Mallard Use of a Managed Public Hunting Area in Mississippi

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Abstract: Managers of public lands affording waterfowl hunting strive to provide quality hunting opportunities while supporting biological needs of birds during winter. Understanding responses by mallards (*Anas platyrhynchos*) to diurnal hunting activities would help shape hunt regimes that satisfy management goals. We examined use of a wildlife management area (WMA) in western Mississippi by 28 radio-marked female mallards when waterfowl hunting season was closed and during the season when none, half, or all of the WMA was hunted during two winters 2010–2012. The proportion of each day that mallards occupied the WMA was best explained by date ($w_i = 1.0$) and declined 0.5%/day (±0.05% [SE]). Mallard presence on the WMA was best explained by date plus an interaction of hour-of-day and extent the WMA was hunted ($w_i = 1.0$). Females used the WMA most when the waterfowl hunting season was closed (7.5%; CI 5.4%–10.0%), followed by periods when half (6.8%; CI 4.8%–9.4%), none (6.4%; CI 4.6%–8.9%), or all (5.2%; CI 3.7–7.3%) of the WMA was hunted during hunting season. Mallard presence declined more rapidly when the entire WMA was hunted than when none or half was hunted or the season was closed; however, mallard presence was similar from 2000 to 0800 hours regardless of hunt extent. Because nocturnal use was similar among hunt regimes, mallard harvest did not differ when all or half of the WMA was hunted, and hunting the entire WMA allowed 40 additional hunters/day, managers may consider hunting the entire WMA during morning and afternoon hours.

Key words: Hunting disturbance, mallard, wildlife management area, public hunting, waterfowl

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Wildlife conservation areas in the southeastern United States and elsewhere are frequently managed to provide waterfowl habitat and hunting opportunities (Miller and Hay 1981, St. James et al. 2013). Naturally inherent in responsible public land management is uncertainty related to meeting hunter satisfaction while buffering against excessive waterfowl disturbance and provisioning the birds' biological and ecological needs (Thornburg 1973, Madsen and Fox 1995, Fox and Madsen 1997, Madsen 1998, St. James et al. 2013). Unregulated hunting on public lands may lead to diminished waterfowl use, overcrowding or interference among hunters, decreased harvest, and ultimately dissatisfied stakeholders (Thornburg 1973, Fox and Madsen 1997, Knapton et al. 2000, Bregnballe and Madsen 2004, Brochet et al. 2009, St. James 2011). Alternatively, over-restricting hunting (e.g., one hunt-day/wk) may promote hunting success temporarily but also may result in increased abundances of birds that can deplete foods and ultimately cause them to seek resources elsewhere (Lima and Dill 1990, St. James et al. 2013). Indeed, waterfowl managers generally seek balance between satisfying hunters and sustaining needs of waterfowl.

Several independent or combined strategies may minimize waterfowl disturbance from hunting including: 1) temporal regulation by limiting the number of hunting days/wk or ceasing hunting at a specific hour of the day (Fox and Madsen 1997, Bregnballe and Madsen 2004, St. James et al. 2013); 2) establishing inviolate sanctuaries (Fox and Madsen 1997, Madsen 1998, Evans and Day 2002, Mathevet and Tamiser 2002, Brochet et al. 2009); and 3) limiting hunter density, such as the number of hunters per party or number of parties allowed to hunt the area per day (Fox and Madsen 1997, St. James 2011). The underlying challenge for managers is to minimize disturbance so waterfowl can exploit resources but not deplete them below unprofitable thresholds causing birds to seek increased rewards elsewhere (Abrahams and Dill 1989, Lima and Dill 1990, Fox and Madsen 1997, Greer et al. 2009, Hagy and Kaminski 2012). Waterfowl can modify their circadian habitat use when experiencing disturbance, but more fully understanding diurnal and nocturnal responses by waterfowl to hunting activity amid different degrees of hunting (i.e., extent of area open to hunting) on public lands is warranted (Madsen and Fox 1995, Madsen 2001, Bregnballe and Madsen 2004, St. James et al. 2013).

We used a remote data-collecting station to examine presence and absence of radio-marked female mallards (*Anas platyrhynchos*) on a wildlife management area (WMA) in western Mississippi during periods of closure of the regular waterfowl hunting season (i.e., before, during closed splits, and after season) and three extents of waterfowl hunting during the open waterfowl hunting season (i.e., all, half, or none of the WMA open to hunting) on the WMA during winters 2010–11 and 2011–12. Our objectives were to: 1) determine if the proportion of each 24 hour day that mallards used the WMA was related to date, hunter density, and hunt extent on the WMA; 2) determine if presence/absence of mallards on the WMA was related to date, hour of the day, and hunt extent; and 3) recommend a hunt extent that maximizes hunter opportunity and mallard harvest, while not prohibiting mallards from using the WMA for refugia and resource exploitation. We predicted the proportion of time spent on the WMA each day would decline through winter (Cox and Afton 1997) and mallard presence/absence would vary hourly and be influenced by the extent of hunting on the WMA.

Study Area

We conducted our study at Muscadine Farms WMA (hereafter Muscadine or the WMA) near Avon, Mississippi (331329.32 N, 905901.51 W). Muscadine is a 576-ha retired aquaculture complex owned by the U.S Army Corps of Engineers and managed by the Mississippi Department of Wildlife, Fisheries, and Parks for wintering waterfowl and public hunting. Hunting was permitted on 496 ha of Muscadine in 21 hunting units and the remaining 80 ha was inviolate sanctuary. Plant communities were predominately moist-soil species (Fredrickson and Taylor 1982), non-mast producing trees (e.g. willow [*Salix* spp.]), and plantings of browntop and Japanese millets, and sorghum-sudan grass.

Waterfowl hunters were selected by a pre-season lottery and arrived at Muscadine the morning of the hunt for a guaranteed hunting opportunity. Hunt permit holders entered a lottery to select a hunting unit in a randomly drawn order. Additionally, 'stand-by' hunters entered a second lottery after permit holders to fill units available from absent pre-season permit holders. A hunting party was 1 to 4 hunters, and parties could access hunt units immediately following 0500 hour draws. Hunting began one half hour before sunrise, ceased at 1200 hours, and hunting parties were required to vacate all hunted units by 1300 hours.

Methods

Hunting Extents

We divided the hunted portion of Muscadine WMA into two blocks of relatively equal area and habitat composition (St. James et al. 2013). We randomly assigned a hunting frequency of 2- or 4-days/wk to blocks for the duration of the Mississippi waterfowl hunting season during winters 2010–11 and 2011–12 (St. James et al. 2013). Hunting was permitted in the 4-day/wk block on Tuesdays, Thursdays, Saturdays, and Sundays; whereas the 2-day/wk block was hunted Tuesday and Saturday. This manipulative created three hunting extents through winter: 1) the entire WMA was open to hunting (i.e., both the 2- and 4-day/wk blocks) on Tuesdays and Saturdays; 2) half of the WMA (i.e., only the 4-day/wk block) was hunted on Thursdays and Sundays; and 3) none of the WMA was hunted and public access was prohibited on Monday, Wednesday, and Friday during hunting season. Additionally, we monitored mallard use of Muscadine before, during closed splits, and after the waterfowl hunting season which were collapsed into an extent of hunting season closure.

Mallard Capture and Remote Station Data Collection

We attempted to capture female mallards from 4 November 2010 to 24 January 2011 and 2 November 2011 to 23 November 2011 on Muscadine using modified swim in traps baited with corn, rice, or sweet potatoes (Hunt and Dahlka 1953, Lancaster 2013). We banded each female with a U.S. Geological Survey aluminum leg band and attached a 23-g very high frequency (VHF) backpack transmitter (Dwyer 1972). Transmitters had a pulse rate of 55 beats per minute, a life expectancy of 150 days, and were equipped with a mercury mortality sensor that doubled the pulse rate when a transmitter was motionless for ≥8 hours, indicating likely death of the radio-marked female. Transmitters weighed 2.1% (± 0.02% [SE], n = 113) of female body mass on date of capture (Lancaster 2013). We provided birds *ad libitum* access to corn and water and held females captured in mornings 4–6 hours and afternoon captured birds 12–18 hours (overnight) for birds' acclimation to their transmitter and ensure its proper fit (Davis et al. 2009). We released females with captured conspecific males or females to minimize possible disassociation of paired birds (Cox and Afton 1998). Our capture, handling, and marking methods were approved by the Mississippi State University Institutional Animal Care and Use Committee (protocol #10-070).

We erected a data collection station in the geographic center of Muscadine to record presence of radio-marked female mallards on the area between 17 November and 26 February of each winter (Ackerman et al. 2009). The station contained a data-logging telemetry receiver (model 4500S, Advanced Telemetry Systems Inc., Isanti, Minnesota) linked to a two decibel omni-directional antenna mounted on a 10-m mast. The telemetry receiver was powered by a 12-volt marine battery and was recharged through a 5 W solar panel. Prior to data collection, we adjusted the antenna so that the system would detect a transmitter within the bounds and not beyond Muscadine (2.4 km) by placing reference transmitters at and beyond Muscadine's boundary and adjusting the antenna height until transmitters on the border were detected but not those transmitters beyond the WMA. The 2.4-km detection radius included the bounds of Muscadine but also included several private wetlands which were rarely (< 5% of triangulated mallard locations in range of data-logger) used by radio-marked individuals during our study (Lancaster 2013). We programmed radio-marked mallard frequencies into the receiver and scanned for presence of each living female every 20 min, 24 h/day (Ackerman et al. 2009). We placed a reference transmitter at the outer boundary of Muscadine and also incorporated two false frequencies not associated with deployed radio-transmitters in all scans to validate the receiver operated effectively during each scan (Ackerman et al. 2009). We interpreted lack of signal detection as true absence of radio-marked females from Muscadine when the system recorded the reference transmitter but not any false frequencies (Ackerman et al. 2009). Occasionally, the remote station lost power and stopped recording, so we omitted those data from analyses (Ackerman et al. 2009). We included data for individual females beginning three days post-release and excluded birds from analysis if they abandoned the study area or died (Ackerman et al. 2009).

Statistics

To reduce the volume of data accumulated by the data-logger, we converted presence-absence data originally acquired in 20-min increments to an hourly scale. We considered a radio-marked female present on Muscadine during an hour if it was recorded during one or more incremental scans during that hour and considered a female absent if she was undetected during the hour (Ackerman et al. 2009).

During our study, varying numbers of hunting units were occupied by hunters during hunt events. Therefore, we indexed hunter density as high (>66%), medium (33%–66%), or low (<33%) based on the percentage of available hunting units occupied by hunters within a daily hunting extent. For example, seven hunting parties equaled 64% of 11 available units occupied when half of Muscadine was hunted or 33% when all 21 units were hunted.

We quantified the number of mallards harvested per hunter on days when half or all of Muscadine was hunted during winters 2010–11 and 2011–12. Mallard harvest was enumerated from daily use permits required to be completed by hunters at the conclusion of each hunt (St. James 2011). We tested for differences in mean harvest per hunter between days when half or the entire WMA was hunted using a two-tailed *t*-test (Proc TTEST, SAS 2012) with $\alpha = 0.05$ and equal variance.

Daily proportional use of Muscadine WMA by mallards. Our goal in this analysis was to determine the proportion of each 24-h day that radio-marked mallards used Muscadine during winter (17 November 26–February). We calculated this proportion by dividing the number of hours a female was present each day by 24 (Ackerman et al. 2009). We included only 24-hour periods when the remote station was functional and had no reason to exclude data (i.e., reference transmitter recorded and no detection of false frequencies). We tested whether the proportions of the days that mallards used the WMA were related to date, hunt extent, and hunter density using generalized linear mixed model (PROC MIXED; SAS 2012). We arcsine-square root transformed proportion data and included the radio-marked female nested within winter of study as a random effect with an autoregressive (AR1) covariance structure to control for potential autocorrelation from repeated measures of individuals (Ackerman et al. 2009). We analyzed four models that we predicted *a priori* may explain variation in the proportion of 24-h days females were on Muscadine. We used $\alpha = 0.15$ to calculate 85% confidence intervals on proportional daily use to determine the competitiveness models within 2 ΔAICc for model averaging (Arnold 2010). We examined output statistics including Akaike's Information Criterion adjusted for small sample sizes (AIC_c), differences between AIC_c values of each model and the model with minimum AIC_c (ΔAIC_c), and model weights (w*i*; Burnham and Anderson 2002).

Presence of Mallards on Muscadine WMA. We also investigated presence-absence of radio-marked females by testing whether the probability of birds' presence on Muscadine was influenced by date, hunt extent, and hour of the day using linear-circular logistic regression (Proc GLIMMIX; SAS 2012). We used $\alpha = 0.15$ and a logit link function in each of the models (Arnold 2010). For this analysis, we converted hour of the day (0000–2400 hours) into a circular continuous variable by: 1) dividing the hour by 24 to scale it proportionately between 0 and 1; 2) multiplying this value by 2π to convert the quotient to radians; and 3) calculating the sine (sin-hour) and cosine (cos-hour) of this value (Zar 1984, 1999; Ackerman et al. 2009). To evaluate models containing hour of the day, we included both the sin-hour and cos-hour variables, because they were required to describe the relationship accurately (Ackerman et al. 2009). We included female nested within winter of study with an autoregressive (AR1) covariance structure as a random effect to control for potential autocorrelation among repeated measurements of individuals (Ackerman et al. 2009).

Pseudo-estimation techniques render comparison inappropriate between models because true log likelihoods are not estimated (Crozier et al. 2006, Pieron et al. 2013). Therefore, we used Laplace's methods to estimate marginal likelihoods, which are suitable for comparing among competing models. We again used information theoretic analyses as already described to evaluate model support (Burnham and Anderson 2002).

Results

We radio-marked 35 females in winter 2010–11 and 6 females in winters 2011–12, but excluded 13 females captured in winter 2010–11 from analyses because three females died or experienced transmitter failure within three days of release, and 10 females were captured late in the hunting season (mid-late January 2011) and would not yield season-long data. The remote station recorded data for 59 and 73 full 24-h periods in winters 2010–11 and 2011–12, respectively. Radio-marked mallards were present during 5,285 (19%) of 28,128 hours of remote station scans, including 1,940 (17%) of 11,313 hours when the hunting season was closed, 917 (19%) of 4,920 hours when the entire WMA was hunted, 1,107 (21%) of 5,187 hours when half of the WMA was hunted, and 1,321 (20%) of 6,708 hours when none of the WMA was hunted.

When the entire WMA was hunted, a maximum of 84 hunters can be accommodated each hunt day; whereas, when hunting is restricted to half of the WMA, up to 44 hunters can hunt. During the 2010–11 and 2011–12 hunting seasons combined, 868 hunters harvested 269 mallards on days the entire WMA was hunted; while 486 hunters harvested 129 mallards on days when half of the WMA was hunted. Mean mallard harvest per hunter did not differ ($t_{1,352}$ = 1.13; P = 0.26) among days when half (0.27 mallards/hunter; 95% CI 0.21–0.33) or all (0.31 mallards/hunter; 95% CI 0.26–0.36) of the WMA was hunted.

Daily Proportional Use of Muscadine WMA by Mallards

The proportion of each day female mallards used the WMA was best explained by date (w_i = 1.0; Table 1). This proportion was negatively correlated with date and declined 0.50%/day (± 0.05% [SE]) through winter.

Table 1. Models explaining the proportion of the day spent on Muscadine Farms Wildlife Management Area (WMA) by radio-marked female mallards in winters 2010–11 and 2011–12. Date = date of winter (17 November as day zero); Hunters = proportion of available units occupied on a given day; Hunt Extent = periods when hunting season was closed, or when none, half, or all of Muscadine Farms WMA was hunted during waterfowl season.

Model	*k*	AIC_c	ΔAIC_c	w_i
Date	2	1161.3	–	1.0
Hunters	3	1313.5	152.2	0.0
Null	1	1327.8	166.5	0.0
Hunt Extent	4	1329.7	168.4	0.0

Presence of Mallards on Muscadine WMA

The most parsimonious model explaining presence of radio-marked female mallards on Muscadine included date and an interaction of hunt extent and hour of day (w_i = 1.0; Pearson chi-square/df = 1.23; Table 2). Female presence was negatively correlated with date and declined 0.51%/day (± 0.08% [SE]) during winter. Radio-marked females were 1.46 (85% CI; 1.34 to 1.58) and 1.17 (85% CI; 1.09–1.26) times more likely to be present on Muscadine when the hunting season was closed (7.5% ± 1.7% [SE]) than when all (5.2% ± 1.2%) or none (6.4% ± 1.5%) of it was hunted for waterfowl, respectively. Additionally, females were 1.31 (85% CI; 1.20–1.43) and 1.24 (85% CI; 1.14–1.35) times more likely to be present on Muscadine during the hunting season when either half (6.8% ± 1.6%) or none (6.4% ± 1.5%) was hunted versus when the entire WMA was hunted, respectively. Moreover, females were 1.11 (85% CI; 1.03–1.20) times more likely to be present when the hunting season was closed (7.5% ± 1.7%) than when half (6.8% ± 1.6%) of the WMA was hunted, and 1.06 (85% CI; 0.97–1.15) times more likely to be present when half (6.8% ± 1.6%) of the WMA was hunted than when none of it was hunted (6.4% ± 1.5%).

The probability that a radio-marked female was present on Muscadine was greatest at 0300 hours and declined until 1500 hours regardless of hunt extent (Figure 1). There was no difference in slopes of hourly presence of mallards on the WMA when hunting season was closed or when none or half of the WMA was hunted, but these slopes collectively differed from the slope when the entire WMA was hunted. Between 2000 to 0800 hours regardless of hunt extent, 85% confidence intervals of females' presence overlapped.

Table 2. Models explaining the probability of presence of radio-marked female mallards on Muscadine Farms Wildlife Management Area (WMA) in winters 2010–11 and 2011–12. Date = date of winter (17 November as day zero); Hour = hour of day (0000–2400 hours); Hunt Extent = periods when hunting season was closed, or when none, half, or all of Muscadine Farms WMA was hunted during waterfowl season.

Model	*k*	AIC_c	ΔAIC_c	w_i
Date + Hour + Hunt Extent + Hour*Hunt Extent	13	17711.5	–	1.0
Date + Hour + Hunt Extent	7	17737.7	26.2	0.0
Date + Hour	4	17766.7	55.2	0.0
Date + Hunt Extent	5	18201.7	490.2	0.0
Date	2	18229.2	517.6	0.0
Hour + Hunt Extent + Hour*Hunt Extent	12	20498.5	2786.9	0.0
Hour + Hunt Extent	6	20523.7	2812.2	0.0
Hour	3	20604.5	2893.0	0.0
Hunt Extent	4	20935.1	3223.6	0.0
Null	1	21013.3	3301.7	0.0

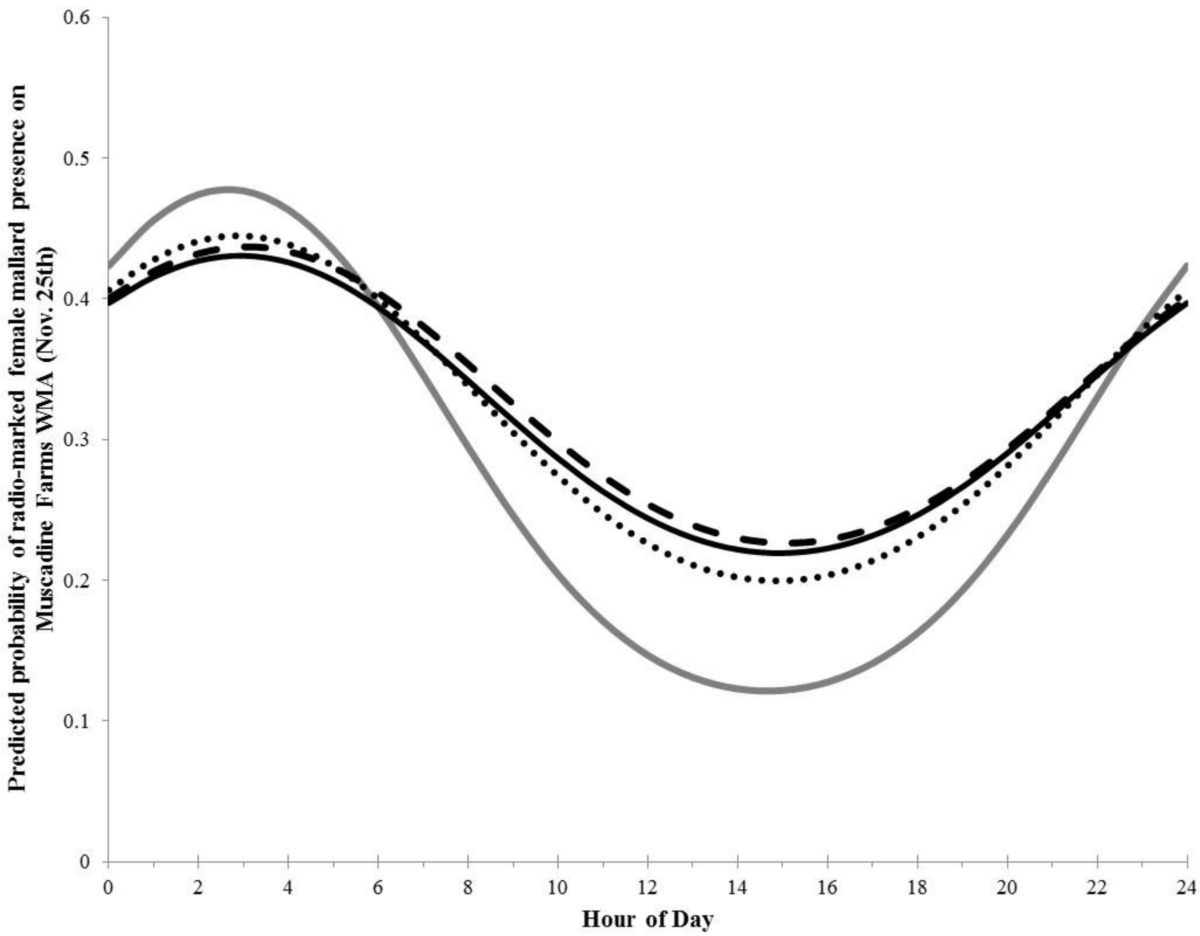

Figure 1. Predicted hourly probability of presence by radio-marked female mallards on Muscadine Farms Wildlife Management Area (WMA) at the beginning of waterfowl hunting season if: 1) hunting season was closed (dashed line); and during hunting season if 2) none of the WMA was hunted (solid black line); 3) half of the WMA was hunted (dotted black line); and 4) all of the WMA was hunted (solid gray line) during winters 2010–11 and 2011–12.

Discussion

The proportion of the day spent on Muscadine WMA by radio-marked female mallards declined through winter, from 35% of the day prior to hunting season (17 November) to abandonment of the area by the end of hunting season in late January. There was no evidence that the proportion of each day spent on Muscadine varied by hunt extent, likely because greatest use of the WMA generally occurred nocturnally and was not influenced by diurnal hunting-related activities. Moreover, because most mallard use occurred nocturnally, the density of hunters on the WMA did not influence the proportion of the day mallards spent on the WMA. Previous studies of radio-marked ducks demonstrate greater distances moved as winter progressed possibly in search of food, safety, or other factors (Cox and Afton 1997, Brown and Kotler 2004). Therefore, mallards that were marked prior to hunting season on Muscadine may have sought resources or sanctuary in the region, such as at Yazoo National Wildlife Refuge located 10 km south of Muscadine WMA where harvest related risk of mortality was nonexistent (Lancaster 2013).

Radio-marked females were present most on the WMA when the hunting season was closed, followed by extents within hunting season when none, half, or all of the WMA was open to hunting. This pattern was consistent with the amount of sanctuary available to waterfowl on the WMA during each hunt extent. When the hunting season was closed or when none of the WMA was hunted during hunting season, all 576 ha of the WMA functioned as an inviolate sanctuary. However, when half or the entire area was hunted, there were 280 and 80 ha, respectively, of sanctuary available to waterfowl.

Presence of radio-marked females on the WMA was greatest during nocturnal periods regardless of diurnal hunt extent. This pattern suggested that nocturnal use was not influenced by diurnal activities on the WMA and supports the notion that nocturnal foraging may be preferred by waterfowl because it is more profitable or predation risk is minimized (Girard 1941, Conroy et al. 1989, McNeil et al. 1992, Madsen and Fox 1995, Cox and Afton

1997, Guillemain et al. 2002). Availability of moist-soil managed wetlands on the WMA also may encourage nocturnal foraging and other activities among waterbirds (Anderson and Smith 1999), perhaps because these wetlands provide quality food, thermal cover, and possibly a means to avoid avian or other nocturnal predators (Evans 1987, Anderson and Smith 1999).

Although nocturnal use of the WMA by mallards did not appear to be influenced by diurnal hunt extent, day use was impacted when the entire WMA was hunted. Mallard presence on the WMA declined at a more rapid rate to the lowest level when the entire WMA was hunted than during other tested extents. If most radio-marked birds spent nocturnal periods on the portion of the WMA hunted 2-days/wk, then hunters entering this portion on mornings when the entire WMA was hunted may have influenced the rapid departure of mallards. The 2-day/wk portion of the WMA was only hunted when the entire WMA was hunted thus this pattern would not be seen during other hunt extents. An alternative explanation is that several birds exited the WMA at sunrise every morning regardless of hunters entering the WMA. However, when the entire WMA was open to hunting, additional radio-marked mallards likely departed the WMA because of hunting-related disturbance (Thornburg 1973, Fox and Madsen 1997, Madsen 1998). Model estimates of peak presence of radio-marked mallards was at 0300 hours, suggesting that mallards departed the WMA prior to sunrise or hunter arrival; however, this trend was simply a smoothing of the predicted values and there was a steep decline in the raw data between 0700 and 0800 hours.

Previous studies have examined behavioral differences between radio-marked and unmarked mallards, but primarily for birds during breeding seasons when they are more sedentary and behaviors more easily monitored (Pietz et al. 1993). However, we must acknowledge that the patterns we witnessed are representative of the larger mallard population at Muscadine. Additionally, we realize that patterns documented for female mallards in our study may not reflect those of other waterfowl species using Muscadine WMA during winter. Mallards, northern shoveler (*Anas clypeata*), and green-winged teal (*A. crecca*) were the most abundant and harvested species in a previous study at Muscadine WMA (St. James 2011, St. James et al. 2013). Waterfowl with shorter life-spans (e.g., green-winged teal) are more risk-inclined than those with greater longevity (e.g., mallard; Ackerman et al. 2006). Therefore, increased hunting pressure may elevate harvest of shorter lived ducks potentially increasing hunter satisfaction should such a trend sustain itself.

Management Implications

Because females were less likely to be present when the entire WMA was hunted, managers might consider restricting hunting to half of the WMA 4 days/wk. However, our study revealed that on days when all of the WMA was hunted, female mallards did not reduce their nocturnal use of the WMA, potentially enabling mallards to exploit resources or meet other needs in WMA wetlands (McNiel et al. 1992). Restricting hunting to half of the WMA would accommodate only 44 hunters/hunt day, whereas hunting the entire WMA would accommodate up to 84 hunters to hunt/day. During winters 2010–11 and 2011–12 there was no difference in average harvest of mallards per hunter on days when half or all of the WMA was hunted. Therefore, by allowing the entire WMA to be hunted 4 days/wk, managers may provide increased opportunity to hunters without negatively impacting harvest of mallards and continuing to provide habitat for use by mallards nocturnally.

Bregnballe and Madsen (2004) reported that waterfowl hunting near sunset resulted in significantly decreased numbers of mallards present the following day. If afternoon hunting is desired to increase hunting opportunities at Muscadine WMA, we suggest managers consider terminating hunting and ensuring hunters exit the WMA prior to sunset, such as at 1600 hours. The hypothesis that mallards may avoid wetland units a day(s) following afternoon hunting and implementation of the aforementioned recommendations should be topics for future research.

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