BLUE HILLS
STATE RESERVATION

WHITE-TAILED DEER MANAGEMENT PROGRAM

2016
Program Overview & Results

2017
Results of Deer Abundance Surveying

A Joint Publication of the
Massachusetts Department of Conservation & Recreation
and the
Massachusetts Division of Fisheries & Wildlife

Commonwealth of Massachusetts

Charles D. Baker
Governor

Karyn E. Polito
Lt. Governor

Executive Office of Energy & Environmental Affairs

Matthew A. Beaton
Secretary

Department of Conservation & Recreation

Leo P. Roy
Commissioner

Department of Fish & Game

Ronald Amidon
Commissioner

Massachusetts Division of Fisheries & Wildlife

Jack Buckley
Director

Table of Contents

Executive Summary **4**

1.0 The DCR Blue Hills Reservation **8**

2.0 Context for Deer Management in the Blue Hills Reservation **8**

3.0 Rationale & Objectives for Deer Management in the Blue Hills Reservation **10**

4.0 2016 Controlled Hunt Program Logistics & Operations **10**

5.0 2016 Harvest Results **16**

6.0 Synopsis of the 2016 Controlled Hunt **19**

7.0 2017 – Estimating Deer Densities Using Pellet-Group Counts **20**

8.0 2017 – Estimating Deer Abundance Using Distance Sampling **24**

9.0 Deer Abundance Surveying – Conclusions & Management Implications **30**

10.0 Vegetation Monitoring Efforts **32**

Appendix A: 2016 Controlled Hunt General Rules & Provisions **33**

Appendix B: Estimating Deer Abundance in the Blue Hills using Distance Sampling **36**
(MassWildlife Full Report)

Executive Summary

Context & Rationale for Deer Management in the Blue Hills Reservation

From the canopy to the understory, healthy forest ecosystems are made up of trees and plants of multiple species and age classes and the diversity of vegetation provides suitable and sustainable habitat for a rich and varied wildlife community. From the perspective of long-term forest management, tree regeneration is critical to the survival of forests and their ability to recover from natural disturbances. Forests that contain high deer population densities prohibit forest regeneration as deer over-browse on young tree seedlings. In addition, extremely high deer densities can promote the spread of some invasive species and significantly reduce biodiversity.

As manager and steward of the Blue Hills Reservation, the Department of Conservation & Recreation (DCR) has become increasingly concerned with the long-term health of the Reservation's forest and the ecological impacts of sustained high deer densities on this natural resource. In light of these concerns, DCR's mission to preserve the properties and resources under its care, the recommendations out lined in the 2011Blue Hills Resource Management Plan, the result of deer abundance surveying in 2013, and a legislative mandate detailed in the 2014 Environmental Bond Bill, DCR and the Massachusetts Division of Fisheries & Wildlife (MassWildlife) developed a deer management plan for the Blue Hills Reservation that led to a controlled hunt in 2015.

In deciding to undertake a deer management program in the Blue Hills Reservation, the primary objective and rationale for intervening is to maintain an ecologically sustainable deer density that allows for the continuous growth and development of forest regeneration. In particular, DCR wishes to reduce the negative impacts that high deer densities have on the regenerating forest to ensure a healthy forest composed of adequate diversity of species and age classes. Moreover, DCR's program for white-tailed deer management is not intended to provide a new recreational opportunity in the Blue Hills. Rather, the program provides a concrete, practical, and workable solution intended to deal with a critical environmental problem.

2016 Controlled Hunt Program & Harvest Results

To continue the successful efforts undertaken in 2015, DCR and MassWildlife implemented a second controlled hunt in the Blue Hills Reservation over the course of four days during the 2016 shotgun season in late November/early December 2016. Of the Reservation's more than 7,000 acres, 226 acres were opened to archery hunting and 3,495 acres were opened to shotgun hunting across ten (10) distinct management zones.

In four days, a total of 58 deer were harvested from approximately 5.8 mi^2 of forest land opened to hunting. This represents a reduction of 10 deer/mi^2 of hunted area or 8 deer/mi^2 of all forest within the approximate 7 square miles of forest land in the Blue Hills. The following table presents daily and overall harvest numbers for each of the hunted areas within the 10 management zones.

Management Zone	Square Miles Hunted	Day 1 11/29/16	Day 2 11/30/16	Day 3 12/6/16	Day 4 12/7/16	Total Deer Harvest	Total Harvest Per mi^2
1A – Fowl Meadow (Shotgun)	0.52	3	1	1	1	**6**	**12**
1B – Fowl Meadow (Archery)	0.08	1	1	1	0	**3**	**38**
2 – Little Blue (Archery)	0.11	2	0	1	0	**3**	**27**
3 – Great Blue (Shotgun)	0.55	2	6	0	0	**8**	**15**
4 – Brookwood Farm (Archery)	0.04	0	0	N/A	N/A	**0**	**0**
5 – Houghton's Pond (Shotgun)	0.90	1	1	1	2	**5**	**6**
6 – Chickatawbut (Shotgun)	1.57	4	3	0	0	**7**	**4**
7 – Wampatuck (Shotgun)	0.88	4	2	3	3	**12**	**14**
8 – Ponkapoag (Shotgun)	0.78	6	2	1	2	**11**	**14**
9 – Nike Site (Shotgun)	0.28	1	0	1	0	**2**	**7**
10 – Braintree Site (Archery)	0.12	0	1	0	0	**1**	**8**
TOTAL	**5.83**	**24**	**17**	**9**	**8**	**58**	**10**

An important outcome of the 2016 controlled hunt is that 27 female deer were harvested, equating to at least 98 fewer deer in the spring of 2017. This number includes both the 58 deer that were harvested and a conservative estimate of the potential number of young that could have been added to the deer herd using an average of 1.5 fawns per female harvested.

During the 2015 controlled hunt, 47 females were removed, which equites to about 10.6 females/mi^2 of hunted land (or 4.9 females/mi^2 of all forest in the Blue Hills. In 2016, 27 females were harvested, which equates to 4.7 females/mi^2 of hunted hand (or 2.8 females/mi^2 of all forest in the Blue Hills).

DCR and MassWildlife are pleased with the results and smooth operational implementation of the 2016 Blue Hills Reservation controlled deer hunt. The controlled hunt represents continued progress toward addressing deer overabundance and its impacts in the Reservation. Despite increasing the scope of the controlled hunt (in terms of both acreage and number of hunters) and adding archery to the acceptable forms of hunting, the 2016 hunt demonstrated that hunting can be safely conducted in a suburban/urban setting.

Results of Deer Abundance Surveying in 2017

During the spring of 2017, DCR and MassWildlife worked together to conduct two separate deer abundance surveys in the Blue Hills utilizing two different methodologies. The first method – distance sampling – is similar in nature and scope to the method used in 2013 by MassWildlife to initially estimate deer abundance in the Blue Hills. The second method – pellet count surveys – is similar in nature and scope to the method used by DCR's Division of Water Supply Protection (DWSP) to estimate deer abundance at the Quabbin Reservoir Reservation.

***Distance Sampling Survey Results*:** Distance sampling surveys were conducted prior to leaf-out (early/mid-April 2017) and a representative sample of available roads and trails within the Blue Hills Reservation was selected as transects for distance sampling surveys. Surveys were started no earlier than 30 minutes after sunset and lasted approximately 5-6 hours.

Over four nights of surveying, 79 groups of deer (199 individual deer) were detected over 112 miles of transect. The estimate of density was 23 deer/mi^2 of deer habitat (95% Confidence Interval [CI] = 12 – 44).

It is important to note when interpreting this density estimate that the distance sampling survey was unable to incorporate the Fowl Meadow section of the Reservation because of a lack of navigable trails. MassWildlife surveyed the one trail available through this area in 2013 with distance sampling, but the vegetation and

wetlands surrounding the trail made it difficult to see any deer that were present and many sections were flooded or surrounded by wetland. During the 2017 distance sampling survey, we were unable to travel down this transect because of flooding. Thus, the distance sampling estimates from both years are likely underrepresenting deer density for the overall Reservation.

***Pellet Survey Results*:** Recent advances in pellet count survey methodology have allowed more accuracy in these surveys. Counting deer droppings instead of individuals has several distinct advantages:

- Deer droppings are easy to see, don't move, and can be counted over a longer period of time.
- Counting droppings is relatively straightforward and can be done with a minimal amount of equipment or personnel.
- Pellet count surveys allow a finer-scale look at deer numbers by area within the Reservation.
- Pellet counts allow data to be collected in a more representative and random way in and around the Reservation and does not rely on the roads and trail network, which can limit the bias and lead to more realistic estimates of density.

Given these benefits, DCR and MassWildlife conducted deer pellet count surveys a few weeks prior to the distance sampling survey.

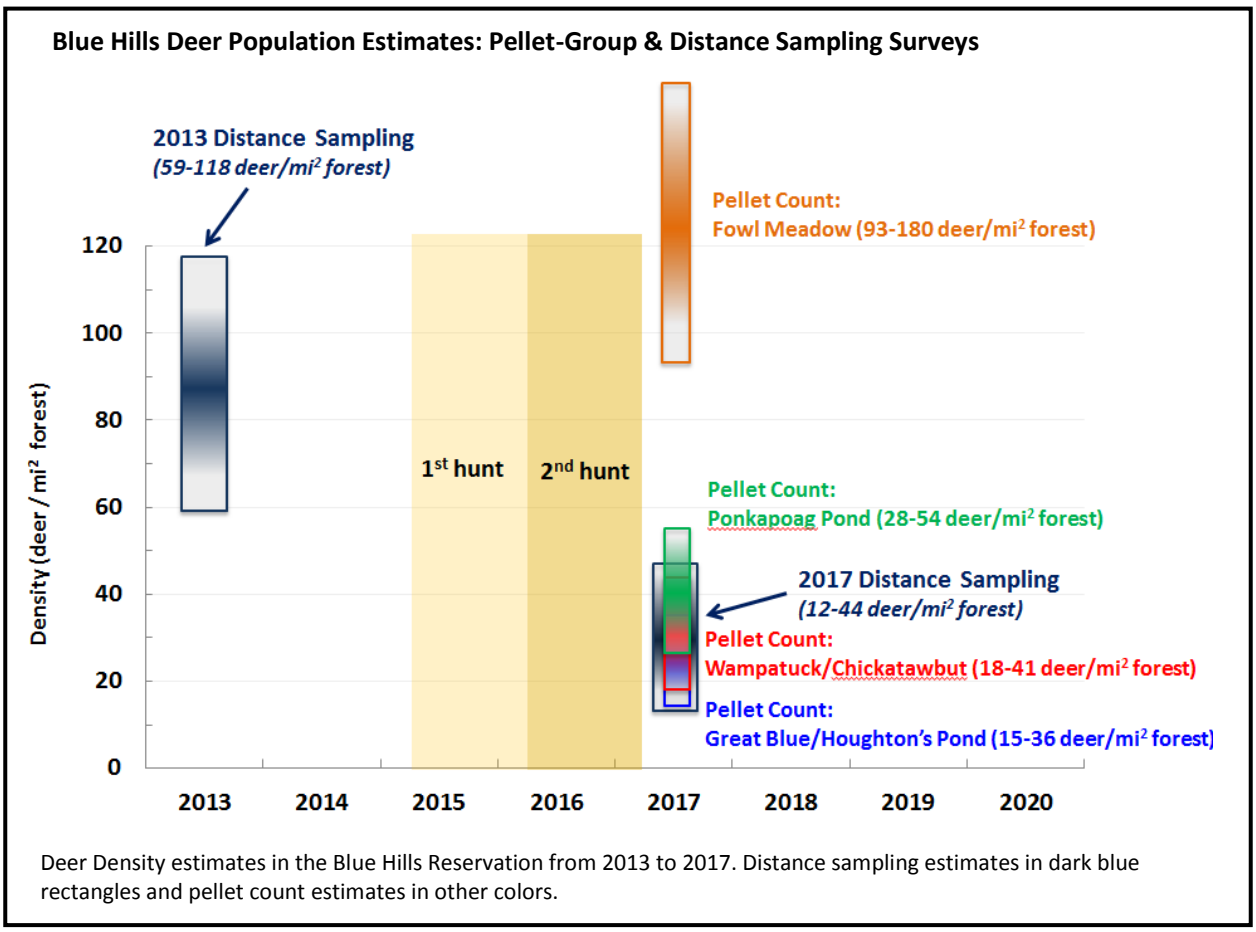
To conduct the pellet-count survey, the Blue Hills Reservation was divided into four (4) areas: Fowl Meadow/Little Blue, Great Blue/Houghton's Pond, Wampatuck/Chickatawbut, and Ponkapoag/Nike Site. At each site, transects of 800 meters (1/2 mile) long were identified and generated in ArcGIS and then transferred to hand-held GPS units that were used for navigation. All transects were laid out in true north/south orientation. Transects were walked between February 28 and April 5, 2017. Participants in the study collectively walked over 50 km and deer pellets were counted in each study area.

Deer densities were calculated and ranged from a low of 25.4 deer/mi^2 in the Great Blue/Houghton's Pond area to a high of 136.4 deer/mi^2 in the Fowl Meadow area (see table below). The overall average density estimate for the Blue Hills Reservation utilizing this methodology was about 52 deer/mi^2, or 37 deer/mi^2 excluding the high estimate in Fowl Meadow that pulls the overall average up.

Unadjusted Deer Densities Expressed as # of Deer/mi^2 (km^2) and 95% Confidence Intervals, 2017

Study Site	Density Estimate	95% Confidence Interval
Blue Hills – Overall	51.6 mi^2 (19.9 km^2)	38.8 mi^2 (15.0 km^2) – 64.5 mi^2 (24.9 km^2)
Fowl Meadow/Little Blue	136.4 mi^2 (52.7 km^2)	93.1 mi^2 (35.8 km^2) – 180.0 mi^2 (69.5 km^2)
Great Blue/Houghton's Pond	25.4 mi^2 (9.8 km^2)	14.5 mi^2 (5.6 km^2) – 36.3 mi^2 (14.0 km^2)
Wampatuck/Chickatawbut	29.5 mi^2 11.4 km^2)	17.9 mi^2 (6.9 km^2) – 41.1 mi^2 (15.9 km^2)
Ponkapoag/Nike Site	40.8 mi^2 (15.8 km^2)	28.0 mi^2 (10.8 km^2) – 53.7 mi^2 (20.7 km^2)

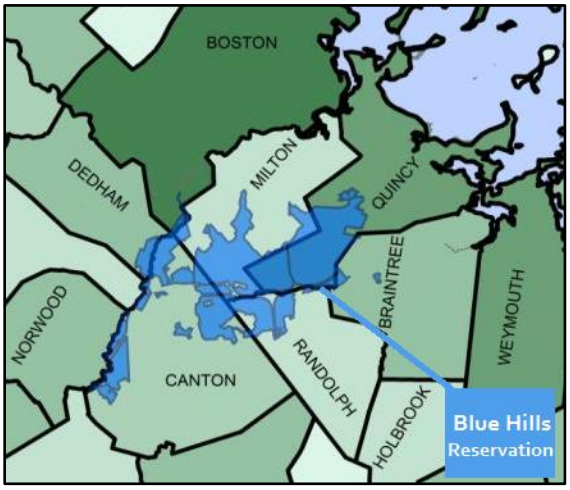
***Summary*:** The two years of deer reductions likely led to a population reduction within the huntable areas and a slight population reduction across the larger area. Rather than looking at the point estimates, it is more useful to look at the trends with confidence intervals included (see following figure). Combining the data from the 2017 distance sampling survey and the 2017 pellet count survey provides a wide interval around the estimate, but the trend is that deer numbers are lower than they were in 2013, but still above the statewide goal of 6-18 deer/mi^2 of forest that is important for reducing impacts to the habitat and forest within and around the Blue Hills Reservation.



Deer Density estimates in the Blue Hills Reservation from 2013 to 2017. Distance sampling estimates in dark blue rectangles and pellet count estimates in other colors.

1.0 The DCR Blue Hills Reservation

The Massachusetts Department of Conservation and Recreation (DCR) manages and stewards the Blue Hills Reservation. The Reservation encompasses an area of over 7,000 acres and is situated less than ten miles south of downtown Boston in the communities of Braintree, Canton, Dedham, Milton, Quincy, and Randolph. A small portion of Fowl Meadow (north and west of the Neponset River) is located within the Hyde Park neighborhood of the City of Boston. The protection of this area as public open space began over 120 years ago with its establishment in 1893 by the Metropolitan Park Commission. As a public parkland and forested area, the Reservation contains a wide variety of natural resources, vegetation, wildlife, and cultural and archaeological resources, and its topography includes prominent hills (Great Blue Hill and Chickatawbut Hill), as well as open fields and several ponds and streams.



2.0 Context for Deer Management in the Blue Hills Reservation

The Massachusetts Department of Conservation and Recreation (DCR) and the Massachusetts Division of Fisheries and Wildlife (MassWildlife) have legislative mandates and missions to protect and manage a myriad of natural resources including forests, wildlife, and the habitats upon which a diversity of wildlife depends. From the canopy to the understory, healthy forest ecosystems are made up of trees and plants of multiple species and age classes and the diversity of vegetation provides suitable and sustainable habitat for a rich and varied wildlife community. From the perspective of long-term forest management, tree regeneration is critical to the survival of forests and their ability to recover from natural disturbances. Forests that contain high deer population densities prohibit forest regeneration as deer over-browse on young tree seedlings. In addition, extremely high deer densities can promote the spread of some invasive species and significantly reduce biodiversity.

As manager and steward of the Blue Hills Reservation, DCR has become increasingly concerned with the long-term health of the Reservation's forest and the ecological impacts of sustained high deer densities on this natural resource. DCR's management of the Blue Hills Reservation is guided by the existence of a comprehensive Resource Management Plan (RMP) that was approved by the DCR Stewardship Council in April 2011 following a robust planning and development process involving input from local residents, stakeholders, and the Friends of the Blue Hills.[1] The Blue Hills RMP noted a growing concern over the size of the deer population within the Reservation and the impact of over-browse on rare plants and other vegetation throughout the Reservation. In addition, the RMP explicitly recommended that the agency work with MassWildlife to ascertain the size of the deer population, determine its impacts on the Reservation's natural

[1] The Friends of the Blue Hills is a non-profit organization that works both independently and in cooperation with the DCR to preserve the natural resources of and enhance recreational opportunities in the Blue Hills Reservation. For more information visit: www.friendsofthebluehills.org.

resources, and discuss deer management options.[2] As such, DCR and MassWildlife worked together to conduct a deer population survey in 2013 to estimate deer density in and around the Blue Hills Reservation. Using distance sampling as a survey method, MassWildlife estimated that there were about 85 deer per square mile of deer habitat within the Blue Hills (95% Confidence Interval [CI] = 59 – 118).[3]

2.1 – Legislative Mandate

In addition to following the recommendations within the Blue Hills RMP, DCR and MassWildlife were issued a legislative mandate in the 2014 Environmental Bond Bill (Chapter 286 of the Acts of 2014), which was signed into law by former Governor Deval Patrick in August 2014.[4] Specifically, Section 43 of the bond bill directs DCR (in consultation with MassWildlife) to "identify areas in which deer overpopulation is negatively impacting forestation, water resources, or plant growth on department-owned land" and "to develop and implement a harvest management plan for the identified areas."

2.2 – Initiation of Deer Management in the Blue Hills Reservation

In light of each agency's mission, the recommendations outlined in the Blue Hills RMP, the results of the deer abundance survey, and the legislative mandate detailed in the 2014 Environmental Bond Bill, DCR and MassWildlife began developing a deer management plan for the Blue Hills Reservation in late 2014. Recognizing that deer management activities can take several forms, both agencies worked together to analyze, assess, and consider the relative impacts and efficacy of several alternative management approaches for a location like the Blue Hills. This planning process and several public information sessions held in the fall of 2015 resulted in the release of a final Blue Hills Deer Management Plan that recommended the phased implementation of an annual controlled deer hunt similar to the very successful annual hunt managed by DCR's Division of Water Supply Protection at the Quabbin Reservation. The Quabbin hunt successfully reduced and has maintained deer densities of less than 20 deer per square miles over the course of more than two decades.[5]

It is important to note that the decision to manage the overpopulation of deer in the Blue Hills Reservation is not dependent upon perceptions regarding the role of deer in relation to Lyme disease or other tick-borne illnesses. DCR recognizes the myriad of research that has demonstrated mixed results over the last several decades with regard to the correlation between deer densities, tick abundance, and Lyme disease contraction rates among humans. Furthermore, attempting to solve Lyme disease or reduce contraction rates is not a primary goal of DCR's deer management plan for the Blue Hills. Rather, as stewards of the Blue Hills Reservation, it is DCR's objective to reduce (and in the long-term reverse) the negative impacts of high deer densities on the Reservation's vegetation, promote the restoration of healthy habitat for other wildlife, and bring deer densities to a level more aligned with what the forest can sustain.

---

[2] To view a copy of the approved 2011 Blue Hills Resource Management Plan please visit: https://www.mass.gov/eea/docs/dcr/stewardship/rmp/bh/sections1-4.pdf. Appendices can be viewed at: http://www.mass.gov/eea/docs/dcr/stewardship/rmp/bh/appendices.pdf.

[3] To view a copy of MassWildlife's 2013 Blue Hills deer abundance survey report, please visit: https://www.mass.gov/eea/docs/dcr/parks/south/blue-hills-deer-survey-report.pdf.

[4] To view Chapter 286 of the Acts of 2014, please visit: https://malegislature.gov/Laws/SessionLaws/Acts/2014/Chapter286.

[5] To view the 2015 Blue Hills Reservation Deer Management Plan, which includes a detailed background on the deer overabundance problem and an overview of the various management approaches analyzed, please visit: http://www.mass.gov/eea/docs/dcr/news/public-meetings/materials/parklands/blue-hills-deer-management-plan.pdf.

3.0 Rationale & Objectives for Deer Management in the Blue Hills Reservation

In deciding to undertake a deer management program in the Blue Hills Reservation, the primary objective and rationale for intervening is to maintain an ecologically sustainable deer density that allows for the continuous growth and development of forest regeneration. In particular, DCR wishes to reduce the negative impacts that high deer densities have on the regenerating forest to ensure a healthy forest composed of adequate diversity of species and age classes. Moreover, DCR's program for white-tailed deer management is not intended to provide a new recreational opportunity in the Blue Hills. Rather, the program provides a concrete, practical, and workable solution intended to deal with a critical environmental problem.

4.0 2016 Controlled Hunt Program Logistics & Operations

To continue the successful efforts undertaken in 2015, and as outlined in the initial Blue Hills Deer Management Plan, DCR and MassWildlife implemented a second controlled hunt in the Blue Hills Reservation during the 2016 shotgun season in late November/early December 2016.[6]

As was acknowledged in the 2015 management plan, managing deer populations is a complex and dynamic process that is shaped and influenced by a variety of interdependent factors. As a result, DCR recognizes that effective deer management programs must provide and maintain a good degree of flexibility in order to make modifications and adjustments that are grounded in experience and ongoing assessment.

Based upon the experience of implementing and assessing the 2015 controlled hunt, DCR and MassWildlife worked together to develop enhancements to increase the efficacy of the Blue Hills Deer Management Program. Such enhancements included: the opening of additional areas to hunting (most notably the areas south of I-93) and allowing for limited archery hunting in designated areas. The following sections provide an overview of several key program components that were implemented as part of the 2016 controlled hunt.

4.1 – Controlled Hunt Timing & Length

The 2016 Blue Hills controlled deer hunt took place during the regular shotgun season in Massachusetts over the course of four (4) weekdays:

- Tuesday, November 29th
- Wednesday, November 30th
- Tuesday, December 6th
- Wednesday, December 7th

In accordance with state regulations, hunting was allowed to begin one half hour before sunrise until one half hour after sunset. All hunters were required to check out of the Reservation each day by 6:00 PM.

4.2 – Hunting Implements

In 2016, participants were allowed to use shotguns with slugs only. In addition, the limited use of archery hunting was allowed in certain designated areas of the Reservation. The inclusion of archery hunting was designed to help reach the management objectives for deer population reduction by limiting the areas where

[6] To view a copy of the 2016 Blue Hills Deer Management Plan, please visit: http://www.mass.gov/eea/docs/dcr/deer-management-plan-2016.pdf.

deer could avoid hunting pressure and to complement other deer management efforts that are already taking place on a number of private properties adjacent to or near the Blue Hills Reservation.

4.3 – Management Zones

In 2016, hunting was allowed to take place in areas of the Reservation both north and south of I-93 and east of the Neponset River in Fowl Meadow. Of the Reservation's more than 7,000 acres, 226 acres were opened to archery hunting and 3,495 acres were opened to shotgun hunting across ten (10) distinct management zones. The boundaries of the ten management zones were established using not only the existing state setback laws and regulations, but also hard boundary delineations, such as trails, roads, and pathways that could be easily identified on the ground. As such, in some cases, the boundaries that were delineated were further away from roads or buildings than required by state setback standards of 150-feet from a hard surfaced highway and 500-feet from a dwelling in use.

Hunting was not allowed south of Wolcott Path in the Great Blue section as well as in the southwest areas of the Ponkapoag section (including Ponkapoag Golf Course). While general public access for recreation was not restricted in the areas in which hunting took place, DCR encouraged the general public to utilize the trails and amenities available in the areas closed to hunting. Members of the general public who chose to enter those areas in which hunting took place were advised to take proper precautions by wearing blaze orange clothing.

4.4 – Hunter Interest, Participation, and Distribution

As anticipated, the prospect of deer hunting in the Blue Hills Reservation continued to attract the interest of many licensed hunters from across Massachusetts and other New England states. The application process was open from October 7 through October 21, 2016 and permittees were selected utilizing a random lottery system.

Licensed hunters were offered the opportunity to apply on-line using a web-based form or by mail using a paper application. DCR issued separate applications for archery hunting and shotgun hunting and licensed hunters were only allowed to submit one application for one form of hunting. In other words, an applicant submitting an application for archery hunting was prohibited from also submitting an application for shotgun hunting and vice-versa. While archery hunters were allowed to hunt during all four days of the controlled hunt, shotgun hunters were only allowed to hunt for one day. As such, four separate groups of shotgun hunters were selected for each of the four days of the hunt.

A total of 956 hunters submitted applications to DCR. Of these 736 were for shotgun hunting and 220 were for archery hunting. Of the 736 shotgun hunting applications, 5 were either found to be incomplete or removed from the applicant pool due to violations committed by the hunter during the 2015 controlled hunt. As such, a total of 951 hunters were entered into the random lottery: 731 for shotgun hunting and 220 for archery hunting.

The maximum number of hunters allowed per day was 117 shotgun hunters and 15 archery hunters. Therefore, 468 shotgun hunters and 15 archery hunters were selected during the random lottery on October 27, 2016 at the Brookwood Farm Conference Center. DCR also selected an additional 10 alternate archery hunters and 65 alternate shotgun hunters in an effort to help mitigate any hunter withdrawals from the hunt.

Out of the 15 archery hunters selected, 14 permits were issued for the first two days and 11 permits were issued for the second two days. In addition, out of the 468 shotgun hunters selected, 419 permits were issued. This was due largely to scheduling conflicts or other unforeseen circumstances that did not allow a number of selected applicants or alternates to either attend one of the mandatory orientation sessions or participate in the hunt. Actual participation figures for shotgun and archery hunters each day as well as other data regarding hunter distribution, deer harvest, and success rates by management zone are presented in the following tables.

2016 Blue Hills Controlled Deer Hunt Summary Data

	Day 1 - November 29, 2016											
Number of Permittees Selected	117 Shotgun & 15 Archery											
Number of Permits Issued	105 Shotgun (90%) & 14 Archery (93%)											
	Zone 1-A Fowl Meadow Shotgun (330 acres)	Zone 1-B Fowl Meadow Archery (51 acres)	Zone 2 Little Blue Archery (71 acres)	Zone 3 Great Blue Shotgun (353 acres)	Zone 4 Brookwood Farm Archery (27 acres)	Zone 5 Houghton's Pond Shotgun (574 acres)	Zone 6 Chickatawbut Shotgun (1,004 acres)	Zone 7 Wompatuck Shotgun (561 acres)	Zone 8 Ponkapoag Shotgun (497 acres)	Zone 9 Nike Site Shotgun (176 acres)	Zone 10 Braintree Site Archery (77 acres)	TOTAL (3,721 acres)
Number of Hunters Participating	11	3	5	12	1	14	28	17	16	4	3	114
Hunter Distribution	1/30 acres	1/17 acres	1/14 acres	1/29 acres	1/27 acres	1/41 acres	1/35 acres	1/33 acres	1/31 acres	1/44 acres	1/26 acres	1/33 acres
Number of Deer Harvested	3	1	2	2	0	1	4	4	6	1	0	24
Success Rate*	27%	33%	40%	17%	0%	7%	14%	24%	38%	25%	0%	21%
Number of Females Harvested	2	0	2	0	0	1	2	0	3	1	0	11
Number of Males Harvested	1	1	0	2	0	0	2	4	3	0	0	13
Number of Deer Harvested with Shotgun	3	N/A	N/A	2	N/A	1	4	4	6	1	N/A	21
Number of Deer Harvested with Archery	N/A	1	2	N/A	0	N/A	N/A	N/A	N/A	N/A	0	3
Number of Deer Harvested from Tree Stand	3	1	2	1	0	0	0	0	1	0	0	8
Number of Deer Harvested from Ground	0	N/A	N/A	1	N/A	1	4	4	5	1	N/A	16
Number of Hunters that Harvested Deer	2	1	2	2	0	1	3	4	4	1	0	20

	Day 2 - November 30, 2016											
Number of Permittees Selected	117 Shotgun & 15 Archery											
Number of Permits Issued	111 Shotgun (95%) & 14 Archery (93%)											
	Zone 1-A Fowl Meadow Shotgun (330 acres)	Zone 1-B Fowl Meadow Archery (51 acres)	Zone 2 Little Blue Archery (71 acres)	Zone 3 Great Blue Shotgun (353 acres)	Zone 4 Brookwood Farm Archery (27 acres)	Zone 5 Houghton's Pond Shotgun (574 acres)	Zone 6 Chickatawbut Shotgun (1,004 acres)	Zone 7 Wompatuck Shotgun (561 acres)	Zone 8 Ponkapoag Shotgun (497 acres)	Zone 9 Nike Site Shotgun (176 acres)	Zone 10 Braintree Site Archery (77 acres)	TOTAL (3,721 acres)
Number of Hunters Participating	11	1	5	12	1	18	30	17	15	6	3	119
Hunter Distribution	1/30 acres	1/51 acres	1/14 acres	1/29 acres	1/27 acres	1/32 acres	1/33 acres	1/33 acres	1/33 acres	1/29 acres	1/26 acres	1/31 acres
Number of Deer Harvested	1	1	0	6	0	1	3	2	2	0	1	17
Success Rate*	9%	100%	0%	50%	0%	6%	10%	12%	13%	0%	33%	14%
Number of Females Harvested	1	0	0	2	0	0	2	1	1	0	0	7
Number of Males Harvested	0	1	0	4	0	1	1	1	1	0	1	10
Number of Deer Harvested with Shotgun	1	N/A	N/A	6	N/A	1	3	2	2	0	N/A	15
Number of Deer Harvested with Archery	N/A	1	0	N/A	0	N/A	N/A	N/A	N/A	N/A	1	2
Number of Deer Harvested from Tree Stand	1	1	0	1	0	1	0	1	0	0	1	6
Number of Deer Harvested from Ground	0	N/A	N/A	5	N/A	0	3	1	2	0	N/A	11
Number of Hunters that Harvested Deer	1	1	0	5	0	1	3	2	2	0	1	16

* Calculated by dividing the number of deer harvested by the number of hunters participating.

** Shotgun hunters were allowed only 1 day to hunt, therefore a different set of 117 shotgun hunters were selected for each day. The 15 selected archery hunters were allowed to hunt all four days.

*** To avoid double-counting, archery hunters who participated on multiple days were counted only once.

2016 Blue Hills Controlled Deer Hunt Summary Data

	Day 3 - December 6, 2016											
Number of Permittees Selected	117 Shotgun & 15 Archery											
Number of Permits Issued	105 Shotgun (90%) & 11 Archery (73%)											
	Zone 1-A Fowl Meadow Shotgun (330 acres)	Zone 1-B Fowl Meadow Archery (51 acres)	Zone 2 Little Blue Archery (71 acres)	Zone 3 Great Blue Shotgun (353 acres)	Zone 4 Brookwood Farm Archery (27 acres)	Zone 5 Houghton's Pond Shotgun (574 acres)	Zone 6 Chickatawbut Shotgun (1,004 acres)	Zone 7 Wompatuck Shotgun (561 acres)	Zone 8 Ponkapoag Shotgun (497 acres)	Zone 9 Nike Site Shotgun (176 acres)	Zone 10 Braintree Site Archery (77 acres)	TOTAL (3,721 acres)
Number of Hunters Participating	10	2	5	9	0	16	31	14	16	6	2	111
Hunter Distribution	1/33 acres	1/25 acres	1/14 acres	1/39 acres	N/A	1/36 acres	1/32 acres	1/40 acres	1/31 acres	1/29 acres	1/38 acres	1/34 acres
Number of Deer Harvested	1	1	1	0	N/A	1	0	3	1	1	0	9
Success Rate*	10%	50%	20%	0%	N/A	6%	0%	21%	6%	17%	0%	8%
Number of Females Harvested	1	1	0	0	N/A	1	0	1	0	0	0	4
Number of Males Harvested	0	0	1	0	N/A	0	0	2	1	1	0	5
Number of Deer Harvested with Shotgun	1	N/A	N/A	0	N/A	1	0	3	1	1	N/A	7
Number of Deer Harvested with Archery	N/A	1	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	2
Number of Deer Harvested from Tree Stand	1	1	1	0	N/A	0	0	0	1	1	0	5
Number of Deer Harvested from Ground	0	N/A	N/A	0	N/A	1	0	3	0	0	N/A	4
Number of Hunters that Harvested Deer	1	1	1	0	N/A	1	0	3	1	1	0	9

	Day 4 - December 7, 2016											
Number of Permittees Selected	117 Shotgun & 15 Archery											
Number of Permits Issued	98 Shotgun (84%) & 11 Archery (73%)											
	Zone 1-A Fowl Meadow Shotgun (330 acres)	Zone 1-B Fowl Meadow Archery (51 acres)	Zone 2 Little Blue Archery (71 acres)	Zone 3 Great Blue Shotgun (353 acres)	Zone 4 Brookwood Farm Archery (27 acres)	Zone 5 Houghton's Pond Shotgun (574 acres)	Zone 6 Chickatawbut Shotgun (1,004 acres)	Zone 7 Wompatuck Shotgun (561 acres)	Zone 8 Ponkapoag Shotgun (497 acres)	Zone 9 Nike Site Shotgun (176 acres)	Zone 10 Braintree Site Archery (77 acres)	TOTAL (3,721 acres)
Number of Hunters Participating	10	2	5	9	0	14	20	18	16	4	3	101
Hunter Distribution	1/33 acres	1/25 acres	1/14 acres	1/39 acres	N/A	1/41 acres	1/50 acres	1/31 acres	1/31 acres	1/44 acres	1/26 acres	1/37 acres
Number of Deer Harvested	1	0	0	0	N/A	2	0	3	2	0	0	8
Success Rate*	10%	0%	0%	0%	N/A	14%	0%	17%	13%	0%	0%	8%
Number of Females Harvested	1	0	0	0	N/A	1	0	2	1	0	0	5
Number of Males Harvested	0	0	0	0	N/A	1	0	1	1	0	0	3
Number of Deer Harvested with Shotgun	1	N/A	N/A	0	N/A	2	0	3	2	0	N/A	8
Number of Deer Harvested with Archery	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
Number of Deer Harvested from Tree Stand	0	0	0	0	N/A	0	0	3	0	0	0	3
Number of Deer Harvested from Ground	1	N/A	N/A	0	N/A	2	0	0	2	0	N/A	5
Number of Hunters that Harvested Deer	1	0	0	0	N/A	2	0	3	2	0	0	8

* Calculated by dividing the number of deer harvested by the number of hunters participating.

** Shotgun hunters were allowed only 1 day to hunt, therefore a different set of 117 shotgun hunters were selected for each day. The 15 selected archery hunters were allowed to hunt all four days.

*** To avoid double-counting, archery hunters who participated on multiple days were counted only once.

2016 Blue Hills Controlled Deer Hunt Summary Data

	Four-Day Summary											
Number of Permittees Selected**	468 Shotgun & 15 Archery											
Number of Permits Issued	419 Shotgun (90%) & 14 Archery (93%)											
	Zone 1-A Fowl Meadow Shotgun (330 acres)	**Zone 1-B Fowl Meadow Archery (51 acres)**	**Zone 2 Little Blue Archery (71 acres)**	**Zone 3 Great Blue Shotgun (353 acres)**	**Zone 4 Brookwood Farm Archery (27 acres)**	**Zone 5 Houghton's Pond Shotgun (574 acres)**	**Zone 6 Chickatawbut Shotgun (1,004 acres)**	**Zone 7 Wompatuck Shotgun (561 acres)**	**Zone 8 Ponkapoag Shotgun (497 acres)**	**Zone 9 Nike Site Shotgun (176 acres)**	**Zone 10 Braintree Site Archery (77 acres)**	**TOTAL (3,721 acres)**
Number of Hunters Participating***	42	3	5	42	1	62	109	66	63	20	3	416
Number of Deer Harvested	6	3	3	8	0	5	7	12	11	2	1	58
Success Rate*	14%	100%	60%	19%	0%	8%	6%	18%	17%	10%	33%	14%
Number of Females Harvested	5	1	2	2	0	3	4	4	5	1	0	27
Number of Males Harvested	1	2	1	6	0	2	3	8	6	1	1	31
Number of Deer Harvested with Shotgun	6	N/A	N/A	8	N/A	5	7	12	11	2	N/A	51
Number of Deer Harvested with Archery	N/A	3	3	N/A	0	N/A	N/A	N/A	N/A	N/A	1	7
Number of Deer Harvested from Tree Stand	5	3	3	2	0	1	0	4	2	1	1	22
Number of Deer Harvested from Ground	1	N/A	N/A	6	N/A	4	7	8	9	1	N/A	36

* Calculated by dividing the number of deer harvested by the number of hunters participating.

** Shotgun hunters were allowed only 1 day to hunt, therefore a different set of 117 shotgun hunters were selected for each day. The 15 selected archery hunters were allowed to hunt all four days.

*** To avoid double-counting, archery hunters who participated on multiple days were counted only once.

4.5 – Hunter Orientation

As outlined in the 2016 Blue Hills Deer Management Plan, all permittees were required to attend an orientation session that was organized and hosted by DCR, MassWildlife, the Massachusetts Environmental Police (MEP), and the Massachusetts State Police (MSP). Orientation sessions were conducted on the evenings of November 15, 16, and 17, 2016. All selected applicants who completed an orientation session were given DCR-issued access permits to participate in the controlled hunt.

During the orientation sessions, permittees were provided an overview of the 2016 Blue Hills Deer Management Plan and the rationale and objectives for conducting a controlled deer hunt. In addition, DCR, the MEP, and the MSP presented and provided information on public safety, hunter safety, and firearms safety. Permittees were provided a thorough review of the management zone maps and boundaries, the check-in and check-out procedures to be followed during the hunt, and the specific rules and regulations that would govern the conduct of the four-day hunt (see Appendix A). MassWildlife also provided permittees with information on pre-hunt scouting, field dressing and tagging of harvested deer, and how to obtain antlerless deer permits specific to the Blue Hills controlled hunt.

4.6 – Antlerless Deer Permits

In 2016 MassWildlife made antlerless deer permits specific to the Blue Hills controlled hunt available to permittees who had completed the mandatory orientation session. Each antlerless permit specified a valid date that reflected the date(s) in which each hunter was permitted to hunt. Given the purpose of the controlled hunt is to facilitate a reduction of the deer herd, and since the most effective way to achieve this goal is by reducing the number of female deer, hunters were required to purchase at least two Blue Hills-specific antlerless permits and were allowed to purchase up to four permits. While MassWildlife prohibited the use of any Zone 10 antlerless permits for hunting in the Blue Hills, any antlered deer (bucks) harvested during the controlled hunt were counted toward each hunter's statewide bag limit of two antlered deer.

4.7 – Road Closures

DCR and MSP successfully closed Chickatawbut Road (from Route 28/Randolph Avenue to Route 37) and Wampatuck Road (from Chickatawbut Road to Route 37) to vehicular travel during each of the four hunting days. The road closures were announced two weeks in advance of the controlled hunt via traffic advisories and social media posts as well as variable message boards stationed at key park entrances and intersections in and around the Reservation. On each day of the controlled hunt, these roads were re-opened to vehicular traffic by 5:30 PM. MSP officers patrolling the roadways and highways in and around the Blue Hills reported no significant impacts to regular morning and evening commutes as a result of the road closures.

4.8 – Unified Command

The safe, successful, and smooth operation of the 2016 Blue Hills controlled hunt is largely due to the integrated and meticulous inter-agency coordination among DCR, MassWildlife, MEP, MSP, and local law enforcement agencies facilitated by the unified command structure implemented during the controlled hunt. Utilizing an operations and communications trailer provided by the MSP, a Unified Command Center (UCC) was established and stationed near the Park Headquarters and the MSP Barracks on Hillside Street. The UCC was staffed throughout the controlled hunt by operational decision-makers from DCR, MEP, and MSP, as well as representatives from local police departments. The unified command structure, supported by the use of two-way radio systems by all staff throughout the field, allowed for centralized coordination of on-the-ground resources, efficient communication, and effective management of any issues or situations that arose in any part of the Blue Hills Reservation.

4.9 – Program Costs

Primary costs associated with implementing the Blue Hills controlled hunt included: DCR overtime staffing; State Police details; Environmental Police details; space rental for hunter orientations; and signage, printing, equipment, and supplies. The majority of these expenses were associated with staffing. In anticipation of protests, the MSP and MEP also mustered resources to ensure the safe operation of the controlled hunt while affording protestors an organized and safe area from which to stage their demonstration. The chart below provides a cost for each of the main cost categories. Despite enhancing the scope of the hunt in terms of acreage and the number of hunters allowed, the total cost of the 2016 controlled hunt represents a decrease of approximately $33,950 (24% reduction) from the 2015 hunt.

Description	Amount
MA State Police Details	$42,140
MA Environmental Police Details	$29,163
DCR Staffing	$30,083
Space Rental for Hunter Orientations	$1,200
Signage, Printing, Equipment, & Supplies	$4,163
Total	**$106,749**

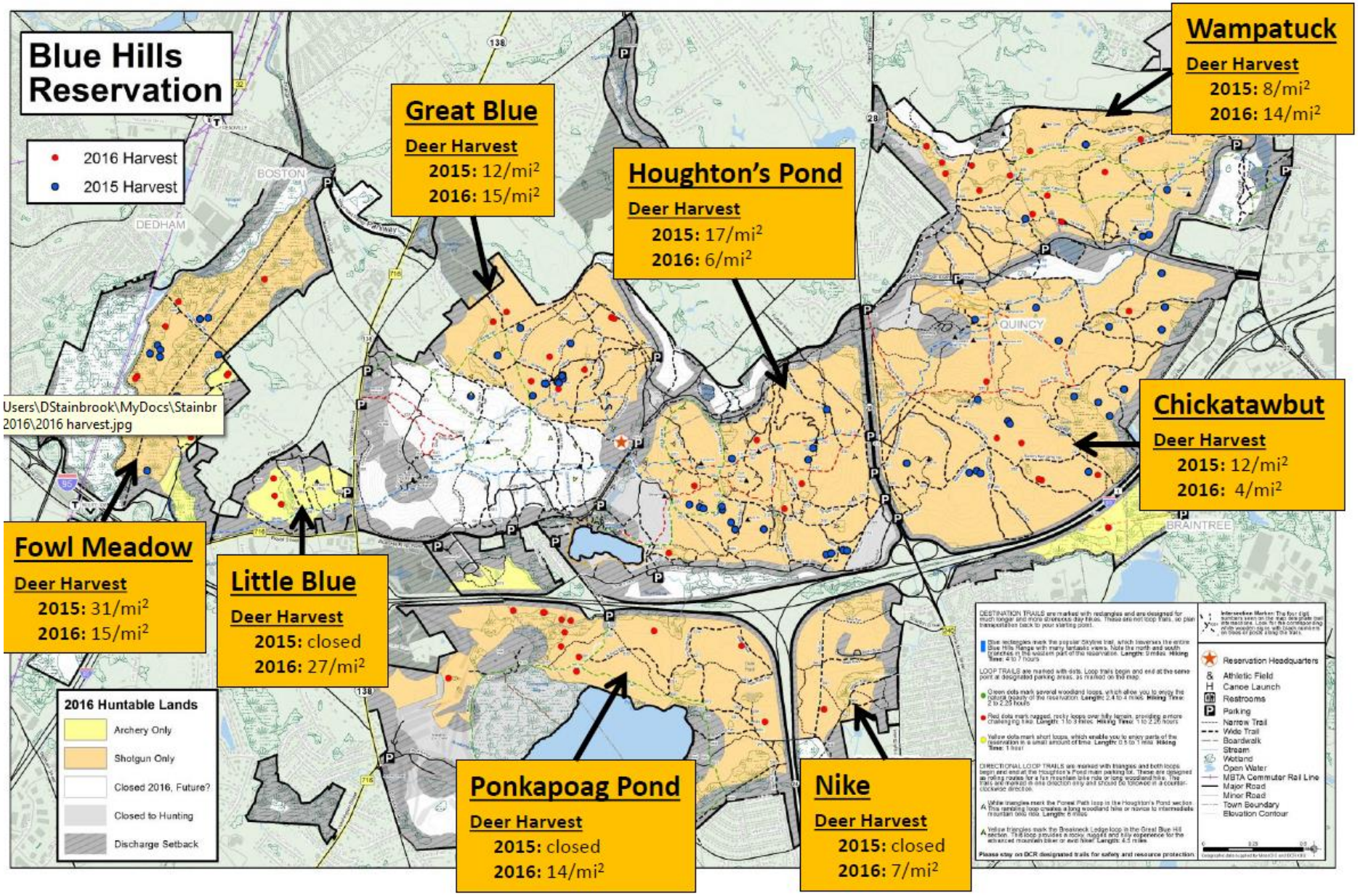
5.0 2016 Harvest Results

5.1 – Overall Deer Harvest

In just four days, a total of 58 deer were harvested from approximately 5.8 mi^2 of forest land opened to hunting. This represents a reduction of 10 deer per square miles from the hunted areas. When extended to the approximate 7 mi^2 of forest land in the Blue Hills, however, the total harvest of 58 deer represents a reduction of about 8 deer/mi^2 of forest. The following table presents daily and overall harvest numbers for each of the hunted areas within the 10 management zones.

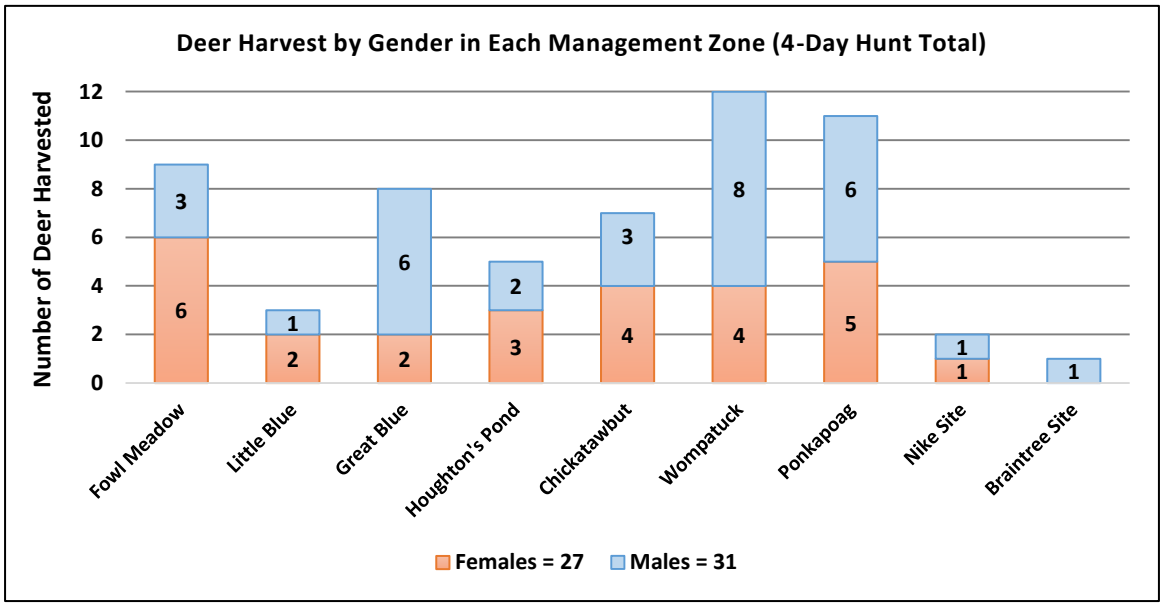
Management Zone	Square Miles Hunted	Day 1 11/29/16	Day 2 11/30/16	Day 3 12/6/16	Day 4 12/7/16	Total Deer Harvest	Total Harvest Per mi^2
1A – Fowl Meadow (Shotgun)	0.52	3	1	1	1	**6**	**12**
1B – Fowl Meadow (Archery)	0.08	1	1	1	0	**3**	**38**
2 – Little Blue (Archery)	0.11	2	0	1	0	**3**	**27**
3 – Great Blue (Shotgun)	0.55	2	6	0	0	**8**	**15**
4 – Brookwood Farm (Archery)	0.04	0	0	N/A	N/A	**0**	**0**
5 – Houghton's Pond (Shotgun)	0.90	1	1	1	2	**5**	**6**
6 – Chickatawbut (Shotgun)	1.57	4	3	0	0	**7**	**4**
7 – Wampatuck (Shotgun)	0.88	4	2	3	3	**12**	**14**
8 – Ponkapoag (Shotgun)	0.78	6	2	1	2	**11**	**14**
9 – Nike Site (Shotgun)	0.28	1	0	1	0	**2**	**7**
10 – Braintree Site (Archery)	0.12	0	1	0	0	**1**	**8**
TOTAL	**5.83**	**24**	**17**	**9**	**8**	**58**	**10**

The map on the following page shows the boundaries of each of the management zones and provides the deer harvest per square mile for both 2015 and 2016. In addition, the blue and red dots identify the approximate deer harvest locations for each year.


Blue Hills Reservation
2016 Harvest
2015 Harvest
Users\DStainbrook\MyDocs\Stainbr
2016\2016 harvest.jpg
2016 Huntable Lands
Archery Only
Shotgun Only
Closed 2016, Future?
Closed to Hunting
Discharge Setback
Wampatuck
Deer Harvest
2015: 8/mi²
2016: 14/mi²
Great Blue
Deer Harvest
2015: 12/mi²
2016: 15/mi²
Houghton's Pond
Deer Harvest
2015: 17/mi²
2016: 6/mi²
Chickatawbut
Deer Harvest
2015: 12/mi²
2016: 4/mi²
Fowl Meadow
Deer Harvest
2015: 31/mi²
2016: 15/mi²
Little Blue
Deer Harvest
2015: closed
2016: 27/mi²
Ponkapoag Pond
Deer Harvest
2015: closed
2016: 14/mi²
Nike
Deer Harvest
2015: closed
2016: 7/mi²
BOSTON
DEDHAM
QUINCY
BRAINTREE
Reservation Headquarters
Athletic Field
Canoe Launch
Restrooms
Parking
Narrow Trail
Wide Trail
Boardwalk
Stream
Wetland
Open Water
MBTA Commuter Rail Line
Major Road
Minor Road
Town Boundary
Elevation Contour

5.2 – Harvest by Gender

An important outcome of the 2016 controlled hunt is that 27 female deer were harvested, equating to at least 98 fewer deer in the spring of 2017. This number includes both the 58 deer that were harvested and a conservative estimate of the potential number of young that could have been added to the deer herd using an average of 1.5 fawns per female harvested. The following chart presents harvest by gender in each of the ten management zones across all four days of the controlled hunt.



5.3 – Harvest Rates

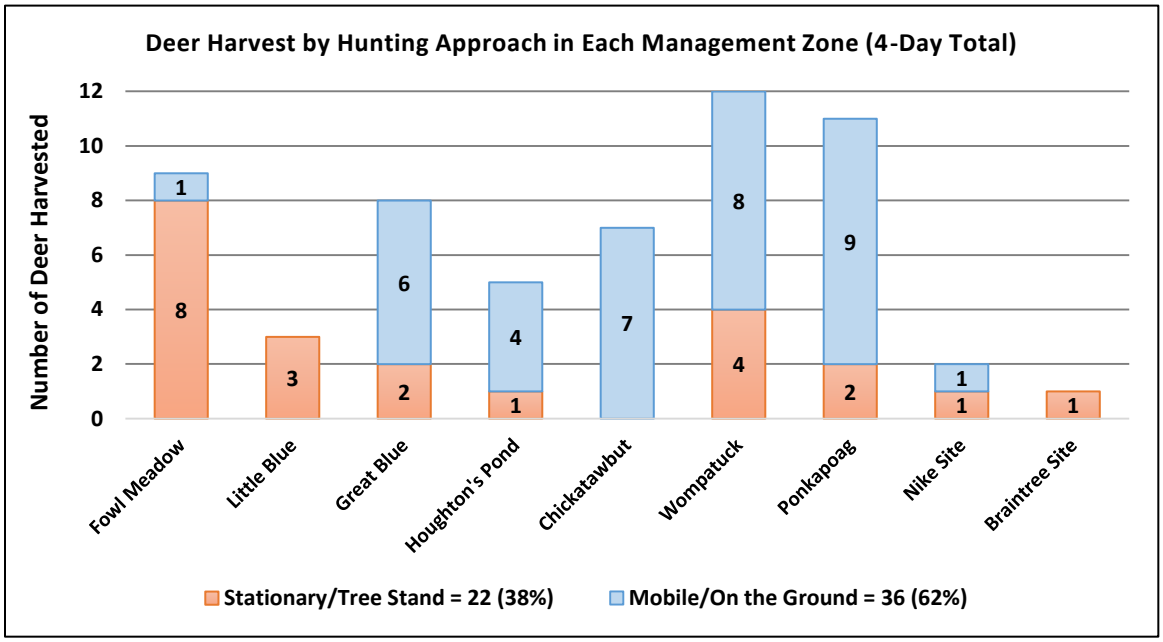
Harvest rate is calculated by dividing the number of deer harvested by the number of hunters. Rates varied greatly by zone and is likely related to differences in habitat and deer distribution. The table below provides daily harvest rates across each of the four days of hunting.

	# of Hunters	Total Harvest	Harvest Rate
Day 1 – November 29th	114	24	21%
Day 2 – November 30th	119	17	14%
Day 3 – December 6th	111	9	8%
Day 4 – December 7th	101	8	8%
TOTAL/AVERAGE	**416***	**58**	**14%**

** To avoid double-counting, archery hunters who participated on multiple days were counted only once.*

Differences in harvest between management zones might also be attributable to hunting method (i.e., whether hunters were in a tree stand or mobile on the ground). Nearly two-thirds of the total harvest (36 deer) was taken by hunters who reported they were hunting from the ground at the time of harvest. The zones yielding the highest harvests (Zones 3, 6, 7, and 8) saw a greater percentage of harvested deer being taken by hunters who were hunting from the ground. Of the 38 deer taken in these four zones, a total of 30 (79%) were harvested from the ground. Hunting from the ground may have given these hunters more opportunities to encounter deer, particularly if deer were stationary during the day and not visible to hunters in tree stands.

The following chart provides the number of deer taken in each zone according to whether the hunter was reportedly on the ground or in a tree stand at the time of harvest.



6.0 Synopsis of the 2016 Controlled Hunt

As was acknowledged in the initial 2015 Blue Hills Deer Management Plan, managing deer populations is a complex and dynamic process that is shaped and influenced by a variety of interdependent factors. As a result, effective deer management programs must incorporate and maintain a good degree of flexibility in order to make modifications and adjustments that are grounded in experience and ongoing assessment.

DCR and MassWildlife are pleased with the results and smooth operational implementation of the 2016 Blue Hills Reservation controlled deer hunt. The controlled hunt represents continued progress toward addressing deer overabundance and its impacts in the Reservation. From the perspective of public safety, all agencies involved in coordination and implementation of the controlled hunt are satisfied. In advance of the controlled hunt, considerable time was spent assessing a myriad of operational aspects associated with conducting a controlled hunt within the Reservation and developing a plan that addressed these operational concerns. The successful execution of this plan and buy-in from permitted hunters to the overall goal of safety represents a significant achievement. Despite increasing the scope of the controlled hunt (in terms of both acreage and number of hunters) and adding archery to the acceptable forms of hunting, the 2016 hunt demonstrated that hunting can be safely conducted in a suburban/urban setting.

7.0 2017 – Estimating Deer Abundance Using Pellet-Group Counts

7.1 – Introduction

Aside from the Blue Hills Reservation, the only other properties where DCR has made long-term concerted efforts to track deer densities is on Division of Water Supply Protection (DWSP) lands at the Quabbin Reservoir and Wachusett Reservoir Reservations. For example, DCR has investigated (and in some cases used) a variety methods to independently assess deer populations at Quabbin Reservation, including aerial infra-red surveys, distance sampling, mark-recapture techniques, and trail cameras. In 2007, DCR hired a contractor to survey deer and moose populations on Quabbin Reservation using aerial infra-red technology. Unfortunately, the results of the study were inconclusive; the contractor didn't observe enough deer or moose to calculate an estimate. In 2010, DCR made another attempt to use aerial infra-red technology and collaborated with a researcher from Mt. Holyoke College. This attempt also provided no useable information. Trail cameras have been used in small landscapes with success, but they are cost prohibitive.[7] Finally, mark-recapture studies can provide an unbiased estimate of deer densities but would require DCR to capture and mark a number of deer prior to the implementation of any controlled hunts.

Counting deer droppings instead of individuals has several distinct advantages. First, droppings are easy to see, don't move, and can be counted over a longer period of time. In addition, counting droppings is relatively straight forward and can be done with a minimal amount of equipment or personnel. Further, a recently published paper has provided a solid framework for conducting this type of survey over large forested areas.[8]

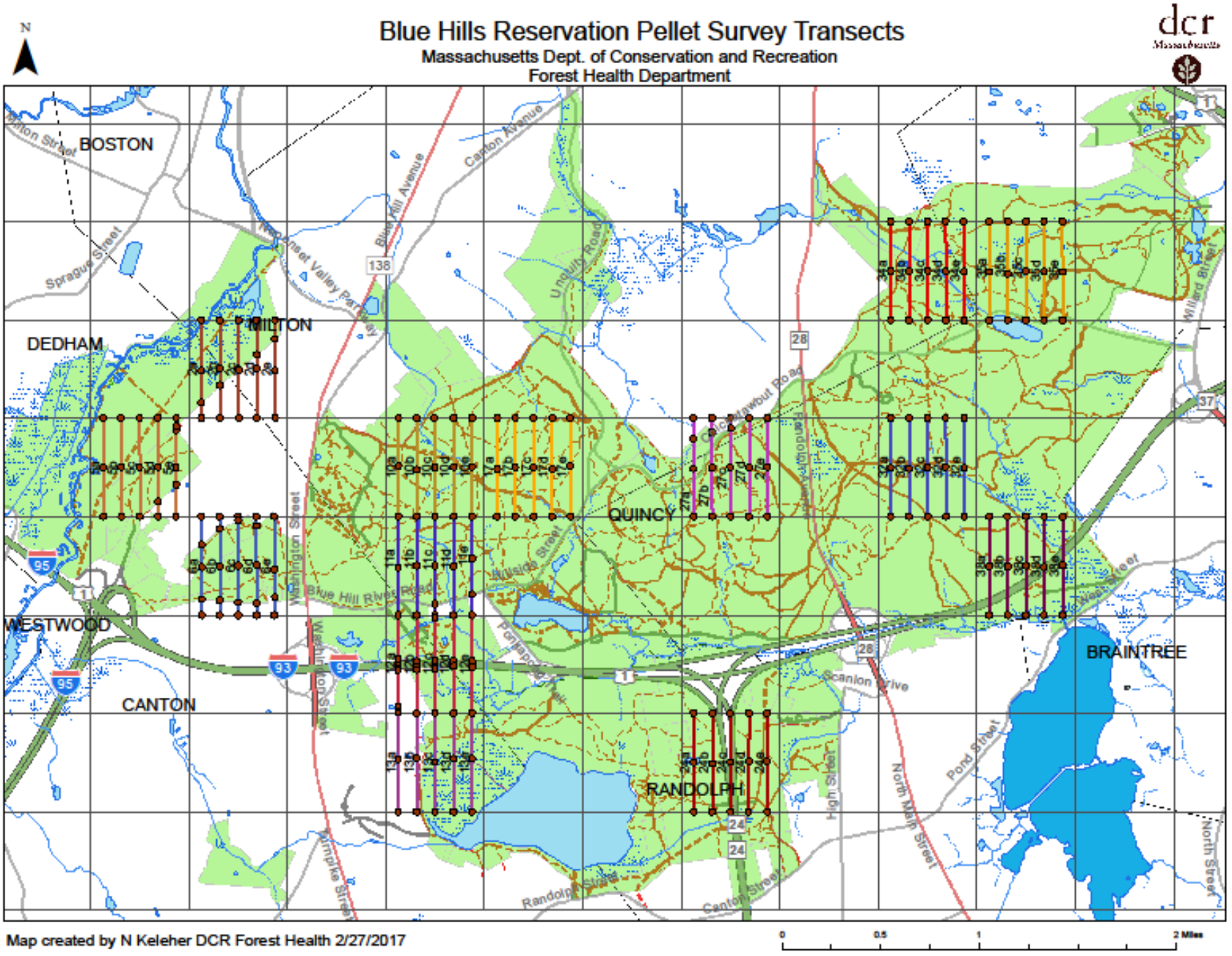
7.2 – Methodology: Survey Area and Sampling Protocol

The Blue Hills Reservation was divided into four (4) areas based on current hunting zones or other delineations: Fowl Meadow/Little Blue, Great Blue/Houghton's Pond, Wampatuck/Chickatawbut, and Ponkapoag/Nike Site. At each site, a grid of points 805 meters (1/2 mile) apart was laid out in a north-south and east-west direction. Depending on the size of each study area, 3-9 points were randomly selected. At each selected point, a second grid was constructed comprised of five (5) transects 800 meters (1/2 mile) long and spaced 150 meters (500 feet) apart. Each originally selected point formed the mid-point of the middle transect. All points and lines were generated in ArcGIS and transferred to hand-held GPS units that were used for navigation. In some cases, the total 800 meter line could not be created because the line left DCR property, entered a waterbody, etc. All transects were laid out in true north/south orientation. The figure on the following page shows a map of the Blue Hills and delineates the pellet survey transects used to estimate deer densities.

Most transects were walked by at least two (2) observers. The lead observer used a GPS and compass to identify the start and end of each transect and walk a straight line. The lead observer paced out 30.5 meter (100 feet) intervals and established a plot center by placing a wire flag at their feet. The second observer followed the lead person and counted deer pellet groups within 1.2 meter (4 foot) radius plots centered on the wire flag. Pellet groups were tallied if there were ≥10 pellets in a group and at least half of the pellets in a group were within the plot boundary. Second observers carried a 1.2 meter (4 foot) pole or measuring tape to identify the edges of a plot. Approximately 26 plots/transect were surveyed. However, observers kept an accurate record of how many plots per transect were actually sampled.

[7] Curtis, P.D., B. Bazartseren, P.M. Mattison, and J.R. Boulanger. 2009. Estimating deer abundance in suburban areas with infrared triggered cameras. Human-Wildlife Conflicts 3:116-128.

[8] DeCalesta, D.S. 2013. Reliability and precision of pellet-group counts for estimating landscape-level deer density. Human-Wildlife Interactions 7(1):60-68.


Blue Hills Reservation Pellet Survey Transects
Massachusetts Dept. of Conservation and Recreation
Forest Health Department
dcr
N
BOSTON
DEDHAM
MILTON
QUINCY
WESTWOOD
CANTON
RANDOLPH
BRAINTREE
Sprague Street
Blue Hill Avenue
Canton Avenue
Unquity Road
Willard Street
Hillside Street
Washington Street
Pond Street
North Main Street
North Street
Randolph Street
Canton Street
Scanlon Drive
Map created by N Keleher DCR Forest Health 2/27/2017
0
0.5
1
2 Miles

7.3 – Methodology: Calculating Density from Pellet-Group Counts

Unadjusted deer densities (#/km^2) were calculated using the following formula:

Deer/km^2 = ∑number of pellet groups counted/(pellet-group deposit rate x deposition period x ∑ plot area in m^2/1,000,000 m^2)

To convert this estimate into deer/mi^2, the estimate was divided by 0.386.

Based staff observations, a leaf-off date of November 22, 2016 was used. The deposition period was determined by calculating the number of days between leaf-off and the survey date. The sum of the plot area was the area of an individual plot (4.52 m^2) multiplied by the number of plots.

The pellet-group deposit rate can be the most challenging variable to determine and can influence the final density estimate. A range of defecation rates have been reported on both captive and free-ranging white-tailed deer (see table below). Some studies have suggested picking a single rate (i.e., 25 for deer), but unless there is local knowledge of the herd, this can lead to an over or under estimate of density. An alternative to picking a single defecation rate is to use an average rate. We averaged the reported defecation rates for deer into a single value (see table below). We then calculated three unadjusted density estimates using three defecation rates: (1) the average defecation rate, (2) one standard deviation above the average, and (3) one standard deviation below the calculated average. An overall unadjusted density estimate was calculated by averaging the density estimate obtained for each of the 3 defecation rates (average rate + 1 standard deviation above + 1 standard deviation below).

Reported Defecation Rates for White-Tailed Deer from Different Studies (Defecation Rate is Pellet-Groups/Individual/Day)

Defecation Rate	Study Site	Environment	No. deer/sex (M: Male, F: Female)	Reference
34.0	USA	Free Ranging	7F	Rogers, 1987[9]
26.9	USA	Captivity	1M, 3F	Sawyer et al. 1990[10]
19.6	USA	Captivity	4F	Rollins et al., 1984[11]
13.6	USA	Semi-captive	?	McCullough, 1982[12]
12.0	USA	Captivity	18M, 1F	Eberhardt and Van Etten, 1956[13]
13.2	USA	Captivity	?	Van Etten, 1959[14]

Avg. 19.8

Std. Dev. 8.9

[9] Rogers, L.L. 1987. Seasonal changes in defecation rates of free-ranging white-tailed deer. Journal of Wildlife Management 51:330-333.

[10] Sawyer, T.G., R.L. Marchinton, and W.M. Lentz. 1990 Defecation rates of female white-tailed deer in Georgia. Wildlife Society Bulletin 18:16-18.

[11] Rollins, D., F.C. Bryant, and R. Montadon. 1984. Fecal pH and defecation rates of eight ruminants fed known diets. Journal of Wildlife Management. 48:807-813.

[12] McCullough, D.R. 1982 White-tailed deer pellet-group weights. Journal of Wildlife Management 46:829-832.

[13] Eberhardt, L., and R. C. Van Etten. 1956. Evaluation of the pellet group count as a deer census method. Journal of Wildlife Management. 20:70-74.

[14] Van Etten. 1959. Development and evaluation of new deer census techniques. Michigan Dept. Cons. Federal Aid Wildlife Restoration. Project W-70-R. 8pp.

However, the unadjusted density estimate doesn't account for deer that were killed or died during the period after leaf-off but before the transects were completed. The unadjusted estimates represent average overwinter densities. To calculate spring densities, the number of pellet groups produced by deer that died before spring surveys was subtracted from an estimate of all pellet groups (across the study area, not just the ones counted) deposited by deer that died and deer that survived until spring. For this estimate, average deposit rates for deer of 19.8 per animal per day were used. If adjusted density estimates were ≤0.05% of the unadjusted estimate, then the unadjusted estimate was used.

Confidence intervals (95%) were calculated for the whole Blue Hills Reservation and each study site. Five replicate samples were drawn from each study site by randomly assigning each transect within each grid a number from 1 to 5. Replicate 1 consisted of all the transects assigned number 1 and so on. Mean deer density estimates, standard deviations, and confidence intervals were calculated from the 5 replicates.

7.4 – Results: Pellet Group Data Analysis

Transects were walked between February 28 and April 5, 2017. Participants in the study collectively walked over 50 km (see table below). Deer pellets were counted in each study area. Very few dead deer were encountered on transects.

Survey Effort and Number of Pellet-Groups Seen in Each Study Area, 2017

Study Site	Size of Study Site	No. of Transects	No. of km Walked	No. of Plots Sampled	No. of Pellet Groups
Blue Hills – Overall	15 km^2	76	52.0	1,707	320
Fowl Meadow/Little Blue		15	10.4	342	170
Great Blue/Houghton's Pond		25	17.1	563	42
Wampatuck/Chickatawbut		21	16.2	531	58
Ponkapoag/Nike Site		15	8.3	521	44

A. <u>Deer Densities</u>: Unadjusted deer densities were calculated averaging the three deposition rates (average from table on previous page ± one (1) standard deviation) and ranged from a low of 25.4 deer/mi^2 in the Great Blue/Houghton's Pond area to a high of 136.4 deer/mi^2 in the Fowl Meadow area (see table below). Adjusted deer densities were calculated for the Blue Hills to account for deer harvested during controlled deer hunts. However, adjusted deer density estimates were almost identical to unadjusted densities, so unadjusted densities are presented.

Unadjusted Deer Densities Expressed as # of Deer/mi^2 (km^2) and 95% Confidence Intervals, 2017

Study Site	Density Estimate	95% Confidence Interval
Blue Hills – Overall	51.6 mi^2 (19.9 km^2)	38.8 mi^2 (15.0 km^2) – 64.5 mi^2 (24.9 km^2)
Fowl Meadow/Little Blue	136.4 mi^2 (52.7 km^2)	93.1 mi^2 (35.8 km^2) – 180.0 mi^2 (69.5 km^2)
Great Blue/Houghton's Pond	25.4 mi^2 (9.8 km^2)	14.5 mi^2 (5.6 km^2) – 36.3 mi^2 (14.0 km^2)
Wampatuck/Chickatawbut	29.5 mi^2 11.4 km^2)	17.9 mi^2 (6.9 km^2) – 41.1 mi^2 (15.9 km^2)
Ponkapoag/Nike Site	40.8 mi^2 (15.8 km^2)	28.0 mi^2 (10.8 km^2) – 53.7 mi^2 (20.7 km^2)

7.5 – Discussion

Collecting deer pellet-group data was relatively straightforward and simple. Because the actual sample plots (4.52 m^2) were small, and only pellets on top of the leaves were counted, it is unlikely that any pellet-groups were missed. Most transects were easy to locate and walk. However, there were a few transects that bisected large wetlands, areas of thick invasive species, or steep slopes. In a few cases, short detours were necessary when observers were walking the lines in order to avoid open water or deep wetlands.

The biggest potential influence on deer estimates is the pellet-group deposit rate. While published literature provided useful guidance, these studies were conducted outside Massachusetts. As a result, deposit rates for deer in Massachusetts may be different, and deposition rates may vary throughout the winter. Using the average deposition rate ± one standard deviation provides a reasonable alternative when the exact deposition rate is unknown.

Our deer density estimates in the Blue Hills Reservation were highly variable from site to site. This information will be useful when making year to year management decisions on where to hunt and with what intensity. Deer density estimates in other DCR areas (namely areas of the Quabbin Reservation) where hunting has traditionally occurred were well below the accepted limit of 20 deer/mi^2 that is needed for adequate tree regeneration and growth. In the Blue Hills, where hunting only recently began, deer densities were much higher. Deer densities sustained at levels above 20 deer/mi^2 can lead to concerns about forest regeneration and tree species composition.

8.0 2017 – Estimating Deer Abundance Using Distance Sampling

8.1 – Introduction

The Massachusetts Division of Fisheries and Wildlife (MassWildlife) uses a harvest-based estimator to model deer density and trends for 15 Wildlife Management Zones (WMZ) across the Commonwealth, such that the density estimate for huntable areas in WMZ 10, where the Blue Hills Reservation is located, is approximately 15-35 deer/mi^2 of forested land. However, in areas where hunting has historically been prohibited, such as the Blue Hills (prior to 2015), deer densities are typically much higher than the WMZ 10 estimate.

Quantifying deer density in the Blue Hills Reservation is important for managers of the reservation within the DCR to establish baseline information for future management decisions and also for monitoring effectiveness of management actions. Deer density estimates for the Blue Hills Reservation are important for MassWildlife because they can be used to provide an independent density estimate at a small scale that can be extrapolated to similar lands in WMZ 10 that are closed to hunting. Also, because hunting was allowed on the property starting in the fall of 2015, the survey can be used to track population reductions related to management actions.

A. **Distance Sampling:** This method of estimating deer densities was utilized in the Blue Hills in 2013 and a detailed outline of results from this survey can be found by reviewing MassWildlife's 2013 Blue Hills Deer Abundance Survey Report. Distance sampling using line transects is a generalization of the strip transect sampling method, in which all objects within sample strips are detected. Distance sampling allows a proportion of objects to be missed away from the line or transect, thus allowing a wider strip to be sampled and increasing sample size and efficiency.[15] Distance sampling often provides a practical, cost-effective method of estimating density for a broad range of applications, from walking

[15] 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, Oxford, United Kingdom.

transects to detect inanimate objects or plants in a terrestrial setting to traversing transects in a ship to detect moving objects such as whales in a marine setting.[16]

The distance sampling estimator is more appealing than estimators that require marked animals (mark-recapture methods) because animals do not need to be captured or handled, allowing the method to be far less expensive when used to estimate population size. Also, distance sampling is more applicable to a wider range of species and areas of inference than harvest-based models because removals are not required.

However, assumptions may be difficult to meet to obtain unbiased population estimates of highly mobile animals such as deer.[17] Assumptions include: (1) surveys are conducted from randomly-placed points or transects; (2) all objects on or near a point or transect are detected with certainty; (3) objects are detected at their initial location and any movement prior to detection is independent of observers; and (4) measurements are accurate.[18]

Common methods of ground navigation of random transects or points include walking, horseback, and all-terrain vehicles; but these may result in deer moving in response to observers before detection, which results in negatively biased estimates of density.[19] Aerial surveys using the distance sampling method can avoid the problem of deer movement in response to the observer, but are expensive, animals may move in response to a low-flying plane or helicopter, and it is difficult to ensure that all deer on the transect are detected, especially in forested landscapes.[20] Surveying from roads using distance sampling is a convenient and commonly used method,[21] which can reduce movement in response to observers. However, roads are not random; thus, sampling from them violates the critical

---

[16] Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5-14.

[17] Buckland, et al. 2001.

Koenen, 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.

Fewster, R. M., C. Southwell, D. L. Borchers, S. T. Buckland, and A. R. Pople. 2008. The influence of animal mobility on the assumption

[18] Buckland, et al. 2001.

[19] Koenen, et al. 2002.

[20] Naugle, D. E., J. A. Jenks, and B. J. Kernohan. 1996. Use of thermal infrared sensing to estimate density of white-tailed deer. Wildlife Society Bulletin 24:37-43.

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 24:37-43.

Thomas, et al. 2010.

[21] Gill, R. M. A., M. L. Thomas, and D. Stocker. 1997. The use of portable thermal imaging for estimating deer population density in forest habitats. Journal of Applied Ecology 34:1273-1286.

Heydon, M.J., J.C. Reynolds and M.J. Short. 2000. Variation in abundance of foxes (*Vulpes vulpes*) between three regions of rural Britain, in relation to landscape and other variables. Journal of Zoology, London, 251:253–264.

Koganezawa, M., and Y. Li. 2002. Sika deer response to spotlight counts: implications for distance sampling of population density. Mammal Study 27:95-99.

Ruette, S., P. Stahl, and M. Albaret. 2003. Applying distance-sampling methods to spotlight counts of red foxes. Journal of Applied Ecology 40:32-43.

Ward, A. I, P. C. L. White, and C. H. Critchley. 2004. Roe deer *Capreolus capreolus* behaviour affects density estimates from distance sampling surveys. Mammal Review 34:315-319.

Bates, S. 2006. White-tailed Deer Density Monitoring Protocol Version 1.1. Inventory and Monitoring Program, National Capital Region Network, National Park Service. Washington, D.C., USA.

assumption of randomly placed transects and can result in biased estimates of density, which may be unrepresentative of the population.[22]

Furthermore, if the distribution of deer was correlated with the location of roads, then the estimator for detection probability may be biased, leading to a biased estimator of density. The direction of the bias would depend on whether deer were avoiding or selecting for areas near roads, and the magnitude of the bias would depend on the amount of non-uniformity of the distribution of deer relative to transects. Typically, deer avoid areas near roads, such that the bias in density estimates would be negative, leading to an estimate of abundance lower than actual.[23] Nevertheless, navigating existing trails or roads with vehicles at night using spotlights (deer eyes reflect light) seems to be the best balance of limiting bias when surveying highly mobile animals such as deer. Further, if the bias is constant from year to year, estimates can be used to investigate trends.

8.2 – Methodology: Survey Area and Sampling Protocol

A representative sample of available roads and trails within the Blue Hills Reservation was selected as transects for distance sampling surveys. MassWildlife identified 11-14 survey routes or transects of similar length (range = 0.78–3.86 mi, mean length = 2.32 mi) rather than a few long routes to better estimate the variance related to encounter rate.[24] Approximately half of the transects were dirt trails and the other half were paved roads; however, busy highways were not surveyed for safety reasons. Due to the density of houses and development, much of the private lands surrounding the Blue Hills were not surveyed. Transects included only segments of roads where spotlights could be used and were considered deer habitat (sections near buildings, parking lots, open water, etc. were excluded).

Approximately 80% of the study area was forested and/or shrubland and considered deer habitat. A GIS (ArcView 10.0, Environmental Systems Research Institute. Redlands, California, USA) was used to measure transect lengths. The map on the following page shows the transects used in 2017 for the distance sampling surveys and the locations of observed deer and number of deer in each group from one night of surveying.

8.3 – Methodology: Distance Sampling Surveys

Distance sampling surveys were conducted prior to leaf-out (early/mid-April 2017). Surveys were started no earlier than 30 minutes after sunset and lasted approximately 5-6 hours. Two crews were used to completely survey the study area in one night and this was repeated for 4 nights to reach an adequate sample size of observations for calculations. One crew used a pick-up truck and traversed paved roads and wider trails and the other crew used an all-terrain vehicle (ATV) and traversed more of the smaller dirt trails. Each crew consisted of two observers and one driver. The observers illuminated their respective sides of each transect with handheld spotlights while standing in the bed of the pick-up truck or ATV.

Transects were traversed at 5-10 mph and initial starting points were varied to minimize temporal influences in deer detection that may have existed because of deer activity patterns. Surveys were not conducted on nights in which adverse environmental conditions existed (wind $\geq$10 mi/hour, rain, visibility $\leq$1 mi).

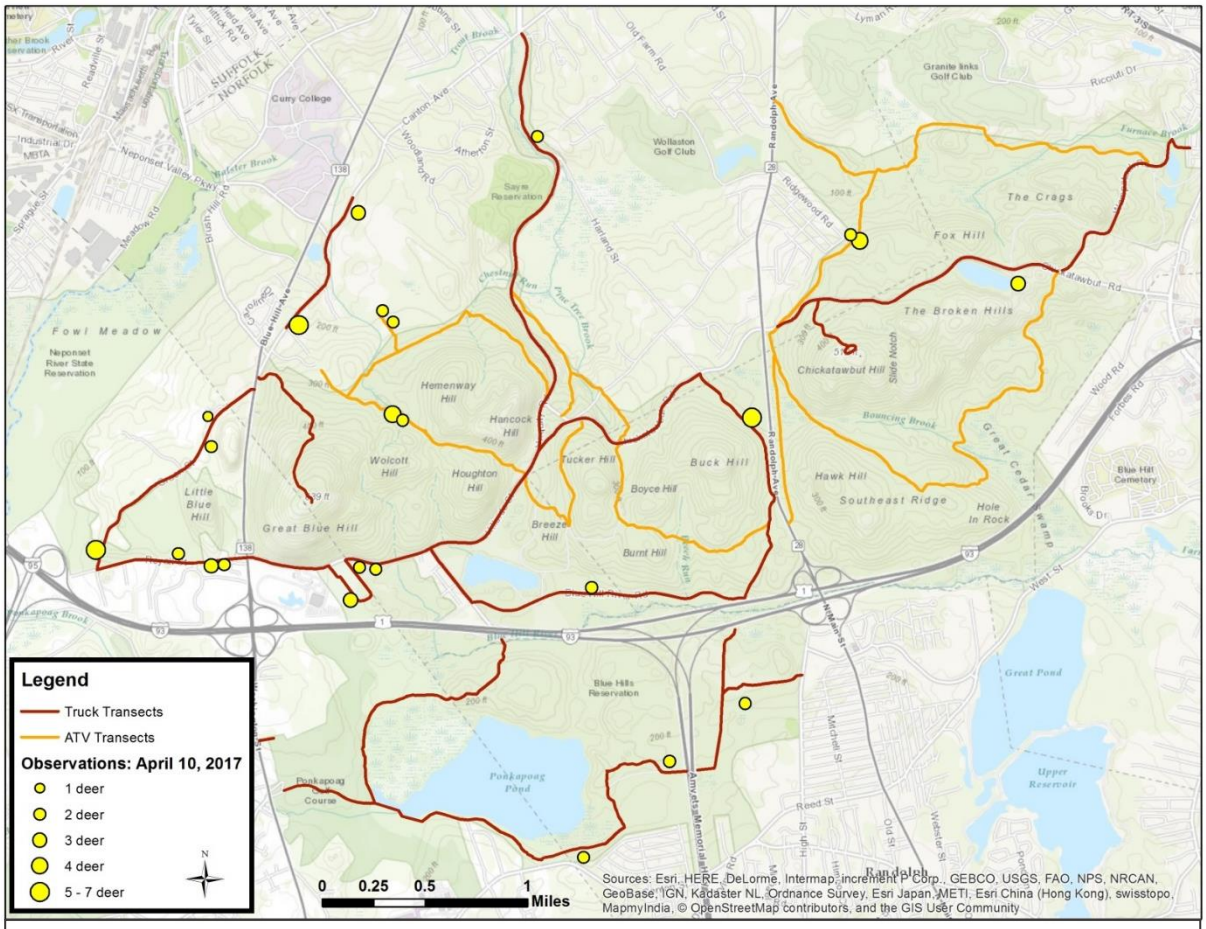
---

[22] Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294-1297.

Buckland, et al. 2001

[23] Stainbrook, D. P., and D. R. Diefenbach. 2011. Methods of estimating white-tailed deer abundance at Gettysburg National Military Park: testing assumptions of distance sampling. Natural Resource Technical Report NPS/NER/NRTR—2011. National Park Service, Fort Collins, Colorado.

[24] Buckland, et al. 2001.



Map of the Blue Hills Reservation showing the transects used for the 2017 distance sampling survey. Also displayed are the locations of observed deer and number of deer in each group from one night of surveying (April 10, 2017).

When deer were detected, the observer recorded group size, perpendicular distance, and whether the deer were located in open or forested habitat. Groups were defined based on behavioral cues and proximity to one another. Each deer in a group was no more than one-half the distance from the closest deer in its group than to the next closest deer of a neighboring group. Perpendicular distance was obtained using a handheld laser rangefinder (LTI-TruPulse, Laser Technology, Inc., Centennial, CO, USA).

The program DISTANCE[25] was used to estimate density of deer groups and employed a size-bias regression method to model group size as a function of distance from the transect. If this regression was not significant ($\alpha = 0.05$), we used mean group size. Because the detection function is likely different for open areas than for wooded areas, the habitat type for each observation (open or forested) was utilized as a covariate, using multiple covariate distance sampling (MCDS). Both half-normal and hazard-rate key functions were used to model the detection function and models were constrained to use no adjustment terms to ensure the detection function was monotonically non-increasing.[26] We used Goodness of Fit tests and Akaike's Information Criterion (AIC) as aids in model selection for the detection function curve.[27]

[25] Thomas, et al. 2010.

[26] Marques T. A., L. Thomas, S. G. Fancy, and S. T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. The Auk. 124:1229-1243.

[27] Burnham K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer, New York, New York, USA.

8.4 – Results: Distance Sampling Data Analysis

Over four nights of surveying, 79 groups of deer (199 individual deer) were detected over 112 miles of transect. The estimate of density, using MCDS with habitat type as a covariate and the half-normal key function, was 18 deer per square mile (95% Confidence Interval [CI] = 59 – 118) (see table below) or **23 deer per square mile of deer habitat (95% Confidence Interval [CI] = 12 – 44)**, which is calculated by dividing the density estimate by the proportion of the study area considered deer habitat (80% forested and other cover).

Estimates of density ($\hat{D}$) of white-tailed deer with measures of precision from the April 2017 distance sampling survey, using habitat type (field or forest) of each observation as a covariate, Blue Hills Reservation, Massachusetts.

Model[a]	*n*[b]	$\hat{D}$ (deer/mi^2)	*E(S)*[c]	$\hat{P}$ [d]	$\hat{D}$ 95% CI [e]
hn	79	18	2.52	0.46	10 – 35

[a] hn = half-normal key function
[b] *n* = no. of observed clusters
[c] E(S) = expected cluster size (mean cluster size or [+]size-biased regressed cluster size)
[d] $\hat{P}$ = detection probability
[e] CI = confidence interval
[f] CV = coefficient of variation

8.5 – Discussion

There is no perfect solution for meeting all assumptions of distance sampling when surveying for highly mobile animals such as deer. Even if completely random transects are used, it is difficult to detect all animals on the transect from aerial surveys[28] and walking transects often results in avoidance of the observer.[29] Additionally, as discussed in Buckland et al. (2001) and Fewster et al. (2008), the use of non-random roads or tracks as transects for distance sampling can result in considerable bias because roads may affect the distribution of animals. An inaccurate or biased estimator with good precision, such as distance sampling, may be more useful for management and predicting trends than an accurate estimator with poor precision. Additionally, the logistical advantages of using roads as transects may outweigh disadvantages.[30] Nevertheless, any study using roads or tracks as transects with distance sampling should carefully consider and explain the effects of bias.

For instance, if roads are used as transects and animals avoid roads, abundance estimates should be interpreted cautiously (considered conservative estimates), but can be very useful if treated as indices of abundance. For example, the true density may not be known exactly, but if the bias is consistent each year, plotting those estimates over time can be very telling of the actual population trends.

We observed fewer groups of deer near transects than slightly further away. Fewer detections near the road may be for a number of reasons, including avoidance of the areas near roads (e.g., because of disturbance or

[28] Fewster, et al. 2008.

[29] Koenen, et al. 2002.

[30] Heydon, et al. 2000.

correlation of habitat with roads),[31] movement away from roads in response to observers, or missed observations near roads.[32] Stainbrook and Diefenbach (2011) observed fewer deer near transects during surveys (from GPS collar locations) likely because of avoidance of areas near roads rather than movement in response to observers. However, we cannot rule out movement of deer in response to our vehicles in the Blue Hills Reservation because we did not have GPS-collared deer to investigate their movement. On the other hand, we rarely observed deer moving in response to our presence (most deer were bedded) and observers were trained to always look ahead to ensure all observations on the transect were detected and that observations were recorded at their initial location.

Regardless of the reason, a lack of observations near roads would lead to negatively biased estimates of density or estimates of density that are lower than actual. Our results likely concluded that the distribution of deer was correlated to the distribution of the roads we surveyed, such that deer likely avoided areas near transects. Therefore, we expected the estimated detection probability was positively biased, leading to negatively biased estimates of density (abundance estimates are likely lower than actual).

Also, because we were unable to survey much of the adjoining private land and areas behind houses that offer supplemental food (landscaping) and sanctuary bedding areas, our estimate is likely an underestimate of abundance for the larger region. In 2013, deer density on and off the Reservation may have been quite similar since it was all closed to hunting. However, the 2015 and 2016 hunts removed deer from the Reservation interior, such that deer densities in the Reservation interior may be much lower than the outside areas that are still closed to hunting. Further, some of the surviving deer may have adjusted their range and movement patterns relative to the hunting pressure, leading to less time spent in the Reservation.

One of the questions after the 2013 survey was whether deer numbers were high everywhere or higher in some areas than others. The hunter harvest data and sightings suggested that deer numbers were much higher in some areas than in others. Recent advances in pellet count survey methodology have allowed more accuracy in these surveys.[33] One major benefit to the pellet count survey is that it allows a finer-scale look at deer numbers by region within the Reservation, which was a limitation of the distance sampling surveys, which provide an overall average estimate.

Given the benefits, MassWildlife worked with DCR to conduct deer pellet count surveys a few weeks prior to the 2017 distance sampling survey (as outlined in Section 7 of this report). The pellet counts also allow data to be collected in a more representative and random way in and around the Reservation and does not rely on the roads and trail network, which can limit the bias and lead to more realistic estimates of density.

For instance, the distance sampling surveys were unable to incorporate the Fowl Meadow section of the Reservation because of a lack of navigable trails. From vegetation impact data, deer sign, and hunter harvest data, the Fowl Meadow area appears to have the highest deer density in the Reservation. We surveyed the one trail available through this area in 2013 with distance sampling, but the vegetation and wetlands surrounding the trail made it difficult to see any deer that were present and many sections were flooded or surrounded by wetland. As a result, we likely underrepresented deer numbers there in 2013. Further, in the 2017 distance sampling survey, we were unable to travel down this transect because of flooding. Thus, the distance sampling estimates from both years are likely underrepresenting deer density for that area. We were, however, able to survey this area with pellet counts, and it ended up being the area with the highest deer density (see section 7.4(A) of this report). Thus, the distance sampling surveys were unable to include the high deer numbers there, so are likely unrepresentative for average deer density across the entire Reservation.

Another potential factor influencing deer distribution could be the timing of the surveys relative to leaf-out and herbaceous growth on the forest floor that can provide seasonal food. The 2013 survey was conducted in

[31] Fewster, et al. 2008.

[32] Buckland, et al. 2001.

[33] DeCalesta, 2013.

early May, but leaf-out was a little late that year. The 2017 survey was conducted in early to mid-April, but leaf-out was a little early that year. So, they did not appear to be that much different with respect to timing of leaf-out, but there is the potential for the amount of foliage and herbaceous growth to be slightly further along during the 2013 survey, which could have provided additional food availability in the Reservation. This could have led to more representative distribution of deer in the 2013 survey, but a bias in the 2017 survey where deer spent more time in neighboring areas with more supplemental food sources, such as landscaping.

In summary, the 2017 survey likely provided a slightly negatively biased estimate of average deer density across the Reservation. Additionally, the estimate may not be completely representative of the true density in the larger region, especially for the privately owned sanctuary areas outside of the Reservation.

Also, our estimate is lower than the estimate from pellet counts that were also conducted during this time. The pellet count survey was able to cover a random and representative area of the Reservation and may offer a more accurate estimate of deer density for the Reservation. Another benefit of incorporating pellet counts is that can offer finer scale data on deer density and use throughout the Reservation.

Note: To see MassWildlife's full report on the 2017 distance sampling survey, please see Appendix B.

9.0 Deer Abundance Surveying – Conclusions & Management Implications

The estimate of deer density in the Blue Hills Reservation during the spring of 2013 was 67 deer per square mile or 85 deer per square mile of deer habitat (95% CI = 59 – 118). Density estimates, whether negatively biased or not, were well-above MassWildlife's statewide deer management range or goal of 6-18 deer/mi^2 of forest and the threshold density of 18-20 deer/mi^2 of forest where major impacts can be seen in northeastern forests.[34] It was recommended by MassWildlife for DCR to begin taking management action using regulated hunting to reduce the deer population, with a priority on removing female deer.

Beginning in the fall of 2015, regulated hunting (in the form of short controlled hunts) was allowed in portions of the Blue Hills to reduce the deer population. The 2015 hunt was allowed on 4.44 mi^2 of the approximately 9.6 mi^2 area in and around the Blue Hills Reservation. The huntable area for the 2016 hunt was increased to 5.8 mi^2. In 2015, 64 deer were removed (17 males and 47 females) for an average of 14 deer/mi^2 of forest removed (range per huntable section of 8-48 deer/mi^2 of forest removed). In 2016, 58 deer were removed (31 males and 27 females) for an average of 10 deer/mi^2 of forest removed (range per huntable section of 0-38 deer/mi^2 of forest removed). Also, there were additional deer taken on private lands surrounding the Blue Hills Reservation as part of private landowner efforts to manage deer on their property.

Since females are the reproductive segment of the population, looking at rates of removal can be informative of how effective hunting was. In the western part of the state (Wildlife Management Zones 1-4), an average of 0.3 females/mi^2 of forest is removed. In the central part of the state (Wildlife Management Zones 5-9), an average of 0.6 females/mi^2 of forest is removed. In the eastern part of the state (Wildlife Management Zones 10-12), an average of 1.2 females/mi^2 of forest is removed.

In the Blue Hills hunt, the 47 females removed in 2015 equates to about 10.6 females/mi^2 of hunted land or 4.9 females/mi^2 of all forest in the Blue Hills. This is at least three times as many females than the eastern average or over twice the 1.9 females/mi^2 of forest taken in Wildlife Management Zone 10. The 2016 hunt

[34] Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53:524-532.

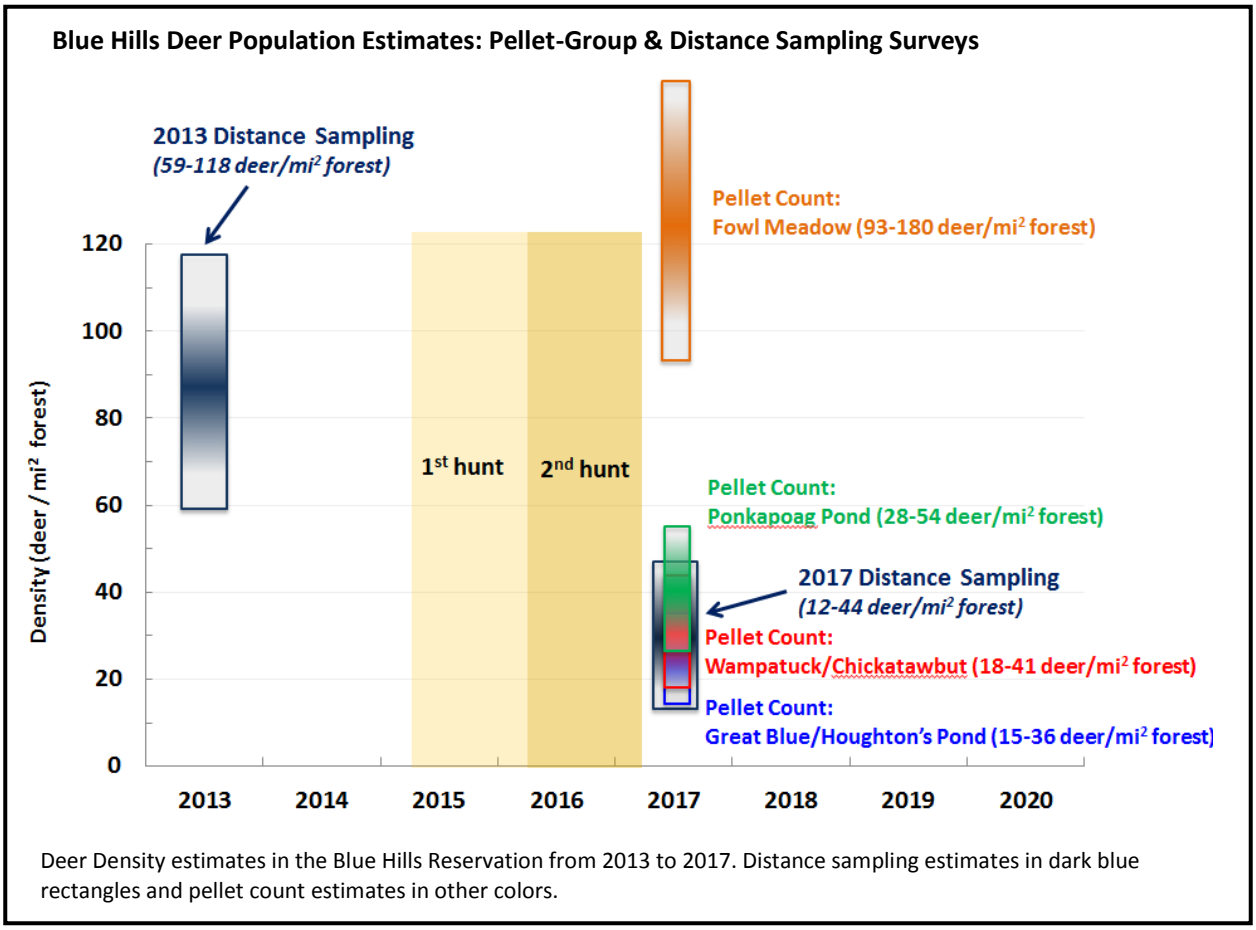
Horsley, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impacts on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13: 98-118.

took 27 females, which equates to 4.7 females/mi^2 of hunted land or 2.8 females/mi^2 of all forest in the Blue Hills.

MassWildlife also recommended conducting that another deer abundance survey would not be necessary until at least two or three years after management action was taken, so that estimates would actually be informative and be able to detect a population reduction, given their corresponding confidence limits. As outlined in Section 8 of this report, another distance sampling survey was conducted in the spring of 2017 (after two years of limited hunting). The estimate of density from this survey was 18 deer/mi^2 or 23 deer/mi^2 of deer habitat (95% Confidence Interval [CI] = 12 – 44). Additionally, as outlined in Section 7 of this report, a pellet count survey was conducted in April 2017, which estimated approximately 52 deer per square mile (95% Confidence Interval [CI] = 45 – 64). The pellet count may provide a more accurate and representative estimate of density than the distance sampling survey because assumptions are not as difficult to meet.

The distance sampling survey yields an average density across the entire surveyed area, but cannot provide estimates of density at any one individual section of the Reservation. Thus, some areas likely had much higher deer numbers than others. Variability across the region was also seen with the harvest data. Some areas had a lot of deer removed, while others very few. The pellet count data provides a look at variability across the region as well.

In summary, the two years of deer reductions likely led to a population reduction within the huntable areas and a slight population reduction across the larger area. Rather than looking at the point estimates, it is more useful to look at the trends with confidence intervals included (see figure below). Combining the data from the 2017 distance sampling survey and the 2017 pellet count survey provides a wide interval around the estimate, but the trend is that deer numbers are lower than they were in 2013, but still above the statewide goal of 6-18 deer/mi^2 of forest that is important for reducing impacts to the habitat and forest within and around the Blue Hills Reservation.



Deer Density estimates in the Blue Hills Reservation from 2013 to 2017. Distance sampling estimates in dark blue rectangles and pellet count estimates in other colors.

10.0 Vegetation Monitoring Efforts

DCR's Bureau of Forest Fire Control and Forestry will continue with existing vegetation monitoring efforts to further study impacts to vegetation by deer in the Reservation.

10.1 – Deer Exclosures

As part of the effort to quantify the impacts of deer within the Blue Hills, deer exclosures were established in 2011 to measure vegetation species abundance and growth patterns growing within the exclosure and at a control point just outside of the exclosure where deer can browse. There are two such exclosures in the Blue Hills. These exclosures are inventoried on a yearly basis to measure growth inside and outside the exclosures. A new exclosure will be installed in 2018 to expand on the data collection.

10.2 – Vegetation Sampling

To determine if the understory is responding to the reduction of deer in the Blue Hills, the regeneration vegetation sampling that was conducted in the summer of 2015 will occur in 2020. The same format of sampling 400 plots will occur. See the 2015 Blue Hills Deer Management Plan for details of the sampling technique.

In 2016 a forest type map was created from aerial photo interpretation and 532 field plots. The top 5 upland forest types of the Blue Hills Reservation are: Eastern white pine - oak (2,360 acres); mixed oak (1,223 acres); oak – hardwoods (743 acres); Eastern white pine (202 acres); and Pitch pine – scrub oak (63 acres).

APPENDIX A

Blue Hills State Reservation

2016 Controlled Deer Hunt Program

All permittees are required to know and understand the information contained in this document. Please review and read this document carefully and thoroughly prior to attending your assigned hunter orientation.

Background:

Since its acquisition by the Commonwealth over 120 years ago, hunting has not been permitted within the Blue Hills Reservation. With the absence of any form of deer management, population densities within the Reservation have consequently increased to significant levels. Over-browsing of trees and plants as a direct result of these high deer densities has compromised the long-term health of the Reservation's forests and its ability to successfully regenerate. This situation is negatively impacting plants and animals in the Reservation; including rare species.

The Department of Conservation and Recreation (DCR), in consultation with the Massachusetts Division of Fisheries and Wildlife (DFW), has determined that the considerable size of the deer herd is negatively impacting the Department's mandate to protect the natural resources of the Blue Hills Reservation. As environmental agencies with the legal mandate and mission to conserve the state's natural resources, it is the responsibility of DCR and DFW to take action to protect the natural resources of the Blue Hills for the enjoyment and appreciation of current and future generations. Moreover, DCR and DFW have concluded that the most practical, workable, and effective management option to accomplish the goal of reducing deer densities is through the use of controlled/permitted hunting.

The use of controlled hunting is designed to serve as a management tool in achieving the goal of maintaining an ecologically sustainable deer population that allows for the continuous growth and development of forest regeneration. **Moreover, the Blue Hills Controlled Hunt is not a recreational hunt.** DCR and DFW view the hunters selected to participate in the hunt as partners in successfully achieving the primary objectives of deer management in the Blue Hills. As partners in this effort, DCR and DFW expect all selected permittees to abide by and comply with the rules of the Blue Hills Controlled Hunt Program, DCR's regulations for use of its parklands, DFW's rules and regulations related to hunting, and all Commonwealth laws regarding the possession and discharge of firearms.

Selected permittees who violate any rules or regulations will be immediately removed from the property, permanently ineligible for participation in future years, and subject to any relevant fines or penalties prescribed by applicable state laws and/or regulations.

General Rules & Provisions for the 2016 Blue Hills Controlled Deer Hunt

1. **Hunting by Access Permit Only:** Hunting of white-tailed deer shall be allowed in designated areas of the Blue Hills Reservation by those persons holding an access permit issued by the DCR. All persons to whom such a permit has been issued are also required to have a valid 2016 Massachusetts Hunting/Sporting License issued by DFW. All persons to whom such a permit has been issued who are also residents of the Commonwealth of Massachusetts must have a valid FID card or license to carry. All licenses must be valid on the days in which the controlled hunt is scheduled to take place.

   Interested hunters are required to submit an application in order to participate in the controlled hunt. Permittees are then selected via a random permit drawing from among the larger applicant pool.

   DCR-issued access permits are valid only for the person named on the permit and for the date/time period specified on the permit.

2. **Organization & Timing:** The 2016 Blue Hills Controlled Deer Hunt will take place during the annual shotgun season over the course of four (4) days:
   - Tuesday, November 29th
   - Wednesday, November 30th
   - Tuesday, December 6th
   - Wednesday, December 7th

3. **Management Zone Assignments:** Each permittee is assigned to a particular management zone. The management zone shall be noted and identified on the DCR-issued access permit. Permittees are required to remain within the boundaries of their assigned management zone while hunting. In addition, shotgun hunters are not allowed to hunt in areas designated for archery hunting. Similarly, archery hunters are not allowed to hunt in areas designated for shotgun hunting.

   The boundaries of the management zones have been delineated using not only the existing state firearms discharge setback laws, but also hard boundary delineations such as trails, roads, and pathways. In some areas, DCR has posted no hunting signs to delineate the boundary of a management zone. All permittees are required to know the boundaries of their management zone. Absolutely no hunting or discharge of firearms is allowed outside of the delineated boundaries. Permittees will be provided detailed trail maps with the boundaries of their management zone clearly delineated.

4. **General Hunting & Discharge Prohibitions:** No hunting or discharge of firearms is allowed outside of the boundaries of the designated management zones, within 500 feet of any building or dwelling, within 150 feet of any roadway, or in any area posted as no hunt zones. In 2016, no hunting will be allowed west of the Neponset River (in the Fowl Meadow area), south of Wolcott Path in the Great Blue Hill section, and in the southwest areas of the Ponkapoag section (including Ponkapoag Golf Course).

5. **Hunter Orientation Required:** All permittees are required to attend a hunter orientation session in order to be allowed to participate in the Blue Hills Controlled Hunt. Selected hunters who do not fulfill the hunter orientation requirement will not receive a permit and will not be eligible to participate in the controlled hunt.

6. **Deer Hunting Only:** The Blue Hills Controlled Deer Hunt is restricted to white-tailed deer only. The shooting or injury of any other bird or animal species is strictly prohibited.

7. **Hunting Implements:** Permittees selected to participate in the 2016 controlled hunt will be allowed to use shotguns with slug only. The use of buckshot is prohibited. In addition, the limited use of archery hunting will be allowed in certain designated areas of the Reservation. Although the archery hunting season in Massachusetts typically begins in October, archery hunting will only be allowed within the Reservation during the days of the controlled hunt.

8. **Scouting:** Permittees are allowed to scout within their management zone prior to the controlled hunt. While scouting, permittees are required to have the following on their person:
    - DCR Notice of Selection Letter
    - 2016 Massachusetts Hunting/Sporting License
    - Valid photo ID

    The use of trail/game cameras for the purposes of scouting is prohibited. In addition, scouting will not be allowed on those days in which the controlled hunt is actually taking place.

9. **Tree Stands:** Permittees will be allowed to use tree stands while participating in the controlled hunt. Tree stands must be either a climbing tree stand or a hang-on tree stand with climbing sticks (please be sure to bring the bottom section of the climbing sticks with you on the day of the controlled hunt).
    - Permittees selected to hunt on either November 29th or 30th will be allowed to install tree stands beginning Saturday, November 26th and must remove the tree stand by Friday, December 2nd.
    - Permittees selected to hunt on either December 6th or 7th will be allowed to install tree stands beginning Saturday, December 3rd and must remove the tree stand by Friday, December 9th.

    The installation of a tree stand does not entitle a hunter to a particular area of the Reservation. Hunters possessing a permit to hunt in a particular management zone may hunt in any area within the boundaries of that zone. The only exception to this rule is that shotgun hunters are not allowed to hunt in areas designated for archery hunting and archery hunters are not allowed to hunt in areas designated for shotgun hunting.

    In accordance with DCR's regulations at 302 CMR 12.11 (10), the installation of a permanent tree stand is not allowed. Permanent tree stands are defined as a type of hunting platform or structure (emplaced for any period of time) which is fastened to a tree by nails, bolts, wire or other fasteners which intrude through the bark into the wood of the tree.

10. **Hunting Blinds:** The use of on-the-ground hunting blinds is prohibited.

11. **Vegetation Cutting:** Cutting of branches, trees, or shrubs is prohibited.

12. **Minor Permittees:** Any permittee selected to participate in archery hunting who is also under the age of 18 years must be accompanied by an adult over the age of 21 years who is also a registered hunter possessing a valid Massachusetts Hunting/Sporting License. The accompanying adult must attend a mandatory orientation session (with the minor permittee) and is responsible for supervising the minor permittee at all times while hunting and may not bring or discharge any firearms himself/herself.

    With regard to shotgun hunting, individuals possessing a valid Massachusetts Hunting/Sporting License who are also under the age of 18 years must apply with a co-applicant who is over the age of 21 years and is also a registered hunter possessing a valid Massachusetts Hunting/Sporting License. As co-applicants, both individuals are considered permitted hunters and are allowed to participate in the controlled hunt.

13. **Antlerless Permits:** DFW will make antlerless deer permits specific to the Blue Hills Controlled Deer Hunt available to all permitted who successfully complete the mandatory orientation session. All hunters selected to participate must purchase two (2) antlerless permits. No more than four (4) antlerless permits can be purchased. The use of any Zone 10 antlerless permits is prohibited in the Blue Hills. Antlerless deer harvested during the Blue Hills Controlled Deer Hunt are considered "bonus deer" and do not count towards state bag limits. Antlered deer will count toward the statewide bag limit of two (2) antlered deer.

14. **Parking & Vehicular Access:** Permitted hunters are not allowed to park their vehicles along the sides of Route 24 or I-93. In addition, vehicular access is prohibited on the Reservation's trails. Permittees should make use of designated parking areas. Permittees will also be allowed to park in the pull-off parking areas on Chickatawbut Road and Wampatuck Road. Where there is sufficient space, permittees may also park along the sides of Chickatawbut Road and Wampatuck Road so long as the vehicle is completely beyond the painted white shoulder line.

15. **Check-In & Check-Out:** All permittees are required to check-in and check-out each day they are scheduled to hunt. Failure to check-in and check-out by the appropriate times will disqualify a permittee from participating in the hunt. Check-in will take place between 4:30 and 7:00 AM. All permittees must check-out by 6:00 PM.

During check-in and while hunting, all permittees must have the following on their person:

- DCR Blue Hills Controlled Hunt Access Permit
- DFW Blue Hills Antlerless Deer Permits
- 2016 Massachusetts Hunting/Sporting License
- Valid FID card or license to carry
- Valid Photo ID

Failure to provide any of these documents during check-in, or while hunting, will disqualify a permittee from participating in the hunt.

16. **Deer Driving:** Only permitted hunters may participate in any deer driving. Permittees are not allowed to invite or bring family or friends for the purpose of deer driving. Permittees are prohibited from driving deer toward roadways/highways, private property, or areas of the Reservation where hunting is not be allowed.

17. **Deer Tracking:** Permittees are prohibited from tracking any wounded deer onto private property or a roadway. If you wound a deer and it crosses onto private property, contact the Blue Hills Controlled Hunt Unified Command Center (UCC). An Environmental Police Office will meet you at your location and accompany you onto private land to search for the deer. The UCC phone number shall be printed on the back of the DCR-issued access permits.

18. **Deer Cleaning:** Permittees who harvest a deer are required to move the deer at least 100 feet away from a trail for the purposes of gutting and cleaning the deer. In addition, no deer parts can be disposed of within 100 feet of the Blue Hills Reservoir. Harvested deer must be legally tagged prior to moving. To the greatest extent possible, permittees are encouraged to select areas that are generally out of view for the disposal of deer parts.

19. **Deer Removal & Check Station:** Permittees who harvest a deer must first legally tag the deer, and then are responsible for transporting the deer to their vehicle (may not be concealed from view) and must bring the deer to the Blue Hills deer check station on the day of harvest (the 48 hours does not apply and online checking is not allowed). A hunter may harvest a deer, legally tag it, and then continue to hunt and harvest one more deer prior to checking both deer. Once those two deer are checked, the hunter may go back out that day.

20. **Compliance with Rules & Requests:** All permittees within the Blue Hills Reservation shall obey the directions of posted regulatory signs, any state or local law enforcement official, Environmental Police Officer, DCR Ranger, DCR employee, and DFW employee.

21. **Carry In – Carry Out:** No litter or refuse of any sort may be thrown or left in or on any land or water within the Blue Hills Reservation while hunting.

22. **Conduct & Alcohol:** Any form of disorderly conduct is strictly prohibited during the controlled hunt. Possession or consumption of alcoholic beverages while participating in the controlled hunt is strictly prohibited.

23. **Pets & Animals:** Permittees may not bring any pets or other animals with them during the controlled hunt.

24. **Property Damage/Vandalism:** DCR is not responsible for any damage or vandalism to a permittee's property, vehicle, tree stand, or other possessions.

25. **DFW Rules & Regulations:** Massachusetts Division of Fisheries and Wildlife rules and regulations related to hunting shall apply to the Blue Hills Reservation Controlled Deer Hunt. In the event of a conflict, the Blue Hills Controlled Deer Hunt rules and provisions take precedence over the rules and regulations of the DFW.

26. **Cancellation:** The controlled hunt (in its entirety or specific dates) may be cancelled at any time due to severe weather conditions or security situations. In the case of cancellation, DCR will make all efforts to provide advance notice to permittees.

APPENDIX B

DIVISION OF
FISHERIES & WILDLIFE

1 Rabbit Hill Road | Westborough, MA 01581
MASS.GOV/MASSWILDLIFE

Director: Jack Buckley

dcr Department of Conservation and Recreation

Estimating White-tailed Deer Abundance at the Blue Hills Reservation using Distance Sampling

DRAFT Technical Report – June 2017

David P. Stainbrook[1]

[1]Deer and Moose Project Leader
The Commonwealth of Massachusetts
Division of Fisheries and Wildlife
Westborough, MA 01581

Photo taken by Bill Byrne

Contents

Page

Figures ii

Tables ii

Acknowledgments 1

List of Acronyms 1

Introduction 2

Distance Sampling 2

Study Area 4

Methods 5

Distance Sampling Surveys 6

Results 7

2013 Distance Sampling Data Analysis 7

2017 Distance Sampling Data Analysis 8

Discussion 9

Conclusions and Management Implications 12

Literature Cited 14

Figures

Page

Figure 1. Map of the Blue Hills Reservation, in eastern Massachusetts, showing the transects used for the 2013 distance sampling survey and the locations of observed deer and number of deer in each group from one night of surveying (May 7, 2013). 4

Figure 2. Map of the Blue Hills Reservation, in eastern Massachusetts, showing the transects used for the 2017 distance sampling survey and the locations of observed deer and number of deer in each group from one night of surveying (April 10, 2017). 5

Figure 3. Deer density estimates in the Blue Hills Reservation from 2013 to 2017. Distance sampling estimates in dark blue rectangles and pellet count estimates in other colors.. 11

Tables

Page

Table 1. Estimates of density ($\hat{D}$) of white-tailed deer with measures of precision from the May 2013 distance sampling survey, using habitat type (field or forest) of each observation as a covariate, Blue Hills Reservation, Massachusetts. 7

Table 2. Estimates of density ($\hat{D}$) of white-tailed deer with measures of precision from the April 2017 distance sampling survey, using habitat type (field or forest) of each observation as a covariate, Blue Hills Reservation, Massachusetts. 8

Acknowledgments

Abundance surveys in the Blue Hills Reservation were a coordinated effort between the Commonwealth of Massachusetts Division of Fisheries and Wildlife and the Department of Conservation and Recreation. I would like to give a special thanks to Alexandra Echandi, Natural Resources Specialist with the Department of Conservation and Recreation, for her exceptional effort to ensure that surveys ran smoothly.

List of Acronyms

AIC	Akaike's Information Criterion
ATV	All-terrain Vehicle
CI	Confidence Interval
DCR	Commonwealth of MA Department of Conservation and Recreation
DFW	Commonwealth of MA Division of Fisheries and Wildlife
GIS	Geographic Information System
MA	Massachusetts
MCDS	Multiple Covariate Distance Sampling
WMZ	Wildlife Management Zone

Introduction

The abundance of white-tailed deer (*Odocoileus virginianus*) in the Blue Hills Reservation, a 7000-acre state park owned and operated by the Department of Conservation and Recreation (DCR), has never been empirically estimated, but forest and habitat impacts have suggested a deer density above our statewide management range of 6-18 deer per square mile of forest. The Massachusetts Division of Fisheries and Wildlife (MassWildlife) uses a harvest-based estimator to model deer density and trends for 15 Wildlife Management Zones (WMZ) across the commonwealth, such that the density estimate for huntable areas in WMZ 10, where the Blue Hills is located is approximately 15-35 deer per square mile of forested land. However, in areas where hunting has historically been prohibited, such as the Blue Hills (prior to 2015), deer densities are typically much higher than the WMZ 10 estimate. Quantifying deer density in the Blue Hills Reservation is important for managers of the reservation within the DCR to establish baseline information for future management decisions and also for monitoring effectiveness of management actions. Deer density estimates for the Blue Hills Reservation are important for MassWildlife because they can be used to provide an independent density estimate at a small scale that can be extrapolated to similar lands in WMZ 10 that are closed to hunting. Also, because hunting was allowed on the property starting in the fall of 2015, the survey can be used to track population reductions related to management actions.

Distance Sampling

Distance sampling using line transects is a generalization of the strip transect sampling method, in which all objects within sample strips are detected (Buckland et al. 2001). Distance sampling allows a proportion of objects to be missed away from the line or transect, thus allowing a wider strip to be sampled and increasing sample size and efficiency (Buckland et al. 2001). Distance sampling often provides a practical, cost-effective method of estimating density for a broad range of applications, from walking transects to detect inanimate objects or plants in a terrestrial setting to traversing transects in a ship to detect moving objects such as whales in a marine setting (Thomas et al. 2010).

The distance sampling estimator is more appealing than estimators that require marked animals (mark-recapture methods) because animals do not need to be captured or handled, allowing the method to be far less expensive when used to estimate population size. Also, distance sampling is more applicable to a wider range of species and areas of inference than harvest-based models because removals are not required.

However, assumptions may be difficult to meet to obtain unbiased population estimates of highly mobile animals such as deer (Buckland et al. 2001, Koenen et al. 2002, Fewster et al. 2008). Assumptions include: (1) surveys are conducted from randomly-placed points or transects; (2) all objects on or near a point or transect are detected with certainty; (3) objects are detected at their initial location and any movement prior to detection is independent of observers; and (4) measurements are accurate (Buckland et al. 2001).

Common methods of ground navigation of random transects or points include walking, horseback, and all-terrain vehicles; but these may result in deer moving in response to observers before detection, which results in negatively biased estimates of density (e.g., see Koenen et al. 2002). Aerial surveys using the distance sampling method can avoid the problem of deer movement in response to the observer, but are expensive, animals may move in response to a low-flying plane or helicopter, and it is difficult to ensure that all deer on the transect are detected, especially in forested landscapes (Naugle et al. 1996, Haroldson et al. 2003, Thomas et al. 2010). Surveying from roads using distance sampling is a convenient and commonly used method (e.g., Gill et al. 1997, Heydon et al. 2000, Koganezawa and Li 2002**,** Ruette et al. 2003, Ward et al. 2004, Bates 2006), which can reduce movement in response to observers. However, roads are not random; thus, sampling from them violates the critical assumption of randomly placed transects and can result in biased estimates of density, which may be unrepresentative of the population (Anderson 2001, Buckland et al. 2001).

Furthermore, if the distribution of deer was correlated with the location of roads, then the estimator for detection probability may be biased, leading to a biased estimator of density. The direction of the bias would depend on whether deer were avoiding or selecting for areas near roads, and the magnitude of the bias would depend on the amount of non-uniformity of the distribution of deer relative to transects. Typically, deer avoid areas near roads, such that the bias in density estimates would be negative, leading to an estimate of abundance lower than actual (Stainbrook and Diefenbach 2011). Nevertheless, navigating existing trails or roads with vehicles at night using spotlights (deer eyes reflect light) seems to be the best balance of limiting bias when surveying highly mobile animals such as deer. Further, if the bias is constant from year to year, estimates can be used to investigate trends.

Study Area

We selected a representative sample of available roads and trails within the Blue Hills Reservation as transects for Distance Sampling Surveys conducted in the spring of 2013 (Fig. 1) and 2017 (Fig. 2). We identified 11-14 survey routes or transects (Figs. 1 and 2) of similar length (range = 0.78–3.86 mi, mean length = 2.32 mi) rather than a few long routes to better estimate the variance related to encounter rate (Buckland et al. 2001). Approximately half of the transects were dirt trails and the other half were paved roads; however, we did not survey busy highways for safety reasons. We were also unable to survey much some of the private lands surrounding the Blue Hills because of the density of houses and development. Transects included only segments of roads where spotlights could be used and were considered deer habitat (e.g., sections near buildings, parking lots, open water, etc. were excluded). Approximately 80% of the study area was forested and/or shrubland and considered deer habitat. We used a GIS (ArcView 10.0, Environmental Systems Research Institute. Redlands, California, USA) to measure transect lengths.

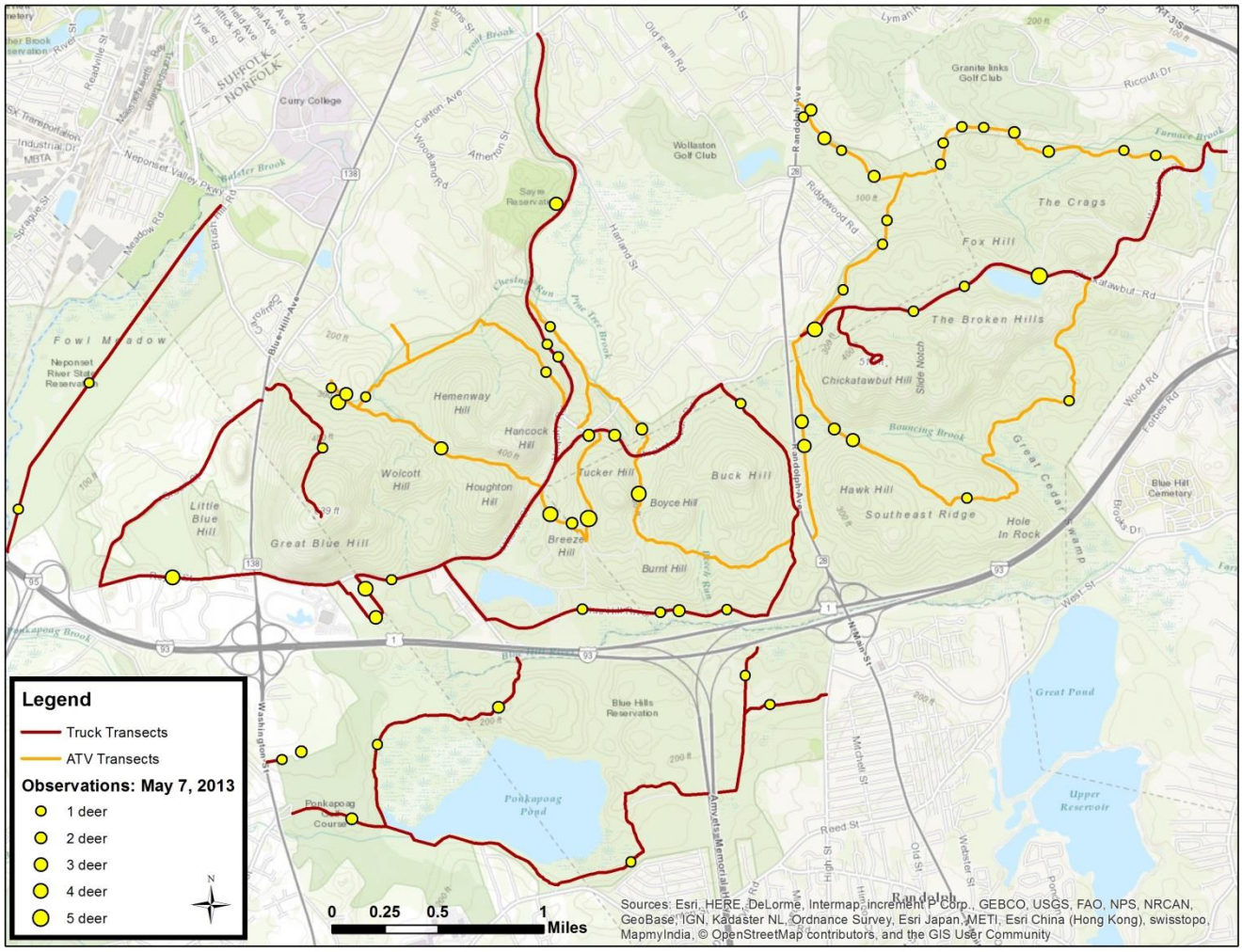


Figure 1. Map of the Blue Hills Reservation, in eastern Massachusetts, showing the transects used for the 2013 distance sampling survey. Also displayed are the locations of observed deer and number of deer in each group from one night of surveying (May 7, 2013).

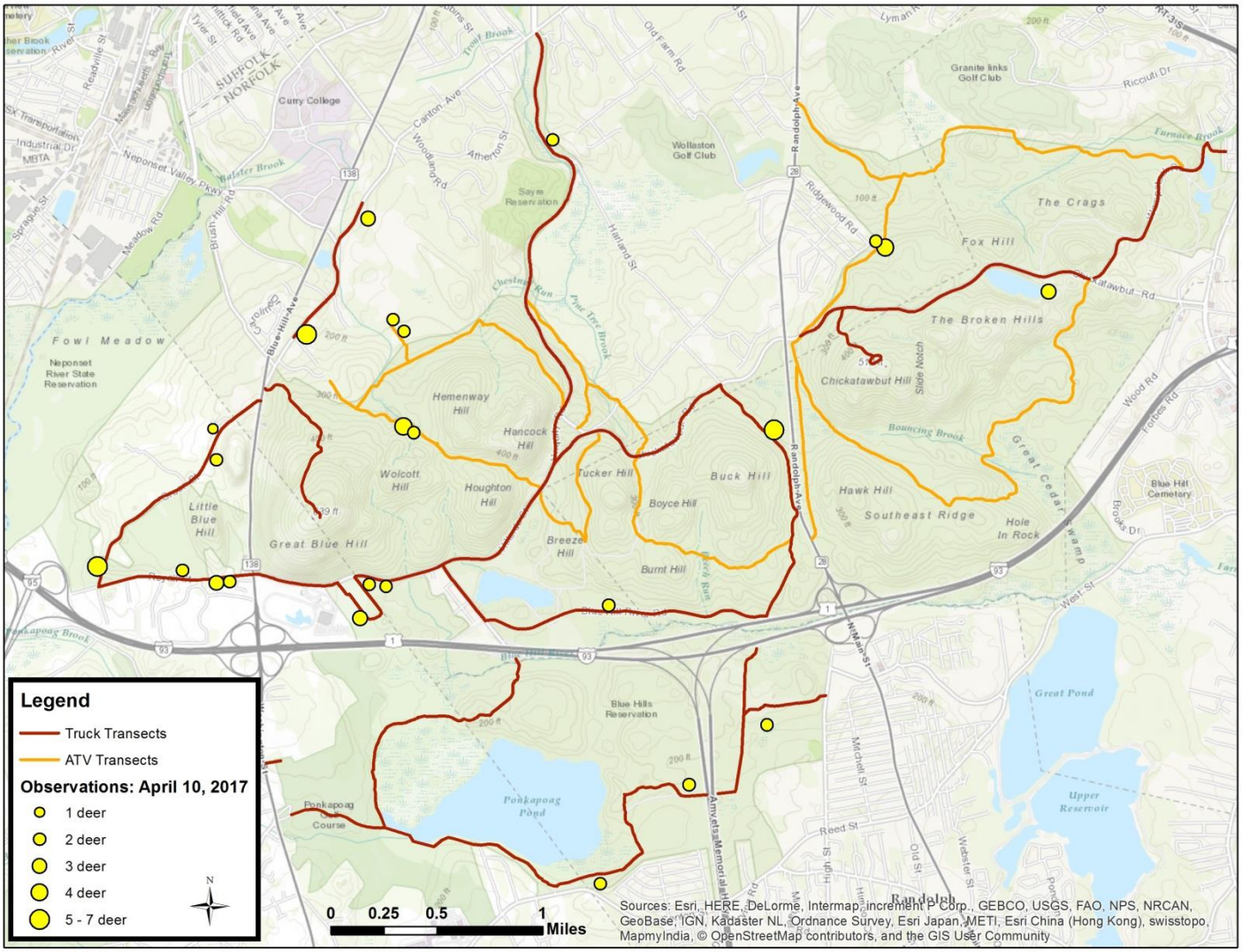


Figure 2. Map of the Blue Hills Reservation, in eastern Massachusetts, showing the transects used for the 2017 distance sampling survey. Also displayed are the locations of observed deer and number of deer in each group from one night of surveying (April 10, 2017).

Methods

Distance Sampling Surveys

We conducted distance sampling surveys prior to leaf-out (early May of 2013 and early/mid-April of 2017). We started surveys no earlier than 30 minutes after sunset, and surveys lasted approximately 5–6 hours. We used two crews to completely survey the study area in one night and repeated this for 2.5 nights in 2013 and 4 nights in 2017, to reach an adequate sample size of observations for calculations (Typically over 80-100 observations are recommended; Buckland et al. 2001). One crew used a pick-up truck and traversed paved roads and wider trails and the other crew used an all-terrain vehicle (ATV) and traversed more of the smaller dirt trails. Each crew consisted of two observers and one driver. The observers illuminated their respective sides of each transect with handheld spotlights while standing in the bed of the pick-up truck or ATV.

We traversed transects at 5-10 mph and varied initial starting points to minimize temporal influences in deer detection that may have existed because of deer activity patterns. We did not survey on a particular night if adverse environmental conditions existed (wind $\geq$10 mi/hr, rain, visibility $\leq$1 mi).

When deer were detected, the observer recorded group size, perpendicular distance, and whether the deer were located in open or forested habitat (Appendix a). We defined groups based on behavioral cues and proximity to one another. Each deer in a group was no more than one-half the distance from the closest deer in its group than to the next closest deer of a neighboring group. We obtained perpendicular distance using a handheld laser rangefinder (LTI-TruPulse, Laser Technology, Inc., Centennial, CO, USA).

We used program DISTANCE (Thomas et al. 2010) to estimate density of deer groups and employed a size-bias regression method to model group size as a function of distance from the transect. If this regression was not significant ($\alpha = 0.05$), we used mean group size. Because the detection function is likely different for open areas than for wooded areas, we used the habitat type for each observation (open or forested) as a covariate, using multiple covariate distance sampling (MCDS). We used both half-normal and hazard-rate key functions to model the detection function and constrained models to use no adjustment terms to ensure the detection function was monotonically non-increasing (Marques et al. 2007). We used Goodness of Fit tests and Akaike's Information Criterion (AIC; Burnham and Anderson 1998) as aids in model selection for the detection function curve.

Results

2013 Distance Sampling Data Analysis

The estimate of density, using MCDS with habitat type as a covariate and the half-normal key function, was 67 deer per square mile (Table 1, Appendix b) or **85 deer per square mile of deer habitat (95% Confidence Interval [CI] = 59 – 118)**, calculated by dividing the density estimate (Table 1 and Appendix b) by the proportion of the study area considered deer habitat (removing impervious surfaces and using forested and other cover = 80%). Over 2.5 nights of surveys we detected 129 groups of deer (249 individual deer) over 65 miles of transect (Fig. 1, Appendix b).

Table 1. Estimates of density ($\hat{D}$) of white-tailed deer with measures of precision from the May 2013 distance sampling survey, using habitat type (field or forest) of each observation as a covariate, Blue Hills Reservation, Massachusetts.

Model[a]	*n*[b]	$\hat{D}$ (deer/mi^2)	*E(S)*[c]	$\hat{P}$ [d]	$\hat{D}$ 95% CI [e]	CV [f]
hn	129	67	1.93	0.51	47 – 94	0.17

[a] hn = half-normal key function
[b] *n* = no. of observed clusters
[c] E(S) = expected cluster size (mean cluster size or [†]size-biased regressed cluster size)
[d] $\hat{P}$ = detection probability
[e] CI= confidence interval (Note: the 2013 report used an 85% CI)
[f] CV= coefficient of variation

2017 Distance Sampling Data Analysis

The estimate of density, using MCDS with habitat type as a covariate and the half-normal key function, was 18 deer per square mile (Table 2, Appendix d) or **23 deer per square mile of deer habitat (95% Confidence Interval [CI] = 12 – 44)**, calculated by dividing the density estimate (Table 2 and Appendix d) by the proportion of the study area considered deer habitat (80% forested and other cover). Over four nights of surveys we detected 79 groups of deer (199 individual deer) over 112 miles of transect (Fig. 2, Appendix d).

Table 2. Estimates of density ($\hat{D}$) of white-tailed deer with measures of precision from the April 2017 distance sampling survey, using habitat type (field or forest) of each observation as a covariate, Blue Hills Reservation, Massachusetts.

Model[a]	*n*[b]	$\hat{D}$ (deer/mi^2)	*E(S)*[c]	$\hat{P}$ [d]	$\hat{D}$ 95% CI[e]	CV[f]
hn	79	18	2.52	0.46	10 – 35	0.31

[a] hn = half-normal key function
[b] *n* = no. of observed clusters
[c] E(S) = expected cluster size (mean cluster size or [†]size-biased regressed cluster size)
[d] $\hat{P}$ = detection probability
[e] CI= confidence interval
[f] CV= coefficient of variation

Discussion

There is no perfect solution for meeting all assumptions of distance sampling when surveying for highly mobile animals such as deer. Even if completely random transects are used, it is difficult to detect all animals on the transect from aerial surveys (Fewster et al. 2008) and walking transects often results in avoidance of the observer (e.g., Koenen et al. 2002). Additionally, as discussed in Buckland et al. (2001) and Fewster et al. (2008), the use of non-random roads or tracks as transects for distance sampling can result in considerable bias because roads may affect the distribution of animals. An inaccurate or biased estimator with good precision, such as distance sampling, may be more useful for management and predicting trends than an accurate estimator with poor precision. Additionally, the logistical advantages of using roads as transects may outweigh disadvantages (Heydon et al. 2000). Nevertheless, any study using roads or tracks as transects with distance sampling should carefully consider and explain the effects of bias.

For instance, if roads are used as transects and animals avoid roads, abundance estimates should be interpreted cautiously (considered conservative estimates), but can be very useful if treated as indices of abundance. For example, the true density may not be known exactly, but if the bias is consistent each year, plotting those estimates over time can be very telling of the actual population trends.

We observed fewer groups of deer near transects than slightly further away. Fewer detections near the road may be for a number of reasons, including avoidance of the areas near roads (e.g., because of disturbance or correlation of habitat with roads; Fewster et al. 2008), movement away from roads in response to observers, or missed observations near roads (Buckland et al. 2001). Stainbrook and Diefenbach (2011) observed fewer deer near transects during surveys (from GPS collar locations) likely because of avoidance of areas near roads rather than movement in response to observers. However, we cannot rule out movement of deer in response to our vehicles in the Blue Hills Reservation because we did not have GPS-collared deer to investigate their movement. On the other hand, we rarely observed deer moving in response to our presence (most deer were bedded) and observers were trained to always look ahead to ensure all observations on the transect were detected and that observations were recorded at their initial location.

Regardless of the reason, a lack of observations near roads would lead to negatively biased estimates of density or estimates of density that are lower than actual. Our results likely concluded that the distribution of deer was correlated to the distribution of the roads we surveyed, such that deer likely avoided areas near transects. Therefore, we expected the estimated detection probability (Tables 1 and 2, Appendices b-e) was positively biased, leading to negatively biased estimates of density (abundance estimates are likely lower than actual).

Also, because we were unable to survey much of the adjoining private land and areas behind houses that offer supplemental food (landscaping) and sanctuary bedding areas, our estimate is likely an underestimate of abundance for the larger region. In 2013, deer density on and off the

Reservation may have been quite similar since it was all closed to hunting. However, the 2015 and 2016 hunts removed deer from the Reservation interior, such that deer densities in the Reservation interior may be much lower than the outside areas that are still closed to hunting. Further, some of the surviving deer may have adjusted their range and movement patterns relative to the added hunting pressure, leading to less time spent in the Reservation.

One of the questions that came up after the 2013 survey was whether deer numbers were high everywhere or higher in some areas than others. The distance sampling estimate provides an average density across the entire area and does not provide estimates for each section of the reservation. The hunter harvest data and sightings suggested that deer numbers were much higher in some areas than in others. Other methods, such as pellet counts, could provide additional data at a finer-scale, but have only recently become more accepted in the field after advances in pellet count survey methodology have allowed more accuracy in these surveys (DeCalesta 2013). Thus, we worked with DCR to conduct deer pellet count surveys a few weeks prior to the 2017 distance sampling survey (Clark 2017). The pellet counts also allow data to be collected in a more representative and random way in and around the Reservation and does not rely on the roads and trail network, which can limit the bias and lead to more realistic estimates of density. The method also allowed estimates to be made for several regions of the Reservation rather than one average estimate.

For instance, the distance sampling surveys were unable to incorporate the westernmost section, called Fowl Meadow because of a lack of navigable trails. From vegetation impact data, deer sign, and hunter harvest data, the Fowl Meadow area appears to have the highest deer density in the Reservation. We surveyed the one trail available through this area in 2013 with distance sampling, but the vegetation and wetlands surrounding the trail made it difficult to see any deer that were present and many sections were flooded or surrounded by wetland. Censoring this transect from the 2013 data analysis did not change the estimate. Further, in the 2017 survey, we were unable to travel down this transect because of flooding. Thus, the estimates from both years are likely underrepresenting deer density for that area. However, we were able to survey this area with pellet counts, and it ended up being the area with the highest deer density (Clark 2017). Thus, the distance sampling surveys were unable to incorporate the high deer numbers there, so distance sampling estimates are likely unrepresentative for average deer density across the entire Reservation.

Another potential factor influencing deer distribution could be the timing of the surveys relative to leaf-out and herbaceous growth on the forest floor than can provide seasonal food. The 2013 survey was conducted in early May, but leaf-out was a little late that year. The 2017 survey was conducted in early to mid-April, but leaf-out was a little early that year. So, they did not appear to be that much different with respect to timing of leaf-out. However, there is the potential for the amount of foliage and herbaceous growth present in the reservation and landscaping and other supplemental foods in the surrounding neighborhoods during the time of the survey to have some influence on deer presence and the estimates.

In summary, the 2017 survey likely provided a slightly negatively biased estimate of average deer density across the Reservation. Additionally, the estimate may not be completely representative of the true density in the larger region, especially for the privately owned sanctuary areas outside of the Reservation. The pellet count data, with the exception of Fowl Meadow, actually lined up fairly well with the Distance Sampling estimate (Clark 2017; fig. 3).

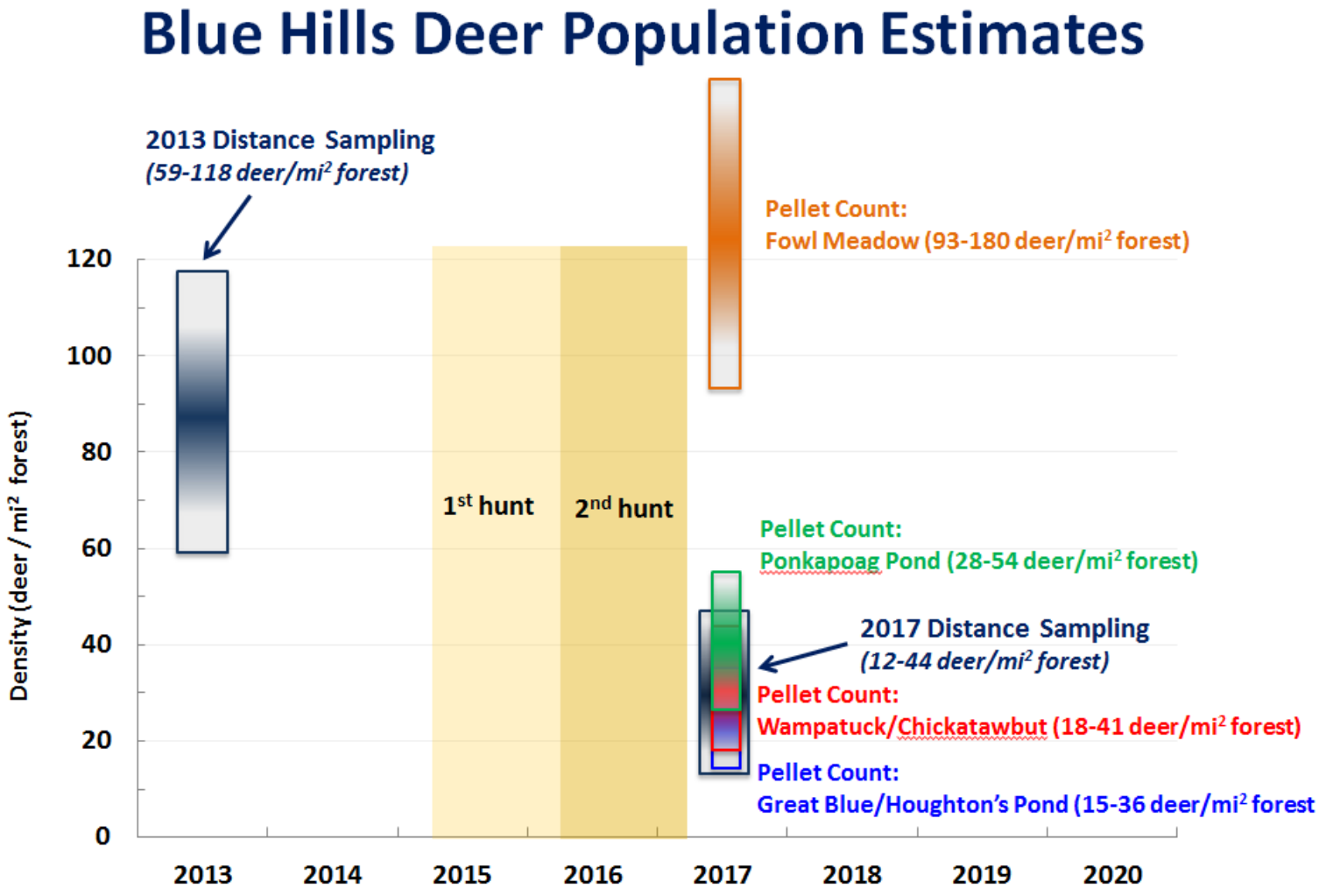


Figure 3. Deer density estimates in the Blue Hills Reservation from 2013 to 2017. Distance sampling estimates in dark blue rectangles and pellet count estimates in other colors.

Conclusions and Management Implications

The estimate of deer density in the Blue Hills Reservation during the spring of 2013 was 67 deer per square mile (Table 1, Appendix b) or **85 deer per square mile of deer habitat (95% CI = 59 – 118)**. Density estimates, whether negatively biased or not, were well-above MassWildlife's statewide deer management range or goal of 6-18 deer/mi^2 of forest and the threshold density of 18-20 deer/mi^2 of forest where major impacts can be seen in northeastern forests (Tilghman 1989, Horsley et al. 2003). It was recommended by MassWildlife for DCR to begin taking management action using regulated hunting to reduce the deer population, with a priority on removing female deer.

Beginning the fall of 2015, regulated hunting (in the form of short, controlled hunts) was allowed in portions of the Blue Hills to reduce the deer population. The 2015 hunt was allowed on 4.44 mi^2 of the approximately 9.6 mi^2 area in and around the Blue Hills Reservation. In 2015, 64 deer were killed (17 males and 47 females) for an average of 14 deer per square mile of forest removed (range per huntable section of 8-48 deer per square mile of forest removed). In 2016, the huntable area was increased to 5.8 mi^2 and 58 deer were killed (31 males and 27 females) for an average of 10 deer per square mile of forest removed (range per huntable section of 0-38 deer per square mile of forest removed). Also, there were an additional approximately 30 deer per year taken on private lands surrounding the Blue Hills Reservation.

Since females are the reproductive segment of the population, looking at rates of removal can be informative of how effective hunting was. In the western part of the state (Wildlife Management Zones 1-4), we remove an average of 0.3 females per square mile of forest. In the central part of the state (Wildlife Management Zones 5-9), we remove an average of 0.6 females per square mile of forest. In the eastern part of the state (Wildlife Management Zones 10-12), we remove an average of 1.2 females per square mile of forest. In the Blue Hills hunt, the 47 females removed in 2015 equates to about 10.6 females per square mile of hunted land or 4.9 females per square mile of all forest in the Blue Hills. This is at least 3 times as many females than the eastern average or over twice the 1.9 females per square mile of forest taken in Wildlife Management Zone 10. The 2016 hunt took 27 females, which equates to 4.7 females per square mile of hunted land or 2.8 females per square mile of all forest in the Blue Hills.

MassWildlife also recommended that another survey would not be necessary to conduct until at least two or three years after management action was taken, so that estimates would actually be informative and be able to detect a population reduction, given their corresponding confidence limits. Thus, another distance sampling survey was conducted in the spring of 2017, after two years of hunting. The estimate of density from the 2017 survey was 18 deer per square mile (Table 2, Appendix d) or **23 deer per square mile of deer habitat (95% Confidence Interval [CI] = 12 – 44).** Additionally, a pellet count survey was conducted in April 2017, which estimated approximately 52 deer per square mile, but the high estimate in the Fowl Meadow area pulled up this average number. Looking at the estimates by region provides more information, such that point estimates ranged from 25 – 50 deer per square mile, excluding Fowl Meadow.

The distance sampling survey yields an average density across the entire surveyed area, but cannot provide estimates of density at any one individual section of the Reservation. Thus, some areas likely had much higher deer numbers than others. Variability across the region was also seen with the harvest data. Some areas had a lot of deer removed, while others very few. The pellet count data provides a look at variability across the region as well (Clark 2017).

In summary, the two years of deer reductions likely led to a population reduction within the huntable areas and a slight population reduction across the larger area. Rather than looking at the point estimates, it is more useful to look at the trends with confidence intervals included (Fig. 3). Combining the data from the 2017 distance sampling survey and the 2017 pellet count survey provide a wide interval around the estimate, but the trend is that deer numbers are much lower than they were in 2017, but still above the statewide goal of 6-18 deer per square mile of forest that is important for reducing impacts to the habitat and forest within and around the Blue Hills Reservation. MassWildlife recommends continuing to investigate and monitor forest and habitat impacts as well as conduct pellet count surveys, to ensure that deer numbers reach levels that are low enough to be in balance with the habitat. MassWildlife also recommends increasing huntable areas and hunting effort (days) in the Reservation, and working to increase hunting access in surrounding areas.

Literature Cited

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294-1297.

Bates, S. 2006. White-tailed Deer Density Monitoring Protocol Version 1.1. Inventory and Monitoring Program, National Capital Region Network, National Park Service. Washington, D.C., USA.

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, Oxford, United Kingdom.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer, New York, New York, USA.

Clark, D. 2017. Estimating deer and moose densities on DCR Division of Water Supply Protection Lands using pellet-group counts. 2017 Results. Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection, Natural Resources Section, West Boylston, Massachusetts.

DeCalesta, D. S. 2013. Reliability and precision of pellet-group counts for estimating landscape-level deer density. Human-Wildlife Interactions 7(1):60-68.

Fewster, R. M., C. Southwell, D. L. Borchers, S. T. Buckland, and A. R. Pople. 2008. The influence of animal mobility on the assumption of uniform distances in aerial line-transect surveys. Wildlife Research 35:275-288.

Gill, R. M. A., M. L. Thomas, and D. Stocker. 1997. The use of portable thermal imaging for estimating deer population density in forest habitats. Journal of Applied Ecology 34:1273-1286.

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 24:37-43.

Heydon, M.J., J.C. Reynolds and M.J. Short. 2000. Variation in abundance of foxes (*Vulpes vulpes*) between three regions of rural Britain, in relation to landscape and other variables. Journal of Zoology, London, 251:253–264.

Horsley, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impacts on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13: 98-118.

Koenen, 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.

Koganezawa, M., and Y. Li. 2002. Sika deer response to spotlight counts: implications for distance sampling of population density. Mammal Study 27:95-99.

Marques, F. C., S. T. Buckland, D. Goffin, C. E. Dixon, D. L. Borchers, B. A. Mayle, and A. J. Peace. 2001. Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland. Journal of Applied Ecology 38:349-363.

Marques T. A., L. Thomas, S. G. Fancy, and S. T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. The Auk. 124:1229-1243.

Naugle, D. E., J. A. Jenks, and B. J. Kernohan. 1996. Use of thermal infrared sensing to estimate density of white-tailed deer. Wildlife Society Bulletin 24:37-43.

Ruette, S., P. Stahl, and M. Albaret. 2003. Applying distance-sampling methods to spotlight counts of red foxes. Journal of Applied Ecology 40:32-43.

Stainbrook, D. P., and D. R. Diefenbach. 2011. Methods of estimating white-tailed deer abundance at Gettysburg National Military Park: testing assumptions of distance sampling. Natural Resource Technical Report NPS/NER/NRTR—2011. National Park Service, Fort Collins, Colorado.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5-14.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53:524-532.

Ward, A. I, P. C. L. White, and C. H. Critchley. 2004. Roe deer *Capreolus capreolus* behaviour affects density estimates from distance sampling surveys. Mammal Review 34:315-319.

Appendix

(a) Example distance sampling datasheet for surveys conducted at the Blue Hills Reservation.

Distance Sampling Data Sheet

Date _____
Start Time _____
End Time _____

Driver _____
Driver's Side Observer _____
Passenger's Side Observer _____

Temp (Far.) _____
Cloud Cover (%) 0 25 50 75 100
Wind _____ mph
Precip None Sprinkle Drizzle Sleet Snow
Ground Dry Damp Wet Snow
Visibility 0 1 2 3 or **Miles** _____
Comments: _____
_____
_____

Transects Surveyed (in order)

_____

	Number of Deer in Group	Transect	Woods /Field (W or F)	Time	Observer (initials)	Perpendicular Distance (yards)	GPS Location and Direction Other Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							

(b) 2013 Survey: Multiple Covariate Distance Sampling Output: Forested versus open land as covariates for detection function

```
# observations:    129

 Model
    Half-normal key
```

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
p	0.50513	0.32415E-01	6.42	0.44494	0.57345
n/L	1.9868	0.28394	14.29	1.4614	2.7013
E(S)	1.9302	0.11914	6.17	1.7085	2.1807
D	66.812	11.250	16.84	47.343	94.288

Estimate of deer per square mile was 66.8; however this area includes areas not considered deer habitat (e.g., development, roads, etc.)

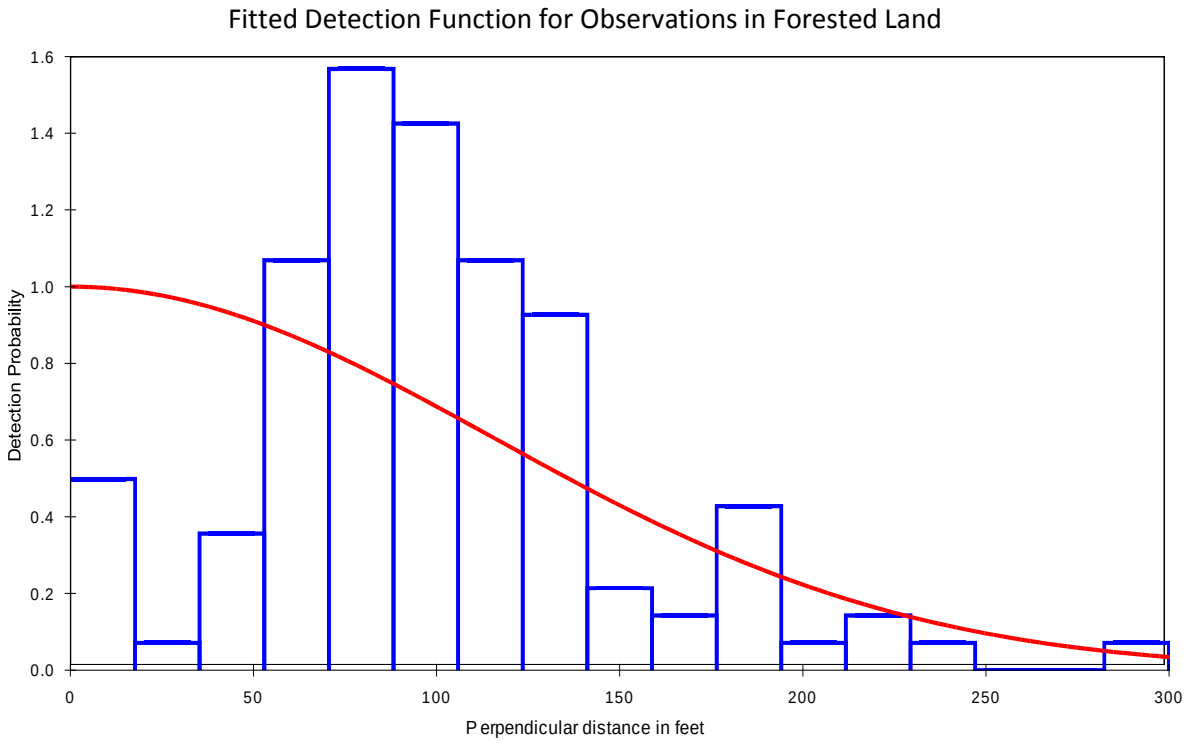
To calculate deer per square mile of deer habitat we simply divide this density estimate by the proportion of the area considered deer habitat (forested and other cover) = 80% or 0.80
= 85 (95% CI: 59 – 118) deer per square mile of deer habitat

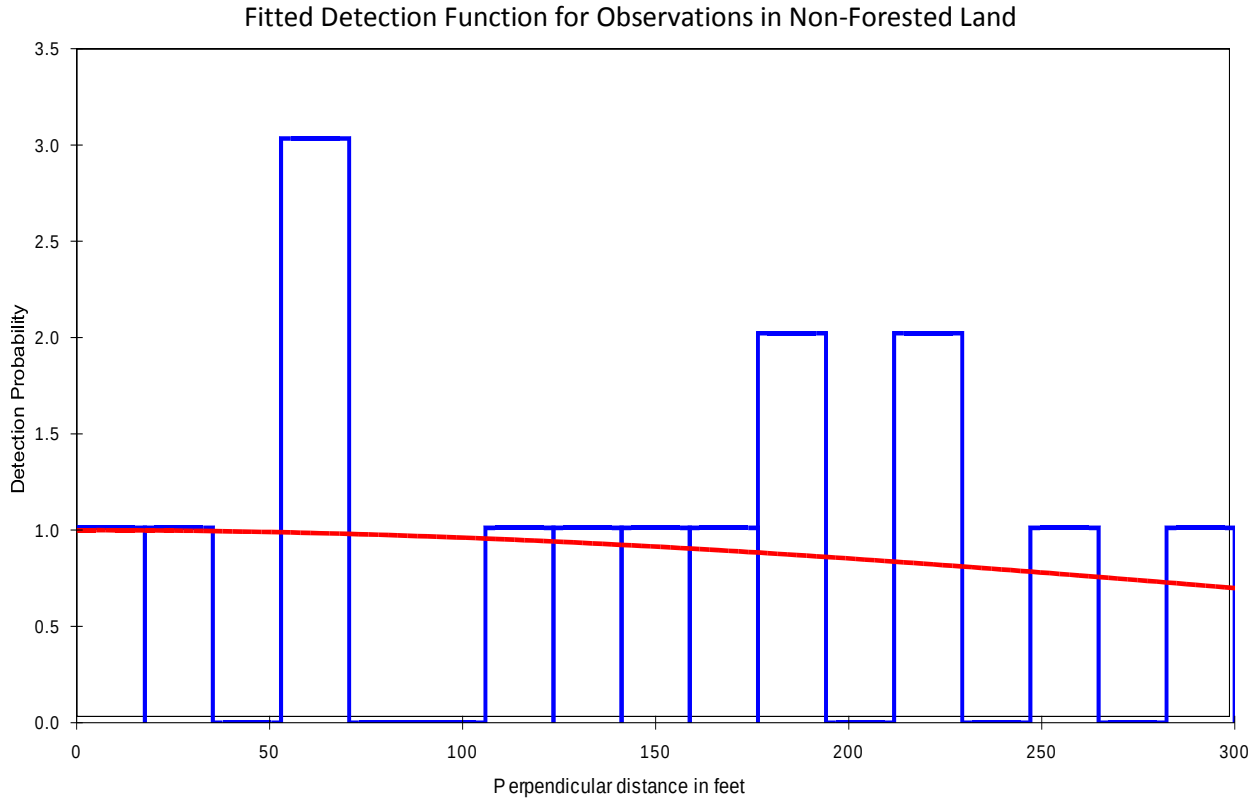
Glossary of terms

Data items:
n - number of observed objects (single or clusters of animals)
L - total length of transect line(s)
W - width of line transect or radius of point transect

Parameters or functions of parameters:
p - probability of observing an object in defined area
E(S) - estimate of expected value of cluster size
D - estimate of density of animals

(c) 2013 Survey: Multiple Covariate Distance Sampling Output: Forested versus open land as covariates for detection function





(d) 2017 Survey: Multiple Covariate Distance Sampling Output: Forested versus open land as covariates for detection function

```
# observations:    79

 Model
    Half-normal key
```

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95% Percent Confidence Interval	
p	0.45821	0.40580E-01	8.86	0.38426	0.54639
n/L	0.70495	0.20281	28.77	0.37608	1.3214
E(S)	2.5190	0.18883	7.50	2.1702	2.9238
D	18.270	5.6676	31.02	9.5147	35.081

Estimate of deer per square mile was 66.8; however this area includes areas not considered deer habitat (e.g., development, roads, etc.)

To calculate deer per square mile of deer habitat we simply divide this density estimate by the proportion of the area considered deer habitat (forested and other cover) = 80% or 0.80
= 23 (95% CI: 12 – 44) deer per square mile of deer habitat

Glossary of terms

Data items:
n - number of observed objects (single or clusters of animals)
L - total length of transect line(s)
W - width of line transect or radius of point transect

Parameters or functions of parameters:
p - probability of observing an object in defined area
E(S) - estimate of expected value of cluster size
D - estimate of density of animals

(e) 2017 Survey: Multiple Covariate Distance Sampling Output: Forested versus open land as covariates for detection function