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Effect Of Hunting Frequency On Duck Abundance, Harvest, And Hunt Quality In Mississippi

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EFFECT OF HUNTING FREQUENCY ON DUCK ABUNDANCE, HARVEST, AND HUNT QUALITY IN MISSISSIPPI

By

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Waterfowl hunting is important historically, culturally, and economically in Mississippi and North America. I evaluated effect of hunting frequency (2 or 4 days/week) on duck abundance, harvest, and hunters' perceived quality of their experience on Mississippi Wildlife Management Areas (WMAs). Neither relative abundance nor harvest of all ducks, mallard (*Anas platyrhynchos*), northern shoveler (*A. clypeata*), or green-winged teal (*A. crecca*) differed between experimental hunting frequencies. Duck harvest increased with hours spent afield. Hunters' perceived quality did not differ between hunting frequencies but was greatest when hunters harvested $\geq$ 4 ducks/ day and increased with harvest of larger sized ducks. I suggest WMAs may be hunted 4 days/week without impacting duck abundance, harvest, or hunt quality. I recommend continued evaluations of hunting frequency on duck abundance, harvest, and hunt quality to sustain science-guided management of waterfowl hunting on Mississippi public lands.

Keywords: abundance, duck, harvest, hunt quality, hunting frequency

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CHAPTER I

EFFECT OF WATERFOWL HUNTING FREQUENCY AND DUCK ABUNDANCE ON MISSISSIPPI WILDLIFE MANAGEMENT AREAS

Introduction

The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), other public agencies, and non-governmental conservation organizations provide or assist with management of public wildlife hunting areas in the state and elsewhere. To sustain and recruit waterfowl hunters, most agencies seek to provide quality public hunting opportunities (i.e., areas where waterfowl can be seen and harvested legally; Miller and Hay 1981, Vaske et al. 1986). Studies have observed waterfowl movements, abundance, and distribution in response to disturbances (e.g., predation, human recreation [boating, hiking]) in Europe and North America (e.g., Hockin et al. 1992, Klein et al. 1995, Fox and Madsen 1997). However, few studies, especially in North America, have conducted experimental tests of the effect of hunting frequency on waterfowl abundance (e.g., Korschgen et al. 1985, Knapton et al. 2000). Thus, most managers rely on expert opinions and comparisons of past hunting pressure and success to make decisions about hunt management on public and private lands (E. J. Penny, MDWFP, personal communication). Scarcity of information regarding effect of hunting frequency on waterfowl abundance warranted an investigation to assist biologists and managers in developing quality opportunities for seeing and harvesting waterfowl.

Food resources and disturbance can influence habitat use by waterfowl (Jorde et al. 1984, Madsen 1998*a*). Waterfowl abundance, especially during the non-breeding season, may be related to availability of food resources (van Eerden 1984, Reinecke et al. 1989), which may influence waterfowl harvest (Delnicki and Reinecke 1986; Madsen 1998*a*, *b*). However, tradeoffs exist between energy gained from food and risk of natural or hunting mortality when choosing and using a feeding location (Lima 1986). If disturbance is too great, foraging opportunities for waterfowl may decrease because food resources are functionally unavailable during these events (Morton et al. 1989, Perry and Deller 1996, Fox and Madsen 1997). Increased hunting frequency can displace waterfowl to spatial or temporal refugia (e.g., sanctuaries, nocturnal feeding), potentially leading to avoidance of hunting areas during legal harvest hours (Hockin et al. 1992, Madsen and Fox 1995, Fox and Madsen 1997). Conversely, low hunting frequency may result in loss of hunting opportunity and depletion of food resources in sanctuaries (Reinecke et al. 1989, Greer et al. 2009). To avoid these consequences on Wildlife Management Areas (WMAs), managers typically aim to provide quality foraging habitat to attract waterfowl and also regulate hunting pressure (e.g., frequency and times of weekly hunting events).

Waterfowl may react to disturbance by increasing flight time and decreasing foraging time (Thornburg 1973, Korschgen et al. 1985, Madsen and Fox 1995, Evans and Day 2002). Increased flying can increase energy expenditures, and decreased foraging time may affect ability of waterfowl to meet energetic demands (Hockin et al. 1992). If energy expenditure becomes too great, birds may decrease their use in disturbed portions of the full home-range and exploit lower quality foraging areas or nearby sanctuaries (Hockin et al. 1992, Madsen and Fox 1995, Evans and Day 2002). Life-history strategies may determine if a species is more likely to use or avoid an area with hunting disturbances (Ackerman et al. 2006). Species with relatively longer lifespan and larger body size (e.g., mallard [*Anas platyrhynchos*]) have greater capacity to store nutrients and may take fewer risks than species with shorter life-span and smaller body size (e.g., green-winged teal [*A. crecca*; hereafter teal]; Nagy 2005, Ackerman et al. 2006). Thus, frequency of daily or weekly hunting may influence waterfowl species composition and abundance at hunting areas.

Managers attempt to provide undisturbed areas for waterfowl by creating temporal or spatial sanctuaries (Madsen 1998*a*). Sanctuaries may restrict hunting partially (i.e., selected hours or days of the week) or completely (i.e., non-hunting sanctuaries; Fox and Madsen 1997). Waterfowl abundance may decrease when areas are hunted consecutive mornings, afternoons, or days; thus, non-hunting periods may be necessary to maintain or increase duck harvest at hunting areas (Fox and Madsen 1997). Waterfowl use of sanctuaries may increase with increased hunting pressure of nearby areas (Evans and Day 2002). Sanctuaries may provide undisturbed foraging areas, retain waterfowl near hunting areas, and attract migrating and local birds (Hockin et al. 1992, Fox and Madsen 1997, Madsen 1998*a*). Temporal sanctuaries may increase waterfowl abundance on an area, but spatial sanctuaries may sustain waterfowl abundance more than areas temporally closed to hunting (Fox and Madsen 1997). However, few studies have evaluated the relationship between temporal sanctuaries and waterfowl abundance (e.g., Fox and Madsen 1997).

Little information is available on waterfowl response to varying levels of hunting frequency and, to my knowledge, no such studies have been conducted in the United States (cf., Korschgen et al. 1985). Therefore, managers have used conservative or prior hunting management schemes (e.g., 2-3 hunt days/week, morning hunting only; Ringelman 1997, E. J. Penny, personal communication). Historically, the MDWFP permitted either daily waterfowl hunting or hunting 2-3 mornings per week on its WMAs during the regular waterfowl hunting season, but no experiments have been conducted to evaluate effect of weekly frequency of hunting on duck abundance, harvest, and hunter satisfaction in Mississippi. In this chapter, my objectives were to determine: 1) the relationship between duck abundance and weekly hunting frequency (i.e., 2 or 4 mornings of hunting per week), 2) if abundance of dabbling duck species with different life-history strategies varied between weekly hunt frequencies, and 3) if hunt frequency influenced use of sanctuaries by ducks on WMAs.

Study Area

My study areas were WMAs managed by MDWFP for waterfowl hunting where hunting had been allowed $\leq$ 3 mornings/week before my study. In the Mississippi Alluvial Valley (MAV) portion of Mississippi, the WMAs were Howard Miller WMA (770 hunted ha, 971 total ha; 32º49'48.93" N, 90º58'51.61" W) and Muscadine Farms WMA (273 hunted ha, 316 total ha; 33º13'29.32" N, 90º59'01.51" W). In east-central Mississippi, the WMA was Trim Cane WMA (82 hunted ha, 324 total ha; 33º31'30.27"

N, 88º50’47.19” W; Figure 1.1). Although number and area of hunting units (i.e., site for one hunting party of 1- 4 people) varied among WMAs, I attempted to equalize number and area of units between experimental treatments of 2 and 4 hunting days/week as much as logistically possible within WMAs (Table 1.1). Hunt units and sanctuaries were managed for moist-soil vegetation (Fredrickson and Taylor 1982, Kross et al. 2008) and occasionally supplemental plantings of corn, Egyptian wheat, grain sorghum, Japanese and browntop millets, rice, soybean, or Sudan-grass. Between 2008 and 2009, Muscadine Farms WMA increased in area by 48% with acquisition of an additional 291 ha (458 hunted ha, 607 total ha 33º12’48.62” N, 90º57’55.49” W; Figure 1.1; Table 1.1).

Methods

Land Cover Types

I used ArcMap (ArcGIS) to determine area of different land cover types within impoundment units managed for waterfowl at each WMA (ESRI 2009). I categorized cover types as the aforementioned supplemental plantings, forested or scrub-shrub, aquatic bed (i.e., areas dominated by wetland obligate vegetation [e.g., *Ludwigia* spp.]), and moist-soil emergent vegetation (Cowardin et al. 1979). I identified and digitized forested and scrub/shrub areas depicted on 2007 aerial photographs of WMAs using ArcMap (ESRI 2009, USDA NRCS 2010). Managers confirmed accuracy of my interpretation of the aerial photographs. In the field, I validated forest or scrub-shrub areas in hunting and sanctuary units and estimated area of aquatic bed, moist-soil wetland, and supplemental plantings also in hunting and sanctuary units by pacing the perimeters of these cover types in August 2008 and October 2009. I paced the perimeters because land cover types were primarily regular geometric shapes (e.g., rectangle). Subsequently, I incorporated measurements of cover types into ArcMap (ArcGIS) and determined their area (ESRI 2009).

Experimental Hunting Frequencies

I divided each WMA into 2 treatment zones of approximately equal area and similar cover types. I randomly assigned each zone a hunt frequency treatment of 2 or 4 days/week. I chose these treatments because 4 days/week doubled the previous hunting frequency at Muscadine Farms and Trim Cane WMAs. At Howard Miller WMA, the previous hunting frequency was 3 days/week. In 2009, area of supplemental plantings was disproportionate in the 2008 treatment zones at Howard Miller WMA. Therefore, I reassigned treatment zones in 2009 at Howard Miller WMA to equalize representation of cover types (Figure 1.1). Additionally, I modified demarcation between treatment zones and reassigned hunt frequencies at Muscadine Farms WMA because hunted and sanctuary areas increased between 2008 and 2009 as result of additional land acquisition (Figure 1.1). Finally, hunters were selected by the MDWFP using an online pre-hunting season random lottery system, or they could arrive on the morning of the hunt as stand-by hunters. On the day of each hunt, hunters selected from available hunting units based on a random draw system. A maximum of 4 hunters were able to use a hunting unit per day.

Duck Density Surveys

Hunt Unit Surveys

I conducted 2 ground surveys weekly during December and January 2008-2010 at WMAs to create an index of duck abundance for units hunted 2 and 4 days/week. I conducted surveys on non-hunting days, so as not to disturb hunters while hunting. I counted all waterbirds by species during surveys but restricted analyses to ducks because observations of waterbirds other than ducks were minimal (< 10%). Detection bias was similar between hunting frequencies because a surveyor surveyed both hunting frequencies survey period. I conducted surveys 1 and 3 days after hunt units were open to hunting within the 2 days/week treatment zone. In the 4 days/week zone, I conducted surveys one day after the hunt units were open to hunting, because the areas could not receive 3 consecutive days of rest. I conducted flush count surveys while walking or from an ATV along levees adjacent to hunt units (e.g., Kaminski and Prince 1981). I reversed the starting point of surveys between sequential weeks, so as not to survey each unit at approximately the same time of day. I used binoculars to identify and count ducks within hunt units before they flushed. When ducks flushed, I noted the number that landed in hunt units yet to be surveyed and subtracted these from subsequent counts. I conducted hunt unit surveys mid-morning (10:00-11:30 h) when ducks exhibit a resting tendency (Paulus 1984).

Sanctuary Surveys

I surveyed sanctuary units 6 times/week to generate 2 indices of duck use among mornings when (1) all hunt units within the WMAs were open to hunting, (2) only areas with hunting frequency of 4 days/week were open for hunting, and (3) WMAs were closed to hunting. I used binoculars and scan sampling from a concealed tree stand or ground blind to observe ducks using sanctuaries (Altmann 1974, Havens et al. 2009). For the first index, I identified and counted ducks within a standardized visible area every 15 min for 7 scan samples over a 1.5 h observation period beginning 15 min before sunrise. For the second index, I counted numbers of flying ducks entering and leaving sanctuary areas every 10 min for 5 min intervals (n = 6 observation periods per day) to calculate percentage relative change in all duck use during observation periods.

Statistical Analyses

Foraging Habitat Index

I determined area (ha) of moist-soil vegetation, corn, grain sorghum, Japanese and browntop millets combined, rice, and soybean to develop an index of potentially available foraging habitat within each hunt unit. I did not include forest or scrub-shrub (i.e., non-mast producing tree species [e.g., willow; *Salix spp.*]) or aquatic bed wetlands (e.g., primrose [*Ludwigia spp*.]) as potential waterfowl foraging areas, because propagules of the aforementioned plants are not important foods of waterfowl in the MAV (Reinecke et al. 1989, Kaminski et al. 2003, Fleming 2010). Egyptian wheat and Sudan-grass were planted to provide concealment for hunters and not food for waterfowl

(E. J. Penny, personal communication). Based on area of potential foraging habitat within hunt units, I calculated total potential duck energy days (DEDs/ha) for each hunt unit (*sensu* Miller and Eadie 2006, Wiseman 2009). I calculated DEDs using the following formula (LMVJV 2007):

$$DED = \sum_{i=1}^{n} \left(\frac{(mass_i - [FT \times pM_i]) \times 1000g / kg \times TME_i}{DER} \right) \quad (1\text{-}1)$$

where:

DED = carrying capacity (DED/ha),

n = total number of food sources,

$mass_i$ = mean mass (kg (dry mass)/ha) of food type *i*,

FT = assumed foraging threshold (50 kg/ha; Greer et al. 2009),

pM_i = proportion of $mass_i$ in hunt area to total seed mass,

TME_i = true metabolizable energy of food type *i* (kcal/g; Kaminski et al. 2003), and

DER = average daily energy requirement of dabbling ducks (294.35 kcal/g; Reinecke and Uihlein 2006, Reinecke and Kaminski 2007, Murray et al. 2009, Wiseman 2009)

I used ANOVA and blocked by WMA to test null hypothesis of no difference in DEDs/ha between areas open for hunting 2 or 4 days/week (FREQ; PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Hunting season was a random variable. Residuals of data exhibited equal variances and were distributed normally. I used Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c) to evaluate covariance structures of DEDs/ha in models. I selected compound symmetry (cs) from a suite of covariate structures for all analyses, because cs had the least AIC_c values and variances were generally homogenous (Littell et al. 2006). I designated $\alpha = 0.10$ a priori for all models, because it is acceptable for management-based experiments (Tacha et al. 1982).

Hunt Unit Duck Density

I calculated weekly mean density of all ducks (ducks/ha) for areas hunted 2 or 4 days/week at WMAs. I analyzed weekly mean density of all ducks instead of daily surveys, because number of rest days before surveys differed between hunt frequencies and thus confounded treatment effects. I tested if density of all ducks differed between FREQ using ANOVA with repeated measure (hunt week; WEEK) in a randomized complete block design (WMAs). Hunting season was a random effect. I tested the null hypothesis of no difference in all duck density between FREQ (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007).

Mallard, northern shoveler (*A. clypeata*; hereafter shoveler), and teal were the most abundant dabbling ducks observed comprising 30%, 20%, and 16% of all ducks detected, respectively. I used ANOVA with repeated measure (WEEK) in a block design (WMAs) to test if densities of these species differed between FREQ (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Hunting season was a random effect.

Sanctuary Duck Density

To assess possible influences of hunting disturbance on sanctuary use, I partitioned data into 3 disturbance categories (DISTURB): 1) ENTIRE (all hunt units within the WMA were open to hunting), 2) PART (only areas with hunting frequency of 4 days/week were open for hunting), and 3) NONE (WMA was closed to hunting). I rationalized a category for PART to be areas with a hunting frequency of 4 days/week instead of 2 days/week because areas hunted 2 days/week were always open for hunting when areas hunted 4 days/week were open; however, the converse is untrue. I calculated mean number ducks/ha present during each observational scan ($n = 7$) to generate mean use of ducks/ha for each sampling day. I used ANOVA with repeated measure (WEEK) in a randomized complete block design (WMAs) to test if density of all ducks (ducks/ha) in sanctuaries differed among categories of DISTURB. I also calculated mean densities of mallard, shoveler, and teal/ha because these species comprised 12%, 15%, and 8%, respectively, of all ducks observed. I tested the null hypothesis of no difference in weekly mean density of all ducks, mallard, shoveler, and teal among fixed effect of DISTURB and (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Hunting season was a random effect.

I calculated percentage relative change (increase or decrease) in use of all ducks by subtracting number of ducks exiting WMA sanctuaries from those entering and dividing by the summed total of ducks entering and exiting WMA sanctuaries during each observational period ($n = 6$). I used ANOVA with repeated measure (WEEK) in a block design (WMAs) to test if percentage relative change differed among fixed effect of DISTURB (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Hunting season was a random effect.

Results

Foraging Habitat Index

Areas assigned randomly for waterfowl hunting 2 days/week ($\bar{x}$ [SE] = 11,521.00 [1,577.42]) had greater pre-hunting season DEDs/ha than areas where hunting would be allowed 4 days/week ($\bar{x}$ [SE] = 8,833.83 [1,577.42]) at WMAs ($F_{1, 10} = 3.99$, $P = 0.074$).

Hunt Unit Duck Density

Despite greater potential DEDs before the hunting season on areas designated for hunting 2 versus 4 days/week, abundance of all ducks during the hunting season did not differ between treatment areas ($F_{1, 5.44} = 1.17$, $P = 0.326$; Table 1.2). Additionally, I neither detected a difference in abundance of mallard ($F_{1, 6.26} = 0.18$, $P = 0.687$), shoveler ($F_{1, 2.01} = 2.32$, $P = 0.266$), nor teal ($F_{1, 5.36} = 1.32$, $P = 0.299$) between areas with different weekly hunt frequencies (Table 1.2).

Sanctuary Duck Density

Abundance of all ducks did not vary among mornings when the ENTIRE, PART, or NONE of the WMA was hunted ($F_{2, 9.45} = 1.84$, $P = 0.211$; Table 1.3). Additionally, I neither detected a difference in mallard ($F_{2, 7.82} = 2.59$, $P = 0.137$), shoveler ($F_{2, 3.97} = 1.61$, $P = 0.308$), nor teal ($F_{2, 3.88} = 1.69$, $P = 0.297$) abundances among the aforementioned comparisons (Table 1.3). Percentage change in relative abundance of all ducks within sanctuaries did not differ among the 3 comparisons (i.e., ENTIRE WMA hunted, $\bar{x}$ = 28% $\pm$ 7%; PART, $\bar{x}$ = 32% $\pm$ 7%; NONE, $\bar{x}$ = 33% $\pm$ 6%; $F_{2, 7.16}$ = 0.19, P = 0.834).

Discussion

Managers of waterfowl hunting areas can manipulate spatial and temporal sanctuaries to maintain duck abundance and provide quality hunting opportunities (Miller and Hay 1981, Vaske et al. 1986, Madsen 1998*a*, Fox and Madsen 1997). I evaluated effect of weekly hunting frequency on duck density in hunt units and sanctuaries at WMAs in Mississippi to assist managers in planning hunting activity. Density of all ducks, mallard, shoveler, and teal did not differ between areas hunted 2 or 4 days/week, although percentage difference in mean densities of all ducks and selected dabbler species ranged from 6-49% between weekly hunt treatments. The consequence of no detectable differences may have been influenced by variability in duck use of hunt units resulting in low statistical power (i.e., Type II error; $-0.62 \leq \hat{\rho} \leq 0.13$ $[(\bar{x}_1 - \bar{x}_2)]$; Table 1.2). Nonetheless, previous research has found duck use increased as days between hunting increased (Fox and Madsen 1997). In my study, both hunt frequencies were imposed within WMAs (blocks) to ensure presence of treatments amid local environmental conditions (e.g., habitat composition, landscape juxtaposition, weather). However, I cannot be certain that hunt treatments were independent on the WMAs because I do not know the temporal and spatial scale at which ducks respond to disturbances on hunting areas. Therefore, future studies are needed to determine the temporal and spatial scale at which ducks respond to disturbances.

Additionally, mean duck density from my study conducted on public hunting areas (Tables 1.2 and 1.3) was less than those recorded in moist-soil habitats on federal, state, and private sanctuaries (minima $\bar{x}$ = 32.7 $\pm$ 8.0 ducks/ha; Hagy 2010) and Wetlands Reserve Program lands (minima $\bar{x}$ = 4.51 $\pm$ 2.05 ducks/ha; Fleming 2010) in the MAV during the same hunting seasons. Moist-soil wetlands on WRP lands generally received $\leq$ 2 days waterfowl hunting/week (S. Fleming, personal communication). Differences in duck densities among sanctuaries and hunted WMAs and WRP lands are consistent with ducks responding to varying levels of disturbance (Hockin et al. 1992; Madsen 1998*a*, *b*). Further, density of all ducks, mallard, shoveler, and teal increased in sanctuaries across hunting seasons regardless of hunting pressure (i.e., when all, part, or none of the WMA was hunted), suggesting ducks may have been using spatial sanctuaries even when temporal sanctuaries were available. Therefore, I suggest a need to radio-mark and track individual ducks to determine their movements relative to disturbance regimes on the WMAs.

Waterfowl use can be influenced by availability of food resources and disturbance (e.g., Jorde et al. 1984, van Eerden 1984, Reinecke et al. 1989). Birds may select feeding areas that balance benefits of food abundance and disturbance (Lima 1986, Gill et al. 1996). Increased food density and quality can increase intake rate, reduce foraging time, and increase attraction of waterfowl to feeding sites with disturbance such as managed hunting areas (Newton 1998). I found greater potential DEDs/ha before the hunting season in areas designated for hunting 2 instead of 4 days/week, but did not detect a difference in density of all ducks or specific species between hunting regimes. Responses of ducks to food quantity and quality are beginning to be investigated in the MAV (e.g., Fleming 2010, Hagy 2010), but experiments that concurrently measure food resources and disturbance are necessary to determine relative contributions of food quality and disturbance to use of habitats by ducks. Understanding the interaction between food resources and disturbance on duck use of WMAs would inform managers which factors to manipulate for increased duck use and hunter success.

The potential for exposure to disturbances and predation (e.g., harvest by waterfowl hunters) have been linked to species-specific life history traits of ducks (Ackerman et al. 2006). I evaluated 3 species representing longer lifespan and larger body size (mallard), intermediate lifespan and medium size (shoveler), or shorter lifespan and smaller size (teal). Lifespan and body size can have an inverse relationship on responses to hunting disturbance and risk-taking behavior (Ackerman et al. 2006), but I did not detect a difference in density of mallard, shoveler, or teal between hunt frequencies. I conducted surveys on non-hunt days, thus I cannot ascertain that observed birds were present at the density observed during hunting periods. The relationship between duck density and harvest on WMAs is unknown and requires further study (Chapter 2).

Use of sanctuaries by birds may increase with increasing disturbance of nearby habitats (Hockin et al. 1992, Madsen and Fox 1995, Evans and Day 2002). In contrast, I found that relative change in use of sanctuaries by ducks did not differ with changing hunting pressure in nearby hunt units. However, I found that duck use of sanctuaries among hunting seasons increased regardless of disturbance regime (i.e., mornings when none, half, or all hunt units were open to hunting), which may imply that ducks find and use spatial sanctuaries more than temporal sanctuaries (Fox and Madsen 1997).

Sanctuaries can attract migrating waterfowl and retain birds near hunting locations (Hockin et al. 1992, Fox and Madsen 1997, Madsen 1998*a*). Although I cannot ascertain the origin of ducks on the WMAs (e.g., immigration or movement within WMAs), duck use of sanctuaries among hunting seasons increased an average 30% during morning surveys. Patterns of use of sanctuaries may indicate that ducks in my study area were conditioned to use spatial sanctuaries during morning hunting hours regardless of hunting regime.

Management and Research Implications

My data indicate that Mississippi WMAs may be hunted 4 days/week without decreasing duck use. However, information on how duck use influences harvest and hunter satisfaction also is necessary for managers to make informed decisions regarding levels of hunting activity on WMAs in Mississippi and elsewhere (Chapters 2 and 3). Spatial sanctuaries were used regularly by ducks during my study and may be vital to attract and retain ducks on WMAs. In addition to sanctuaries on WMAs, managers also may consider creating partnerships with adjoining public and private landowners to increase potential temporal and spatial sanctuaries available to waterfowl near WMAs, which may further aid in attracting and retaining waterfowl near public hunting and viewing locations. Future research evaluating individual duck movements (e.g., radio or satellite telemetry) within WMAs and other habitats will be essential to determine duck use in relation to various disturbance regimes.

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Table 1.1 Number (*n*) and area (ha) of hunt units by experimental hunt frequencies of 2 or 4 days/week within Wildlife Management Areas (WMAs) in Mississippi, December – January 2008-2009 and 2009-2010 waterfowl hunting seasons.

		Howard Miller		Muscadine Farms[a]		Trim Cane	
Hunting season	Hunt frequency	*n*	ha	*n*	ha	*n*	ha
2008	2 days/week	12	399	5	123	3	41
	4 days/week	12	370	6	150	3	41
2009	2 days/week	12	397	10	186	3	41
	4 days/week	12	372	11	273	3	41

[a]Area of hunting units increased between hunting seasons at this WMA because of additional acquisition of WMA property.

Table 1.2 Least-squared mean (SE) density of all ducks and selected species (ducks/ha) observed in areas hunted 2 (n = 94) or 4 (n = 94) days/week at Mississippi Wildlife Management Areas, December – January 2008-2009 and 2009-2010 waterfowl hunting seasons.

Ducks	2 days/week	4 days/week
All ducks	2.49	3.11
	(0.69)	(0.69)
Mallard (*Anas platyrhynchos*)	0.86	0.81
	(0.09)	(0.09)
Northern shoveler (*A. clypeata*)	0.64	0.51
	(0.11)	(0.11)
Green-winged teal (*A. crecca*)	0.37	0.55
	(0.26)	(0.26)

Table 1.3 Least-squared mean (SE) density of ducks (ducks/ha) observed in sanctuaries on mornings when the entire (all hunt units within a Mississippi Wildlife Management Area [WMA] were open; $n = 93$), part (only areas with a hunting frequency of 4 days/week were open; $n = 92$), or none (closed; $n = 89$) to hunting during the December – January 2008-2009 and 2009-2010 waterfowl hunting seasons.

Ducks	Entire	Part	None
All ducks	15.46	4.57	5.38
	(4.42)	(4.49)	(4.69)
Mallard (*Anas platyrhynchos*)	0.65	1.11	1.37
	(0.37)	(0.37)	(0.37)
Northern shoveler (*A. clypeata*)	1.19	1.07	1.78
	(0.78)	(0.78)	(0.78)
Green-winged teal (*A. crecca*)	0.89	0.65	0.46
	(0.35)	(0.36)	(0.35)

Figure 1.1 Location of areas hunted for waterfowl 2 or 4 days/week and sanctuaries at Howard Miller, Muscadine Farms, and Trim Cane Wildlife Management Areas in Mississippi, December – January 2008-2009 and 2009-2010 waterfowl hunting seasons.

CHAPTER II

EFFECT OF WATERFOWL HUNTING FREQUENCY AND DUCK HARVEST ON MISSISSIPPI WILDLIFE MANAGEMENT AREAS

Introduction

Waterfowl hunting is important historically, culturally, and economically in Mississippi and elsewhere (Miller and Hay 1981, Grado et al. 2001, NFC and WMI 2006). The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), other public agencies, and non-profit conservation organizations provide or assist with the management of public hunting areas in the state and elsewhere. To sustain and recruit waterfowl hunters, most agencies seek to provide quality public hunting opportunities (i.e., areas where waterfowl can be seen and legally harvested; Miller and Hay 1981, Vaske et al. 1986). However, few studies have evaluated the effect of hunting frequency on harvest (e.g., Macaulay and Boag 1974, Bromley 1996). Thus, managers rely on expert opinions and comparisons of past hunting success in relation to hunt frequency to make management decisions concerning hunting regulations (e.g., number of hunting days per week; E. J. Penny, MDWFP, personal communication).

Habitat use by waterfowl often varies positively with availability of food resources and negatively with disturbance (Jorde et al. 1984, van Eerden 1984, Reinecke et al. 1989, Madsen 1998*a*). However, tradeoffs between energy gained from food and possible survival risks related to natural or hunting disturbance exist for waterfowl at foraging and other habitat sites (Lima 1986). Increased frequency of disturbance may decrease foraging opportunities for waterfowl because food resources may become functionally unavailable during these events (Morton et al. 1989, Perry and Deller 1996, Fox and Madsen 1997). Disturbance also may reduce body condition by increasing energy expended in avoidance behavior (i.e., flight and vigilance; Hockin et al. 1992, Madsen and Fox 1995). Thus, increased hunting frequency can displace waterfowl to temporal or spatial refugia (e.g., sanctuaries, nocturnal feeding), potentially leading to avoidance of areas during hunting hours (Hockin et al. 1992, Madsen and Fox 1995, Fox and Madsen 1997). Decreased use or avoidance of an area can decrease numbers of birds seen and harvested by hunters (Delnicki and Reinecke 1986, Fox and Madsen 1997, Ringelman 1997, Madsen 1998*b*). Conversely, low hunting frequency may result in a loss of hunting opportunity and cause a sanctuary effect whereby food resources may be exploited below a threshold of availability for ducks (Reinecke et al. 1989, Greer et al. 2009, Hagy 2010).

Ducks can move to sanctuaries from foraging areas and adapt behavior otherwise to decrease exposure to potential risks associated with hunting disturbance (Thornburg 1973, Madsen 1995, Evans and Day 2002). Ducks may increase flight time in response to disturbance while simultaneously decreasing foraging time and consequently increasing energy expenditures (Hockin et al. 1992, Madsen and Fox 1995). However, differences in life-history strategies among species may determine risk behavior and susceptibility to harvest in ducks (Ackerman et al. 2006*a*). Species with relatively longer lifespan and larger body size (e.g., mallard [*Anas platyrhynchos*]) may take fewer risks than species with shorter lifespan and smaller body size (e.g., green-winged teal [*A. crecca*; hereafter teal]; Ackerman et al. 2006*a*). Relative costs (e.g., starvation, nutrient deficiencies) associated with foregoing or decreasing foraging are lower in large-bodied species because these ducks have increased capacity to store nutrients and decreased metabolic rates relative to body size (Nagy 2005, Ackerman et al. 2006*a*). Thus, increased frequency of hunting on areas may decrease harvest of large-bodied ducks whereas harvest of smaller, shorter lived species may be less affected by hunting frequency.

Managers create temporal and spatial sanctuaries for ducks (i.e., hunting is restricted to certain times or completely prohibited, respectively) to provide undisturbed habitat near hunting areas with the aim of sustaining waterfowl use and harvest on managed areas (Fox and Madsen 1997, Madsen 1998*a*). Duck harvest may decrease when areas are hunted consecutive days; thus, non-hunting periods may be necessary to maintain or increase duck harvest at hunting areas (Fox and Madsen 1997). Alternatively, if decreasing hunting frequency is not possible or temporal sanctuaries are ineffective, creation of spatial sanctuaries near hunted areas may be necessary to sustain harvestable numbers of ducks at WMAs (Madsen 1995, Madsen 1998*a*, Evans and Day 2002).

Currently, no research in the United States has documented the effect of weekly hunting frequency on waterfowl harvest on public or private lands. Therefore, managers use conservative or prior hunt management schemes (e.g., 2-3 days/week, morning hunting only; Ringelman 1997, E. J. Penny, personal communication). Historically, the MDWFP permitted either daily waterfowl hunting or hunting 2-3 mornings per week on its WMAs during the regular waterfowl hunting season, but no experiments have been conducted to evaluate the effect of weekly frequency of hunting on duck abundance, harvest, and hunter satisfaction in Mississippi. In this chapter, my objectives were to determine: 1) relationships among duck harvest and weekly hunting frequency (i.e., 2 or 4 mornings per week), and 2) if harvest of dabbling duck species with different life history strategies differed between weekly hunt frequencies.

Study Area

My study areas were WMAs managed by MDWFP for waterfowl hunting where hunting had been allowed ≤ 3 mornings/week before my study. In the Mississippi Alluvial Valley (MAV) portion of Mississippi, the WMAs were Howard Miller WMA (770 hunted ha, 971 total ha; 32º49'48.93" N, 90º58'51.61" W) and Muscadine Farms WMA (273 hunted ha, 316 total ha; 33º13'29.32" N, 90º59'01.51" W). In east-central Mississippi, the WMA was Trim Cane WMA (82 hunted ha, 324 total ha; 33º31'30.27" N, 88º50'47.19" W; Figure 1.1). Although number and area of hunting units (i.e., site for one hunting party of 1- 4 people) varied among WMAs, I attempted to equalize number and area of units between experimental treatments of 2 and 4 hunting days/week as much as logistically possible within WMAs (Table 1.1). Hunt units and sanctuaries were managed for moist-soil vegetation (Fredrickson and Taylor 1982, Kross et al. 2008) and occasionally supplemental plantings of corn, Egyptian wheat, grain sorghum, Japanese and browntop millets, rice, soybean, or Sudan-grass. Between 2008 and 2009, Muscadine Farms WMA increased in area by 48% with acquisition of an additional 291 ha (458 hunted ha, 607 total ha 33º12'48.62" N, 90º57'55.49" W; Figure 1.1; Table 1.1).

Methods

Land Cover Types

I used ArcMap (ArcGIS) to determine area of different land cover types within impoundment units managed for waterfowl at each WMA (ESRI 2009). I categorized cover types as the aforementioned supplemental plantings, forested or scrub-shrub, aquatic bed (i.e., areas dominated by wetland obligate vegetation [e.g., *Ludwigia* spp.]), and moist-soil emergent vegetation (Cowardin et al. 1979). I identified and digitized forested and scrub/shrub areas depicted on 2007 aerial photographs of WMAs using ArcMap (ESRI 2009, USDA NRCS 2010). Managers confirmed the accuracy of my interpretation of the aerial photographs. In the field, I validated forest or scrub-shrub areas in hunting and sanctuary units and estimated area of aquatic bed, moist-soil wetland, and supplemental plantings also in hunting and sanctuary units by pacing the perimeters of these cover types in August 2008 and October 2009. I paced the perimeters because land cover types were primarily regular geometric shapes (e.g., rectangle). Subsequently, I incorporated measurements of cover types into ArcMap (ArcGIS) and determined their area (ESRI 2009).

Experimental Hunting Frequencies

I divided each WMA into 2 treatment zones of approximately equal area and similar cover types. I randomly assigned each zone a hunt frequency treatment of 2 or 4 days/week. I chose these treatments because 4 days/week doubled the previous hunting frequency at Muscadine Farms and Trim Cane WMAs. At Howard Miller WMA, the previous hunting frequency was 3 days/week. In 2009, area of supplemental plantings was disproportionate in the 2008 treatment zones at Howard Miller WMA. Therefore, I reassigned treatment zones in 2009 at Howard Miller WMA to equalize representation of cover types (Figure 1.1). Additionally, I modified demarcation between treatment zones and reassigned hunt frequencies at Muscadine Farms WMA because hunted and sanctuary areas increased between 2008 and 2009 as result of additional land acquisition (Figure 1.1). Finally, hunters were selected by the MDWFP using an online pre-hunting season random lottery system, or they could arrive on the morning of the hunt as stand-by hunters. On the day of each hunt, hunters selected from available hunting units based on a random draw system. A maximum of 4 hunters were able to use a hunting unit per day.

Duck Harvest and Hunter Use

I placed waterfowl check stations at exits of WMAs. As hunters departed WMAs, I recorded the number and species of ducks harvested by each hunter. I also recorded hunters' assigned hunt unit, number of hunters per hunting unit, and time in minutes each party hunted. Each hunter's effort during a hunt represented 1 hunter day.

Statistical Analyses

Foraging Habitat Index

I determined area (ha) of moist-soil vegetation, corn, grain sorghum, Japanese and browntop millets combined, rice, and soybean to develop an index of potentially available foraging habitat within each hunt unit. I did not include forest or scrub-shrub (i.e., non-mast producing tree species [e.g., willow; *Salix spp.*]) or aquatic bed wetlands (e.g., primrose [*Ludwigia spp.*]) as potential waterfowl foraging areas, because propagules of the aforementioned plants are not important foods of waterfowl in the MAV (Reinecke et al. 1989, Kaminski et al. 2003, Fleming 2010). Egyptian wheat and Sudan-grass were planted to provide concealment for hunters and not food for waterfowl (E. J. Penny, personal communication). Based on area of potential foraging habitat within hunt units, I calculated total potential duck energy days (DEDs/ha) for each hunt unit (*sensu* Miller and Eadie 2006, Wiseman 2009). I calculated DEDs using the following formula (LMVJV 2007):

$$DED = \sum_{i=1}^{n} \left(\frac{(mass_i - [FT \times pM_i]) \times 1000g\ /\ kg \times TME_i}{DER} \right) \tag{2-1}$$

where:

DED	=	carrying capacity (DED/ha),
n	=	total number of food sources,
$mass_i$	=	mean mass (kg (dry mass)/ha) of food type i,
FT	=	assumed foraging threshold (50 kg/ha; Greer et al. 2009),
pM_i	=	proportion of $mass_i$ in hunt area to total seed mass,
TME_i	=	true metabolizable energy of food type i (kcal/g; Kaminski et al. 2003), and
DER	=	average daily energy requirement of dabbling ducks (294.35 kcal/g; Reinecke and Uihlein 2006, Reinecke and Kaminski 2007, Murray et al. 2009, Wiseman 2009)

I used ANOVA and blocked by WMA to test null hypothesis of no difference in DEDs/ha between areas open for hunting 2 or 4 days/week (FREQ; PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Hunting season was a random variable. Residuals of data exhibited equal variances and were distributed normally. I used Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c) to evaluate covariance structures of DEDs/ha in models. I selected compound symmetry (cs) from a suite of covariate structures for all analyses, because cs had the lowest AIC_c values and variances were generally homogenous (Littell et al. 2006). I designated $\alpha = 0.10$ a priori for all models, because it is acceptable for management-based experiments (Tacha et al. 1982).

Duck Harvest and Hunter Use

Across WMAs and both hunting seasons, areas with a hunting frequency of 4-days were hunted nearly twice more than areas with a hunting frequency of 2-days (1,668 hunter days, 931 hunter days; respectively). I calculated weekly mean harvest of all ducks (ducks/hunter day) for areas hunted 2 or 4 days/ week at WMAs. I tested the null hypothesis of no difference in weekly mean harvest of all ducks between the fixed effect of FREQ and the random variable of hunting season (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). Minutes hunted per hunter was designated as a covariate to account for possible differences in harvest due to increased hunt duration.

Green-winged teal (47%), northern shoveler (*A. clypeata*; hereafter; 25%), and mallard (8%) were the most commonly harvested ducks (80%); hence, I analyzed harvest data for these species. I used ANOVA with repeated measure (WEEK) in a block (WMAs) design to test if mallard or shoveler harvest differed between FREQ. Mallard and shoveler data residuals neither met homogeneity of variance nor normality assumptions transformed or not transformed ($\log_e$ of $x + 0.01$ or square root of $x + 0.01$; Ott and Longnecker 2001). Nonetheless, I used analysis of variance (ANOVA) because it is robust to departures from normality (Littell et al. 2006, McDonald and White 2010). Despite teal comprising most of harvest, covariance matrices ($n = 23$ covariance structures tested) would not converge for this species. Inspection of the data indicated harvest during week 7 of the hunting seasons was an outlier. Removal of week 7 data allowed remaining data to converge. Transformed data residuals also did not meet assumptions of homogeneity of variance or normality (Ott and Longnecker 2001). Nevertheless, I was used ANOVA to test the null hypothesis of no difference in mallard, shoveler, and teal harvest between the fixed effect of FREQ and the random variable of hunting season (PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007).

Results

Foraging Habitat Index

Areas assigned randomly for waterfowl hunting 2 days/week ($\bar{x}$ [SE] = 11,521.00 [1,577.42]) had greater pre-hunting season DEDs/ha than areas where hunting would be allowed 4 days/week ($\bar{x}$ [SE] = 8,833.83 [1,577.42]) at WMAs ($F_{1, 10} = 3.99$, $P = 0.074$).

Duck Harvest and Hunter Use

Despite increased potential DEDs before the hunting season on areas hunted 2 days/week during the hunting season, I did not detect a difference in harvest of all ducks between areas hunted 2 or 4 days/week ($F_{1, 2.19} = 0.21$, $P = 0.691$; Table 2.1). Additionally, I did not detect a difference in harvest of mallard ($F_{1, 1.89} = 8.84$, $P = 0.104$), shoveler ($F_{1, 2.14} = 1.88$, $P = 0.296$), or teal ($F_{1, 1.00} < 0.10$, $P = 0.971$) between treatment hunt frequencies (Table 2.1). Harvest of all ducks ($F_{1, 2575} = 161.63$, $R^2 = 0.33$, $P < 0.001$), mallard ($F_{1, 2553} = 63.90$, $R^2 = 0.68$, $P < 0.001$), shoveler ($F_{1, 2568} = 25.73$, $R^2 = 0.17$, $P < 0.001$), and teal ($F_{1, 2011} = 81.26$, $R^2 = 0.19$, $P < 0.001$) increased with time spent hunting (Figure 2.1). Specifically, harvest of all ducks increased by 0.48 ducks/hunter for each additional hour afield (mallard = 0.06; shoveler = 0.11; teal = 0.27). Hunters spent the same amount of time hunting at WMAs ($\bar{x} = 192.4 \pm 2.1$ min for areas hunted 2 days/week; $\bar{x} = 192.2 \pm 1.7$ min for areas hunted 4 days/week).

Discussion

Managers of public and private waterfowl hunting areas manage vegetation, hydrology, and temporal and spatial refugia to provide quality hunting opportunities and maintain harvest and viewing of waterfowl (Miller and Hay 1981, Vaske et al. 1986, Reinecke et al. 1989, Madsen 1998*a*). I evaluated duck harvest in response to weekly hunting frequency at WMAs in Mississippi to aid biologists in planning and managing waterfowl hunting on WMAs. Harvest of all ducks, mallard, shoveler, and teal per hunter day did not differ between areas hunted 2 or 4 days/week, which is consistent with my evaluation of the effect of weekly hunt frequency on duck abundance on Mississippi WMAs (Chapter 1). The consequence of no detectable differences may have been influenced by variability in duck harvest in hunt units resulting in low statistical power, especially for green-winged teal (i.e., Type II error; $0.01 \leq \hat{\rho} \leq 0.10$ [$(\bar{x}_1 - \bar{x}_2)$]. I imposed both hunting frequencies within WMAs in a block design to ensure presence of treatments amid local environmental conditions (e.g., waterfowl abundance, habitat composition, landscape juxtaposition, weather). However, I do not know the temporal and spatial scale at which ducks respond to disturbances on hunting areas, raising the question of independence between hunt treatments. Future similar experiments or studies of radio-marked ducks on WMAs with hunt frequencies imposed in my study may elucidate the extent to which my hunt frequency treatments were independent or confounded with temporal and spatial scale of experimental application.

Mean duck harvests were similar in my study (1.95 ducks/hunter day) and during recent hunting seasons at the same WMAs (2006-2008; 1.82 ducks/hunter day) at Howard Miller, Muscadine Farms, and Trim Cane WMAs, suggesting increasing hunting frequency to 4 day/week on portions of the WMAs did not result in a detectable effect on duck harvest. Yearly fluctuations in habitat conditions (e.g., food availability, management intensity at WMAs, weather conditions) may cause variability in harvest levels (Reinecke et al. 1988, Pearse 2007). However, I do not have measurements for these variables and am not able to determine the effect of the landscape on harvest rates for previous hunting seasons. Further, my study area was an open system (i.e., immigration and emigration occurred) and duck movement within and migration to the MAV could influence duck recognition and response to hunting disturbance (Ackerman et al. 2006*b*). Continued studies that evaluate how annual landscape metrics influence duck movements, and subsequently harvest, in the MAV and elsewhere are needed to assist managers in manipulating habitat conditions to maximize quality hunting opportunities.

Duck use of habitat and harvest can be influenced by availability of food resources and disturbance (e.g., Jorde et al. 1984, van Eerden 1984, Reinecke et al. 1989, Chapter 1). Birds may select feeding areas which balance benefits and costs of habitat use including food abundance and encountered disturbance (Lima 1986, Gill et al. 1996). Increased food density and quality can increase attraction of waterfowl to hunted sites (Newton 1998). I detected greater potential DEDs/ha before hunting seasons on areas of WMAs designated for hunting 2 days than 4 days/week but did not find a difference in harvest of all ducks and commonly harvested species. Responses of ducks to potential and actual food resources (e.g., Fleming 2010, Hagy 2010) and disturbance have been investigated in the MAV (e.g., Chapter 1), but experiments have not been conducted which concurrently measured food resources and hunting regimes throughout fall-winter to determine the relative contributions of food resources and hunting regimes on harvest of ducks. Additional experiments investigating the interaction between food resources and disturbance regimes on risk taking behavior by ducks and resultant hunter harvest would help managers in determining which factors to manipulate for increased hunter success.

Species-specific life history traits of ducks may determine exposure to disturbances and predation (e.g., harvest by waterfowl hunters; Ackerman et al. 2006*a*). I evaluated 3 species representing longer lifespan and larger body size (mallard), intermediate lifespan and medium body size (shoveler), or shorter lifespan and smaller body size (teal; Bellrose 1980, Ackerman et al. 2006*a*). The distance at which a duck approaches decoys can have an inverse relationship with lifespan and body size (Ackerman et al. 2006*a*). Although I did not detect a difference in mallard, shoveler, or teal harvest between hunt frequencies, comparison of harvests/hunter day with duck densities at WMAs are consistent with differences in susceptibility to harvest among species (Gilmer et al. 1989). In my study, mallard comprised 30% of the all ducks observed in hunt units (Chapter 1) but accounted for 8% of all ducks harvested. In contrast, teal were 16% of all ducks seen but accounted for 47% of duck harvest. Shoveler abundance (20% of ducks seen) and harvest (25% of ducks harvested) were similar. Findings suggest hunters may have fewer shooting and harvesting opportunities for longer-lived and larger bodied species at WMAs even if they are relatively abundant at WMAs during non-hunting hours. Additionally, although I did not detect a difference, harvest did trend in the predicted direction for all species (greater harvest/hunter day on areas with less disturbance), especially for mallards ($d = 0.10$). Greater aversion to disturbance by mallards relative to teal may influence hunt quality because mallards, especially males, may be highly sought by hunters (Gilmer et al. 1989, Metz and Ankney 1991). Determining how species-specific harvest influences hunt quality requires further study (Chapter 3).

Duck density increased approximately 30% in nearby sanctuaries within the first 1.5 hrs of sunrise regardless of hunting intensity at WMAs (Chapter 1). These findings suggest ducks may have been conditioned to use spatial sanctuaries during morning hunting hours even on days closed to hunting (Hockin et al. 1992, Madsen and Fox 1995, Fox and Madsen 1997, Chapter 1). Hunters who remained afield longer realized greater harvest, but only 55% of hunters remained afield for greater than 3 hours and < 25% hunted 4 or more hours. Thus, ducks may have used sanctuaries during morning when hunter numbers were greater at WMAs and moved to hunting units where they were increasingly available for harvest later in the morning. Investigation of the diurnal movements of individual ducks during periods hunting and non-hunting are necessary to understand behavioral response of ducks to changes in daily hunting activity and intensity.

Previous studies have found decreases in duck harvest when areas are hunted consecutive days (Fox and Madsen 1997). In my study, consecutive days of hunting occurred once each week on areas hunted 4 days/week (e.g., Saturday and Sunday); however, hunting pressure was spaced relatively evenly throughout the week to reduce potential effects of consecutive hunting. Additionally, at least one spatial sanctuary was located at each WMA, which may have retained or attracted ducks near hunting locations during consecutive days of hunting disturbance (Hockin et al. 1992, Madsen 1998*a*, Evans and Day 2002). Future studies testing effect of consecutive days of hunting on harvest in Mississippi and elsewhere will assist managers charged with determining maximum public hunting opportunity.

Management and Research Implications

Hunter harvest of all ducks on areas hunted 4 days per week on Mississippi WMAs was 5% less, on average, than on areas hunted 2 days per week. I did not detect a difference between these levels of harvest; thus, I conclude that Mississippi WMAs in this study may be hunted 4 days/week without appreciably decreasing total duck harvest. However, MDWFP biologists should consider that mean harvest of mallards, on average, was nearly double on areas of WMAs hunted 2 than 4 days per week, and hunt quality is related positively to body size of harvested ducks (e.g., mallards; Chapter 3). On small

WMAs where mallards are common winter residents (e.g., Trim-Cane WMA), MDWFP biologists and managers may desire to evaluate duck abundance, harvest, and hunter satisfaction in response to hunting 3 days per week. Indeed, continued evaluations of relationships among duck abundance, duck harvest, and quality of hunts are needed to assist biologists and managers in making informed decisions regarding hunting frequency in Mississippi and elsewhere. Moreover, future studies evaluating: 1) temporal and spatial scales at which individually radio-marked ducks respond to hunting disturbance and 2) differential habitat use of hunted and sanctuary areas by these ducks will allow biologists and managers to understand how hunting pressure influences individuals' behavior and survival.

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Table 2.1 Least-squared mean (SE) harvest of all ducks and selected species (ducks/hunter day) in areas hunted 2 (n = 931 hunter days) or 4 days/week (n = 1,668 hunter days) at Mississippi Wildlife Management Areas, December – January 2008-2009 and 2009-2010.

Ducks	2 days/week	4 days/week
All ducks	1.55	1.47
	(0.28)	(0.27)
Mallard (*Anas platyrhynchos*)	0.20	0.11
	(0.03)	(0.02)
Northern shoveler (*A. clypeata*)	0.39	0.29
	(0.06)	(0.05)
Green-winged teal (*A. crecca*)	0.51	0.50
	(0.15)	(0.13)

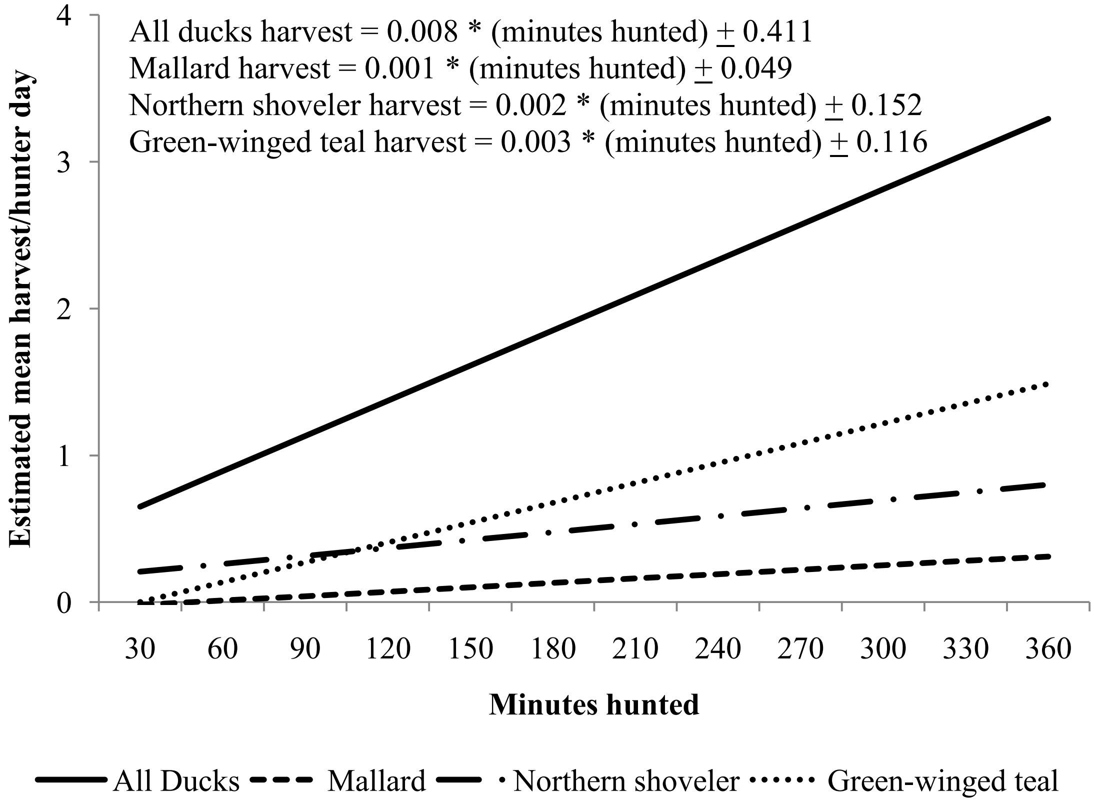

Figure 2.1 Linear relationship between estimated harvest (ducks/hunter day) of all ducks, mallard (*Anas platyrhynchos*), northern shoveler (*A. clypeata*), and green-winged teal (*A. crecca*) and minutes hunted at Mississippi Wildlife Management Areas, December – January 2008-2009 and 2009-2010.

CHAPTER III

EFFECT OF WATERFOWL HUNTING FREQUENCY AND DUCK HUNTER PERCEIVED HUNT QUALITY ON MISSISSIPPI WILDLIFE MANAGEMENT AREAS

Introduction

Hunters provide funding for conservation through purchases of hunting licenses, migratory bird stamps, hunting equipment, and memberships in conservation organization (Enck 1993, Grado et al. 2001, NFC and WMI 2006). Purchases and contributions from hunters provide substantial funds used to conserve and manage habitat for waterfowl and other migratory birds on public wildlife management areas, federal waterfowl production areas, and national wildlife refuges (Decker et al. 2001, Loveridge et al. 2007). Public hunting areas often provide waterfowl hunting opportunities at minimal costs compared to private hunting areas (Decker et al. 2001, Grado et al. 2001). Indeed, a primary objective of public wildlife conservation agencies is to provide quality hunting opportunities (i.e., conditions where waterfowl harvest and abundance are sustained or increased) as a means of retaining and recruiting waterfowl hunters (Miller and Hay 1981, Vaske et al. 1986). Identifying and understanding hunters' perceptions of quality experiences on public hunting areas assist managers in fulfilling management goals to retain hunters and generate revenue for conservation (Enck et al. 1993, Ringelman 1997, Brunke and Hunt 2007).

Previous research suggests hunter satisfaction is multifaceted and includes achievement (e.g., harvesting a daily limit of ducks), affiliative (e.g., being defined as a hunter), and appreciative –oriented factors (e.g., being outdoors; Hendee 1974, Enck et al. 1993, Brunke and Hunt 2007). However, managers of public areas believe hunter attitudes are primarily related to achievement-oriented factors (Vaske et al. 1986, Enck et al. 1993, Ringelman 1997, Brunke and Hunt 2008). Discrepancies between research findings and manager opinions may result from different interactions with hunters. Researchers often contact hunters following a hunting season and ask questions directed related to the entire season (e.g., NFC and WMI 2006). In contrast, managers observe hunters immediately after a hunting experience, when achievement-oriented factors may be important for hunters. Thus, researchers seemingly study hunter satisfaction, whereas managers observe perceptions of hunt quality (Brunke and Hunt 2007). Few studies have evaluated relationships between hunting opportunities and hunter perceived quality; however, these studies only investigated the effect of season length on hunt quality and did not address effect of number of number of allowable hunting days per week (Ringelman 1997, NFC and WMI 2006).

Habitat use by waterfowl often varies positively with availability of food and other necessary resources and negatively with disturbance (Jorde et al. 1984, van Eerden 1984, Reinecke et al. 1989, Madsen 1998*a*). Hunting is a primary disturbance for waterfowl during the nonbreeding season in many locales and increased hunting frequency may displace waterfowl from habitats (Hockin et al. 1991, Madsen and Fox

1995, Fox and Madsen 1997). Decreased use or avoidance of an area can decrease numbers of birds seen and harvested by hunters (Fox and Madsen 1997, Ringelman 1997, Madsen 1998*b*). Conversely, low frequency of hunting on certain areas may result in lost hunting opportunities on other areas, caused by sanctuary effects on the former areas and food resources may be exploited below a threshold of availability for ducks because of aggregations of birds (Reinecke et al. 1989, Greer et al. 2009, Hagy 2010). However, waterfowl behaviorally adjust to disturbances, and life-history strategies may determine if a duck is more likely to use or avoid an area with hunting disturbances (Thornburg 1973, Madsen 1995, Ackerman et al. 2006). Species with relatively longer lifespan and larger body size (e.g., mallard [*Anas platyrhynchos*]) have greater capacity to store nutrients and may take fewer risks than species with shorter life-span and smaller body size (e.g., green-winged teal [*A. crecca*; hereafter teal]; Nagy 2005, Ackerman et al. 2006). Therefore, frequency of hunting may influence composition of ducks seen or harvested, possibly affecting hunt quality.

Although perceptions of hunt quality is influenced by achievement, affiliative, and appreciative –oriented factors, my focus was only on achievement-oriented factors because number and species of ducks harvested is potentially related to weekly hunt frequency. Therefore, my objectives were to determine: 1) if hunt quality was related to hunting frequency at Wildlife Management Areas (WMAs) in Mississippi and 2) if the abundance and species composition of ducks harvested (i.e., achievement-oriented factors) influenced hunt quality at these areas.

Study Area

My study areas were WMAs managed by MDWFP for waterfowl hunting where hunting had been allowed ≤ 3 mornings/week before my study. In the Mississippi Alluvial Valley (MAV) portion of Mississippi, the WMAs were Howard Miller WMA (770 hunted ha, 971 total ha; 32º49’48.93” N, 90º58’51.61” W) and Muscadine Farms WMA (458 hunted ha, 607 total ha; 33º13’29.32” N, 90º59’01.51” W). In east-central Mississippi, the WMA was Trim Cane WMA (82 hunted ha, 324 total ha; 33º31’30.27” N, 88º50’47.19” W; Figure 1.1). Although number and area of hunting units (i.e., site for one hunting party of 1- 4 people) varied among WMAs, I attempted to equalize number and area of units between experimental treatments of 2 and 4 hunting days/week as much as logistically possible (Chapters 1 and 2, Table 1.1). Hunt units and sanctuaries were managed for moist-soil vegetation (Fredrickson and Taylor 1982, Kross et al. 2008) and occasionally supplemental plantings of corn, Egyptian wheat, grain sorghum, Japanese and browntop millets, rice, soybean, or Sudan-grass.

Methods

Hunt Quality

I determined hunt quality based on responses by hunters to the Mississippi Waterfowl Hunting Permit (MWHP). The MWHP was developed by MDWFP and included 6 questions: “I got plenty of shooting opportunities”, “I had an enjoyable hunting experience”, “I saw plenty of ducks”, “I harvested a sufficient number of ducks”, “I hunted in well managed waterfowl habitat”, and “Other parties interfered with my hunt" (Table 3.1). The last question, "Other parties interfered with my hunt" was reverse coded to reduce response-set bias. Response-set bias occurs when respondents provide the same response regardless of the question being asked, usually due to an incomplete reading of the question (Hair et al. 2010). Responses to the MWHP were determined using a five-point Likert type scale with the response format of 1 = "strongly disagree," 2 = "disagree," 3 = "neutral," 4 = "agree," 5 = "strongly agree". I asked hunters using WMAs to complete the MWHP individually and immediately after each hunt. Following the hunting season, MDWFP provided me with hunt quality data. Hunters provided 1,440 surveys for the 2009 waterfowl hunting season and 1,106 were returned usable which provided an effective response rate of 77%. Returned but unusable surveys had missing information (e.g., no hunt unit number, not all questions answered).

Experimental Hunting Frequencies

I divided each WMA into 2 treatment zones of approximately equal area and similar cover types (Chapters 1 and 2). I randomly assigned each zone a hunt frequency treatment of 2 or 4 days/week. I chose these treatments because 4 days/week doubled the previous hunting frequencies at Muscadine Farms and Trim Cane WMAs, and was greater than the previous 3 days/week at Howard Miller WMA. Hunters were selected by the MDWFP using an online pre-hunting season random lottery system, or they arrived on the morning of a hunt as "stand-by" hunters. On the day of each hunt, hunters selected from available hunting units based on a random draw system. A maximum of 4 hunters were able to use a hunting unit per day.

Duck Harvest and Hunter Use

I placed waterfowl check stations at exits of WMAs. As hunters departed WMAs, I recorded the number, species, and weight of each duck (to the nearest 5 g) harvested by each hunter. I also recorded hunters' assigned hunt unit, number of hunters per hunting unit, and time in minutes each party hunted. Each hunter's effort during a hunt represented 1 hunter day.

Statistical Analyses

I conducted principal component analysis with Varimax rotation to determine extent of correlation among hunt quality measurements (Hair et al. 2010). Individual MWHP questions were retained within factor if: 1) its factor loading was > 0.50, and 2) the MWHP question contributed to a Cronbach's alpha > 0.70 for all items in the factor (Table 3.1; Kim and Mueller 1978, SPSS Inc. 2009). Questions 1-5 factored together and had a Cronbach alpha = 0.868, thus items could be combined for a hunt quality score (Table 3.1). Question 6 did not factor into the hunt quality score; however, I did not expect this question to factor into the hunt quality score because it focuses on the social interactions of hunting whereas the other question are related to duck abundance and harvest. My data residuals met homogeneity of variance assumptions but were distributed nonnormally even after transformation ($\log_e$ of x + 0.01 or square root of x + 0.01; Ott and Longnecker 2001). Nonetheless, I used analysis of variance (ANOVA) because it is robust to departures from normality (Littell et al. 2006, McDonald and White 2010). I used a randomized complete block ANOVA with repeated measure (hunt week [WEEK], n = 8) to test the null hypothesis of no difference in hunt quality score between fixed effect of weekly hunting frequency (FREQ; PROC MIXED; SAS Institute Inc. 2002, Gutzwiller and Riffell 2007). I used Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c) to evaluate covariance structures of hunt quality score in models. I selected compound symmetry (cs) from a suite of available covariate structures for all analyses, because cs had the least AIC_c values and variances were generally homogenous (Littell et al. 2006). I designated $\alpha = 0.10$ a priori for all models, because it is acceptable for management oriented experiments (Tacha et al. 1982).

I measured total duck harvest and mean weight of harvest (WEIGHT) as covariates to assess the possible relationships between hunt quality, ducks harvested, and certain species harvested. I calculated WEIGHT by dividing total weight of duck harvest by total number of ducks harvested to standardize the calculation because total weight alone may not relate to bag composition (e.g., weight of 1 mallard is similar to 3 teal). Total weight of duck harvest was calculated by multiplying mean weight (g) of each species with number of that species harvested. I calculated a Pearson's correlation coefficient to ensure covariates were uncorrelated ($0.06 \leq r \leq 0.55$, $n = 1{,}106$). My initial model included the main effects of FREQ, harvest, and WEIGHT, their 3-way interaction, and all possible 2-way interactions. Interactions were evaluated and the initial model was reduced using backward elimination of interactions and appropriate main effects ($P > 0.10$).

Results

I did not detect interactions of factors possibly influencing hunt quality scores (i.e., 3-way [FREQ*harvest*WEIGHT], 2-way [FREQ x harvest, FREQ x WEIGHT, harvest x WEIGHT]; $P > 0.10$). Additionally, hunt quality score did not differ between areas hunted 2 ($\bar{x} = 3.83 \pm 0.08$) or 4 ($\bar{x} = 3.95 \pm 0.07$) days/week ($F_{1, 5.44} = 1.17$, $P = 0.326$). However, hunt quality score was affected by number of ducks harvested by hunters ($F_{6, 1091} = 31.78$, $P < 0.001$; Figure 3.1) and WEIGHT of ducks bagged ($F_{1, 1095} = 7.44$, $R^2 = 0.50$, $P = 0.007$; Figure 3.2). Specifically, hunt quality score increased for each duck harvested between 0 and 4 ducks, but hunt quality score did not differ when harvest was greater than 4 ducks (Figure 3.1). Hunt quality score increased 1 Likert scale point for each 900 g increase in WEIGHT (approximate mean weight of northern pintail [*A. acuta*, hereafter pintail]).

I tested for a difference in potential duck energy days (DEDs) between areas assigned a hunting frequency of 2 or 4 days/week to ensure differences did not exist. I did not detect a difference in DEDs between areas open to hunting 2 ($\bar{x}$ [SE] = 8,769.10 [583.42]) or 4 days/week ($\bar{x}$ [SE] = 7,549.08 [583.42]; $F_{1, 6} = 2.19$, $P = 0.190$) during the 2009 waterfowl hunting season.

Discussion

I evaluated the effect of weekly hunting frequency on hunters' attitudes following their hunt(s). Using answers to the MWHP, I found perceived quality of hunting did not differ between areas hunted 2 or 4 days/week, which is consistent with results in Chapters 1 and 2. However, duck abundance, harvest, and hunters' attitudes are dynamic; thus, continued evaluation of hunt quality is necessary to ensure WMA managers are providing hunters with quality hunting experiences.

Achievement-oriented factors, including number of ducks harvested and shooting opportunities, can influence hunt quality (e.g., Frey et al. 2003, Brunke and Hunt 2007). In a study of Mississippi waterfowl hunters, researchers found hunters expected to bag 4.3 ducks/hunter day during seasons with a daily bag limit of 6 ducks/hunter (Brunke and Hunt 2008). Similarly, I found hunt quality was greatest when hunters harvested 4 or more ducks/hunter day. These findings suggest achievement-oriented factors are important influences of hunt quality at Mississippi WMAs. However, I did not investigate affiliative or appreciative –oriented factors. Few studies have addressed these potential influences of hunt quality (e.g., NFC and WMI 2006, Brunke and Hunt 2007). Therefore, continued studies of hunters' attitudes and determinants of hunt quality will assist managers in developing and sustaining programs to retain and recruit hunters.

Abundance and harvest of specific duck species did not differ between areas hunted 2 or 4 days/week (Chapters 1 and 2). However, average weight of harvested ducks did influence hunters' perceived quality of hunts. Longer lived, larger bodied ducks (e.g., mallard, pintail) may be preferentially harvested by hunters (Gilmer et al. 1989), but my study is the first to demonstrate this relationship with perceived hunt quality. Ducks with longer lifespan and larger body size are less likely to approach decoys than species with shorter lifespan and smaller body size (Ackerman et al. 2006); thus, hunters may have fewer harvest opportunities for larger bodied ducks and may experience a sense of achievement when successful at harvesting larger ducks. Alternatively, hunt quality may be related positively to average weight of ducks harvested because of increased food obtained (i.e., recreation and meat hunting motivation; Heberlein and Willibrand 1998). Fisheries and white-tailed deer (*Odocoileus* *virginianus*) studies have evaluated hunter attitudes in relation to body size within select species (e.g., Collier and Krementz 2007, Baker 2009); however, few studies have been conducted to determine the relationship between hunter attitudes and types of waterfowl harvested (e.g., Gilmer et al. 1989, Metz et al. 1991). Thus, additional studies are needed to determine why average weight of ducks harvested influenced hunt quality. Understanding the motivation for preference in ducks harvested may assist managers in promoting hunting and retaining hunters.

Availability of food resources can influence duck use and harvest (e.g., Jorde et al. 1984, van Eerden 1984, Reinecke et al. 1989), which can affect hunt quality (Ringelman 1997). I did not detect a difference in pre-hunting season DEDs/ha, duck abundance, or duck harvest between hunting frequencies (Chapters 1 and 2); thus finding no difference in hunt quality between areas hunted 2 or 4 days/week was not surprising. Birds may select feeding areas which balance benefits and costs of habitat use including food abundance and encountered disturbance (Lima 1986, Gill et al. 1996). Waterfowl may have an increased attraction to hunted sites when food quality and density are increased (Newton 1998). Responses of ducks to potential and actual food resources and disturbance have been investigated in the MAV (Havens et al. 2009, Fleming 2010, Hagy 2010), but experiments have not been conducted which concurrently measured food resources and hunting regimes throughout fall-winter to determine the relative contributions of food resources and hunting regimes on harvest of ducks and hunt quality. Additional experiments investigating the interaction between food resources and disturbance regimes on duck use, harvest, and resultant hunt quality would help managers identify factors to manipulate to create quality public hunting opportunities.

Management and Research Implications

Hunters perceived hunting experiences equivalently on areas hunted 2 or 4 days/week on Mississippi WMAs; thus, I recommend allowing hunting 4 days/week on these WMAs because it will maximize the number of hunting opportunities. However, quantity and composition of harvest did have an effect on hunt quality, suggesting that hunt quality at WMAs is achievement-oriented. Hunters were more satisfied when they harvested 4 or more ducks/hunt or larger bodied ducks (e.g., mallards, pintail) than when they harvested smaller bodied ducks (e.g., teal, bufflehead [*Bucephala albeola*]). Therefore, managers should continue to provide complexes of habitat which provide sanctuary habitat to help sustain or increase diverse waterfowl populations on WMAs and local waterfowl areas (Pearse 2007). Continued evaluation of hunter attitudes will be instrumental in coupling hunt quality and habitat management on public lands and ensuring hunters are preceding they are receiving quality hunting conditions on WMAs.

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Table 3.1 Questions asked on the Mississippi Waterfowl Hunting Permit during the 2009 waterfowl hunting season and Varimax rotated component matrix of factor loadings for hunter responses[a].

	Component[b]	
Question	1	2
1. "I got plenty of shooting opportunities"	0.871	0.249
2. "I had an enjoyable hunting experience"	0.848	-0.227
3. "I saw plenty of ducks"	0.821	0.149
4. "I harvested a sufficient number of ducks"	0.818	0.334
5. "I hunted in well managed waterfowl habitat"	0.701	-0.397
6. "Other parties interfered with my hunt[c]"	0.090	0.877

[a]Responses were determined using a five-point Likert type scale with the response format of 1 = "strongly disagree," 2 = "disagree," 3 = "neutral," 4 = "agree," 5 = "strongly agree".
[b]Cronbach alpha = 0.868
[c]Question was reverse coded

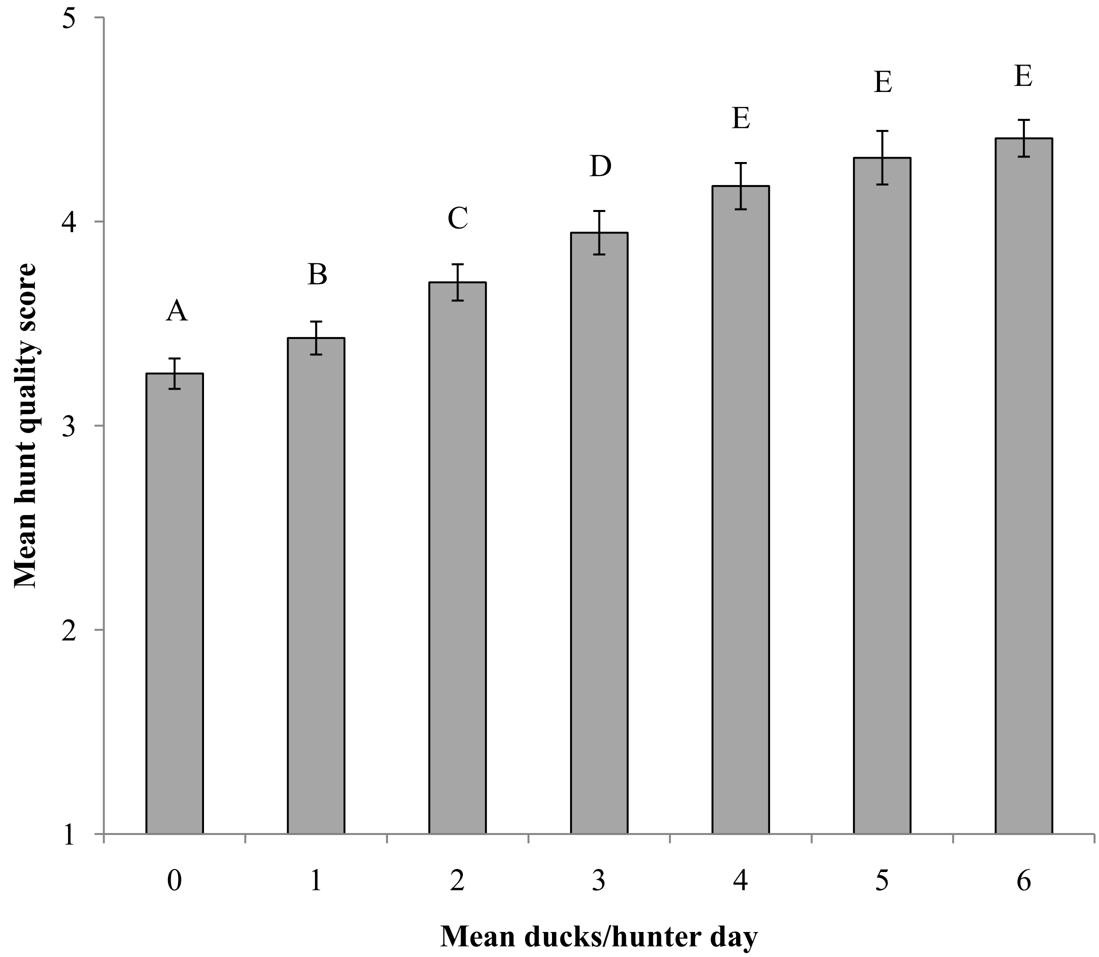

Figure 3.1 Relationship between mean hunt quality score[a] and duck harvest at Wildlife Management Areas in Mississippi during the 2009 waterfowl hunting season.

[a]Hunt quality score was comprised of 5 questions ("I got plenty of shooting opportunities", "I had an enjoyable hunting experience", "I saw plenty of ducks", "I harvested a sufficient number of ducks", and "I hunted in well managed waterfowl habitat"; Cronbach alpha = 0.868). Responses were determined using a five-point Likert type scale with the response format of 1 = "strongly disagree," 2 = "disagree," 3 = "neutral," 4 = "agree," 5 = "strongly agree".

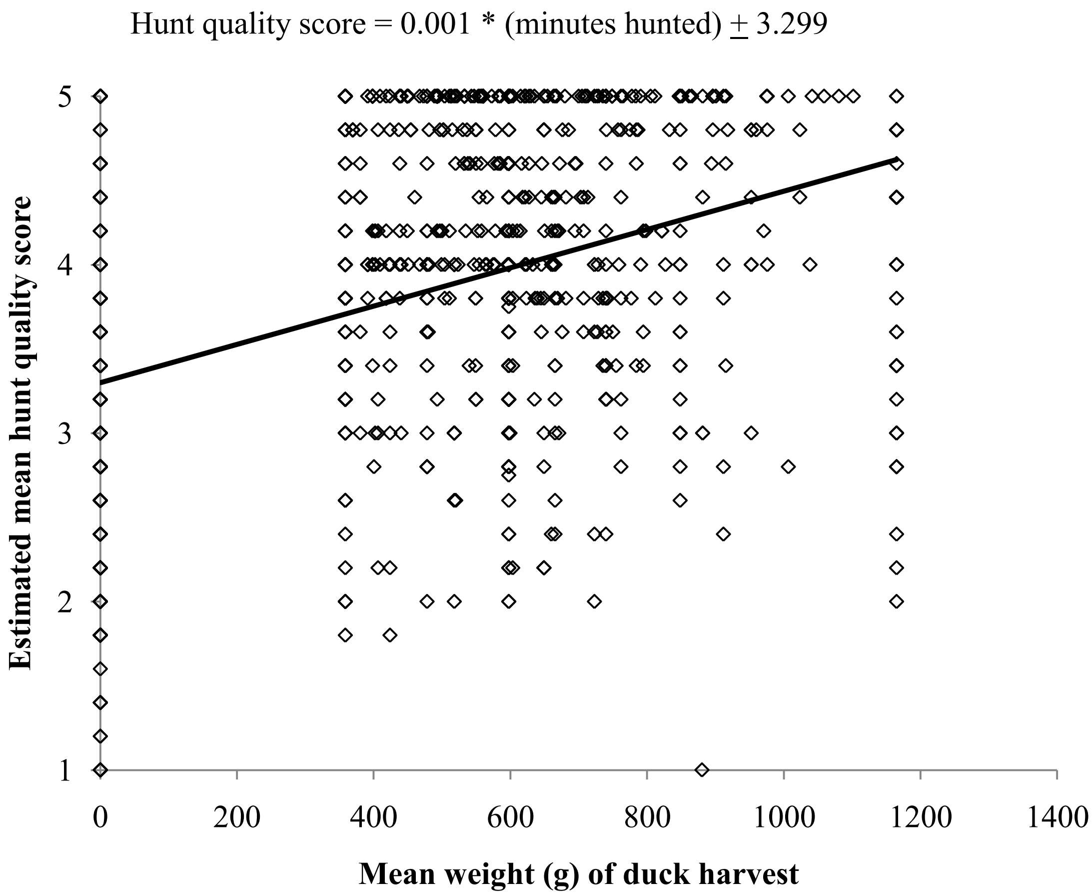

Figure 3.2 Relationship between observed sample points, estimated mean hunt quality score[a], and mean weight (g) of duck harvest at Wildlife Management Areas in Mississippi during the 2009 waterfowl hunting season.

[a]Hunt quality score was comprised of 5 questions ("I got plenty of shooting opportunities", "I had an enjoyable hunting experience", "I saw plenty of ducks", "I harvested a sufficient number of ducks", and "I hunted in well managed waterfowl habitat"; Cronbach alpha = 0.868). Responses were determined using a five-point Likert type scale with the response format of 1 = "strongly disagree," 2 = "disagree," 3 = "neutral," 4 = "agree," 5 = "strongly agree".

CHAPTER IV

SYNTHESIS

Waterfowl hunting is important historically, culturally, and economically in Mississippi and throughout North America (Miller and Hay 1981, Grado et al. 2001, NFC and WMI 2006). The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP), other public agencies, and non-governmental conservation organizations provide or assist with the management of public wildlife hunting areas in the state. Contributions from hunters (e.g., purchase of hunting licenses, migratory bird stamps, hunting equipment, conservation organization memberships [i.e., Delta Waterfowl Foundation, Ducks Unlimited, Inc.]) provide substantial funds to conserve habitat for waterfowl and other migratory birds through the creation of wildlife management areas, federal waterfowl production areas, and national wildlife refuges (Enck 1993, Decker et al. 2001, Grado et al. 2001, NFC and WMI 2006, Loveridge et al. 2007). Public hunting areas provide accessible waterfowl hunting opportunities at lower costs than private hunting areas (Decker et al. 2001, Grado et al. 2001). Thus, to sustain and recruit waterfowl hunters, many agencies seek to provide opportunities for quality hunting on public lands (i.e., areas where waterfowl can be seen and legally harvested; Miller and Hay 1981, Vaske et al. 1986). However, few studies have evaluated the effect of hunting frequency on waterfowl abundance, harvest, and hunt quality (e.g., Macaulay and Boag

1974, Korschgen et al. 1985, Bromley 1996, Ringelman 1997, Knapton et al. 2000). Managers often rely on expert opinions and comparisons of past hunting success to make management decisions concerning hunting regulations (e.g., number of hunting days per week; E. J. Penny, MDWFP, personal communication). Understanding how weekly hunting frequency may affect duck abundance, harvest, and hunt quality will assist biologists and managers to develop quality hunting opportunities, increase or retain hunter use, and generate revenue for conservation (Enck et al. 1993, Ringelman 1997, Brunke and Hunt 2007).

In Chapter I, I evaluated the effect of weekly hunting frequency (2 or 4 days/week) on duck density in hunt units open to waterfowl hunting and sanctuaries at public Wildlife Management Areas (WMAs) in Mississippi (i.e., Howard Miller, Muscadine Farms, and Trim Cane WMAs). Density of all ducks, mallard (*Anas platyrhynchos*), northern shoveler (*A. clypeata*; hereafter shoveler), and green-winged teal (*A. crecca*; hereafter teal) in hunt units did not differ between areas hunted 2 or 4 days/week. Additionally, density of all ducks, mallard, shoveler, and teal in sanctuaries did not vary among mornings when none, half, or all hunt units were open to hunting. Duck use of sanctuaries increased an average of 30% during morning surveys (1.5 hr) regardless of the number a hunt units open for hunting (i.e., none, half, or all). Therefore, I concluded that Mississippi WMAs may be hunted 4 days/week without decreasing duck use, but continued evaluation of hunting frequency on WMAs is necessary to ensure these areas are maintaining harvestable numbers of ducks and providing quality public hunting opportunities. Sanctuaries were regularly used by ducks during my study and may be vital to retain ducks on WMAs.

In Chapter II, I evaluated duck harvest in response to weekly hunting frequency and time hunters remained afield at WMAs in Mississippi. Hunter harvest of all ducks on areas hunted 4 days per week on Mississippi WMAs was only 5% less, on average, than on areas hunted 2 days per week. Additionally, I did not detect a difference in harvest of mallard, shoveler, and teal between areas hunted 2 or 4 days/week. Hunters remaining afield longer harvested more total ducks, mallards, shoveler, and teal. The responses in duck harvest are consistent with results on duck abundance in Chapter I, hence further supporting my recommendation that WMAs may be hunted 4 days/week without appreciably decreasing total duck harvest. Determining how abundance and harvest of ducks on WMAs may influence hunter satisfaction will assist managers providing areas that satisfy and retain hunters.

In Chapter III, I evaluated the effect of hunting frequency on hunter's perception of hunt quality following a hunt. Using hunter responses from the Mississippi Waterfowl Hunting Permit, I found quality of hunting, as perceived by hunters, did not differ between hunters experiencing areas hunted 2 or 4 days/week. However, hunt quality was greatest when hunters harvested 4 or more ducks per day. Additionally, I calculated average body weight of ducks harvested by hunters as an index of hunter bag composition and possible influence on hunt quality. I found hunt quality was positively related to average weight of harvested ducks suggesting hunters were more satisfied with increased harvested of larger bodied ducks.

Duck abundance, harvest, and hunt quality were similar between areas open to hunting 2 or 4 days/week, suggesting weekly hunting frequency could be 4 days/week at WMAs. Increasing hunting frequency to 4 days/week will maximize hunting opportunities, optimize hunt quality, and maintain duck abundance and harvest at WMAs. However, duck populations, habitats, and hunter attitudes are dynamic. Continued evaluations of hunting frequency and the metrics measured in this study will enable biologists and managers to provide quality public hunting opportunities. Future studies to determine individual duck responses (e.g., radio telemetry) to hunting disturbance and differential habitat use of hunted and sanctuary areas by these ducks will allow biologists and managers to understand how hunting pressure influences individuals' behavior and survival. Continued evaluation of hunt quality is necessary to ensure hunters perceive they are experiencing quality hunts on public lands.

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