permits for the 2007 and 2008 hunting seasons. Therefore, any hunter who applied for a POS permit obtained a permit for that year. If the hunter applied for the POS permit mid-season, the permit becomes valid at the time of purchase and the hunter could then hunt doves on CF from that time forward

for the remainder of that season. POS permits allowed hunters to harvest small game species, including eastern cottontails (*Sylvilagus floridanus*), eastern gray squirrels (*Sciurus carolinensis*), fox squirrels (*Sciurus niger*), American woodcock (*Scolopax minor*), northern bobwhite (*Colinus virginianus*), and mourning doves.

Each hunter who applied for a SH or POS permit to hunt doves on CF was required to provide their Customer Identification Number to the NCWRC, which was linked to their hunting license information: full name, address, date of birth, gender, phone number, and county of residence (for North Carolina residents only). The NCWRC also conducted an annual harvest survey of all hunters obtaining a permit through the PHOP in North Carolina, by mailing a brief survey to successful applicants with their permit. Therefore, each hunter who received a SH or POS permit to hunt doves on CF for the 2007 or 2008 season also received this harvest survey attached to their permit. The annual harvest survey was designed to obtain information from hunters on their overall hunt experience, including the total number of days and hours they hunted game lands, the total number and species of game harvested, their overall satisfaction with the hunt, and the factors influencing their satisfaction.

STUDY AREA

This study was conducted at Conoho Farms (CF), a segment of the RRWGL. RRWGL is publicly owned and managed by the NCWRC and consists of 16,985 ha in Bertie, Halifax, Martin, and Northampton counties, North Carolina (Figure 1). RRWGL is a

permit-only hunt area for hunting white-tailed deer, wild turkey (*Meleagris gallopavo*), small game, mourning dove, and waterfowl.

The NCWRC manages 5 fields in CF specifically for mourning dove hunting; all are located off Hwy 125 North in Williamston, North Carolina (Figure 6). These fields have been managed intensively for dove hunting since 1997, and range in size from 1.5 ha to 13.4 ha. These dove fields were chosen for this study because they were: 1) concurrently being used for other work in which hunter effort needed to be quantified (Douglass 2011); 2) reported as having heavy hunter use; 3) consistently managed; and 4) all included in the NCWRC PHOP.

METHODS

Study Design

Self-administered diary surveys were mailed to every individual receiving a SH or POS permit during the 2007 and 2008 dove hunting seasons on CF, using the modified Tailored Design method (Dillman 2000), to collect hunter use, effort, and success data for each hunting season (Douglass 2011; Appendix A).

Multiple contacts were made with each hunter, by name, via mail with personalized letters (signed by hand) printed on NCWRC letterhead accompanying each survey. The survey instruments and letters were worded carefully to reduce confusion, appear friendly, and emphasize the importance of responding. Each mailing included a letter, survey instrument, map of the study area, and a postage-paid business reply

envelope. Four survey instruments, very similar in composition, were sent to hunters depending on the type of permit they received for each hunting season (SH 2007, POS 2007, SH 2008, and POS 2008).

Twelve 25.4 cm × 30.5 cm plastic signs were placed at the entrance and along the edges of each field to identify the field as Field A, B, C, D, or E (Douglass 2011; Appendix B). Two 43.2 cm × 74.9 cm metal signs were attached to 10.2 cm × 10.2 cm wooden posts behind plastic mailboxes at each parking lot to remind folks to complete the survey (Douglass 2011; Appendix C). Blank surveys for the appropriate permit type and hunting season were left in the mailboxes in case hunters wanted to use them to keep track of their hunt as it occurred or to complete in lieu of the survey mailed to them.

For this study, we assumed that: 1) survey participants told the truth and kept track of the specific information requested; 2) non-respondents would not have answered differently than respondents; and 3) each portion of each field had an equal chance of being hunted.

Mailings

A total of 4 mailings were sent to the SH permit holders and 6 mailings to the POS permit holders. All mailings were sent via regular postage, except the final mailing to the POS permit hunters which was sent via priority mail each year.

Four mailings were sent to SH permit hunters: 1) first mailing (survey) was sent to all permittees 2 weeks prior to the opening of the dove season, 2) second mailing (post

card reminder) was sent to all permittees 2 days after their last permitted SH day; 3) third mailing (survey) was sent to all non-respondents 2 days after the last SH day; and 4) fourth mailing (survey) was sent to all non-respondents 2 weeks after the third mailing. Six mailings were sent to POS permit hunters: 1) first mailing (survey) was sent to all permittees on the second week of the dove season (i.e., 1 week prior to the start of the POS season) for hunters purchasing a permit prior to the season, and three times per week throughout the remainder of the season for hunters as they purchased a permit mid-season, 2) second mailing (post card reminder) was sent to all permittees on the last day of the first split in the season; 3) third mailing (post card reminder) was sent to all permittees on the last day of the second split in the season; 4) fourth mailing (survey) was sent to all non-respondents 1 week after the end of the dove season; 5) fifth mailing (survey) was sent to all non-respondents 3 weeks after the end of the dove season; and 6) sixth mailing (survey) was sent to all non-respondents 5 weeks after the end of the dove season. We mailed an additional post-card reminder and non-response survey instrument to hunters obtaining a POS permit to encourage hunters to respond despite season length.

Data collected by hunter included the number of hours hunted, shots fired, and doves harvested, and weapon (including gauge for shotguns), shot size, and shot weight primarily used for each day (specific date) and each field (A, B, C, D, E). Multiple hunts within a day by a single hunter were recorded as individual hunting events.

Statistical Analysis

Statistical analyses were completed using SAS software (Version 9.2 of the SAS System for Windows, SAS Institute, Inc., Cary, NC). We used the χ^2 goodness of fit to examine differences in response by gender, age group, and residency, and we compared mean age of respondents and non-respondents using the Wilcoxon rank sum test. We used the Kruskal-Wallis test to evaluate differences in hunting effort and success between the 2007 and 2008 hunting seasons, among the 5 fields, and between the SH and POS permit types. Estimates for the total number of hours hunted, shots fired, and birds harvested were calculated using an adaption of the cell mean imputation method, where the missing values for survey items from non-respondents are replaced with the mean value of respondents for the corresponding survey items, and using the percent of respondents who reported hunted for the non-respondents as well (Pollock and Wen 2009).

RESULTS

Response Rates

Of the survey instruments (N = 845) mailed to permitted dove hunters on CF during the 2007 and 2008 hunting seasons, 620 (73.4%) were returned (respondents), 210 (24.9%) were not returned (non-respondents), and 15 (1.8%) were returned as undeliverable (Table 8). Undeliverable surveys were returned from the POS 2007 (n = 9) and POS 2008 (n = 6) mailings. An adjusted overall response rate of 74.7% was calculated after

undeliverable surveys were removed. Adjusted response rates by permit type and year ranged from 69.5-83.2% (Table 8).

The mean number of SH days for which permittees were drawn for the 2007 and 2008 hunting seasons were 2.02 (SE 0.06) and 2.10 (SE 0.06), with a range of 1-3 SH permit days for both years. Of the 845 individuals obtaining a permit to hunt doves on CF during the 2007 and 2008 hunting seasons, 633 (74.9%) obtained only 1 permit (SH or POS, 2007 or 2008 (Table 9)). Eleven (1.3%) individuals obtained 3 permits; 200 (23.7%) individuals obtained 2 permits; and only 1 (0.1%) individual obtained 4 permits.

Data Cleaning

All responses within legal limits (e.g., number of doves harvested within bag limits or number of hours hunted within legal shooting hours) were retained for analysis. Comments received from 1 hunter indicated his responses to the survey were cumulative for him and his 2 children; therefore, his survey responses were censored.

Three questionable responses for weapon, shot size, and shot weight primarily used were considered unknown because they were incorrect or unrealistic; these responses included "bird shot" for shot size, "3 oz" for shot weight, and "8" for shot weight. Three recognizable, but incomplete, responses for shot weight, including "⅛ oz," "⅜ oz," and "8-1 oz," were reported as realistic shot weights of "1 ⅛ oz, " "1 ⅜ oz," and "1 oz," respectively.

Permit Use and Hunter Effort

Of the 620 respondents, only 141 (22.7%) reported hunting doves at CF. Using the same percentage of respondents who hunted (22.7%), approximately 192 individuals of the 845 permitted individuals would have hunted on or around the 5 fields at CF during the 2007-2008 dove hunting seasons, when estimated to the entire population of permitted dove hunters. Permit use for dove hunting was higher for the SH permits (76.0% and 63.6%) than the POS permits (0.5% and 2.4%) for 2007 and 2008, respectively (Table 8).

Overall, 141 dove hunters expended a total of 801.75 hours and fired 6,782 shots on or around the 5 fields at CF during the 2007-2008 dove hunting seasons. When estimated to the entire population of permitted dove hunters using CF, approximately 1,092.17 hours were expended and 9,239 shots fired on or around the 5 fields at CF during the 2007-2008 dove hunting seasons. Hunters reported using 1 to 4 fields per day across all seasons and permit types, with the majority (90.2%) hunting only 1 field per day. Eleven (7.7%) permittees reported hunting in 2 fields per day; one (0.7%) reported hunting in 3 fields per day; and two (1.4%) reported hunting in 4 fields per day. Hunters reported expending an average of 4.01 hours (SE 0.13, median 4.0) and shooting 33.91 shells (SE 2.25, median 25.0) per hunting event (Table 10).

There were no differences in hunter effort between years. The mean number of hours hunted ($P = 0.0854$) and the mean number of shots fired ($P = 0.5619$) per hunting event did not differ between the 2007 and 2008 hunting seasons (Table 10). There was, however, a difference in the hunter effort between permit types. The mean number of

hours hunted (P = 0.0075) and the mean number of shots fired (P = 0.0003) per hunting event was significantly greater for the SH permittees. SH permittees hunted more hours ($\bar{x}$ = 4.08, SE 0.13) and fired more shots ($\bar{x}$ = 35.24, SE 2.31) than POS permittees ($\bar{x}$ = 2.50, SE 0.16; $\bar{x}$ = 5.67, SE 0.82). The most dove hunting occurred during the SH days, with 97.2% of the hours hunted and 99.2% of the shots fired, occurring within the first 2 weeks of the season across both years (Table 10).

Field A was hunted more frequently than any other field. The total number of hours hunted (492.75 or 61.5%), shots fired (4,370 or 64.4%), and hunting events (123 or 61.2%) were greater than the sum of the remaining fields. Although the mean number of hours hunted for Field A ($\bar{x}$ = 4.04, SE 0.16) was lower than Field C ($\bar{x}$ = 4.57, SE 0.26), the mean number of shots fired for Field A ($\bar{x}$ = 35.82, SE 2.87) was higher than Field C ($\bar{x}$ = 34.55, SE 4.53; Table 10).

Hunter Success

Overall, dove hunters harvested 1,331 doves on or around the 5 fields at CF during the 2007-2008 dove hunting seasons, with a mean of 6.66 doves (SE 0.36, median 6.0) per hunting event (Table 11). When estimated to the entire population of permitted dove hunters using CF, approximately 1,813 birds were harvested on or around the 5 fields at CF during the 2007-2008 dove hunting seasons. One hundred thirty (92.2%) of the 141 hunters harvested ≥ 1 dove during ≥ 1 hunting event during the 2007-2008 hunting

seasons. The mean number of shots fired per harvested dove ranged from 0.38-31.0, with an overall mean of 5.68 (SE 0.33) shots fired per harvested dove.

There was no difference in hunter success between years (P = 0.1059; Table 11). We did, however, document a difference in hunter success between permit type (P = 0.0011) and field (P = 0.0370). SH permittees harvested more doves ($\bar{x}$ = 6.90, SE 0.37) than POS permittees ($\bar{x}$ = 1.56, SE 0.23; Table 11).

Dove hunters in Field A harvested more birds than hunters in any other field. The total number of doves harvested, 911 (68.4%), was greater than the sum of the remaining fields, and the mean number of doves harvested ($\bar{x}$ = 7.41, SE 0.46) per hunting event was highest in Field A.

Weapon and Ammunition Preferences

The two weapons most often used for dove hunting on CF included 12-gauge (85.6%) and 20-gauge (11.4%) shotguns (Table 12). Hunters reported using 16-gauge shotguns, 28-gauge shotguns, or another gauge of shotgun < 3% of the time. Hunters reported using No. 7 ½ (55.2%) and No. 8 (37.8%) sized shot more often than any other shot size. The other 3 responses (No. 6, No. 7, and unknown) totaled < 7%. Hunters reported using 28.35 g (1 oz; 46.3%) and 31.89 g (1 ⅛ oz; 32.3%) more often than any other shot weight.

Non-response Bias

Given our 74.7% adjusted response rate, we did not quantify non-response bias and assumed that respondents represented all dove hunters on CF. Given the length of the hunting seasons each year, we felt the recall error of responses obtained post-season would have outweighed the benefits of attempting to quantify non-response.

Comparisons of gender ($P = 0.1934$) and North Carolina residency ($P = 0.4281$) post-survey were not different between respondents and non-respondents (Table 13). However, non-residents ($n = 37$, or 4.5%) and females ($n = 18$, or 2.2%) constituted only a small fraction of the permitted dove hunters ($N = 845$).

Mean age ($P \leq 0.0001$) and age group ($P = 0.0004$) differed between respondents and non-respondents (Table 14). The mean age of respondents ($\bar{x} = 48.07$, SE 1.08; median = 48) was higher than non-respondents ($\bar{x} = 42.65$, SE 0.63; median = 44). Age of permittees ranged from 10 yr to 77 yr for non-respondents and 6 yr to 90 yr for respondents. Age ranged from 10 yr to 69 yr ($\bar{x} = 40.54$, SE 1.10) for respondent hunters.

DISCUSSION

Our adjusted response rate of 74.7% was higher than those typically obtained by the NCWRC for harvest surveys. Pollock and Wen (2009) obtained a response rate of 56% over 3 mailings for the North Carolina Hunter Harvest Mail Survey in 2007-2008, whereas Palmer (2007) reported an adjusted response rate of 60.4% for a survey of North

Carolina hunters in 2005-2006. Our response rate could be higher than those previously reported because of our localized and census-type surveying method. Pollock and Wen (2009) and Palmer (2007) both targeted a random sample of 2% of all North Carolina hunters (> 475,000 hunters). Our survey population contained 845 hunters over a 2-year period. Of those, 212 (25.1%) individuals were repetitive customers who obtained > 1 permit during the 2007 and 2008 hunting seasons. Repetitive customers received multiple surveys for each permit they obtained, and therefore, may have been more likely to respond to succeeding requests for survey response. The NCWRC requires individuals obtaining a permit to hunt tundra swans (*Cygnus columbianus*) in North Carolina to return a harvest survey, received with their permit, to remain eligible for obtaining a swan permit the following year. Because of that requirement, our response rate could have increased if hunters assumed they would lose eligibility to obtain a permit for CF the following year if they did not return the survey for this study. The hunters receiving our survey also received the annual harvest survey mailed by the NCWRC to all hunters obtaining a permit through the PHOP in North Carolina. Our response rate could have decreased if hunters in this study assumed they had satisfied our request for response by responding to the annual harvest survey instead.

The annual harvest surveys for the 2007 and 2008 hunting season included the same SH and POS permittees as this study. The annual harvest surveys for the 2007-2009 hunting seasons only provide response rate data for small game hunting by the POS permittees (D.R Palmer, NCWRC, unpublished data). Therefore, we were unable to

compare our results with those of the annual harvest surveys for the POS permittees who hunted doves. These data, however, were available for dove hunting by the SH permittees. For the 2 hunting seasons covered in this study (2007 and 2008), the response rates by the same population of SH permittees to the annual harvest survey was 33.9% and 42.7%, respectively – much lower than the response rates we received (77.4% and 83.2%, respectively). We suspect the difference in response rates is due to differences in how the surveys were conducted and the number of survey mailings used. The annual harvest survey is mailed to permittees only once (i.e., included no-follow mailings), whereas we used multiple mailings under the modified Tailored Design method (Dillman 2000).

Overall, permit use on CF for dove hunting was low (22.9%). The annual harvest surveys for the 2007-2009 hunting seasons do not provide permit use data for dove hunting by the POS permittees (D.R Palmer, NCWRC, unpublished data). Therefore, we were unable to compare our results with those of the annual harvest surveys for the POS permittees. These data, however, were available for dove hunting by the SH permittees. Permit use by respondents within the same population of SH permittees, as determined from the annual harvest survey data, for the 2007 and 2008 seasons was 83.3% and 71.4%, respectively – slightly higher than the permit use we reported (76.0% and 63.6%, respectively). The lower permit use in 2007, reported in both the annual harvest survey and our study, may be attributed the presence of Tropical Storm Hanna in eastern North Carolina on opening weekend.

Within our study, permit use by SH permittees was greater than POS permittees for both years (Table 8). Increased permit use by SH permittees could be a result of economic justification. Both the SH and POS permits cost $5.00 (U.S. currency), therefore POS permittees had the option to hunt doves 48 or 49 days in 2007 and 2008, whereas SH permittees could only hunt doves on potentially 1-5 days, for the same cost. However, the increased permit use by SH permittees is most likely based on conflicts with other game seasons or a lack of advertisement for dove hunting under the POS permits. White-tailed deer hunting, especially, could have impacted permit use by POS permittees. Deer attract more hunters than any other game species in North Carolina (Pollock and Wen 2009), and the bow season for white-tailed deer opened < 2 weeks after the opening of each dove season in North Carolina in 2007 and 2008. Also, the POS permits for 2007 and 2008 were valid for any small game species, including eastern cottontails, eastern gray squirrels, fox squirrels, American woodcock, northern bobwhite, and mourning doves. Although doves are the second most popular game species in North Carolina, in the number of hunters they attract, squirrel hunting and rabbit hunting are the third and fifth most popular game species in North Carolina (Palmer 2007; Pollock and Wen 2009). The concurrent seasons for these species could have impacted the hunter's choice to use their permit (or to purchase a POS permit) to hunt doves during the POS hunt days. In addition, the POS permits for small game are not readily advertised by the NCWRC as including doves. Information on the POS permit regulations is posted on the NCWRC website and printed annually in a PHOP booklet. However, verbal and written

feedback received from the POS respondents indicated their lack of awareness that the POS permit for small game allowed dove hunting.

Overall, hunter effort was significantly higher on the SH hunt days than the POS hunt days in both the hours hunted ($P = 0.0075$) and shots fired ($P = 0.0003$) by respondents (Table 10). The decrease in hunter effort after the first 2 weeks of the dove season could be a result of conflicting game seasons (i.e., white-tailed deer gun season) or a lack of advertisement for dove hunting under the POS permits. In addition, changes in dove behavior and activity through the season could also impact hunter effort. Foraging activity by doves in managed fields may vary throughout the hunting season as a result of migration patterns or seed availability due to changes in crop condition. Hunter effort was also higher in Field A than any other field at CF. Hunters may have chosen to hunt Field A more often because it was the largest of the 5 dove fields, had a power line running along the south side of the field, and was easily accessed via a parking lot. The remaining fields were smaller in size and located behind a locked gate, forcing hunters to walk 250 m to 1,000 m from the secondary parking lot to hunt these fields. Hunter success was also greater in Field A, most likely because of the increased hunter effort.

All survey responses were within legal limits, including the number of hours hunted per day given the established shooting times and the number of doves harvested given the bag limit, excluding the 1 outlier. Overall, 92.2% of respondent hunters were successful in harvesting doves. Again, we were unable to compare our results with those

of the 2007-2009 NCWRC annual harvest surveys for the POS permittees (D.R Palmer, NCWRC, unpublished data). However, hunter success rates for the SH respondent hunters were 94% and 90% – similar to the data we received (93% and 94%) – for the 2007 and 2008 hunting seasons, respectively.

Within our study, SH hunters were more successful than POS hunters (P = 0.0011), which is most likely a function of the effort expended by hunters (Table 11). The mean number of hours hunted and shots fired, a direct measure of the effort expended by hunters, was significantly higher for SH hunters than POS hunters. In addition, the mean number of doves harvested per hunting event was significantly higher for SH hunters ($\bar{x}$ = 6.90, SE 0.37) than POS hunters ($\bar{x}$ = 1.56, SE 0.23). The temporal reduction in hunter success between SH and POS hunters is similar to that reported by Haas (1977), who found a decrease in hunter success after the second week of the 1973 and 1974 dove hunting seasons in South Carolina, apparently due to a reduction in the number of doves present.

Similarly, our results on the mean number of shots fired per harvested dove ($\bar{x}$ = 5.68, SE 0.33) falls within the range of shooting rates reported by Lewis and Legler (1968), Haas (1977), and Schulz et al. (2002). Lewis and Legler (1968) reported a range of 5.4 to 8.3 shells fired per harvested dove over 2 days in a field in Tennessee. Haas (1977) reported an average of 8.6 shots fired (range of 7.3 to 9.5) per bird bagged, from observations of 1,230 dove hunters across north-central South Carolina. Schulz et al.

(2002) documented a range of 6.3 to 6.6 shots fired per harvested dove, as reported by 788 dove hunters on 2 fields in Missouri.

Variation in the number of shots fired, as reported by SH ($\bar{x}$ = 35.24, SE 2.31) and POS hunters ($\bar{x}$ = 5.67, SE 0.82) in this study, is most likely a function of shooting skill and hunting experience. The variation in shooting skill may be explained by the variation in age (10 yr to 69 yr) of CF dove hunters.

The 2 most popular weapons used by CF dove hunters were 12- and 20-ga shotguns (97.0% combined). The 2 most popular shot sizes (2.41 mm and 2.29 mm) and weights (28.35 g and 31.89 g) constituted 93.0% and 78.6% of the ammunition used by CF hunters. Weapon selection by hunters may be based on availability (i.e., hunter access to certain firearms), and ammunition selection may be based on manufacturer production and the resulting availability, cost, and killing power of certain ammunition loads or personal preference.

MANAGEMENT IMPLICATIONS

The current permitting system in North Carolina for the PHOP allows any hunter purchasing a POS permit to hunt small game, including mourning doves, on the particular game land for which they applied. POS hunters may not be aware they may legally harvest doves after the second week of the season, as indicated by the minimal amount of hunter effort expended by POS hunters for dove hunting, and as a result, may divert their hunting effort to other small game species. If increased participation in dove hunting

after the second week of the dove season is of interest, the NCWRC may consider a more clear and direct advertisement of which species may be legally harvested under a POS permit for small game. With the majority of hunter effort and success occurring during the first 2 weeks of the season, dove hunting opportunities in North Carolina may be increased by increasing the number of SH hunt days available. These results may also be useful when establishing the federal framework for dove hunting seasons within the Atlantic Flyway. We believe that dove hunting regulations may be used to maximize hunting opportunity while maintaining the current dove harvest in the Atlantic Flyway by regulating the amount of hunter activity within the first 2 weeks of the current season structure.

ACKNOWLEDGMENTS

Funding for this study was provided by the North Carolina Wildlife Resources Commission, through the Pittman-Robertson Wildlife Restoration Act (W-57). We thank D.R. Palmer for assistance with survey design, analysis, and thesis review. We thank the hunters who obtained a permit to hunt doves on Conoho Farms and responded to our survey. We also thank the Commission staff responsible for managing the dove fields at Conoho Farms, North Carolina State University for supporting this research, and J.L. Wilson for editing.

LITERATURE CITED

Douglass, K.E. 2011. The effects of tillage on shot concentrations in publicly managed mourning dove fields in North Carolina. Thesis, North Carolina State University, Raleigh, North Carolina, USA.

Dillman, D.A. 2000. Mail and internet surveys: the tailored design method. John Wiley and Sons, Inc, New York, New York, USA.

Haas, G.H. 1977. Unretrieved shooting loss of mourning doves in North-Central South Carolina. Wildlife Society Bulletin 5:123-125.

Lewis, J.C. and E. Legler. 1968. Lead shot ingestion by mourning doves and incidence in soil. Journal of Wildlife Management 32:476-482.

Palmer, D.R. 2007. 2005-2006 Harvest survey of North Carolina hunters. North Carolina Wildlife Resources Commission, Raleigh, NC, USA.

Pollock, K.H. and Z. Wen. 2009. Analysis of the North Carolina Hunter Harvest Survey 2007-2008. North Carolina Wildlife Resources Commission, Raleigh, NC, USA.

Schulz, J.H., J.J. Millspaugh, B.E. Washburn, G.R. Wester, J.T. Langian III, and J.C. Franson. 2002. Spent-shot availability and ingestion on areas managed for mourning doves. Wildlife Society Bulletin 30:112-120.

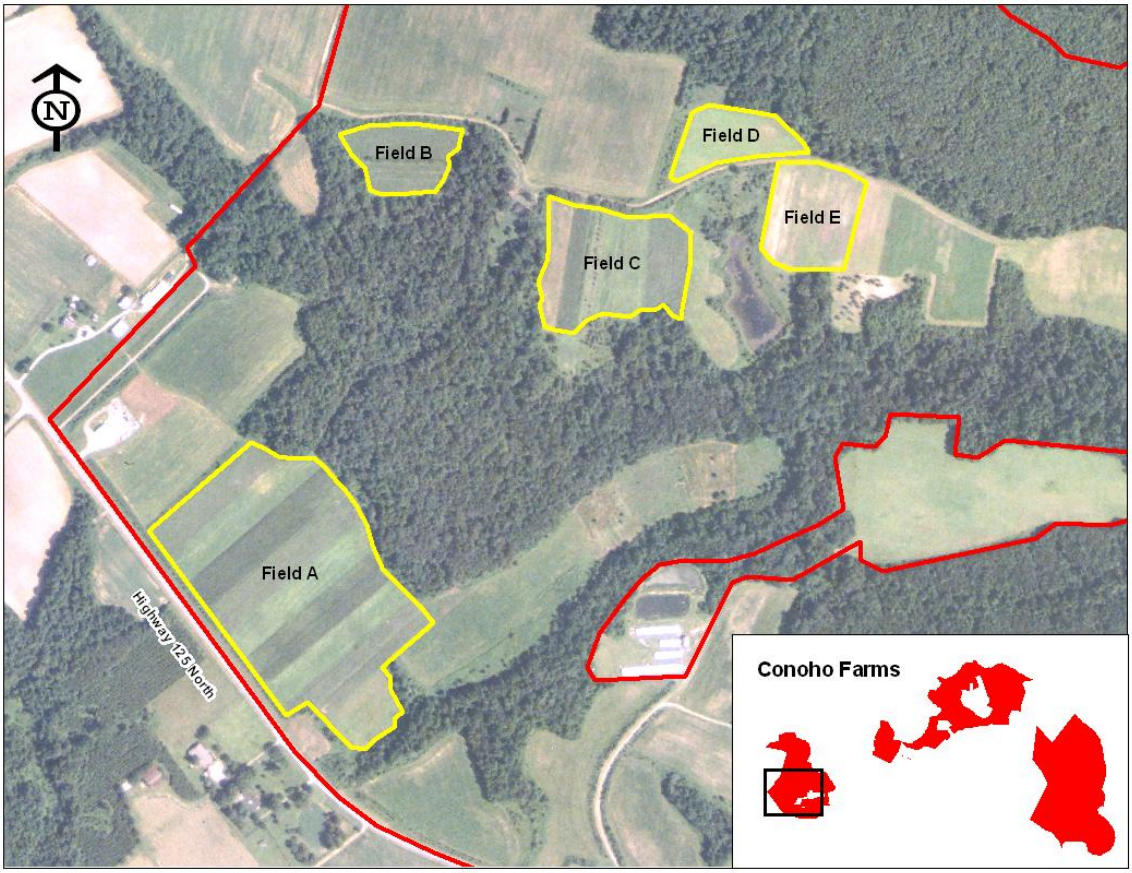


Figure 6. Five publicly managed dove fields used to study hunter effort and success within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

Table 8. Survey response rates and permit use by year and permit type on Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 2007 and 2008 hunting seasons.

		Response rates	Permit use
Year, Permit type	No. of permittees[a]	No. of respondents (%)	No. of respondents who reported hunting (%)
2007 Special hunt	124	96 (77.4)	73 (76.0)
2007 Point-of-sale	282	213 (75.5)	1 (0.5)
2008 Special hunt	119	99 (83.2)	63 (63.6)
2008 Point-of-sale	305	212 (69.5)	5 (2.4)

[a]The number of permittees does not include the number of undeliverable surveys (*n*=9 for point-of-sale 2007 and *n*=6 for point-of-sale 2008).

Table 9. Number of permittees obtaining ≥ 1 permit to hunt doves on Conoho Farms, a segment of Roanoke River Wetlands Game Land, Martin County, North Carolina, 2007 and 2008 hunting seasons.

Permit combinations	No. of permits within each combination	No. of individuals with each permit combination (%)
1 SH[a] or POS[b] permit	1	633 (74.9)
POS permits for both years	2	135 (16.0)
SH permits for both years	2	61 (7.2)
SH and POS permits within 1 year	2	4 (0.5)
1 SH permit and POS permits for both years	3	4 (0.5)
SH permits for both years and 1 POS permit	3	7 (0.8)
SH and POS permits for both years	4	1 (0.1)

[a]SH = special hunt

[b]POS = point-of-sale

Table 10. Comparison of hunting effort per hunting event, between the 2007 and 2008 dove hunting seasons, between the special hunt (SH) and point-of-sale (POS) permittees, and among the 5 fields (A-E) as reported by dove hunters using Conoho Farms, a segment of Roanoke River Wetlands Game Land, Martin County, North Carolina.

Category	No. of hunters	No. of hunting events[a]	Total hours hunted by all respondents (%)	Mean hours hunted per hunting event (SE)	Total shots fired by all respondents (%)	Mean shots fired per hunting event (SE)
Year 2007	74	104	440.5 (54.9)	4.24 (0.19)	3,175 (46.8)	30.53 (2.59)
Year 2008	68	96	361.25 (45.1)	3.76 (0.18)	3,607 (53.2)	37.57 (3.73)
				$P = 0.0854$		$P = 0.5619$
SH Permit	136	191	779.25 (97.2)	4.08 (0.13)	6,731 (99.2)	35.24 (2.31)
POS Permit	6	9	22.5 (2.8)	2.50 (0.16)	51 (0.8)	5.67 (0.82)
				$P = 0.0075$		$P = 0.0003$
Field A	68	122	492.75 (61.5)	4.04 (0.16)	4370 (64.4)	35.82 (2.87)
Field B	4	4	9.5 (1.2)	2.38 (0.75)	96 (1.4)	24.00 (18.78)

Table 10. Continued

Field C	46	49	224 (27.9)	4.57 (0.26)	1693 (25.0)	34.55 (4.53)
Field D	7	7	22.5 (2.8)	3.21 (0.68)	114 (1.7)	16.29 (7.00)
Field E	17	18	53 (6.6)	2.94 (0.48)	509 (7.5)	28.28 (8.42)
				$P = 0.0042$		$P = 0.1348$
Combined	142	200	801.75	4.01 (0.13)	6782 (100)	33.91 (2.25)

[a]The number of hunting events for which hunters responded to this question; not all hunters reported information for all days.

Table 11. Comparison of hunting success per hunting event, between the 2007 and 2008 dove hunting seasons, between the special hunt (SH) and point-of-sale (POS) permittees, and among the 5 fields (A-E) as reported by dove hunters using Conoho Farms, North Carolina.

Category	No. of hunters	No. of hunting events[a]	Total doves harvested by all respondents (%)	Mean doves harvested per hunting event (SE)
Year 2007	74	105	634 (47.6)	6.04 (0.45)
Year 2008	68	96	697 (52.4)	7.34 (0.58)
				$P = 0.1059$
SH Permit	136	191	1,317 (98.9)	6.90 (0.37)
POS Permit	6	9	14 (1.1)	1.56 (0.23)
				$P = 0.0011$
Field A	68	123	911 (68.4)	7.41 (0.46)
Field B	4	4	13 (1.0)	3.25 (2.93)
Field C	46	48	287 (21.6)	5.98 (0.69)
Field D	7	7	32 (2.4)	4.57 (2.14)
Field E	17	18	88 (6.6)	4.89 (1.29)
				$P = 0.0370$
Combined	142	201	1,331 (100)	6.66 (0.36)

[a]The number of hunting events for which hunters responded to this question; not all hunters reported information for all days.

Table 12. Primary weapon type, shot size, and shot weight used by dove hunters with special hunt and point-of-sale permits across the 5 dove fields on Conoho Farms, North Carolina, during the 2007 and 2008 dove hunting seasons.

Response[a]	No. of hunting events[b]	Percent of Respondents (%)
Weapon		
12-gauge shotgun	172	85.57
16-gauge shotgun	4	1.99
20-gauge shotgun	23	11.44
28-gauge shotgun	1	0.50
Unknown/Incomplete	1	0.50
Shot size		
# 6 shot	1	0.50
# 7 shot	5	2.49
# 7 ½ shot	111	55.22
# 8 shot	76	37.81
Unknown/Incomplete	8	3.98
Shot weight		
¾ ounce (21.26 g)	1	0.50
⅞ ounce (24.81 g)	15	7.46

Table 12. Continued

1 ounce (28.35 g)	93	46.27
1 ⅛ ounce (31.89 g)	65	32.34
1 ¼ ounce (35.44 g)	10	4.98
1 ⅜ ounce (38.98 g)	1	0.50
1 ½ ounce (42.52 g)	3	1.49
Unknown/Incomplete	13	6.47

[a]Responses were combined across years and permit types.

[b]The total number of hunting events recorded by the 142 respondents who reported hunting; hunters could have responded differently for each field or day they hunted; therefore all responses are represented here.

Table 13. Comparison of North Carolina residency and gender between respondents and non-respondents of individuals permitted to hunt doves on Conoho Farms, North Carolina during the 2007 and 2008 hunting seasons.

	Residency		Gender	
Survey response	No. of non-residents (%)	No. of residents (%)	No. of females (%)	No. of males (%)
Respondents	31 (3.7)	589 (71.0)	12 (1.5)	608 (73.3)
Non-respondents	6 (0.7)	204 (24.6)	6 (0.7)	204 (24.6)
		$P = 0.1934$		$P = 0.4281$

Table 14. Comparison of age groups between respondents and non-respondents of individuals permitted to hunt doves on Conoho Farms, North Carolina, 2007 and 2008 hunting seasons.

	No. of permittees in each age group (%)						
Survey response	1-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs	50-59 yrs	60-69 yrs	70-89 yrs
Respondents	19 (2.3)	30 (3.6)	38 (4.6)	46 (5.5)	49 (5.9)	19 (2.3)	9 (1.1)
Non-respondents	23 (2.8)	63 (7.6)	97 (11.7)	146 (17.6)	126 (15.2)	116 (14.0)	49 (5.9)
$P = 0.0004$							

The Effects of Tillage on Shot Concentrations in Mourning Dove Fields

KELLY E. DOUGLASS, *North Carolina Wildlife Resources Commission*, PO Box 31063, Raleigh, NC 27612, USA

DAVID T. COBB, *North Carolina Wildlife Resources Commission*, 1722 Mail Service Center, Raleigh, NC 27699-1722, USA

PHILLIP D. DOERR, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7646, Raleigh, NC 27695, USA

KENNETH H. POLLOCK, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7617, Raleigh, NC 27695, USA

RICHARD A. LANCIA, *North Carolina State University*, Fisheries, Wildlife, and Conservation Biology Program, Box 7646, Raleigh, NC 27695, USA

ABSTRACT Despite the research on lead (Pb) shot deposition and ingestion by mourning doves (*Zenaida macroura*), there has been no research to determine how management practices may be utilized to effectively reduce Pb shot concentrations and potentially reduce shot availability in fields managed for dove hunting. We measured shot concentrations in 5 publicly managed mourning dove fields in North Carolina to determine if concentration levels were significantly affected by tillage. We used a complete block design with 12 plots, each of which received a combination of the following planting and management treatments: 3 crops (sunflower (*Helianthus annuus*), millet (*Setaria italica* or *Brachiaria ramosa),* or corn (*Zea mays*)) and 2 treatments (till or

no-till). Soil samples (N = 4,204) were collected before, during, and after dove hunting seasons for 2 years from August 2007 to August 2009. Data were analyzed using a generalized linear mixed model, with a negative binomial distribution, to evaluate differences in shot concentrations among crops and seasons, and between treatments and areas of high and low hunter effort. Shot concentrations differed among seasons and crops and between areas of high and low hunter effort, including a significant interaction between crop and effort. We could not detect any significant effect of treatment, indicating that tillage does not reduce shot concentrations in dove fields. Managers could effectively reduce shot concentrations in dove fields and, therefore, reduce Pb exposure to doves, by limiting hunter access and/or effort or requiring nontoxic shot on managed dove fields.

KEY WORDS habitat management, hunting, lead, North Carolina, mourning dove, Pb, pellets, shot concentrations, tillage, Z*enaida macroura*.

The Journal of Wildlife Management: 00(0): 000-000, 20XX

Shortly after the North American prohibition on the use of lead (Pb) shot for waterfowl hunting, a surge of research occurred throughout the world on Pb exposure, ingestion, and toxicity in other avian species. Research has documented the ingestion of Pb ammunition by over 120 avian species (Tranel and Kimmel 2009). Reported frequencies of Pb shot ingestion by mourning doves (*Zenaida macroura*) have ranged from 0.2% to 6.5%, based on manual or x-ray examination of gizzards for pellets, and 10.9% to 60.0%, based on tissue analysis of Pb levels in blood, liver, kidney, and bone (Locke and Bagley

1967, Kendall and Scanlon 1979, Best et al. 1992). The ingestion of Pb shot may cause short-term and long-term health effects, including mortality. Health effects, such as weight loss, lethargy, abnormal behavior, and decreased food intake from the chronic effects of Pb toxicosis from low Pb doses, may result in morbidity and possibly indirect mortality from increased predation or susceptibility to disease (Carrington and Mirarchi 1989, Castrale and Oster 1993). Alternatively, doves may ingest multiple Pb pellets and may die quickly from the effects of acute Pb toxicosis (Schulz et al. 2006). Kendall et al. (1996) reported that ingestion of spent shot was the primary means of Pb exposure for upland game birds, especially mourning doves, and that doves tend to forage in heavily hunted fields that are managed specifically to attract doves, thereby increasing their risk of Pb exposure and ingestion. High concentrations of Pb shot have been found in dove fields especially during and immediately following the hunting season when doves may be foraging in these areas (Kendall et al. 1996). Studies have reported Pb shot concentrations in the top soil layers of managed dove fields ranging from 0 pellets/ha to 107,639 pellets/ha (Anderson 1968, Lewis and Legler 1968, Castrale 1989, Schulz et al. 2002). Despite the research on Pb shot deposition, there has been no research to determine how management practices may be utilized to effectively reduce Pb shot concentrations and potentially reduce shot availability in fields managed for dove hunting.

Goals of our study were to determine shot concentrations in publicly managed mourning dove fields in North Carolina (located within the Eastern Management Unit of

the Atlantic Flyway) and to determine if concentration levels were significantly affected by tillage. Objectives of our study included: 1) measuring the concentration of shot pellets in soil samples taken from 5 dove fields in eastern North Carolina from August 2007 to August 2009; 2) categorizing hunter effort on these fields during the 2007 and 2008 dove hunting seasons, based on the results of other work (Douglass 2011); and 3) determining the effects of season, tillage, crop type, and hunter effort on the shot concentrations found in these fields.

Hunting Seasons

The U.S. Fish and Wildlife Service determines the federal framework for all dove hunting seasons in the United States, including the maximum number of hunt days, season date range, daily bag limit, and the number of season splits. Each state wildlife agency then establishes the dove season for their state within the federal framework. The North Carolina Wildlife Resources Commission (NCWRC) adopted dove hunting seasons using the maximum allowable hunting opportunity provided by the frameworks for 2007 and 2008. The season dates, daily bag limits, and possession limits for 2007 and 2008, respectively, were: 1 September 2007 – 12 January 2008 (bag: 12; possession: 24) and 1 September 2008 – 10 January 2009 (bag: 15; possession 30). Each season had 3 splits, and allowed a maximum of 61 and 62 hunt days, respectively. Dove hunting is not allowed on Sundays in North Carolina.

STUDY AREA

This study was conducted at Conoho Farms (CF), a segment of the Roanoke River Wetlands Game Land (RRWGL). RRWGL is publicly owned and managed by the NCWRC and consists of 16,985 ha in Bertie, Halifax, Martin, and Northampton counties, North Carolina (Figure 1). RRWGL is a permit-only hunt area for hunting white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), small game, dove, and waterfowl.

The NCWRC manages 5 fields in CF specifically for mourning dove hunting; all are located off Hwy 125 North in Williamston, North Carolina (Figure 7). These fields have been managed intensively for dove hunting since 1997, and range in size from 1.5 ha to 13.4 ha. Although six different soils occurred on the 12 study plots, the dominant soils, Norfolk and Bonneau, represent 95.5% of the total plot area and therefore they have similar soil characteristics (Douglass 2011). Temperature and precipitation data were obtained from the National Oceanic and Atmospheric Administration for Williamston, North Carolina during the study period (Douglass 2011).

These fields were chosen for this study because they were: 1) located < 1 km from each other, minimizing environmental variation due to precipitation, topography, and soil characteristics; 2) reported as having heavy hunter use; 3) consistently managed; 4) large enough in size to meet the study design requirements; and 5) all included in the NCWRC permit hunt system, allowing for hunter effort to be quantified (Douglass 2011).

METHODS

Study Design

We used a complete block design, with 12 plots in 2 blocks (Figure 7). Plots were not randomly assigned to each block. Each block contained 6 plots; Field A was considered one block and Fields B, C, D, and E were considered the other block. Each plot received a combination of the following planting and management treatments: 3 crops and 2 treatments. Crops and treatments remained the same within plots over the study period.

Although crops are typically rotated each year for weed management purposes, crop rotation was suspended on the 12 plots during the course of the study to provide consistency and prevent bias. Each plot was planted in one of 3 crops: sunflower (*Helianthus annuus*), millet (*Setaria italica* or *Brachiaria ramosa)*, or corn (*Zea mays*). For this study, both millet species were considered one crop. These crops were chosen because they are representative of the 3 most common crops planted on publicly managed dove fields in North Carolina. Each crop was planted using one of 2 treatments: no-till or till. Tilled plots were disked annually in April or May in 2008 and 2009 to a depth of 10.16 cm to 15.24 cm. Each tilled plot was disked twice. Herbicides and/or fertilizers were used on each plot consistently throughout the study to control weeds and maintain dominant crops (Douglass 2011).

Plots were not assigned randomly to each block because each plot had already been planted and treated prior to the commencement of this study. Sample sizes within plots were unequal across sampling periods. Sample locations were randomized within

each plot using Geographic Information System software. Samples were located on the ground using a Trimble® 5800 RTK Global Positioning System survey unit with sub-centimeter accuracy. Previous sample locations were excluded from the list of possible sample locations for remaining sampling periods within a year to avoid sample bias (i.e., each 30.5 × 30.5 cm sample location within a plot was used only once within 1 calendar year).

Sampling Periods

Soil samples were collected from each plot during the following periods: 1) pre-hunt – prior to the opening of the dove season and after treatments were applied; 2) mid-hunt – between the first and second splits; and 3) post-hunt – after the close of the dove season and prior to treatments being applied. Samples were collected for 2 consecutive years, surrounding the 2007 and 2008 dove hunting seasons in North Carolina, and included 1 base-line sampling event. Each sampling event was held within 1 week of the date that the sampling event occurred in the previous year, despite the length of time that occurred between seasons and treatments, to provide consistency.

Sample Collection

Soil sampling methods were similar to those described by Castrale (1989). Standing vegetation on the sample was cut off at ground level and heavy vegetative debris on the soil surface was removed. Each sample was collected using a 30.5 cm × 30.5 cm × 1.3

cm box made of plywood and angle iron. To collect the sample, the box was set upside down on the soil, pressed down into the soil completely so that the plywood was level with the soil surface, and was dug out and inverted using a steel shovel made by NCWRC staff (Douglass 2011; Appendix D). Once the steel shovel was driven completely under the sample, the shovel and sample were lifted from the ground, inverted together, and the sample box (right side up) was slid from beneath the shovel. Excess soil was scraped off the top of the sample, level with the edges of the collection box, so a uniform volume of soil was collected. Soil was transferred from the sample box to a bucket, and then to a Ziploc®-style plastic bag. Sample bags were labeled with the plot number, sample number, and date collected, and transported to North Carolina State University for sieving. Soil samples were washed through 3 sieves (4.0 mm, 2.0 mm, and 1.0 mm mesh screens) and visually inspected for shot pellets prior to disposal. Shot pellets were collected directly from the sieves and transferred to 7.62 cm × 5.08 cm Ziploc®-style bags; all pellets were dried before cataloguing and storage. Pellets were tested for their magnetic nature to determine ferrous composition (i.e., Pb or nontoxic shot).

Statistical Analysis

Statistical analyses were completed using SAS software (Version 9.2 of the SAS System for Windows, SAS Institute, Inc., Cary, NC). We used a generalized linear mixed model (GLMM), with a negative binomial distribution, to evaluate differences in shot concentrations among seasons and crops, and between treatments and hunter effort. Plot

sums were used to account for pseudoreplication within plots. Hunter effort data were standardized by area and categorized (high/low) by block based on the results of a hunter survey we conducted during the 2007 and 2008 dove hunting seasons on CF (Douglass 2011). The model included the covariate plot as a random effect to account for non-randomization of plots within blocks.

RESULTS

We collected and sieved a total of 4,204 samples from CF during the study period. We found a total of 2,654 pellets, with 38.0% of samples containing ≥1 pellet. The mean number of pellets per sample was 0.63 (SE 0.02), with a range of 0-7 pellets/sample. The overall estimated shot concentration on CF, over time and across all crops and treatments, as based on the mean number of pellets per sample in the top 1.3 cm of soil, was approximately 67,813 pellets/ha. Thirteen (0.5%) of the pellets were magnetic, and therefore, made of ferrous material (i.e., not composed of Pb).

Shot concentrations differed over time ($P \leq 0.0001$) with the highest concentrations occurring in the mid-hunt sampling periods and the lowest in the pre-hunt sampling periods (Figure 8). Shot concentrations also differed in areas of high and low hunter effort ($P \leq 0.0001$) with the highest concentrations occurring in the areas that received high hunting pressure (Figure 9). Shot concentrations differed among crops ($P \leq 0.0001$), with the highest concentrations occurring in millet and the lowest in corn (Figure 10).

In addition, a significant interaction occurred among crops between areas of high and low hunting pressure ($P \leq 0.0001$), with higher concentrations occurring in millet in areas of high hunter effort, and higher concentrations occurring in sunflower in areas of low hunter effort (Figure 11). The interaction among crops between treatments indicated that tillage reduced shot concentrations in corn, had no effect on concentrations in millet, and increased concentrations in sunflower (Figure 12); however, we could not detect a significant interaction between crop and treatment ($P = 0.0631$) in this study.

Shot concentrations did not differ between treatments ($P = 0.4189$). There were also no significant effects of any other interactions: crop by season ($P = 0.6712$), treatment by season ($P = 0.5736$), treatment by effort ($P = 0.1529$), season by effort ($P = 0.5674$), or crop by treatment by season ($P = 0.9993$).

DISCUSSION

Shot concentrations differed among seasons, and were highest immediately after the first split in the dove season (i.e., mid-hunt). Concentrations decreased over the remaining season segments (i.e., post-hunt) to the lowest concentrations just before the season opened the following year (i.e., pre-hunt). The decrease in shot concentrations over time, from mid-hunt to post-hunt to pre-hunt, which was most likely caused by pellets settling in the soil below the depth we sampled or being ingested by animals. The overall shot concentration on CF and the increases in shot concentrations we documented as a result of hunting were similar to those reported by Anderson (1986), Lewis and Legler (1968),

Castrale (1989), and Schulz et al. (2002). Our results also correspond to those documented in a concurrent hunter survey on CF; Douglass (2011) found that 97.2% of the hours hunted and 99.2% of the shots fired by hunters using the CF dove fields during the study period occurred during the first 2 weeks of the dove season. The mid-hunt samples, in which we found the highest concentrations, were collected after the first 4 weeks of the season and, therefore, after the majority of hunting occurred.

We found higher shot concentrations in areas of high hunter effort and lower concentrations in areas of low hunter effort, which is most likely a function of the number of hours hunted or shots fired by hunters (Douglass 2011). Plots in Block 2 (Figure 7) were separated geographically by patches of trees and paths, whereas Block 1 was located within 1 field. Field configuration, location, access, and size could have affected the degree of hunter effort in each block (Douglass 2011), which may have resulted in the differences in shot concentrations we documented in each block.

Shot concentrations were higher in millet than sunflower or corn, suggesting that the root structure of millet may be more effective at retaining pellets or that wildlife may be foraging more often in corn or sunflower and ingesting pellets, making them unavailable for sampling. However, the differences among crops may be mitigated by hunter effort (Figure 11), suggesting that this pattern may only hold in heavily hunted areas. Alternatively, differences between crops could simply be due to hunter site selection, thereby increasing hunter effort and shot concentrations in certain crops.

Although tillage appeared to affect shot concentrations among crops (Figure 12), we could not detect a significant interaction between crop and treatment in this study. In addition, shot concentrations did not differ overall between treatments nor in any first-order treatment interactions, indicating that tillage may not affect shot concentrations in dove fields in our study on CF.

MANAGEMENT IMPLICATIONS

Based on the results of this study, tillage may not be an effective means of reducing shot concentrations in publicly managed mourning dove fields. Managers could effectively reduce shot concentrations in dove fields and, therefore, reduce Pb exposure to doves, by limiting hunter access and/or effort or requiring nontoxic shot on managed dove fields. Given the importance of this research and its potential implications, we suggest similar research be conducted in a controlled environment, using non-hunted fields upon which a known quantity of shot pellets have been randomly distributed, to test the effects of tillage on reducing shot concentrations. Studies examining differences in pellet retention among crops or foraging behavior and preference of doves among crops in managed dove fields should also be considered.

ACKNOWLEDGMENTS

Funding for this study was provided by the North Carolina Wildlife Resources Commission, through the Pittman-Robertson Wildlife Restoration Act (W-57). We

would like to thank the NCWRC staff responsible for managing the dove fields at Conoho Farms, and acknowledge the multitude of individuals who helped collect and sieve soil samples. We also thank North Carolina State University for supporting this research, J.A. Osborne for statistical consultation, and J.L. Wilson for editing.

LITERATURE CITED

Anderson, W.L. 1986. Investigations of abundance of spent shotgun pellets in soil and sediment in Illinois. Pages 43-49 *in* J. S. Feierabend and A. B. Russell, editors. Proceedings of the symposium on lead poisoning in wild waterfowl: a workshop. National Wildlife Federation, Washington, D.C., USA

Best, T.L., T.E. Garrison, and C.G. Schmitt. 1992. Availability and ingestion of lead shot by mourning doves (Zenaida macroura) in Southeastern New Mexico. Southwestern Naturalist 37:287-292.

Castrale, J.S. 1989. Availability of spent lead shot in fields managed for mourning dove hunting. Wildlife Society Bulletin 17:184-189.

Castrale, J.S. and M. Oster. 1993. Lead and δ-aminolevulinic acid dehydratase in the blood of mourning doves dosed with lead shot. Proceedings of the Indiana Academy of Science 102:265-272.

Carrington, M.E. and R.E. Mirarchi. 1989. Effects of lead shot ingestion on free-ranging mourning doves. Bulletin of Environmental Contamination and Toxicology 43:173-179.

Douglass, K.E. 2011. The effects of tillage on shot concentrations in publicly managed mourning dove fields in North Carolina. Thesis, North Carolina State University, Raleigh, North Carolina, USA.

Kendall, R.J. and P.F. Scanlon. 1979. Lead concentrations in mourning doves collected from middle Atlantic game management areas. Proceedings of the 33rd Annual Conference Southeastern Association of Fish and Wildlife Agencies 33:165-172.

Kendall, R.J., T.E. Lacher, Jr., C. Bunck, B. Daniel, C. Driver, C.E. Grue, F. Leighton, W. Stansley, P.G. Watanabe, and M. Whitworth. 1996. An ecological risk assessment of lead shot exposure in non-waterfowl avian species: upland game birds and raptors. Environmental Toxicology and Chemistry 15:4-20.

Lewis, J.C. and E. Legler. 1968. Lead shot ingestion by mourning doves and incidence in soil. Journal of Wildlife Management 32:476-482.

Locke, L.N. and G.E. Bagley. 1967. Lead poisoning in a sample of Maryland mourning doves. Journal of Wildlife Management 31:515-518.

Schulz, J.H., J.J. Millspaugh, B.E. Washburn, G.R. Wester, J.T. Langian III, and J.C. Franson. 2002. Spent-shot availability and ingestion on areas managed for mourning doves. Wildlife Society Bulletin 30:112-120.

Schulz, J.H. J.J. Millspaugh, A.J. Bermudez, X. Gao, T.W. Bonnot, L.G. Britt, and M. Paine. 2006. Acute lead toxicosis in mourning doves. Journal of Wildlife Management 70:413-421.

Tranel, M.A. and R.O Kimmel. 2009. Impacts of lead ammunition on wildlife, the environment, and human health–A literature review and implications for Minnesota. Pages 318-337 *in* R.T. Watson, M. Fuller, M. Pokras, and W.G. Hunt (Eds.). Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans. The Peregrine Fund, Boise, Idaho, USA.

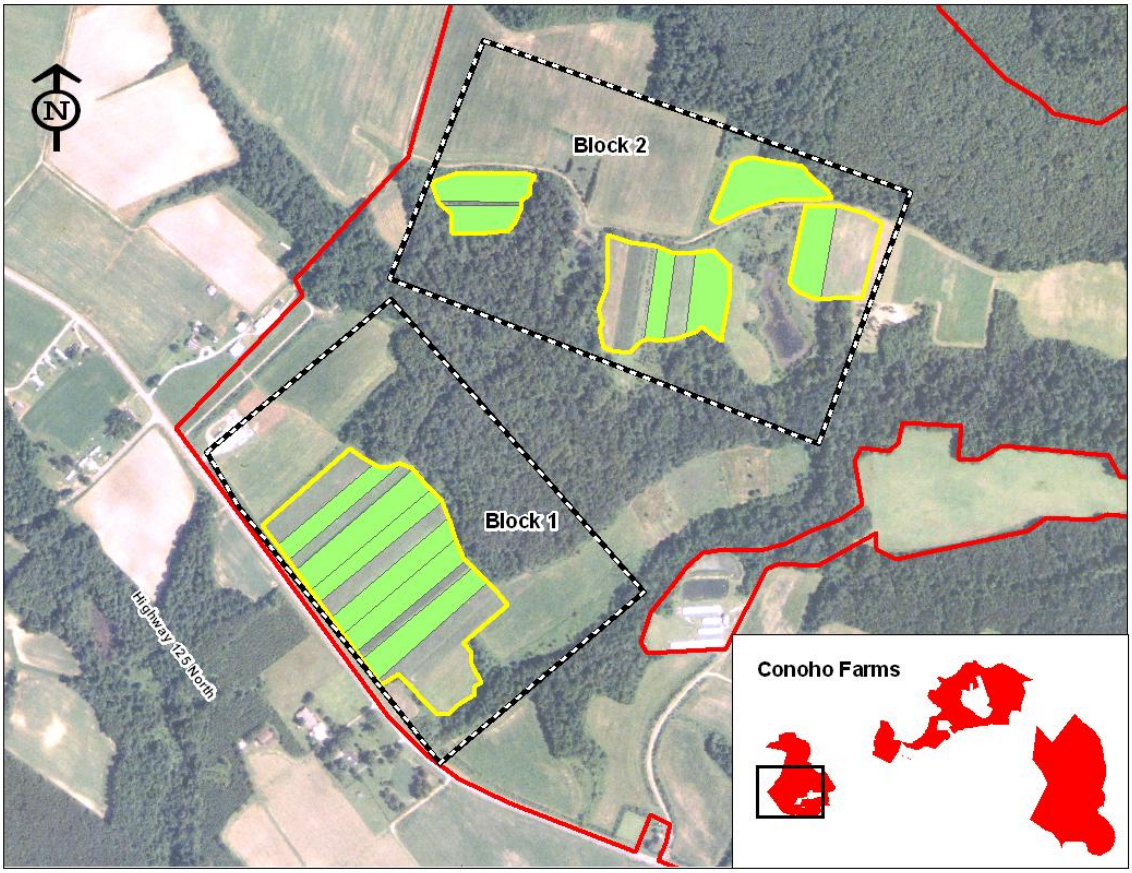


Figure 7. Twelve plots within 2 blocks of 5 publicly managed dove fields used to study shot concentrations within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

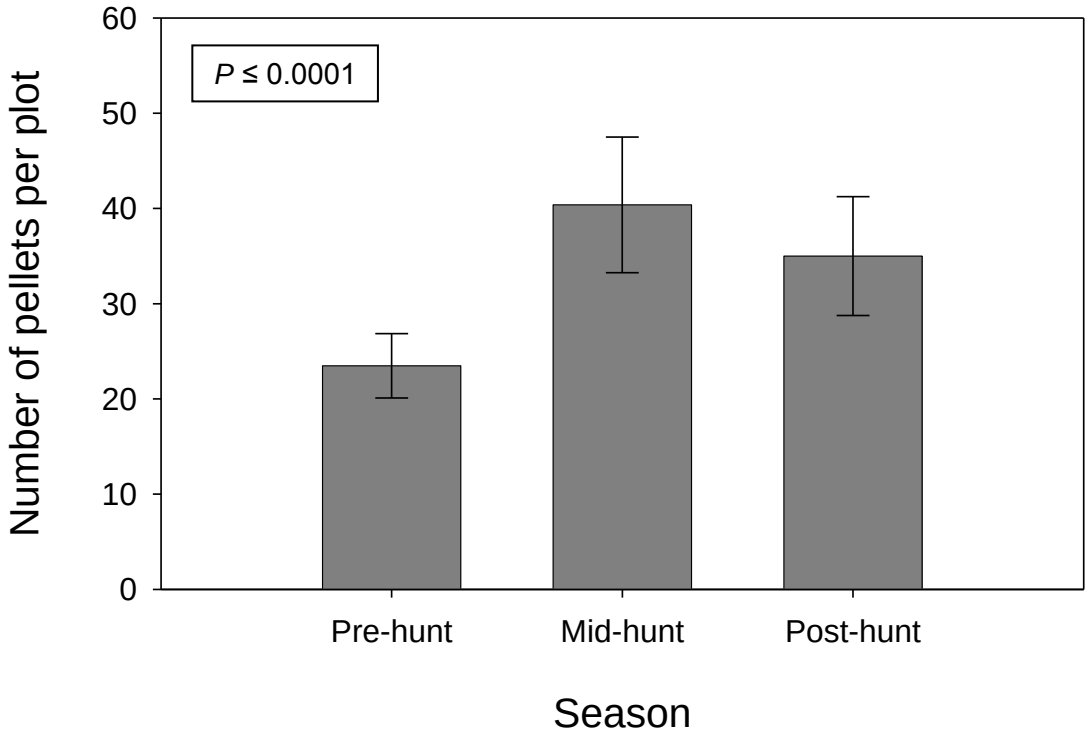


Figure 8. Shot concentrations by season within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

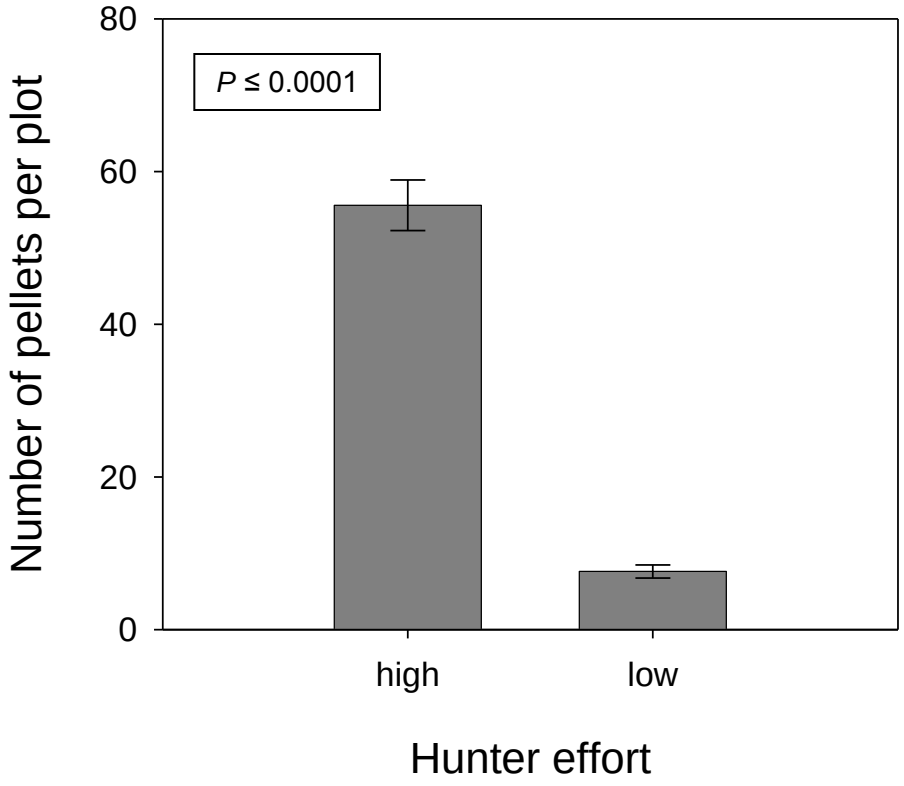


Figure 9. Shot concentrations by areas of high and low hunting pressure within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

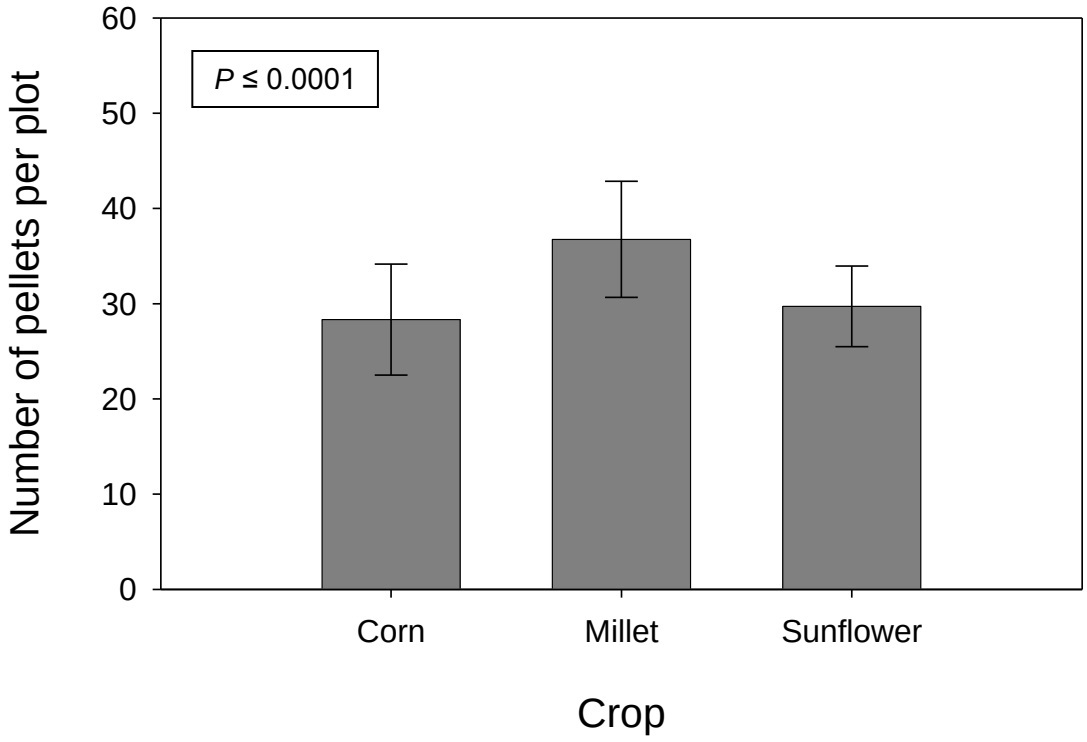


Figure 10. Shot concentrations among crops within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

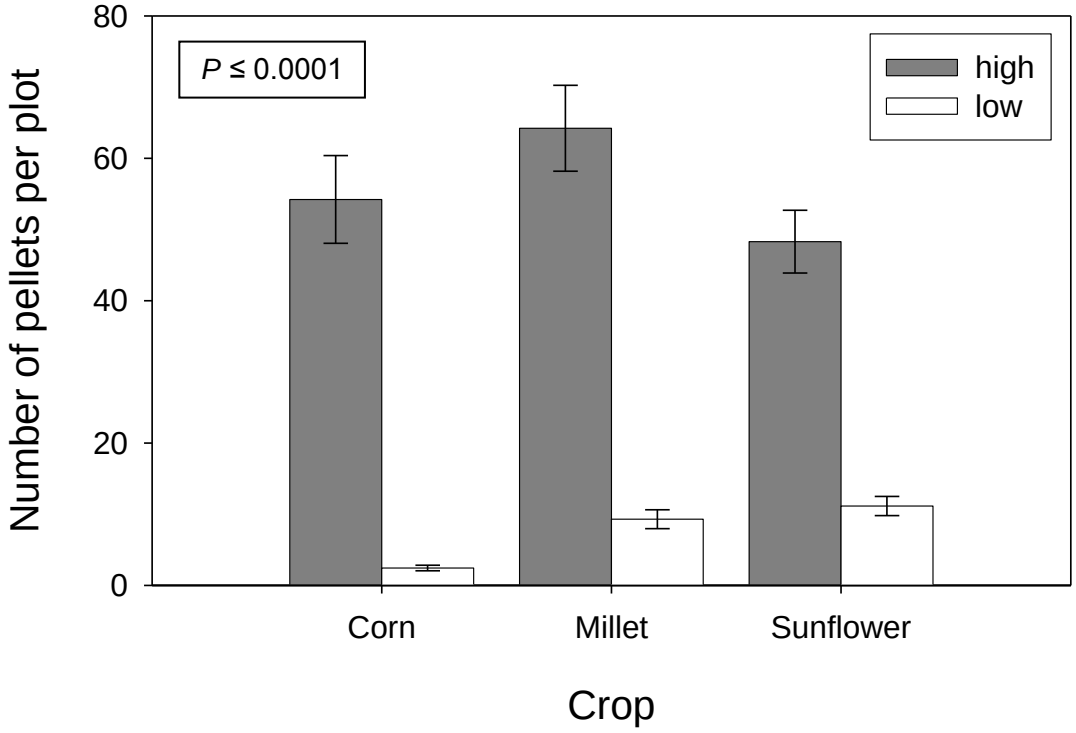


Figure 11. Shot concentrations among crops by hunter effort within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

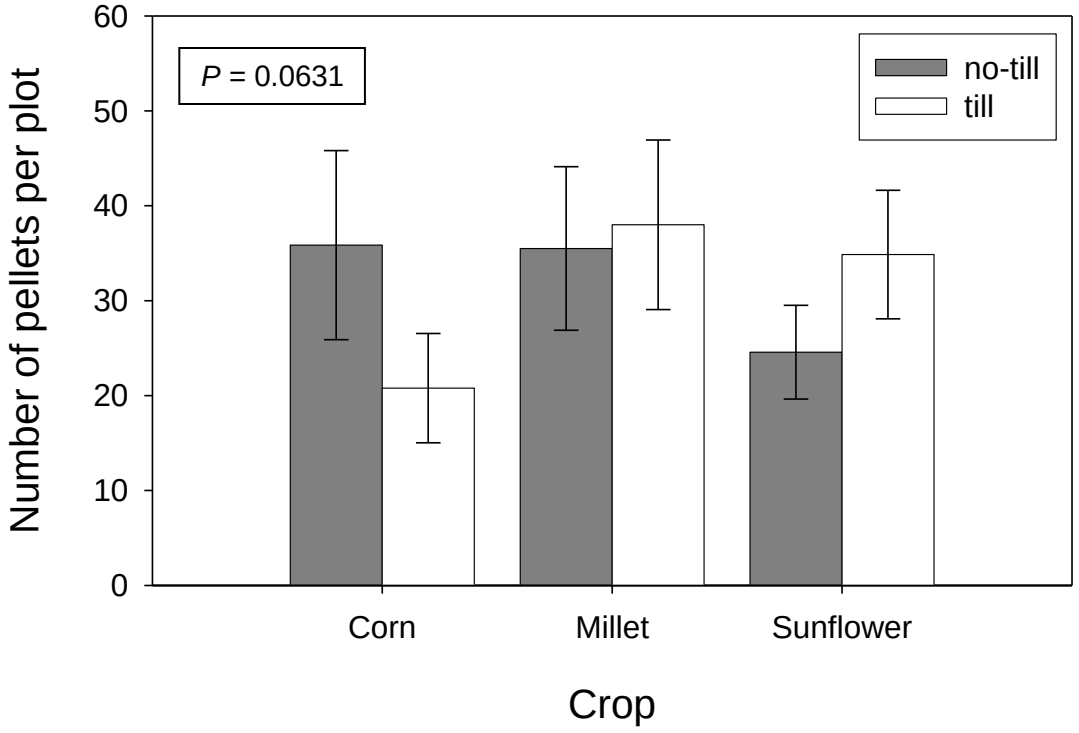
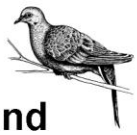


Figure 12. Shot concentrations among crops by treatment within Conoho Farms, a segment of the Roanoke River Wetlands Game Land, Martin County, North Carolina, 1 August 2007 – 31 September 2009.

APPENDICES

Permit No._____



Roanoke River Wetlands Game Land
Dove Hunter Survey

This survey is an opportunity for you to let us know about dove hunting experiences you may or may not have on the Roanoke River Wetlands Game Land during the permitted dove hunts September 1-15, 2007. As you hunt, please complete the chart on page 2 and return this survey after the last day for which you are permitted to hunt mourning doves on the Roanoke River Wetlands Game Land during the special dove hunt day(s) in 2007.

1. Did you use the enclosed permit to hunt for mourning doves on the Roanoke River Wetlands Game Land during September 1-15, 2007? **Check one.**
   - ☐ Yes → **Continue to question 2.**
   - ☐ No → **Please stop here and return the survey.**

2. For each day you hunt during the permitted dove hunts September 1-15, 2007 on Roanoke River Wetlands Game Land, please record which field(s) in which you hunt using the chart on page 2 and the map on page 3. Also record the total number of hours you hunt per field, the total number of shots you fire (shells discharged) per field, and the number of birds you harvest per field. Finally, please record the type of weapon (including gauge), shot size, and shot weight you primarily use. Only fill in information for the days you hunted. Record only your personal hunting experiences and not those of others with whom you hunted.

   For example, let's say you are permitted to hunt on September 15th and you chose to start your hunt in Field A. You stay there for 3 hours, shoot a total of 30 shells, and harvest 10 doves. That afternoon, you walk over to field B and hunt that field for 2 hours, shoot a total of 5 shells, and harvest no birds. Then you walk back over to Field A, hunt it for 3 more hours, shoot 5 shells, and harvest 2 doves, then you would fill out the chart as indicated below. Record data similarly for any additional days you hunt for which you are permitted.

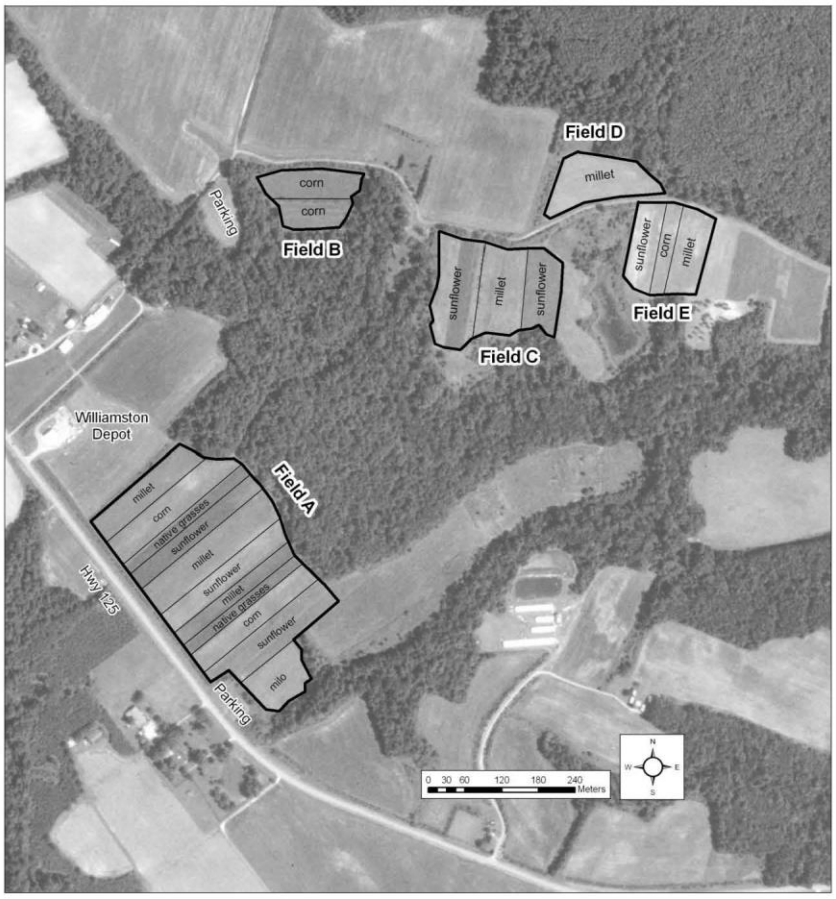
Date	Field (A-E)	Total Number of Hours Hunted	Total Number of Shots Fired	Total Number of Doves Harvested	Type of Weapon Primarily Used (include gauge)	Shot Size Primarily Used	Shot Weight Primarily Used
9/15/2007	Field A	**6**	**35**	**12**	**12-gauge shotgun**	**No. 7 ½**	**1 ounce**
	Field B	**2**	**5**	**0**	**12-gauge shotgun**	**No. 8**	**1 ounce**
	Field C	0	0	0			
	Field D	0	0	0			
	Field E	0	0	0			

1

As you hunt during the days for which you have a permit, please complete the chart below for the total number of hours hunted, total number of shots fired, and total number of doves harvested by you *personally* during the permitted dove hunts on Roanoke River Wetlands Game Land during September 1-15, 2007.

Date	Field (A-E)	Total Number of Hours Hunted	Total Number of Shots Fired	Total Number of Doves Harvested	Type of Weapon Primarily Used (include gauge)	Shot Size Primarily Used	Shot Weight Primarily Used
9/1/2007	Field A						
	Field B						
	Field C						
	Field D						
	Field E						
9/3/2007	Field A						
	Field B						
	Field C						
	Field D						
	Field E						
9/8/2007	Field A						
	Field B						
	Field C						
	Field D						
	Field E						
9/10/2007	Field A						
	Field B						
	Field C						
	Field D						
	Field E						
9/15/2007	Field A						
	Field B						
	Field C						
	Field D						
	Field E						

Map of Fields A-E on the Roanoke River Wetlands Game Land designated as mourning dove hunting areas during the special dove hunt day(s) in 2007. These fields are located off Hwy 125 approximately six miles west of Williamston. Each field is outlined in bold and crop strips are labeled for your convenience in identifying which field(s) you hunt.



Please continue the survey on Page 4

Thank you for helping us with this survey!

If you have any other comments you would like to share with us, please use the space below.

Please use the enclosed addressed and postage-paid envelope, or return this survey to:

Dove Hunter Surveys
N.C. Wildlife Resources Commission
1722 Mail Service Center
Raleigh, NC 27699-1722

Please contact Kelly Douglass by phone at (919)707-0055 or by email at kelly.douglass@ncwildlife.org with any questions.

4

APPENDIX B

Roanoke River Wetlands Game Land

Dove Hunter Survey

FIELD

A

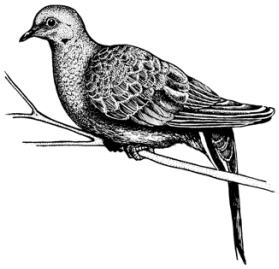
N.C. Wildlife Resources Commission, Division of Wildlife Management
N.C. State University, Fisheries and Wildlife Sciences Program

APPENDIX C

Attention Dove Hunters!

Please keep track of your dove hunting experience on Conoho Farms while you hunt this season.

If you did not receive a survey or simply misplaced the one you did receive, please take one from the box below. Please be sure to include your WRC Customer Number on your survey so that we can check your name off the mailing list when it is returned.



This study is part of an attempt to learn about dove hunting effort and success during the permitted hunts on the Roanoke River Wetlands Game Land throughout this dove season.

In this survey, we ask for specific information about which fields you hunt, the number of hours you hunt, the number of shots you fire, the number of doves you harvest, and the type of firearm and ammunition you use. Therefore, we ask that you complete this survey as you hunt mourning doves on this property throughout this dove season. Please return this survey after your last hunt day.

If you have any questions or concerns about this study, please contact Kelly Douglass by phone at (919) 707-0055 or by email at kelly.douglass@ncwildlife.org.

APPENDIX D