INFLUENCE OF OPENING WEEKEND AND WEATHER ON WHITE-TAILED DEER HARVESTS AT MILAN ARMY AMMUNITION PLANT, TENNESSEE.

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Deena R. Francis, B.S.

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ABSTRACT

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By

Deena Rae Francis, B.S.

Texas State University-San Marcos

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SUPERVISING PROFESSOR: FLOYD W. WECKERLY

Maximizing white-tailed deer (*Odocoileus virginianus*) harvest is helpful to reduce overabundant populations. Yet, the number of hunters is declining in many hunt programs. In order to maximize harvests, deer managers require knowledge of hunt attributes that increase harvests relative to hunter effort. I hypothesized that opening weekend (first Saturday and Sunday of a hunt) conditions and weather variables could influence white-tailed deer harvests, when controlling for hunter effort. Three opening weekend conditions were evaluated: higher opening weekend hunter effort, resulting in higher opening weekend harvests; higher opening weekend harvest sizes relative to hunter effort due to flushing of deer; or the occurrence of both. Harvest and hunter effort data was collected from 1988-2000 at Milan Army Ammunition Plant, Tennessee. Daily precipitation and minimum and maximum temperatures were obtained from the National Oceanic and Atmospheric Administration. Three hunt types, either-sex archery (AES), either-sex muzzleloader (MES), and buck-only gun (GBO), were compared using data from the first week of each season or the first 2 weeks of each season (GBO and AES only). The data was analyzed using ANOVAs and mixed effect regressions. Regressions most likely to fit the data were selected using the AIC approach. Hunter effort and harvest sizes were higher during opening weekend than other time periods for all hunt types. Only during GBO hunts were harvest sizes higher relative to hunter effort during the opening weekend. A slight, inverse relationship was detected between harvest and daily temperature for MES and GBO hunts when controlling for hunter effort. Weather appears to have little influence on hunter effort-harvest size relationships of this deer population. All hunt types had higher opening weekend harvest sizes due to increased hunter effort; but only GBO hunts had higher harvests relative to hunter effort, indicating a flushing effect.

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) populations are often overabundant (McShea et al. 1997). Harvest of deer is helpful to ameliorate anthropogenic conflicts and habitat degradation from deer herbivory (McShea et al. 1997, Stromayer and Warren 1997, Augustine and deCalesta 2003, Kilpatrick and LaBonte 2003, Pedersen and Wallis 2004). The numbers of hunters in many hunt programs, however, are declining (Brown et al. 2000, Enck et al. 2000, Peterson 2004). In order to maximize harvests, deer managers require knowledge of hunt attributes that increase harvests relative to hunter effort (Weckerly et al. *in press*).

Opening weekend constitutes the first Saturday and Sunday of a hunt season. During these 2 days, the enthusiasm of hunters for the new hunt season may result in more hunters pursuing deer (Barick 1968, Thorton 1970, Vieira et al. 2003). Increases in number of hunters during the opening weekend could result in an increase in harvest from a "pushing effect" or "flushing effect" (hereafter flushing) on deer. Consequently, deer are more active and vulnerable to harvest (Roseberry et al. 1969, Vercauteren and Hygnstrom 1998).

Particularly in northern portions of the geographic ranges of *Odocoileus*, variability in precipitation and temperature influences the behavior of deer, hunters, and presumably hunter effort-harvest size relationships (Fobes 1945, Curtis 1971, Hansen et al. 1986, Jenson 2002, Hunter and Runge 2004). Hansen et al. (1986) found daily harvest related negatively to precipitation in Illinois. Fobes (1945) determined light or moderate rainfall enhanced deer harvest in Maine. Extreme conditions such as heavy rain or snowfall, had negative effects on deer harvest in Virginia, Colorado and Maine (Fobes 1945, Peterson 1969, Mechler 1970). Curtis (1971) found heavy rainfall discouraged hunter participation and harvest in Virginia.

The affect of temperature on hunter effort-harvest size relationships of white-tailed deer in the southern United States has not been thoroughly evaluated. Montgomery (1963) suggested that variations in evening foraging activity of deer may relate to differences in temperature which influences sightings by hunters. Deer sightings also negatively correlated with temperature in Virginia (Curtis 1971). Fewer deer sightings due to temperature may result in decreased harvests. Fobes (1945) associated higher harvests with warmer conditions in Maine; similarly, Hansen et al. (1986) determined cold conditions in Illinois correlated negatively with late-in-season harvests.

The objectives of my study were: (1) to explore the “opening weekend effect,” by evaluating 3 possible scenarios and (2) to examine the effects of rainfall and minimum and maximum temperature on hunter effort-harvest size relationships in a southern white-tailed deer population. Possible opening weekend scenarios were: whether opening weekend hunter effort and harvests are greater than hunter effort and harvests during the rest of the season, whether harvests relative to hunter effort are larger on opening weekend compared to the rest of the season due to hunter exploitation of flushed animals, and finally a situation in which the 2 previous scenarios occur simultaneously.

STUDY AREA

Hunts of white-tailed deer occurred on the 24.25 km^2 Milan Army Ammunition Plant (MLAAP) in Gibson and Carroll counties, Tennessee. The landscape is comprised of open pasture (*Festuca* spp.), oak-hickory forest (*Quercus* spp.), pine forest (*Pinus* spp.), agricultural fields, and urbanized industrial-use areas including buildings and roads (Babb and Kennedy 1989, Weckerly et al. *in press*). During data collection, the landscape of MLAAP was not altered. Natural predators of white-tailed deer on MLAAP were the coyote (*Canis latrans*) and bobcat (*Lynx rufus*) (Babb and Kennedy 1989). There were no estimates of deer density on MLAAP (Weckerly et al. *in press*).

METHODS

Deer hunts occurred on MLAAP from late September into January, 1988-2000. There were six different types of white-tailed deer hunts: archery hunts, either sex hunts with a gun (shotgun or center-fire rifle), either sex hunts with a muzzleloader, antlerless (fawns and does) gun hunts, buck only (antlered bucks with $\geq$ 2 points) gun hunts, and buck only hunts with a muzzleloader (Weckerly et al. *in press*). Hunters checked in and out daily and were assumed to remain in field the entire day. Hunter effort was measured as hunter days, the sum of hunters in the field on each day of a hunt. Hunter effort data was not recorded for 1989 or 1999. Tooth replacement was used to age harvested deer as fawns ($\leq$ 0.5yrs) or adults (> 0.5yrs) and age and sex were recorded (Severinghaus 1949).

I chose 3 of 6 hunt types, archery either sex (AES), muzzleloader either sex (MES), and gun buck only (GBO), for analysis because these hunts always began on Saturday, were consistent in length, and occurred in many years. Hunters were allowed to harvest 2-4 deer during these hunts. Archery either sex hunts occurred during the entire month of October. Muzzleloader either sex hunts lasted 7 days in early November. Occasionally, a second 7-day MES hunt also occurred in early December. Gun buck only hunts usually spanned 2 separate 14-day intervals, the first in late November and the second in mid December. For MES and GBO hunts, data from only the first hunt was used to minimize potential confounding influences from deer exposure to the first hunt.

The years used in my analysis differed slightly for each hunt type. I selected years based on the occurrence and length of the hunt. For instance, GBO hunts that did not last 14 days were excluded from the analysis. All years with available hunter effort data were used for AES hunts. Data for MES hunts included the years 1992 to 2000. The analysis of GBO hunts included data from 1990-1998.

I obtained weather data from the weather station, at Milan Experimental Observation Station, Gibson County, Tennessee (National Oceanic and Atmospheric Administration 1988-2000). However, weather data for November 1988 and the 1993 and 1994 hunting seasons was missing from Milan Experimental Station. I calculated Pearson's correlation coefficients comparing precipitation, minimum temperature, and maximum temperature at Milan Experimental Station to weather data obtained from the Greenfield, Tennessee weather observation station for September through January 1996. The Greenfield Weather Observation Station was 28.44 km away in Weakley County, Tennessee. If the Greenfield weather data was highly correlated to the Milan data, then I substituted data for November 1988 and for the 1993 and 1994 hunting seasons from the Greenfield weather station to complete the Milan data set.

I conducted single factor analyses of variances to compare hunter effort and harvest sizes on opening weekend to the rest of the hunt season for each hunt type (Quinn and Keough 2002). I also calculated mixed effect regressions of the data for each hunt type (Pinheiro and Bates 2000). Parameters were estimated with maximum likelihood estimators (Pinheiro and Bates 2000). Year was used as a random effects predictor because the same deer population was studied from 1988-2000. I considered the following as possible fixed predictors: hunter effort, prior harvest, opening weekend, precipitation, and minimum and maximum temperature. An interaction between opening weekend and hunter effort was also considered to determine if differences existed in the slope of the regression for opening weekend versus slopes of the regressions for the remainder of the hunt relative to hunter effort. If no interaction is present, then the slopes for the regressions will be similar (Quinn and Keough 2002). Prior harvest was the number of deer harvested of an age-sex class based on the quota for a particular hunt type. For each hunt type, I analyzed the first week of AES, MES and GBO hunts and the first 2 weeks of AES and GBO hunts. I coded opening weekend as an indicator variable (Quinn and Keough 2002). For the analysis of hunts 1 week in length, opening weekend had 1 indicator variable. I coded 3 indicator variables for opening weekend, week days of the first week, the second weekend, and week days of the second week for hunts 2 weeks in length.

I constructed 14 regression models *a priori* (Anderson et al. 2000). Models were tested in stages for each hunt type and time frame (1 or 2 weeks) to evaluate the effects of hunter effort, opening weekend, minimum temperature, maximum temperature and precipitation on harvest size. I calculated Akaike Information Criterion values corrected for small sample size (AIC_c) for each model from log-likelihoods, number of parameter estimates and sample size (Burnham and Anderson 1998). Regression models with smaller AIC_c values represent the data better than models with larger AIC_c values. I also calculated and compared Akaike weights of models in stages to identify the best-fit model. Akaike weights range from 0 to 1 and reflect the likelihood a model represents the data relative to other models in the comparison (Burnham and Anderson 1998). Models with weights closer to 1 indicate the probability is high that the model fits the data (Burnham and Anderson 1998). I invoked the principle of parsimony when regression models had similar Akaike weights and AIC_c values (Burnham and Anderson 1998).

I evaluated the regression models in 3 stages. Fryxell et al. (1991) and Roseberry and Woolf (1991) found hunter effort affects white-tailed deer harvest size. Stage 1 of my analysis tested whether the hunter effort was related to harvest size. The model selected at stage 1 was included for comparison with stage 2 models. Also, the model selected in stage 2 had the predictors recommended in stage 1 preceding all other predictors.

Stage 2 of the analysis evaluated the influence of opening weekend and prior harvest. The model selected in stage 2 was included in stage 3, and its predictors preceded predictors of models considered in stage 3.

Stage 3 estimated the influence of precipitation, minimum temperature or maximum temperature on harvest size. All possible combinations of these 3 predictors were tested in regression models 8 through 14. The model selected in stage 1 was also included in the stage 3 comparison, if it exhibited an extremely high Akaike weight in stage 1.

For the selected model, I calculated intraclass correlation coefficients to determine if separate regressions were necessary each year (Pinheiro and Bates 2000). Intraclass correlation coefficients range from 0 to 1. An intraclass correlation coefficient of 0 indicates 1 regression will do, and a coefficient of 1 indicates separate regressions are needed each year. To graphically visualize fit of selected models to data, I constructed scatterplots of predicted versus observed harvest size for all regression models selected after stage 3 of the analysis. I plotted a straight line with y-intercept = 0 and slope = 1. Selected regression models accurately and precisely estimated deer harvest based on how the predicted points clustered around the straight line (Pinheiro and Bates 2000).

RESULTS

Hunter effort and harvest sizes

Analyses of variance indicated substantial differences exist between hunter effort during opening weekend versus the rest of the season for all 3 hunt types (AES–$F_{3,150}$ = 87.78, P < 0.001; MES–$F_{1,54}$ = 187.13, P < 0.001; GBO–$F_{3,122}$ = 47.56, P < 0.001). Archery either sex opening weekend days exhibited higher hunter effort than week 1, weekend 2 or week 2 days (opening weekend: [$\bar{x}$ ± 1 SE] 112.59 ± 9.31, week 1: 36.24 ± 2.16, weekend 2: 76.77 ± 6.55, week 2: 26.16 ± 1.64, Appendix). An average of 49% of total hunter effort occurred during the first 2 weeks of the 5 to 6 week AES hunts. Muzzleloader either sex opening weekend days (130.94 ± 9.56) had higher hunter effort than week 1 days (34.25 ± 2.39). Hunter effort was also higher during opening weekend days (104.83 ± 11.94) of GBO hunts versus the rest of the season (week 1: 46.71 ± 4.06, weekend 2: 52.94 ± 6.34 and week 2: 13.78 ± 1.61).

Substantial differences were also detected between harvest sizes of opening weekend and the rest of the season for all 3 hunt types (AES-$F_{3,150}$ = 31.32, P < 0.001; MES-$F_{1,54}$ = 97.55, P < 0.001; GBO-$F_{3,122}$ = 32.79, P < 0.001). Opening weekend harvests (9.86 ± 1.54) were higher than harvests during the remainder of time periods in AES hunts (week 1: 2.93 ± 0.32, weekend 2: 6.05 ± 0.91, week 2: 1.67 ± 0.23). An average of 50% of total AES harvests occurred during the first 2 weeks of AES hunts. Muzzleloader either sex opening weekend harvests (34.25 ± 4.32) were higher than week

1 harvests (5.90 ± 0.63). Harvests were also higher during opening weekend days of GBO hunts (22.17 ± 4.48) than during the remainder of the GBO season (week 1: 5.20 ± 0.65, weekend 2: 5.06 ± 0.79, week 2: 0.98 ± 0.25).

Weather

Pearson's correlation coefficients reveal a strong correlation between Milan and Greenfield weather data (precip. $r = 0.89$, $P < 0.001$; min. temp $r = 0.98$, $P < 0.001$; max. temp $r = 0.99$, $P < 0.001$). Hence, weather data for Greenfield is substituted for weather data missing at Milan. Respective mean precipitation, minimum temperature and maximum temperature for AES hunts were 0.27 ± 0.07 cm, 9.89° ± 0.40°C, and 25.29° ± 0.37°C. Mean precipitation, minimum temperature and maximum temperature for MES hunts were 0.56 ± 0.19 cm, 2.89° ± 0.92°C, and 15.73° ± 0.77°C, respectively. Mean precipitation, minimum temperature, and maximum temperature for GBO hunts were 0.36 ± 0.09 cm, 1.43° ± 0.52°C, and 14.53° ± 0.53°C, respectively.

Archery either sex

First week of hunt

In stage 1, model 2 is selected based on its high Akaike weight (> 0.999, Table 1). Model 2 contains the fixed predictor, hunter effort; thereby hunter effort is included as a predictor in further model selection evaluations of 1-week AES hunts.

In stage 2, prior harvest has no influence on hunter effort-harvest size relationships because inclusion of the prior harvest variable resulted in models with low Akaike weights (Table 1). Similarly, opening weekend does not influence the first week of AES hunts (Table 1). There is little variation among AIC_c values of models with highest Akaike weights in stage 2 (Table 1). Thus, although it does not exhibit the highest Akaike weight, I invoked the principle of parsimony and selected model 2 once again (Table 1).

Model 2 is also chosen during stage 3 of the analysis as the best model to describe first week of AES hunt seasons (Table 1). Although this model has a low Akaike weight of 0.058, it differs little in AIC_c values from models with higher Akaike weights and has fewer parameters (Table 1). In summary, opening weekend, prior harvest, and weather do not influence hunter effort-harvest size relationships during the first week of AES hunts.

Mixed effect regression results for model 2 indicate that for every 100 hunters, harvest changes by 10 animals during the first week of the AES hunting season (Table 2). The residual standard deviation for the regression of model 2 is 2.72. Model 2 also has a low intraclass correlation coefficient value (0.22). Thus, it is not necessary to report regressions for the first week of AES hunts for each year.

First two weeks of hunt

I selected model 2 in stage 1 of the AES 2-week analysis because of its high Akaike weight (Table 1). Model 2 includes the fixed predictor hunter effort. Thereby, the predictor hunter effort was incorporated into all further model selection evaluations.

Due to the small Akaike weights of all stage 2 models containing prior harvest, I determined that this variable has no effect on hunter effort-harvest size relationships during the first 2 weeks of AES hunts (Table 1). With the exception of model 6, models including opening weekend also display small Akaike weights (Table 1). There is, however, little difference in the AIC_c values of models 2 and 6. I followed the principle of parsimony and chose model 2 over model 6 in stage 2 of the analysis. Opening weekend and prior harvest have no effect on hunter effort-harvest size relationships during the first 2 weeks of AES hunts.

There is minimal variation in AIC_c values of stage 3 models (Table 1). In stage 3, I selected model 2 as the best model to describe the first 2 weeks of AES hunts. Despite its low Akaike weight, model 2 is the most parsimonious model ($w = 0.098$, Table 1). Model 2 contains only 1 fixed predictor, hunter effort. Thus, weather does not influence hunter effort-harvest size relationships during the first 2 weeks of AES hunts.

Model 2 regression coefficients and residual standard deviation are similar to 1-week data of the AES hunts (Table 2). For every 100 hunters, harvests change by 10 animals. The residual standard deviation of the regressions is 2.48. The intraclass correlation coefficient for model 2 is 0.22. Thereby, variation among years is minimal and 1 regression sufficiently describes the data.

Muzzleloader either sex

In stage 1 of the MES analysis, model 2 is chosen to represent the data. Model 2 exhibits a high Akaike weight and contains the fixed predictor hunter effort (Table 3). As a result, hunter effort is included as a predictor in further model comparisons.

I invoked the principle of parsimony and selected model 2, over model 3, during stage 2 of the analysis (Table 3). I determined that neither prior harvests nor opening weekend influence MES hunter effort-harvest size relationships due to small Akaike weights of models containing these predictors (Table 3).

During stage 3, I concluded that temperature influences hunter effort-harvest size relationships of MES hunts. Model 9 is selected to describe the MES hunt season because it exhibits the highest Akaike weight ($w = 0.368$, Table 3). Model 9 includes the fixed predictors, hunter effort and minimum temperature.

Mixed effect regression results for model 9 indicate a negative relationship between minimum temperature and harvest, when controlling for hunter effort (MIN coefficient = -0.57, Table 2). For every 10°C change in temperature, harvest changes by about 6 animals controlling for hunter effort. A positive relationship exists between hunter effort and MES harvest size in that, for every 100 hunters, harvest changes by 26 deer (Table 2). Model 9 has a residual standard deviation of 8.01 and an intraclass correlation coefficient value < 0.001. There is little need of regressions for each year.

Gun buck only

First week of hunt

Model 2 has a high Akaike weight, > 0.999; therefore, I chose model 2 to describe the first week of GBO hunts in stage 1 of the analysis (Table 4). Model 2 exhibits the fixed predictor, hunter effort; therefore, hunter effort is included in subsequent stages.

In stage 2 of the analysis, I chose model 6 because it has the highest Akaike weight (w = 0.770, Table 4). Model 6 contains the fixed predictor, hunter effort, the indicator variable, opening weekend, and an interaction between opening weekend and hunter effort. Opening weekend does influence hunter effort-harvest size relationships during the first week of GBO hunts.

I selected model 10 to represent the first week of GBO hunts in stage 3 of the analysis. Model 10 has the highest Akaike weight of the stage 3 models (Table 4). In addition to the fixed predictor and indicator variables of the model chosen in stage 2, model 10 contains the fixed predictor, maximum temperature.

According to the mixed effects regression, a negative relationship occurs between maximum temperature and harvest size during the first week of GBO hunts (MAX coefficient = -0.28, Table 4). Harvest decreases by 3 deer, controlling for hunter effort, as maximum temperature increases by 10°C. Regression of model 10 also suggests that opening weekend harvest is 4-5 times higher per unit hunter effort, than harvest during week days of week 1 of GBO season (Table 2). The selected model has a residual standard deviation of 4.40. Model 10 also has an intraclass correlation coefficient equal to 0.25. This small coefficient indicates that variation among years is minimal for the first week of GBO hunts and one regression is adequate.

First two weeks of hunt

I chose model 2 in stage 1 of the 2-week GBO hunt analysis because it has the highest Akaike weight (Table 4). Thus, hunter effort is included in all further model selection analyses.

During stage 2 of the 2-week GBO hunt analysis I selected model 6. Model 6 has the highest Akaike weight and contains the fixed predictor, hunter effort, indicator variables, opening weekend, week 1, and weekend 2, and interactions between the indicator variables and hunter effort (Table 4). In stage 2, I found that opening weekend does influence hunter effort-harvest size relationships for the first 2 weeks of GBO hunts.

Model 9 is chosen in stage 3 to characterize the first 2 weeks of GBO season because it has the highest Akaike weight (Table 4). Model 9 contains the same fixed predictor, indicator variables, and interaction variables of the model selected in stage 2 plus minimum temperature. The mixed effects regression indicates a negative relationship between harvest and minimum temperature (MIN coefficient = -0.22, Table 2). Harvest increases by 2 animals, controlling for hunter effort, when minimum temperature declines 10°C. The regression for model 9 also suggests, as hunter days increase by 100 hunters, deer harvests increase most during opening weekend (29 deer/100 hunters), and next highest during the last week of the hunt (8 deer/100 hunters) (Table 2). According to the regressions, increases in harvest numbers are lowest during the first week (6 deer/100 hunters) and second weekend (11 deer/100 hunters) of GBO hunting season (Table 2). The residual standard deviation for model 9 was 3.39. Model 9 also has a low intraclass correlation coefficient value (0.12). Thus, it was not necessary to report regressions for the first two weeks of GBO hunts by year.

Scatterplots

Scatterplots show that selected models depict harvest data for all hunt types (Fig. 1 and 2). Observed harvests are similar to predicted harvests for AES models because the points cluster around the straight line (Fig. 1). The selected MES model more accurately predicts harvest when observed harvest is lower. This is evident because points are tightly clustered around the straight line at harvest values of 0-20 and spacing of points expands when greater than 20 deer are harvested (Fig. 1). Points are also clustered around the straight line for models representing GBO hunts, indicating observed and predicted harvests are similar (Fig. 2).

DISCUSSION

Opening weekend effect

Opening weekend hunter effort and harvests do affect the 3 hunt types on MLAAP. Although hunter effort is similar among the 3 hunt types, opening weekend hunter effort is higher than hunter effort during the remainder of the hunt for each hunt type. My results also indicate that harvests on opening weekend are higher compared to other time periods of the hunts. Opening weekend represents the beginning of a new season, thus participation is higher during this weekend, resulting in higher harvests for all 3 hunt types (Thorton 1970, Vieira et al. 2003).

However, the relationships between hunter effort and harvest sizes are equivalent between opening weekend and the rest of the hunt for AES and MES hunts, therefore flushing is not evident. The slopes of the regressions depicting harvest per unit hunter effort is lower during both AES and MES hunts (ca. 10 deer/100 hunters and 26 deer/100 hunters, respectively) when compared to GBO hunts (ca. 29 deer/100 hunters) during opening weekend. Archery and muzzleloader hunters, therefore, harvested fewer deer at similar hunter efforts (Table 2). Although research suggests archery and muzzleloader hunts are effective when reducing populations of white-tailed deer, the lower harvests relative to hunter effort for AES and MES hunts could be attributed to type of firearms used by hunters (Hansen and Beringer 1997, Kilpatrick and Walter 1999, Kilpatrick et al. 2002, Kilpatrick and LaBonte 2003). Archery either sex harvests per unit hunter effort may also be lower because female white-tailed deer are known to expand their home ranges during archery hunts, resulting in fewer sightings by hunters (Kilpatrick and Lima 1999).

It was unexpected that opening weekend did not influence hunter effort-harvest size relationships of MES hunts because these hunts exhibited somewhat higher participation and harvest sizes compared to the other 2 hunt types (Appendix). With the knowledge that GBO hunts follow MES hunts, MES hunters may have been influenced by hunter preference and anticipation for taking a buck (McCullough et al. 1990, Roseberry and Woolf 1991). A hunter anticipating the opportunity to take an antlered deer, may disregard the opportunity to shoot an antlerless animal. Thus, harvests relative to hunter effort are lower despite the slightly higher hunter participation of MES hunts compared to GBO hunts.

Opening weekend did affect hunter effort-harvest size relationships of GBO hunts. Higher GBO harvests on opening weekend compared to the rest of the hunt may be attributed to the increase of deer vulnerability when hunting with a centerfire rifle. Rifles provide more accuracy at further distances than other forms of firearms. Thus, when rifle hunters see bucks they may be more likely to harvest them (Roseberry et al. 1969). The increase in take during GBO hunts also may be influenced by hunter preferences for bucks rather than antlerless deer (McCullough et al. 1990, Roseberry and Woolf 1991).

Gun buck only hunter effort-harvest size relationships reveal an increase in the number of deer harvested per 100 hunters during opening weekend (28-29 deer/100 hunters) compared to the remainder of the season (Table 2). At maximum values of hunter effort for each time period, harvests relative to hunter effort are reduced to ca. 10-20% of opening weekend harvests during the first week, second weekend, and second week of GBO season (Table 2). The reduction in harvests after opening weekend may be the result of reduced hunter effort and behaviors of deer that increase vulnerability to rifle hunts (Kilpatrick et al. 2002). It does not appear to be due to a reduced buck population because prior harvest is not influential.

One- and 2-week regressions have similar predictors and coefficients for AES and GBO hunts (Table 2). Also, the extent of decline in hunter effort between opening weekend and week days is similar in MES and the other 2 hunts. These results indicate that 1- or 2-week hunts may not have a large influence on whether an opening weekend effect is present.

Prior harvest

Prior harvest, as discovered by Weckerly et al. (*in press)*, is not influential when predicting harvests relative to hunter effort for 6 different analyzed hunt types. Several hunt types occurred on MLAAP in addition to the ones I evaluated. The sequence of hunt types did not usually vary from year to year. The consistency of hunt order and the hunter participation within hunts may have reduced the influence of prior harvest. As stated previously, hunter participation is similar among hunt types (Appendix). If AES hunts always occur first, and AES harvests are always lower relative to hunter effort, then many deer are available to harvest during MES and GBO hunts. If GBO hunts occurred earlier in the season there may be fewer bucks available for harvest during subsequent hunt types. In the future it would be beneficial to analyze years where hunt order is alternated to determine if sequence affects the influence of prior harvest.

Weather

Weather does not appear to substantially influence hunter effort-harvest size relationships of AES hunts at MLAAP. These results are not surprising for archery hunts because they occur during October, when temperatures are mild and precipitation is moderate in western Tennessee.

Temperature did affect hunter effort-harvest size relationships for MES and GBO harvests. MES hunts occurred during early November while GBO hunts occurred during late November. Generally, the first seasonal cold fronts arrive in the southern United States at this time and temperatures occasionally reach extremes. Severe cold can cause hunter participation to decline (Curtis 1971). Hansen et al. (1986) found that cold conditions cause decreases in late-in-season harvests. Thus, it was anticipated that minimum or maximum temperature would influence MES and GBO harvests. My results support similar studies that conclude an inverse relationship exists between temperature and harvest size when controlling for hunter effort (Curtis 1971, Hansen et al. 1986).

Although the regression results suggest a negative relationship, the effect of temperature on harvest size, controlling for hunter effort, is not immense. For every 10°C change in either minimum or maximum temperature, harvest size changed from 2 to 6 deer.

Although I found that only minimum temperature influenced harvests during MES hunts, I had a discrepancy between the 1-week and 2-week regression results for GBO hunts. The regression of the data set representing the first week of GBO hunts suggests that only maximum temperature affects deer harvest, while the 2-week regression indicates that only minimum temperature affects deer harvest. The regression coefficients for temperature are similar for both data sets (MAX = -0.28 and MIN = -0.22, Table 2). The disagreement between the regressions is probably due to a correlation between minimum and maximum daily temperature. If the daily maximum temperature is low, then the daily minimum temperature will respond similarly. Therefore, I conclude that there is a slight, inverse relationship between temperature and harvest for MES and GBO hunts.

Peterson (1969) and Curtis (1971) found that heavy rainfall (> 2.5 cm) and deep snow (20-23 cm) discourage hunter participation. There were 4 instances of heavy rainfall documented for AES hunts, 2 instances for MES hunts, and 2 instances for GBO hunts during 10-study years. All incidences of heavy rain occurred in different hunt years. Hunter effort and harvests did not appear to be affected on days when precipitation was high. Thus, hunter participation was not deterred, because a heavy downpour lasting only a short period of time most likely occurred on these 8 days. Occurrences of snow are also uncommon in the southern United States, therefore it is not surprising that precipitation did not influence hunter effort-harvest size relationships.

MANAGEMENT IMPLICATIONS

Similar to Fryxell et al. (1991) and Weckerly et al. (*in press)*, I detected a linear relationship between hunter effort and harvest size. In the absence of population abundance data, straight-forward hunter effort-harvest size relationships can be used to gauge the relative impact of harvest sizes on deer abundance (Weckerly et al. *in press*).

Other investigators have found that rifle hunts are effective in reducing white-tailed deer populations (Roseberry 1969, Hansen and Beringer 1997, Kilpatrick et al. 2002). My results are consistent with these studies in that harvests were higher for GBO hunts. Yet, I also found that opening weekend conditions influence rifle deer harvests. Opening weekend GBO hunts exhibited higher harvests than harvests throughout the remainder of the rifle season when controlling for hunter effort. However, buck only hunts are not adequate methods for managing population growth of white-tailed deer (Fryxell et al. 1991, Roseberry et al. 1991). Either sex, or antlerless hunts, with adult female deer constituting the majority of harvests, must be implemented to reduce population size. Weckerly et al. (*in press)*, determined that antlerless and either sex rifle hunts on MLAAP had higher harvests than GBO hunts when accounting for hunter effort and extraneous sources of variation. It may be beneficial to evaluate the opening weekend effect on hunter effort-harvest size relationships of either sex or antlerless rifle hunts.

It also may be informative for managers to conduct experiments to assess whether the opening weekend effect can be duplicated within a hunt season. Rifle hunts can be staged over weekends followed by at least a 5 day no-hunt interval. The interval of no-hunting may minimize deer avoidance of hunted areas, while simultaneously augmenting hunter participation by heightening anticipation (Hansen and Beringer 1997, Kilpatrick and Lima 1999). Kilpatrick et al. (2002) found this strategy effective at reducing deer populations with archery hunts.

Weather is often discussed as a factor influencing harvest sizes (Fobes 1945, Curtis 1971, Hansen et al. 1986). Controlling for hunter effort, I found a slight influence of temperature on harvest sizes for MES and GBO hunts. It seems unlikely that weather is going to have a substantial impact on harvests of southern white-tailed deer.

My results indicate that a flushing effect on opening weekend most likely occurs when effective firearms are used. A simple increase in the number of hunters may not be adequate to increase harvest size relative to hunter effort. However, because hunter effort-harvest size relationships are also influenced by hunter density and deer vulnerability due to landscape composition of habitats, it would be helpful to explore the extent to which flushing is affected by hunter effort and firearms in other hunted populations (Foster et al. 1997, Weckerly et al. *in press*).

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Table 1. Stages of model selection for archery either sex hunts on Milan Army Ammunition Plant, Tennessee, 1988-2000. Models had year as a random effects predictor. Shown are the fixed-effect predictors, log-likelihoods (LL), number of parameters estimated (K), AIC_c, and Akaike weights (w) for models used to estimate harvest size.

Model	Fixed predictors[a]	LL	K	AIC_c	w
	First Week of Season				
	Stage 1				
1	Constant	235.73	3	477.80	<0.001
2	HE	188.76	4	386.03	>0.999
	Stage 2				
2	HE	188.76	4	386.03	0.099
3	HE + OWD	186.63	5	384.10	0.259
4	HE + PH	186.34	5	387.52	0.047
5	HE + OWD + PH	186.60	6	386.38	0.083

Table 1. Continued

6	HE + OWD + OWD:HE	185.07	6	383.33	0.380
7	HE + OWD + OWD:HE + PH	184.90	7	385.43	0.133
		Stage 3			
2	HE	188.74	4	386.03	0.058
8	HE + PR	188.71	5	388.27	0.019
9	HE + MIN	185.68	5	382.20	0.392
10	HE + MAX	188.48	5	387.80	0.024
11	HE + PR + MIN	185.08	6	383.36	0.219
12	HE + PR + MAX	188.45	6	390.11	0.008
13	HE + MIN + MAX	185.37	6	383.94	0.164
14	HE + PR + MIN + MAX	184.50	7	384.62	0.117

Table 1. Continued

	First Two Weeks of Season				
	Stage 1				
1	Constant	446.63	3	899.41	<0.001
2	HE	362.19	4	732.66	>0.999
	Stage 2				
2	HE	362.19	4	732.66	0.259
3	HE + OWD +W1 + WD2	360.73	7	734.66	0.095
4	HE + PH	362.13	5	736.23	0.043
5	HE + OWD +W1 + WD2 + PH	360.73	8	738.46	0.014
6	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE	355.03	10	731.59	0.442
7	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE	354.97	11	733.81	0.146

Table 1. Continued

		Stage 3			
2	HE	362.19	4	732.66	0.098
8	HE + PR	362.18	5	734.76	0.034
9	HE + MIN	359.72	5	729.84	0.403
10	HE + MAX	361.70	5	733.81	0.055
11	HE + PR + MIN	359.66	6	731.89	0.145
12	HE + PR + MAX	361.69	6	735.95	0.019
13	HE + MIN + MAX	359.45	6	731.47	0.178
14	HE + PR + MIN + MAX	359.32	7	733.41	0.068

[a]HE = hunter effort, OWD = opening weekend indicator variables, PH = prior harvest size, PR = daily precipitation (cm), MIN = daily minimum temperature (C), MAX = daily maximum temperature (C), colons denote interaction between predictors.

Table 2. Regression equations for selected models by hunt type on Milan Army Ammunition Plant, Tennessee, 1988-2000.

Model	Time		Equations[a]	Residual s[b]
			Archery Either Sex	
2	First week of hunt		HAR = -0.96 + 0.10HE	2.72
2	First 2 weeks of hunt		HAR = -0.83 + 0.10HE	2.48
			Muzzleloader Either Sex	
9	Entire hunt		HAR = -0.72 + 0.26HE – 0.57MIN	8.01
			Gun Buck Only	
10	First week of hunt			4.40
		OWD	HAR = -5.10 + 0.28HE – 0.28MAX	
		W1	HAR = 5.86 + 0.06HE – 0.28MAX	
9	First 2 weeks of hunt			3.39
		OWD	HAR = -9.12 + 0.29HE – 0.22MIN	
		W1	HAR = 1.13 + 0.08HE – 0.22MIN	
		WD2	HAR = 2.09 + 0.06HE – 0.22MIN	
		W2	HAR = -0.63 + 0.11HE – 0.22MIN	

[a]HAR = harvest size, HE = hunter effort, OWD = opening weekend, W1 = week 1, WD2 = weekend 2, W2 = week 2, MIN = daily minimum temperature (C), MAX = daily maximum temperature (C). [b]s = standard deviation

Table 3. Stages of model selection for muzzleloader either sex hunts on Milan Army Ammunition Plant, Tennessee, 1992-2000. Models had year as a random effects predictor. Shown are the fixed-effect predictors, log-likelihoods (LL), number of parameters estimated (K), AIC_c, and Akaike weights (w) for models used to estimate harvest size.

Model	Fixed predictors[a]	LL	K	AIC_c	w
	Stage 1				
1	Constant	234.60	3	475.65	<0.001
2	HE	201.20	4	411.17	>0.999
	Stage 2				
2	HE	201.20	4	411.17	0.271
3	HE + OWD	199.64	5	410.49	0.381
4	HE + PH	201.15	5	413.50	0.085
5	HE + OWD + PH	199.61	6	412.93	0.113
6	HE + OWD + OWD:HE	199.57	6	412.86	0.117
7	HE + OWD + OWD:HE + PH	199.51	7	415.34	0.034
	Stage 3				
2	HE	201.20	4	411.17	<0.01
8	HE + PR	200.94	5	413.08	<0.01
9	HE + MIN	195.96	5	403.12	0.368

Table 3. Continued

10	HE + MAX	196.50	5	404.20	0.214
11	HE + PR + MIN	195.94	6	405.59	0.107
12	HE + PR + MAX	196.50	6	406.72	0.061
13	HE + MIN + MAX	195.37	6	404.45	0.189
14	HE + PR + MIN + MAX	195.37	7	407.07	0.051

[a]HE = hunter effort, OWD = opening weekend indicator variables, PH = prior harvest size, PR = daily precipitation (cm), MIN = daily minimum temperature (C), MAX = daily maximum temperature (C), colons denote interaction between predictors.

Table 4. Stages of model selection for gun buck only hunts on Milan Army Ammunition Plant, Tennessee, 1990-1998. Models had year as a random effects predictor. Shown are the fixed-effect predictors, log-likelihoods (LL), number of parameters estimated (K), AIC_c, and Akaike weights (w) for models used to estimate harvest size.

		First Week of Season			
		Stage 1			
Model	Fixed predictors[a]	LL	K	AIC_c	w
2	HE	181.21	4	371.20	>0.999
		Stage 2			
2	HE	181.21	4	371.20	<0.001
3	HE + OWD	180.06	5	371.32	<0.001
4	HE + PH	180.43	5	372.06	<0.001
5	HE + OWD + PH	179.77	6	373.26	<0.001

Table 4. Continued

6	HE + OWD + OWD:HE	167.09	6	347.90	0.770
7	HE + OWD + OWD:HE + PH	166.99	7	350.32	0.230
	Stage 3				
2	HE + OWD + OWD:HE	167.09	6	347.90	0.099
8	HE + OWD + OWD:HE + PR	165.70	7	347.73	0.108
9	HE + OWD + OWD:HE + MIN	165.32	7	346.97	0.158
10	HE + OWD + OWD:HE + MAX	164.62	7	345.57	0.317
11	HE + OWD + OWD:HE + PR + MIN	164.95	8	348.95	0.058
12	HE + OWD + OWD:HE + PR + MAX	164.09	8	347.27	0.138
13	HE + OWD + OWD:HE + MIN + MAX	164.52	8	348.10	0.090
14	HE + OWD + OWD:HE + PR + MIN + MAX	164.08	9	350.08	0.033

Table 4. Continued

		First Two Weeks of Season			
		Stage 1			
1	Constant	402.69	3	811.60	<0.001
2	HE	335.71	4	679.80	>0.999
		Stage 2			
2	HE	335.71	4	679.80	<0.001
3	HE + OWD +W1 + WD2	328.72	7	672.51	<0.001
4	HE + PH	335.21	5	680.99	<0.001
5	HE + OWD +W1 + WD2 + PH	328.41	8	674.22	<0.001
6	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE	302.36	10	626.90	0.747
7	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE	302.21	11	629.06	0.253

Table 4. Continued

	Stage 3				
2	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE	302.36	10	626.90	0.003
8	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + PR	301.01	11	626.65	0.003
9	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + MIN	296.52	11	617.67	0.305
10	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + MAX	297.07	11	618.77	0.176
11	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + PR + MIN	296.33	12	619.81	0.105
12	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + PR + MAX	296.02	12	619.19	0.143
13	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + MIN + MAX	295.76	12	618.67	0.186
14	HE + OWD +W1 + WD2 + OWD:HE + W1:HE + WD2:HE + PR + MIN + MAX	295.33	13	620.36	0.079

[a]HE = hunter effort, OWD = opening weekend indicator variables, PH = prior harvest size, PR = daily precipitation (cm), MIN = daily minimum temperature (C), MAX = daily maximum temperature (C), colons denote interaction between predictors.

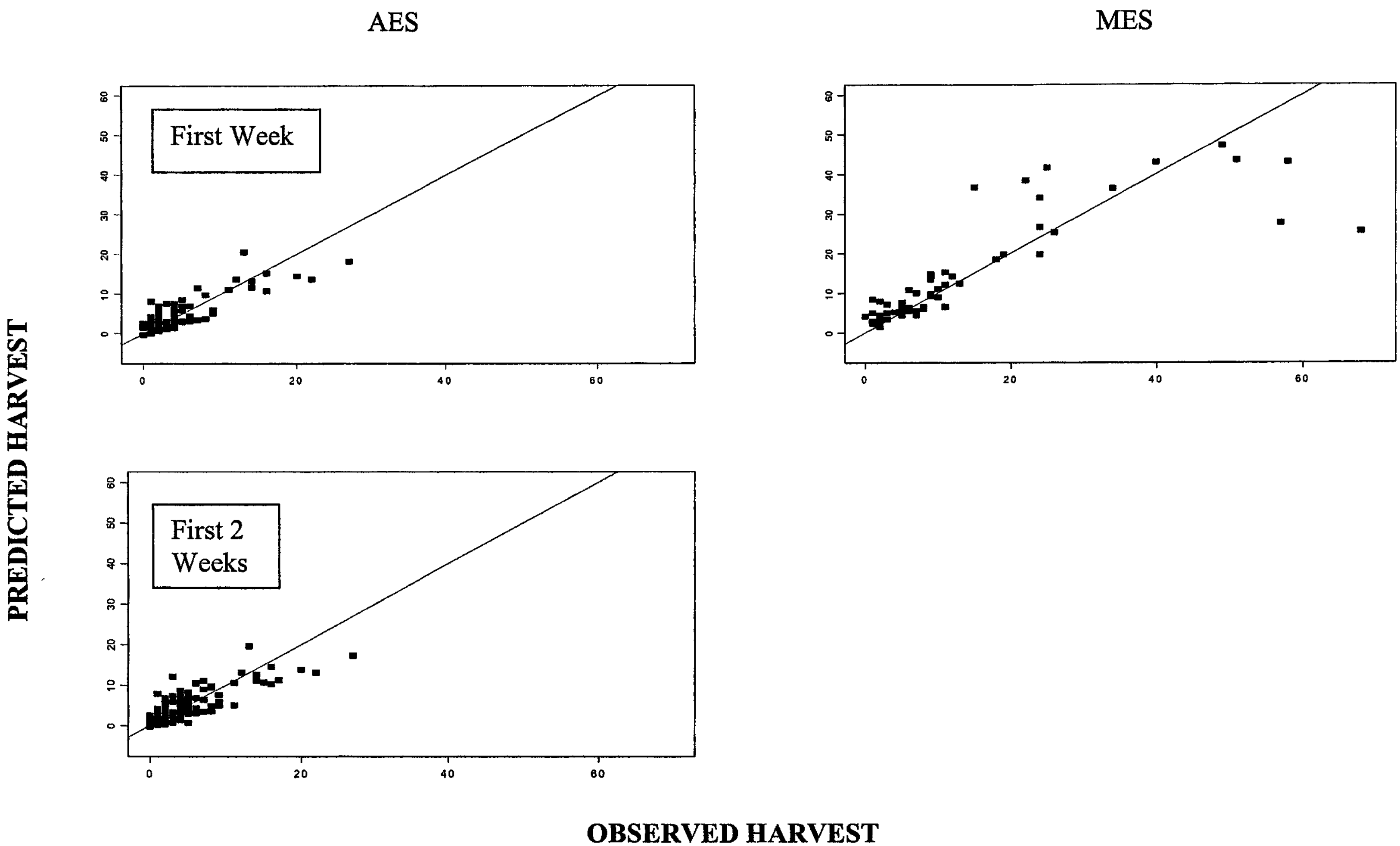

Figure 1. Scatterplots of observed versus predicted harvest sizes of archery either sex and muzzleloader either sex hunt types, Milan Army Ammunition Plant, Tennessee, 1988-2000.

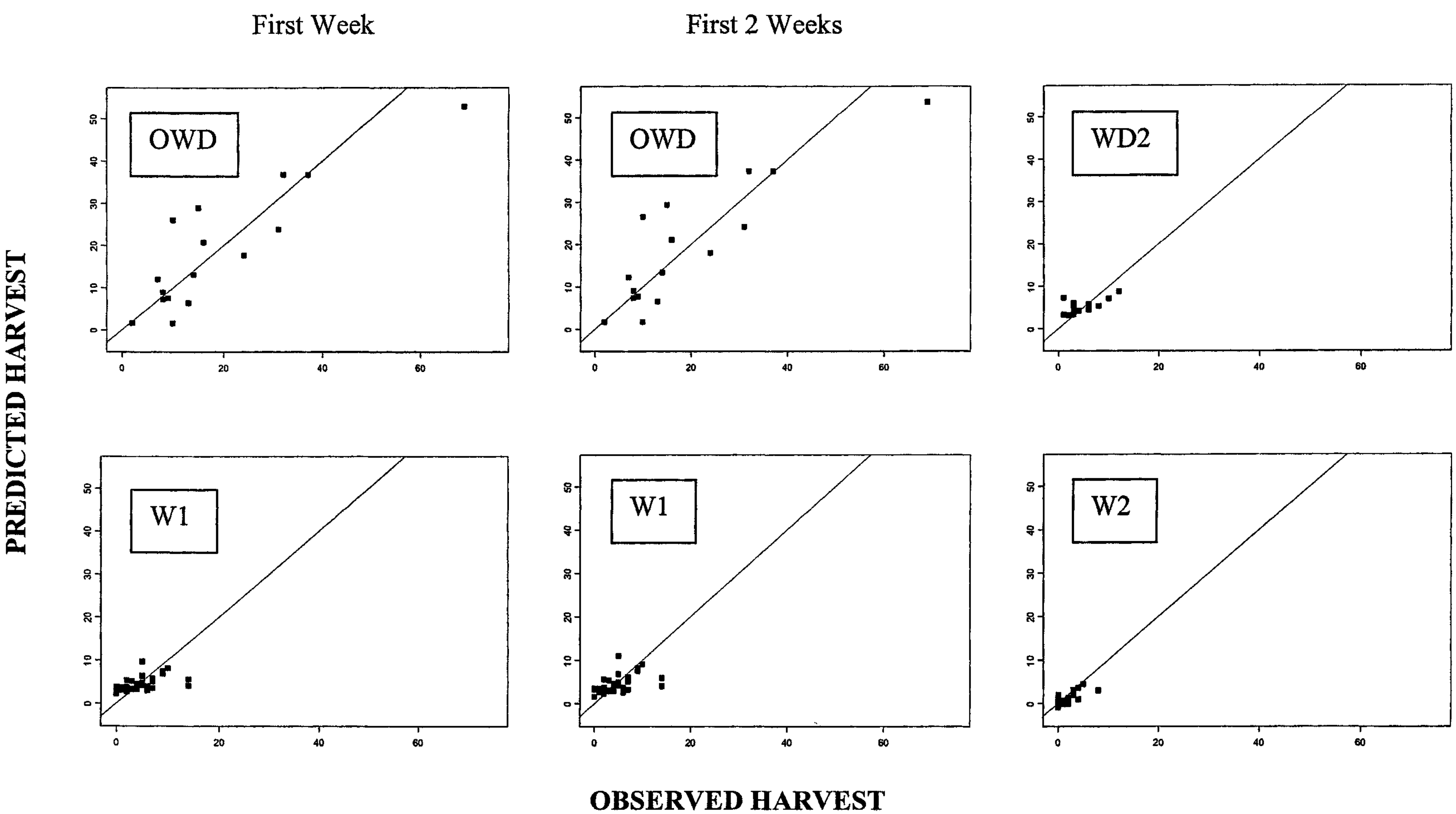

Figure 2. Scatterplots of observed versus predicted harvest sizes of gun buck only hunts, Milan Army Ammunition Plant, Tennessee, 1990-1998. Regressions include: OWD = opening weekend, W1 = week 1 of season, WD2 = second weekend of season, and W2 = week 2 of season.

Appendix. Hunter effort and harvest sizes of white-tailed deer by hunt type on Milan Army Ammunition Plant, Tennessee, 1988-2000.

Year	Opening Weekend	Week 1	Weekend 2	Week 2
	Hunter Effort, Harvest Sizes			
		Archery Either Sex		
1988	169, 6	138, 7	117, 8	109, 3
1990	270, 36	190, 18	212, 15	172, 14
1991	342, 47	268, 25	246, 32	195, 13
1992	373, 29	283, 22	233, 7	149, 9
1993	246, 22	224, 23	156, 12	152, 9
1994	264, 23	251, 19	196, 10	143, 10
1995	209, 10	152, 8	134, 15	135, 8
1996	210, 21	157, 12	113, 13	104, 8
1997	125, 10	113, 10	88, 12	62, 2
1998	131, 7	89, 7	99, 3	120, 10
2000	138, 6	128, 10	95, 6	98, 6
		Muzzleloader Either Sex		
1992	294, 73	121, 22	NA[a]	NA
1993	275, 77	173, 35	NA	NA

Appendix. Continued

1994	310, 59	255, 35	NA	NA
1995	252, 82	119, 22	NA	NA
1996	194, 76	119, 22	NA	NA
1997	299, 37	146, 23	NA	NA
1998	165, 80	224, 43	NA	NA
2000	306, 64	213, 33	NA	NA
		Gun Buck Only		
1990	281, 94	315, 54	153, 18	40, 5
1991	385, 106	369, 40	124, 5	95, 10
1992	212, 22	277, 22	173, 18	76, 3
1993	290, 42	239, 17	132, 16	75, 1
1994	172, 24	226, 26	100, 6	97, 8
1995	156, 33	180, 20	98, 14	69, 8
1996	177, 39	159, 24	46, 3	67, 6
1997	95, 23	150, 15	45, 5	40, 3
1998	119, 16	187, 16	82, 6	61, 0

[a] NA = Not applicable. MES hunts were only 7 days, or 1 weekend and 1 week, in length.

VITA

Deena Rae Francis was born in Austin, Texas, on June 20, 1979, the daughter of Diana Alaniz Klenke and Weldon Ray Klenke. After completing her work at L.C. Anderson High School, Austin, Texas, in 1997, she entered The University of Texas at Austin. She received the degree of Bachelor of Science, specializing in Ecology, Evolution and Conservation, from The University of Texas in May 2002. In September of 2002, she entered the Graduate College of Texas State University-San Marcos.

Permanent Address: 2303 W. Hwy 290
Dripping Springs, Texas 78620

This thesis was typed by Deena Rae Francis.