

## **Analysis of Fox Activity and Survival in Foxhound Training Enclosures**

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### **Executive Summary**

We worked collaboratively with the Virginia Department of Game and Inland Fisheries (DGIF) to examine the activity patterns and fate of fox placed in a foxhound training enclosure. We used various techniques to answer several basic questions regarding fox fate, activity, and how other factors affected survival during dog trials. In summary, we observed the following:

- The population of radio-collared fox in the enclosure varied throughout the study from a minimum of 3 to a maximum of 29. The average daily number of radio-collared fox in the enclosure was 12.
- We examined 66 fox for these analyses. We categorized 10 of these as “unknown” because fate was indeterminable based on observed signal patterns. Of the remaining 56, we classified 49 fox as having died during our study (87.5%) with 28 classified as DTR and 21 as DNT (50.0% and 37.5% respectively). We categorized 7 fox as surviving (12.2%) through the end of data collection period (5 March 2004).
- The number of days fox survived in the enclosure ranged from 3 to 575 days.
- We observed only one fox death during trials with 200 or fewer dogs (> 4 acres per dog). Trials with 400 or more dogs (< 2 acres per dog) accounted for 23.4% of the trials but accounted for 68.4% of the DTRs observed.
- 11 of the 28 DTRs occurred during a single 3-day trial event (from 3-5 October 2002) with 9 and 2 fox killed on the first and second days respectively. There were 25 radio-collared fox within the enclosure at the start of the trial placing the overall mortality at 44%. Of these 25 fox, 9 had been in the enclosure for fewer than 7 days (36%). Six of these 9 (75%) fox were killed. Only 5 of the 16 (31%) fox with greater than 7 days experience within the enclosure were killed.
- Fox activity followed a pattern of higher activity at night than during the day. Activity tended to be highest between dusk and midnight. This general pattern is typical of free-ranging wild fox.
- The greatest differences in activity between non-trial and trial activity tended to occur for fox that were relatively new to the enclosure and inexperienced with dog trials (naïve). It should be noted that sample sizes for these fox were relatively low.

- When comparing Kernel Density Estimates (KDE) activity curves for individual foxes, we found the mean  $\Delta$ KDE = 0.787 (0.739-0.835) with a range of 0.253 – 0.941. We observed that 49 (75%) of our foxes had a  $\Delta$ KDE > 0.754. When comparing this value against our simulated data, this suggests that actual activity changed less than 10% for these animals between non-trial and trial days. If foxes are continuously run during trails we would expect the deviation of activity to be much greater as shown by our simulations.
- The annual survival probability was estimated at 8.0% (SE 3.0%).
- Significant factors influencing radio-collared fox survivability were fox experience but more important the interaction of fox experience and density of dogs during a trial (Prob >  $\chi^2$  = 0.0006). The resulting model outputs were applied to various dog densities (dogs/acre) to be used as a management tool. These figures are provided herein.

We analyzed the 25 fox that were alive for the 3 October 2002 trial day to note specific characteristics of fox. We observed:

- 9 naïve fox (with < 7 days in the enclosure) and 16 experienced fox (> 35 days in the enclosure) were in the enclosure at the beginning of the trial.
- Of the 9 naïve fox, 6 (67%) were killed compared to 3 of the 16 experienced fox (19%).
- In the days leading up to the trial, we observed that naïve fox had a significantly higher mean activity than experienced fox in all daily periods except 0300-0900.
- We determined the likely period of death for the 9 fox that died on 3 October. Of these, 7 (78%) appear to have died between 03:00-09:00 (early in the morning on the first day of the trial).
- We observed significant differences in activity index values between fox that survived the trial and those that did not for the morning period only.

These observations should be considered with a full understanding of the limitations identified as part of the analysis including:

- This study was conducted in the largest and most active enclosure in the state and results likely represent a “worst-case scenario” with regard to fox mortality from training.
- We do not know the actual number of fox within the enclosure at any time. All observations are for radio-collared fox only.
- We do not have any information about the number of dogs within the enclosure on days not recorded as “trial days”. It is likely that dogs were active within the enclosures during some non-trial days also, although in much lower numbers. We assume that any

day without a formal trial was considered to have small amounts (low density) of foxhound activity (<50 dogs present).

- Our information on the number of dogs and hunters participating in each trial are provided at the event level (we do not know actual numbers for specific days on multi-day events).
- Activity index ranges from 0-64 (low to high). Since we did not visually observe radio-collared foxes while they were being monitored, we do not know what specific fox behaviors are represented by calculated activity index values.
- A large proportion of the fox analyzed were classified as “died, non-trial” related. We do not know the causes of these presumed mortalities.

## **Introduction**

This project provided initial analyses of data from a study designed to monitor fox activity in a foxhound training enclosure. The study was conducted by the Virginia Department of Game and Inland Fisheries (VDGIF) from August 2002 through March 2004. In summary, red foxes (and 2 gray foxes) were captured, outfitted with radio transmitter collars (Telonics Inc., Meza, AZ, model: MOD-225), and released into Poole's foxhound training enclosure (841 acres; 806 acre training enclosure and 35-acre acclimation enclosure) in Greensville County, Virginia. Collars were monitored regularly from one or two automated receiving tower locations.

Our objective was to analyze the raw data collected from the radio-collared foxes to provide answers to the following questions:

1. What was the fate of foxes placed in the enclosure?
2. What were the activity patterns for foxes within the enclosure?
3. Does fox activity change in the presence of foxhound trials?
4. What sorts of factors affect fox activity during trials?
5. What was the survival rate of foxes within the enclosure?
6. What was the effect of trial size and fox experience on survival?

This report provides information on the actions taken to answer these questions and provide some thoughts on the appropriate interpretation of the results. We have organized the sections that follow to clarify the processes, approaches, and results.

## **General Methods**

We received 3 types of raw data files to conduct these analyses. The bulk of the information came from activity information collected in the field. We also had access to files containing information about when foxhound trials were conducted, as well as the number of dogs that participated in each event. Information related to the individual foxes that received radio collars (i.e. species, sex, date of entry into the enclosure) was also provided.

### *Fox Activity Data*

Activity information from foxes in the enclosure was collected by automated data loggers connected to receiving towers placed in the North and South portions of the property. These towers collected information continuously (while operational) by cycling through the frequencies of all active collars. This information was compiled into a single file that was retrieved from each tower and stored. We refer to these files as the "raw" files.

Raw data from the radio collars were provided in ASCII text format. These files contained fox activity information recorded in single of lines of data for each fox for each observation. Each

observation consisted of data recording the frequency of the collar, date, time, signal strength, and pulse interruption rates (800 – 2000 mSec.) for each collar detected. We concatenated all raw files into a single file then parsed the information into subsets for each fox.

First, we merged the tower files into single month/year files, then we parsed line (i.e., by collar frequency) into a separate file for each fox. These individual month/year files were then merged together using an MS-DOS batch file to create a single data file for each collar frequency containing all data collected over the length of the study for that individual.

We added several fields to this database that were necessary for our analyses. These fields include a classification of time into one- and ten-minute time blocks, time of day scaled between 0-1 (with 0 representing 00:00:00 hours and 1 representing 23:59:59 hours), and Julian date.

#### *Data Quality and Reduction*

Activity files for individual foxes were often very large, especially if the fox remained in the study for the entire period. We elected to reduce the datasets by removing the lowest signal strengths. We examined the distribution of signal strength and opted to remove the lowest 10% of signals. We accomplished this by examining the signal strength distribution from a random set of 13 collars and identifying the signal strength that corresponded to the lowest 10% of the observations. The signal strength ranged from 0 – 255 (no units) with a mean of 124.8 (SE=0.11). We determined that the lowest 10% of all observations occurred at a signal strength of 70, so we removed records with strengths equal to or less than this value from further analyses for all foxes. We also removed any records with spurious information (e.g., pulse rates out of the 800-2000 mSec. range). These datasets were referred to as “cleaned” and used for all analyses.

#### *Radio-Collared Fox Data*

We received a hard copy spreadsheet containing information on fox that were radio-collared and placed into the training enclosure. This information included radio-collar frequency, species, sex, and enclosure entry date. This data set was joined to the cleaned activity data. It should be noted that we observed additional foxes in the activity dataset that were not included on this list and incorporated them into the final analysis.

#### *Foxhound Field Trial Data*

We were also provided with information that included the dates when foxhound field trials occurred within the enclosure, the name of the event, number of hounds participating, and the number of hunters registered. This information was joined to the fox activity datasets by date.

### *Classifying Activity*

We defined activity based on the pulse switch interruptions reported by the collar. The pulse rates recorded and transmitted by the collars ranged from 2000 mSec. (low activity) to 800 mSec. (high activity); however, based on information provided by Telonics Inc.<sup>1</sup>, the scale between these values was not linear (Figure 1). In order to use this information for basic descriptive statistics, we needed to transform it. We transformed the pulse rates to a linear activity level through the following cubic-logarithmic function derived using JMP statistical software (SAS Institute Inc. 2010):

$$\text{Activity} = 27112.946 - 10583.374 * \text{Log}(\text{Pulse}) + 1377.8089 * \text{Log}(\text{Pulse})^2 - 59.824353 * \text{Log}(\text{Pulse})^3$$

The activity level index values generated from this transformation ranged from 0 (low activity) to 64 (high activity). The observed  $R^2$  and adjusted  $R^2$  values for this equation were greater than 0.99 and indicated a good fit.

Further, we also classified fox activity values into “low”, “moderate”, and “high” activity categories. Ideally, these classes would be established by directly observing a target animal (or surrogate) wearing a radio-collar to calibrate pulse rates to observed behavior (i.e., resting, walking, running, etc.). No such calibration was performed during this study, so we did not have any information to suggest which values corresponded to actual fox behavior.

Gilbert *et al.* (2009) used similar collars to assess the activity levels of pine martens in Wisconsin by directly observing the behaviors of radio-collared ferrets and recording the resulting pulse rate transmitted. We opted to use the same categorical thresholds reported by Gilbert *et al.* (2009) for our analysis. These classifications were based on percent of total switch closures during observed behavioral activities (high  $\geq 55\%$ ; moderate 15% - 54%; and low  $< 15\%$ ).

We applied these percent thresholds based on the pulse rate range set for this study. We defined high activity as any activity index value greater than, or equal to, an activity index of 35.18 (pulse rate  $\leq 968$  mSec.), moderate activity as any activity index greater than or equal to 9.62 and less than 35.18 (968 mSec.  $<$  pulse rate  $\leq 1321$  mSec.), and low activity was classified as any activity index value lower than 9.62 (pulse rate  $> 1321$  mSec.).

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<sup>1</sup> Telonics, Inc. 932 E. Impala Avenue, Mesa, AZ, 85204-6699 USA 480-892-4444.

## **Question #1: What was the fate of foxes placed in the enclosure?**

### **Methods**

We examined activity information for each fox to determine its fate in the enclosure. We assumed that collars on fox that had been killed would have relatively few high activity pulse transmissions shortly after of death (with the exception of likely repeated disturbances by other animals post-mortem). Then we calculated the total proportion of daily activity observations categorized as “high”. We used that value to determine if, and when, the fox collar was largely inactive by plotting the value through time and noting when the proportion of high activity decreased to a low, sustained level. We also examined the total number of observations collected per day to better understand the effect of low daily sample sizes on proportion of high activity, as well as to assist in determining when a fox may have been killed (Figure 2).

Once a date had been identified, we recorded it in a table along with a categorization of fate. If the date of death was found to be on a trial day, or within one day after, the fox was categorized as “Died – trial related” (DTR). If no dog trial was recorded for those days, we categorized the fate as “Died non-trial related” (DNT). If the fox exhibited no changes in high activity we categorized it as “Survived”. We also recorded the date of the earliest and last activity signals and recorded any specific observations for the individual fox as warranted.

We calculated the number of days each fox was in the study based on the first data record and the last day the fox was recorded alive (either the date of death or the end of the study depending on fate). We also tallied the number of trials experienced by each fox. We used this information to characterize the overall fate of foxes placed in the training enclosure.

We observed that data were collected from 8 August 2002, through 5 March 2004; however towers were (at minimum) not collecting data between 5 June 2003 and 1 October 2003 (118 day period) when no field trials were reported to have occurred. We also noted a gap in data collections from December 19, 2002 and December 31, 2002; however no fox were determined to have died during that period.

### **Results**

We examined 66 fox for these analyses. We categorized 10 of these as “unknown” because fate was indeterminable based on observed signal patterns. Of the remaining 56, we classified 49 fox as having “died” during our study (87.5%) with 28 classified as DTR and 21 as DNT (50.0% and 37.5% respectively; Table 1). We categorized 7 fox as surviving (12.5%) through the end of data collection on 5 March 2004 (Figure 3).

The population of radio-collared fox in the enclosure varied throughout the study from a minimum of 3 to a maximum of 29. The average daily number of radio-collared fox in the enclosure was 12.

#### *How long did fox survive in the enclosure?*

We determined a length of time (in days) each fox spent in the enclosure based on the earliest date when data were recorded and the last day the fox was alive during the study (i.e., the last day of the study was used for surviving fox; Table 1). We used this information to describe the number of animals surviving through time (Figure 4). The number of days fox survived in the enclosure ranged 3 to 575 calendar days.

#### *How did the number of dogs in the trials affect fox survival?*

We examined the distribution of the size of dog trials and compared that with the number of radio-collared fox classified as DTR during those trials. We used hound density, calculated as the number of hounds per unit area of enclosure (in acres), to create a density of hounds per acre. This will facilitate the application of the information to other enclosures (Table 2). We observed only one fox death during trials with hound densities lower than 1 dog per 4 acres. Trials with hound densities exceeding 1 per 2 acres accounted for 36.5% of the trials but accounted for 67.9% of the DTRs observed (Figure 5).

We noted that 11 of the 28 DTRs occurred during a single 3-day trial event (3 - 5 October 2002), with 9 and 2 fox killed on the first and second days respectively. There were 25 radio-collared fox within the enclosure at the start of this trial, placing the overall mortality of collared foxes at 44.0%. Of these 25 fox, 9 had been in the enclosure for fewer than 7 days (36%). Seven of these 9 (77.7%) inexperienced foxes were killed. Only 4 of the 16 (25%) fox with greater than 7 days experience within the enclosure were killed. No other event had more than 4 radio-collared fox killed.

## **Question #2: What were the activity patterns for radio-collared foxes within the enclosure?**

### **Methods**

We examined each individual fox's activity in the enclosure, then attempted to draw general observations from all foxes. We attempted to represent the daily activity patterns of foxes so that they could be readily understood by all users.

#### *Kernel Density Estimates*

We described individual fox behavior by examining the amount of high-activities recorded by time of day (in continuous time) using a kernel density estimate (KDE). First, we selected only those activity records categorized as “high” using pulse rate values (pulse  $\leq 968$ ; activity index  $\geq 35.18$ ). The KDE categorizes the strength of high activity patterns throughout the 24 hour day. Calculations were made using a custom script designed for use in the R statistical software (R-Development-Core-Team 2008) along with the R packaged Bootstrap and Circular (for circular temporal data) modules (Ridout and Linke 2009). This technique provided three estimates each for both the non-trial and trial subsets based on user-selected smoothing factor (we chose to use  $c=1.0$  since it is the most conservative estimator). This was conducted for both trial and non-trial scenarios for each fox collar in order to compare the resulting functions and calculate a  $\Delta$ KDE value that reflects the degree of overlap between the two scenarios.

One drawback to this approach was the difficulty in interpreting the differences in the coefficient of overlap between non-trial and trial days. We did not have a way to interpret how divergent the activity curves would need to be to generate a substantial difference in KDE. In other words, how does a  $\Delta$ KDE of 0.75 translate to the magnitude of difference in fox activity?

We addressed this issue by simulating activity changes for real collar data in order to generate a known difference that we could then relate to the observed coefficient of overlap information. With that, we could compare the observed coefficient of overlap value between non-trial and trial days and better understand how this value translated to actual increases or decreases in activity.

We started with one of the fox chosen at random. To simulate differences in activity, we forced high activity for the duration of the period when trials were thought to occur within the training enclosure (i.e., we changed all pulse rate values received between 06:00 and 18:00 hours to 800). This would represent the “maximum difference” case where the fox would be on continuous high activity throughout the training period and yield the lowest coefficient of overlap from the non-trial day observations.

We then repeated this process with an introduced random assignment of high activity (i.e., a pulse rate of 800 mSec.) for each observation at 75%, 50%, 25%, 10%, 5%, 2%, and 1% to produce similar  $\Delta$ KDE functions and related coefficient of overlap values for each of those activity changes (Table 3).

## **Results**

*What were the daily activity patterns of radio-collared fox on non-trial and trial days?*

Activity values derived from the Kernel Density Estimates for each fox/collar are provided graphically (Appendix A). Activity differs for each fox, but patterns are generally consistent. We

observed a general pattern for all radio-collared individuals resembling what we would expect for a primarily nocturnal animal (Figure 6). For non-trial days, activity levels were relatively low between the hours of 06:00 and 18:00 then sharply increased to a 24-hour period high between 18:00 and 24:00 hours before declining to a lower activity level (but higher than the daytime period) until approximately 06:00<sup>2</sup>. Activity commonly peaked shortly after dusk and was relatively uniform and low during the daylight hours.

### **Question #3 – Does the activity of fox change in the presence of foxhounds?**

We compared the KDEs generated from non-trial and trial days for each fox. The resulting  $\Delta$ KDEs were compared to the results of the  $\Delta$ KDE simulation to estimate the level of difference between the values (Table 4, Figure 7). The lower the  $\Delta$ KDE value, the greater the difference in activity between non-trial and trial days. We observed that the greatest differences in activity between non-trial and trial activity tended to occur for fox that were relatively new to the enclosure and inexperienced with dog trials (i.e. naïve). It should be noted that the sample sizes for these fox were relatively low (Table 4).

We were able to calculate  $\Delta$ KDE for 52 foxes in the study. There were 5 foxes with insufficient activity data for trial days, so no comparison could be made (i.e., DNT prior to their first trial event). The overall mean  $\Delta$ KDE was 0.787 (0.739-0.835) with a range of 0.253 – 0.941. We observed that 49 (75%) foxes had a  $\Delta$ KDE > 0.754. Comparing this value against our simulated data suggests that actual activity between non-trial and trial days changed less than 10%. If foxes were continuously active during trails, we could expect the deviation of activity to be much greater than those observed.

The remaining 13 (25%) foxes with  $\Delta$ KDE < 0.754 had a mean experience of 14 days with the median of 4 days. These values indicate a greater difference in activity between trial and non-trial days; however the relatively low number of observations for these foxes may be the primary reason for these differences rather than an actual activity difference. While there was a significant relationship of activity change to days in the study (F ratio = 27.503,  $p > F < 0.001$ ,  $R^2 = 0.7013$ ) we cannot say if this is a correlation or provides evidence for a difference.

### **Question # 4 – Does experience level affect fox activity during trials?**

In order to analyze fox activity during trials we needed to create a dataset that would allow us to examine individual fox and attributes within the context of specific days. For example, if we hypothesize that the experience (i.e., number of days in the enclosure) of the fox may have

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<sup>2</sup> Study period encompassed a range of day/night durations which would result in a “mean” change in activity around 0600 and 1800 hours. We would hypothesize the observed changes in activity on any given day to dawn/dusk events rather than actual time of day.

some influence on fox activity during a specific trial, then we would need that information for each individual relative to the day it was placed in the enclosure. Since fox were introduced to the enclosure at various times throughout our study period it was important to be specific about trials and the population of fox present at the time.

Further, our dataset was extremely large. So large, in fact, that dealing with the entirety of the information simultaneously was computationally and logistically impossible. We elected to examine trial-related questions requiring more specific fox/trial-level information by sub-setting our dataset.

#### *Subset for 30 September 2002 through 3 October 2002 Trial Event*

We examined the fox that were present on 30 September 2002 through a large foxhound trial event held on 3 October 2002. This trial had the largest number of radio-collared fox killed, and a relatively large number of hounds involved. It also had the highest radio-collared fox population observed during our study period and contained fox of varying experience. Many of the fox had experienced smaller trials between the start of the project and 3 October while others had been introduced only days before the event.

We examined the 25 fox alive within the enclosure on midnight 3 October in more detail. We then categorized fox by their fate in this trial event day as survived or died. We also classified their experience (in days) as naïve (< 7 days in the enclosure) or experienced (> 35 days) as of 3 October<sup>3</sup>.

In order to gain the most accurate values for true activity, we examined the mean activity by period in an attempt to filter out those observations that occurred after the animal was likely killed.

## **Results**

### *What are the overall activity values for fox during non-trial and trial days?*

The overall mean activity index for radio-collared fox in the enclosure was 20.6 (SE= 0.14). We also summarized activity for shorter periods during the day. We divided each day into 5 periods corresponding to early morning (00:00-03:00), morning (03:00-09:00), day (09:00-15:00), evening (15:00-21:00), and night (21:00-00:00) blocks (Table 5). We chose these blocks so that dawn and dusk periods were located near the middle of the blocks to reduce the effects of changing day length.

### *What happened to fox during the 3 October trial day?*

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<sup>3</sup> There were no fox in the enclosure with greater than 7 days and less than 35 days experience.

As previously noted, this trial day resulted in a relatively large number of fox mortalities; 9 of 25 fox were classified as DTR during on this day of the event. We attempted to examine some aspects of the fox involved in this trial day.

We classified fox with less than 7 days experience in the enclosure as “naïve” and the rest as “experienced”. We had a total of 9 naïve fox and 16 experienced fox in the enclosure on October 3 at the beginning of the trial. We then determined whether the fox died during or survived the event (Table 6).

Of the 9 naïve fox, 6 (67%) were classified as “died” during the event compared to 3 of the 16 experienced fox (19%). This suggests that fox newly introduced to the enclosure were more likely to perish in the trial than fox that had been in the enclosure for a longer period of time.

We examined period-specific activity patterns for each fox in order to more accurately determine the times when individual foxes may have been killed. By identifying when a fox likely perished, we could remove any subsequent activity information that would impact our analysis, as very low activity signals from inactive foxes would bias the results.

We determined the likely period of death for the 9 fox that died on 3 October (Table 7). Of these, 7 (78%) appear to have died between 03:00-09:00. One fox appears to have died between 09:00-15:00, and the other between 15:00-21:00. We removed these data by-period for each fox as appropriate.

*Do mean activity values differ between new and experienced fox?*

We examined activity index values (by periods) for naïve fox and experienced fox using the same subset of activity information starting on 30 September (when the newest fox were introduced) and ending on 2 October (when all fox were known to be alive in the enclosure) to determine if there was a difference.

Naïve fox had a significantly (statistically) higher activity in all daily periods than did experienced fox over the same time (Table 8). Activity of naïve foxes was significantly higher than experienced foxes during all but the 03:00-09:00 time period, when the reverse was true. The observed differences in activity between naïve and experienced fox ranged from -3.0 to 9.7 with the greatest differences observed in the evening and night periods when fox were typically the most active.

We also calculated the mean activity for naïve and experienced fox on 3 October for each period (Table 9). Naïve fox exhibited significantly greater activity index values for the early morning and morning periods but were not different than experienced fox for the remaining periods.

*What was the activity observed for fox that survived vs. died on 3 October?*

We also examined the activity on 3 October between fox that died versus fox that survived the day (9 and 16 respectively). We found significant differences in activity index values for the morning period only (Table 10). The morning period was also the period in which most of the fox were presumed killed, so the lower activity could be the result of several low activity observations during that period.

### **Question # 5: What was the survival rate of radio-collared foxes within the enclosure?**

#### **Methods**

We examined overall fox survival within the enclosure. This was calculated using weekly survival histories starting from the initial point the fox was radio-collared and placed into the enclosure. This represents a survival probability a fox will persist each month (4 week interval/ sampling occasion) out to twelve months (48 sampling occasions). We included all radio-collared foxes with a known fate in this analysis. Monthly survival probabilities were calculated utilizing the “known fate” models within program MARK v7.1 (White and Burnham, 1999). We ran two standard known fate models with the parameter index matrix (PIM): 1. Survival is not affected by time  $\{S(\cdot)\}$ ; 2. Survival is time dependent  $\{S(t)\}$ . The top model was selected based on a minimum  $\Delta AICc > 2.0$ . For competing models ( $\Delta AICc < 2.0$ ), we selected the model with the lowest AICc to report the survival probability.

#### **Results**

Our survival analysis included 56 radio-collared foxes. The overall probability of survival (with 95% confidence interval values) was highest during the first month ( $(S(p))_i = 0.732 \pm 0.115$  or  $73.2\% \pm 11.5\%$ ) and followed a decreasing logistic curve ( $R^2 = 0.976$ ) through the end of the 12 month analysis (Figure 8). The annual survival probability of a radio-collared fox within the enclosure is estimated at  $S(p)_a = 0.080 \pm 0.062$  ( $8.0\% \pm 6.2\%$ ). Our top models for the first 3 months were the time dependent model  $\{S(t)\}$ , during the fourth month, the two models were competing, by the fifth month all top models exhibited no time effect (Table 11). This data suggests that after radio-collared foxes had been in the enclosure for 4 months, time was no longer the strongest factor is determining survival.

## **Question # 6: What is the effect of trial size and fox experience on survival?**

We wanted to provide a management tool for understanding trial related mortality, so we investigated the interaction of fox experience and trial size on fox survival; both factors that could be successfully managed. We consulted with the Virginia Tech Laboratory of Interdisciplinary Statistical Analysis (LISA) to identify the most appropriate analysis for obtaining this information given the type of data available. We determined that a logistic regression approach would provide the most appropriate model for analyzing experience and trial size.

### **Methods**

First, we extracted daily survival information from the dataset. We determined fate for each fox for each trial day they were placed in the enclosure as indicated by a zero or one. We also calculated the number of days the fox had been in the enclosure for each of the trial days. We used this information to build a two-factor factorial logistic regression model predicting fox fate using the SAS Jmp Pro 10.0.0 Platform (SAS 2010). This resulted in 412 records for analysis.

The dependent variable was fate (defined as a binary variable where 0 = Lived, and 1 = Died for any given trial day). Independent variables for the model included the number of days of experience (e.g. time in enclosure), the number of dogs involved in the trial day, and the interaction between the number of dogs and the amount of experience. We chose a logistic model approach because we assumed that each fox and trial event (or day in the case of multiple day trials) to be independent variables, and the resulting model would allow us to calculate the probability of survival under different experience and dog density scenarios.

### **Results**

Results from the model indicated a good whole model fit (Prob > ChiSq = < 0.0001), with convergence in 8 iterations (Full model results are presented in Table 12 and Table 13). It should be noted that in general,  $R^2$  values for nominal logistic models are generally lower than those provided in a typical linear regression model.

Parameter estimates for the model indicated that experience (Prob > ChiSq = 0.0024), and the interaction of the number of dogs and experience are significant factors (Prob > ChiSq = 0.0006) in determining daily survival during trials. The number of dogs by itself was not significant (Prob > ChiSq = 0.782); however due to the interaction of experience and the number of dogs, it is included in the model (Full model statistics are presented in Table 14 and Table 15).

The goodness-of-fit lists the negative log-likelihood for error due to Lack of Fit, error in a saturated model (i.e., pure error), and the total error in the fitted model (Table 15). The observed values suggest that the lack of fit Chi-Square is not significant (Prob > ChiSq = 1.000)

and supports the conclusion that there is little to be gained by introducing additional variables in the model. So, we feel that the resulting model would be useful for informing decision makers about how fox experience and dog density affect daily trial survival.

We fit the models with varying values for foxhound density ranging from one acre per dog (1:1; high density) to 5 acres per dog (5:1; low density). Then we entered days of experience and recorded the resulting daily survival rate produced by the model. These results were graphed for each hound density level (Figure 9 and 10). These graphs can be used to reference specific hound density and experience combinations impacts on daily survival to assist decision makers.

### **Considerations for Applying this Information**

It is important to note there are a number of limitations to this work. Many of these are obvious but worth stating explicitly to avoid improper interpretation and support appropriate use.

The results of this study were derived from the operations and practices of a single hound training preserve. Further, this preserve is the largest of its kind in Virginia and hosted many trial events. This preserve does not accurately reflect the frequency and size of trials held in any other facility. We feel the use of this information does represent a “worst-case scenario” with regard to fox mortality from training, but other localized factors not examined (e.g., habitat types within enclosure, fox density, etc.) should not be discounted.

It is likely that the number of foxes in the enclosure would also have an impact on individual fox survival during trial events. We have no way of knowing how many foxes were actually in the enclosure during the study, nor do we know what proportion of the total population our radio-collared sample comprised. When the total number of radio-collared foxes in the enclosure was low our power to consider impacts as representative of the whole population is low. It is reasonable to assume that activity observations from radio-collared fox are representative of activities non-collared fox.

We do not have any information about the number of dogs within the enclosure on days not recorded as “trial days”. It is likely, and we assumed, that dogs were active within the enclosures during non-trial days although in lower numbers (< 50 for this study).

Similarly, the available information on the number of dogs and hunters participating in each trial are provided at the event level. We do not know exactly how many hounds were in the enclosure simultaneously during the events. This is particularly important to note for multi-day events where it is likely that hound density within the enclosure decreased as the trial

proceeded. We assumed a constant hound density for all days in a multi-day trial at the maximum number of hounds reported. Further, when more than one trial was conducted on the same day we considered the total number of hounds to be additive and simultaneous which likely results in an overestimate of actual hound density.

The activity index values ranged from 0-64 (low to high), and we used this information to classify activity as low, moderate, or high. We do not have any direct behavioral observation data of radio-collared fox to use in calibrating activity values to specific behaviors. Using activity information from this study to draw conclusions about what how individual radio-collared foxes were behaving would be guesswork; however the activity information used in relation to other observations (as was done here) does allow us to determine if a fox was more, or less, active.

While we are confident that our methods allowed us to accurately determine when a fox collar was no longer active (i.e., moving) we did not actually document fox mortality or the causes of it. We assumed that when a collar became inactive it was due to the demise of the fox. We further assumed that these events, particularly when occurring on or immediately after a trial event, were related to hound activity in the enclosure. While we remain confident that hounds are the likely cause of these observed mortality events we cannot say with certainty that is the case.

**Table 1. Basic information recorded for each fox in the analysis. This included radio collar frequency, total number of activity observations, enclosure entry and exit dates, fate, total days survived, and number of field trials experienced for all fox used in this analysis.**

<b>Frequency</b>	<b>N</b>	<b>First Date</b>	<b>Last Date</b>	<b>Fate<sup>1</sup></b>	<b>Total Days</b>	<b>Total Trials</b>
148.000	63,075	1/16/2003	3/22/2003	DTR	65	10
148.040	3,658	9/30/2002	10/3/2002	DTR	3	1
148.060	12,611	3/19/2003	5/31/2003	DTR	73	13
148.080	28,366	2/14/2003	4/16/2003	DNT	61	9
148.100	87,993	1/22/2003	3/5/2004	Survived	408	37
148.120	89,770	8/8/2002	11/12/2002	DNT	96	18
148.140	1,767	9/30/2002	10/3/2002	DTR	3	1
148.180	123,114	9/30/2002	8/2/2003	DNT	306	40
148.200	13,259	1/16/2003	1/31/2003	DTR	15	1
148.220	89,699	1/22/2003	11/6/2003	DNT	288	29
148.240	93,909	1/16/2003	3/5/2004	Survived	414	37
148.260	21,793	2/14/2003	8/2/2003	DNT	169	18
148.280	19,494	2/14/2003	4/25/2003	DTR	70	11
148.300	10,456	2/14/2003	3/18/2003	DNT	32	5
148.320	8,076	2/14/2003	3/1/2003	DTR	15	2
148.340	4,724	3/18/2003	4/20/2003	DNT	33	4
148.400	219,398	8/8/2002	8/2/2003	DNT	359	46
148.420	50,802	1/21/2003	4/24/2003	DTR	93	14
148.460	52,526	2/14/2003	3/5/2004	Survived	385	33
148.480	2,718	9/30/2002	10/3/2002	DTR	3	1
148.500	24,393	2/14/2003	4/27/2003	DTR	72	12

(Continued)						
Frequency	N	First Date	Last Date	Fate <sup>1</sup>	Total Days	Total Trials
148.520	56,454	8/8/2002	11/19/2002	DNT	103	18
148.540	2,798	3/18/2003	4/16/2003	DNT	29	4
148.580	136,520	8/8/2002	12/17/2002	DNT	131	21
148.600	123,544	8/8/2002	11/26/2002	DNT	110	19
148.620	50,760	8/8/2002	10/3/2002	DTR	56	7
148.640	42,037	2/14/2003	11/2/2003	DTR	261	25
148.660	3,569	9/30/2002	10/4/2002	DTR	4	2
148.700	138,928	8/8/2002	12/10/2002	DNT	124	21
148.720	18,934	2/14/2003	3/22/2003	DTR	36	6
148.760	40,961	8/8/2002	10/3/2002	DTR	56	7
148.800	77,721	2/14/2003	2/22/2004	DNT	373	32
148.820	84,788	8/27/2002	11/24/2002	DTR	89	17
148.840	101,759	8/27/2002	12/17/2002	DNT	112	19
148.900	83,946	2/14/2003	3/5/2004	Survived	385	33
148.940	118,210	8/8/2002	12/9/2002	DTR	123	21
148.960	91,787	9/30/2002	12/18/2002	DNT	79	15
149.000	5,643	3/18/2003	5/15/2003	DNT	58	8
149.040	41,244	8/8/2002	9/21/2002	DTR	44	5
149.060	2,779	9/30/2002	10/3/2002	DTR	3	1
149.080	35,585	8/8/2002	9/21/2002	DTR	44	5
149.100	103,177	8/8/2002	12/8/2002	DTR	122	21
149.200	49,616	8/8/2002	10/3/2002	DTR	56	7

(Continued)						
Frequency	N	First Date	Last Date	Fate <sup>1</sup>	Total Days	Total Trials
149.240	346	3/18/2003	3/21/2003	DNT	3	0
149.260	75,738	1/22/2003	2/29/2004	Survived	403	37
149.300	8,665	3/18/2003	3/4/2004	Survived	352	28
149.380	592	3/18/2003	3/21/2003	DNT	3	0
149.440	761	3/18/2003	3/22/2003	DTR	4	1
149.480	54,821	8/8/2002	11/22/2002	DNT	106	18
149.500	118,093	8/8/2002	3/5/2004	Survived	575	61
149.540	14,539	8/27/2002	10/4/2002	DTR	38	6
149.659	3,613	9/30/2002	10/3/2002	DTR	3	1
149.680	1,008	3/18/2003	3/22/2003	DTR	4	1
149.720	4,931	3/19/2003	4/24/2003	DTR	36	5
149.780	3,526	3/18/2003	4/15/2003	DNT	28	4
149.860	2,287	9/30/2002	10/3/2002	DTR	3	1

<sup>1</sup>Fate: DNT= Died-non-trial related, DTR= Died trial-related

Table 2. Number of DTRs compared to trial size. The relationships suggest that more foxes died at higher density trials than would be expected if the number of dogs had no impact on the number of DTRs. The number of DTRs was disproportionately high when dog density surpasses 1 dog per 2 acres and was likewise low when dog density was less than 1 dog per 5 acres.

Dogs Per Acre	DTRs		Trial Days	
	N	%	N	%
< 1 dog per 5 acres	1	3.6%	18	28.6%
1 dog per 4-5 acres	0	0.0%	3	4.8%
1 dog per 3-4 acres	4	14.3%	6	9.5%
1 dog per 2-3 acres	4	14.3%	13	20.6%
> 1 dog per 2 acres	19	67.9%	23	36.5%
Total	28		63	

Table 3. Observed  $\Delta KDE$  and results of activity level simulations on  $\Delta KDE$  values. Percentages reported reflect the proportion of activity observations taken between 06:00 – 18:00 hours that were forced into high activity.

Simulation Run	N	$\Delta KDE$	Std. Error
Actual	5370	0.869	0.015
1%	5715	0.891	0.01
5%	6456	0.839	0.009
10%	7277	0.794	0.008
25%	10090	0.644	0.007
50%	14608	0.517	0.005
75%	19062	0.447	0.004
100%	23499	0.41	0.003

Table 4.  $\Delta$ KDE values between high activities recorded on non-trial and trial days. The closer the  $\Delta$ KDE value is to 1.0, the less differences observed between non-trial and trial day activities. Observed differences in  $\Delta$ KDE are related to the total number of points available, with lower sample sizes often resulting in lower  $\Delta$ KDE values.

Frequency	No. of Points		$\Delta$ KDE	SE
	Non-trial	Trial		
148.000	5568	1195	0.914	0.014
148.040	119	43	0.566	0.074
148.060	1106	296	0.873	0.032
148.080	2358	420	0.882	0.03
148.100	8933	1644	0.905	0.012
148.120	5810	1314	0.869	0.015
148.140	135	0	NA	NA
148.180	14145	2748	0.934	0.009
148.200	708	40	0.519	0.061
148.220	5967	1110	0.905	0.015
148.240	8714	1326	0.902	0.013
148.260	1960	252	0.869	0.023
148.280	1317	299	0.776	0.026
148.300	463	65	0.872	0.057
148.320	499	24	0.63	0.102
148.340	359	111	0.89	0.053
148.400	16951	3213	0.916	0.009
148.420	4733	837	0.895	0.017
148.460	4998	839	0.921	0.019
148.480	294	124	0.746	0.046
148.500	1490	372	0.796	0.028
148.520	4728	715	0.869	0.018
148.540	340	38	0.619	0.076
148.580	8040	1564	0.9	0.014
148.600	7860	1570	0.85	0.012
148.620	3212	297	0.78	0.03
148.640	3457	835	0.905	0.187
148.660	184	185	0.53	0.045
148.700	10374	2374	0.923	0.01
148.720	1470	384	0.901	0.025
148.760	3135	271	0.816	0.03
148.800	7229	1046	0.913	0.013
148.820	6346	1527	0.846	0.014
148.840	5976	1198	0.893	0.013
148.900	6350	959	0.89	0.016
148.940	8872	1879	0.887	0.011
148.960	8509	2485	0.941	0.011
149.000	390	27	0.679	0.081
149.040	4307	328	0.796	0.027

Frequency	No. of Points		$\Delta$ KDE	SE
	Non-trial	Trial		
(continued)				
149.060	189	24	0.253	0.073
149.080	3461	368	0.819	0.026
149.100	6112	1188	0.874	0.016
149.200	5176	327	0.792	0.034
149.240	NA	NA	NA	NA
149.260	5756	1207	0.934	0.015
149.300	572	90	0.845	0.046
149.380	NA	NA	NA	NA
149.440	48	12	0.479	0.109
149.480	NA	NA	NA	NA
149.500	9755	1313	0.904	0.012
149.540	1173	130	0.643	0.043
149.659	373	65	0.321	0.045
149.680	58	22	0.505	0.092
149.720	520	92	0.896	0.046
149.780	419	115	0.809	0.043
149.860	237	80	0.357	0.055

Table 5. Mean activity for all fox in the enclosure from 30 Sep through 3 Oct 2002 by time period.

Period	Time	Activity	
		Mean	SE
Early Morning	00:00-03:00	21.5	0.4
Morning	03:00-09:00	19.4	0.3
Day	09:00-15:00	10.8	0.3
Early Evening	15:00-21:00	23.6	0.3
Night	21:00-24:00	26.8	0.4

Table 6. Fate of radio-collared foxes on 3 October 2002 by experience class. Two of the foxes listed as surviving in this table were killed on the second day of the trial (4 October 2002).

<b>Experience Class</b>	<b>Died</b>	<b>Lived</b>	<b>Total</b>
Naïve	6	3	9
Experienced	3	13	16
Total	9	16	25

Table 7. Mean activity values by period for each fox killed during the 3 October 2002 trial. This information was used to determine when the fox was killed so remaining periods could be removed from the analysis. Time period of demise is given in bold.

Frequency	Mean Activity Index Value				
	Early Morning	Morning	Day	Early Evening	Night
148.040	20.9	<b>18.9</b>	3.2	3.6	5.3
148.140	5.3	<b>5.4</b>	3.7	2.7	3.7
148.480	9.0	<b>22.2</b>	4.4	5.1	3.6
148.620	10.4	10.9	10.7	<b>21.0</b>	4.8
148.760	15.0	23.0	<b>10.1</b>	2.6	1.7
149.060	3.4	<b>13.0</b>	9.5	.	.
149.200	19.9	<b>23.7</b>	.	1.7	1.6
149.659	36.9	<b>21.2</b>	3.6	1.6	2.8
149.860	36.8	<b>36.6</b>	3.4	5.6	4.4

Table 8. Comparison of mean activity values by period for naïve and experienced fox in the enclosure from 30 September through 2 October 2002 (pre-trial). Activity difference was significant for all time periods (alpha level of 0.05). While statistically significant, the significance of actual behavioral differences is unknown.

Period	Time	Experienced		Naïve		P-value
		Mean	SE	Mean	SE	
Early Morning	00:00-03:00	20.9	0.5	23.0	0.9	0.04
Morning	03:00-09:00	19.7	0.3	16.7	0.7	0.0001
Day	09:00-15:00	9.8	0.4	13.6	0.6	0.0001
Early Evening	15:00-21:00	22.2	0.4	27.7	0.5	0.0001
Night	21:00-24:00	24.4	0.5	34.1	0.6	0.0001

Table 9. Comparison of mean activity values for naïve and experienced fox on the first day of the trial (3 October 2002). Note that fox were killed during the morning, day, and early evening periods.

Period	Time	Experienced			Naïve			P-value
		No. Died	Mean	SE	No. Died	Mean	SE	
Early Morning	00:00-03:00	0	19.3	0.8	0	25.8	1.2	0.0001
Morning	03:00-09:00	1	18.3	0.7	6	24.3	1.0	0.0001
Day	09:00-15:00	1	9.4	0.7	0	7.5	1.4	0.23
Early Evening	15:00-21:00	0	20.2	0.8	1	16.3	1.7	0.04
Night	21:00-24:00	0	18.7	0.9	0	22.6	2.1	0.09

Table 10. Comparison of mean activity values by period for fox that survived the trial versus those that died on 3 October 2002. Note that all fox that died were killed prior the night period, so no comparison was possible.

Period	Time	Lived		Died		P-value
		Mean	SE	Mean	SE	
Early Morning	00:00-03:00	21.8	0.9	21.1	1.1	0.57
Morning	03:00-09:00	21.6	0.7	19.1	0.9	0.03
Day	09:00-15:00	8.8	0.7	10.4	1.8	0.42
Early Evening	15:00-21:00	19.4	0.7	21	2.8	0.58
Night	21:00-24:00	19.4	0.8	.	.	.

Table 11. Survival model outputs for monthly survival of radio-collared foxes from date of release into the training enclosure. Estimates were derived in Program MARKv7.1 using the “Known Fate” models. Only the top models are presented based on a minimum AICc > 2.0.

Month	Survival Probability S(p)	SE	Lower 95% CI	Upper 95% CI	Model <sup>1</sup>	AICc	w AICc	Number of Parameters	Deviance
1	0.732	0.059	0.602	0.832	S(t)	96.2474	0.99403	4	0
2	0.589	0.066	0.457	0.710	S(t)	159.3471	0.9937	8	0
3	0.411	0.066	0.29	0.543	S(t)	232.5235	0.91209	12	0
4	0.321	0.062	0.213	0.454	S(t) <sup>2</sup>	274.4432	0.67911	16	0
5	0.225	0.051	0.141	0.341	S(.)	311.3725	0.75424	1	37.2039
6	0.194	0.049	0.116	0.307	S(.)	318.7889	0.83815	1	44.6217
7	0.162	0.045	0.093	0.269	S(.)	330.6666	0.97021	1	49.4479
8	0.144	0.042	0.079	0.247	S(.)	336.6876	0.99133	1	55.4693
9	0.129	0.040	0.069	0.229	S(.)	342.3228	0.99797	1	61.1049
10	0.111	0.036	0.057	0.205	S(.)	353.1763	0.9998	1	65.0746
11	0.090	0.032	0.044	0.174	S(.)	369.1759	0.99999	1	67.8708
12	0.080	0.030	0.038	0.161	S(.)	373.0336	1	1	71.7287

1 Model types are S(t)=time dependent; S(.)= time constant

2 Represents a competing model based on AICc < 2.0

Table 12. Whole model results for the two factor factorial logistic regression model. The Prob>ChiSq = <0.0001 indicates that as a whole, the model is significant (N = 412).

	LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	16.140233	3	32.28046617	<.0001
Full	38.116688			
Reduced	54.256921			

Table 13. Goodness of Fit test for two factor factorial logistic regression model presented in Table 12.

Measure	Training	Definition
Entropy RSquare	0.2975	$1 - \text{Loglike}(\text{model}) / \text{Loglike}(0)$
Generalized RSquare	0.3255	$(1 - (L(0)/L(\text{model}))^{2/n}) / (1 - L(0)^{2/n})$
Mean -Log p	0.0925	$\sum -\text{Log}(\rho[j]) / n$
RMSE	0.1485	$\sqrt{\sum (y[j] - \rho[j])^2 / n}$
Mean Abs Dev	0.0442	$\sum  y[j] - \rho[j]  / n$
Misclassification Rate	0.0291	$\sum (\rho[j] \neq \rho_{\text{Max}}) / n$

Table 14. Full parameter estimates and for the two factor factorial logistic regression model. The constant (Intercept), experience, and the interaction of experience and number of dogs are all significant in the model.

	Estimate	StdError	ChiSquare	Prob>ChiSq
Intercept	3.44	1.4690	5.49	0.0191
Experience	0.01493	0.006597	5.12	0.0236
Num_dogs	-0.0007278	0.002682	0.07	0.7861
(Experience-119.255) *(Num_dogs-376.823)	0.0000709	2.06954E-05	11.75	0.0006

Table 15. Goodness of Fit test for two factor factorial logistic regression model parameter estimation presented in Table 13.

	DF	LogLikelihood	ChiSquare	Prob>ChiSq
Lack Of Fit	154	16.8983	33.7966	1
Saturated	157	21.2183		
Fitted	3	38.1166		

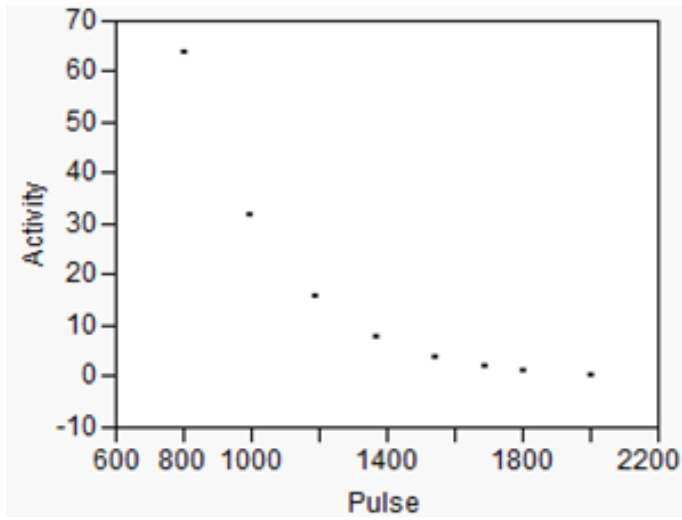


Figure 1. Activity value as a function of pulse rate transmitted by the collars (provided by Telonics, Inc.).

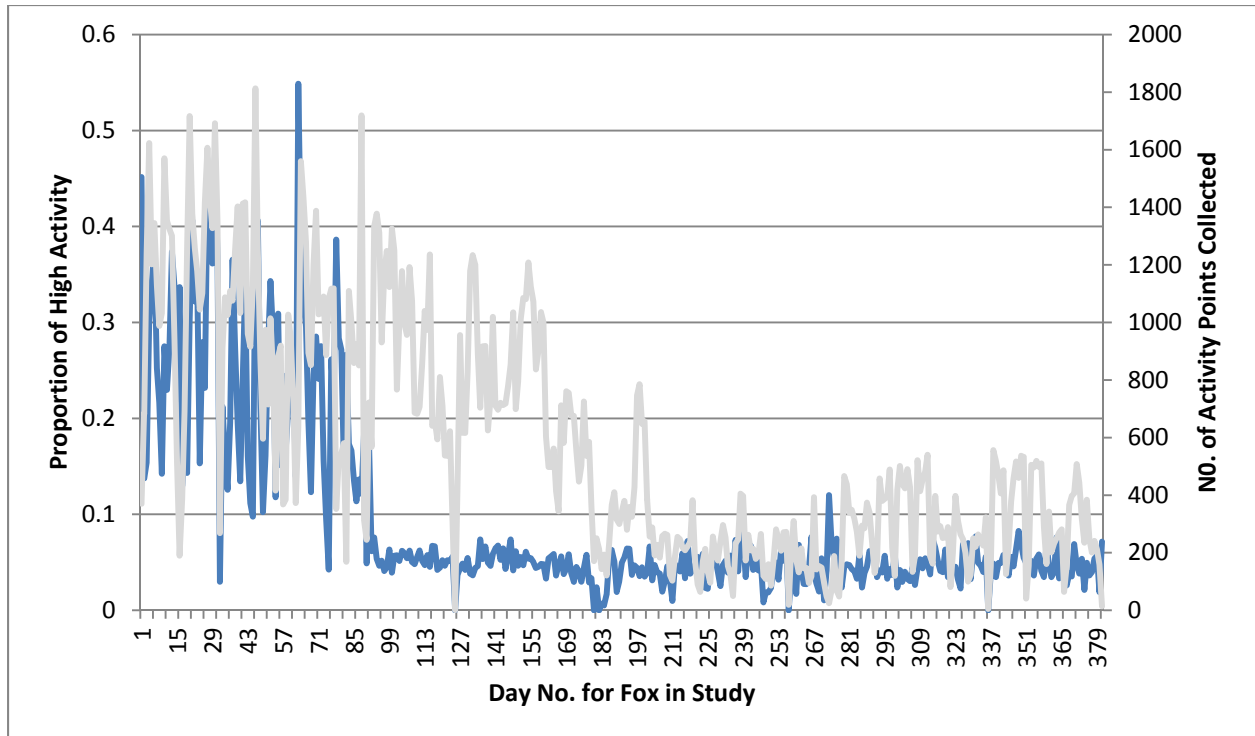


Figure 2. Example of the proportion of daily activity observations categorized as "high" for an individual fox (frequency 148.120). The resulting line (blue) depicts a drastic change in pattern around day 90 that indicates the death of the fox. The gray line shows the total number of points recorded for this fox per day (right Y axis). Low numbers of observations often accounted for high activity spikes after the fox was likely deceased.

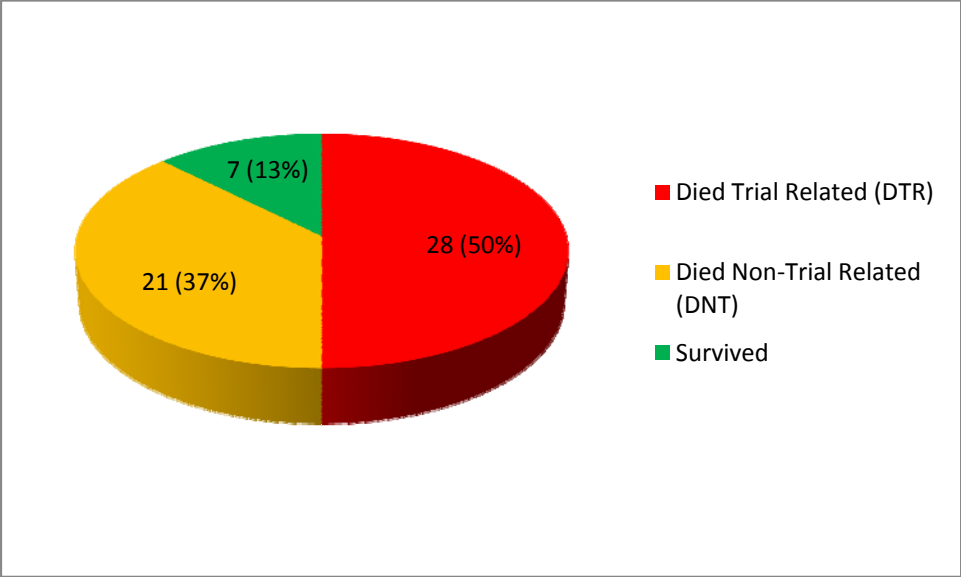


Figure 3. Fate of fox included in our analysis (N=56). Both the total number and proportion of each fate class are provided.

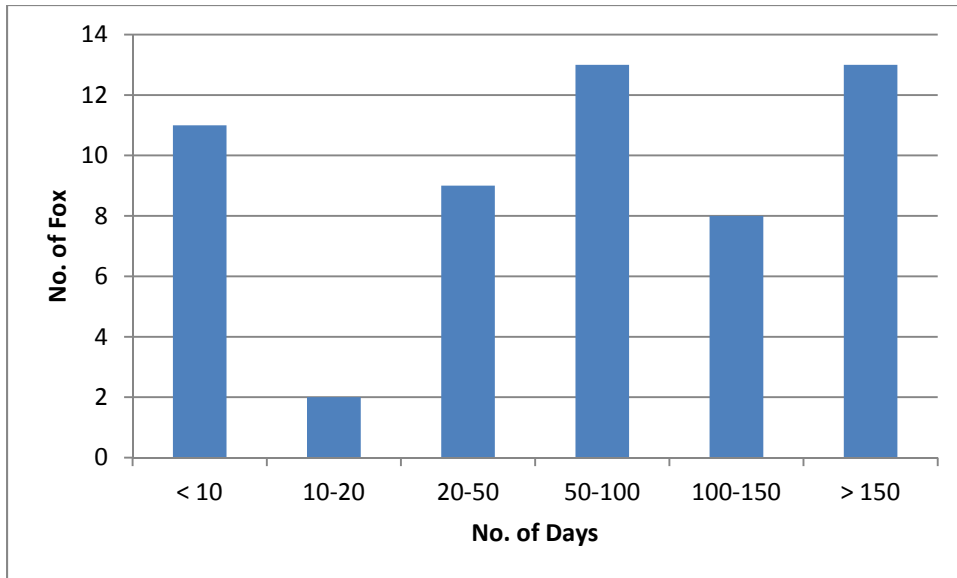


Figure 4. Number of fox surviving by classes of days. Fox were introduced periodically throughout the study.

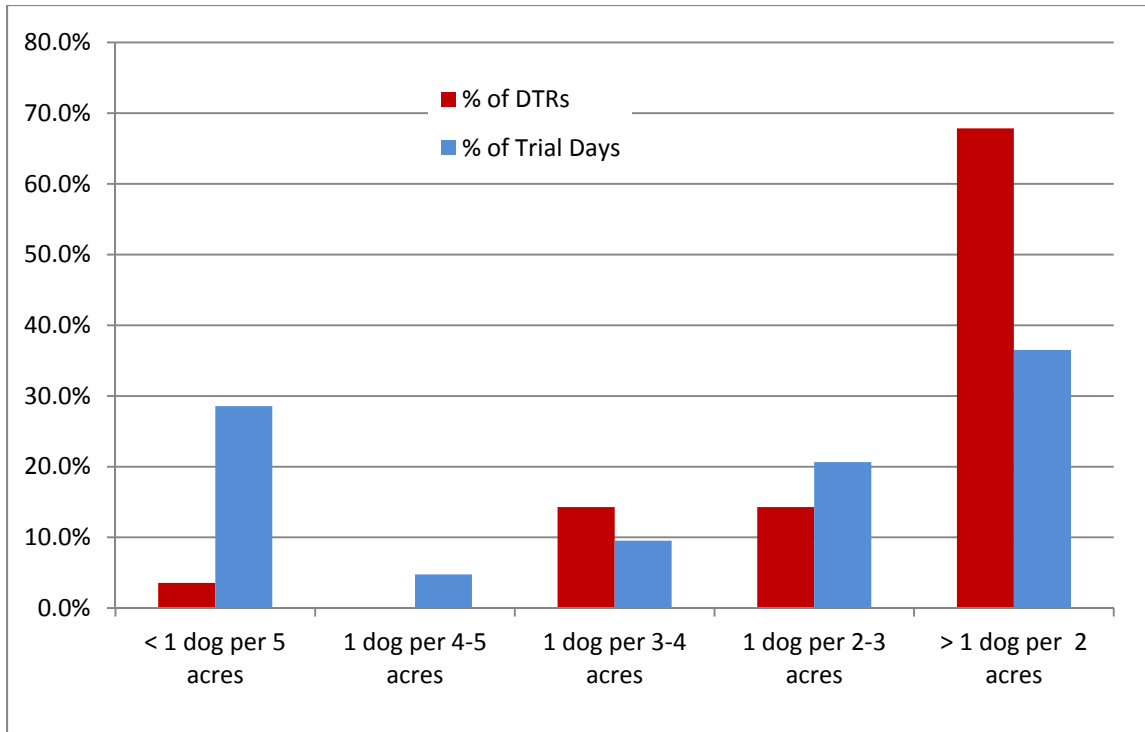


Figure 5. Proportion of fox surviving by number of trials experienced and number of dogs in event.

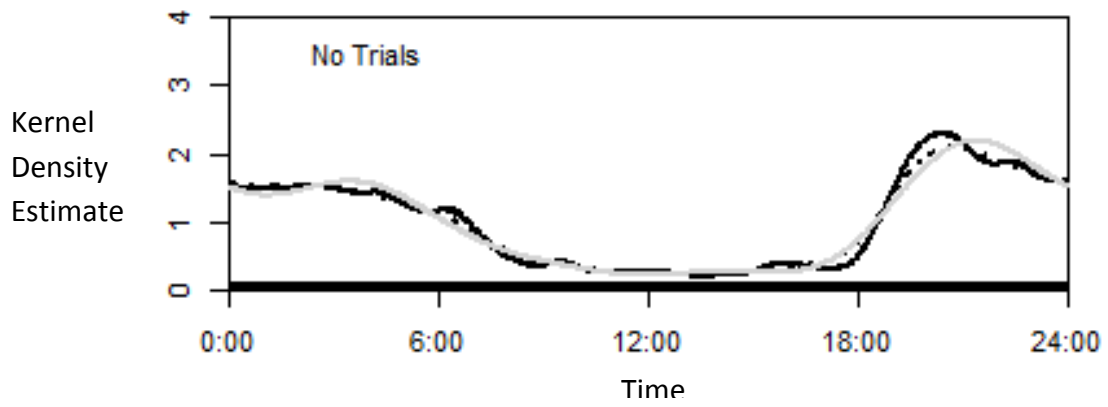


Figure 6. Example of a typical 24-hour activity pattern for an individual fox in this study (non-trial day). The three lines represent various smoothing factors from the kernel density estimate (KDE). We used the most conservative estimator ( $c=1.0$ ) which is represented by the solid black line.

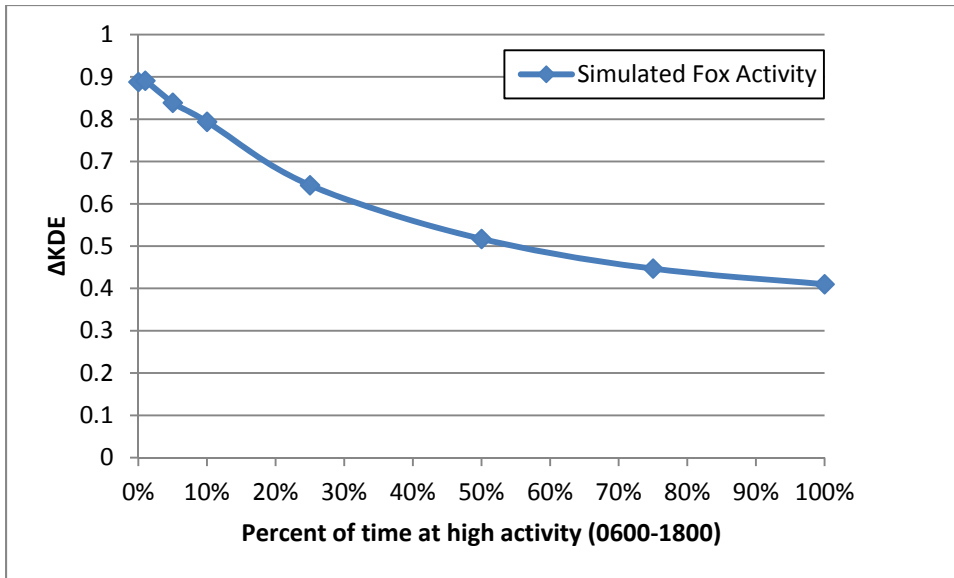


Figure 7. Graph of simulated high activity percentages (between 06:00-18:00 hours) on KDE values. Results from this simulation were used to better understand how changes in observed activity affected  $\Delta$ KDE values.

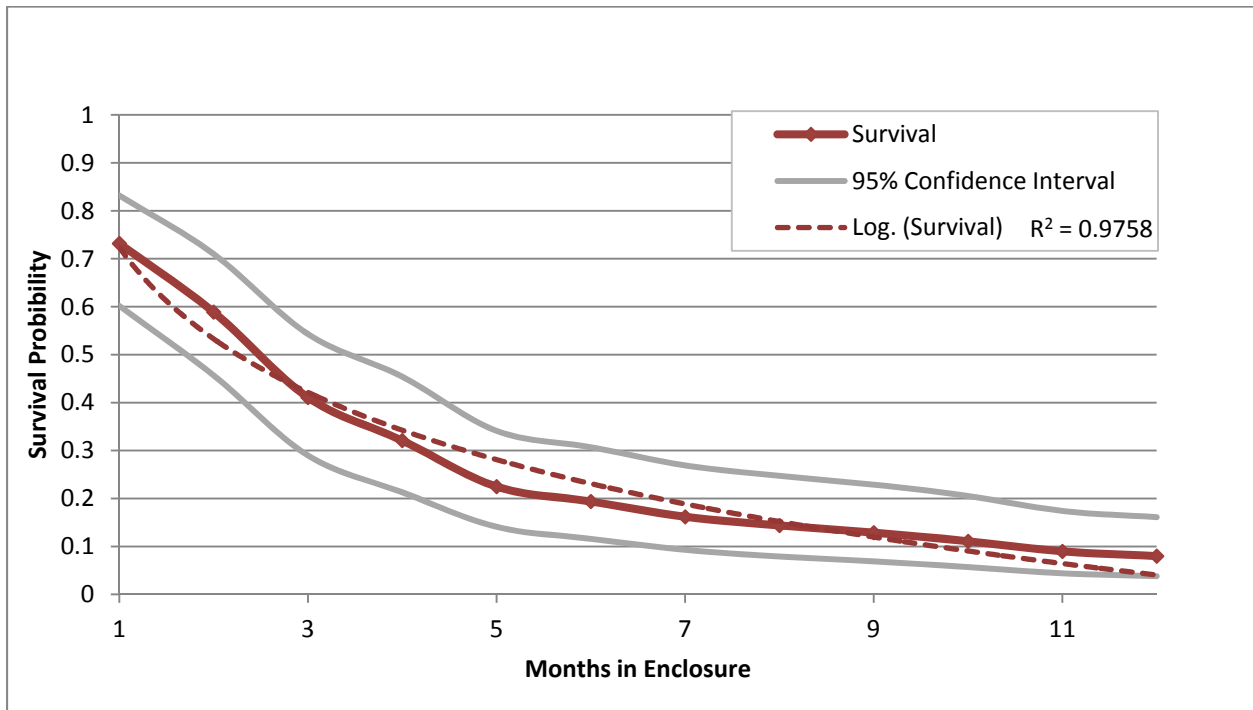


Figure 8. Monthly survival estimates out to one year, for all radio-collared fox from entry into the training enclosure.

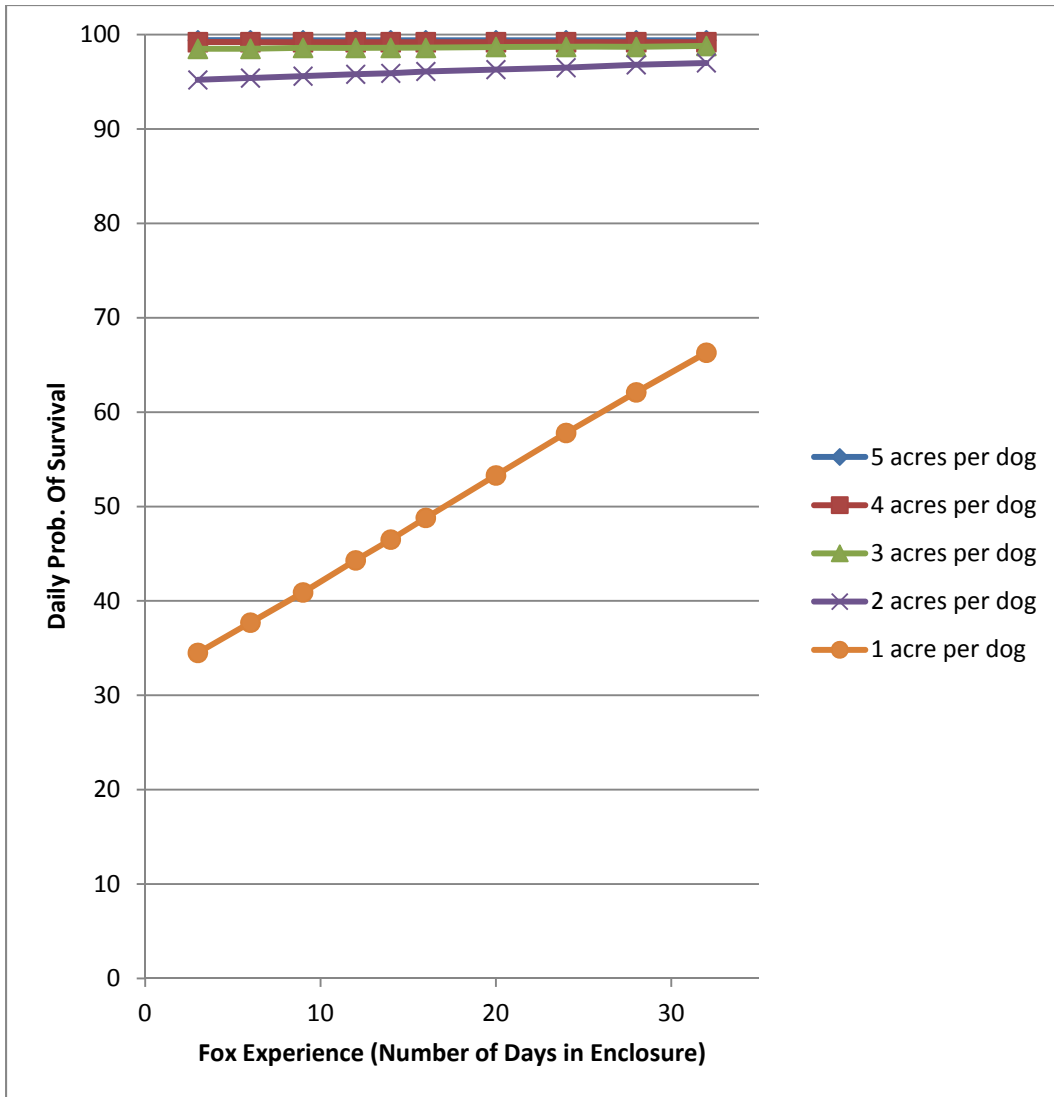


Figure 9. Daily trial survival by experience under several dog density scenarios. This information is useful for evaluating management options.

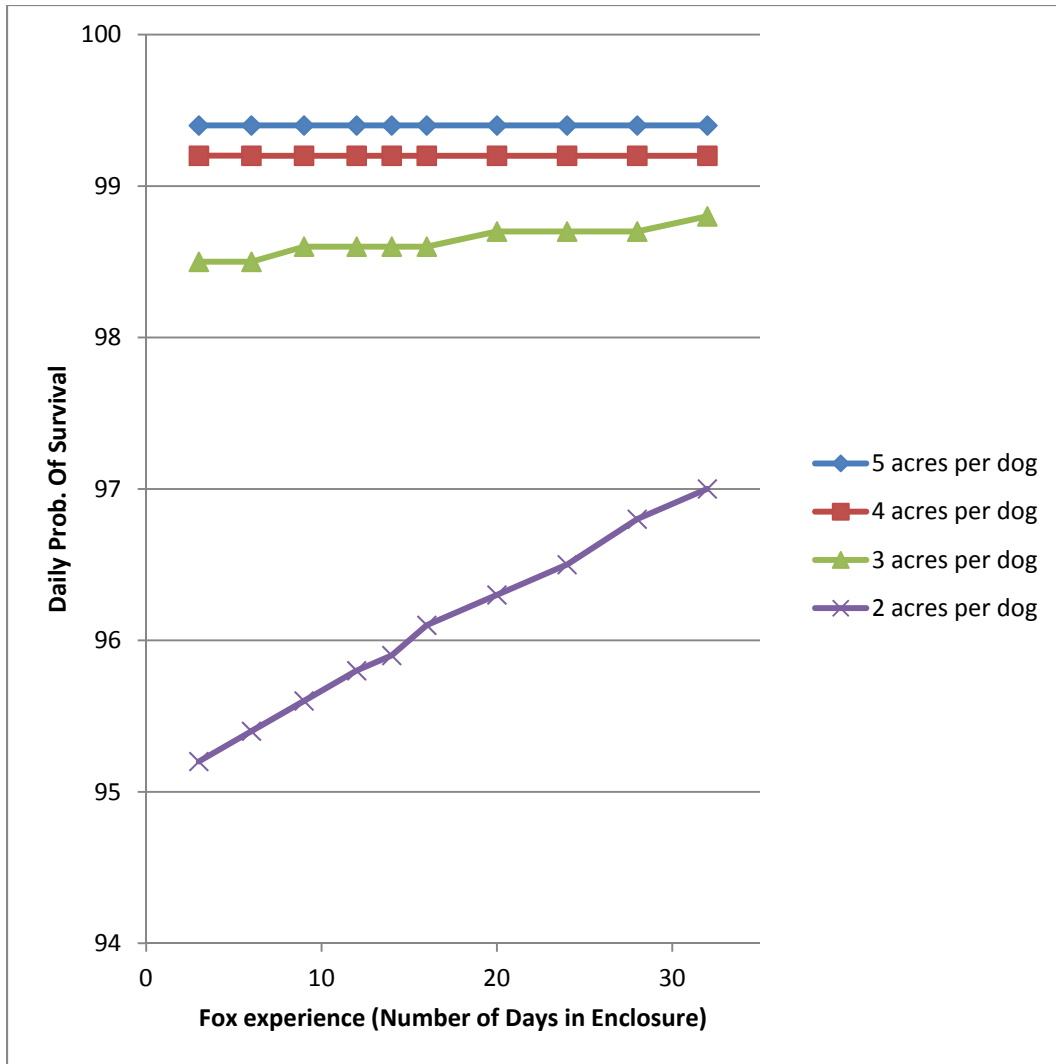


Figure 10. Same as Figure 9, but the Y scale minimum is set at 94% to facilitate the examination of survival differences for hound densities between 2 and 5 acres per hound.

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