

National Capital Region Network Inventory and Monitoring Program

White-Tailed Deer Density Monitoring Protocol Version 1.1:

Distance and Pellet-Group Surveys

Scott Bates

Wildlife Biologist

National Park Service

Center for Urban Ecology

4598 MacArthur Blvd, NW

Washington DC 20007

Last Update: 1 December 2006

CONTENTS

Contents.....	v
ACRONYMS	viii
1. Deer Monitoring Overview	1
1.1 Rationale for Monitoring Deer	1
1.2 Specific Monitoring Objectives	2
1.3 Rationale for Distance Sampling.....	2
1.3.1 Alternative Methods Considered But Dropped – Aerial Infrared Surveys	3
1.3.2 Alternative Methods Considered But Dropped – Mark and Recapture Surveys	4
1.3.3 Alternative Methods Considered But Dropped – Fixed-Area (Strip) Transects.....	4
1.4 Rationale for Pellet-Group Counts as an Abundance Indices	5
1.4.1 Alternative Method Considered But Dropped – Remote Cameras.....	5
2. Standard Operating Procedures – Distance Sampling.....	6
2.1 Sampling Design	6
2.2 Field Methods.....	8
2.2.1 Survey Timing	8
2.2.2 Survey Sequence	8
2.2.3 Survey Frequency.....	8
2.2.4 Survey Methodology	8
2.3 Data Management.....	9
2.3.1 Data Field Definitions.....	10
2.4 Data Analysis	11
2.4.1 Sex Ratios.....	12
2.4.2 Power to Detect A Trend	12
2.4.3 Coefficient of Variation.....	13
2.4.4 Minimum Detectable Rate of Change.....	13
2.5 Reporting Schedule.....	14
2.6 Administration/Implementation of the Monitoring Program.....	14
2.6.1 Personnel.....	14
2.6.2 Equipment Needs	14
2.6.3 Budget Considerations	15
3. Standard Operating Procedures — Pellet-group Counts (HAFE only)	16
3.1 Sampling Design	16
3.2 Field Methods.....	16

3.2.1	Survey Timing	16
3.2.2	Survey Sequence	16
3.2.3	Survey Frequency.....	17
3.2.4	Survey Methodology	17
3.3	Data Management.....	17
3.3.1	Data Definitions.....	17
3.4	Data Analysis	18
3.4.1	Power Analysis	19
3.4.2	Reporting Schedule	19
3.5	Administration/Implementation of the Monitoring Program	19
3.5.1	Personnel.....	19
3.5.2	Equipment Needs	19
4.	Budget Considerations	20
5.	References	24
Appendix A: Distance Sampling Protocol Revision History		26
Appendix B: Deer Distance Sampling Data Sheet.....		27
Appendix C: Distance Sampling Routes		30
Appendix D: Pellet-Group Survey Protocol Revision History		31
Appendix E: Pellet-group Sampling Plot Locations		32
Appendix F: Pellet-group Data Sheet.....		33
Appendix G: Microsoft Access Database Structure.....		34

LIST OF FIGURES

Figure 1. Fall 2003 histogram of Antietam Distance data using a uniform key function and cosine series expansion.	21
Figure 2. The Process.xls file for calculating temporal variation.*	22
Figure 3. The Inputs and Projections tab page from the Power.xls file.*	23

LIST OF TABLES

Table 1. The level of population change that can be detected using distance sampling and pellet surveys (for HAFE only).....	3
Table 2. Percent of park area covered by following existing roads for distance sampling.	7
Table 3. Projected and actual transect route lengths.	7
Table 4. Hours needed to complete Distance Sampling for each park.	15
Table 5. Estimated costs of scenario A. ^a	15
Table 6. Estimated costs ^a	20

ACRONYMS

ANOVA

ANTI Antietam National Battlefield

CATO Catoctin Mountain Park

CHOH Chesapeake & Ohio Canal National Historic Park

CV

EAC

GIS Geographic Information System

GPS Global Positioning System

GREE Greenbelt Park

GWMP George Washington Memorial Parkway

HAFE Harpers Ferry National Historic Park

MANA Manassas National Battlefield

MONO Monocacy National Battlefield

NACE National Capital Parks-East

NCR National Capital Region

NCR National Capital Region

NCRN National Capital Region Network

NPS National Park Service

PISC Piscataway Park

PRWI Prince William Forest Park

ROCR Rock Creek Park

SOP Standard Operating Procedure

VAFO Valley Forge National Historical Park

National Capital Region Network White-Tailed Deer Density Monitoring Protocol

1. DEER MONITORING OVERVIEW

1.1 RATIONALE FOR MONITORING DEER

In 1981 Catocin Mountain Park (CATO) became the first park in the National Capital Region (NCR) to recognize overpopulation of deer as a resource issue (URS Corporation 2004). Concerns were expressed that an unregulated deer population might bring about a long-term decline in both the abundance and diversity of native plant species (USDI-NPS 2000). The park noted the loss of tree regeneration and herbaceous plants (USDI-NPS 2000). Langdon (1985) found that among the direct impacts were

- the loss of mountain laurel (*Kalmia latifolia*) from stands that occurred on the eastern ridge of the park, and
- browsing of white pines (*Pinus strobus*) so that all saplings accessible to deer were severely damaged or dead.

DeCalesta (1997) summarized the effect of deer overpopulation on forested ecosystem processes (tree regeneration) and forested communities in northwest Pennsylvania (loss of shrub and herbaceous plant species along with a reduction in avian species that relied on plant cover from a height interval of 0 to 7.6 meters). Horsley et al. (2003) found that plant species avoided by deer or resilient to deer browsing (ferns, grasses, and sedges) showed positive linear trends with increasing deer density in managed stands of hardwood forests. These species may have indirect effects on plant-plant interactions and on wildlife habitat quality for small mammals, birds, and deer (Horsley et al. 2003). Deer may also facilitate the spread of exotic plant species such as garlic mustard (*Alliarda petiola*) by removing competitors and through exposing the soil and seedbed by trampling (Kalisz 2003).

National Park Service (NPS) *Management Policy 4.4.2* for active management of native plants and animals allows for management the following criteria are met:

1. when the concentration of a population are unnaturally high or low as a result of human influences
2. when it is not possible to mitigate the effects of the human influences
3. when there is a need to protect rare, threatened and endangered species
4. when such actions meets specific park management objectives (USDI-NPS 2001). Tilghman (1989) stated that deer densities exceeding 16 deer/square kilometer (40 deer/square mile) would be considered an overpopulation. Every park in the National Capital Region Network (NCRN) currently exceeds this density limit.

1.2 SPECIFIC MONITORING OBJECTIVES

Given the evidence that deer can reduce tree regeneration, and decrease plant species diversity and nesting cover for ground-nesting birds, deer density data are needed to establish trigger points for implementing management practices to control the deer population when it exceeds desired capacity. Deer density data will be used to document trends in deer population density and in correlation analyses with forest health monitoring (Augustine and Jordan 1998). Each park will have to decide the deer density that prevents the park from achieving its mission.

By applying the standard distance sampling methodology presented in this protocol, we can detect a 10% upward or downward trend within 5 years (Dr. Brian Underwood, USGS-BRD, pers. comm.). In parks where distance sampling cannot be implemented because of limited access, pellet counts will be used.

1.3 RATIONALE FOR DISTANCE SAMPLING

Distance sampling is a reliable analytical method for estimating population densities (Buckland et al. 2001; Thompson et al. 1998), and has been used for estimating deer densities on public lands in North America (Underwood et al. 1998). Distance sampling is conducted by an observer who travels along a transect and records the distance to all detected objects of interest. The method allows for a proportion of objects within a distance x of the line to be missed. Unbiased estimates of density can be obtained from the distance data if three assumptions are met:

1. objects on the line or point are detected with certainty
2. objects are detected at their initial location
3. distance measurements are exact (Buckland et al. 2001, Thompson et al. 1998, Underwood et al. 1998).

A problem with distance sampling in past surveys has been using roads and trails as the transect. Recent research and discussion concerning a curved line transect has alleviated many of the conflicts; however, using roads and trails still carries the risk of bias from unrepresentative sampling of available habitats (Buckland et al. 2001; Hiby and Krishna 2001). To decrease the potential bias, transects have been established to maximize coverage of the park area. Buckland et al. (2001), however, state that few studies have attempted to verify whether the resulting density estimates are unbiased for the wider study area. Pellet-group surveys were conducted in fall 2004 at several NCRN parks to test the effect of roads on deer densities. Specific parks are mentioned in the Site Selection, Sampling Frequency, and Replication sections.

Using data from 1999–2003 and using the calculations described in the data analysis section below, table 1 shows the percent change in population that can be detected by this monitoring protocol.

Table 1. THE LEVEL OF POPULATION CHANGE THAT CAN BE DETECTED USING DISTANCE SAMPLING AND PELLET SURVEYS (FOR HAFE ONLY).

Park	2003 Deer Density (per sq km)	2003 Standard Error	Annual Level of Detectable Change (%)	Number of Years Surveyed
ANTI	49.8	10.3	81	3
CATO	74.5	5.6	7	4
CHOH	39.9	7.7	55	3
GWMP	35.2	7.1	74	3
MANA	73.5	11.5	6	4
MONO	63.5	17.7	41	3
NACE (GREE)	51.6	9.1	170	3
NACE (PISC)	69.8	10.0	113	3
PRWI	17.8	3.4	607	3
ROCR	38.0	6.6	41	4
HAFE	32.0	6.1	87	4

Notes:

ANTI = Antietam National Battlefield

CATO = Catoclin Mountain Park

CHOH = Chesapeake & Ohio Canal National Historic Park

GWMP = George Washington Memorial Parkway

HAFE = Harpers Ferry National Historic Park

MANA = Manassas National Battlefield

MONO = Monocacy National Battlefield

NACE (GREE) = National Capital Region – East (Greenbelt Park)

NACE (PISC) = National Capital Region – East (Piscataway Park)

PRWI = Prince William Forest Park

ROCR = Rock Creek Park

Most parks will be able to meet the goal of being able to detect a 10% change within 5 years. Slight improvements in sampling variation, such as lowering the CV, along with an additional year of sampling, can reduce the detectable change by 30%–50%.

1.3.1 ALTERNATIVE METHODS CONSIDERED BUT DROPPED – AERIAL INFRARED SURVEYS

Infrared helicopter surveys have been used to determine deer densities at Valley Forge National Historical Park (VAFO), ROCR, and GWMP. The surveys, however, did not work well and were relatively expensive at \$1.50/acre (Mike Coffey, NPS Wildlife Program Manager, pers. com.; Bert Frost, NPS Great Basin CESU Coordinator, pers.

com.; John Karish, NPS Mid-Atlantic Region Natural Resources Officer, pers. com.). Experienced observers who could tell the difference between a deer and a raccoon were difficult for the company (EAC of Minneapolis, MN) to train and retain. Haroldson et al. (2003) found that infrared deer detection rates in a Missouri forest ranged from 31% to 89%. They stated that variability in detection rates was attributed to inconsistent sensor operation and variable thermal contrast between deer and background objects.

1.3.2 ALTERNATIVE METHODS CONSIDERED BUT DROPPED – MARK AND RECAPTURE SURVEYS

Mark and recapture surveys have also been used frequently to estimate population densities. The effectiveness of marked subsample methods, however, depends on the sampling intensity and 'recapture' (resighting) success, which is likely to be very low within heavily forested parks. The most optimistic scenario within NCR would be to use a park with the smallest population (ROCR estimated 250 animals from distance surveys conducted from 2000–2002) and capture 3% (8 deer), mark them, and conduct enough spotlight surveys to achieve a pre-specified level of precision. To safely capture and mark 8 deer would require a minimum of 3 people. Kilpatrick et al. (1997) calculated a mean of 4.4 hours to capture and mark deer from platforms and vehicles at night. This means that it would take roughly 36 hours at a minimum to capture and mark 8 deer. That translates into a minimum of 3 weeks of capture effort, assuming 3 hours per night devoted to the operation. It also assumes that marked deer were captured using a systematic procedure so that all marked deer did not come from the same section of the park. Once this has been completed, if the desired precision is 50% of the marked population to be resighted, with at least 3% of the population marked, 17 spotlight surveys would have to be undertaken. Even at a precision of 30%, at least 10 surveys would have to be carried out. The equipment and manpower costs to reach this level of precision exceed the current distance surveys by several magnitudes.

Buckland et al. (2001) recommended a sample size n of 60-80, though they state that as few as 40 may be adequate for some purposes. Data from NCRN surveys have shown that even when only half of the required observations have been collected, distance has been proven to be robust. Examination of distance detection probability in NCR parks during the fall of 2002 shows a range from 47% to 64%. Most of these surveys were carried out over three nights with a CV of less than 20%. It is doubtful that a marked subsample survey would achieve that level of precision over three nights in a forested park. Also, where deer are observed in the more open battlefield parks, longer distances would make it difficult to observe the marks on an individual deer.

1.3.3 ALTERNATIVE METHODS CONSIDERED BUT DROPPED – FIXED-AREA (STRIP) TRANSECTS

Fixed-area (strip) transects have been used extensively to estimate deer density and have been used at MANA since 1999. Fixed-area spotlight transects, however, are inaccurate because they do not account for deer missed or deer that were counted even though they were located outside of the strip transect (Buckland 2001; Burnham and Anderson 1984; Caughley and Sinclair 1994). For example, an object well beyond the

visible distance that marks the end of the transect, as judged by an observer from the point of closest approach along the line, might be easily visible to the observer from other points along the line. Assessment of the visible distance is often subjective and prone to bias. Fixed-area transects also require annual adjustments to the maximum distance that can be seen by the observer. Distance surveys account for missed observations (Buckland et al. 2001).

1.4 RATIONALE FOR PELLET-GROUP COUNTS AS AN ABUNDANCE INDICES

For parks without an adequate road system in place for distance surveys and with study areas located more than 300 meters from a road, pellet-group counts are a reliable and systematic method to assess deer populations. Pellet-group counts have been used to calculate deer density since the 1940s (Bennett et al. 1940). The critical assumption is that the relationship between observed amount of scat and animal abundance is constant. The most recent study (Fuller 1991) compared pellet counts with estimates of deer density from aerial surveys over a 5-year study and found poor correlation of the index with the survey estimates. White (1992) questioned the basis for this inference and noted that the statistical power of Fuller's test was very low. Despite the problems inherent with pellet-group counts, peer-reviewed journals continue to publish them (Augustine and Jordan 1998) and they are being used by other researchers in NCRN (W. McShea, Smithsonian Institution, pers. comm.). The detectable percent change in population abundance for HAFE (87%, table 1) compares favorably with the distance sampling being used at the other parks.

1.4.1 ALTERNATIVE METHOD CONSIDERED BUT DROPPED – REMOTE CAMERAS

Remote cameras have been used to census white-tailed deer (Jacobson et al. 1997). If the photos can be used to identify individual deer by some type of distinctive mark (e.g., antler, ear tag, collar, etc.) it is possible to use the Lincoln-Petersen index to estimate abundance. Jacobson et al. (1997) placed one camera per 65 hectares. Better coverage would be one camera per 20 hectares (48 acres). Maryland Heights (HAFE) is 293 hectares so about 17 cameras would be required (two for backup). Seventeen cameras (\$200 each) would cost \$3400. One camera would require at least two rolls of film per week. Assuming that the camera survey would run for four weeks, 40 rolls of film would have to be purchased for \$120 (\$3.00 per roll). Bulk 9v battery cost would be \$30. Jacobson et al. (1997) generated a mean of 3,000 photographs during their 2-year study using 49 cameras. Camera surveys were conducted in February of both years. It can be assumed that HAFE would generate over 300 photographs in one month. Assuming \$8.00 per developed roll (24 exposures), it would cost \$104 to develop the exposures ($300 \text{ photos} / 24 \text{ exposures} = 12.5$; $12.5 \times \$8.00 = \$104$). Cameras would have to be placed along deer trails. Assuming that no extra costs or time would be incurred in a marking operation, antler characteristics would have to be used to estimate the population. Total material costs would then be \$3,654. The only material cost for pellet-group counts was for the rebar and paint to mark the plots. Additional time and costs would have to be used to check camera operations twice a week and analyze the photographs.

2. STANDARD OPERATING PROCEDURES – DISTANCE SAMPLING

The following sections provide the Standard Operating Procedure (SOP) for distance sampling. The SOP covers sampling design, field methods, data management, data analysis and reporting, administration, and sampling schedule. Changes to the SOP are provided in revised versions of the protocol. The changes are tracked in appendix A.

2.1 SAMPLING DESIGN

Survey routes for nine NCRN parks were established in 2000 and 2001 during a pilot study with the assistance of Dr. Brian Underwood, USGS (see maps at the end of this document). Survey routes were established along roads and trails within NCRN parks. Routes were established in order to survey at least 10% of the total park area or an area in which inference is to be made. The 10% figure was recommended by Dr. Underwood. The length of each route was multiplied by the mean perpendicular distance to each deer group (as calculated by program distance). This was divided by total park acreage to estimate the sampling area of each park (table 2):

Since documentation is lacking for the minimum 10% sampling area, another measure of adequate transect length is the formula

$$L = (b/CV_D^2) * (L_i/n_i)$$

where

L = estimated line length required

b = 1.5, and

L_i/n_i = ratio of line length and deer observed in a preliminary sample (Buckland et al. 2001). Burnham et al. (1980) warned that the value of 1.5 for b may underestimate the line length needed to achieve the required precision.

Table 3 shows the results of the formula using data from 2001 (the first NPS survey), assuming a CV of 20%. Data were not available for ANTI or MONO.

Five of the parks below would seem to need longer transect lengths; however, none have a mean CV over 20%. The above-mentioned pellet-group counts should be implemented in these five parks to verify distance estimates.

Table 2. PERCENT OF PARK AREA COVERED BY FOLLOWING EXISTING ROADS FOR DISTANCE SAMPLING.

Park	Area Covered by Distance Sampling (percent)
ANTI	17.9
CATO*	5.2
CHOH	33
GWMP*	7.3
MANA	12.2
MONO	28.1
NACE (GREE)*	9.4
NACE (PISC)	19.4
PRWI*	2.6
ROCR	11.5

* CATO, GREE, GWMP and PRWI have area calculations of less than 10%. Considering the small size of most NCR parks it is not difficult to assume that the densities found in the sampled areas are representative of the entire park. Pellet-group surveys will be conducted at CATO, PRWI, and GREE during the fall of 2004 in order to test the assumption that the distribution of deer is not affected by roads. (A 33-plot survey of pellet-groups in CATO conducted in October-November 2004 indicated a density of 128/square mile. The Distance estimate was 105/square mile. There was no correlation with distance to the nearest point on the transect route and pellet-group abundance, indicating that deer distribution in the park may be independent of roads).

Table 3. PROJECTED AND ACTUAL TRANSECT ROUTE LENGTHS.

Park	Projected Line Length	Actual Line Length	Mean CV (2001–2004)
CATO	8.75	14	8.4
CHOH	1.9	8.9	15.4
GWMP	11.5	6	15.7
MANA	5.5	12	13.0
NACE(GREE)	10	5	17.4
NACE (PISC)	9.7	6.5	15.6
PRWI	42	25.6	13.6
ROCR	23	16	13.3

2.2 FIELD METHODS

2.2.1 SURVEY TIMING

Distance surveys are conducted between the time of the first leaves falling from the trees (first week of October) and before deer firearms season begins in Maryland and Virginia (Thanksgiving).

2.2.2 SURVEY SEQUENCE

Parks with more open landscapes (PISC and MANA) are surveyed first because leaf drop is minimal in early October and most deer at these parks are seen in open areas. The survey order for the remaining parks is selected randomly. CATO surveys are conducted in late October – this has been the practice since 1989.

2.2.3 SURVEY FREQUENCY

Surveys are conducted for three consecutive nights. Exceptions to the consecutive night schedule occur when surveys are postponed due to ambient conditions or reasons of personal safety (i.e., heavy traffic). Additional surveys will be added when the coefficient of variation associated with the number of deer groups encountered after three nights of sampling exceeds 20 % or if the detection probability variation exceeds 25% (see Data Analysis). The CV and the detection variation do not have to be calculated until the third survey has been completed. They are recalculated after each subsequent survey until the above-mentioned criterion is satisfied.

2.2.4 SURVEY METHODOLOGY

Spotlighting equipment is assembled and checked at least two weeks prior to beginning the surveys. 600-volt marine grade cable is used to conduct current from the vehicle battery to the spotlights. Miniature battery clamps are spliced onto the cable. The red clamp is attached to the red (positive) battery post. The black clamp is attached to the black (negative) battery post or to a bare metal surface that provides grounding. A 20-volt fuse within a fuseholder is spliced onto the wiring of the red clamp. A 12-volt receptacle is spliced onto the other end of the cable. An adapter is used to connect the spotlights to the receptacle. The male connector is plugged into this receptacle while the spotlight connections are plugged into the female connectors.

Laser rangefinders are also checked for operability and battery life at this time.

Ambient conditions should meet minimum standards (Wind: < 19 mph; Rain: < heavy; Visibility: > 2 miles; Temperature: > 35 degrees Fahrenheit) as reported from the nearest official National Oceanographic Atmospheric Administration weather data site (www.weatherunderground.com) prior to the start of each survey. Surveys will be postponed if ambient conditions are believed to have exceeded minimum standards during the survey.

Surveys begin no earlier than 30 minutes after sunset. A minimum three-person crew is required to execute the survey: a driver (data recorder) and two observers. Survey routes are driven at speeds ranging from 6–10 mph. Initial starting points along the route are varied, where possible, in order to reduce temporal bias; reversing routes from one night to the next is an option. Observers use handheld spotlights to illuminate the habitat on both sides of the transect; each observer focuses attention to one side of the transect. Upon detection of a deer, the observer directs the driver to position the vehicle such that the perpendicular (90 degree angle to the transect) distance can be measured. Because the transect is curved, more than one perpendicular distance may be available; the shortest perpendicular distance should be measured (Hiby and Krishna 2001). In cases where a perpendicular distance is not possible, a radial distance may be measured. When measuring a radial distance, using a handheld compass, the bearing of the transect and white-tailed deer location is obtained. The radial distance is then multiplied by the sine of the angle (the difference of the bearing measurements) to obtain the perpendicular distance. In all instances, the distance measured should be to the initial location of the deer prior to any movement. The distance is measured utilizing a laser rangefinder. The distance measured should be to an individual deer or, in the case of a group of deer, to the deer closest to the center of a group. In order to detect deer directly on the transect, the driver is required to observe groups of deer on the transect line and record their distance, if any, from the transect line.

Deer are categorized by group size (e.g., individuals are a group of one and five deer is a group of five). Deer are partitioned into groups by using behavioral cues and by using the nearest neighbor criterion (LaGory 1986). Deer that repeatedly look back at each other can be counted as a group. Additionally, if an individual deer is less than half the distance from the closest deer than it is from its next nearest neighbor, then that individual deer is counted as part of a group. When large groups of deer are seen in open fields, group classification will be attempted prior to positioning the vehicle for a distance measurement in order to minimize a flight response due to vehicle presence. In cases where the deer flee, the observer notes the initial location of the group and a distance measurement is obtained to the location of first detection.

Data are recorded on a standard Deer Distance Sampling Datasheet (appendix B). Demographic classification is collected only when bucks, does, and fawns can be clearly identified; 'unknown' is the demographic classification default.

2.3 DATA MANAGEMENT

All data are entered into standard data sheets (appendix B). Data are entered into a database at the end of each day in the field. The Deer Database is based on the NPS Inventory and Monitoring (I&M) Database Template which includes three levels of tables: Locations, Events, and Deer Data. All staff should be familiar with the SOP for Data Entry prior to the start of data collection.

2.3.1 DATA FIELD DEFINITIONS***Locations Table***

Location ID –

Park Name: Record the name of the park (e.g., Antietam, Catoclin) and the park sub-unit, as appropriate (e.g., NACE – Greenbelt). Global Positioning System (GPS) points for each end point of the survey route.

Events Table

Event ID –

Date: Record month, day, and year of the survey (e.g., 10/15/2005).

Start Time: Record the time (military) the survey was started.

Start Location: Record the location of the starting points (e.g., corner of Manahan and Park Central, or Turkey Run Office).

Wind: Record as indicated by use of a wind meter, in whole numbers.

Sky Code: Record the sky code as follows:

0 = Clear or few clouds	5 = Showers or light rain
1 = Partly cloudy or variable	6 = Heavy rain
2 = Cloudy or overcast	7 = Sleet or hail
3 = Fog	8 = Snow
4 = Mist or drizzle	

Temperature: Record the temperature in Fahrenheit, 1 meter above the ground.

Moon: Record the current phase of the moon as Full, New, First Quarter, Last Quarter, Half.

Observers: Record the full name of both people conducting the survey.

Recorder: Record the full name of the person filling out the data sheet.

Deer Data Table

	Record #
Distance:	Record the distance in meters (whole number) from the observer to the group of deer.
Angle:	Record the acute angle from the transect to the deer (default is 90°).
Number in Group:	Record the total number of deer comprising the individual group.
Number of Bucks:	Record the number of male deer within the group.
Number of Doe:	Record the number of female deer within the group.
Number of Fawn:	Record the number of fawns within the group.
Number Unknown:	Record the number of deer of unknown gender and age within the group.
Notes:	Record ancillary data of interest for which no space is provided. Include other species observed.

2.4 DATA ANALYSIS

Data are analyzed using Program Distance (Thomas et al. 2003). Distance provides estimates of density with well-defined confidence intervals. Minimum data required are the dates of survey, park area, transect length, number in group, and distance.

When all of the data have been input (manually or from Access), the user will enter the input section of the analysis browser to select the number of distance intervals. For the initial analysis it is standard to automatically divide the distances into 10–12 equal intervals. Once this has been done, the user will define the model by selecting a combination of key functions and series expansions. Conceptually, the detection function $g(y)$, the probability of detecting an object, given that it is at distance y from the random point or line) is modeled in the following general form: $g(y) = \text{Key}(y)[1+\text{series}(y)]$ (Buckland et al. 2001). The model is used to analyze the detection function, which is closely linked to density. The key functions are half-normal, uniform, hazard-rate, and negative exponential. Selection of a key function is dependent on the shape of the histogram of distance intervals. The negative exponential model, where there is a sharp drop in detection probability close to the transect line, has never been selected as the best model. The uniform key function (where detection is constant with increasing distance) is usually not the best model. The half-normal key function, where the 0.50 probability of detection is equal to half the maximum distance interval, is a bit more common. The hazard rate model has been selected as the best fit most often because it

has a marked shoulder that can be nearly flat for some distance from the line or point. This is because most of our distance histograms have many detections for the first 40 meters and then there is a drop off.

The user then selects the series expansion (cosine, simple polynomial, hermite polynomial) to improve the fit of the model to the distance data.

Whichever key function is chosen, the first objective is to obtain a smooth histogram of distance intervals that decrease in size with increasing distance (detection probability plot). Intervals can be expanded, narrowed, or dropped from the analysis to produce a smooth shoulder (figure 1) as the distance from the observer to the deer increases. Once a satisfactory shoulder is produced, the four key functions and series expansions are used to create models to fit to the data. The four criteria used to choose the best fit are:

1. percent coefficient of variation (CV) less than 20
2. the detection probability variation less than 30%
3. Goodness-of-fit probability of finding a better model <0.2
4. lowest Akaike's Information Criterion (AIC) score. Program Distance calculates all four measures.

The user can select the best model or average the density from all of the models that are run to determine density. When the best fitting model has been selected, the analysis ID number should be noted in the file properties box for future reference. The 95% confidence interval, standard error, CV will also be generated for reporting purposes.

2.4.1 SEX RATIOS

The sex ratios are defined as buck:doe and fawn:doe. The buck:doe ratio is calculated by dividing the number of does seen by the number of bucks seen. For example, 40 does divided by 10 bucks is expressed as 1 buck: 4 does.

The fawn:doe ratio is expressed as the number of fawns per doe. In 2003 at Greenbelt, the surveys produced 51 does and 32 fawns. Divide 32 by 51 = 0.63 fawns per doe.

2.4.2 POWER TO DETECT A TREND

Section 1.2.1. states that our monitoring goal, recommended by Dr. Underwood, is to be able to detect a 10% change in population after 5 years of monitoring. Dr. Underwood provided NCR with several programs to do this. They are in a file called nrexcel. The nrexcel folder is opened (with the Excel add-in program PopTools). There are four files within this folder (Process.xls, Power.xls, Lndata.xls, and Ttests.xls).

The Process file partitions the variation into sampling variation and process variation. This is done because typical ANOVA procedures do not account for the fact that sampling variance is usually a function of population size (Thompson et al. 1998). The

sampling variation is the variation among plots in a sampling frame and the incomplete counts within those plots. The process variation is the temporal and spatial variation affecting animal numbers and distribution.

The Power file uses the information from the Process file to calculate the total CV.

The Monte Carlo module within the Power file has never worked so Gerrodette's (1991) online Trends program is used to calculate power (<http://swfsc.nmfs.noaa.gov/PRD/software/Trends.html>). Since Trends does not account for temporal variation, the Process and Power files are used to derive the final CV for Trends.

The t-test file can be used to test for significant differences between surveys but is not used in calculating power.

2.4.3 COEFFICIENT OF VARIATION

The Process file is opened (figure 2). For each park all of the previous years of density and density coefficient of variation calculated by Distance are entered. Density means are entered under the xbar column and coefficient of variation into the CV column. It is important to adjust the formula values for the number of survey years, e.g., for each new survey there will be an additional value in the column. When values have been calculated for cells E11-J11 and N18-19, the next step is to change the value in cell F13 until the value in cell J13 is equal to 1.00. The final products desired from this program are the temporal coefficient of variation (process variation, cell B34), CV_T , and the process:sampling (P:S) variation ratio (cell B33). The reciprocal of this ratio is used in the Power file because what is needed is the sampling variation as a multiple of the process variation.

The Power file is opened (figure 3). The process variation (temporal variation, CV_T), and the reciprocal of the P:S (cell B:33 in figure 2) are entered. The initial survey density is also entered, along with the growth rate (desired minimum rate of change to detect = 0.1). The program will then calculate the total coefficient of variation (CV_{P+S} , as shown in figure 3). This CV is entered into Trends, which is set to solve for power. You must also enter the number of survey years, rate of change per time step (0.1), and significance level (0.1).

2.4.4 MINIMUM DETECTABLE RATE OF CHANGE

It is also possible to use Trends to calculate the minimum detectable rate of change (see Level of Change in table 1). Select for Trends to solve the rate of change per time step. Enter the rest of the data as outlined above. For power, enter 1- power. For example, if CATO's power is 55%, $1-55 = 45$. Otherwise the parks with the highest power will have the highest minimum detectable rate of change. Our objective is to be able to detect a 10% change within 5 years of the initial survey.

2.5 REPORTING SCHEDULE

Annual reports will follow the outline in the I&M Annual Reports SOP. The Annual Report will present the results of the density analysis and power analysis presented above.

Every 3–5 years, an Analysis and Synthesis Report will be generated to review population trends. See SOP Analysis and Synthesis Report for details.

2.6 ADMINISTRATION/IMPLEMENTATION OF THE MONITORING PROGRAM

2.6.1 PERSONNEL

Distance sampling requires at least three field personnel. One to drive and record data and two to make deer observations and measure distances.

Project Lead – The project lead ensures that the protocols are followed appropriately and provides training to assistants. The lead is also responsible for data entry, verification and validation as well as analysis and reporting, and data archiving.

Field Assistant (2) – The project lead requires two assistants. Assistants can be Bio-Technicians, volunteers, or park staff. Any assistant will be given training from the Project Lead on deer identification, equipment use, and data recording.

2.6.2 EQUIPMENT NEEDS

One 4 × 4 pick-up truck	Available from Center for Urban Ecology
One datasheet (per survey; appendix B)	NA
One Survey Route Maps (appendix C)	NA
One clipboard	\$10.00
Two laser rangefinders	\$800.00
Two compasses	\$100.00
Two 1-million candlepower spotlights	\$150.00

To power the spotlights, a cigarette adapter may be used or the spotlights can be powered from the vehicle battery by utilizing:

One 12-volt adapter

One 12 foot, 600-volt marine grade electrical cable

One 20-volt fuse

One fuse holder

Two battery clips

Total Equipment Costs	\$1060.00
-----------------------	-----------

2.6.3 BUDGET CONSIDERATIONS

Personnel hours are estimated in table 4. Various personnel scenarios may be applied.

Table 4. HOURS NEEDED TO COMPLETE DISTANCE SAMPLING FOR EACH PARK.

Park	Survey Hours	Personnel	Number of Hours	Number of Days	Total Hours
CATO	5	3	15	4	60
CHOH	3	3	9	4	36
GREE	2	3	6	5	30
GWMP	3	3	9	4	36
MANA	4	3	12	3	36
PISC	5	3	15	4	60
PRWI	5	3	15	8	120
ROCR	3	3	9	4	36
Total	30	3	90	36	414

Note:

Columns 1 and 2 are multiplied to produce column 3. Columns 3 and 4 are multiplied to produce column 5.

SCENARIO A—One scenario is to fill the Project Lead with a GS-7 Bio-Tech along with two GS-5 Bio-Technicians to assist (table 5).

Scenario B—Costs will vary depending on the availability of park staff or volunteers to assist field work. During 200-2003, CHOH, GWMP, GREE, PISC, and MANA have been able to supply enough personnel for the surveys. They may be able to continue assisting the NCR wildlife biologist who has served as Project Lead. This scenario would have zero personnel costs to the I&M program.

In addition to personnel costs, equipment costs for replacing worn or defective items and gas should be at least \$1000.00 annually.

Table 5. ESTIMATED COSTS OF SCENARIO A.^a

Technician	Hours Needed ^b	Cost (per hour)	Total Cost
GS-7/Step 5	300	15.87	4761.00
GS5/Step 5	200	14.99	2998.00
GS5/Step 5	200	14.99	2998.00
Total			10,757.00

Notes:

- a. Estimates based on 2004 General Schedule Salary Table for Washington DC.
- b. Extra hours were added to estimate training and material set up.

3. STANDARD OPERATING PROCEDURES — PELLET-GROUP COUNTS (HAFE ONLY)

The following sections provide the SOP for pellet-group counts. The SOP covers sampling design, field methods, data management, data analysis and reporting, administration, and sampling schedule. Changes to the SOP are provided in revised versions of the protocol. The changes are tracked in appendix D.

3.1 SAMPLING DESIGN

Pellet-group plots were established at HAFE in the Fall of 2000. Plots were established in the Maryland Heights, Elk Run, Loudon Heights, and Short Hill sections of the park. The sample size, as determined from Davis (1982), was one plot per fifteen acres of area. Plot locations were randomly located on slopes of less than 25% in order to avoid establishing plots on steep rocky terrain where deer were unlikely to be found (appendix E). Forty-two plots were established at Maryland Heights, the section of the park where resource personnel suspected deer overpopulation. This met Gibbs (2000) criteria for establishing enough plots to detect a 10% change at $p = 0.05$ with a likelihood of >0.95 if surveys are conducted for 10 years given the fact that there is one annual survey at Maryland Heights. Since the regional timeframe is five years instead of ten, the number of plots will be doubled in 2004. Plots are 22 meters long by 4 meters wide, as recommended by Davis (1982). Each plot contains an area of 88 square meters or 0.02 acres. Plot corners were marked with 18-inch long rebar sunk to a depth of six inches and spray-painted orange to increase the likelihood of relocating the plot.

3.2 FIELD METHODS

3.2.1 SURVEY TIMING

Surveys begin after leaf-off and continue for 90 days. Recommended dates for surveys, established during previous surveys at Harpers Ferry, begin in mid – November and conclude in March.

3.2.2 SURVEY SEQUENCE

It is critical that plots are monitored within a set time (i.e., 90 days), and, therefore, only the number of plots that can be monitored in a single day should be cleared in a single day. Unless work is to be conducted on weekends, a calendar should be used to determine the day of the week on which the 90-day interval will fall.

3.2.3 SURVEY FREQUENCY

All sampling plots must be surveyed annually.

3.2.4 SURVEY METHODOLOGY

After leaf-off, remove all deer pellets (feces) from the top of the leaf litter in each plot. It is not necessary to dig through the leaves. Record the date the plot is cleared of deer pellets. Deer pellets are typically oblong and usually have a tip at the end; deer pellets resemble Raisinets and are often confused with rabbit pellets, which are round and resemble M&M's. All plots will be monitored 90 days post-pellet removal.

From 2001-2003, only one park employee was available to check the plots. This led to a range of post-pellet removal intervals (usually 3–5). This added another layer of complexity to the calculations since the intervals had to be tested for significant differences. Only in 2003 was an interval dropped from the analysis because of a significant difference. In order to facilitate the use of a 90-day interval, starting in 2004, milacre plots (1/1000 acre radial circles) will be used instead of the rectangular plots. The circle will be located within the center of the original rectangular plots.

Data are recorded on a standard datasheet for the Deer Pellet-Group Survey (appendix F). The name of the park, plot number and GPS location, the date the plot was cleared of pellets, the date the plot was monitored, and names of the observers and data recorder are noted.

3.3 DATA MANAGEMENT

Data are entered into an Access database at the end of each day in the field (appendix G). The database is based on the NPS I&M Database Template that includes three levels of tables: Locations, Events, and Deer Data. All staff should be familiar with the SOP for Data Entry prior to the start of data collection.

3.3.1 DATA DEFINITIONS

Locations Table

Location ID – HAFE001, HAFE002

- | | |
|------------------|---|
| Park Name: | Record the name of the park (e.g., Antietam, Catoctin) and the park sub-unit, as appropriate (e.g., NACE – Greenbelt, GWMP – Turkey Run). |
| Location Number: | Record the assigned number for the specific sampling point. <ul style="list-style-type: none"> • GPS N: Record the North waypoint coordinate displayed on the GPS unit. • GPS E: Record the East waypoint coordinate displayed on the GPS unit. |

Error:	Record the error for the location displayed on the GPS unit.
Date Established:	Record the month, day, and year in which the plot was cleared of deer pellets (e.g., 11/15/2005).
	If multiple plots per location we could establish a PlotID. This could also be part of a separate table.

Events Table

Date Monitored:	Record the month, day, and year in which the plot was monitored for deer pellets (e.g., 02/13/2005).
	Observer

Deer Data Table

	Record #
Total Number of Pellet-groups:	Record the total number of pellet-groups identified within the plot.
Habitat:	Place an "x" next to the habitat description that best describes the surrounding habitat.
Notes:	Record ancillary data of interest for which no space is provided.

3.4 DATA ANALYSIS

The calculations for determining density are straightforward and can be found in Davis (1982, p. 354–356). Whatever plot size is used, the calculations are as follows:

1. Determine the mean number of groups per plot.
For example, 6.63 groups were found per plot at MD Heights (HAFE) in 2002.
2. Determine the mean number of groups per unit area.
 $6.63 / 0.02 \text{ acres (from section 3.1)} = 331.5 \text{ groups/acre}$
3. Determine the total number of groups within the area of interest.
 $331.5 \times 787 \text{ acres in MD Heights} = 260,890 \text{ groups}$
4. Divide the total number of groups by the daily defecation rate (22.3) to obtain the number of deer days. The winter defecation rate is from Rogers (1987).
 $260,890 / 22.3 = 11,699.12 \text{ deer days}$
5. Divide the number of deer days by the interval of days between clearing the plot and checking the plot. This will give the number of deer.
 $11,699.12 / 96 \text{ days} = 121.86 \text{ deer}$

6. For density calculations the number of deer will be adjusted by the total area of interest. For example, Maryland Heights is 1.22× the area of a square mile (640 acres). The total number of deer is divided by 1.22 to give a density per square mile.

$$121.86/1.22 = 99.88 \text{ per square mile or } 99.88/2.59 = 38.56 \text{ per square kilometer}$$

7. Confidence interval calculations are in Davis (1982), and are calculated by using the mean number of groups per plot, standard error, and t-table value for a 95% confidence level and associated degrees of freedom (number of plots minus 1). With 6.63 groups per plot, a standard error of 0.92 (calculated by Systat10 using pellet count data from 2002), and a t-table value of 1.68 for $\alpha=0.05$ (38 degrees of freedom; 39 -1) the following is generated:

$$6.63 + 1.68 (0.92) = 8.17 \text{ groups per plot}$$

$$6.63 - 1.68 (0.92) = 5.09 \text{ groups per plot}$$

The groups per plot numbers are used in steps 1–6 to produce the 95% confidence interval. This produces a 95% confidence interval of 29.6–47.5 deer/square kilometer.

3.4.1 POWER ANALYSIS

For HAFE, the same methodology for calculating power is used as with Distance except for that the CV of mean number of pellet-groups per plot can be calculated by Excel or Systat 10. This CV is entered into Process.xls and the procedure described above is repeated.

3.4.2 REPORTING SCHEDULE

Annual reports will follow the outline in the I&M Annual Reports SOP. The Annual Report will present the results of the analysis and power analysis presented above.

Every 3–5 years, an Analysis and Synthesis Report will be generated to review population trends.

3.5 ADMINISTRATION/IMPLEMENTATION OF THE MONITORING PROGRAM

3.5.1 PERSONNEL

Project Lead — The project lead ensures that the protocols are followed appropriately and provide training to assistants. The lead is also responsible for data verification and validation as well as analysis and reporting, and data archiving.

3.5.2 EQUIPMENT NEEDS

- One datasheet (appendix F)
- One survey route maps (appendix C)
- One clipboard

4. BUDGET CONSIDERATIONS

The work can be completed under various scenarios.

Scenario A — It takes approximately one person 2 hours to survey each plot. At 40 plots, this requires 80 hours. With added training, data entry, and traveling to and from survey sites, at least 150 hours is needed by a GS7/Step 5 Bio-Technician (table 6).

TABLE 6. ESTIMATED COSTS^a

Technician	Hours Needed ^b	Cost per hour	Total Cost
GS-7/Step 5	150	15.87	2380.50
GS-5/Step 5 ^c	80	14.99	1199.20
Total			3,579.70

Notes:

a. Estimates based on 2004 General Schedule Salary Table for Washington DC.

b. Extra hours were added to estimate training and material set up.

c. Safety guidelines require presence of at least two field technicians.

Scenario B — The surveys have been conducted by the HAFE Resource Manager 2000–2003 and this person may be able to continue to conduct the surveys with the assistance of NCR wildlife biologist.

FIGURE 1. FALL 2003 HISTOGRAM OF ANTIETAM DISTANCE DATA USING A UNIFORM KEY FUNCTION AND COSINE SERIES EXPANSION.

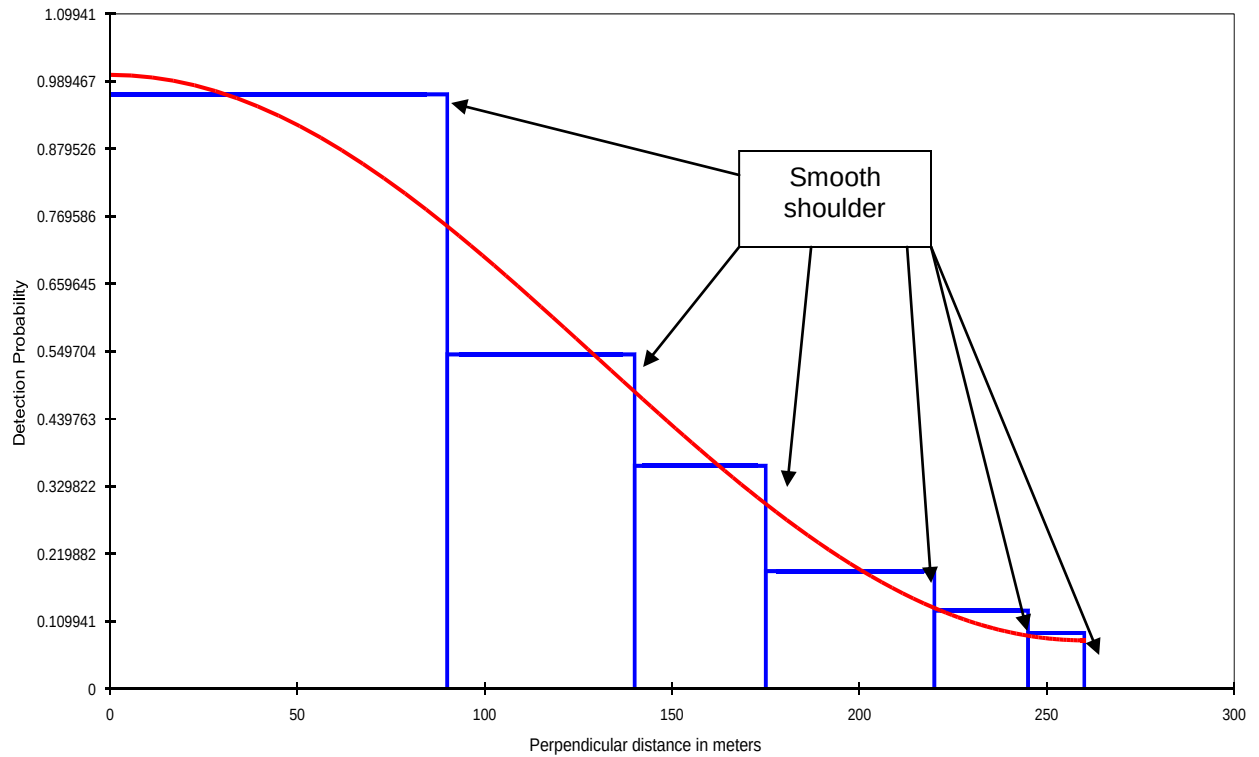


FIGURE 2. THE PROCESS.XLS FILE FOR CALCULATING TEMPORAL VARIATION.*

Estimating CV_T from a time series of deer densities.

YEAR	UNIT	XBAR	CV	VAR	1/VAR	$N_i - \text{NBAR}$	$(N_i - \text{NBAR})^2$	$1/\text{VAR} * ((N_i - \text{NBAR})^2)$	$W_i * ((N_i - \text{NBAR})^2)$
1995	K-L	79.6	29.5	550.9888	0.0018	14.7258	216.8497	0.3936	0.7855
1996	K-L	90.1	13.0	136.2620	0.0073	25.2958	639.8783	4.6959	2.3179
1997	K-L	107.1	11.3	146.0701	0.0068	42.2058	1781.3309	12.1950	6.4528
1998	K-L	74.1	14.1	109.1923	0.0092	9.2658	85.8554	0.7863	0.3110
1999	K-L	64.2	21.6	193.2527	0.0052	-0.6042	0.3650	0.0019	0.0013
2000	K-L	40.8	30.4	153.2350	0.0065	-24.0842	580.0479	3.7853	2.1012
2001	K-L	41.2	18.1	55.5903	0.0180	-23.6742	560.4670	10.0821	2.0303
Sums:				1344.5910	0.0548		3864.7942	31.9402	14.0000
				change this	0.0036			Until this number	1.0000

N =	7
NBAR =	71.0
NBAR _w =	64.8

value of W_i

Test :

192.0844

This is the average of the 36 variance

estimates, which should approximate the sampling error computed by difference below.

equals 1.0

Assuming Equal Sampling Variances:

Unweighted Analysis

$F^2_{\text{Total}} =$ 644.1324

$F^2_{\text{Time}} =$ 452.0479

%

192.084429

29.8206

This is an estimate of the sampling variance (Cell B23- Cell B24) expressed as a percentage of the total variance.

Assuming Unequal Sampling Variances:

Weighted Analysis

$F^2_{\text{Total}} =$ 468.1412

%

192.0844

41.0313

This is an estimate of the sampling variance (Cell B29- Cell B30), also expressed as

$F^2_{\text{Time2}} =$	276.0567	a	percentage of the total variance.
------------------------	----------	---	-----------------------------------

Ratio of P:S =	1.44
CV_T (%) =	25.62

* Inputs required are xbar (mean density) and density cv, year and unit (park). The formulas and number of survey year must match or the macros will not function. Data are from Fire Island.

FIGURE 3. THE INPUTS AND PROJECTIONS TAB PAGE FROM THE POWER.XLS FILE.*

Specify the Process Variation:	11.23
Specify the Sampling Variance as a Multiple of the Process Variation:	2.27
Specify the Initial Abundance (Number or Density):	15.4
Specify the Growth Rate Multiplier (or λ):	1.1
Intermediate Variables:	
Sampling Variance:	25.4921
Total Variance:	36.7221
CV_{P+S} :	0.393498

*The process variation is from cell B:34 of the Process.xls file. The sampling variance as a multiple of the process variation is from cell B:33 of the Process.xls file. The growth rate multiplier represents a annual rate of 10%. The CV_{P+S} is the total CV needed for input into Trends. Data are from Prince William (2001–2003).

5. REFERENCES

- Augustine, D.J., and P.A. Jordan. 1998. Predictors of white-tailed deer grazing intensity in fragmented deciduous forests. *Journal of Wildlife Management* 62:1076-1085.
- Bennett, L.J., P.F. English and R. McCain. 1940. A study of deer populations by use of pellet-group counts. *Journal of Wildlife Management* 4: 398-403.
- Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, New York, NY 432 pp.
- Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling in biological populations. *Wildlife Monographs* 72:1-202.
- Burnham, K.P. and Anderson, D.R. 1984. The need for distance data in transect counts. *Journal of Wildlife Management* 48:1248-1254.
- Caughley, G. and A.R.E. Sinclair. 1994. *Wildlife ecology and management*. Blackwell Science, Cambridge, MA 334 pp.
- Davis, D.E. 1987. Calculations used in census methods. Pages 344-369 in D.E. Davis, ed. *Handbook of census methods for terrestrial vertebrates*. CRC Press, Boca Raton, FL 397 pp.
- DeCalesta, D.S. 1997. Ecosystem management for deer. Pages 267-279 in *The Science of Overabundance*. (W.J. McShea, H.B. Underwood, and J.H. Rappole, eds.) Smithsonian Institution Press, Washington, DC 402 pp.
- Fuller, T.K. 1991. Do pellet counts index white-tailed deer numbers and population change? *Journal of Wildlife Management* 55: 393-396.
- Gerrard, T. 1991. Models for power of detecting trends – a reply to Link and Hatfield. *Ecology* 72:1889-1892.
- Gibbs, J.P. 2000. Monitoring populations. Pages 213-215 in *Research Techniques in Ecology*. (L. Boitani and T.K. Fuller, eds.) Columbia University Press, New York, NY 442 pp.
- Haroldson, B.S., E.P. Wiggers, J. Beringer, L.P. Hansen, and J.B. McAninch. 2003. Evaluation of aerial thermal imaging for detecting white-tailed deer in a deciduous forest environment. *Wildlife Society Bulletin* 31(4):1188-1197.
- Hiby, L., and M.B. Krishna. 2001. Line transect sampling from a curving path. *Biometrics* 57:727-731.
- Horsley, S.B., S.L. Stout, and D.S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 13(1):98-118.
- Jacobson, H.A., J.C. Kroll, R.W. Browning, B.H. Koerth, and M.H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. *Wildlife Society Bulletin* 25(2):547-556.
- Kalisz, S. 2003. National Science Foundation grant proposal. 15 pp.
- Kilpatrick, H.J., S.M. Spohr, and A.J. DeNicola. 1997. Darting urban deer: techniques and technology. *Wildlife Society Bulletin* 25(2): 542-546.
- Koenen, K.K., G. S. DeStefano, and P.R. Krausman. 2002. Using distance sampling to estimate seasonal densities of desert mule deer in a semidesert grassland. *Wildlife Society Bulletin* 30:53-63.
- LaGory, K.E. 1986. Habitat, group size, and the behavior of white-tailed deer. *Behavior* 98:168-179.

- Langdon 1985. White-tailed deer action plan. Supplement to Natural Resource Management Plan, Catoctin Mountain Park. Thurmont, MD.
- Rodgers, L.L. 1987. Seasonal changes in defecation rates of free-ranging white-tailed deer. *Journal of Wildlife Management* 51:330-333.
- Thomas, L., Laake, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Hedley, S.L., Pollard, J.H. and Bishop, J.R.B. 2003. Distance 4.1. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. <http://www.ruwpa.st-and.ac.uk/distance/>
- Thompson, W.L., G.C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, CA 365 pp.
- Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. *Journal of Wildlife Management* 53:524-532.
- Underwood, H.B., F.D. Verret, and J.P. Fischer. 1998. Density and herd composition of white-tailed deer on Fire Island National Seashore. Final Report to the National Park Service, Syracuse, New York.
- URS Corporation. 2004. Catoctin Mountain Park Deer Management Plan – Internal Scoping Report. Final Report to the National Park Service, Denver, CO. 50 pp.
- USDI-NPS. 2000. Environmental assessment of white-tailed deer management in Catoctin Mountain Park. United States Department of the Interior-National Park Service.
- USDI-NPS. 2001. Management Policies. United States Department of the Interior-National Park Service. 137 pp.
- White, G.C. 1992. Do pellet-counts index white-tailed deer population change?: a comment. *Journal of Wildlife Management* 56:611-612.

Appendix A: Distance Sampling Protocol Revision History

October–November 2000 — Drs. Brian Underwood and Frank Verret teach Distance to NCR natural resource personnel. CATO, CHOH, MANA, and ROCR are surveyed by Dr. Verret.

April–July 2001 — Dr. Frank Verret returns to finish the remaining parks plus a spring survey of CATO. Surveys were limited to 3 nights per park as called for in the contract.

October–2001/May 2003 — All fall and spring surveys are run until $CV < 25\%$ CV and detection probability variation $< 30\%$.

October 2003 — Surveys are run until $CV < 20\%$ and detection probability variation $< 25\%$.

Spring surveys are permanently cancelled. Parks were initially surveyed also in the spring from 2000–2003. Spring surveys were discontinued because: (1) Classification by sex and age is not possible because males do not have antlers and fawns are difficult to see; and (2) Spring weather patterns were less stable than fall weather patterns thereby disrupting deer behavior and encounter rates.

Sampling order was altered. In 2001–2002 the survey order was determined by random sampling (except for CATO because of their experience with doing spotlight surveys in late October since the late 1980's). The sampling order was changed so that parks with more open landscapes (PISC and MANA) can be surveyed first because leaf drop is minimal in early October and most deer at these parks are seen in open areas. The survey order for the remaining parks continues to be selected randomly. CATO surveys are conducted in late October as they have been doing since 1989.

NATIONAL CAPITAL REGION NETWORK
INVENTORY and MONITORING PROGRAM

START TIME _____ (Military) START LOCATION _____

[illegible]

NOTES

Sky Codes

0	Clear or few clouds
1	Partly cloudy (scattered) or variable sky
2	Cloudy or overcast
3	Fog
4	Mist or drizzle
5	Showers or light rain (not affecting hearing ability)
6*	Heavy rain
7*	Sleet or hail
8*	Snow

* Survey should not be conducted.

Military Time Table

Standard Time	Military Time
12 am	0000
1 am	0100
2 am	0200
3 am	0300
4 am	0400
5 am	0500
6 am	0600

7 am	0700
8 am	0800
9 am	0900
10 am	1000
11 am	1100
12 pm	1200
1 pm	1300
2 pm	1400
3 pm	1500
4 pm	1600
5 pm	1700
6 pm	1800
7 pm	1900
8 pm	2000
9 pm	2100
10 pm	2200
11 pm	2300

Appendix C: Distance Sampling Routes

Antietam National Battlefield

Catoctin Mountain Park

Chesapeake and Ohio Canal National Historical Park

George Washington Memorial Parkway

Harpers Ferry National Historical Park

Manassas National Battlefield

Monocacy National Battlefield

National Capital Park – East (Greenbelt)

National Capital Park – East (Piscataway)

Prince William Forest Park

Rock Creek Park

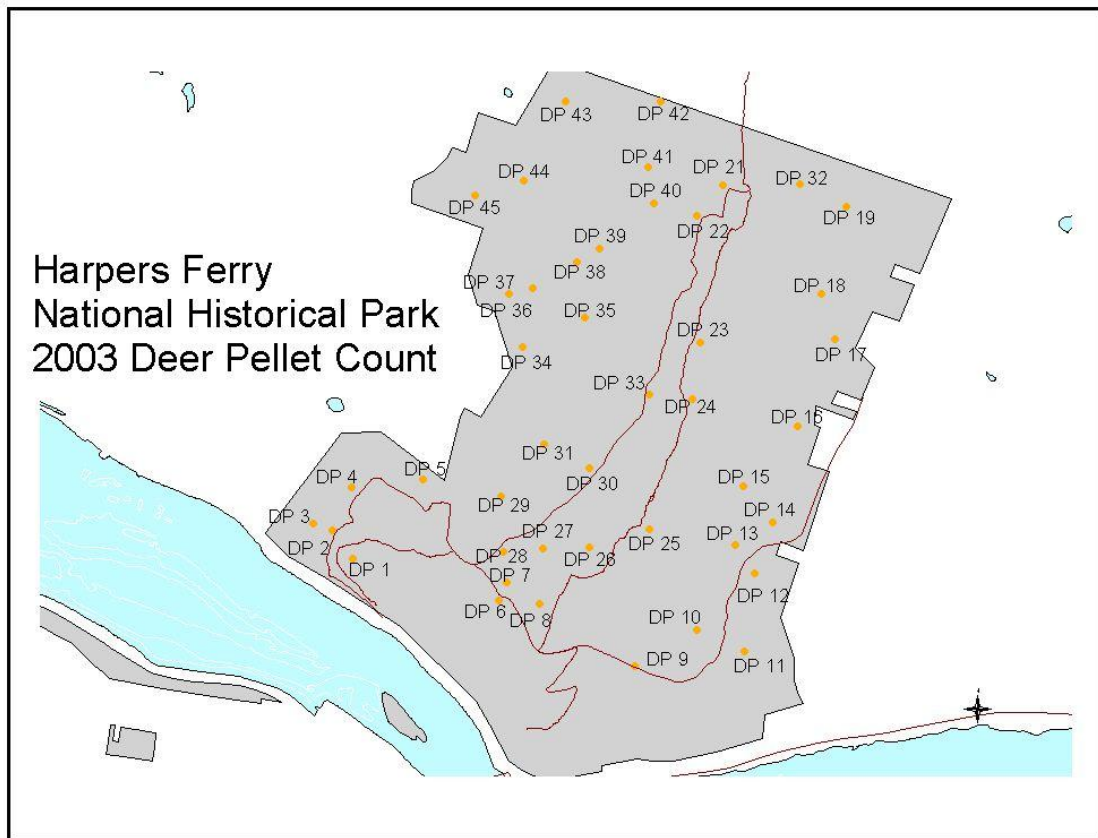
Appendix D: Pellet-Group Survey Protocol Revision History

October 2000 — Forty-three 22×4 m rectangular plots are established at HAFE.

October 2003 — In order to save Dale Nisbet (Resource Manager, HAFE) some time and possibly get one time interval for the pellet-group survey, 25 of the rectangular plots are surveyed using pellet-group counts and 25 are run using Distance methods as described by Buckland et al. (2001, p. 186). No estimate of pellet-group decay was attempted.

October 2004 — The rectangular plots will be replaced by circular plots that are smaller and easier to check in shrubs and brush. One circular plot will be located in the center of the original rectangular plot. Forty additional plots will be randomly located by a Geographic Information System (GIS) algorithm. When this has been done there will be a total of 80 plots. This should be enough to detect a 10% change within the five-year timeframe based on Gibbs (2000) recommendations for using index methods.

Appendix E: Pellet-group Sampling Plot Locations



Appendix F: Pellet-group Data Sheet

DEER PELLETT-GROUP SURVEY

NATIONAL CAPITAL REGION NETWORK
INVENTORY and MONITORING PROGRAM

PARK NAME _____

Sub-Unit _____

LOCATION # _____

GPS N _____

GPS E _____

ERROR _____ $\pm$ m

DATE ESTABLISHED _____

mm/dd/yyyy

DATE MONITORED _____

mm/dd/yyyy

OBSERVER "A" _____ DATA RECORDER _____

OBSERVER "B" _____

	Identified by Observer "A"	Missed by A Identified by "B"	Identified by Observer "B"	Missed by "B" Identified by "A"
# Pellet-Groups				

TOTAL NUMBER OF PELLETT-GROUPS _____

HABITAT (place an "x" next to appropriate habitat category)

Forested _____

Old Field / Grassland _____

Agriculture _____

Edge / Shrub _____

Turf _____

Notes

Appendix G: Microsoft Access Database Structure

