

Seasonal meal patterns affecting radiocesium levels in white-tailed deer at Brookhaven
National Laboratory

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ABSTRACT

Seasonal food intake affecting ^{137}Cs levels in white-tailed deer at Brookhaven National Laboratory. ESPERANZA V. FLORENDO (Los Angeles Mission College, Sylmar, CA, 91342) DR. TIMOTHY GREEN (Brookhaven National Laboratory, Upton, NY 11973).

Food intake by ruminants is mainly controlled by photoperiod, meaning that food intake is higher during the summer months when days are longer than in the winter months.

While ^{137}Cs continues to be present in the environment due to radioactive fallout, at Brookhaven National Laboratory (BNL), there are increased levels of ^{137}Cs levels due to soil contamination. From 2000 to 2003, ^{137}Cs levels were obtained in deer killed at three different areas: BNL, within a mile's distance from BNL (<1 mile), and in areas greater than a mile from BNL (>1 mile). Data from all the years were compressed and divided into the first half and second half of the year. T-tests showed that deer >1 mile from BNL had significantly lower ^{137}Cs levels than the other three groups (BNL, <1 mile, and BNL and <1 mile combined). Deer <1 mile from BNL also had significantly higher ^{137}Cs levels than BNL deer. Within each group, there were significantly higher ^{137}Cs levels for the second half of the year, which was expected since there was an increase in food intake during the summer months and equilibrium levels were reached within 100 days.

INTRODUCTION

Food intake by many ruminants fluctuates with seasons. This change is mainly attributed to photoperiod [1], which is the amount of light in the light/dark cycle. During the summer months, when daylight is longer, there is a daily increase in food intake [1], resulting in increased body weight and body fat by the end of the year [2, 3]. Body weight and fat are maximized in preparation for the winter months when food and essential nutrients needed for survival are scarce.

Potassium, an element found in organic matter, plays an essential role in maintaining proper body functioning. $^{137}\text{Cesium}$, a radionuclide, acts similarly to potassium [4]. Because of nuclear weapons testing in the 1950s and 1960s as well as the Chernobyl accident, $^{137}\text{Cesium}$ is present in the environment and continues to circulate because of its relatively long physical half-life of approximately 30 years [5]. As ^{137}Cs settles into the ground, it easily binds to the organic components found in soil or sediments. Due to its binding ability, a high percentage of ^{137}Cs stays in the top 5 cm of organically rich soil and migrates slowly deep into the soil [5]. Since topsoil is where plants obtain their nutrients, ^{137}Cs can effectively compete with potassium for absorption, especially when there are low levels of potassium in the soil [6]. Via root uptake, ^{137}Cs is then transported throughout the plant and becomes available in plant matter that is edible to animals. In turn, animals graze in contaminated areas and ingest the edible parts of contaminated plants, resulting in higher ^{137}Cs levels in their body composition. Thus, the soil-plant-animal transfer contributes to the bioaccumulation of ^{137}Cs in animals. In white-tailed deer (*Odocoileus virginianus*), ^{137}Cs has a biological half-life of 100 days, meaning that if deer had daily ingestion of ^{137}Cs , equilibrium would be reached by 100

days. At equilibrium, the amount of ^{137}Cs leaving the body would be the same as the amount entering it [7].

Aside from global fallout, Brookhaven National Laboratory, historically, has had soil contamination. Thus elevated levels of ^{137}Cs are present in soil and vegetation that are accessible to deer. Previous studies have shown that BNL deer have higher ^{137}Cs levels than deer that are too far away to graze on contaminated soil. Though soil remediation was implemented at BNL in 2000 and clean up continued until 2003, there are still some contaminated areas, namely areas of Operable Units (OU) I/VI and V, that are awaiting clean up as funds become available. While these areas are fenced and essentially unavailable to deer, plant roots surrounding these areas could have some access to the organic matter in these contaminated soils, thereby allowing ^{137}Cs to be available above ground.

For the purposes of this paper, four different deer groups are being assessed: 1) deer found at the BNL site (BNL); 2) deer within a mile radius from BNL (<1 mile); 3) deer more than a mile from BNL (>1 mile); and 4) combined group of deer found at BNL and deer within a mile radius from the site (BNL and <1 mile). The fourth group was formed because the home range of white-tailed deer is approx. $\frac{1}{2}$ to $1\frac{1}{2}$ square miles [8]; thus, there is a possible interaction between BNL deer and deer <1 mile from BNL as there is no fence to separate them. Deer roaming on either side of BNL's borders can easily cross over. Since there is no current method for distinguishing between BNL deer and deer just beyond BNL property, one must take into account a possible interaction between them.

All remediated areas open to deer have been cleaned up so that ^{137}Cs levels are ≤ 67 pCi/g [9]. This is in compliance with the total dose limit of 15 mrem/yr above background provided by EPA [9]. In other words, contaminated soils containing ≤ 67 pCi/g of ^{137}Cs may be beneath the soil that has been remediated. Therefore, plants that have deeper root systems may have access to contaminated soil where they can absorb and, thereby, transfer ^{137}Cs to above ground biomass. Since ^{137}Cs continues to be accessible above ground, it is hypothesized that the BNL deer and deer <1 mile from BNL will have significantly higher ^{137}Cs levels than deer >1 mile from BNL. While BNL deer and deer <1 mile from BNL are two separate groups, their home ranges can overlap since there are no physical borders separating them. Thus, there should be no significant difference between these two groups, though a general trend of higher ^{137}Cs levels for BNL deer is likely. Within each deer type, it is expected that ^{137}Cs levels would increase during the second half of the year. During the summer, deer increase their food intake, which, in turn, increases ^{137}Cs levels. Since the biological half-life of ^{137}Cs is 100 days (about 3 months), elevated ^{137}Cs levels should continue towards the end of the year.

MATERIALS AND METHODS

Between 2000 and 2003, deer samples were taken from road kill on and near BNL, hunter donations, and deer killed in or near Fish & Wildlife Service (FWS) properties in Long Island, namely Wertheim National Wildlife Refuge. BNL sampling technicians collected and analyzed the samples. Analyses involved ^{137}Cs values in “dry” and “wet” weight.

For the purposes of this experiment, “wet” weight concentrations were used, as these were the values that were likely to be found in consumed meat. Only values taken

from deer flesh were considered in this paper. Samples from other parts of the deer (e.g., liver and bone) were taken only when possible and therefore, there was no consistent data set available for these ^{137}Cs values. Because accumulation rates vary for different body parts, these values could not be compared with ^{137}Cs values for deer flesh. When multiple analyses were performed for some of the deer samples, only the first value was taken into account. One data sample from 2002 was also excluded from analysis because one of the detectors produced erroneous readings.

RESULTS

Data from all years (2000 to 2003) were combined and divided into the four deer types: 1) BNL ($n=78$); 2) <1 Mile Deer ($n=62$); 3) BNL and <1 Mile Deer combined ($n=140$); and >1 Mile Deer ($n=58$). Means and standard errors are shown in Figure 1. A one-way ANOVA showed that mean ^{137}Cs levels for the four groups differed significantly ($p < 0.05$). Individual t-tests indicate that there were significant differences ($p < 0.05$) within the following group sets: 1) BNL and <1 mile; 2) BNL and >1 mile; 3) <1 mile and >1 mile; and 4) BNL & <1 mile and >1 mile. Deer <1 mile from BNL had a higher ^{137}Cs mean than the deer found within BNL. Deer >1 mile from BNL had a lower ^{137}Cs mean than the other three groups. No significant differences were found within the following group sets: 1) BNL and BNL & <1 mile, and 2) <1 mile and BNL & <1 mile.

Within the four deer types (BNL, <1 mile, >1 mile, and BNL & <1 mile), the data was divided into the first half (January to June) and the second half (July to December) of the year. Individual t-tests showed that, within all four groups, ^{137}Cs levels significantly increased ($p < 0.05$) from the first half to the second half of the year (see Figure 2). A one-way ANOVA showed that there were significant differences between

groups during the first half of the year. T-tests showed significant differences between the following group sets: 1) BNL and >1 mile; 2) <1 mile and >1 mile; and 3) BNL & <1 mile and >1 mile. Deer found >1 mile from BNL had lower ^{137}Cs levels. On the other hand, there were no significant differences between groups during the second half except for the following: 1) BNL and <1 mile and 2) <1 mile and >1 mile.

DISCUSSION AND CONCLUSIONS

While BNL has made efforts to remediate contaminated lawn soils in 2000, some areas will continue to contain contaminated soil until their scheduled clean up from 2003 to 2005 [6]. Though these areas have been fenced off and unavailable to deer, ^{137}Cs just below remediated soil may continue to be available to deep-rooted plants. Since this allows ^{137}Cs to be available above ground, deer that consume vegetation growing in contaminated areas within BNL would be expected to have higher ^{137}Cs levels. Thus, as predicted, BNL deer, deer <1 mile from BNL, and their combined group had significantly higher ^{137}Cs levels than deer found >1 mile from BNL. An unexpected finding showed that deer <1 mile from BNL had a significantly higher ^{137}Cs level than BNL deer. Many of these samples are from deer that have been hit along William Floyd Parkway, which is on the western boundary of BNL [6]. It is possible that the majority of deer killed <1 mile from BNL are deer that are actually from BNL. The deer could simply be grazing along the boundary of BNL and then subsequently hit by a moving vehicle. Regardless, a closer examination is warranted to determine if there are possible factors, such as sex, age, and mating season, that could drive BNL deer away from the property.

Within the four groups, ^{137}Cs levels significantly increased during the second half of the year as expected. Due to the need to increase food intake during the summer

months, the likelihood of eating contaminated plants at the BNL site also rises. Though food intake begins to decrease around October [2], the biological half-life of ^{137}Cs is approximately 100 days and therefore, ^{137}Cs levels continue to be elevated until the end of the year. While deer >1 mile from BNL do not have access to contaminated soil, there continues to be small amounts of ^{137}Cs present in the environment. As such, an increase in their ^{137}Cs levels was also expected.

By the beginning of the year, deer are eating less, which results in less intake of ^{137}Cs . While it is expected that ^{137}Cs levels are lower during the first half of the year for all four groups, deer >1 mile from BNL continue to have significantly lower ^{137}Cs levels than the other three groups. This was expected since this group is only exposed to global ^{137}Cs and not to contaminated soil whereas BNL deer and deer <1 mile from BNL continue to have access to contaminated areas.

Comparing the means for the second half of the year yielded unexpected results. There was no significant difference between BNL deer and deer >1 mile from BNL. Also, it is unclear why deer <1 mile from BNL had significantly elevated ^{137}Cs levels than BNL deer and deer >1 mile. Again, it may be possible that the deer samples from the surrounding area <1 mile from BNL may actually be deer belonging to the BNL site. Thus, values for deer <1 mile from BNL may not be accurately portraying ^{137}Cs values for deer exclusively belonging to the area surrounding BNL.

Since 2000, BNL has attempted to remediate contaminated areas in order to decrease the spread of ^{137}Cs . While it is possible that deer killed on the BNL site actually belong off-site, thereby causing lower ^{137}Cs levels for the second half of the year, it should also be noted that remediation plans have assisted in decreasing the available

^{137}Cs on-site. Even though, overall, BNL deer have higher ^{137}Cs values than deer >1 mile, there is a general trend of decreasing ^{137}Cs values.

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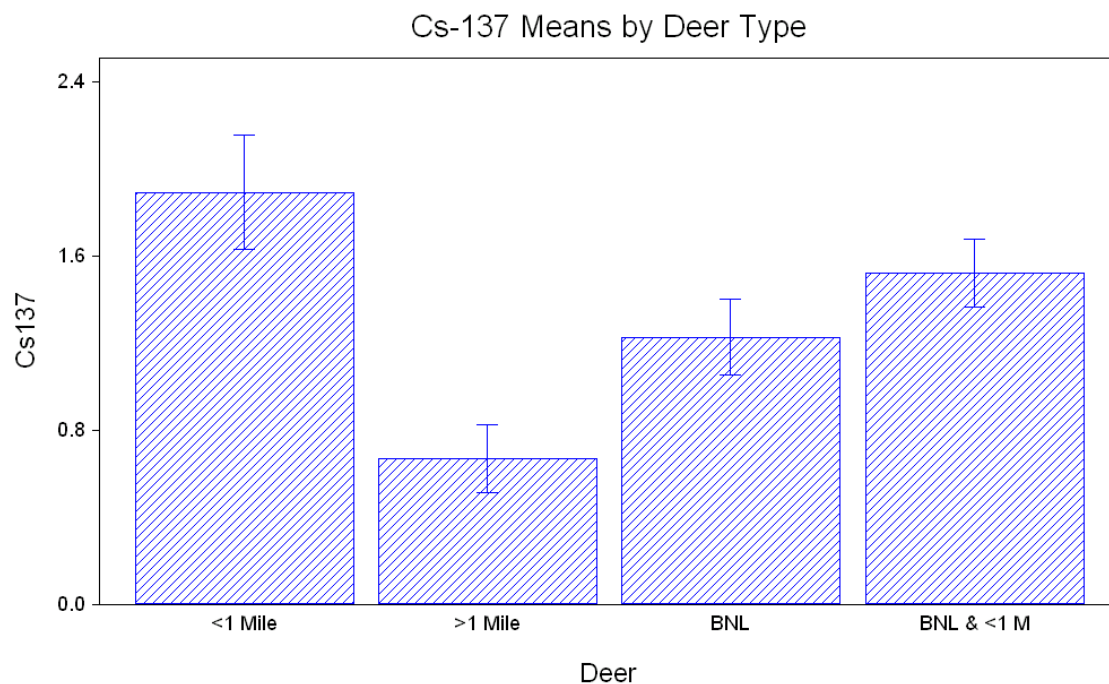


Figure 1. The ^{137}Cs mean for each deer type.

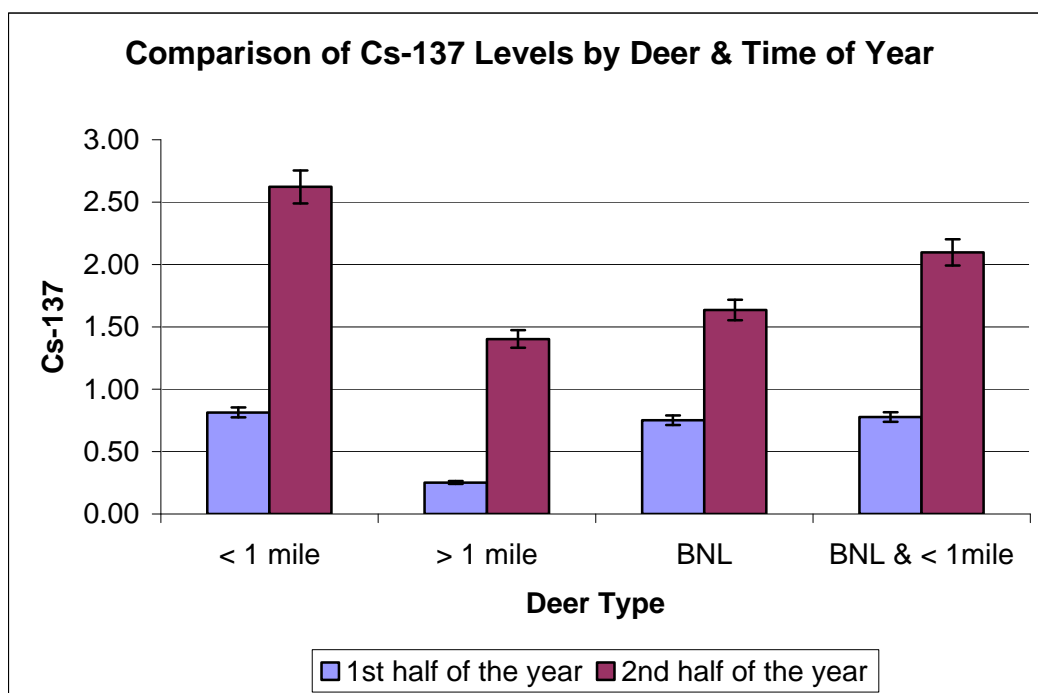


Figure 2. A comparison between the 1st half to the 2nd half of the year of ^{137}Cs means within each deer type. Error bars are shown.