


Spring June 12th, 2014

# Comparing Population Density Estimation Techniques for Columbia Black-tailed Deer (*Odocoileus Hemionus Columbianus*): Fecal Standing Crop and Distance Sampling Methods

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Distinguishing Morality From Convention: Evidence of Nativism

COMPARING POPULATION DENSITY ESTIMATION TECHNIQUES  
FOR COLUMBIA BLACK-TAILED DEER  
(*ODOCOILEUS HEMIONUS COLUMBIANUS*):  
FECAL STANDING CROP AND DISTANCE SAMPLING METHODS

by

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A project submitted in partial fulfillment  
of the requirements of the University Scholars Program

Seattle Pacific University

2014

Approved \_\_\_\_\_

Date \_\_\_\_\_

## ABSTRACT

I estimated deer density and population size on Blakely Island, WA, using the fecal standing crop (FSC) method described by Martin et al. (2011). I compared the FSC method with a well established and broadly applicable estimation method, distance sampling. Additionally, architecture of a commonly browsed shrub, Ocean Spray (*Holodiscus discolor*), was measured as an indicator of browsing pressure. Fecal standing crop was estimated by counting pellet groups along 26, 100 x 2m line transects. Deer density was estimated using these data and the equation derived by Martin et al. (2011). Distance sampling consisted of recording perpendicular distance from transect line to deer, along 16 saw-toothed transects placed across Blakely Island. An average architecture value (ratio of plant diameter at 1 and 2m) of 0.223 indicated a high browsing pressure on the island, suggesting high deer density. Deer density based on FSC method was 1.72 (95% CI: 1.21 – 2.23) deer ha<sup>-1</sup>, whereas the concurrent deer density based on distance sampling was 0.23 (95% CI: 0.138 – 0.375) deer ha<sup>-1</sup>. Previous studies on Blakely using the latter method have shown deer density at ≈0.3 deer ha<sup>-1</sup>. As the FSC density estimation was much greater than that of distance sampling, and because it did not compare to other high-density island populations of deer, I concluded that this newer technique may not be comparable to well established methods. Further experimentation is necessary to parse out the possible confounding factors associated with the FSC technique.

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## ACKNOWLEDGMENTS

Many thanks to everyone who helped me through this process, especially my wonderful readers, Dr. Long and Dr. Congdon, for their wise words and confidence in me. To my research partner Andrew Zeiders for being such fun to work with, and for all the editing help. To my fellow University Scholars for their friendship, support, and commiseration. To all my professors over the last four years for challenging me to think deeply. And to my family for their endless encouragement and reminders of the light at the end of the tunnel.

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INTRODUCTION

Over the past few decades abundant evidence has shown the increases in density of various deer species across the United States, especially in ecosystems lacking predators (Cote et al. 2004, Garrott et al. 1993). Many of these studies reveal the wide-ranging ecological impacts deer have on an environment, from depressing invertebrate diversity to the increased risk of zoonotic disease spread (Cote et al. 2004). Sylvain et al. (2005) documented the massive damage deer cause to island songbird populations, while Brissette et al. (2012) investigated several processes and trophic levels, showing that biodiversity as a whole has been decreased by high deer density. Additionally, Alverson and Waller (1997) studied the correlation between white-tailed deer (*Odocoileus virginianus*) abundance and eastern hemlock (*Tsuga canadensis*) regeneration, suggesting increased ungulate populations resulted in decreased size and numbers of hemlock seedlings. Clearly, these ungulates have an effect on many parts of their wide-ranging ecological niches.

The Blakely Island black-tailed deer (*Odocoileus hemionus columbianus*) population has been studied continuously for nearly a decade, resulting in a growing amount of data. This information suggests the population may be too large for regeneration of common tree species, such as Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*). Due to extensive logging in the early 1900s, understory vegetation has accumulated providing deer with more food sources than would be available in a late successional or climax forest. In addition, the island's small size has not allowed for a major predator to function as a top-down regulator of

the ungulate population. Schmitz and Sinclair (1997) used a trophic interaction model designed by Hairston et al. (1960) to predict what would happen if large carnivores were missing from an ecosystem – herbivore abundance would greatly increase, along with a concomitant decline in plant abundance.

Two deer density estimation techniques have been utilized on Blakely Island in the past several years (specifically, line transect distance sampling and mark-resight population estimates). I tested a new and potentially more efficient deer density estimator on Blakely Island following the fecal standing crop (FSC) method developed by Martin et al. (2011) across 18 of the Gulf and San Juan Islands in the northern Puget Sound. I compared estimates of FSC with the previous two density estimators to see if FSC generated comparable estimates. The two approaches used previously showed the same trends and population fluxes, indicating they were at least consistent methods. The distance sampling method was employed again during this research period to compare results of FSC and distance sampling.

## MATERIALS & METHODS

Blakely Island (1685 ha) is located in northern Washington's Puget Sound. I estimated the density of black-tailed deer on Blakely Island from 25 June to 24 August 2013. Methods for estimating deer density from fecal density at a random sample of points were drawn directly from Martin et al. (2011). Initially, I randomly placed 26 points across the island, however one point was eliminated from sampling as it was too close in proximity to another (< 100 m; Fig. 1a).

First, at each point I estimated FSC. A 100m measuring tape was run from the selected point directly north, and 2-4 people then counted all deer feces within 1 m on either side of the transect line. The qualifier for feces was defined as at least 18 pellets within 20 cm<sup>2</sup> (Fig. 2,

Martin et al. 2011). Martin et al. (2011) developed this FSC technique using Piers Island, which was small enough to find a known deer population density by counting all individuals. Martin et al. (2011) then estimated fecal density and related it to the known deer density, creating the following equation:

$$D_i = \frac{0.22}{42.2} * FSC_i$$

where  $D_i$  is equal to density on island  $i$ ,  $0.22/42.2$  represents the ratio of deer density per ha to FSC density per ha on Piers Island, and  $FSC_i$  refers to average fecal standing crop per ha on island  $i$ . Martin et al. (2011) used this equation to estimate deer populations on other Gulf and San Juan Islands with unknown deer density. Therefore, I applied this equation to estimate deer density on Blakely Island.

In conjunction with this, I measured the architecture of a commonly browsed shrub, ocean spray (*Holodiscus discolor*). In each of the 100 x 2m transects, I measured the ratio of the circumference of live, upward growing shoots at 1 versus 2 m for the northern most ocean spray, as described by Martin et al. (2011); if not found in a transect area, the closest plant outside it was selected. I also collected data on irradiance, soil pH, and canopy coverage to investigate possible covariates to the FSC equation derived by Martin et al. (2011). Each of these measurements was taken at the same three points along the 100m transect: 0 m, 50 m, and 100 m. Irradiance measurements were taken directly from the ground, where feces would have landed, beneath any brush that was present. Similarly, pH of the soil was recorded from the same location, unless rocky substrate prevented a reading. A picture was also taken from each of the three points straight upwards to show the amount of canopy coverage; the images were later analyzed by two individuals who separately scored the amount of coverage using the same

system, and then averaged the two scores to obtain total coverage. Each of these possible covariates was compared with FSC count data using a linear regression test.

The second set of data, distance sampling, was collected by dividing the island into 16 transects, 8 on the east side and 8 on the west (Fig. 1b). Each transect line was walked twice, each time by a different observer who took note of any deer sighted during that time. Age (adult vs. juvenile) and gender of adults were recorded. The angular distance of an animal from the transect line was determined using a compass, and the distance in meters of the animal from the line was measured with a laser range finder. These measurements were then converted into a perpendicular distance from the transect line. I subsequently used these data to estimate deer density in Program Distance 6.0 (Thomas et al. 2010). Potential fitting functions (half-normal with a cosine adjustment, hazard rate curve with a polynomial adjustment, uniform curve with a cosine adjustment, and half-normal with a Hermite adjustment) were compared with AIC.

## RESULTS

In the 25 transects, I counted an average of 6.6 FSC's (SE = 0.95). Thus, coverage of fecal density was 4.69 FSC's  $\text{ha}^{-1}$ . Average deer density according to the FSC method was 1.72 deer  $\text{ha}^{-1}$ , with a 95% confidence interval of 1.21 – 2.23 deer  $\text{ha}^{-1}$ . Line transect distance sampling suggested approximately 0.23 deer  $\text{ha}^{-1}$ , with a 95% confidence interval of 0.138 – 0.375 deer  $\text{ha}^{-1}$ , and an estimated strip width of 15.8 m (Fig. 3). Previous studies on Blakely using the latter method have shown the deer density at  $\approx 0.3$  deer  $\text{ha}^{-1}$ . An ocean spray architecture value (circumference at 1 m divided by circumference at 2 m) of 0.223 indicated a high browsing pressure on the island, as Martin et al. (2011) defined high browsing pressure as a mean ratio of 0.27 or below.

Results from linear regression tests suggested that potential covariates did not significantly predict fecal density. Irradiance was not a predictor of FSC count ( $P = 0.084$ ,  $F_{1,21} = 3.311$ ). Neither was FSC dependent on soil pH data ( $P = 0.708$ ,  $F_{1,21} = 0.145$ ). Canopy coverage also did not have a significant effect on FSC count ( $P = 0.200$ ,  $F_{1,21} = 1.758$ ).

## DISCUSSION

Line transect distance sampling is a well-established density estimator that has been implemented on Blakely Island since 2007, and using this method in the current study resulted in estimates comparable to other high-density island populations of deer (Sherrill et al. 2012). Distance sampling seems to be a reliable method for estimating deer density on Blakely Island for three reasons. First, distance sampling was correlated with an independent method of density estimation (mark-resight sampling) from 2007-2009, and point estimates were consistently close ( $\pm 10\%$ ; E.S. Long, unpublished data). Second, the average FSC density on Blakely Island was 51% greater than the maximum FSC estimate reported by Martin et al. (2011), and 274% greater than their average deer density on islands with deer. However, my distance sampling results were comparable to their range of deer densities (Martin et al. 2011). Third, the FSC deer density estimate greatly exceeded that of other island populations of deer; although, distance sampling results were comparable to these high deer density islands (Sherrill et al. 2012). Subsequently, I determined I could use distance sampling as a useful benchmark with which I could compare the FSC method.

As the FSC population density estimate was much larger than that of distance sampling, I concluded that the FSC technique did not generate reliable deer density estimates on Blakely Island. For instance, Martin et al. (2011) reported  $42.2 \text{ FSC ha}^{-1}$  on Piers Island, meaning that on a  $2 \times 100 \text{ m}$  transect they would encounter an average of 0.844 FSCs. None of the transects on

Blakely Island had fewer than 1 FSC, and four transects had more than 10 pellet groups, causing me to question the repeatability of the FSC technique.

One possible reason for this unreliability was the Martin et al. (2011) FSC equation, as it was developed using a single, small island, and was not validated on any subsequent island with a known deer density. Another problem with the FSC method modeled by Martin et al. (2011) was the omission of defecation rate. If defecation rate varied significantly across islands this would confound broad application of their equation. Other studies have understood the importance of estimating defecation rate, and incorporated defecation rates into their methods for using fecal density to estimate deer density (Campbell et al. 2004).

To better understand more possible reasons behind the large variance in population density estimates, I collected irradiance, soil pH, and canopy coverage data. The results of these measurements revealed that none of these environmental factors were significant predictors of FSC count; however, these data should not be completely disregarded. As decomposition can vary greatly across different microclimates (Taylor et al. 1988), it is reasonable to believe that some pellet groups would last much longer than others on an island the size of Blakely. Differences in irradiance, soil pH, and canopy coverage would be indicative of varying decomposition rates, which could lead to unreliable results using FSC methods. Other studies using fecal densities to estimate deer densities have included decomposition rates of the pellet groups, which eliminates at least one variable and allows for increased accuracy (Campbell et al. 2004). Clearly, further experimentation is necessary to parse out the possible confounding factors associated with FSC techniques.

Different habitats may be more suited to certain estimation methods over others. This is why Acevedo et al. (2010) compared several methods for estimating roe deer (*Capreolus*

*capreolus*) densities to see which was best for the Mediterranean woodlands of Spain. Another study carried out in the UK uplands concluded that if decomposition rates are unknown for an area, fecal accumulation rate (FAR) techniques should be used rather than FSC methods (Campbell et al. 2004). Determining which technique is the most parsimonious, cost effective, and reliable for a certain study area is important for accurate estimation of population densities. As far as the specific FSC methods used by Martin et al. (2011), it seems that many more factors need to be accounted for before it can be considered useful on a large scale.



## TABLES & FIGURES

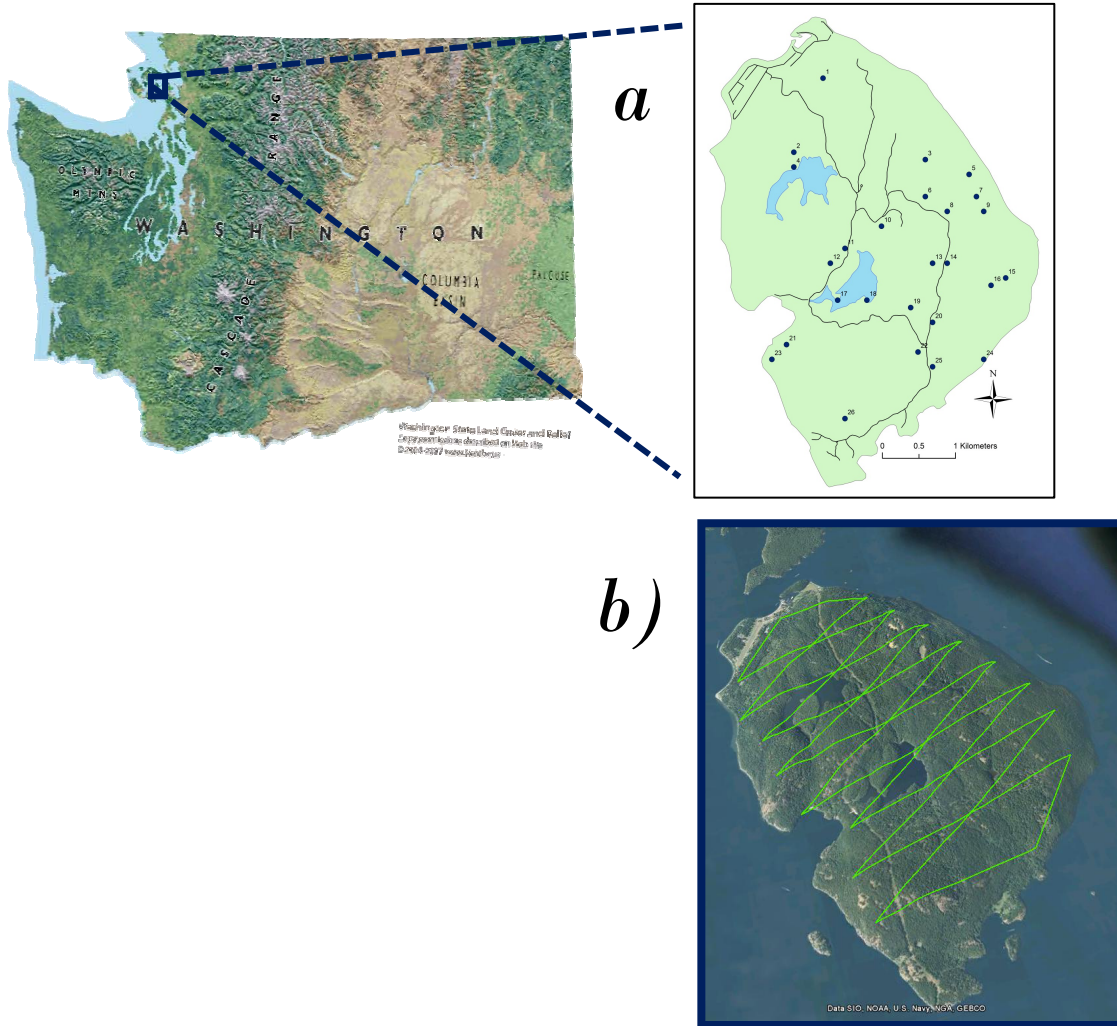


Figure 1. a) Blakely Island, Washington, USA, with 26 random FSC transect points (one was excluded from data collection), b) 16 saw-tooth distance sampling transects.



Figure 2. One pellet group defined as 18 or more pellets within  $20 \text{ cm}^2$  and within 1 m of the transect line (Campbell et al. 2004).

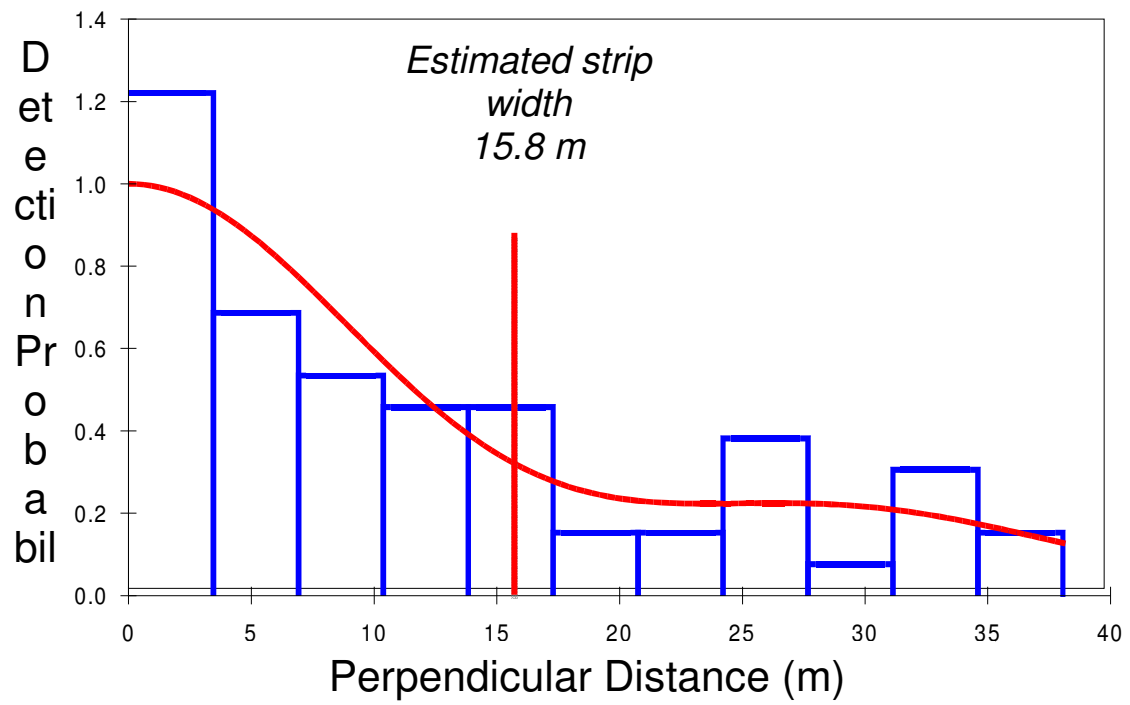


Figure 3. Distance sampling detection function for 2013, using Half-normal + Cosine adjustments. N deer observed = 60, distance walked = 83.3 km

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## INTEGRATION OF FAITH AND LEARNING

Fascinated with the mechanisms of life from a very young age, I believe my mind and heart are best put to use studying biology. I finally discovered this niche in college, after struggling with various majors that did not satisfy my deep yearnings to know about the countless organisms filling the universe, and their place, as well as mine, in it. Reflecting on the last four years, I realize how much my thinking has changed and developed, particularly concerning my faith.

Growing up, my worldview was very limited to what I was told to believe, but over the past few years I have enjoyed seeing the world from many different perspectives, discovering new ideas and challenging those that I already held to be true. Throughout this time in college I believe I have developed into a more loving, openhearted and open-minded person, learning to listen to and respect others' views no matter how different. Additionally, I have learned to hold mine lightly. As strange as that sounds, I do not believe being right is necessarily the point of life. On the contrary, one of the most important lessons I have learned is that true scholars readily admit they do not have everything figured out, and never will. Despite this, they continue to use their minds and skills to study nature's difficult mysteries, doing their best to figure out what it all might mean.

I have been privileged to deeply investigate many facets of education during college, especially the miraculous world of biology. Even from a young age, I understood the value of life, and believe deeply that everyone is accountable to do his or her part in caring for creation. This research project illustrates one practical way to do so, as managing wildlife is an essential part of maintaining healthy habitats. As an ecologist I feel a personal responsibility to "tend and keep" the world, just as stated in Genesis 2:15 (NKJV). Studying ecology has solidified even

more my desire to study nature's inner workings, and humbles me to realize that we are not lord over the earth, but servant to it.

Similarly, I believe that an important part in gaining knowledge is what you choose to do with it. One of the most compelling aspects of the ecology major for me was being able to learn practical skills and gain an understanding of nature. For, "In the same way, faith by itself, if it is not accompanied by action, is dead" (James 2:17). Seeing needs and doing your best to meet them with the skills and resources you possess is one way to utilize the valuable knowledge with which we were gifted.

A common Haitian proverb illustrates well our responsibility to the earth and to one another: "*Bondye konn bay, men li pa konn separe,*" in literal translation, 'God gives, but doesn't share.' This meant... 'God gives us humans everything we need to flourish, but he's not the one who's supposed to divvy up the loot. That charge was laid upon us'" (Kidder 79). People are clearly accountable for properly using every resource God has given us, meaning we are right to be concerned with maintaining appropriate interactions within nature. The earth is far from infinite; its beauty and benefits should be shared equally. By being in tune to the world as a whole, and discovering new information about the creation within it, we are able to help it flourish and be enjoyed by everyone, from the metropolis businesswoman to the most remote tribes people on the planet.