CONTRIBUTIONS OF DEER MANAGEMENT COOPERATIVES TO WILDLIFE CONSERVATION

by

HUNTER PRUITT

(Under the Direction of Mark D. McConnell)

ABSTRACT

Engaging private landowners to achieve landscape-level conservation is widely practiced; however, established mechanisms to encourage voluntary conservation practices are lacking. White-tailed deer (*Odocoileus virginanus*) management is an increasingly popular conservation tool. Deer management cooperatives (DMCs) represent a novel approach to engage private landowners and hunters to improve deer herd and hunting quality for broader conservation use. DMCs are 'a group of landowners and hunters voluntarily working together to improve the quality of wildlife (white-tailed deer), habitat, and hunting experiences on their collective acreage'. We evaluated 45 DMCs across five U.S. states: Georgia, Michigan, Missouri, New York, and Texas; surveying member attributes and motivations, and compared DMC landcover to the surrounding landscape. We report higher amounts of multiple 'wildlife centric' land cover types in DMCs across states, and lower amounts of 'agriculturally centric' land cover in three of four states. Land cover differences illustrate DMC benefits to broader landscape conservation.

INDEX WORDS: Deer Management Cooperatives (DMCs) , Private Landowners, Conservation, Land Cover, Membership Motivation.

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CONSERVATION

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DEDICATION

I dedicate this thesis to my grandfather, Herman James Pruitt. My granddad passed down a love for wildlife and our hunting heritage to my father, who subsequently passed that love down to me. My father instilled in me a love for land, and the necessity of managing wildlife populations for the next generation while leaving our land better than we found it. At the age of nine, my father took me deer hunting - as my grandfather did for him. This experience lit an eternal fire in my soul, producing a love for white-tailed deer and the natural environments they call home. Without that spark, I would not be where I am today.

As I grew up, my granddad constantly reminded me that, “The one who reads, is the one who leads.” After this process, I truly see the merit in his wisdom. I have grown not only in personal academic achievement, but as a leader throughout this graduate process. I want to thank my father and grandfather for inspiring me to reach this goal. Less than a month after beginning graduate school, my grandfather passed away from dementia complications. I find it only fitting to dedicate this body of work to him and his love for the outdoors.

Herman James Pruitt “UmUm”: November 22, 1932 - August 28, 2016.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

The Quality Deer Management Association (QDMA) defines deer management cooperatives (DMCs) as groups of ‘landowners and hunters voluntarily working together to improve the quality of wildlife, habitat, and hunting experiences on their collective acreage’ (Murphy 2011, Adams and Ross 2017). Considering state-based wildlife conservation is increasingly incentivized on smaller private landholdings cooperating across property boundaries (Wigley and Melchiors 1987), DMCs may help achieve state and region-wide specific management goals via prioritization to increase actively managed wildlife habitat for large suites of cohabitating species within fragmented landscapes. However, targeting deer hunters to achieve landscape-level conservation has not yet been used, although white-tailed deer (*Odocoileus virginianus*) are the most pursued game animal in North America (USFWS 2016). Thus, deer management cooperatives provide a novel method to achieve desired deer management goals while countering decreased connectivity and producing quality habitat patches. Research suggests that natural resource planners lack systematic prioritization to guide conservation decision-making (Margules and Pressey 2000, Knight et al. 2006). Thus, evaluation of privately owned DMCs, their role within a landscape context, and factors that generate success is warranted.

This idea stems from the use of an umbrella species concept, where single-species management is used as a shortcut to multi-species management faced with limited resources (Roberge and Angelstam 2004). DMC deer-driven habitat management may be used as a tool to

increase landscape management aggregating single properties under collective habitat management. We evaluate land cover differences between DMCs and their adjacent landscapes to quantify extent, composition, and configuration using FragStats® landscape analysis software.

Managed DMC landscapes may increase conservation utility by providing conservation planners with established private landowner assemblages engaging in game and habitat management. With previous research describing DMC involvement producing increased hunting satisfaction of DMC members (Mitterling 2013), DMCs may serve as a viable means to accomplish multiple objectives with positive externalities for landscapes and hunters alike. Increased deer hunter enthusiasm for habitat management creates a vector to increase habitat management, while DMCs provide the conduit linking management across property lines. Resulting DMC landscape management may provide more wildlife friendly landscape habitat patches, benefitting game and non-game species. The resulting conservation utility of increased hunter satisfaction and connected quality landscape patches provides wildlife managers with a novel conservation tool operating within both deer management and land-use paradigm shifts.

Collectively, previous research highlighted overall success of DMC implementation and resulting deer hunter satisfaction. Although previous research indicates benefits for deer harvest (Enck et al. 2007), hunter satisfaction (Mitterling 2013), and habitat within DMCs (Stout et al. 2013), many aspects of DMCs are still unknown. DMCs contain millions of acres and thousands of members across the United States (Adams and Ross 2017), but little is known about DMC members and the properties they manage. We surveyed 481 members from 45 DMCs across 5 states to fill important information gaps concerning membership motivational variety and attributes that contribute to overall DMC success. Our research provides a national extent to DMC landscape and actively managed land cover characteristics never before described. If

DMCs are to be utilized by managers, it is imperative to describe their current extent, needs of their members, and landscape-level conservation planning utility.

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CHAPTER 2

CONTRIBUTIONS OF DEER MANAGEMENT COOPERATIVES TO WILDLIFE CONSERVATION

[1] Pruitt, H. P., B. B. Boley, N. P. Nibbelink, G. J. D'Angelo, and M. D. McConnell. To be submitted to *The Journal of Wildlife Management*

Abstract

Engaging private landowners to achieve landscape-level conservation is widely practiced; however, established mechanisms to encourage voluntary conservation practices are lacking. White-tailed deer (*Odocoileus virginanus*) management is an increasingly popular conservation tool. Deer management cooperatives (DMCs) represent a novel approach to engage private landowners and hunters to improve deer herd and hunting quality for broader conservation use. DMCs are 'a group of landowners and hunters voluntarily working together to improve the quality of wildlife (i.e. white-tailed deer) habitat, and hunting experiences on their collective acreage'. We quantified land cover for 32 DMCs across four U.S. states: Georgia, Michigan, Missouri, and New York; totaling almost 180,000 acres and compared DMC landcover to the surrounding landscape. We report higher amounts of multiple 'wildlife centric' land cover types in DMCs across states, and lower amounts of 'agriculturally centric' land cover in three of four states. Land cover differences illustrate DMC benefits to broader landscape conservation.

Introduction

Targeting deer hunters to achieve landscape-level conservation success has not yet been used, even though white-tailed deer are the most pursued game animal in North America, annually generating just under 50% of Pittman-Robertson funding (USFWS 2016). Deer management also plays a major role in land use and habitat conservation (Gordon et al. 2004). Annually, 9.2 million deer hunters contribute nearly $14.8 billion to state and local economies (Conover 1997, USFWS 2016), utilizing approximately 356 million acres – roughly 19% of the contiguous United States land area – for lease or ownership. Private land ownership and leasing

generates a combined $16.28 billion annual investment in wildlife associated private land/long term lease recreation opportunities (Macauley 2016).

Simultaneously, global habitat fragmentation and loss are the leading causes for decreasing biodiversity (Hobbs 2002, Pascual-Hortal and Saura 2006, Chisholm et al. 2011, Adams et al. 2016). Habitat connectivity is critical to the maintenance of biodiversity in fragmented landscapes with differing effects based on the arrangement of patches across a landscape (Chisholm et al. 2011). Previous conservation efforts have relied heavily on large "Nature Reserves"; however, nature reserves do not fully capture or increase biodiversity across a large geographic and ecological range (Scott et al. 2001). The drawback to nature reserves stems from land ownership patterns. High elevation publicly owned lands, with less than average biodiversity, are protected, while privately owned low-to mid-elevation lands are subject to increased habitat fragmentation (Scott et al. 2001). This suggests a possible paradigm shift for wildlife conservation planning: managing wildlife on smaller private landholdings with many cooperating landowners may be better at providing elevated biodiversity. Thus, landowner cooperatives may provide a method to counter decreasing connectivity between habitat patches by linking numerous parcels under common management styles. For example, European Union (EU) farmers voluntarily enroll in agri-environment schemes to promote landscape-level game and non-game biodiversity conservation (Wilson and Hart 2000). Kleijn and Sutherland (2003) analyzed 62 different agri-environment scheme studies of which 53% showed increases in biodiversity while only 6% of showed decreases. The agri-environmental scheme approach can be applied with deer management cooperatives (DMCs) in the United States via collaboration among private landowners and hunters to achieve deer management goals on collective acreage (QDMA 2005).

DMCs represent a novel approach to connect deer hunters and landowners to provide the additional conservation benefits of a well-connected landscape. Research suggests that natural resource planners lack systematic prioritization approaches that guide conservation decision making (Margules and Pressey 2000, Knight 2006). A lack of systematic prioritization results in an "implementation crisis" (Knight et al. 2008) on private land to increase biodiversity and habitat-patch connectivity (Lacher and Wilkerson 2013, Creech et al. 2014). Before conservation prioritization can take place, a systematic assessment of possible tools should be performed (Knight 2006). Thus, it is imperative to evaluate privately owned DMCs and their role within a landscape context. Landscape context determines how different habitats, cover types, or populations are arranged, and the subsequent effect on a given landscape (Wiens 2009). Therefore, a particular DMC could function as an island under island biogeography theory in a sea of human use. Using this framework, DMCs could function as patches of high-quality habitat within a hostile landscape matrix (i.e., agriculture). By aggregating multiple properties to meet desired deer management goals, DMCs may facilitate increased habitat quality and connectivity within the landscape matrix. Habitat networks consist of protected and managed properties that provide sufficient connection to increase landscape biological diversity and conservation potential (Gutzwiller 2002). DMC's could operate as a conservation-planning tool implemented to gain high quality habitat patches between managed properties. By connecting private landowners and hunters under common deer management goals, DMCs can increase habitat connectivity of high-quality land cover for wildlife species other than white-tailed deer within a fragmented landscape.

Deer management cooperatives may help achieve state and region-wide specific management goals via prioritization to increase actively managed wildlife habitat. Although

white-tailed deer are beneficiaries of habitat fragmentation within the wildlife-human interface of suburban and agricultural areas across the United States (Cornicelli et al. 1996), DMCs may benefit large suites of cohabitating species. Landscape heterogeneity may provide biodiversity conservation when large-scale landscapes are conserved (Rosenzweig 1995). This idea stems from the use of an umbrella species concept, where the management and conservation of one focal species indirectly benefits many other species that cohabitate within the same ecosystem (Branton and Richardson 2010). The umbrella species concept is increasingly used as a shortcut to conservation planning when faced with limited resources, time, and funding (Roberge and Angelstam 2004). For example, Desert bighorn sheep (*Ovis canadensis nelsoni*) and wolverine (*Gulo gulo*) research has shown promise using the umbrella species concept for landscape conservation prioritization to increases cohesion between geographically and genetically isolated metapopulations of a single species (Inman et al. 2013, Creech et al. 2014). By determining species-specific patch-based conservation needs that increase connectivity within designated regions and habitats, conservation planners may subsequently increase connectivity for cohabitating species on the same landscape suffering from habitat fragmentation (Branton and Richardson 2010). In this manner, DMC landowner cooperation within a fragmented landscape could function within metapopulation theory (Verboom et al. 2001) as distinct population units, with differing extinction and dispersal probabilities, separated by space and linked by dispersion (Opdam 1991).

Connectivity among habitat patches is at the basis of habitat 'availability' within the patch itself (Pascual-Hortal and Saura 2006). The implementation of 'wildlife reserves' and 'key patches' stems from this interpretation of habitat availability (Scott et al. 2001, Verboom et al. 2001). However, if holistic conservation of any species is to be achieved, reserves should be

viewed within the context of their surrounding landscapes (Pascual-Hortal and Saura 2006, Chisholm et al. 2011). Thus, interpreting habitat network quality across a given landscape should theoretically increase with increased cooperation among neighboring properties due to the neighbor or neighborhood effect (Taylor et al. 1993). The neighbor effect is defined as the impact that a neighboring habitat patch has on nearby patches; this influence increases as distance between patches decreases and connectivity increases (Taylor et al. 1993). Thus, DMCs may connect habitat patches and certain land cover types within designated regions under collective management and may provide habitat for cohabitating species within a previously fragmented landscape (Branton and Richardson 2010).

Active land management decisions influence landscape structure, habitat use, and exposure to edge; all of which affect species movement and presence (Johnson et al. 1992). Landscape habitat amount has a consistently positive effect across varying landscape area (Smith et al. 2011), following the ‘habitat amount hypothesis’ (Fahrig 2013). Edge amount has varying impacts on native species diversity (Harris 1988, Rosenzweig 1995, Dijak and Thompson III 2000). For example, most migrating neotropical and grassland birds experience decreased density with increased total edge density and increased suburban edge (Flethcher and Koford 2002, Bock et al. 1999), while certain types of edge habitat increase avian use (Best et al. 1990) and small mammal abundance (Anderson et al. 2003). Landscape heterogeneity and patch size have also been shown to influence deer (Kie et al. 2002) and grassland bird abundance (Herkert 1994, Helzer and Jelinksi 1999, and Horn and Koford 2000). With a large body of research indicating that landcover composition and configuration affects species abundance and diversity, DMC landscape evaluation is warranted.

DMCs may be used as a tool to increase landowner driven landscape management

aggregating single properties under collective deer and habitat management goals. DMC active habitat management may inadvertently provide benefits to cohabitating suites of game and non game species relying on habitat components created by timber thinning, prescribed fire, early successional habitat maintenance, and wildlife openings (Adams and Ross 2017). We compare land cover percentages between DMCs and surrounding landscapes to quantify differences in active habitat management occurring on DMCs that may benefit species other than white-tailed deer within a fragmented landscape. We quantify the land cover composition and configuration of DMCs compared to the surrounding landscape using FragStats® software to quantify potential DMC utility in landscape conservation planning.

Study Area

Working with the Quality Deer Management Association (QDMA) employees and cooperative specialists, we identified 32 DMCs across four states within representative regions of the whitetail's range: Georgia (Southeast US: 7 DMCs), Missouri (Midwest US: 7 DMCs), Michigan (Northern US: 8 DMCs), and New York (Northeastern US: 10 DMCs) (Figure 2.1). DMC acreage that participated in land cover analysis totaled almost 180,000 acres (179,829 acres): (Georgia: 69,607 acres, Missouri: 27,449 acres, Michigan: 42,605 acres, and New York: 40,168 acres). Cooperatives averaged 5,620 acres in size across all states (range: 534 - 28,159 acres) (Table 2.1), with 84 members and 34 landowners. Each region has distinct differences in landscape and land-use trends (Brown et al. 2005), reflected in average DMC size within states ranging from 3,921 acres in Missouri to 9,944 acres in Georgia.

Methods

We identified DMCs using state agencies, Quality Deer Management Association (QDMA) cooperative specialists, and a QDMA Email to membership within each state. DMC leaders provided us with DMC name, county, closest city/town, size (acres), number of members and landowners, establishment year, and an updated boundary map. DMC boundary maps were mandatory for land cover analysis to accurately determine DMC area. We sampled 32 DMCs across four states representing four regions: Georgia (7 DMCs: Southeast), Michigan (8 DMCs: North), Missouri (7 DMCs: Midwest), and New York (10 DMCs: Northeast) (Table 2.1, Figure 2.2).

We downloaded National Agriculture Imagery Program (NAIP) county mosaics using the USDA/NRCS Geospatial Data Gateway (USDA/NRCS 2018). We used ArcMap software (V. 10.x, ESRI, Redlands, CA) to “heads-up” digitize DMCs and surrounding land cover. We classified land cover type using NAIP imagery and Google earth pro (2018) historical imagery into one of 18 categories (Table 2.2). Landcover shapefiles were converted to raster format (5-meter cell size) for subsequent land cover analysis (Figure 2.3). All landcover types did not show up in all DMCs due to variation across state and regional habitats.

Sampling Method

We placed a fishnet grid over each DMC to randomly select individual cells inside the DMC and in the adjacent landscape for landcover sampling (Figure 2.4). The fishnet grid was larger than the DMC to ensure adequate sampling of the adjacent landscape and because DMC extent and shape varied greatly across states. In order to create a grid extent, we determined adjacent landscape size with a state-based DMC to adjacent landscape ratio (Table 2.3). Adjacent landscape size varied with DMC size. For example, the Georgia ratio is 1 to 3.5 (DMC to

Adjacent landscape). Using this example, a 1,000-acre DMC warrants a 3,500-acre adjacent landscape sample area to ensure adequate sampling representation of adjacent landscape. Varying DMC extents produced varied ratios among states (Table 2.3). Cells sampled within DMCs averaged 11.54% of a DMCs overall area. We compared land cover composition within DMC samples to the parent DMC raster to ensure our samples were representative. We calculated the absolute difference between mean state-wide DMC land cover percentage and mean state-wide sample value. Resulting differences averaged less than one percent (0.92%) across all land covers and states. State mean absolute differences ranged from 0.60% in Missouri to 1.16% in New York (Table 2.4).

DMC extent and shape varied greatly across states. Georgia and Missouri DMCs were relatively contiguous, while Michigan and New York DMCs were not as contiguous (Figure 2.5). We randomly sampled DMC land cover and adjacent landscapes using a fish-net grid of 500 m^2 (Georgia & Missouri) and 250 m^2cells (Michigan & New York). We buffered DMC boundaries to ensure cells containing both DMC and adjacent landscape area were not sampled (Figure 2.4). We used smaller cell sizes in both Michigan and New York (250 m^2) to ensure adequate sampling while accounting for DMC border buffers, extent, and shape differences. We sampled ten cells within each DMC and their adjacent landscape, resulting in a 20-cell sample per DMC location.

Analysis

We used FragStats® software (McGarigal et al. 2012) to quantify the composition and configuration of land cover types within DMCs and the adjacent landscape (Table 2.5). DMC and adjacent landscape sample raster layers were numerically reclassified to ensure

standardization across varying landscapes. We converted reclassified raster files to '.tiff' files for class and landscape-level analysis. We evaluated class-level percentage of landscape (PLAND), edge density (ED), patch density (PD), and interspersion & juxtaposition index (IJI) for all 18 land cover types (Appendix A). We focused on five 'wildlife centric' land covers important to large suites of wildlife species: closed canopy deciduous (CCD), early successional (ES), herbaceous wetland (HW), wildlife openings (WO), and woody wetland (WW). We also evaluated three 'agricultural & urban' land covers: developed (D), managed exotic grass (MEG), and row crop (RC). PLAND is evaluated for all eight land covers whereas ED, PD, and IJI are evaluated only for 'wildlife centric' land covers. We evaluated landscape-level metrics for all land cover combined regardless of class. Landscape analysis evaluated ED, PD, and IJI. Chosen metrics measure per unit area, percentage, or scale to standardize for DMC extent and configuration variation. We used Program R (2013) to calculate mean values, 95% confidence intervals, and to preform paired T-tests on land cover analysis metrics. To determine whether differences between DMC landscape and adjacent landscapes were significant, we preformed paired T-tests for all class and landscape-level metrics. Statistical significance levels were determined at an $\alpha \leq 0.05$. A complete breakdown of metrics used is available (Table 2.5-2.7).

Results

Class-level

We analyzed almost 180,000 acres (179,829 acres) of DMC acreage: (Georgia: 69,607 acres, Missouri: 27,449 acres, Michigan: 42,605 acres, and New York: 40,168 acres). Cooperatives averaged 5,620 acres across all states, ranging between 3,921 acres in Missouri to 9,944 acres in Georgia (Table 2.1). All five 'wildlife centric' land cover types composed a higher

percentage of the landscape within DMC boundaries than the adjacent landscape (Figure 2.6), however only three were significantly higher (ES: +4.44%, $p = 0.003$; WO: +1.36%, $p = 0.004$; WW: +2.55%, $p = 0.006$) (Table 2.9). We did not detect significant differences in herbaceous wetland PLAND between DMCs and the adjacent landscape ($p = 0.07$). However, we identified a 1.69% increase on DMCs. While not statistically significant, places that have more herbaceous wetland could differentially contribute to wildlife management for wetland obligate or affiliative species (Gibbs 1993, Gibbs 2001, Russell et al. 2002).

All three 'agricultural & urban' land cover types composed a smaller percentage of the landscape within DMC boundaries than in the adjacent landscape (Figure 2.7). Both developed and managed exotic grass land covers were significantly lower within DMCs (D: -1.56%, $p \leq 0.001$; MEG: -7.43%, $p \leq 0.001$). Row crop land cover was 2.07% lower within DMCs but was not statistically significant ($p = 0.373$). Overall, our described decreases in 'agricultural & urban', coupled with increases in 'wildlife centric' land cover, suggest an overall DMC land cover benefit at the class-level.

Edge density (ED) of 'wildlife centric' land covers was higher on DMCs except closed canopy deciduous (Figure 2.8). However, only herbaceous wetland and woody wetland ED were significantly higher within DMCs (HW: +7.51 meters/hectare, $p = 0.002$; WW: +7.97 meters/hectare, $p = 0.009$) (Table 2.8 and 2.9). Patch density (PD) of 'wildlife centric' land cover was higher for all five categories within DMCs, but only wildlife openings and woody wetland categories were significantly higher (WO: +2.47 patches/100 hectares, $p = 0.018$; WW: +7.97 patches/100 hectares, $p = 0.015$) (Figure 2.9, Table 2.8 and 2.9). Herbaceous wetland PD was higher by 1.77 patches/100 hectares within DMCs and could be biologically significant, although not statistically significant ($p = 0.09$). Interspersion and juxtaposition index (IJI) of 'wildlife

centric' land covers were higher for all five categories within DMCs than their adjacent landscapes, but only early successional and wildlife openings were significantly higher (ES: +7.78%, $p = 0.027$; WO: +10.66%, $p = 0.010$) (Figure 2.10, Table 2.8 and 2.9).

Landscape-level

We report landscape-level ED, PD, and IJI within and across all states. Mean landscape level edge density was lower on DMCs than the adjacent landscape across all states combined and within each state (Figure 2.11). Due to low sample sizes within each state, significantly lower ED within DMCs was only detectable with pooled data (i.e., all states combined) (-40.1 m/ha, $p \leq 0.002$) (Table 2.9). Georgia DMCs had the lowest ED of 157.46 m/ha within boundaries and 185.86 m/ha for the adjacent landscape (-28.4 m/ha within DMCs), while New York DMCs had the highest ED of 259.77 m/ha within boundaries and 311.20 m/ha for the adjacent landscape (-51.43 m/ha within DMCs) (Table 2.8).

We observed lower PD on DMCs versus the adjacent landscape for Georgia, Missouri, and Michigan. New York patch density was marginally higher within DMCs, producing an overall average that was not statistically different (Figure 2.12). Landscape-level IJI was higher within DMCs than their adjacent landscapes in Georgia, Missouri, New York, Michigan, and all states combined. Michigan IJI was essentially equivalent for DMCs and their adjacent landscapes with a slightly higher IJI within DMCs (+0.24%) (Figure 2.13). Across all states IJI was significantly higher within DMCs by an average of 6.07% ($p = 0.023$). (Raw data for class and landscape-level values can be found in Table 2.6-2.8, with significance values in Table 2.9).

Discussion

Land cover analysis of DMCs indicates higher 'wildlife centric' and lower 'agricultural & urban' land cover percentages within DMCs than adjacent landscapes. These two findings suggest that DMCs provide increased wildlife habitat due to intensive deer management. Wildlife centric land covers, such as wildlife openings and early successional communities, are a direct reflection of active management choices within DMC boundaries by land owners. We provide the first data to quantify land cover differences produced by DMC landowner and hunter driven land management. This information can be used by state and federal agencies interested in increasing habitat amount and management on private lands within given focal areas. Following the 'habitat amount hypotheis' (Fahrig 2013), increase habitat amount plays a vital role landscape-level conservation and success.

Our systematic evaluation of 32 DMCs and over 180,000 acres indicated a higher proportion of five 'wildlife centric' land cover types within DMCs than the surrounding landscapes (Figure 2.6), including early successional communities (+4.44%), wildlife openings (+1.36%), and woody wetland (+2.55%). Closed canopy deciduous areas and woody wetlands are not regularly produced as a result of white-tailed deer management but benefit many avian and amphibian cohabiting species. Higher percentages of 'wildlife centric' land cover, coupled with lower amounts of managed exotic grasses (hay/pasture), row crop, and human development (Figure 2.7), indicate a trend of land cover composition toward 'wildlife centric' landscapes within DMCs.

Class-level land cover configuration and composition can indicate relative habitat quality for many cohabitating species (Smith et al. 2011) by quantifying general land cover type, extent, and arrangement. Our analysis indicated decreased edge in closed canopy deciduous habitats,

indicative of intact patches of upland and bottomland hardwoods. We describe greater edge in the remaining wildlife centric land cover classes, likely due to increased patch abundance and PD within the DMC boundary. PD means for all wildlife centric land cover classes were greater within DMC boundaries than the adjacent landscape, indicating that DMCs represent more wildlife centric land cover with more edge and patches than the adjacent landscape.

Small sample sizes limited our ability to detect statistically significant differences by state (See Appendix B for state-based PLAND). Overall landscape-level ED was significantly lower within DMCs, while class-level ED was greater for early successional, herbaceous wetland, wildlife openings, and woody wetland classes. Decreased ED for the entire landscape, coupled with increasing 'wildlife centric' ED indicates that, overall, DMC landscapes are producing higher quality wildlife habitat for game and non-game species than adjacent landscapes. IJI values were greater within DMCs in three of four states, and significantly greater overall. Indicating that DMC landscape structure consisted of more evenly spaced patches and with smaller distances separating patches.

When evaluating the implications of land cover differences, DMC extent should be considered. Although land cover differences between DMCs and their adjacent landscape may seem small, one percent of the mean 5,600-acre DMC (Table 2.1) is 56 acres. With combined statistically significant increases in 'wildlife centric' land cover totaling 8.35%, an additional 468 acres 'wildlife centric' habitat would be present within a 5,600-acre DMC. For example, ED of wildlife openings within DMCs is 11.05 m/ha higher than the adjacent landscape. This difference would equate to 25,043 more meters of wildlife opening associated edge in the average DMC.

Over the past two decades, DMC related research and literature has been limited to deer herd harvest characteristics and implications (Enck et al. 2007, Mitterling 2013), hunter

satisfaction and DMC social fabric (Mitterling 2013), and DMC formation (QDMA 2005). Widespread DMC implementation and advocacy has occurred by a handful of state agencies and conservation organizations, with little known about DMC impacts within a given landscape. Our results affirm that DMCs are producing and conserving wildlife habitat and landscapes across the eastern United States. Landowner and deer hunter enthusiasm for quality or trophy deer management are inadvertently producing and conserving more wildlife friendly landscapes than their adjacent areas. With over 11.6 million hunters (USFWS 2016), of which 86% hunt big game, DMCs have the potential to be an extremely useful landscape conservation tool. DMCs have the ability to leverage deer management enthusiasm to increase habitat quality at minimal cost to state agencies while simultaneously increasing landscape-level benefits to many wildlife species other than white-tailed deer.

Future Research

Further research into DMC land cover should include more states and DMCs. No national database for private land owner DMCs exists. DMC identification proved to be difficult even with a network of state and QDMA employees. Only 32 DMCs, across 4 states, provided adequate maps and information for land cover analysis. Low sample DMC numbers within each state limited statistical inference. Each region and state has distinct differences in landscape and land-use trends (Brown et al. 2005) that affects land cover analysis when pooled. Adequate state DMC sample sizes would increase precision of state-level landcover analysis. Sampling more DMCs and states would increase our understanding of DMC induced land cover change across the whitetails' range.

We also recommend a repeated DMC land cover survey effort every decade to monitor growth of DMC size, and any changes in land cover structure, seral stage, or overall 'wildlife centric' land cover abundance. By temporally tracking land cover, the effect of landowner management decisions can be isolated and tracked within DMC boundaries. Quantifying percentage change in specific land cover types is indicative of landowner management decisions (wildlife openings, early successional, thinned or open timber) not the underlying geophysical template. Temporally tracking DMC land cover metrics would provide resource planners with critical data about DMC habitat impact with DMC age and size to model long-term DMC habitat management influence.

In-situ DMC indicator species sampling should take place to evaluate habitat quality. We conducted passive land cover analysis determined using NAIP and Google earth pro satellite imagery, which can be used to establish the species-habitat relationships present on DMCs. Our land cover type PLAND analysis indicated increased levels of various 'wildlife centric' land covers utilized by many wildlife species across the United States. Private landowners are often reluctant to allow endangered or threatened species sampling on their land due to realized or perceived negative consequences of governmental interest. Therefore, we recommend sampling of non-threatened indicator species, indicative of habitat quality and ecosystem type. Certain avian species can be used as habitat quality and community health inference for other taxa (Blair 1999, Fleishman and Murphy 2009) under the indicator species concept. Examples of the transition between indicator species and multi-species management may include Grasshopper sparrow (*Ammodramus savannarum*) or Northern Bobwhite (*Colinus virginianus*) (Block et al. 1995, Browder et al. 2002). Grasshopper sparrow populations can be used as indicators of grassland condition, while Northern Bobwhite as indicators of active forest management.

Management Implications

DMCs offer conservation planners a viable tool to connect high quality habitat for game and non-game animals alike. Within local habitat networks, DMCs function as islands of high quality habitat for many species of interest. DMC implementation across a given landscape can be used to increase the abundance and distribution of wildlife habitat patches. By aggregating multiple properties to cooperatively manage a greater proportion of the landscape under common deer management goals, hunters and landowners also improve the connectivity and diversity of habitats for a variety of other species. Thus, conservation planners can utilize DMCs to produce high quality patches across focal landscapes.

Habitat management provided by DMCs comes at no monetary expense to state and federal agencies. We recommend increasing state-based cooperative assistance professionals to efficiently and rapidly increase DMC implementation. State and non-governmental organization funded DMC specialists can provide local assistance to form DMCs and provide habitat management expertise and supplement existing DMC management efforts. Landscape-scale habitat management on public land can be expensive and time-consuming relative to private landowner management. Cooperative specialists may easily increase DMC implementation, and thus produce more connected landscapes.

DMC aggregations of like-minded landowners provide wildlife agencies with established networks to aid conservation goals. For example, DMCs already provide state agencies with established landowner networks to increase disease monitoring in Michigan and Missouri (Adams and Ross 2017). DMCs should be utilized by resource managers to effectively meet conservation goals in increasingly fragmented landscapes, while involving and empowering

private landowners with the tool to simultaneously meet their desired deer or wildlife management goals. Ultimately, DMCs are an effective tool for state and federal conservation planners to implement active habitat management on private acreage. By forming DMCs, deer hunters are providing increased connectivity across the landscape and more wildlife friendly land cover resulting in possible benefits to game and non-game species. Private landowner interest in deer management is providing large-scale habitat benefits at minimal cost to wildlife agencies, while conserving the public interest.

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28

Table 2.1 Deer management cooperative (DMC) attributes: name, state, county, size (acres), members/landowners, and establishment year. * indicates a member/landowner combined total for all three Yates County, NY DMCs.

State	**DMC Name**	**County**	**Size** *Acres*	**Members/ Landowners**	**Est.** *Year*

Georgia Superior Pine Pasture Clinch 28,159 120/18 2007 *7 DMCs* Magnolia Swamp DMC Crawford 2,005 20/3 2015 Spring Creek QDM DMC Early 22,791 45/24 2009 Dewberry DMC Emanuel 1,852 15/4 2011 Hawkinsville QDM DMC Pulaski 3,747 12/5 2014 Rebecca DMC Turner/Wilcox/Ben Hill 7,450 40/18 2013 Wildlife Cooperative LLC Wilkes 3,603 11/6 2015 ***GA Average 9,944 34/11 2012***	
Missouri Pure Air Mgmt. DMC Adair 4,797 30/12 2015 *7 DMCs* Big Buffalo DMC Benton/Morgan 3,503 25/25 2009 Salt River DMC Macon 3,074 30/10 2007 Bullskin Creek WMC McDonald 2,195 30/7 2014 Perry QDM DMC Perry 4,597 88/27 2016 Blackbird Creek DMC Putnam 2,364 20/9 2012 River Aux Vases DMC Ste Genevieve 6,919 150/27 2013 ***MO Average 3,921 53/17 2012***	
Michigan Cedar Creek Watershed DMC Barry 4,668 40/35 2011 *8 DMCs* M40 Whitetail DMC Cass 2,110 29/25 2017 East Olive DMC Clinton 6,370 350/140 2006 Battle Creek River Area DMC Eaton 574 30/12 2017 Chasin' Whitetails DMC Hillsdale 534 16/19 2015 Southern Mecosta WMA Mecosta 15,225 300/95 2009 County Line Whitetail DMC Midland/Gladwin 2,969 60/36 2016 Newcosta DMC Newago/Mecosta 10,155 250/119 2013 ***MI Average 5,326 134/60 2013***	
New York Lime Hollow Nature Center Cortland 872 9/5 2013 *10 DMCs* Hoosick Area QDM DMC Rensselaer 12,185 350/92 2014 Otter Creek DMC Rensselaer 4,275 135/60 2013 Beadle Hill DMC Washington 2,764 45/22 2005 MacEachron Hill QDM DMC Washington 3,267 100/25 2008 McAuley Brook QDM DMC Washington 1,703 23/4 2010 Odd Duck QDM DMC Washington 1,220 38/7 2004 Yates-Benton Yates 3,867 288/209* 2009 Yates-Italy Valley Yates 6,829 * 2007 Yates-Milo Barrington Yates 3,186 * 2009 ***NY Average 4,017 99/42 2009***	
32 DMCs Total	***Overall Average 5,620 84/34 2011 Overall Totals 179,829 2,699/1,100***

Table 2.2 List of all 18 land cover designation categories.

Reclass #	Land Cover	Label	Explanation

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	Closed Canopy Deciduous Closed Canopy Evergreen Developed Early Successional Herbaceous Wetland Mixed Evergreen Deciduous Managed Exotic Grasses Open Deciduous Open Evergreen Row Crop Shrub/Scrub Thinned Deciduous Thinned Evergreen Thinned Evergreen Deciduous Thinned Wetland Water Wildlife Opening Woody Wetland	CCD CCE D ES HW MED MEG OD OE RC SS TD TE TED TW W WO WW	Mature Hardwood (bottomland or upland) Mature Pine or Evergreen (planted pine) Human Development (houses, roads, etc.) Old Field, Native Grasses (seral stage 2) Open/Non-Woody Wetland Mixed Forest Hay/Pasture Oak Savanna Pine Savanna Agricultural Row Crop Young cutover (seral stage 3: encroachment) Thinned Deciduous Forest (TSI) Thinned Pine Plantation Thinned Mixed Forest Woody Wetland with Thinning (cypress/tupelo) Lakes, Ponds, Streams Food Plots (openings maintained for hunting) Wetland with Woody Structure

Table 2.3 DMC 10-cell sample metrics for sample-cell size (m^2), average percent of DMC sample included in 10-cell sample inside DMC, and average DMC to landscape ratio used to determine landscape size.

State	DMCs per State	Sample-Cell Dimensions (m^2)	Average DMC Sample Size (%)	Average DMC : Adjacent Landscape Size
Georgia	7	500 m^2	15.61 %	1 : 3.5
Missouri	7	500 m^2	18.18 %	1 : 7
Michigan	8	250 m^2	9.25 %	1 : 7
New York	10	250 m^2	5.88 %	1 : 9

Table 2.4 Absolute percent difference between DMC land cover category state average and 10-cell sample average. Actual Georgia DMC average for closed canopy deciduous (CCD) was 12.45 percent within entire DMCs, while the 10-cell sample estimate was 12.94 percent. The absolute difference between the two values is 0.49 percent. Values represented with an * land cover field lacking within state sample area. Values with an * behind numerical values indicate averages with only one value used.

Land Cover	Georgia	Missouri	Michigan	New York	*Average Diff*

CCD	0.49	0.67	1.03	2.87	1.27
CCE	1.47	0.39	0.10	0.89	0.71
D	0.17	0.20	0.38	0.25	0.25
ES	1.51	0.13	0.03	1.59	0.82
HW	1.21	0.28	2.69	0.62	1.20
MED	1.38	1.40	0.72	0.73	1.06
MEG	1.46	0.62	0.96	4.22	1.82
OD	*	*	0.97	0.06	0.52
OE	1.27	*	*	*	1.27*
RC	2.53	3.15	0.04	3.38	2.28
SS	0.71	0.66	0.10	0.57	0.51
TD	1.65	0.48	1.79	0.06	1.00
TE	1.26	0.24	2.02	0.49	1.00
TED	*	0.28	0.15	2.07	0.83
TW	*	*	*	0.06	0.06*
W	0.12	0.07	0.35	0.39	0.23
WO	0.68	0.23	0.91	0.07	0.47
WW	1.28	0.24	0.49	1.34	0.84
State Average 1.15 0.60 0.79 1.16 0.92					

Table 2.5 Class and landscape-level FragStats metrics, descriptions used for land cover analysis across Georgia, Missouri, Michigan, and New York using a combination of 2015 and 2016 NAIP imagery.

FragStats Analysis Level	Metric	Acronym	Measurement
Class	Percentage of Landscape	PLAND	% of landscape
	Edge Density	ED	Meters/hectare
	Patch Density	PD	Patches/100 hectares
	Interspersion & Juxtaposition Index	IJI	Index from 0-100, 100 = maximum IJI
Landscape	Edge Density	ED	Meters/hectare
	Patch Density	PD	Patches/100 hectares
	Interspersion & Juxtaposition Index	IJI	Index from 0-100, 100 = maximum IJI

Table 2.6 FragStats percentage of landscape (PLAND) inside DMC sample value by DMC. PLAND is measured as percentage of 10-cell sample within DMC boundaries.

INSIDE DMCs

Wildlife Centric	*Agricultural & Urban*
State County/DMC PLAND PLAND PLAND PLAND PLAND (CCD) (ES) (HW) (WO) (WW)	**PLAND PLAND PLAND (D) (MEG) (RC)**
Georgia *Inside DMC* Clinch * 27.57 18.22 * 12.47 Crawford 20.55 19.49 1.78 8.54 15.13 Early 11.40 20.58 0.22 2.48 10.99 Emanuel 12.10 3.84 1.93 1.16 3.06 Pulaski 14.94 16.83 0.63 1.25 13.10 Turner 6.65 25.70 4.73 0.36 15.63 Wilkes 12.04 2.24 0.17 0.40 2.94 ***GA Average 12.94 16.61 3.90 2.36 10.47***	0.001 * 0.001 0.33 * * 0.84 4.80 26.19 0.68 8.96 4.41 0.23 1.65 0.46 1.70 2.37 18.15 2.01 11.62 2.45 ***0.82 5.88 8.61***
Missouri *Inside DMC* Adair 54.74 21.22 0.27 2.21 0.02 Benton/Morgan 48.85 10.92 * 2.46 * Macon 17.43 36.41 0.33 1.49 7.23 McDonald 49.82 1.77 0.07 0.73 * Perry 35.67 2.89 0.05 0.37 * Putnam 41.77 11.74 5.78 2.97 3.99 Ste Genevieve 61.74 1.05 0.01 4.62 * ***MO Average 44.25 12.29 1.08 2.12 3.75***	0.52 12.41 0.38 0.09 1.32 * 1.08 3.46 24.36 0.03 43.63 * 1.85 23.07 29.59 0.57 0.40 20.42 0.84 12.39 0.24 ***0.71 13.81 14.96***
Michigan *Inside DMC* Barry 30.64 6.18 12.37 * 5.20 Cass 24.35 15.65 5.86 2.27 7.29 Clinton 11.55 10.56 1.15 4.39 9.60 Eaton 11.11 11.26 21.05 * 11.66 Hillsdale 46.45 8.33 5.23 1.04 8.73 Mecosta 27.55 11.07 9.06 1.79 2.15 Midland/Gladwin 37.18 8.10 * 0.32 7.41 Newago/Mecosta 25.19 11.69 8.22 2.94 5.73 ***MI Average 26.75 10.35 8.99 2.13 7.22***	0.21 2.14 27.86 1.32 4.41 24.83 1.37 7.15 47.46 0.77 7.66 20.89 0.08 4.25 13.64 1.80 16.92 16.52 0.52 5.34 14.95 2.54 14.00 4.90 ***1.07 7.73 21.38***
New York *Inside DMC* Cortland-LHNC 15.93 7.66 13.32 * 7.20 Hoosick Area 12.94 15.53 3.93 0.08 * Otter Creek 17.28 5.91 2.63 0.58 1.91 Beadle Hill 14.15 6.27 * 0.06 6.54 MacEachron Hill 18.46 5.12 3.61 * 4.28 McAuley Brook 0.69 6.52 * 0.37 * Odd Duck 15.46 5.89 2.84 * * Yates-Benton 5.69 6.53 1.62 * 10.84 Yates-Italy Valley 40.29 10.29 0.79 0.007 0.54 Yates-Milo Bar 4.83 4.52 * * 2.45 ***NY Average 14.57 7.42 4.11 0.22 4.82***	0.69 12.57 21.48 2.19 24.22 19.28 1.03 23.02 17.31 0.67 1.55 60.98 2.70 23.09 9.44 4.40 5.91 39.90 1.46 31.38 8.11 3.88 10.84 45.53 1.48 11.03 4.39 1.96 7.34 48.30 ***2.05 15.10 27.27***
Overall ***Average 24.10 11.23 4.65 1.79 7.04***	***1.24 11.30 19.66***

Table 2.7 FragStats percentage of landscape (PLAND) adjacent landscape sample value by DMC. PLAND is measured as percentage of 10-cell sample for the adjacent landscape surrounding DMC boundaries.

ADJACENT LANDSCAPE

State	County/DMC	*Wildlife Centric* PLAND (CCD)	PLAND (ES)	PLAND (HW)	PLAND (WO)	PLAND (WW)	*Agricultural & Urban* PLAND (D)	PLAND (MEG)	PLAND (RC)
Georgia *Landscape*	Clinch	0.002	16.02	31.23	0.13	17.36	0.82	0.09	1.21
	Crawford	20.34	9.81	0.10	0.42	10.37	3.47	5.12	4.76
	Early	11.37	9.75	0.50	0.03	1.71	0.40	4.87	49.00
	Emanuel	9.32	3.57	0.67	0.33	3.04	2.03	5.91	44.30
	Pulaski	2.55	14.84	1.40	0,03	13.41	5.78	7.80	33.85
	Turner	0.15	10.77	0.73	0.05	17.78	2.05	12.33	23.42
	Wilkes	7.31	5.48	*	0.18	*	8.41	15.94	3.75
	GA Average	***7.30***	***10.03***	***5.77***	***0.17***	***10.61***	***3.28***	***7.44***	***22.90***
Missouri *Landscape*	Adair	36.40	7.56	0.02	0.31	*	0.85	45.39	1.55
	Benton/Morgan	69.78	2.47	*	1.47	*	0.50	8.74	*
	Macon	9.81	2.89	0.09	*	*	1.57	22.86	55.71
	McDonald	45.52	2.48	*	*	*	2.01	48.91	0.02
	Perry	28.31	3.49	0.16	*	2.14	1.89	26.14	27.75
	Putnam	16.28	3.29	0.61	0.02	0.04	1.58	51.58	12.84
	Ste Genevieve	35.24	8.87	*	1.58	*	1.58	23.65	8.70
	MO Average	***34.05***	***4.44***	***0.22***	***0.84***	***1.09****	***1.43***	***32.21***	***17.76***
Michigan *Landscape*	Barry	25.73	6.78	1.71	0.13	3.10	4.80	23.42	13.05
	Cass	32.64	5.02	5.12	0.26	3.80	1.89	7.37	32.85
	Clinton	25.28	8.49	3.31	*	*	5.57	21.95	27.69
	Eaton	22.90	8.72	7.92	*	6.16	2.95	15.50	23.75
	Hillsdale	18.43	14.59	6.39	0.13	2.39	1.41	18.92	29.3
	Mecosta	16.00	7.57	0.45	1.18	2.93	3.37	24.09	27.29
	Midland/Gladwin	37.78	11.63	0.04	0.91	0.49	1.21	8.67	4.09
	Newago/Mecosta	38.14	1.78	6.72	0.11	*	2.58	8.90	*
	MI Average	***27.06***	***8.07***	***3.96***	***0.45***	***3.15***	***2.97***	***16.10***	***22.57***
New York *Landscape*	Cortland-LHNC	27.62	9.80	0.39	*	0.13	4.91	31.44	14.13
	Hoosick Area	27.95	9.80	0.02	*	*	5.20	8.40	21.77
	Otter Creek	18.65	2.31	*	*	0.91	1.29	6.68	23.39
	Beadle Hill	19.84	1.81	2.72	*	0.59	1.42	19.69	21.26
	MacEachron Hill	30.61	5.06	1.10	0.40	1.32	4.76	30.84	3.38
	McAuley Brook	17.32	4.15	*	*	*	2.82	24.98	31.03
	Odd Duck	16.65	5.94	0,82	*	0.46	2.25	31.06	18.78
	Yates-Benton	19.62	2.56	*	*	*	2.05	13.01	59.73
	Yates-Italy Valley	32.20	7.65	1.73	*	1.70	2.37	6.18	1.87
	Yates-Milo Bar	17.97	2.21	0.04	*	*	5.96	20.71	29.68
	NY Average	***22.84***	***5.13***	***0.97***	***0.40****	***0.85***	***3.30***	***19.30***	***22.70***
Overall	***Average***	***22.95***	***6.79***	***2.96***	***0.43***	***4.49***	***2.80***	***18.73***	***21.73***

Table 2.8 Class and landscape-level FragStats metric averages by state and overall: edge density (ED), patch density (PD), and interspersion & juxtaposition index (IJI). Landscape-level ED is measured in m/ha. PD is measured in patches/100 ha. IJI is measured on a scale of 0-100, with 100 as maximum IJI.

State	FragStats®	CCD	ES	HW	WO	WW

Landscape

Metric

Class

Class

Class

Class

Class

Average

Georgia
Inside DMC ED 50.36 40.56 7,94 26.54 31.78 157.46 PD 4.87 6.19 2.61 5.89 5.24 449.43
IJI 46.11 49.46 31.92 46.37 48.74 50.84
Adjacent
Landscape ED 24.82 44.13 4.62 2.71 30.75 185.86 PD 2.51 8.00 1.37 1.30 3.46 894.07
IJI 26.47 37.54 19.75 18.20 3.25 40.76

Missouri
Inside DMC ED 90.42 65.82 4.90 17.12 20.53 187.87 PD 10.48 12.09 1.12 5.42 3.68 596.86
IJI 35.11 34.69 11.24 24.09 17.62 39.38
Adjacent
Landscape ED 89.66 43.27 2.89 6.30 6.58* 218.50 PD 13.23 10.36 1.48 2.33 0.98* 820.35
IJI 28.17 28.66 21.03 16.10 10.31* 33.61

Michigan
Inside DMC ED 87.84 59.11 32.96 13.72 27.11 247.82 PD 33.09 29.96 12.65 5.09 7.83 1343.73
IJI 43.77 37.56 24.65 24.55 22.84 45.79
Adjacent
Landscape ED 97.42 50.13 15.87 6.05 20.08 292.24 PD 14.95 15.91 7.04 3.74 6.70 2052.91
IJI 46.35 34.26 24.72 15.70 16.10 45.55

New York
Inside DMC ED 60.97 57.87 17.54 3.64 20.45 259.77 PD 14.60 16.81 4.36 2.82 5.12 246.25
IJI 40.42 44.08 36.77 14.72 26.21 50.42
Adjacent
Landscape ED 95.07 47.32 7.44 5.31* 6.26 311.20 PD 21.89 17.34 2.64 3.12* 2.58 1631.94
IJI 36.75 34.39 20.13 22.84* 19.06 42.29

Overall
Inside DMC ED 72.50 56.13 16.24 15.82 25.76 218.67 PD 16.56 14.74 5.33 4.91 5.85 1334.26
IJI 41.19 41.57 26.70 27.82 30.41 46.94
Adjacent
Landscape ED 79.11 46.44 8.73 4.77 17.79 258.77 PD 15.14 13.41 3.56 2.44 3.92 1398.24
IJI 35.02 33.79 21.65 17.16 20.65 40.87

Table 2.9 Paired T-test results, comparing values within DMCs to the surrounding landscape. Metrics include percentage of landscape (PLAND), edge density (ED), patch density (PD), and interspersion & juxtaposition (IJI). Significance is determined at α = 0.05. Values below 0.05 are in bold. Values with * were not measured.

FragStat Grouping and Level PLAND ED PD IJI

Class Level (Wildlife Centric)

Closed Canopy Deciduous (CCD) 0.863 0.195 0.811 0.111 Early Succession (ES) **0.003** 0.086 0.539 **0.027** Herbaceous Wetland (HW) 0.073 **0.002** 0.091 0.173 Wildlife Opening (WO) **0.004 0.024 0.018 0.010** Woody Wetland (WW) **0.006 0.009 0.015** 0.252

Class Level (Agriculture & Urban)

Developed (D) **0.000** * * * Managed Exotic Grass (MEG) **0.001** * * * Row Crop (RC) 0.373 * * *

Landscape Level

Georgia * 0.142 0.114 0.150 Missouri * 0.174 0.122 0.328 Michigan * 0.207 0.256 0.968 New York * 0.064 0.514 0.074 Overall * **0.002** 0.878 **0.023**

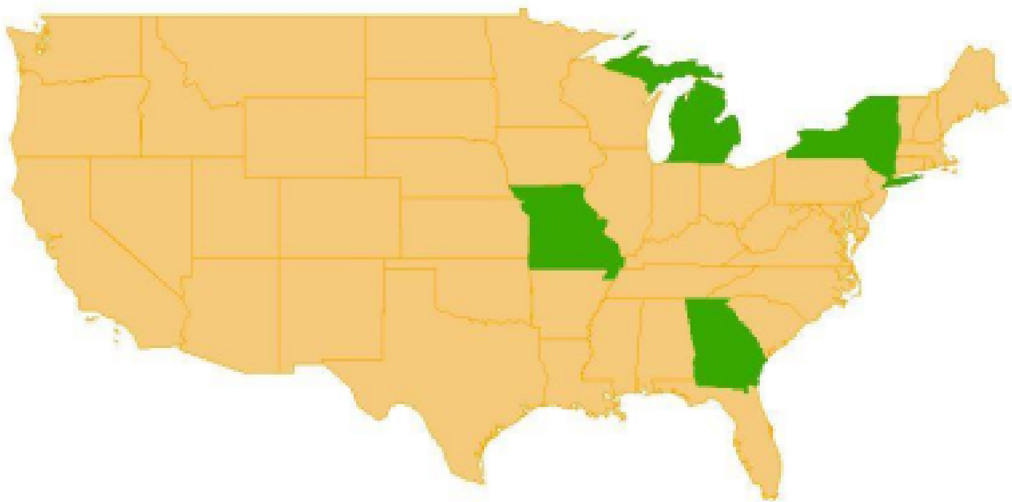

Figure 2.1 Map of lower 48 U.S. States. Green states represent states with DMCs that land cover analysis was conducted within: Georgia, Missouri, Michigan, and New York.

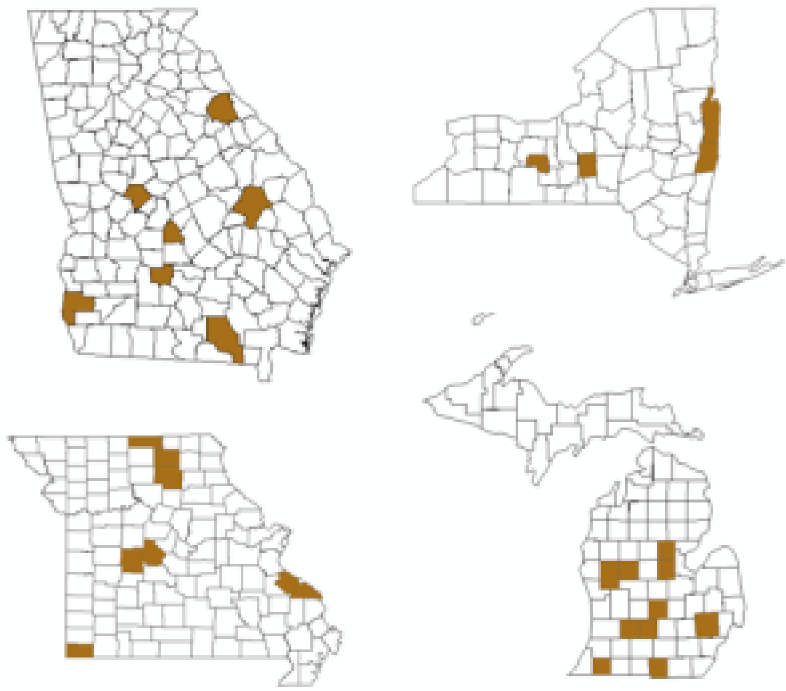

Figure 2.2 DMC county locations within each of the four states included in land cover analysis: Georgia, Missouri, Michigan, and New York. Highlighted counties indicate approximant DMC location.

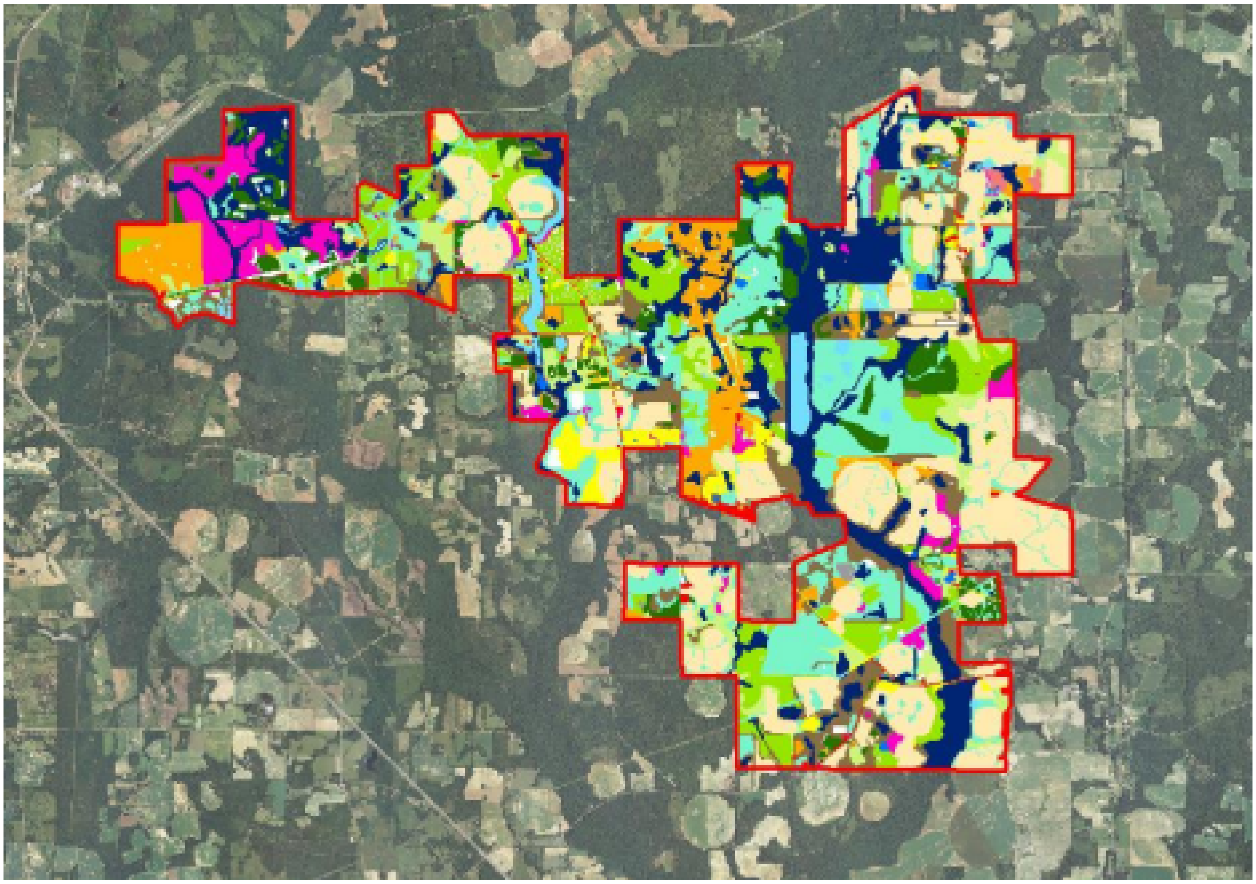

Figure 2.3 Example 18-catgeory land cover raster ($5m^2$) heads-up digitized and categorized. Example DMC is Spring Creek QDM DMC in Early County, Georgia (22,791 acres).

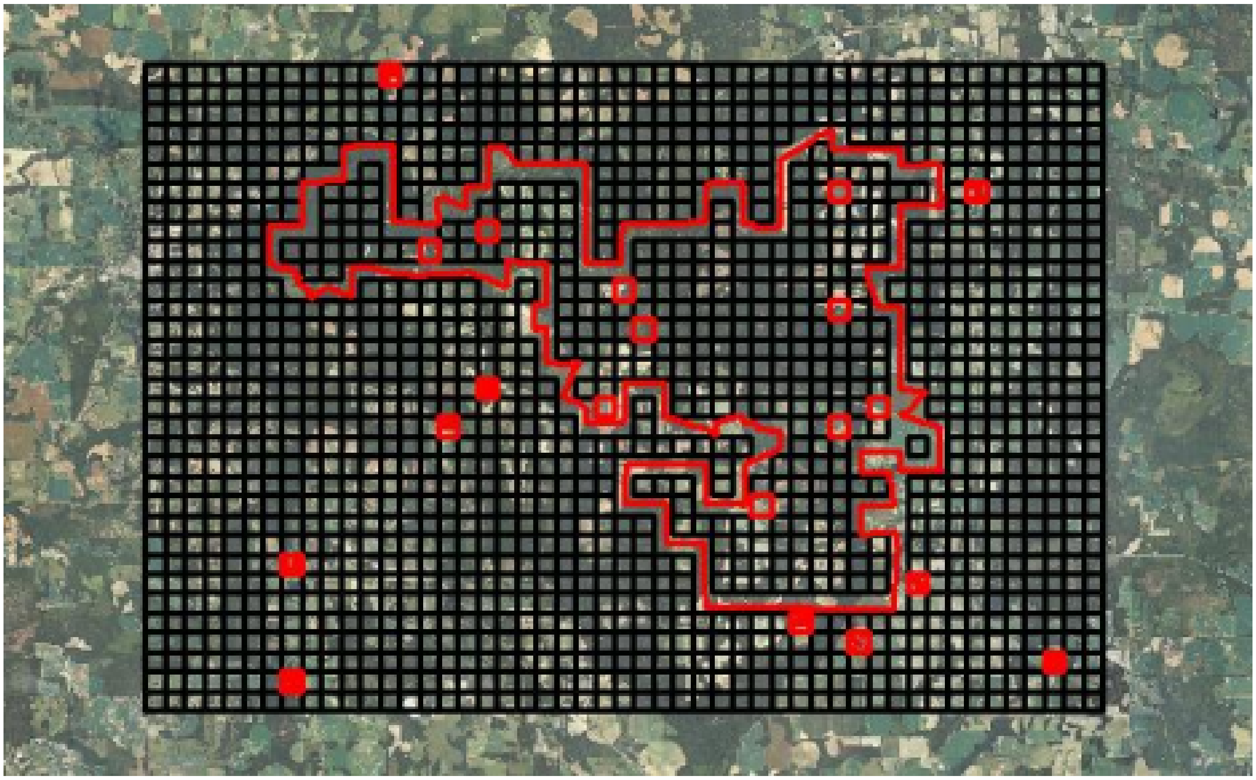

Figure 2.4 Example DMC grid-cell sampling method. DMC border is indicated in red. DMC sample includes ($500m^2$) 10-cell samples within DMCs and for the adjacent landscape surrounding the DMC.

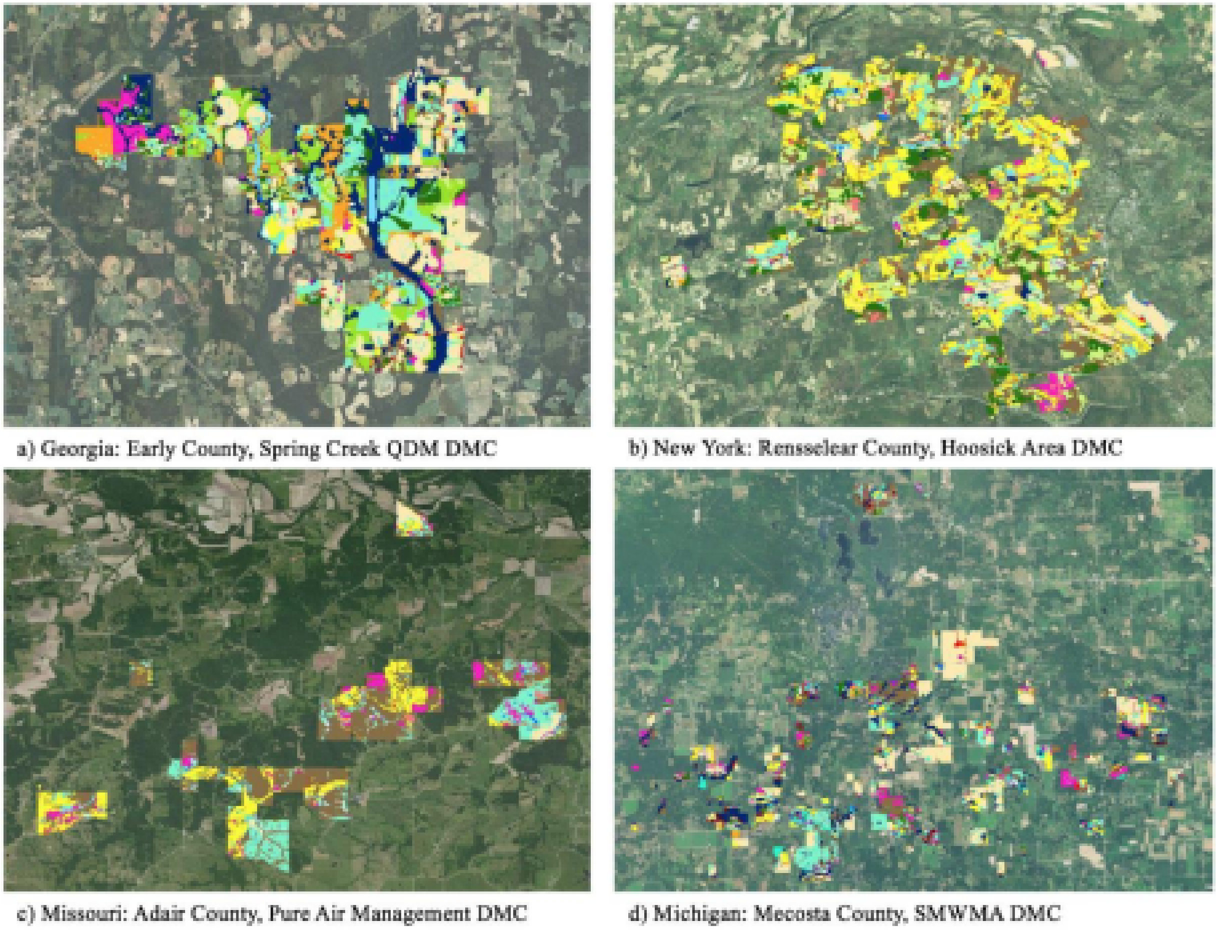

Figure 2.5 Example DMC extent variation in each state: a) Georgia, b) New York, c) Missouri, and d) Michigan.

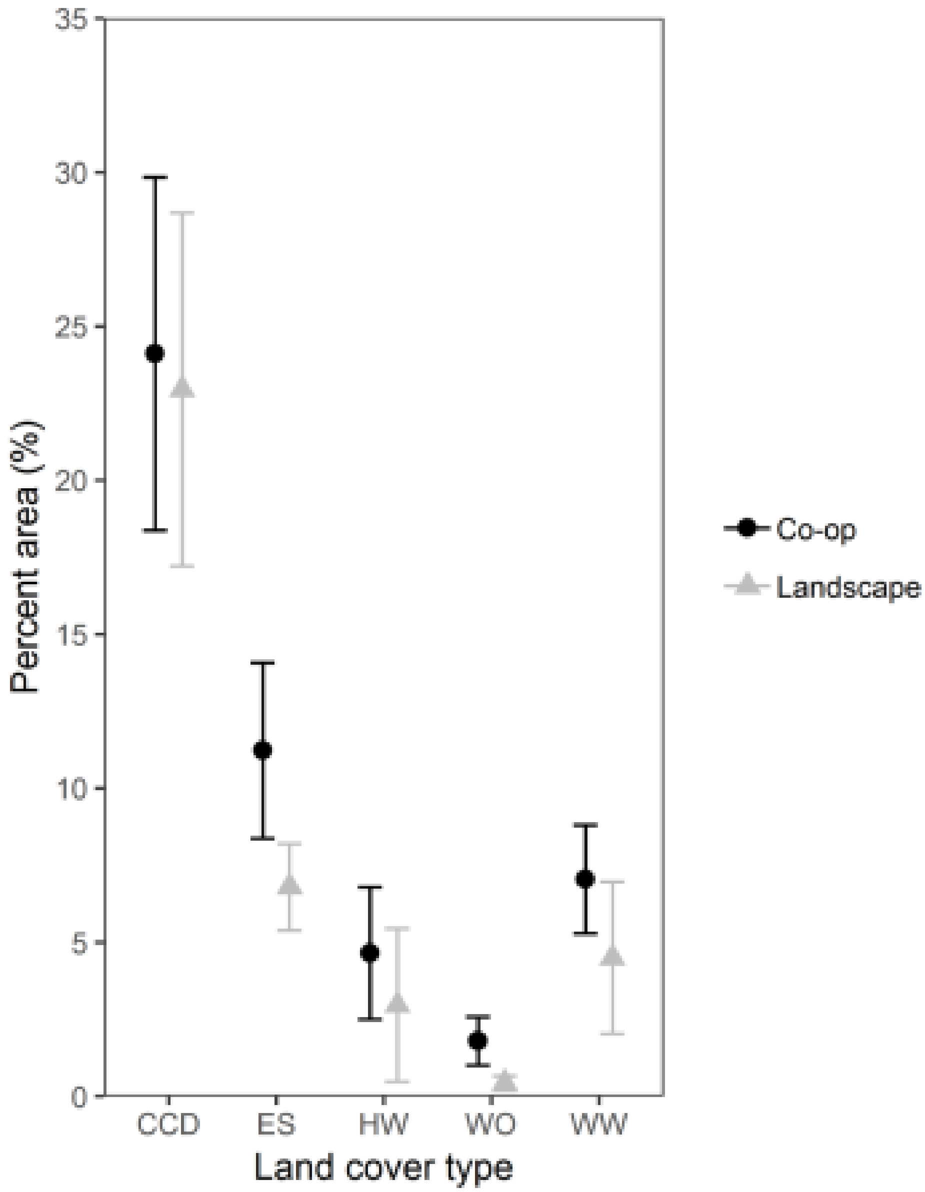

Figure 2.6 Class-level percentage of landscape (PLAND) for 'wildlife centric' land covers. PLAND is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed using 32 DMCs across four states (Georgia, Missouri, Michigan, and New York). Means and 95% confidence intervals are provided.

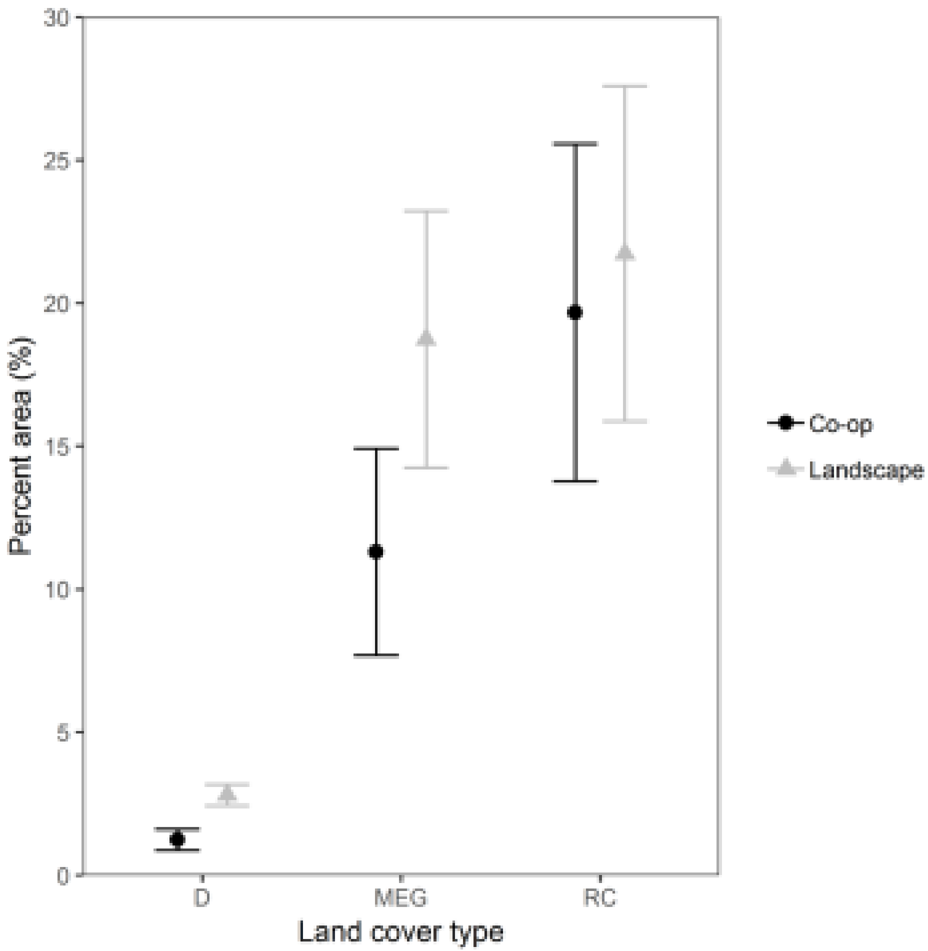

Figure 2.7 Class-level percentage of landscape (PLAND) for 'agricultural & urban' land covers provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape) analyzed using all 32 DMCs across four states (Georgia, Missouri, Michigan, and New York). Means and 95% confidence intervals are provided.

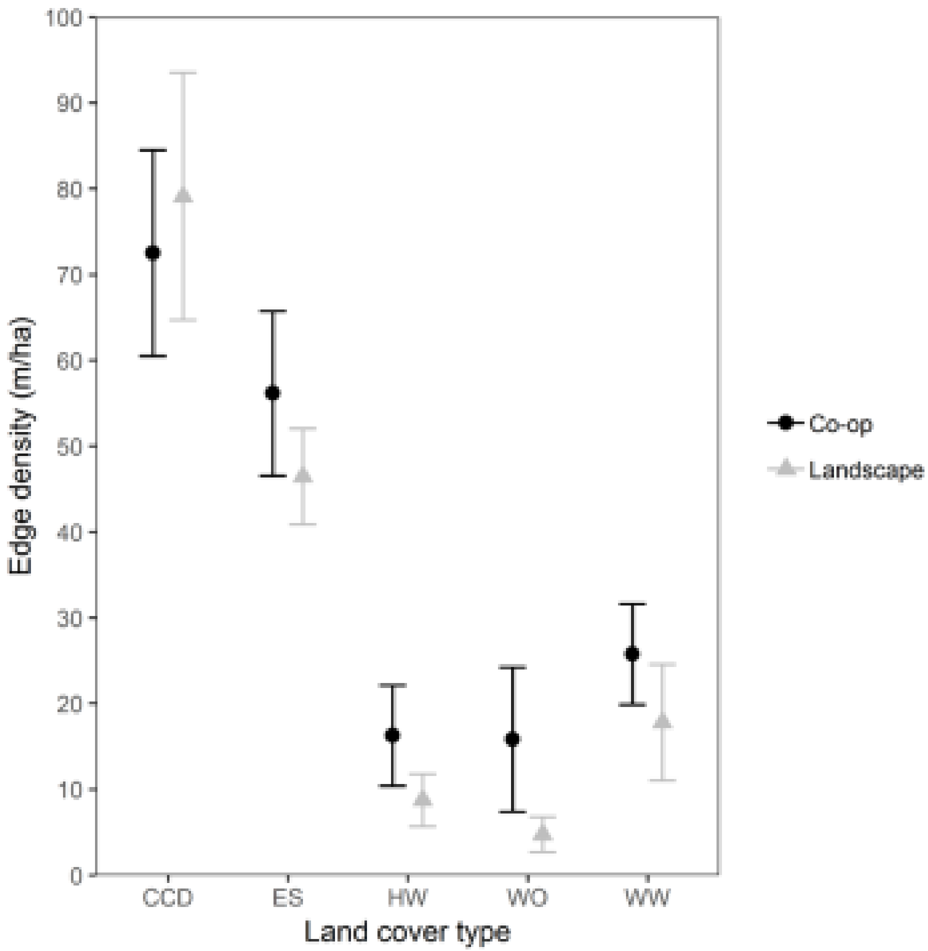

Figure 2.8 Class-level edge density (ED) for 'wildlife centric' land covers. ED is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed using 32 DMCs across four states (Georgia, Missouri, Michigan, and New York). ED is measured in meters/hectare (1 hectare = 2.47 acres).

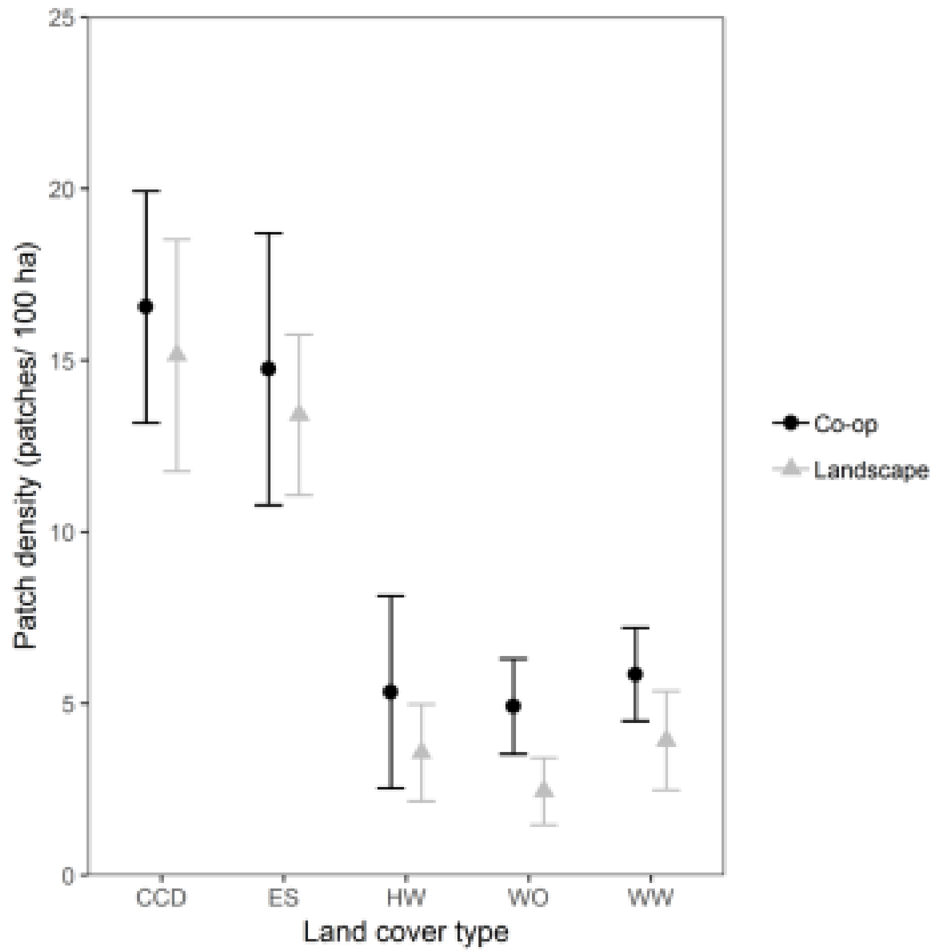

Figure 2.9 Class-level patch density (PD) for 'wildlife centric' land covers. PD is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed using 32 DMCs across four states (Georgia, Missouri, Michigan, and New York). PD is measured in meters/ 100 hectares (100 hectares = 247 acres). Means and 95% confidence intervals are provided.

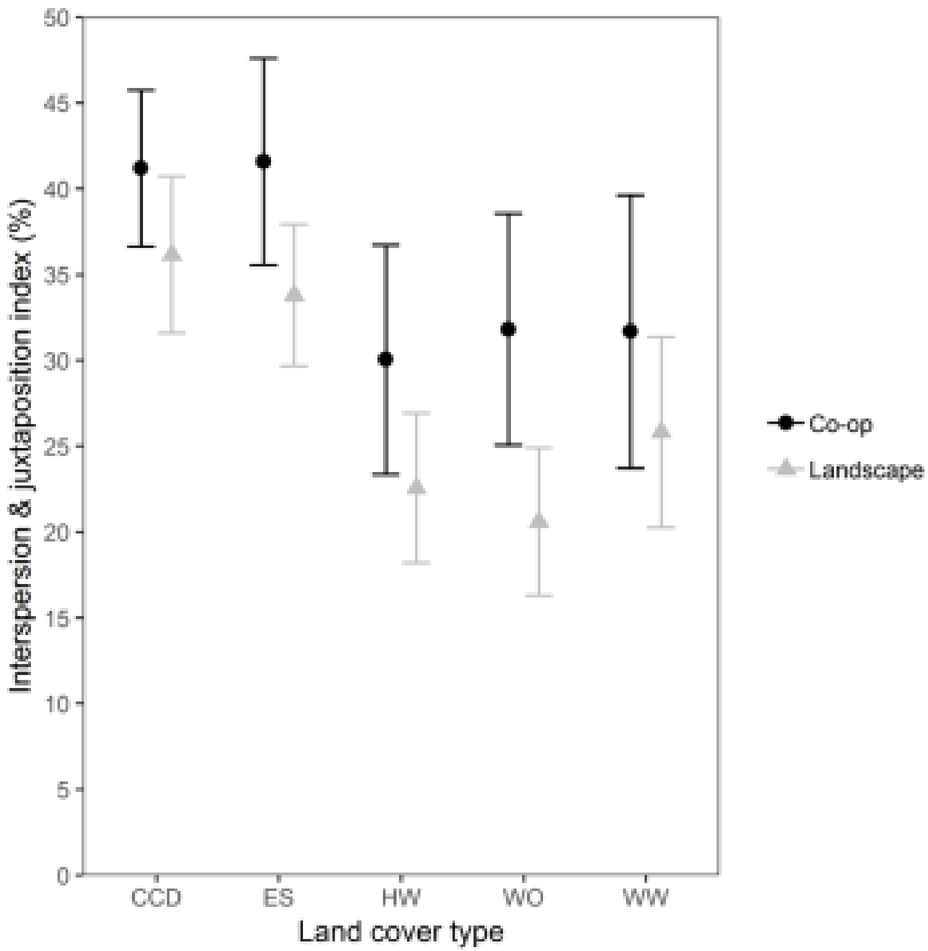

Figure 2.10 Class-level interspersion & juxtaposition index (IJI) for 'wildlife centric' land covers. IJI is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed using 32 DMCs across four states (Georgia, Missouri, Michigan, and New York). IJI is measured on a scale of 0 – 100, with 100 being maximum IJI. Means and 95% confidence intervals are provided.

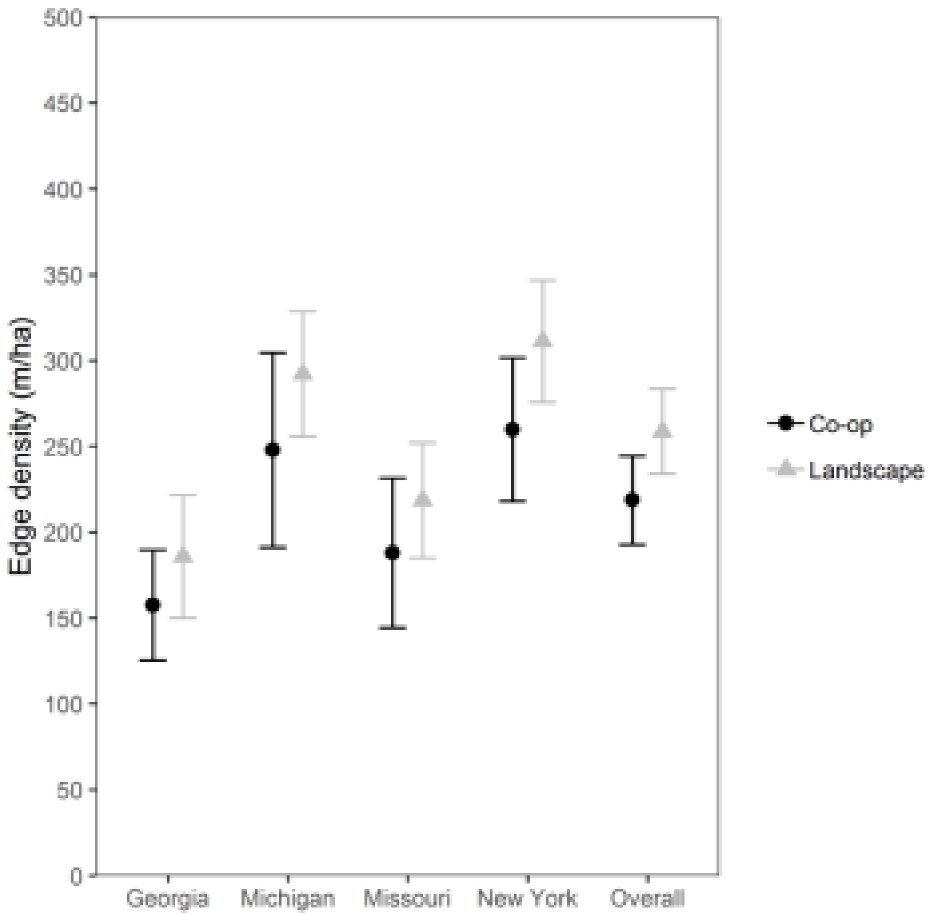

Figure 2.11 Landscape-level edge density (ED) for 'wildlife centric' land covers. ED is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed by state (GA: 7, MI: 8, MO: 7, and NY: 10) and overall (all 32 DMCs). ED is measured in meters/hectare (1 hectare = 2.47 acres). Means and 95% confidence intervals are provided.

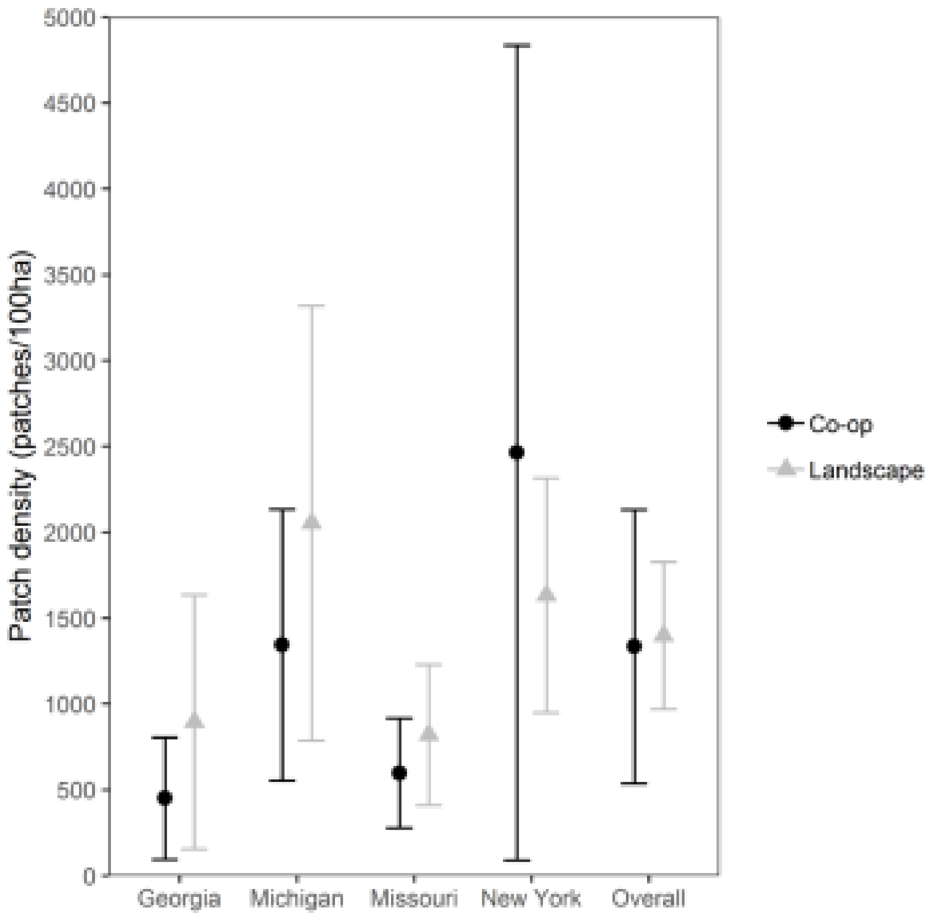

Figure 2.12 Landscape-level patch density (PD) for all land cover patches. PD is provided for both ‘Co-op’ (DMC) and ‘Landscape’ (Adjacent Landscape). These values are analyzed by state (GA: 7, MI: 8, MO: 7, and NY: 10) and overall (all 32 DMCs). PD is measured in patches/100 hectares (100 hectare = 247 acres). Means and 95% confidence intervals are provided.

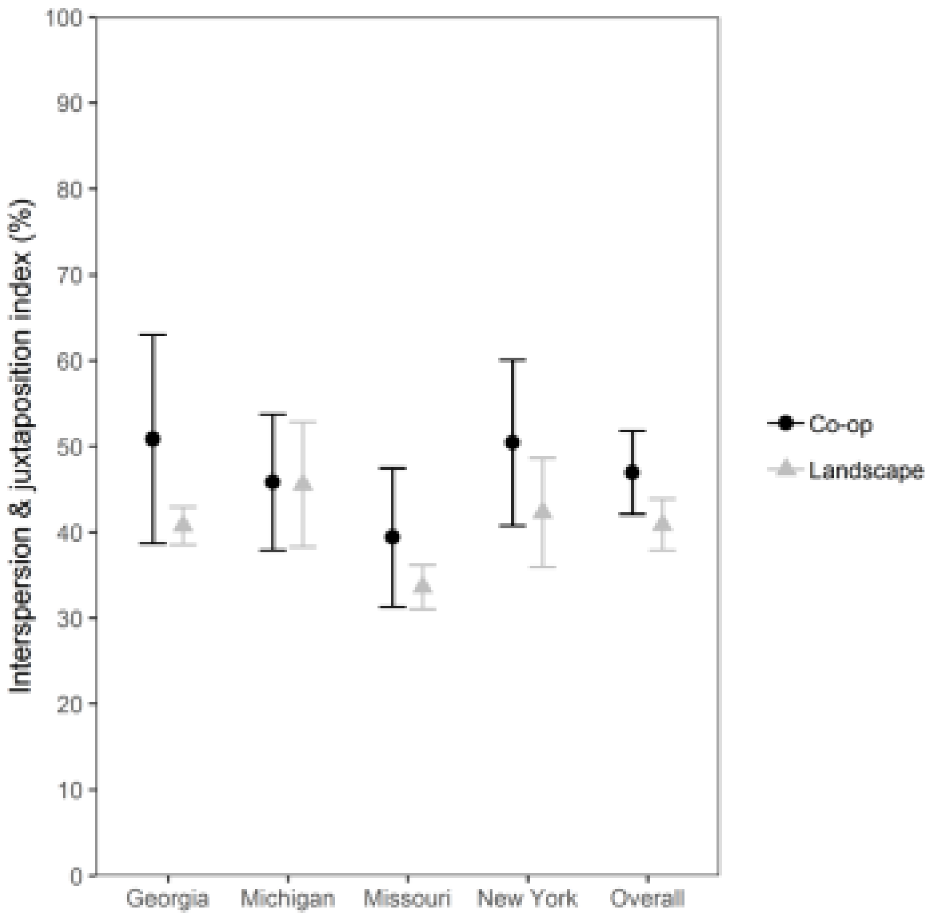

Figure 2.13 Landscape-level interspersion & juxtaposition index (IJI) across all land covers. IJI is provided for both 'Co-op' (DMC) and 'Landscape' (Adjacent Landscape). These values are analyzed by state (GA: 7, MI: 8, MO: 7, and NY: 10) and overall (all 32 DMCs). IJI is measured on a scale of 0 – 100, with 100 being maximum IJI. Means and 95% confidence intervals are provided.

CHAPTER 3

IMPORTANCE – SATISFACTION ANALYSIS OF DEER MANAGEMENT COOPERATIVE MEMBERS

[1] Pruitt, H. P., B. B. Boley, N. P. Nibbelink, G. J. D'Angelo, and M. D. McConnell. To be submitted to *The Wildlife Society Bulletin.*

Abstract

White-tailed deer (*Odocoileus virginanus*) management by landowners is an increasingly popular conservation tool available to conservation planners. Deer management cooperatives

(DMCs) represent a novel approach by private landowners and hunters to collaboratively improve deer herd and hunting quality. DMCs are ‘a group of landowners and hunters voluntarily working together to improve the quality of wildlife, habitat, and hunting experiences on their collective acreage’. We survey 2,800 members in 45 DMCs across five U.S. states: Georgia, Michigan, Missouri, New York, and Texas. We apply Importance-Satisfaction Analysis (ISA) methodology to better understand members’ satisfaction with their DMC by evaluating differences in importance and satisfaction for 22 DMC attributes across four types of DMC members with divergent membership motivations. No previous DMC literature has employed ISA framework to determine discrepancies in perceived DMC member satisfaction. Therefore, we explore the utility of ISA identifying critical attributes for resource managers that influence DMC member satisfaction.

Introduction

Since the 1980s, Quality Deer Management (QDM) has become an increasingly common approach to influence population-level management of white-tailed deer in the eastern United States (Woods et al. 1996, Murphy 2011). QDM is a paradigm shift away from traditional deer management where intensive buck harvest, coupled with limited doe harvest, was used to increase white-tailed deer populations throughout the early-mid 20th century. QDM protects most 1.5-year-old bucks in an effort to increase buck age structure, while harvesting appropriate

numbers of female deer to balance sex ratios and maintain deer density with existing habitat conditions (Brothers and Ray 1975, Harper et al. 2012).

QDM has been used to establish hundreds of deer management cooperatives (DMCs) across the United States, encompassing millions of acres (QDMA 2005, Murphy 2011, Adams and Ross 2017), addressing numerous parcels under differing deer management styles (Alsheimer 2002). DMCs are groups of ‘landowners and hunters voluntarily working together to improve the quality of wildlife (white-tailed deer), habitat, and hunting experiences on their collective acreage’ (Murphy 2011, Adams and Ross 2017) created and maintained by deer hunters. In one study, over 76% of Tennessee hunters preferred hunting on areas practicing QDM (Harper et al. 2012), highlighting the potential of QDM cooperatives to help private landowners and hunters achieve deer management success while increasing hunter satisfaction (Mitterling 2013). Additional research suggests many hunters prefer hunting properties under quality or trophy management practices, highlighting the appeal and utility of DMCs to achieve preferred deer management goals (Mingie et al. 2017).

Assessments of successful cooperatives and factors that determine member satisfaction or frustration are vital to increasing DMCs’ utility as conservation planning tools. Individual cooperative members may vary in degree of adherence and preference for cooperative deer management regulations (e.g., trophy or quality deer management, self-imposed harvest limits, and antler-point restrictions) or habitat management scope (e.g., habitat management for game animals or both game and non-game) causing potential conflict with other co-op members and potential withdrawal from DMC membership. Therefore, understanding what factors make DMCs successful at meeting member goals is critical to implementation as a strategic conservation tool. Thus, research on the DMCs must focus as much on member satisfaction as

management benefits generated from their formation.

Importance-Satisfaction Analysis (ISA) is one technique that can help conservation planners evaluate successes and shortfalls of DMCs. ISA simultaneously examines participant assigned importance values for a set of relevant items, while jointly measuring participant assigned satisfaction of attribute performance (Martilla and James 1977). As a result, stakeholder discrepancies between perceived attribute importance and attribute satisfaction are easily identifiable. Satisfaction and importance ratings are graphed on an x-y axis, respectively, providing resource managers with a visual display of stakeholder attribute perception within one of four managerially relevant ISA quadrants: Quadrant 1: "Concentrate Here," Quadrant 2: "Keep Up the Good Work," Quadrant 3: "Low Priority," Quadrant 4: "Possible Overkill."

ISA is a commonly applied technique within the business literature (e.g., marketing and tourism) to identify attributes that are important to quality customer experiences, while simultaneously evaluating satisfaction with those attributes (Martilla and James 1977, Boley et al. 2017). A theoretical basis for ISA application is the 'expectancy disconfirmation paradigm', sometimes referred to as the 'expectations-confirmation theory' (Oliver 1980). The theory indicates that negative and positive disconfirmation for expectations and performance measure satisfaction; with satisfaction occurring when perceived performance is greater than expectation, and dissatisfaction occurring when expectations are greater than perceived performance (Oliver 1980, Matzler et al. 2003).

Understanding factors and motivations that drive large-scale voluntary cooperative participation is the first step in assessing effectiveness (Wilson and Hart 2000). Previous research has shown DMCs to increase hunter satisfaction (Mitterling 2013) and increase hunter engagement (Stout et al. 2013). A subsequent increase in hunter satisfaction and engagement

after DMC formation further highlights potential for capitalization of grassroots enthusiasm to influence large-scale wildlife conservation goals. However, previous research has involved small sample sizes (Enck et al. 2007) operating within dissimilar hunting cultures (Woods et al. 1996, Mitterling 2013) that cannot be extrapolated across the whitetail's range. Differing hunting cultures, deer herd demographics, and state-level deer management programs are important to determine member motivations and DMC success in geographically distinct areas. This phenomenon has been observed globally, with differing agri-environmental scheme formation motivations across geographically separated regions of the European Union (Wilson and Hart 2000).

Although deer management cooperatives have increased in popularity, minimal research has followed to better understand member satisfaction. Whereas, Kramer et al. (2016) describes various egocentric networks within Michigan DMC membership that result in deer harvest influence on peers, no research has evaluated attribute importance and subsequent performance for a variety of salient DMC membership factors. Furthermore, research into DMC membership motivation is lacking. Previous research has described three primary motivational orientations for white-tailed deer hunters: affiliative-oriented, achievement-oriented, and appreciative oriented (Decker and Connelly 1989). "Affiliative-oriented" describes hunters who become involved in hunting primarily to accompany another person and to enjoy their company. "Achievement-oriented" hunters become involved to primarily to meet some standard of performance. "Appreciative-oriented" hunters primarily seek a sense of peace from their involvement in hunting (Decker et al. 1989). Varying motivational orientations (Kellert 1978, Decker et al. 1980, Gigliotti 2000) and hunting-development phases (Jackson and Norton 1980, Applegate and Otto 1982) are well documented in hunters and may result in varying degrees of

satisfaction with cooperative deer management harvest restrictions, DMC habitat management extent, and overall DMC member satisfaction. Therefore, a more complete understanding of the factors that motivate and satisfy DMC members is warranted.

To address these research gaps, we apply ISA methodology to better understand members' satisfaction with their DMC by evaluating differences in importance and satisfaction for 22 DMC attributes across four types of DMC members with divergent membership motivations. No previous DMC literature has employed the ISA framework to determine discrepancies in perceived DMC member satisfaction. Therefore, we explore the utility of ISA for identifying critical attributes for resource managers that influence DMC member satisfaction. We used Analysis of Variance (ANOVA) to quantify statistical differences in salient DMC attribute values among the four DMC member clusters. Differing motivational orientations may be indicative of members joining cooperatives for differing purposes, producing possible discrepancies in DMC membership satisfaction and subsequent success.

Study Area

Working with the Quality Deer Management Association (QDMA) employees and cooperative specialists, we distributed an electronic survey to 2,702 deer management cooperative members from 45 DMCs across five states within representative regions of the whitetail's range: Georgia (Southeast US: 8 DMCs), Michigan (Northern US: 10 DMCs), Missouri (Midwest US: 7 DMCs), New York (Northeastern US: 10 DMCs), and Texas (Southwestern US: 10 DMCs) (Figure 3.1). Acreage for all DMCs surveyed totaled over 650,000 acres, with 452,000 acres in Texas alone. In the other four states, surveyed DMCs totaled

200,478 acres: (Georgia: 70,955 acres, Michigan: 50,414 acres, Missouri: 27,449 acres, and New York: 51,660 acres).

Methods

QDMA Deer Management Cooperative Member Survey

We identified deer management cooperatives using QDMA employees, their personal or professional connections, and an email 'Eblast' to QDMA membership within each of the cooperating states. Once we identified prospective DMCs, DMC leaders were contacted to obtain basic cooperative information: name, county, town, total DMC acres, start year, total membership, total landowners, DMC map, and DMC leader contact information. Sample members (n = 2,702) were limited to the extent of each DMC leader's social network and available contact information for members, even though total DMC membership for 45 DMCs was estimated at 6,217 members.

We formally contacted DMC leaders four times regarding the survey as recommend by Dillman's 'Tailor Designed Method' (Dillman et al. 2014). Participating DMC leaders received an email announcing the upcoming survey link in July 2017. Working with the QDMA, we formally distributed the "2017 Deer Management Cooperative Survey" to DMC leaders in August 2017 using *Survey Monkey.* Three New York DMCs received hard copy surveys due to a lack of internet connection. We sent surveys to a single contact representing all three New York DMCs who then personally distributed the survey throughout their membership (n = 115). We sent a second reminder to fill out the survey in October 2017 and third and final reminder in December 2017. Survey distribution was incumbent upon DMC leaders distributing the survey link, via email or hard-copy, to represented DMC membership.

We received 481 total responses of 2,702 surveys distributed over the five-month period. We deemed 459 responses usable, with respondents finishing at least 75 percent of the survey and providing answers to the motivational questions (Appendix C). The overall response rate was 17.8%, while state response rates ranged from 5.0% (Texas) to 36.5% (Michigan).

Responses totaled 481 surveys: 60 responses were from Georgia (12.4%), 58 responses from Missouri (12.1%), 167 responses from Michigan (34.7%), 123 responses from New York (25.6%), and 73 responses from Texas (15.2%).

Construct measurement

The QDMA survey was distributed to collect information on DMC member demographic characteristics, deer management type, perception of DMC success, DMC habitat management preferences, rating of current and previous deer hunting quality, along with DMC member satisfaction and performance for various DMC attributes. Additional questions were included to address specific QDMA interests such as: deer harvest tendencies before and after DMC membership, extent of habitat management, level-of-skill as a white-tailed deer hunter, membership of conservation non-governmental organizations other than the QDMA, and DMC assistance ratings.

For ISA questions, we asked respondents to rate their perceived importance level of 22 different DMC attributes across five dimensions (e.g., deer hunting, cooperative harvest criteria, perceived habitat quality and land management practices, human dimensions within the DMC, and monetary aspects of co-op formation) using a 7-point Likert-type scale (Likert 1932). Next, using a 7-point Likert-type scale, we asked DMC members to indicate their level of satisfaction with the current performance of their co-op on the same 22 DMC attributes. The 7-point importance Likert-type scale ranged from 1 = “Not at All Important” to 7 = “Very Important,”

and the 7-point satisfaction scale range from 1= “Completely Dissatisfied” to 7 = “Completely Satisfied.”

Following Kramer et al. (2016), who described varying member motivations for DMC membership, we assed hunter motivational-orientations using 19 questions modified from the existing literature (Jackson et al. 1979, Applegate and Otto 1982, Miller et al. 2013). We based multiple questions on hunting attributes that were indicative of varying hunter-motivational stages (e.g., harvest a mature buck, harvest as many white-tailed deer as possible, make memories, be close to nature, harvest deer for eating) (Jackson et al. 1979, Applegate and Otto 1982). Principal Component Factor Analysis (PCA) with varimax rotation was used to determine a pared-down combination of the 19 motivations that were most indicative of motivations for joining DMCs.

Data analysis

Principal Component Factor Analysis using Varimax rotation reduced the number of motivations from 19 to 14 and identified four unique hunter motivations for joining DMCs: “Disconnecting,” “Locavore,” “Social Inclusion,” and “Harvest Quality” (Table 3.1). “Disconnecting” motivations are characterized by getting away from people, the regular routine, or technology. “Locavore” motivations are characterized by local and sustainable meat procurement. “Social Fabric” motivations include enjoying hunting with others and family. “Quality Harvest” motivations include targeting mature or trophy bucks. All four motivation latent constructs consist of three to four motivation question with factor loadings above 0.6 and Cronbach’s alpha ranging from 0.74 to 0.88, indicating that they were reliable and valid measures of hunter motivation (Nunnally 1978, Santos 1999) (Table 3.1).

Following the EFA, we performed a K-means cluster analysis using the four motivational constructs to segment DMC members by primary motivations for DMC membership (MacQueen 1967). Guidelines for determining specific cluster numbers do not exist in the literature, and it is recommended that the number of clusters be useful to resource managers (Payne 1993). We initially explored K-means cluster analysis using two, three, four, and five clusters. Four clusters were ultimately chosen as the final cluster solution based upon each cluster having adequate cluster membership with managerial appropriate implications (Table 3.4). Cluster centers (e.g. motivational influence means, Table 3.3) from K-means cluster analysis were used to determine overall motivational-orientation, resulting in cluster membership labels: Cluster 1: Solitude Member, Cluster 2: Social Member, Cluster 3: Representative Member, and Cluster 4: Quality Harvest Member.

We illustrate ISA results using a two-dimensional graph in the first quadrant (positive, positive) of the Cartesian system. The first quadrant was subsequently split into four sub quadrants to aid visual assessment of management priorities. The axes display attribute satisfaction (x-axis) and attribute importance (y-axis) values, both ranging from low to high based on Likert-type scale responses. We determined management priorities of given attributes by the discrepancy in mean attribute importance and mean attribute satisfaction. Each sub quadrant area depicts a different management action based on the relationship between importance and satisfaction scores for each attribute. The first sub-quadrant (Q1) depicts high attribute importance and high attribute satisfaction ("Keep Up the Good Work"). The second sub-quadrant (Q2) depicts high attribute importance and low attribute satisfaction ("Concentrate Here"). The third sub-quadrant (Q3) displays low attribute importance and low attribute satisfaction ("Low Priority"), while the fourth sub-quadrant (Q4) displays low attribute

importance and high attribute satisfaction ("Possible Overkill"). Traditional Cartesian-quadrant labels were used (i.e. Q1-Q4), while traditional management action nomenclature (e.g. "Concentrate Here") for each quadrant was followed (Figure 3.2) (Martilla & James 1977).

Researchers commonly determine ISA crosshair placement to create the four managerially relevant quadrants (Boley et al. 2017, Oh 2001). The most transparent way to set crosshairs is the scale-centered method, which sets crosshairs at the middle point of the Likert scale responses. While transparent, Taplin (2012, p.29) criticizes the scale-centered method because most attributes end up falling in the 'Keep Up the Good Work' quadrant as respondents are prone to give high performance and importance ratings. Oh (2001, p. 622) refers to this as the 'ceiling effect' because researchers "tend to use a selected set of key - therefore, 'important' already in its own right - attributes to measure importance." A solution many researchers implement to combat the 'ceiling effect' is data-centered crosshairs (Sever 2015, Boley et al. 2017). The data-centered crosshair placement controls for inflated importance and satisfaction ratings by using crosshairs representing mean importance and satisfaction values to provide a relative comparison of attributes relative to others within the analysis. Another helpful discriminating threshold is an iso-rating line – a 45° diagonal line that separates the first quadrant into two regions. The two regions created depict where satisfaction exceeds importance (i.e., above the line), and where satisfaction falls below importance (i.e., below the line). Our results focus on the data-centered method; however, both scale-centered crosshairs and an iso-rating line are provided on ISA figures to provide transparency and address any concerns about limitations for either approach (Sever 2015, Boley et al. 2017). We calculated mean importance and satisfaction values for all respondents and by motivation-based clusters (Figure 3.3 – 3.7).

We also conducted twenty-two separate ANOVAs to compare means of the four DMC member motivational orientation clusters for attribute importance and satisfaction scores (Table 3.5). We evaluated significance between clusters at the attribute level using an α of 0.05 (Table 3.5) and conducted Bonferroni Post Hoc Tests to determine between which clusters the statistically significant differences existed.

Results

Respondents were primarily male (94.7%) with an average age of 50 years old (SD ± 14.2, range: 18-86). The sample was predominantly Caucasian (95.3%) with most household incomes between $50,000 and $99,999 and a median household income level between $100,000 and $150,000 (Table 3.2). The most common level of education was a bachelor's degree (34%). Only 23% of respondents identified as farmers/ranchers. The majority of respondents had hunting access as private landowners (67.7%), while the remaining respondents either belonged to a hunting club (14.4%), were granted hunting rights from a landowner (13%), or leased hunting rights from an individual (4.9%).

DMCs members motivations for deer hunting varied, with the primary motivation of socializing with other hunters (Social = 5.89; SD ± 0.26) followed by escaping from the regular routine of life (Disconnect = 5.64 ± 0.31), harvesting sustainable locally sourced meat (Locavore = 5.12 ± 0.41), and harvesting mature bucks (Quality Harvest = 4.94 ± 0.69) (Table 3.1). K means cluster analysis was used to segment co-op members into groups based on their primary deer hunting and management motivations (Table 3.3).

K-means cluster analysis resulted in the following four clusters: Solitude Member (n = 53), Social Member (n = 91), Representative Member (n = 224), Quality Harvest Member (n =

91) (Table 3.4). The 'Solitude Member' cluster is the smallest cluster, characterized by an extremely strong negative cluster center for 'social inclusion' (-2.01) while the 'escape' motivation was the only positive motivation (0.06). The 'Social Member' cluster is characterized by positive cluster centers for both 'escape' (0.13) and 'social inclusion' (0.21), with a strong

negative motivation towards ‘harvest quality’ (-1.38). The ‘Representative Member’ cluster, the largest cluster, is characterized by positive cluster centers for all four motivations: ‘escape’ (0.47), ‘locavore’ (0.05), ‘social inclusion’ (0.33), and ‘harvest quality’ (0.44). Finally, the ‘Quality Harvest Member’ cluster was characterized by a strong positive motivation for ‘harvest quality’ (0.41) coupled with a strong negative motivation for the ‘escape’ motivation (-1.33). These clusters were analyzed with univariate ANOVAs and ISAs to understand how hunter motivation influenced DMC attribute importance and subsequent satisfaction. *Overall Importance-Satisfaction Analysis*

All respondents reported the following attributes as most important ($\bar{x} \geq 6$ on a 1-7 scale): A) ‘Seeing mature bucks when hunting’, B) ‘Seeing deer when hunting’, I) ‘Neighbors following Quality Deer Management (QDM) practices’, J) ‘Co-op members sharing similar harvest goals’, K) ‘Control over deer density’, Q) ‘Relationships between co-op members/hunters’, T) ‘Forming relationships with neighboring landowners’ (Table 3.5, Figure 3.3). The attributes reported with the highest levels of DMC member satisfaction ($\bar{x} \geq 5.4$) were: B) ‘Seeing deer when hunting’, E) ‘Harvesting female deer’, H) ‘Co-op harvest restrictions on bucks (e.g. antler point restrictions, lower bag limits, or buck-age harvest criteria) that limit buck harvest more than current state restrictions’, J) ‘Co-op members sharing similar harvest goals’, and Q) ‘Relationships between co-op members/hunters’ (Table 3.5).

Compared to other attribute types, respondents were more satisfied with deer hunting attributes such as C) ‘The number of deer you kill’ ($\bar{x}$ = 5.25, SD ± 1.42), E) ‘Harvesting female deer’ ($\bar{x}$ = 5.44 ± 1.37), F) ‘The antler and body size of bucks harvested’ ($\bar{x}$ = 5.08 ± 1.23), G) ‘The number of fawns seen each season’ ($\bar{x}$ = 5.27 ± 1.29), and J) ‘Co-op members sharing similar harvest goals' ($\bar{x} = 5.47 \pm 1.11$). Conversely, respondents were least satisfied with the current habitat management level attributes: L) 'Habitat for game animals other than deer' ($\bar{x} = 4.96 \pm 1.22$), M) 'Habitat for non-game animals other than deer' ($\bar{x} = 4.85 \pm 1.17$), N) 'Increased habitat management on your co-op' ($\bar{x} = 4.96 \pm 1.17$), and O) 'Land stewardship on your co-op' ($\bar{x} = 4.92 \pm 1.16$). The lowest satisfaction scores occurred for the following attributes: I) 'Neighbors following QDM practices' ($\bar{x} = 4.53 \pm 1.61$), R) 'The amount of technical support received from your state wildlife agencies' ($\bar{x} = 4.74 \pm 1.30$), and U) 'Land-lease value of your co-op property' ($\bar{x} = 4.76 \pm 1.20$).

Importance-Satisfaction Analysis of overall mean importance and satisfaction scores provide a simplistic visual display of DMC shortfalls and benefits for members and resource managers (Figure 3.3). Attributes that fell within sub-quadrant one ("Keep Up the Good Work") include: B) 'Seeing deer when hunting', F) 'The antler and body size of bucks harvested', G) 'The number of fawns seen each deer season', H) 'Co-op restrictions on bucks that limit buck harvest more than current state restrictions', J) 'Co-op members sharing similar harvest goals', Q) 'Relationships between co-op members/hunters', and T) 'Forming relationships with neighboring landowners'. Attributes that fell within sub-quadrant two ("Concentrate Here") include: A) 'Seeing mature bucks when hunting', D) 'Harvesting mature bucks', I) 'Neighbors following QDM practices', L) 'Habitat for game animals other than deer, and N) 'Increased habitat management on your co-op'. Attributes that fell within sub-quadrant three ("Low

Priority") include: M) 'Habitat for non-game wildlife', O) 'Land stewardship on your co-op', R) 'The amount of technical support received from your state wildlife agency', S) 'The amount of technical support received from conservation non-governmental organizations (NGOs), U) 'Land-lease value of your co-op property', and V) 'Preventing crop damage from wildlife'.

Attributes that fell within sub-quadrant four ("Possible Overkill") include: C) 'The number of deer you kill', E) 'Harvesting female deer', and P) 'The size of your co-op'. Attribute K) 'Control over deer density', fell directly on the axis between "Keep Up the Good Work" and "Concentrate Here". The only three attributes that fell below the iso-rating line, indicating that satisfaction exceeds importance, were attributes C) 'The number of deer you kill', E) 'Harvesting female deer', and U) 'Land-lease value of your co-op property' (Figure 2.3).

Motivational Cluster Importance-Satisfaction Analysis

Analysis of all respondents allows for broad interpretation, but to better understand differences in member motivations, we conducted four separate ISAs by motivation cluster. There was some agreement across all four clusters regarding attribute location (Table 3.6). All clusters agreed that B) 'Seeing deer when hunting' and J) 'Co-op members sharing similar harvest goals' fell within the "Keep Up the Good Work" sub-quadrant. Both U) 'Land lease value of co-op property and V) 'Preventing crop damage from wildlife' stayed within the "Low Priority" sub-quadrant across all clusters. Lastly, there was agreement in sub-quadrant one "Concentrate Here" that I) 'Neighbors following QDM practices' should receive more attention.

Clusters differed in what they placed as most important, possibly due to motivational differences. For example, the 'Representative' and 'Quality Harvest' clusters both rated D) 'harvesting mature bucks' as highly important ($\bar{x} = 6.15$, SD $\pm$ 0.90 and 6.03 $\pm$ 0.90;

respectively), while 'Solitude' and 'Social' clusters rated the same attribute below the attribute mean of 5.78 ($\bar{x} = 5.43 \pm 1.25$ and 4.87 ± 1.69). Attribute D) 'harvesting mature bucks' fell within the "Low Priority" sub-quadrant for both 'Social' and 'Solitude', while located in the "Concentrate Here" and "Keep Up the Good Work" sub-quadrants for 'Representative' and

‘Quality Harvest’ members respectively. Additional differences in importance values were seen only by the ‘Representative’ cluster where this cluster had the highest score for importance on 21 of 22 attributes. The only attribute that the ‘Representative’ cluster did not place the highest importance score on was C) ‘the number of deer you kill’ ($\bar{x}$ = 3.37 ± 1.63, scale 1-7). The ‘Representative’ cluster consistently rated habitat management attributes higher than the other three clusters. For example, the ‘Representative’ cluster scored attribute N) ‘increased habitat management on your co-op’ ($\bar{x}$ = 6.00; SD ± 1.04), while the other three clusters rated its importance between 5.51 and 5.57 (Solitude Member: 5.51 ± 1.32, Social Member: 5.57 ± 1.20, and Quality Harvest Member: 5.54 ± 1.02) (Table 3.5).

ANOVA analysis indicated statistical differences among clusters for attribute importance and satisfaction. Univariate ANOVAs highlighted significant differences between cluster attribute importance for 19 of 22 attributes (Table 3.5). The ‘Representative’ cluster consistently placed the highest importance scores on attributes (21 of 22 attributes), with ‘Solitude Members’ routinely assigning the lowest attribute importance scores (11 of 22 attributes). The mean score for all importance scores was 5.62 (SD ± 0.69) on a seven-point scale (between ‘slightly important’ and ‘important’ categories). Mean importance scores for each of the four clusters, calculated using all 22 attributes, fell between five and six on the seven-point scale: ‘Solitude Member’ 5.27 (SD ± 0.68), ‘Social Member’ 5.41 (± 0.72), ‘Representative Member’ 5.82 (± 0.71), and ‘Quality Harvest Member’ 5.54 (± 0.68).

ANOVAs quantified significant differences between cluster attribute satisfaction for 15 of 22 attributes (Table 3.5). For example, the ‘Representative Member’ and ‘Quality Harvest Member’ clusters both rated attribute A) ‘Seeing mature bucks’ at or above average satisfaction ($\bar{x}$ = 5.10, SD ± 1.26 and 5.18 ± 1.19; respectively), while ‘Solitude’ and ‘Social’ clusters rated the same attribute below mean satisfaction of 5.10 ($\bar{x}$ = 4.52 ± 1.53 and 4.79 ± 1.22). In line with importance results, 'Representative Members' indicated the highest cluster satisfaction values for 18 of 22 attributes, while 'Quality Harvest Members' placed the highest satisfaction on 3 of 22 attributes. Attribute C, 'The number of deer you kill', was the only attribute to receive the highest satisfaction value from the 'Social Member' cluster. Attributes concerning DMC harvest goals (E, H, and J) provided higher than average satisfaction scores across all clusters. For example, both H) 'Co-op restrictions on bucks that limit buck harvest more than current state regulations' and J) 'Co-op members sharing similar harvest goals' received satisfaction scores between 5.09 and 5.68 from all DMC member clusters. The mean score for overall satisfaction was 5.08 (± 0.28) on a seven-point scale (just above the 'somewhat satisfied' category). Mean satisfaction scores for each of the four clusters, calculated using all 22 attributes, were as follows: Solitude Member 4.74 (± 0.33), Social Member 4.90 (± 0.28), Quality Harvest Member 5.05 (± 0.31), and Representative Member 5.23 (± 0.30).

Discussion

Factors contributing to the satisfaction of deer hunters can be diverse (Kerr 2017) and DMC member satisfaction is an important factor in member retention and recruitment. Therefore, we applied ISA methodology from the business literature to determine DMC attribute importance and satisfaction for 22 salient hunting, habitat management, and member association

attributes. Additionally, we applied the ISA technique to four different segments of DMC members whose primary motivations for white-tailed deer hunting varied. Deer hunters are routinely described as going through five hunting phases: "shooter", "limiting out", "quality/trophy", "methods", and "sportsman" (Jackson and Norton 1980). Previous research has also described three primary motivational orientations for white-tailed deer hunters: affiliative-oriented, achievement-oriented, and appreciative-oriented (Decker and Connelly 1989), while Messmer and Enck (2012) added a fourth motivation categorized as 'multiple motivations', which includes motivations like seeing others harvest deer and exercise. These past findings suggest that numerous factors can account for observed differences in hunter satisfaction, most often characterized by incongruent expectations and outcomes (Decker et al. 1980). Multiple satisfaction frameworks can be present among a single group of hunters, thus leading to differences in perceived experience and satisfaction within hunter groups. The perceived differences in hunter experience highlight the fundamental relationship between motivational goals and satisfaction (Manfredo et al. 2004) when quantifying hunter satisfaction. Our results confirm the previous findings of Jackson and Norton (1980), Decker and Connelly (1989) and Messmer and Enck (2012) that hunters' motivations vary and that it is prudent to investigate differences in importance and satisfaction by motivations for hunting. Identification of DMC attributes currently producing satisfied members provides conservation planners data to aid in future DMC implementation. Seeing game while hunting is widely cited as one of the most important determinants of hunter satisfaction (McCullough and Carmen 1982; Gigliotti 2000; Fulton and Manfredo 2004; Shrestha et al. 2012). Similarly, B) 'Seeing deer while hunting' received the highest satisfaction score of all 22 DMC attributes that we tested ($\bar{x}$ = 5.55 ± 1.14; 1-7 scale). These results suggest that DMCs provide this important satisfaction

attribute to their members.

Interestingly, the second highest satisfaction attribute score was for H) 'Co-op harvest restrictions on bucks that limit buck harvest more than current state restrictions' ($\bar{x}$ = 5.51 ± 1.32, 1-7 scale), while the second and third highest values of importance were given to J) 'Co-op members sharing similar harvest goals' ($\bar{x}$ = 6.31 ± 0.87, scale 1-7) and I) 'Neighbors following QDM practices' ($\bar{x}$ = 6.29 ± 0.96, scale 1-7). This was to be expected with quality deer management (QDM) or nontraditional management styles serving as the original catalyst and goal for DMC formation (QDMA 2005). Additionally, increased satisfaction with strict buck harvest regulations is also consistent with recent findings that Georgia hunting club members preferred lands with more restrictive buck harvest regulations (Mingie et al. 2017).

Alone, high importance scores can indicate attributes that may have spurred DMC formation, whereas high satisfaction scores indicate how well DMCs are producing benefits for members. When both measures are combined, ISA analysis serves conservation professionals and DMC members with a diagnosis for areas of concern (attribute is of high importance but low satisfaction), areas of excellence (high importance and high satisfaction), areas of inefficient resource allocation (low importance and high satisfaction), and low priority areas (low importance and low satisfaction). Knowing which attributes fall within these categories will aid DMC efficiency and formation goals. Attributes of DMC excellence (both importance > 5.9 and satisfaction > 5.4, scale 1-7) include: B) 'Seeing deer while hunting', J) 'Co-op members sharing similar harvest goals', H) 'Co-op harvest restrictions on bucks that limit buck harvest more than current state regulations', and Q) 'Relationships between co-op members and hunters.' These attributes are highly important to DMC members and provide high satisfaction and can be expected positive externalities of DMC formation.

DMC habitat management attribute values indicate that DMC members value habitat management but are dissatisfied with how well their DMC is meeting habitat management objectives. Overall our results show that attribute L) 'Habitat for game animals other than deer' and N) 'Increased habitat management on your co-op' both fall within the "Concentrate Here" sub-quadrant (Figure 2.3). Attribute L) 'Habitat for other game animals other than deer' also falls within the "Concentrate Here" or "Keep Up the Good Work" sub-quadrant for three of the four DMC member clusters (Table 2.6). Attribute M) 'Habitat for non-game animals other than deer' also fall within the "Concentrate Here" for the 'Representative' cluster. These attributes are not the most important attributes to DMC members, but indicate areas of improvement where importance values are higher than current satisfaction scores.

DMCs are not made up of one "type" of hunter but contain hunters with differing motivations practicing common deer management goals. DMC members from differing motivational clusters had varying top satisfaction scores, top importance scores, and subsequent quadrants for ISA attributes (Figure 2.5). For example, the 'Representative Member' cluster gave the highest importance score to J) 'Co-op members sharing similar harvest goals', while the other three clusters all rated B) 'Seeing deer while hunting' as their most important attribute. The number of attributes that fell within the "Keep Up the Good Work" category (high importance, high satisfaction) and "Low Priority" category (low importance, low satisfaction) also varied among motivational clusters ("Keep Up the Good Work" & "Low Priority" attributes respectively: Solitude cluster – 2 & 12 , Social cluster – 4 & 9, Quality Harvest cluster – 6 & 7, Representative cluster – 15 & 2).

Attribute consensus across all DMC member clusters was rare and only achieved for one attribute in the "Concentrate Here" sub-quadrant: I) 'Neighbors following Quality Deer

Management practices.' All four DMC clusters placed attribute "I" within the "Concentrate Here" category, indicating a consensus of concern about adjacent landowners to DMCs following QDM practices. Consensus among DMC clusters may indicate a looming obstacle across the landscape. Although the proportion of yearling bucks in the national harvest decreased from 62-35% between 1989-2015 (Adams and Ross 2017), more rigorous forms of QDM (e.g., harvest restrictions on bucks younger than 3.5 or 4.5-years-old) are not practiced ubiquitously. DMCs may be experiencing resistance to practicing stringent forms of QDM or even Trophy Deer Management by surrounding hunters. Conservation planners and NGOs should address this issue, and aid DMCs with support and advocacy, because implications could impact future DMC growth, implementation, and recruitment.

Our results can be applied for successful implementation and continuation of DMCs while providing an innovative look into areas of concern for DMCs, and current DMC ability to meet member satisfaction and formation goals. Our ISA results provide a basic understanding of DMC member perceptions on relevant attributes, to aid implementation, viability, and sustainability of DMCs as an increasingly utilized management tool.

Future Research

Further research into DMC member motivations and satisfaction should pursue possible ISA differences by state. Determination of ISA outcomes by state would serve wildlife agencies and conservation planners with critical information about local DMC needs, especially for high satisfaction attributes like co-op harvest restrictions on bucks that limit buck harvest more than current state regulations. Each region, and state, has distinct differences in landscape, hunting culture, hunter density, season structure, deer management history, and land-use trends that may