THESIS

A COMPARISON OF METHODS TO DERIVE AGGREGATED TRANSFER FACTORS: TESTED USING WILD BOAR DATA FROM THE FUKUSHIMA PREFECTURE

Submitted by

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ABSTRACT

A COMPARISON OF METHODS TO DERIVE AGGREGATED TRANSFER FACTORS: TESTED USING WILD BOAR DATA FROM THE FUKUSHIMA PREFECTURE

In March of 2011, the Fukushima Daiichi disaster released airborne radioactive material dominated by Cs-134 and Cs-137. When the radionuclides settled, they contaminated soil and plants, with wild boar also becoming contaminated through various pathways. An estimate of the radiocesium concentration in wild boar tissues can be obtained from an aggregated transfer factor based on soil contamination levels. The aggregated transfer factor (T_{ag}) for purposes of this study, is the ratio of Cs-137 concentration in wild boar tissues (Bq kg^{-1}) divided by the Cs-137 surface contamination of soils (Bq m^{-2}). In this study, two methods were used to estimate the T_{ag} values, and a comparison was made to determine which method reduced uncertainty. Both methods rely on harvesting and measuring radiocesium in wild boar tissues (bicep femoris muscle). The radiocesium value used for soil, however, was different in the two methods. One was obtained from a public database of samples collected by the Japanese government in 2015. Oftentimes, the soil sample paired with the wild boar trap site were not within the home range of the wild boar, reducing accuracy of the predicted radiocesium concentration levels in the animal. The other method used soil samples collected at the point of wild boar capture. The purpose of this study is to ascertain if the use of the database radiocesium soil concentration values is of sufficient granularity to provide a useful estimate of T_{ag} values. The mean T_{ag} value calculated in the Fukushima prefecture for wild boar were 2.3×10^{-3} m^2 kg^{-1} fresh weight. The research revealed that the database radiocesium concentration values for soil (Bq m^{-2}) used in calculating

aggregated transfer factors, do not accurately represent the containment levels in the wild boar. Collecting soil samples within the home range of the animal reduces uncertainty in calculating T_{ag} values to estimate whole body contamination levels of a wild boar. Our data complements and supports the existing monitoring programs conducted by the National and Prefecture governments in Japan by showing lower concentrations of cesium in soil and wild boar within decontaminated areas.

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I would like to thank all of those on my committee for their support and willingness to aid in this research and the development of my thesis.

I also appreciate all the support from my advisors, Dr. Thomas Johnson, Dr. Thomas Hinton and Dr. Kei Okuda.

All my samples and measurements would not have been possible without the help and endless support from the people working at the Institute of Environmental Radioactivity.

DEDICATION

I dedicate my research and work to my parents who have done so much to put me through school; an opportunity they never had.

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INTRODUCTION

Aim:

An estimate of the radiocesium concentration in wild boar can be obtained from an aggregated transfer factor (T_{ag}) based on soil contamination levels. Thus, if the soil contamination level and T_{ag} value are known for an environment, then the contaminant level in the boar can be easily estimated. The T_{ag} is the ratio of Cs-137 concentration in wild boar tissues (Bq kg^{-1}) divided by the Cs-137 deposition in soils (Bq m^{-2}).

$$T_{ag} = \frac{[\text{Cs-137}]_{\text{Wild Boar Tissues}} \ \frac{\text{Bq}}{\text{kg}}}{[\text{Cs-137}]_{\text{soil}} \ \frac{\text{Bq}}{\text{m}^2}}$$

T_{ag} values vary by orders of magnitude because of the natural variation in contaminant levels in soils and in animals (Tagami et al. 2016). Nonetheless, T_{ag} values are commonly used because they are pragmatic, allowing estimates to be made without the expense of capturing animals to conduct radiocesium analyses on each animal. A database of soil samples collected and measured for Cs-137 by the Japanese government is often used to calculate T_{ag}. Researchers currently use the soil sample information in the database (Bq m^{-2}) to estimate the Cs-137 levels in animals (Tagami et al. 2016). Often the nearest soil sample data used in calculating T_{ag} is taken a significant distance from the animal's home range.

The objective of this study was to determine if T_{ag} values derived from soil samples at the location of the boar capture site do not differ from T_{ag} values derived from a data base of soil samples. Accurate estimation of environment of contamination levels is important in evaluating evacuation procedures, durations, and possible health concerns.

Hypothesis:

I. The use of the database radio cesium deposition values of soil is of sufficient granularity to provide adequate estimations of Cs-137 levels in wild boar. Thus, the T_{ag} values derived from database radiocesium deposition values are not significantly different from T_{ag} values derived from soil samples within the home range of the wild boar.

II. Locations closer to the FDNPP will have higher Cs-137 concentrations in wild boar muscles tissues.

III. Wild boar harvested in areas closer to the FDNPP will have similar T_{ag} values than sites further away. Similar T_{ag} values across the sample locations reveal similar bioaccumulation of Cs-137 in wild boar.

IV. Boar sex and age will have an influence on Cs-137 accumulation in muscle tissue.

The hypothesis is that database radiocesium soil concentration values, provided by the Japanese Government (MEXT, 2015), provide a useful estimate of radionuclide uptake in Japanese wild boar. Wild boar were trapped and muscle tissue was collected to estimate wild boar Cs-137 whole-body activity concentrations. Soil samples were gathered at the point of collection of wild boar.

The T_{ag} values of radionuclides in wild boar was determined using two methods. The first method of determining the T_{ag} values used soil measurements performed adjacent to the wild boar collection site (T_{ag1}). The second method of determining the aggregated transfer factor values (T_{ag2}) utilized information obtained from the Japanese government soil contamination database and collected wild boar tissue concentration of radiocesium.

Cs-137 concentration levels in young animals were hypothesized to differ from older animals. Cs-137 concentration levels in male animals were also hypothesized to differ from female animals (Skuterud et al. 2004). Thus, variations in Cs-137 concentration due to the boar's age, sex, and location were investigated. Boar samples were categorized into groups of age, sex, and location of capture. An additional outcome was to ascertain if the measured Cs-137 concentration in boar living near the Fukushima Daiichi Nuclear Power Plant (FDNPP) was higher than in boar in sample locations further away. The distance between boar trap locations and the FDNPP was calculated.

History

In March of 2011, an earthquake of magnitude 9.0 occurred in the northwest Pacific, followed by a massive tsunami. Both events caused immense damage to the Fukushima Daiichi Nuclear Power Plants (FDNPP) and caused a series of explosions which resulted in the release of radionuclides from the FDNPP reactors. The disaster presented many challenges in understanding the environmental behavior and ecological impact of the radionuclides released. Radionuclides, dominated by Cs-137, were released from the nuclear power plant and deposited in the region. Radiocesium was then taken up by the roots of plants and trees and entered into food-webs, resulting in contamination of the environment. Indigenous wild boar have consumed both plants and soils containing radiocesium.

Study Area

Wild boar and soil samples were collected from the areas designated in Figure 1. The Fukushima city sample site is 60 km away, Namie is 7 km away, and Okuma is 4 km away from the FDNPP reactor. All three sample locations were used in the study to compare trends of radiocesium behavior from highly contaminated areas to less contaminated areas.

Figure 1: All samples were taken in Fukushima Prefecture, Japan (left,) and the sample locations (right). The map on the left is courtesy of the University of Texas Libraries, The University of Texas at Austin, and the map on the right is courtesy of Google Earth. Copyright-reference is found in Appendix H.

The majority of the fallout of Cs-137 from FDNPP was deposited in Northern-central parts of Japan in Fukushima Prefecture (Saito et al 2015). Okuma and Namie are among the most affected areas from the contamination. Fukushima City, also affected by the accident, has been decontaminated to background contamination levels (MEXT, 2015). People are currently resettling in Namie. Okuma is still in the evacuation zone and residency is not permitted in the city (Tagami et al. 2016).

Another major nuclear accident: Chernobyl

The Chernobyl Nuclear Power Station (NPP), in Ukraine, experienced a reactor accident with release of radionuclides on April 26, 1986(Steinhauser et al. 2014). An explosion caused by a sudden surge of power during a systems test resulted in the release of radionuclides.

Radionuclides were distributed locally, and carried by winds up to great distances. Emissions continued for ten days after the initial explosion due to a core melt down. Due to the weather conditions, Sweden received the highest fallout of radioactive material in Europe (Chaiko, 2012). The accident's immediate and severe radiation effects killed 28 people, and exposed another 106 workers to receive a high enough dose to cause acute radiation sickness. The post-Chernobyl assessment emphasized the importance of improving reactor system designs, maintaining proper procedures for emergencies, having competent operating staff, and backup safety systems (NRC, 2013).

Chernobyl vs Fukushima accident

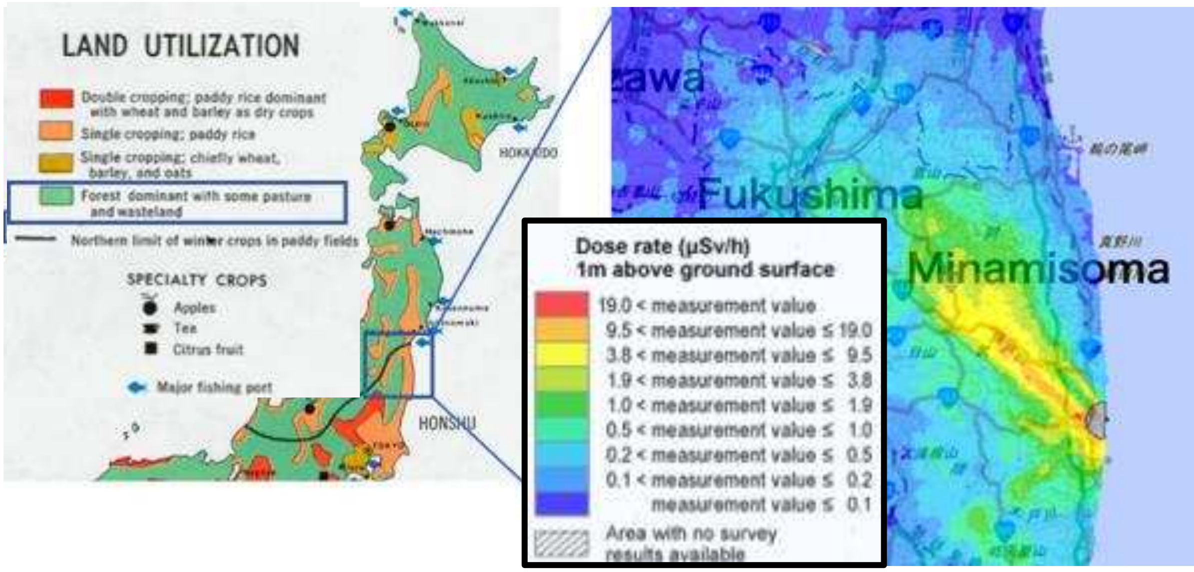
The Chernobyl NPP accident and the Fukushima Daiichi Nuclear Power Plant accident resulted in a world-wide dispersion of radionuclides. The Fukushima accident did not result in any radiation related deaths. Both accidents had negative impacts on the environment that can be studied. Specifically, radionuclides and their environmental impact and ecological behavior can be studied. Each accident deposited material in different ecosystems and had different levels of contamination (Table 1).

Table 1: Similarities and differences of the Fukushima Daichii Nuclear Power Plant and the Chernobyl Nuclear Power Plant accidents (Steinhauser et al. 2014)

	Fukushima Daichii Nuclear Power Plant Accident	Chernobyl Nuclear Power Plant accident
Cause of accident	Magnitude 9.0 East Japan Earthquake occurred, followed by a massive tsunami that destroyed and flooded back up diesel generators that provided electricity to cooling components of the reactor; lack of cooling led to high temperatures and hydrogen explosions	Inappropriate reactor operation at low power and critical warnings not noticed by under trained staff led to an explosion in Unit 4 of the reactor No containment building surrounded the reactors
Radioactivity released	Cesium, iodine and noble gases 520 PBq	Cesium, iodine, noble gases and transuranics 5300 PBq
International Atomic Energy Agency International Nuclear and Radiological Event Scale	7 - Major accident	7 - Major accident
Area contaminated	75% forested, <10% rice paddy fields, <10% agricultural areas and <5% urban areas	43% agricultural, 39% forested, 2% bodies of water
Weather the day of accident	Weather transported an estimated 80% of the radionuclides towards the ocean	Wind carried radionuclides into nearby countries, including: Belarus, Austria, Greece and others
Evacuation	600 km^2, immediate evacuation and stable iodine pills provided	2800 km^2, evacuation was 2-3 days after accident and no stable iodine pills provided
Fatalities due to acute radiation injury after accident	0	28

Decontamination of the Fukushima Prefecture

Decontamination of the land in Fukushima prefecture began shortly after the accident. The Japanese government's goal is to decontaminate the region to allow re-settlement of evacuated areas. Decontamination was initially carried out in inhabited areas. However, large forest areas make up 71% of the contaminated land area and have not been decontaminated (Tagami et al. 2016). The decontamination of the forest has not been performed primarily due to the high cost, the fact that people are not impacted directly, and possible negative environmental side effects. Cleaning the contaminated forests would not sufficiently lower the external radiation dose to people at an effective cost because the regions are less accessible to residents. Since forests will remain untreated, an increased radionuclide bioavailability for biota living in the area is possible. A map of the contaminated region and land utilization is shown in Figure 2. Measurements of any soil samples taken from an area that has been decontaminated may influence the Cs-137 reading, thus impacting the cesium T_{ag} of wild boar in the area.



[1]*Figure 2: Land utilization (left) and the contaminated region (right) show that most of the contaminated area is forest. The dose survey was done on 2016 using an airborne monitoring system. Map on left is courtesy of the University of Texas Libraries, The University of Texas at Austin, and the map on the right is courtesy of Geospatial Information Authority of Japan*[1].

Radionuclide Transfer to Biota

Parameters that estimate radionuclide accumulation, such as the aggregated transfer factor (T_{ag}), are used in assessing doses to biota in contaminated ecosystems. The transfer of radionuclides to biota varies, making modeling and predictions of concentrations of radionuclides in wildlife challenging; nonetheless, there are methods to devise approaches which are credible and acceptable to the scientific community. The most common approach for estimating the transfer of radionuclides is using the surface deposition of soil as a starting point to estimate the concentration of radionuclides in biota. Radiocesium typically will transfer from soil to plant to animal if it is not bound to clay materials in soil (Beresford et al. 2013).

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[1] Map used with permission from Geospatial Information Authority of Japan: http://ramap.jmc.or.jp/map/eng/ information on copyright approval found in Appendix H.

Forest Ecosystems

Fukushima Prefecture is dominated by a forest biome. An estimated seventy one percent of the contaminated area is large forests. The forests have unique soil structure, and they are a complex natural ecosystem, especially when assessing the behavior of Cs-137 bioavailability (Tagami et al. 2014). The forests in the region have vegetation and animal diversity. The relationship and interactions between biota create multiple trophic levels and food chains. The complexity of forests factors into the behavior and mobility of Cs-137.

Cs-137 mobility in boreal forest soils and plants

Cesium-137 may assume different chemical forms in forest soil. The chemical forms are dependent on the isotope's oxidation state. Cesium will generally bind, reversibly, to organic matter. Organic matter can release cesium when it decomposes (Oughton et al. 1994). Decomposing of organic matter releases the cesium back into the forest litter and media. The resuspension of cesium from the decomposing matter generates an increased mobility of the radioactive isotope in forest regions (Oughton et al. 1994).

Cesium can also bind, in some cases irreversibly, to clay minerals. However, clay minerals in forest soils are not typically present. (Giannakopoulos et al. 2011). Mobility of Cs-137 is also dependent on the presence of nutrients available for plants. Forest soils, which lack essential nutrients, like potassium, will uptake elements such as radiocesium due to similar physical and chemical properties (Giannakopoulos et al. 2011). The uptake of Cs-137 in plants will relocate radiocesium above ground as a secondary contamination. The resuspension and relocation generate a long-term mobility cycle for Cs-137 in a forest ecosystem (Giannakopoulos et al.

2011). More than 90% of the Cs-137 stays within the upper five cm of most forest ecosystems (Shaw et al. 2001).

Agricultural ecosystems

Agricultural land is less complex than a forest ecosystem and has several differences. Human activity in the area is the largest difference. Human agricultural activities continuously disturb the soil and reshape the land. Thus, the upper organic layer (forest litter) is absent and Cs-137 is distributed directly in the upper soil layer and on crops at the time of the deposition. If agricultural plants, such as rice stalks, are present during the time of the deposition, most of the cesium will land on the leaves and some fraction absorbed. The remaining radiocesium will drop to the soil by weathering. The agricultural soil structure will decrease the mobility of Cs-137 and reduce the uptake by plants. The agricultural soil is fertilized with potassium, which means the crops and plants will not uptake as much of the Cs-137 (Strebl et al. 2007). When ploughing occurs, Cs-137 will migrate deeper in the soil, thus Cs-137 will be found deeper in agricultural soil than in forest ecosystems (Shaw and Bell, 2001).

Japanese Wild Boar (sus scrofa)

Wild boar, *Sus scrofa leucomystax*, is an omnivorous mammal living in evacuated cities and natural ecosystems. Radiocesium uptake by wild boar is more likely in natural ecosystems. Concentration of radiocesium in wild boar is expected to be higher in areas within four km of FDNPP, such as Okuma. Variation in radiocesium concentration in an ecosystem may alter the concentration levels in the meat of wild boar with time (Hampton et al. 2004).

Wild boar in the evacuation zones have increased in population since the FDNPP accident five years ago (Tanoi et al. 2016). The mammal's aggressive behavior poses a threat to citizens, workers, and farmers in the Fukushima Prefecture. Wild boar of all ages are being harvested by professional hunters within Fukushima Prefecture. The Japanese government is currently attempting to reduce boar populations in the evacuated zones surrounding the damaged reactor complex. Expanding populations of wild boar are considered a triple threat impacting biodiversity, agricultural production, and public health. The culled animals provide a unique resource of tissues that can be made available for scientific study. Wild boar are well suited to be a sentinel mammal for ascertaining T_{ag} values of radiocesium, and wild-life radionuclide uptake (Hampton et al. 2004). The boar's habitat, diet, and mammal characteristics provide useful information to understanding environmental radioactivity.

Wild Boar habitat and home range

Wild boar can be found throughout Japan, save for Hokkaido and the Ryukyu islands. The boar population is now being controlled by the Japanese government, harvesting animals through hunting and trapping. Wild boar have a varying home range, which can vary depending on a boar's threats in a habitat and the season. Most of the boar's threat are from human activities. Human threats can cause wild boar to migrate large distances (Keuling et al, 2009). Wild boar are predominately forest or forest edge species, thriving in natural habitats. However, in summer wild boar are observed to use agriculture fields and little shrubs for shelter. Boar can have a home range of 5 km^2 (Keuling et al, 2009). An example of a boar's home range is shown in Figure 3.

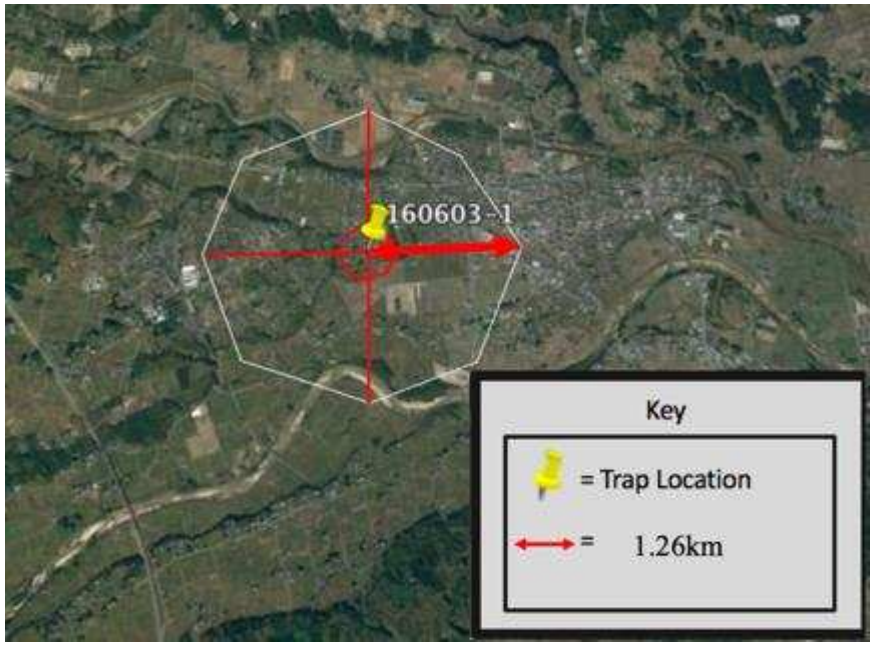

*Figure 3: The boar trap location (160603-1) corresponds to the boar capture site. The boar's home range has an estimated 1.26-kilometer radius from the trap site location. (*Keuling et al, 2009*). The map is courtesy of Google Earth. Copyright information found in Appendix H.*

Wild Boar Diet

Boars are omnivores and may have fluctuating rates of cesium ingestion from their diet. In forest ecosystems, radiocesium is more available for wild boar uptake from plants and fungi (Olsen et al. 1994). Thus, the boar's diet may contribute to an increased ingestion rate of radiocesium based on the consumption of these plants and fungi. Cesium is also more bioavailable because of the soil structure in the ecosystem (Shaw et al. 2001). Radiocesium is less available for uptake in agricultural ecosystems due to decontamination by the Japanese government and the area's soil characteristics (Shaw et al. 2001). Wild boar may migrate from evacuated zones, and the new ecosystem will bring a new diet. Wild boar migrate to find new fields or forest regions with high energy nutrients and safe shelter. The change in range will impact the animal's radiocesium concentration. For example, in some areas of northeastern

Japan, mushrooms grow rapidly and are a highly-contaminated food. The boar consume the mushroom, which results in an increased radiocesium concentration in the boar's meat (Tagami et al. 2014).

Boar may also have variations of radiocesium intake due to changing water consumption sources, and changing concentrations in those same sources.

The sample locations have ecosystems that have sufficient precipitation that the inhalation of contaminated particles from resuspension by wild boar is estimated to be minimal. However, rain-drop splash may cause resuspension. Contaminated particles may then land on plants or shrubs that are consumed by grazing animals, such as wild boar.

Chernobyl Wild Boar Studies

Studies have found high concentrations of radiocesium in wild boar near the areas impacted by the Chernobyl accident. Boar meat collected in the Fukushima Prefecture in 2011 had a maximum activity concentration of 7900 Bq kg^{-1} (Mers et al. 2015). Boar meat collected in 1996 near Chernobyl had a maximum that was two magnitudes higher at 661,000 Bq kg^{-1} (Gulakov et al. 2014). The high concentrations are due to the Chernobyl NPP accident on April 26, 1986 (Table 1). Even in remote areas after the Chernobyl NPP accident, Cs-137 concentrations are much higher in boars surrounding Chernobyl than wild boars in Japan.

A decade and a half after the Chernobyl NPP accident a study on boar Cs-137 concentration in meat was conducted in Croatia in 2000-2002 (Vilic et al. 2005). Several wild boar meat samples were collected in the region, and gamma-spectrometric measurements of Cs-137 were performed. Cesium-137 concentrations ranged from 0.4-611.5 Bq kg^{-1} (fresh weight). The range of concentration varied by three orders of magnitude. Variation in boar meat concentration was postulated to be due to such variables as the animal's diet, home-range, age, or sex. The researchers suggested the large variation is due to the food consumed by the wild boar and variations in the contamination within their habitat. During autumn, a period of high mushroom growth, the boars have higher consumption of mushrooms resulting in higher Cs-137 values in boar meat (Vilic et al. 2005).

Wild Boar radiocesium concentration as a function of age

At all the sample locations of wild boar, a large age variation in wild boar captured in the study period was observed. The age variation of wild boar is between less than five weeks to greater than 220 weeks. The age variation is shown in Appendix E. Radiocesium levels in young boar may differ from mature boar. A previous study at Fukushima University indicated that age of cattle was more important in determining their radiocesium burdens than the contamination level of the environment (Sato et al. 2015). Another study conducted after the Chernobyl accident focused on cesium accumulation in lynx. The study found that age had an influence on radionuclide uptake. Adult lynx tend to have a higher activity concentration than their cubs. Adult lynx had 0.111 Bq kg^{-1} (fresh weight) and cubs had 0.093 Bq kg^{-1} (fresh weight), which was a statistically significant difference (Skuterud et al. 2004). Therefore, the concentration levels in multiple age groups of wild boar were investigated to see if age influences radiocesium accumulation.

Wild boar radiocesium concentration as a function of sex

Uptake of radiocesium in wild boar living in contaminated areas near Fukushima may be influenced by the animal's sex. A post-Chernobyl study in Sweden found a measureable, but not statistically significant, difference between male and female fox radioceisum accumulation

(Lowe et al. 1990). Lynx cubs were studied in affected areas of the Chernobyl accident and the researchers found no significant difference between sexes (Skuterud et al. 2004).

Aggregated Transfer Factors

Modeling radiocesium accumulation in wild boar is important to understanding radionuclide behavior in ecosystems. Aggregated transfer factors (T_{ag}) are used to provide estimates of the concentrations of radioactivity within a biota relative to the habitat. In terrestrial biota, the calculation requires the activity concentration of a radionuclide in the whole-body organism and the radionuclide ground deposition (IAEA 472). Aggregated transfer factors are key parameter values for the evaluation of the transfer of radionuclides from environment to wildlife groups. T_{ag} values can be used to assess potential radiation dose rates and effects on populations in the ecosystem. If the soil contamination level and T_{ag} is known, then the contaminant level of a population can easily be estimated. A T_{ag} is based on the ratio of radionuclide ground deposition (Bq m^{-2}) to wild boar's meat (Bq kg^{-1}).

The activity concentration of a radionuclide in soil is generally reported in Bq kg^{-1}. Radiocesium concentration in soil surrounding the FDNPP is not uniform in soil depth nor in distribution. A thin surface layer of radiocesium of five-centimeters thickness contains most of the soil contamination (Tagami et al). Thus, activity concentrations of a radionuclide in soil are difficult to apply to the Fukushima situation. Therefore, the T_{ag} values determined in this study were developed based on the ratio of soil surface concentration (Bq m^{-2}) to the activity concentration in wild boar's meat (Bq kg^{-1} dry weight). The T_{ag} values were calculated for Fukushima Prefecture to estimate wild boar contamination levels and to determine maximum doses to people who consume the meat (Tagami et al 2014). T_{ag} values can be used to help monitor contamination of an environment. T_{ag} values are also used to estimate an organism's whole body activity concentration when only the ground deposition is known.

Compliance with the Japanese government standard food limit (> 100 Bq kg^{-1}) for radionuclides is ensured by monitoring tissues of hunted animals throughout the Fukushima prefecture. The transfer of Cs-137 from contaminated land to game animals can be quantified using an aggregated transfer factor (Tagami et al. 2016). The aggregated transfer factor is the activity concentration in meat (Bq kg^{-1}) divided by the amount of radioactivity in soil (Bq m^{-2}). T_{ag} values for wild boar are calculated using monitoring data provided by the Japanese government (Ministry of Education, Culture, Sports, Science and Technology Website, Extension Site of Distribution Map of Radiation Dose[3]). Cesium-137 activity concentrations in boar are provided to the public by the Fukushima Prefecture. Soil ground deposition of Cs-137, in Bq m^{-2}, were obtained from the Ministry of Education, Culture, Sports, Science and Technologies. These have been periodically plotted on a map of Japan and are a part of Japan's intensive monitoring program. The plotted Cs-137 concentration data points are shown in Figure 4.

Figure 4: Example Cs-137 ground deposition values from samples, taken by MEXT. The map is taken from the Geospatial Information Authority of Japan[2]

Wild boar muscle tissue samples and soil samples at the boar trap locations were collected to support the hypothesis of this project. Next, T_{ag} values were calculated for each animal. The appropriate database Cs-137 ground deposition (Bq m^{-2}) was paired with the wild boar trap site and a T_{ag} value calculated. Each T_{ag} value was used to estimate the contamination level of a wild boar. Our hypothesis is that the T_{ag} values can be estimated using aggregate data obtained from Prefecture level sampling, and individual animal sampling is not necessary to ascertain radiocesium concentrations in wild boar.

[2] Map used with permission from Geospatial Information Authority of Japan: http://ramap.jmc.or.jp/map/eng/ information on copyright approval found in Appendix H

MATERIALS AND METHODS

This project was reviewed by the Colorado State University Institutional Animal Care and Use Committee on November 11th, 2015 and was found to be exempt. The exemption memo is provided in Appendix A

Sampling

The soil and boar data collection period was from June 5th, 2016 to November 6th, 2016.

Wild Boar sampling

Sixty-one wild boar were captured and 157 tissue samples were taking during the collection period, however more boar were captured after the collection period and the additional measurements were included in this study. Location, sex and age was not available for every wild boar captured during the collection period due to communication errors with hunters. Thus, sample sizes for each analysis varied depending on information collected for each boar. Cs-137 concentration (Bq kg^{-1}) were obtained for sixty-one wild boar. Wild boar were captured using a large metal cage trap (Figure 5). Traps were baited using powdered corn. The traps were triggered by a trip wire. The number of traps in the area varied on location, the hunters, and the boar population.

Trap locations with GPS coordinates are provided in Table 2. Twenty-six traps were installed in Namie town and checked Mondays, Wednesdays, and Fridays. Approximately 40 traps were installed in Okuma, where the boar population is higher. Okuma traps were equipped with an electronic device indicating when triggered, and sent a signal to the hunters. Every trap site where a wild boar was captured is shown in Appendix E.

Boar were euthanized by professional hunters as part of a large-scale culling operation to reduce the boar population. Researchers performed a necropsy on the euthanized boar to collect desired samples. A full set of samples from a boar included ribs, femur, bicep femoris, longissimus, masseter, liver, kidney, heart, lung, tongue, testicles, and thyroids. All samples were packaged in plastic bags with unique identifiers and sent to the IER. Additional information such as sex and age were taken at the trap location.

Table 2: List of all the trap sites and their GPS locations. All trap locations listed caught at least one wild boar for the study.

Namie		
Trap number	Longitude	Latitude
1	37.491431	140.978599
2	37.523055	140.931445
3	37.508634	140.931026
4	37.480354	140.989209
5	37.568932	140.778014
6	37.479072	140.979392
7	37.581339	140.721047
8	37.549639	140.796942
9	37.510019	140.935489
10	37.465361	140.943151
11	37.491317	140.941102
12	37.465361	140.943151
13	37.505422	140.925022
14	37.551871	140.788174
15	37.55606	140.78397
16	37.46466	140.92319
17	37.54061	140.81465
18	37.478359	140.977474
19	37.568932	140.778014
20	37.561920	140.746675
21	37.500294	140.94546
22	37.464554	140.946247
23	37.479347	140.981908
24	37.497798	141.014968
25	37.465529	140.947112
26	37.480657	140.940891

Fukushima City		
Trap Number	Longitude	Latitude
1	37.704008	140.401985
2	37.761529	140.501009
3	37.74873	140.490098
4	37.744412	140.504675

Okuma		
	Longitude	Latitude
1	37.393036	140.995272
2	37.415958	141.012303
3	37.393036	140.995272
4	37.400028	140.989244
5	37.39513	140.97357
6	37.393047	140.997004
7	37.414074	140.987373
8	37.400028	140.989244
9	37.454348	141.002830
10	37.399016	140.971983
11	37.384897	141.009965
12	37.390051	140.998834
13	37.429225	141.009476
14	37.408544	140.975109
15	37.384897	141.009965
16	37.443004	141.007252

Figure 5: (A) The trap once it has been triggered by a wild boar. (B) The trap being prepared to capture boar by professional hunters.

Six captured boar were not killed, but given general anesthesia. During the anesthesia period, a whole-body count was performed using a 1-cm^3 Kromek CZT detector to measure Cs-137 (Figure 6). The boar were then released with a radio-collar (Figure 7). The collar provided GPS location information of the boar, providing an estimate of the boar's home range. The boar collar data is still being analyzed. However, on average, the boar's home range encompassed a radius of 1.26 kilometers from the trap locations *(*Keuling et al, 2009*)*.

Figure 6: (A) 1-cm^3 Kromek CZT detector (B) The whole-body measurement of the boar using the instrument

Figure 7: Radiocollar used on the boar to determine home range and external dose

Cesium does not accumulate equally in all tissues. Cs-137 accumulates 60% higher in muscle tissue than any other organ tissue (Tanoi et al. 2016). Radiocesium is the chemical analogue of the stable element potassium. When radiocesium is ingested it moves in the body like potassium and accumulates in muscle (NCRP Report 154). Therefore, the bicep femoris, a muscle tissue of the wild boar, was collected and measured for Cs-137. All muscle tissue samples were prepared by removing all hair, connective tissue, and fat to reduce uncertainty. The muscle tissue was assumed to represent the whole-body measurement due to cesium's bioaccumulation in the muscle in the wild boar.

All wild boar samples were measured using dry weight (D.W) samples. A D.W sample is dried to remove all water from the sample before it is measured for radiocesium. Fresh weight (F.W) were also measured to develop a correction factor. The correction factor (D.W/F.W), for bicep femoris muscle tissue in the wild boar, was 0.24.

At the IER, each sample was carefully homogenized and transferred to a five-mL plastic bag, weighed, and given the same identification number recorded in the field. The sample was then placed in a freezer for at least two hours at -80 ºC. Once frozen, the sample was freeze-dried for two days. All moisture was eliminated from the sample during the freeze-drying process. After the process was completed, the sample was re-weighed and transferred to a 60-mL plastic bottle. The samples are shown in Figure 8. All boar sample measurement results of Cs-137 concentrations using a HPGe instrument are provided in Appendix E.

Figure 8: (A) Obtained samples from boar were labeled, homogenized, frozen and placed in a 5-mL bag. (B) Example of prepared boar tissue sample

Soil sampling

Method 1

Sixty-three soil samples at 21 sample sites were taken during the collection period. Three soil cores were collected at each boar trap location. The soil samples were collected based on a randomized process that provided a direction between five meters and 300 meters from the trap location. Each soil core was nine centimeters long, had a five-centimeter diameter, and was sliced into three individual parts to be analyzed (Figure 9). Those parts included the top layer (3 cm), middle layer (3 cm), and lower layer (3 cm). The soil sampling process is shown in Figure 10. The radionuclide ground deposition was then calculated using the total activity (Bq kg^{-1}) in each slice, the mass of each slice (kg) and the area of the surface area of the core (m^2). All samples were air-dried and thoroughly homogenized. Stones were removed, and the mass of the samples was determined before gamma-spectrometric measurement. To derive Cs-137 ground deposition (Bq m^{-2}), weight based measurement results (Bq kg^{-1} dry soil) were related to the recorded sample area and the soil bulk density for each depth increment. Equations 1.2 and 1.3 were used to calculate the bulk density of soil (kg m^{-3}) and then find the surface deposition. All data are provided in Appendix D.

Equation 1.2:

$$V = \pi r^2 h$$

$$V = \text{volume}$$

$$r = \text{radius of core}$$

$$h = \text{height of core}$$

Equation 1.3

$$D = \sum C_i p_i z_i$$

$$\text{Where D} = \text{Deposition}\ \left(\frac{\text{Bq}}{\text{Cm}^2}\right)$$

$$C = \text{Concentration}\ \left(\frac{\text{Bq}}{\text{g}}\right)$$

$$p = \text{soil bulk density}\ \left(\frac{\text{g}}{\text{cm}^3}\right) = \frac{\text{mass (kg)}}{\text{volume}}$$

$$z = \text{thickess (cm)}$$

$$i = \text{layer level}$$

Plotting the Cs-137 concentration vs. average depth in soil between soil slice A, B, and C will provide an exponential regression equation for the Cs-137 concentration with depth. Thus, the ground deposition could be found using the regression equation and Equation 1.2. The ground deposition calculated from the obtained soil samples is assumed to represent the home range of the wild boar.

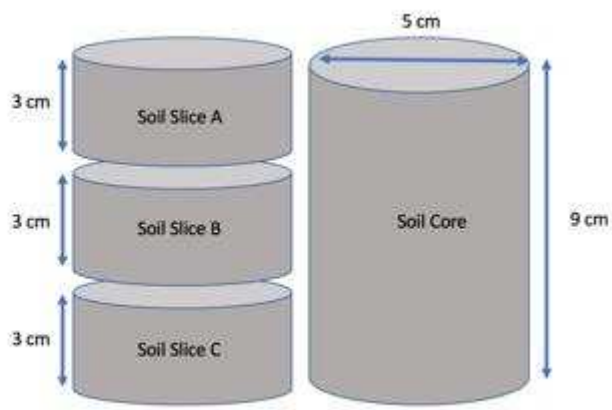

Figure 9: Soil cores taken at each sample site were sliced into three layers.

Figure 10: (A) Soil samples were collected in the boar home range. (B) Samples were sliced into three 3-cm pieces. (C) Example of a prepared sample.

Each layer of soil was placed in a 60-mL plastic container for measurement of Cs-137 using an HPGe instrument. All soil samples were fresh samples and processed in the field. All soil measurement results are provided in Appendix D.

Method 2

After the boar were captured, the location of each boar's trap site was specified on a Japanese public hunter map (Fukushima Prefecture, Fukushima Hunter Map[3]). The map utilizes 31×31 cells, each cell is approximately 5.5 km wide and 4.7 km long, covering the Fukushima prefecture (Tagami et al. 2016). The specified cell can then be used to obtain the corresponding concentration of radiocesium in Bq m^{-2} in the area. The corresponding concentration of

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[3] Fukushima Hunter Map is provided online at: http://wwwcms.pref.fukushima.jp/pcp_portal/PortalServlet;jsessionid=5557128F1DC64A7D BDE2695750E8600E?DISPLAY_ID=DIRECT&NEXT_DISPLAY_ID=U000004&CONTENTS _ID=26118

radiocesium in the area was previously obtained by MEXT in October 2015 by sampling throughout the prefecture. MEXT collected soil samples from June 14th, 2011 to December 2015. The MEXT soil monitoring program was accomplished by collecting five soil samples at one sampling location, and the mean value of the soil concentrations was input as the site's ground deposition. All data from MEXT was decay corrected to the sampling date. MEXT used HPGe spectrometry for Cs-137 measurements (Tagami et al. 2016). The soil values for Cs-137 concentrations from MEXT were plotted on an open source map of Japan (MEXT, 2015). All corresponding area Cs-137 soil ground depositions for each trap site are shown in Appendix D.

The methods of calculating the T_{ag} values were compared using a paired t-test and the Bland-Altman method of agreement (Bland et al. 1986).

Gamma Spectroscopy

All boar and soil samples were analyzed for Cs-137 activity concentration at the IER. A High Purity Germanium detector system (HPGe, Canberra Industries, Meriden, Connecticut) measured activity concentrations through gamma spectroscopy. More information on the instrument and other devices used for measuring radiation is provided in Appendix C.

Data Analysis

Number of Samples

Sex and age class were investigated to determine their influence on Cs-137 accumulation. The wild boar were classified by sex (male and female) and age (adult, juvenile, and squeaker). Age classes (squeaker <12 weeks old, juvenile <52 weeks, and adult >52 weeks) for wild boar are delineated in Table 3 (A) and (B). Boar age was determined at the trap location by tooth erosion. A wild-life biologist at the trap location used a tooth erosion chart that estimated the age of each boar.

Table 3(A): Captured wild boar categorized by age for statistical analysis purposes based on the sample size.

Description (age)	Squeaker (<12 weeks)	Juvenile (≤52 weeks)	Adult (>52 weeks)
Number of Wild Boar	16	30	21

Table 3 (B): Captured wild boar categorized by sex

Description (sex)	Male	Female
Number of Wild Boar	37	33

Calculating Aggregated Transfer Factors

T_{ag} values were calculated using Equation 1.1.

Equation 1.1:

$$T_{ag} = \frac{\text{activity concentration in whole organism} \left(\frac{\text{Bq}}{\text{kg}}, \text{dry weight}\right)}{\text{Cs}-137 \text{ ground deposition} \left(\frac{\text{Bq}}{\text{m}^2}, \right)}$$

The activity deposition in soil (Bq m^{-2}) was obtained by two methods for T_{ag} value comparison. The first calculation involved soil sampling from method one: the soil collected at each boar trap site (T_{ag1}). The second calculation involved local soil sampling from method two: the MEXT public site provided database soil samples (T_{ag2}). Each T_{ag} value's calculation used the activity concentration in boar's muscle for the numerator in Equation 1.1. Both $T_{ag1 \text{ and }} T_{ag2}$ were compared by using Bland Altman's Agreement and a paired T-test (Bland et al. 1983).

After comparison of $T_{ag1 \text{ and }} T_{ag2}$ values, the distance between trap sites and the FDNPP were compared and analyzed.

RESULTS

Wild Boar

Cs-137 concentration in wild boar as a function of location

Activity concentration of Cs-137 in boar muscle tissue was higher in areas closer to FDNPP. The highest activity concentrations of Cs-137 are found in Okuma boar, the sample site closest to the reactor (~4 km). The highest Cs-137 concentration found in the boar bicep femoris (3.7×10^4 Bq kg^{-1} dry weight) was from Okuma. The lowest Cs-137 concentration in the boar bicep femoris (3.0×10^2 Bq kg^{-1} dry weight) was from Fukushima City. Mean Cs-137 levels at the locations differed significantly ($p < .0005$). The data from each location are shown in Figure 11 and Table 4A. The log transformed data mean and standard deviation are shown in Table 4B. This was done because the original data were highly skewed and hence transformation was used to satisfy the assumption of normality. An ANOVA test revealed a significant difference between Cs-137 concentrations in wild boar at Namie and Okuma (note that both were in the plume of the radioactive release) ($p = .001$). The ANOVA statistical analysis is further shown in Appendix G. The wild boar sex and age ANOVA analyses are also included in the model provided in Appendix G.

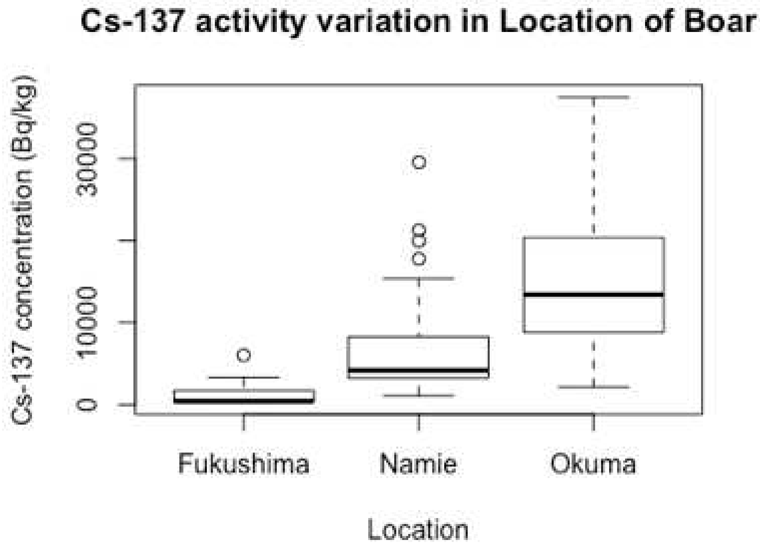

Figure 11: Cs-137 concentration (Bq kg^{-1} dry weight) in wild boar muscle tissue from each sampling site.

Table 4A and 4B: Cs-137 concentration (Bq kg^{-1} D.W) ranges in wild boar muscle tissue (bicep femoris) with means and standard deviations for location of boar, where n = number of samples

Location (A)	Total Boar (*n*)	Cs-137 concentration range Bq kg^{-1}	Mean Cs-137 concentration Bq kg^{-1}	Standard Deviation
Fukushima City	13	3.0×10^2-6.0×10^3	1.4×10^3	1.7×10^3
Namie	30	1.1×10^3-2.9×10^5	7.3×10^3	7.0×10^3
Okuma	20	2.1×10^3-3.7×10^5	7.4×10^3	7.4×10^3

Location (B) Log-transformed data	Total Boar (*n*)	Cs-137 concentration range Log (Bq kg^{-1})	Mean Cs-137 concentration Log (Bq kg^{-1})	Standard Deviation
Fukushima City	13	2.5-3.8	2.9	0.46
Namie	30	3.0-4.5	3.7	.37
Okuma	20	3.3-3.5	4.08	.30

The distance from the boar trap site to the FDNPP was calculated. A semi-log plot of Cs-137 concentration (Bq kg^{-1}) in the boar versus distance (km) to FDNPP is shown in Figure 12. A general linear model revealed that there was a correlation ($R^2 = 0.516$) between the levels of Cs-137 and the location of the trap site. As the distance between the trap site and FDNPP decreased, the Cs-137 levels in boar increased.

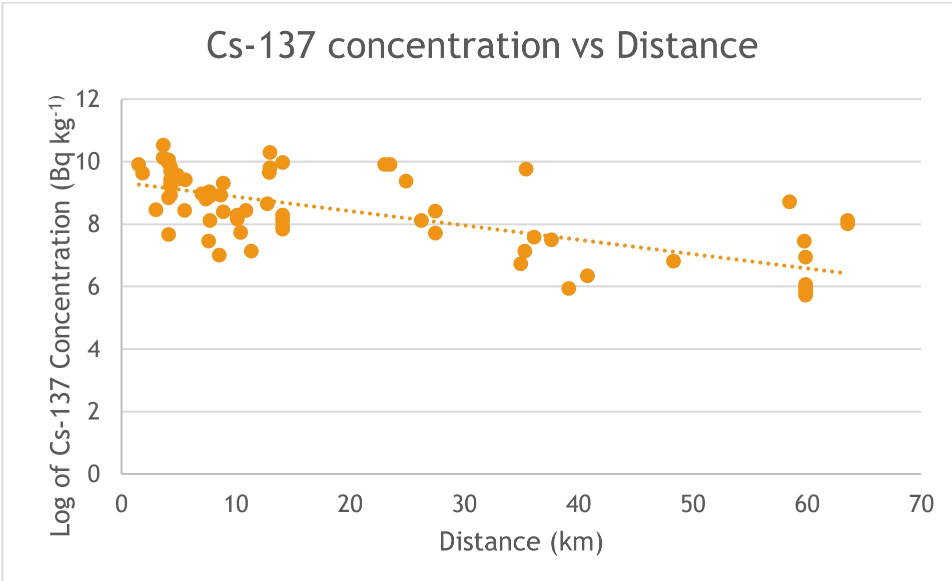

Figure 12: Cs-137 concentration in the boar muscle tissue vs the distance the boar was captured from the FDNPP. The equation for the linear regression line is $y=-0.04x +9.33$.

Cs-137 Concentration in Wild Boar muscle tissues vs. sex

ANOVA was used to ascertain the influence of sex on the levels of Cs-137 activity concentration in the boar. The data were log transformed to satisfy normality assumptions. The sex of the boar had no significant influence on the accumulation of Cs-137 in the muscle tissue ($p = 0.98$) using the log transformed data. The range of Cs-137 concentration in the bicep femoris for both male and female, and the mean for each, are shown in Table 5A. The log transformed data's mean and standard deviation are shown in Table 5B. A boxplot of the sex of boar vs. Cs-137 concentration in the muscle tissue is shown in Figure 13. Male boar did not have a demonstrably higher uptake of Cs-137 than female boar.

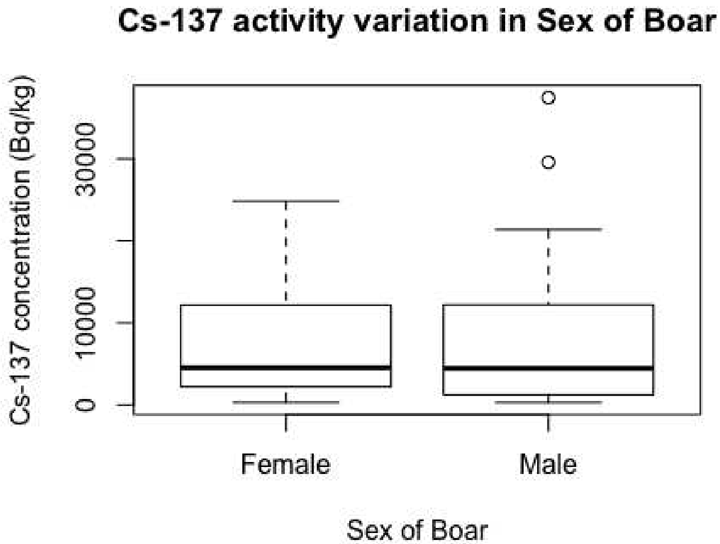

Figure 13: Cs-137 concentrations (Bq kg^{-1}) in wild boar muscle tissues compared by sex

Table 5A and 5B: Cs-137 concentration (Bq kg^{-1} D. W) ranges in wild boar muscle tissue (bicep femoris) with means and standard deviations for sex of boar (male and female), where n = number of samples

Sex (A)	Total Boar (*n*)	Cs-137 concentration range (Bq kg^{-1})	Mean Cs-137 concentration (Bq kg^{-1})	Standard Deviation
Male	37	3.0×10^{2}-3.7×10^{4}	8139.4	7581
Female	33	3.2×10^{2}-2.5×10^{4}	7792.7	8893

Sex (B) Log-Transformed Data	Total Boar (*n*)	Cs-137 concentration range Log (Bq kg^{-1})	Mean Cs-137 concentration Log (Bq kg^{-1})	Standard Deviation
Male	37	2.5-4.6	3.5	0.63
Female	33	2.5- 4.4	3.7	0.54

Cs-137 Concentrations in Wild Boar vs. age

ANOVA was used to determine the influence of age on Cs-137 activity concentration in the boar. The boar were categorized into three groups: squeaker, juvenile, and adult based on their age (Table 6). The age of the boar had no impact on the Cs-137 found in the muscle tissue ($p = 0.62$). A boxplot of each age category is shown in Figure 14. The range of Cs-137 concentration in the bicep femoris for all three categories, and the mean for each, are shown in Table 6A. The log transformed data are shown in Table 6B.

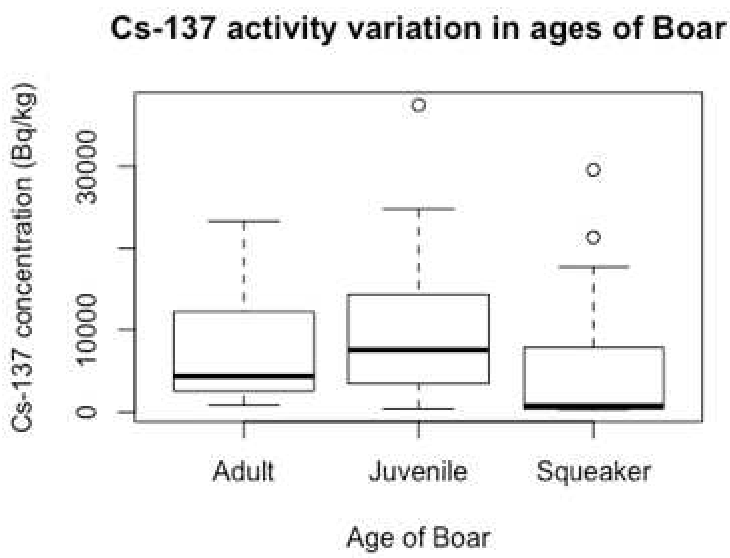

Figure 14: Cs-137 concentrations (Bq kg^{-1}) in wild boar muscle tissue compared by age

Table 6A and 6B: Cs-137 concentration (Bq kg^{-1}) ranges in wild boar muscle tissue (bicep femoris) with means and standard deviations for age of boar (squeaker, juvenile, and adult), where n = number of sample) (A) The log transformed data and corresponding mean and standard deviation (B).

Age (A)	Total Boar (n)	Cs-137 concentration range (Bq kg^{-1})	Mean Cs-137 concentration (Bq kg^{-1})	Standard Deviation
Squeaker (<12 weeks)	16	3.0×10^2-2.1×10^4	6.0×10^3	9.1×10^3
Juvenile (≤52 weeks)	30	4.0×10^2-3.7×10^4	9.8×10^3	8.3×10^3
Adult (>52 weeks)	21	8.0×10^2-2.1×10^4	7.8×10^3	7.6×10^3

Age (B) Log-transformed data	Total Boar (n)	Cs-137 concentration range Log (Bq kg^{-1})	Mean Cs-137 concentration Log (Bq kg^{-1})	Standard Deviation
Squeaker (<12 weeks)	16	2.5-4.3	3.2	0.46
Juvenile (≤52 weeks)	30	2.6-4.6	3.8	0.47
Adult (>52 weeks)	21	2.9-4.4	3.7	0.10

Soil

Cs-137 Concentrations in soil at each location

Method 1:

Sixty-three soil core samples were taken at the twenty-one sites where wild boar were captured. The result of each sliced core measurement is shown in Appendix D. Each site's average radionuclide ground deposition (Bq m^{-2}) and standard deviation are also provided in Appendix D. The Cs-137 average at each location is provided in Table 7. As expected, soil samples collected at the Fukushima City sites had much lower Cs-137 concentrations than both Namie and Okuma. Higher levels of Cs-137 are observed in Okuma. A boxplot of the soil samples at each location is provided in Figure 15. The Cs-137 concentration were log transformed. ANOVA testing revealed a significant difference between the log transformed Cs-137 ground deposition measurements and the location of the soil ($p < 0.0001$).

Fukushima city had little surface contamination from the accident which resulted in lower Cs-137 ground deposition measurements. There was a significant difference between the log transformed Cs-137 ground deposition average values between Okuma and Namie ($p=0.0002$).

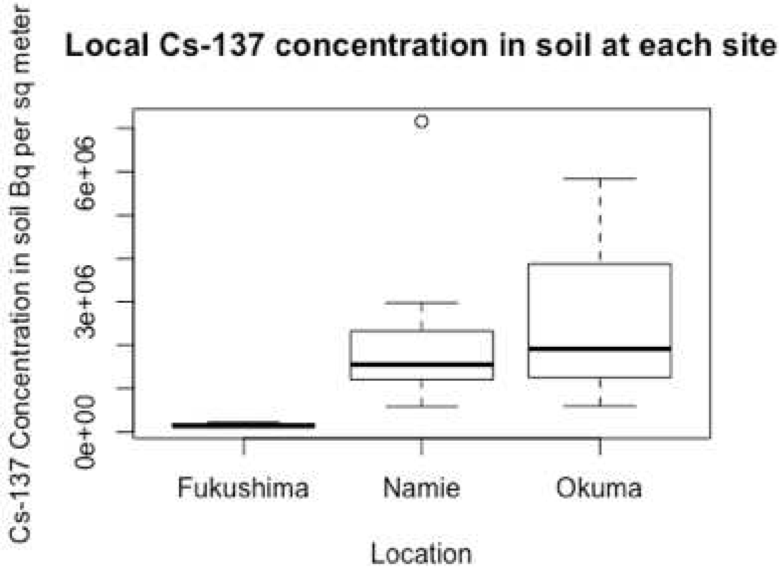

Figure 15: Cs-137 concentrations from collected soil samples from method one (Bq m^{-2}) at each location.

Table 7 (A) and (B): (A) Cs-137 concentrations (Bq m^{-2}) ranges in soil samples collected near the trap site location with means and standard deviations; where n = number of samples. (B) Log transformed data mean and standard deviations at each sample site.

(A) Method 1: Local Soil	(*n*)	Range of Cs-137 ground deposition (Bq m^{-2})	Mean Cs-137 ground deposition (Bq m^{-2})	Standard Deviation
Fukushima	3	1.4×10^5-2.2×10^5	1.2×10^5	4.7×10^3
Namie	16	5.9×10^5– 7.2×10^7	2.0×10^6	1.5×10^6
Okuma	3	6.0×10^5-5.9×10^7	2.8×10^6	2.7×10^6

(B) Method 1: Local Soil Log-transformed data	(*n*)	Range of Cs-137 ground deposition Log (Bq m^{-2})	Mean Cs-137 ground deposition Log (Bq m^{-2})	Standard Deviation
Fukushima	3	5.1-5.3	5.2	0.11
Namie	16	5.8-6.8	6.2	0.26
Okuma	3	5.7-6.7	6.3	0.49

Method 2

MEXT database soil samples were paired with all boar trap site locations where soil samples had been taken for method 1. All Cs-137 soil concentration measurements from the MEXT database are provided in Appendix D. Each site's average Cs-137 soil deposition (Bq m^{-2} fresh weight) and standard deviation are shown in Table 8. A boxplot of the soil samples at each location is provided in Figure 16. The lowest Cs-137 ground deposition was found in Okuma (73000 Bq m^{-2} dry weight). ANOVA testing revealed significance between Cs-137 concentrations and the location of the soil sample ($p = 0.038$).

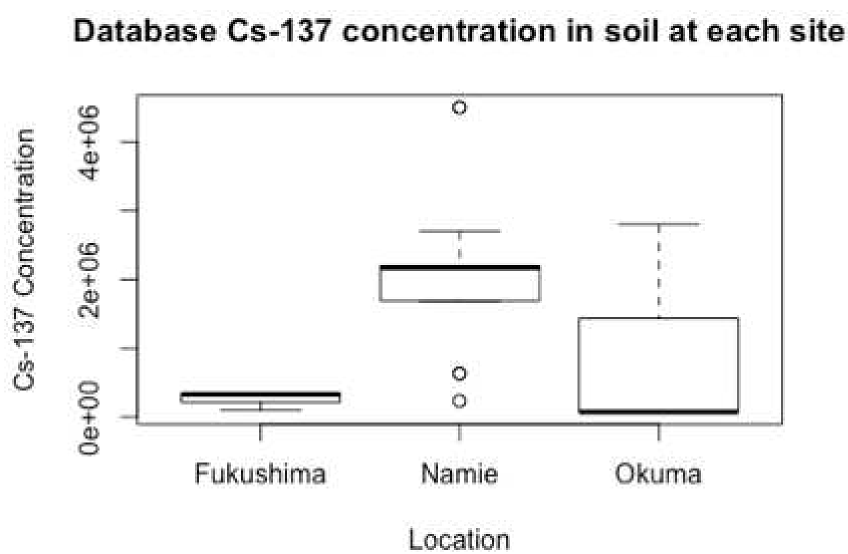

Figure 16: Cs-137 concentration values from soil (Bq m^{-2}) and the respective location.

*Table 8A and 8B: (A) Cs-137 concentration (*Bq m^{-2}*) ranges in soil samples from the Japanese government database with means and standard deviations; where n = number of samples. (B) Log transformed data mean and standard deviations at each sample site.*

(A) Method 2: Map Database Soil	(n)	Range of Cs-137 ground deposition (Bq m^{-2})	Mean Cs-137 ground deposition (Bq m^{-2})	Standard Deviation
Fukushima	3	9.9×10^{3}-2.2×10^{5}	2.5×10^{5}	1.3×10^{5}
Namie	16	2.3×10^{5}-4.5×10^{6}	2.1×10^{6}	1.2×10^{6}
Okuma	3	7.3×10^{4}-2.8×10^{6}	9.8×10^{5}	1.6×10^{6}

(B) Method 2: Map Database Soil Log-transformed Data	(n)	Range Cs-137 ground deposition Log (Bq m^{-2})	Mean Cs-137 ground deposition Log (Bq m^{-2})	Standard Deviation
Fukushima	3	5.0-5.5	5.3	0.30
Namie	16	5.4-6.6	6.2	0.32
Okuma	3	4.8-6.4	5.4	0.91

Comparing Method 1 and Method 2 soil Cs-137 concentrations

The Cs-137 concentration comparisons revealed that there was a significant variance between each method's measured soil samples. The ranges were 6.0×10^{5} to 5.8×10^{7} Bq m^{-2} and 7.3×10^{4} to 2.8×10^{6} Bq m^{-2}, for Methods 1 and 2 respectively.

If the samples collected from Okuma are omitted from the analysis, then there is no significant difference between Methods 1 and 2 Cs-137 ground deposition (after log transformation to satisfy normality). A paired t-test between Methods 1 and 2 had a high p value ($p = 0.4599$) indicating there is no statistically significant difference between the means for the two methods. Due to skewed data and unequal variance, the 95% limits of agreement were found performing a Bland Altman's analysis on the log transformed data. The 95% limits of agreement were -1.07 and 0.902. After back-transforming the limits of agreement, the lower and upper bounds are 0.34 and 2.46. Thus, 95% of the MEXT database soil samples differ from the corresponding Method 1 Cs-137 ground deposition measurements. MEXT database values for soil concentration varied from 70% below to 250% above the corresponding method one value. A graph of the limits after logarithmic transformation is provided in Figure 17.

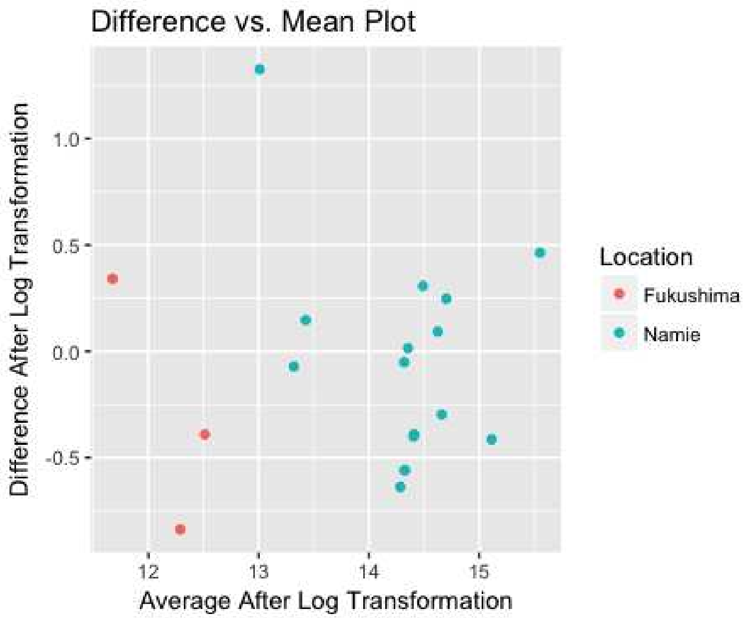

Figure 17: Data after log transformation. The difference was calculated by subtracting Method 2 (database soil samples) Cs-137 concentrations from Method 1 Cs-137 concentration values. The average was calculated by using the formula: $\frac{Method\ 1 + Method\ 2}{2}$*. The graph uses ground deposition (Bq m*$^{-2}$*) data only.*

Aggregated Transfer Factors (T_{ag})

T_{ag} average at each location

Method 1 T_{ag} values used the Cs-137 concentration measurements found in the soil collected in the home-range of the wild boar. Method 2 T_{ag} values used the Cs-137 concentrations in the soil provided by the database. Forty-six wild boar were captured at locations where Method 1 soil samples were obtained. Several wild boars are associated with the same soil samples due to being captured in the same location. Thus, more T_{ag} values can be calculated from the twenty-one soil sample sites. The highest T_{ag} calculated ratio was from using the database soil samples in Okuma. The boar in the Okuma area have a higher Cs-137 concentration than the Cs-137 ground deposition, thus a higher ratio would be expected. A table of averages, ranges and standard deviations from each method is provided in Table 9. A boxplot of the T_{ag} values is provided in Figure 18. All T_{ag} values were calculated using Equation 1.1. The T_{ag} values were then re-calculated using the correction factor (D.W/F.W) on all boar muscle tissue samples (Table 10).

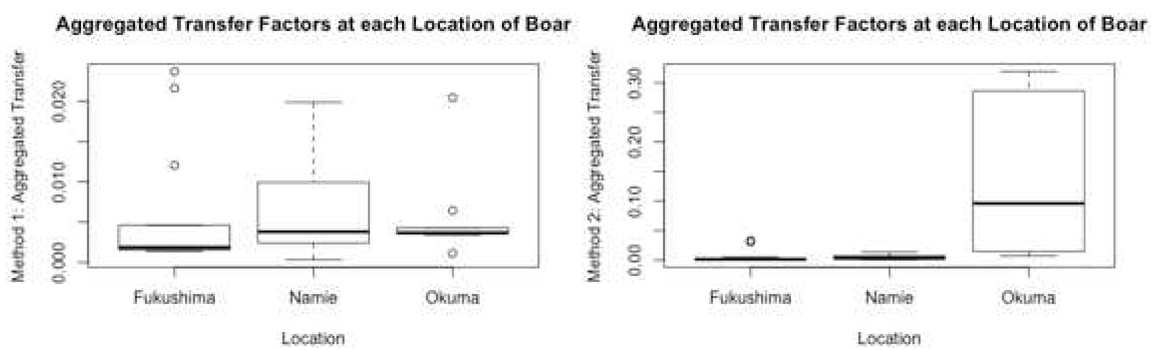

Figure 18: Aggregated transfer factors at each location for Method 1 (left). Method 1 utilized site-specific soil samples. A box plot of concentrations and the location for Method 2 (right). Method 2 utilized soil samples from a MEXT database.

Table 9: The means of the calculated aggregated transfer factors ($m^2 kg^{-1}$ D.W) at each location for wild boar with mean and standard deviation values. Several wild boar are associated with the same soil sample.

Location	(n)	Method 1: Using Local Soil			Method 2: Using Database Soil		
		T_{ag1} range	Mean T_{ag1} ($m^2 kg^{-1}$ D.W)	Standard Deviation	T_{ag2} range	Mean T_{ag2} ($m^2 kg^{-1}$ D.W)	Standard Deviation
Fukushima City	13	0.0014-0.012	0.0059	0.0079	0.0009-0.033	0.0063	0.011
Namie	24	0.0003-0.1985	0.0060	0.0053	0.0005-0.0134	0.0049	0.004
Okuma	9	0.001-0.204	0.0056	0.0057	0.007-0.3197	0.135	0.133

Table 10: The means of the re-calculated aggregated transfer factors ($m^2 kg^{-1}$F. W) at each location for wild boar. Measurements of Cs-137 concentration in dry weight samples were converted using the (D.W/F.W) conversion ratio.

Location Method 1	Mean T_{ag1} ($m^2 kg^{-1}$ F.W)	Mean T_{ag2} ($m^2 kg^{-1}$ F.W)
Fukushima City	0.0017	0.0013
Namie	0.0015	0.0017
Okuma	0.0037	0.03
(Total Meal)	0.0023	0.01 0.0014*

**Okuma was removed from the mean calculation*

Statistical analysis comparing T_{ag1} and T_{ag2}

Okuma was excluded from the statistical analysis because of the inaccurate representation of the Cs-137 concentration in soil, in the wild boar's home range. Measurements of wild boar muscle tissue show a higher Cs-137 concentration than the Cs-137 ground deposition in Okuma samples, thus there would be a large T_{ag} value for Okuma wild boar. The sample of soil might have been taken near a road or within the city, which does not represent the wild boar's habitat.

Thus, only Namie and Fukushima City were used to compare each method of deriving the T_{ag1} and T_{ag2} values. .

A paired t-test was used to compare each sampling method in calculating the T_{ag} values in Namie and Fukushima City on log transformed data. Data were log transformed to satisfy the assumption of normality. There was a significant difference between the means of T_{ag1} and T_{ag2} between Namie and Fukushima City ($p = 0.0001$). The Bland Altman statistical analysis of the log-transformed data found that the lower and upper bounds of the limits of agreement are -0.42 and 0.335, respectively. Taking the inverse of these transformed limits results in new bounds of 0.65 and 2.5. For 95% of cases, the T_{ag1} value differs from T_{ag2} values from 35% below to 250% above. A graph of the limits of agreement is provided in Figure 19.

Figure 19: Data after log transformation. The difference was calculated by subtracting Method 2 T_{ag} values from Method 1 T_{ag} values. The average of T_{ag} values from both Methods 1 and 2 was found and plotted. The graph uses T_{ag} values.

Due to the lack of agreement between T_{ag1} and T_{ag2}, method 1 and method 2 soil concentrations were compared directly to the Cs-137 levels in the boar muscle tissue to determine the better estimator of Cs-137 levels in the boar.

Method 1 (T_{ag1}) of predicting wild boar contamination level using soil concentration from local soil samples vs. Method 2 (T_{ag2}) of predicting wild boar contamination level using soil concentration values from database samples

There is a higher correlation between the measurements from the soil collected at the site and the Cs-137 activity (Bq kg^{-1}) in the wild boar muscle tissue than using database soil measurements. A higher R^2 was found in Method 1 than Method 2. An R^2 of about 0.49 and of about 0.10 was found for Methods 1 (Figure 20) and 2 (Figure 21), respectively. Okuma wild boar samples were included in the graphs.

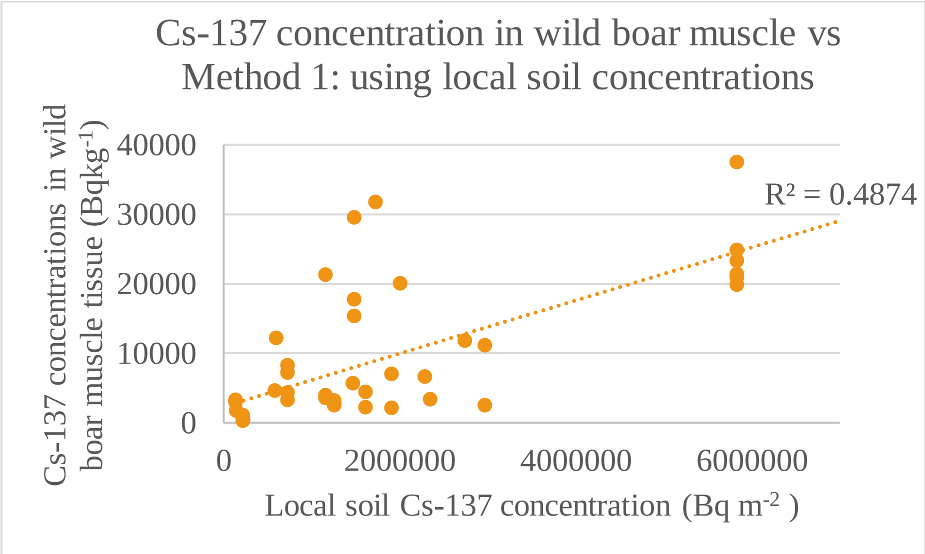

Figure 20: Concentration of Cs-137 (Bq kg^{-1}) in wild boar muscle versus the collected soil samples (Bq m^{-2}). A regression line is graphed with the respective R^2 value.

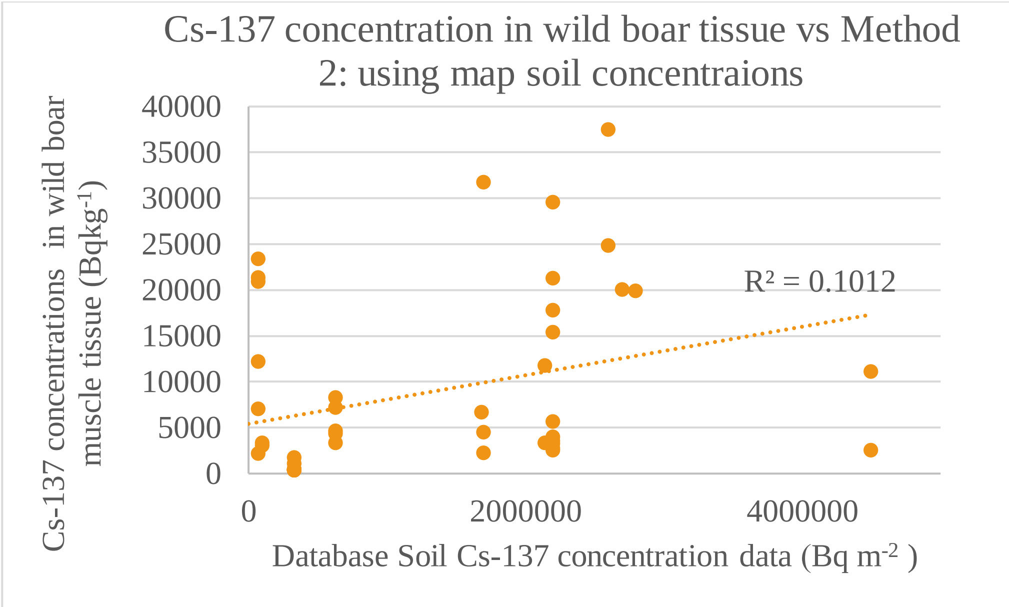

Figure 21: Concentration of Cs-137 (Bq kg^{-1}) in wild boar muscle versus the database soil samples (Bq m^{-2}). A regression line is graphed with the respective R^2 value.

Method 1 better predicts the Cs-137 concentration (Bq kg^{-1}) in wild boar.

DISCUSSION

Lower Cs-137 concentrations were expected in wild boar tissues in the Fukushima City sampling site due to the lower soil contamination. Lower Cs-137 ground deposition was also expected in Fukushima City sampling site. Higher concentrations of Cs-137 in wild boar tissues were expected in Namie and Okuma sampling as they were directly in the plume of the released radioactive material. Areas in Namie and Okuma are in the process of being decontaminated. Lower concentrations are seen in wild boar tissues in decontaminated areas, implying that the decontamination efforts are influencing the bioavailability of radiocesium.

Okuma excluded from Statistical Analysis

Okuma was excluded from the statistical analysis because of the inaccurate representation of the Cs-137 ground deposition in the wild boar's home range. The database provided sample might have been taken near a decontaminated road outside the range of the initial plume. An example MEXT soil location is shown in Figure 22. Thus, utilizing the database Cs-137 ground deposition values could be a significant source of uncertainty.

Figure 22: MEXT soil sample (Bq m^{-2}) taken next to a major highway (Yellow line) in Okuma. The sample was taken in October 2015 and had a soil concentration of 73000 Bq m^{-2}. Map used with permission from the Geospatial Information Authority of Japan. Information regarding copyright approval can be found in Appendix H.

Which technique of calculating T_{ag} values were better?

Using soil within the home-range of the wild boar will give a better aggregated transfer factor for estimating the contamination level in a wild boar. Method 1 is better in predicting the Cs-137 concentration (Bq kg^{-1}) in wild boar tissues. Each soil sample was collected in the home range of the wild boar, reducing the error from changes in soil concentration that result from using radiocesium concentrations obtained further away, which might not represent local concentrations of radiocesium. The MEXT soil sample can save time, effort, and cost. However, using map-collected soil sample information can increase uncertainty. Method 2 utilized the MEXT database radiocesium concentrations, and it had a larger uncertainty in predicting the animal's muscle tissue Cs-137 concentration. If the database radiocesium concentration samples must be used for an estimate of an animal's contamination level, then a better method for determining a more representative soil sample should be used. For example, a new hunter's grid could be characterized to represent the wild boar's home range. The wild boar spend most of their time living in the forests and scavenging in the evacuated cities (Keuling et al, 2009). Thus, the hunter grid should include neighboring forests when the trap site is within city limits. The newly formatted grid will pair more appropriate MEXT soil samples with the wild boar home range.

Comparing Results

In 2011, the wild boar aggregated transfer factor was calculated to be 6.8×10^{-3} m^2 kg^{-1} (F.W) for Fukushima Prefecture (Tagami et al. 2016). In 2015, a value of 3.1×10^{-3} m^2 kg^{-1} (F.W) was found in Fukushima Prefecture boar (Tagami et al. 2016). Method 1 from this research found a mean T_{ag1} value 1.7×10^{-3} m^2 kg^{-1} (F.W), 1.5×10^{-3} m^2 kg^{-1} (F.W), and $3.7\times10^{-3} m^2$ kg^{-1} (F.W) in Fukushima City, Namie and Okuma, respectively.

The mean T_{ag} values calculated in the Fukushima prefecture for wild boar were 2.3×10^{-3} m^2 kg^{-1} (F.W) and 1.4×10^{-3} m^2 kg^{-1} (F.W), for Method 1 and Method 2, respectively. The decrease of T_{ag} values from 2015 studies to 2016 studies is expected and suggests that radiocesium is becoming less bioavailable in the environments. The lower T_{ag} values in this study might also indicate that decontamination efforts are working.

The aggregated transfer factor from Method 1 could be different than Method 2 due to soil sampling methods and the use of the government database radionuclide ground deposition. Wild boar may be exposed to more radiocesium based on their activities of digging in soil and eating roots, possibly contributing to the difference in the reported values of T_{ag} (Tanoi et al 2016). The smaller aggregated transfer factor could have been caused by not collecting a soil sample core and just collecting the surface layer of soil. Cesium migrates deeper in the soil over time. Thus, the sampling method utilized by MEXT may not reflect the full bioavailability of Cs-137 to the wild boar. It is unclear how MEXT collects the soil samples. It is possible only the surface layer of soil is collected. Method 1 in this study uses a nine-centimeter core to collect soil samples, which captures the cesium mobility over the past five years. Increased uncertainty from Method 1 might be caused by the radiocesium that has migrated deeper than nine centimeters.

Method 1 also extrapolates the mean value of surface contamination across the whole home-range of the wild boar using the mean of three soil samples at each location. A superior method would be to take multiple soil samples from an area of 1 m^2 at multiple locations in the boar home-range. The new method might reduce uncertainty in the measurements and better represent the soil values used for the aggregated transfer factors.

CONCLUSION

Aggregated Transfer Factors (T_{ag}) values, in this specific study, varied by orders of magnitude because of the natural variation in contaminant levels in soils and in animals. The use of the hunter's grid to pair soil concentration values to each wild boar created variability in T_{ag1}, especially in Okuma. T_{ag} values are commonly used in spite of the variability because they are pragmatic and save the expense of capturing animals and performing Cs-137 analyses on each animal.

The purpose of this study was to ascertain if the use of the database radiocesium soil concentration values is of sufficient granularity to provide a useful estimate of Cs-137 concentrations in wild boar muscle tissue. The map database soil samples increase the uncertainty in calculating the T_{ag} values. More T_{ag} values should be derived from Method 1 and compared to Method 2 derived T_{ag} values to further characterize the uncertainty.

Both methods used in this study for calculating T_{ag1} and T_{ag2} values have their sources of uncertainty, however, collecting soil samples in the home-range of the boar have reduced uncertainty. Estimating the contamination level in the wild boar may be more accurate if the soil sample measurements accurately represent the home range of the animal. The database soil samples (T_{ag1}) tended to be collected near decontaminated zones, roads, and other areas where Cs-137 would not accumulate or would have been removed.

The two methods did not agree and should not be used interchangeably. The difference in the two method results (T_{ag1} and T_{ag2}) could have been due to the high variability in the database soil samples. Other factors that could contribute to method 1 variability could be the small number of soil samples, mobility of Cs-137, and lack of information regarding the sampling process for the database soil measurements. More information regarding how the government collected their soil samples is needed to better test their methodology for calculating T_{ag1} values.

The locations where the boar were captured influenced the Cs-137 accumulation in the muscle tissues. The relatively high activity concentrations of Cs-137 in soil and wild boar in Okuma suggest that there is still a significant source of bioavailable radiocesium near FDNPP. Lower activity concentrations in Namie and Fukushima City suggest that decontamination efforts have helped reduce the sources of radiocesium. Wild boar living closer to the FDNPP have higher activity concentrations than boar living further away. Other locations should be investigated to see if a similar trend exists.

Fukushima City, Namie and Okuma did not have a significant difference in means of T_{ag} values. Thus, the bioaccumulation of Cs-137 in the wild boar is similar across all three study sites.

Radiocesium is expected to continue to decline in wild boar ecosystems due to the radionuclide’s physical decay, and as the Japanese government continues to decontaminate the prefecture. T_{ag} values will become smaller as the radionuclides become less bioavailable to the animals in the ecosystem.

Conclusively, the main hypothesis of the study, “the T_{ag} values derived from database radio cesium deposition values are not significantly different from T_{ag} values derived from soil samples within the home range of the wild boar,” was not correct. T_{ag1} values derived from database Cs-137 deposition values are significantly different from T_{ag2} values.

Limiting factors of the study

A small sample size of wild boar limited the investigation into factors influencing Cs-137 accumulation due to location, sex, and age.

The most significant factor impacting the Cs-137 concentration in wild boar is the location where it is captured. The variability of Cs-137 in soil might influence the high variability of measurements, which is also dependent on the location. Method 1 and Method 2 had twenty-one sample locations, thus a larger sample size might be required to further test the agreement between each method. Sampling Methods 1 and 2 should be further investigated to ensure soil sampling consistency.

Future Studies

The concentration ratio (CR) is another tool utilized to quickly assess the contamination level in the environment. Similar to a transfer aggregated factor, the CR can be used to save time, money, and obviates animal sampling to calculate the accumulation of radiocesium in an animal. For CR's in terrestrial biota, the calculation requires the activity concentration of a radionuclide in the whole-body organism and the activity concentration of a radionuclide in soil. The CR is the ratio of Cs-137 in muscle tissue (Bq kg^{-1}) over the concentration of Cs-137 in soil (Bq kg^{-1}). The CR can then be compared to the T_{ag} values to determine if the approaches are similar and CR's can be applied to the Fukushima situation.

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APPENDIX A: IACUC APPROVAL

Colorado State University
Research Integrity & Compliance Review Office
Office of Vice President for Research
208 University Services Center
2011 Campus Delivery
Fort Collins, Colorado 80523-2011
TEL: (970) 491-1553
FAX: (970) 491-2293
http://ricro.research.colostate.edu

To: Donovan Anderson

From: Research Integrity and Compliance Review Office (RICRO)

Date: November 11, 2015

RE: IACUC Exemption of "A Comparison of Methods to Derive Concentration Ratios: Tested Using Wild Boar Data from the Fukushima Prefecture"

This is to inform you that your IACUC Exemption request for "A Comparison of Methods to Derive Concentration Ratios: Tested Using Wild Boar Data from the Fukushima Prefecture" has been reviewed by RICRO and the Attending Veterinarian (or his delegate), and is exempt from IACUC oversight. Therefore, an IACUC protocol does not need to be submitted for these activities.

If there are any changes to this project, please submit changes via the IACUC Exemption Form to ensure that this exemption is still valid prior to implementation

Thank you for your diligence in the care and use of animals at CSU. Good luck with your project.

Sincerely,
Research Integrity and Compliance Review Office (RICRO)

Cc: Terry Engle, PhD, IACUC Chair
Lon Kendall, DVM, PhD, Attending Veterinarian
Karen Dobos, PhD, Associate Director, RICRO

APPENDIX B: GAMMA-SPEC ANALYSIS

All samples were measured for Cs-137 at the Institute of Environmental Radioactivity in Fukushima, Japan.

Gamma spec analysis Location: Institute of Environmental Radioactivity

The Institute of Environmental Radioactivity (IER) was established on July 1st in 2013 at Fukushima University. The proximity of IER to the Evacuation zones and the numerous international faculty at IER provide unique opportunities to conduct field-oriented radioecological research. The IER was funding with a grant for promoting national university reform of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Much of the current research at IER focuses on the migration and behavior of radioactivity in the environment, primarily monitoring long-term processes of radionuclide transfers and accumulation in forest and aquatic ecosystems.

Radiation Measuring Devices

There are many methods to measuring radiation. Some methods are more expensive, durable, accurate, and other factors that influence the reading. Professionals use detectors of many kinds to measure specific radiation types. Gas-filled detectors, gas-flow proportional counters, portable surveys, Geiger-Muller counters, semiconductors and other instruments are used to measure certain types of radiation. The semiconductor detector measures the effect of incident charge particles or photons from ionizing radiation. A high-purity germanium detector is a type of semiconductor utilized in the study. The semiconductor is manufactured from ultra-pure germanium crystal, which increases detection efficiency. The detector is used for a wide variety of tasks. The instrument can be used for gamma spectroscopy, which is needed to measure Cs-137 (Knoll 2010).

APPENDIX C: SOURCE OF RADIATION AND BACKGROUND DOSES

Natural sources of radiation have always existed on earth. Most of the radiation that a human is exposed to is from natural sources. However, humans have created new and radioactive elements that have not previously existed on Earth. Anthropogenic sources of background radiation also cause exposure to humanity (United States Environmental Protection Agency, 2007).

Natural Radiation Sources

Natural background radiation comes from cosmic radiation, terrestrial radiation, and internal radiation. Cosmic radiation is a constant stream of exposure to humans from space. Terrestrial radiation comes from the Earth itself. Sources of terrestrial radiation on Earth come from radioactive elements like thorium and uranium. Dissolved uranium and thorium can be found in water and can be ingested by animals or taken up by plant roots. A person's dose from cosmic and terrestrial radiation will vary based on their location. All people, since birth, contain a small amount of radioactive material called internal radiation (NRC, 2014).

Anthropogenic Radiation Sources

Another source of background radiation comes from man-made sources. There are many possible sources of exposure from man-made items that contain radioactive isotopes. The largest source of radiation in this category come from medical sources. The public are also exposed to radiation from uranium mining, uranium milling, the transportation of radioactive materials, and the global fallout from nuclear weapons testing, however these are to a lesser degree. The largest contribution of radiation into the environment is from accidental releases like the Chernobyl and Fukushima accident. A person's dose will vary based on their activity and location. People who work at power plants, nuclear research institutes and other environments containing radioactive material, generally have a higher than background exposure (NRC, 2014).

Effects of radiation on humans

Ionizing radiation effects on humans are characterized by the damage to DNA, a person's genetic information, done by emitted particles of energy from unstable isotopes. All forms of radiation, x- and γ-rays, absorbed in biologic material, have a probability of interacting with parts of the cell. The interaction can cause a trigger events that lead to ionization of atoms and biological change. The amount of damage and health effects caused to a person from ionizing radiation is directly related to dose. Absorbed dose is a physical quantity that is a measure of the energy absorbed per unit mass of tissue. Different types of dose do not necessarily produce equal biological change. An equivalent dose is a quantity of dose representing health effects at low levels. An annual dose of 10 mSv or below is considered a low dose of radiation. The average background dose is 6.2 mSv a year (NCRP 160). Low doses of radiation to humans lack observable symptoms, but may trigger development of a cancer cell (Hall et al. 2012).

Potential source from wild boar meat

A potential source of radiocesium exposure to humans is the consumption of wild boar meat and other foods in the affected area of Fukushima. The sale of wild game animal meat, food plants from forests, and fungi have been banned from zones which were contaminated by the fallout. Consumption by humans of food items exceeding the 100 Bq kg^{-1} Japanese standard limit for total radiocesium is restricted (Tagami et al. 2016).

APPENDIX D: SOIL DATA

FUKUSHIMA CITY

Note: All samples were measured for Cs-134 at the IER, but the only the Cs-137 data was used in the analysis and T_{ag} calculations.

Soil Date	ID	Cs-134 (Bq/kg) Activity	Act. err	Cs-137 (Bq/kg) Activity	Act. err	Cs134/Cs137	err/Activity Cs-134	Cs-137	Dry weight(g)	Live time (s)	Cs-134 Bq	Cs-137 Bq
160720	1A	2.18E+01	6.80E-01	1.28E+02	1.87E+00	0.17	3.1	1.5	90.2	36000	1.97E+00	1.16E+01
160720	1B	3.00E+01	1.07E+00	1.78E+02	3.15E+00	0.17	3.6	1.8	71.1	18000	2.13E+00	1.26E+01
160720	1C	3.62E+02	3.14E+00	2.12E+03	1.05E+01	0.17	0.9	0.5	90.1	18000	3.26E+01	1.91E+02
									Total Activity (Bq)		3.67E+01	2.15E+02
									Total Activity (Bq/m^2)		***1.87E+04***	***1.10E+05***
160720	2A	6.71E+01	9.79E-01	3.87E+02	3.14E+00	0.17	1.5	0.8	93.6	36000	6.28E+00	3.63E+01
160720	2B	1.34E+02	1.93E+00	8.12E+02	6.55E+00	0.16	1.4	0.8	95.4	18000	1.28E+01	7.75E+01
160720	2C	1.01E+03	5.29E+00	5.94E+03	1.82E+01	0.17	0.5	0.3	76.0	18000	7.67E+01	4.51E+02
									Total Activity (Bq)		9.57E+01	5.65E+02
									Total Activity (Bq/m^2)		***4.88E+04***	***2.88E+05***

160720	3A	1.09E+02	2.12E+00	6.35E+02	6.58E+00	0.17	1.9	1.0	74.3	15800	8.11E+00	4.72E+01
160720	3B	8.24E+01	1.62E+00	4.89E+02	5.21E+00	0.17	2.0	1.1	84.5	18000	6.96E+00	4.14E+01
160720	3C	8.47E+02	4.77E+00	4.96E+03	1.63E+01	0.17	0.6	0.3	90.0	18000	7.62E+01	4.46E+02
									Total Activity (Bq)		9.13E+01	5.35E+02
									Total Activity (Bq/m^2)		***4.65E+04***	***2.72E+05***
160617-2	1A	3.86E+01	1.13E+00	2.27E+02	3.50E+00	0.17	2.9	1.5	52.6	24000	2.03E+00	1.19E+01
160617-2	1B	1.75E+02	2.46E+00	1.03E+03	8.35E+00	0.17	1.4	0.8	60.0	18000	1.05E+01	6.20E+01
160617-2	1C	3.69E+02	3.42E+00	2.16E+03	1.16E+01	0.17	0.9	0.5	67.6	18000	2.49E+01	1.46E+02
									Total Activity (Bq)		3.75E+01	2.20E+02
									Total Activity (Bq/m^2)		***1.91E+04***	***1.12E+05***
160617-2	2A	4.25E+02	3.40E+00	2.54E+03	1.15E+01	0.17	0.8	0.5	59.3	24000	2.52E+01	1.51E+02
160617-2	2B	4.08E+02	3.45E+00	2.41E+03	1.16E+01	0.17	0.8	0.5	74.9	18000	3.05E+01	1.81E+02
160617-2	2C	3.77E+02	3.69E+00	2.24E+03	1.26E+01	0.17	1.0	0.6	53.1	18000	2.00E+01	1.19E+02
									Total Activity (Bq)		7.58E+01	4.50E+02
									Total Activity (Bq/m^2)		***3.86E+04***	***2.29E+05***
160617-2	3A	2.66E+01	9.99E-01	1.60E+02	2.97E+00	0.17	3.8	1.9	59.1	24000	1.57E+00	9.45E+00
160617-2	3B	3.55E+01	1.24E+00	2.10E+02	3.86E+00	0.17	3.5	1.8	60.7	18000	2.15E+00	1.27E+01

160617-2	3C	3.93E+02	3.89E+00	2.31E+03	1.33E+01	0.17	1.0	0.6	55.7	18000	2.19E+01	1.28E+02
									Total Activity (Bq)		2.56E+01	1.51E+02
									Total Activity (Bq/m2)		***1.31E+04***	***7.67E+04***
160801-3	1A	4.16E+01	1.16E+00	2.62E+02	3.70E+00	0.16	2.8	1.4	60.0	24000	2.50E+00	1.57E+01
160801-3	1B	6.88E+01	1.82E+00	4.07E+02	5.86E+00	0.17	2.6	1.4	49.3	18000	3.39E+00	2.01E+01
160801-3	1C	4.45E+02	3.80E+00	2.58E+03	1.29E+01	0.17	0.9	0.5	61.5	18000	2.74E+01	1.59E+02
									Total Activity (Bq)		3.33E+01	1.95E+02
									Total Activity (Bq/m^2)		***1.69E+04***	***9.92E+04***
160801-3	2A	4.05E+00	4.67E-01	2.37E+01	1.09E+00	0.17	11.5	4.6	77.5	24000	3.14E-01	1.84E+00
160801-3	2B	1.53E+01	8.03E+00	1.05E+02	2.59E+00	0.15	52.5	2.5	73.2	18000	1.12E+00	7.66E+00
160801-3	2C	5.06E+02	4.81E+00	3.02E+03	1.64E+01	0.17	1.0	0.5	41.4	18000	2.09E+01	1.25E+02
									Total Activity (Bq)		2.24E+01	1.34E+02
									Total Activity (Bq/m^2)		***1.14E+04***	***6.84E+04***
160801-3	3A	1.30E+01	6.63E-01	8.52E+02	2.00E+00	0.20	5.1	0.2	72.8	24000	9.45E-01	6.20E+01
160801-3	3B	2.55E+02	2.62E+00	1.49E+03	8.82E+00	0.17	1.0	0.6	90.9	18000	2.32E+01	1.35E+02
160801-3	3C	9.59E+02	5.84E+00	5.68E+03	2.02E+01	0.17	0.6	0.4	55.7	18000	5.34E+01	3.16E+02
									Total Activity (Bq)		7.76E+01	5.13E+02

									Total Activity (Bq/m^2)		***3.95E+04***	***2.61E+05***

NAMIE

Soil		Cs-134 (Bq/kg)		Cs-137 (Bq/kg)		Cs134/Cs137	err/Activity		Dry weight(g)	Live time (s)	Cs-134	Cs-137
Date	ID	Activity	Act. err	Activity	Act. err		Cs-134	Cs-137			Bq	Bq
160621-1	1A	1.77E+02	3.12E+00	9.25E+02	9.03E+00	0.19	1.8	1.0	41.5	18000	7.36E+00	3.84E+01
160621-1	1B	3.27E+02	6.50E+00	1.97E+03	2.18E+01	0.17	2.0	1.1	69.9	4460	2.29E+01	1.38E+02
160621-1	1C	1.72E+03	1.65E+01	1.01E+04	5.77E+01	0.17	1.0	0.6	57.7	3600	9.91E+01	5.85E+02
									Total Activity (Bq)		1.29E+02	7.61E+02
									Total Activity (Bq/m^2)		***6.58E+04***	***3.87E+05***
160621-1	2A	2.35E+03	8.99E+00	1.21E+04	2.75E+01	0.19	0.4	0.2	58.9	18000	1.39E+02	7.13E+02
160621-1	2B	3.87E+03	2.29E+01	2.27E+04	7.85E+01	0.17	0.6	0.3	41.7	5400	1.61E+02	9.45E+02
160621-1	2C	2.68E+03	2.15E+01	1.58E+04	7.41E+01	0.17	0.8	0.5	56.1	3600	1.50E+02	8.89E+02
									Total Activity (Bq)		4.50E+02	2.55E+03
									Total Activity (Bq/m^2)		***2.29E+05***	***1.30E+06***
160621-1	3A	8.49E+02	5.44E+00	4.34E+03	1.63E+01	0.20	0.6	0.4	51.9	18000	4.40E+01	2.25E+02
160621-1	3B	1.53E+03	1.19E+01	9.18E+03	4.12E+01	0.17	0.8	0.4	72.1	5400	1.10E+02	6.62E+02

160621-1	3C	3.06E+03	2.26E+01	1.85E+04	8.02E+01	0.17	0.7	0.4	48.8	3600	1.49E+02	9.02E+02
									Total Activity (Bq)		3.04E+02	1.79E+03
									Total Activity (Bq/m^2)		***1.55E+05***	***9.11E+05***
160621-2	1A	7.28E+02	5.13E+00	3.70E+03	1.53E+01	0.20	0.7	0.4	56.0	18000	4.07E+01	2.07E+02
160621-2	1B	5.16E+03	2.38E+01	3.01E+04	8.10E+01	0.17	0.5	0.3	55.7	5400	2.87E+02	1.68E+03
160621-2	1C	2.11E+04	7.16E+01	1.24E+05	2.51E+02	0.17	0.3	0.2	35.4	3600	7.47E+02	4.39E+03
									Total Activity (Bq)		1.07E+03	6.27E+03
									Total Activity (Bq/m^2)		***5.47E+05***	***3.20E+06***
160621-2	2A	9.20E+02	5.20E+00	4.86E+03	1.59E+01	0.19	0.6	0.3	72.5	18000	6.67E+01	3.52E+02
160621-2	2B	3.70E+03	1.93E+01	2.19E+04	6.65E+01	0.17	0.5	0.3	66.2	5400	2.45E+02	1.45E+03
160621-2	2C	1.17E+04	4.87E+01	6.94E+04	1.70E+02	0.17	0.4	0.2	41.0	3600	4.81E+02	2.85E+03
									Total Activity (Bq)		7.93E+02	4.65E+03
									Total Activity (Bq/m^2)		***4.04E+05***	***2.37E+06***
160621-2	3A	4.83E+03	1.66E+01	2.47E+04	5.04E+01	0.20	0.3	0.2	32.8	18000	1.58E+02	8.09E+02
160621-2	3B	9.37E+03	3.98E+01	5.48E+04	1.37E+02	0.17	0.4	0.2	40.6	5400	3.80E+02	2.23E+03
160621-2	3C	1.27E+04	6.07E+01	7.42E+04	2.12E+02	0.17	0.5	0.3	29.4	3600	3.73E+02	2.18E+03
									Total Activity (Bq)		9.12E+02	5.22E+03

									Total Activity (Bq/m^2)		***4.64E+05***	***2.66E+06***
160729-1	1A	2.86E+03	1.01E+01	1.49E+04	3.09E+01	0.19	0.4	0.2	56.8	18000	1.63E+02	8.45E+02
160729-1	1B	2.80E+03	1.67E+01	1.65E+04	5.74E+01	0.17	0.6	0.3	66.9	5400	1.87E+02	1.10E+03
160729-1	1C	9.49E+03	4.35E+01	5.64E+04	1.53E+02	0.17	0.5	0.3	42.0	3600	3.99E+02	2.37E+03
									Total Activity (Bq)		7.49E+02	4.32E+03
									Total Activity (Bq/m^2)		***3.81E+05***	***2.20E+06***
160729-1	2A	2.14E+02	2.71E+00	1.12E+03	8.05E+00	0.19	1.3	0.7	66.4	18000	1.42E+01	7.42E+01
160729-1	2B	2.41E+03	1.59E+01	1.43E+04	5.46E+01	0.17	0.7	0.4	64.5	5400	1.55E+02	9.20E+02
160729-1	2C	5.25E+03	2.78E+01	3.07E+04	9.71E+01	0.17	0.5	0.3	67.7	3600	3.55E+02	2.08E+03
									Total Activity (Bq)		5.25E+02	3.07E+03
									Total Activity (Bq/m^2)		***2.67E+05***	***1.56E+06***
160729-1	3A	1.07E+03	6.23E+00	5.51E+03	1.88E+01	0.19	0.6	0.3	51.2	18000	5.45E+01	2.82E+02
160729-1	3B	2.80E+03	1.67E+01	1.65E+04	5.74E+01	0.17	0.6	0.3	69.9	5400	1.96E+02	1.15E+03
160729-1	3C	4.66E+03	2.85E+01	2.80E+04	1.01E+02	0.17	0.6	0.4	48.2	3600	2.24E+02	1.35E+03
									Total Activity (Bq)		4.75E+02	2.78E+03
									Total Activity (Bq/m^2)		***2.42E+05***	***1.42E+06***
160603	1A	1.14E+02	2.41E+00	6.96E+02	7.38E+00	0.16	2.1	1.1	50.1	18000	5.71E+00	3.49E+01

160603	1B	4.25E+02	8.73E+00	2.82E+03	2.99E+01	0.15	2.1	1.1	42.7	5400	1.82E+01	1.20E+02
160603	1C	7.18E+03	5.62E+01	4.69E+04	2.06E+02	0.15	0.8	0.4	19.1	3600	1.37E+02	8.96E+02
									Total Activity (Bq)		1.61E+02	1.05E+03
									Total Activity (Bq/m^2)		***8.20E+04***	***5.35E+05***
160603	2A	1.87E+03	8.88E+00	1.06E+04	2.85E+01	0.18	0.5	0.3	49.8	18000	9.29E+01	5.29E+02
160603	2B	9.47E+02	1.25E+01	6.38E+03	4.53E+01	0.15	1.3	0.7	39.8	5400	3.77E+01	2.54E+02
160603	2C	2.46E+04	9.96E+01	1.63E+05	3.70E+02	0.15	0.4	0.2	19.8	3600	4.88E+02	3.23E+03
									Total Activity (Bq)		6.18E+02	4.01E+03
									Total Activity (Bq/m^2)		***3.15E+05***	***2.04E+06***
160603	3A	5.56E+02	4.89E+00	3.45E+03	1.60E+01	0.16	0.9	0.5	50.7	18000	2.82E+01	1.75E+02
160603	3B	3.33E+02	6.88E+00	2.18E+03	2.42E+01	0.15	2.1	1.1	49.4	5400	1.65E+01	1.08E+02
160603	3C	9.11E+03	5.41E+01	5.98E+04	2.00E+02	0.15	0.6	0.3	25.3	3600	2.31E+02	1.51E+03
									Total Activity (Bq)		2.75E+02	1.80E+03
									Total Activity (Bq/m^2)		***1.40E+05***	***9.14E+05***
160422	1A	8.36E+01	1.48E+00	4.41E+02	4.36E+00	0.19	1.8	1.0	103.0	18000	8.61E+00	4.55E+01
160422	1B	1.98E+02	4.06E+00	1.17E+03	1.34E+01	0.17	2.1	1.1	89.1	5400	1.76E+01	1.04E+02
160422	1C	1.47E+03	1.29E+01	8.80E+03	4.55E+01	0.17	0.9	0.5	90.5	3600	1.33E+02	7.97E+02

									Total Activity (Bq)		1.59E+02	9.46E+02
									Total Activity (Bq/m^2)		***8.10E+04***	***4.82E+05***
160422	2A	1.52E+03	5.84E+00	7.93E+03	1.80E+01	0.19	0.4	0.2	107.0	18000	1.62E+02	8.49E+02
160422	2B	7.70E+03	2.49E+01	4.53E+04	8.54E+01	0.17	0.3	0.2	85.7	5400	6.60E+02	3.88E+03
160422	2C	1.18E+04	3.94E+01	7.03E+04	1.39E+02	0.17	0.3	0.2	70.0	3600	8.28E+02	4.92E+03
									Total Activity (Bq)		1.65E+03	9.65E+03
									Total Activity (Bq/m^2)		***8.41E+05***	***4.91E+06***
160422	3A	7.98E+02	4.68E+00	4.13E+03	1.42E+01	0.19	0.6	0.3	79.5	18000	6.34E+01	3.28E+02
160422	3B	1.11E+03	1.03E+01	6.65E+03	3.53E+01	0.17	0.9	0.5	67.1	5400	7.42E+01	4.46E+02
160422	3C	5.98E+03	2.81E+01	3.56E+04	9.87E+01	0.17	0.5	0.3	69.9	3600	4.18E+02	2.49E+03
									Total Activity (Bq)		5.55E+02	3.27E+03
									Total Activity (Bq/m^2)		***2.83E+05***	***1.66E+06***
160610-2	1A	9.10E+02	4.95E+00	5.13E+03	1.57E+01	0.18	0.5	0.3	78.9	18000	7.18E+01	4.05E+02
160610-2	1B	6.89E+02	7.49E+00	4.33E+03	2.62E+01	0.16	1.1	0.6	94.8	5400	6.53E+01	4.10E+02
160610-2	1C	1.01E+03	1.14E+01	6.50E+03	4.15E+01	0.15	1.1	0.6	81.2	3600	8.16E+01	5.27E+02
									Total Activity (Bq)		2.19E+02	1.34E+03
									Total Activity (Bq/m^2)		***1.11E+05***	***6.84E+05***

160610-2	2A-1	9.39E+02	4.89E+00	5.30E+03	1.55E+01	0.18	0.5	0.3	98.4	18000	9.24E+01	5.21E+02
160610-2	2A-2	9.97E+02	8.09E+00	5.57E+03	2.49E+01	0.18	0.8	0.4	23.9	18000	2.38E+01	1.33E+02
160610-2	2B	1.12E+03	1.04E+01	7.28E+03	3.71E+01	0.15	0.9	0.5	66.2	5400	7.43E+01	4.82E+02
160610-2	2C	1.28E+03	1.24E+01	8.14E+03	4.49E+01	0.16	1.0	0.6	97.2	3600	1.24E+02	7.92E+02
									Total Activity (Bq)		3.15E+02	1.93E+03
									Total Activity (Bq/m^2)		***1.60E+05***	***9.82E+05***
160610-2	3A	1.07E+02	2.02E+00	6.07E+02	5.99E+00	0.18	1.9	1.0	65.1	18000	6.95E+00	3.95E+01
160610-2	3B	2.46E+02	6.43E+00	1.61E+03	2.24E+01	0.15	2.6	1.4	36.0	5400	8.86E+00	5.79E+01
160610-2	3C	2.20E+03	1.74E+01	1.43E+04	6.35E+01	0.15	0.8	0.4	65.1	3600	1.43E+02	9.28E+02
									Total Activity (Bq)		1.59E+02	1.03E+03
									Total Activity (Bq/m^2)		***8.10E+04***	***5.22E+05***
160429	1A	1.65E+02	2.02E+00	9.63E+02	6.79E+00	0.17	1.2	0.7	90.3	18000	1.49E+01	8.69E+01
160429	1B	3.37E+02	5.70E+00	1.93E+03	1.88E+01	0.17	1.7	1.0	69.3	5400	2.33E+01	1.34E+02
160429	1C	2.06E+03	1.63E+01	1.22E+04	5.65E+01	0.17	0.8	0.5	81.1	3600	1.67E+02	9.89E+02
									Total Activity (Bq)		2.06E+02	1.21E+03
									Total Activity (Bq/m^2)		***1.05E+05***	***6.16E+05***
160429	2A	4.83E+02	4.41E+00	2.95E+03	1.49E+01	0.16	0.9	0.5	41.8	18000	2.02E+01	1.23E+02

160429	2B	3.05E+03	2.25E+01	1.80E+03	7.74E+01	0.17	0.7	4.3	30.5	5400	9.30E+01	5.48E+01
160429	2C	3.63E+04	7.04E+01	2.13E+05	2.47E+02	0.17	0.2	0.1	65.7	3600	2.39E+03	1.40E+04
									Total Activity (Bq)		2.50E+03	1.42E+04
									Total Activity (Bq/m^2)		***1.27E+06***	***7.23E+06***
160429	3A	4.05E+03	1.12E+01	2.40E+04	3.83E+01	0.17	0.3	0.2	60.0	18000	2.43E+02	1.44E+03
160429	3B	7.57E+03	2.90E+01	4.45E+04	9.96E+01	0.17	0.4	0.2	55.2	5400	4.18E+02	2.46E+03
160429	3C	4.07E+04	8.37E+01	2.40E+05	2.95E+02	0.17	0.2	0.1	49.8	3600	2.03E+03	1.20E+04
									Total Activity (Bq)		2.69E+03	1.59E+04
									Total Activity (Bq/m^2)		***1.37E+06***	***8.08E+06***
160708	1A	6.20E+03	1.33E+01	3.63E+04	4.56E+01	0.17	0.2	0.1	73.5	18000	4.55E+02	2.67E+03
160708	1B	5.44E+03	2.25E+01	3.21E+04	7.72E+01	0.17	0.4	0.2	73.7	5400	4.01E+02	2.36E+03
160708	1C	6.23E+03	2.76E+01	3.64E+04	9.59E+01	0.17	0.4	0.3	90.3	3600	5.63E+02	3.29E+03
									Total Activity (Bq)		1.42E+03	8.32E+03
									Total Activity (Bq/m^2)		***7.23E+05***	***4.24E+06***
160708	2A	2.99E+03	9.37E+00	1.77E+04	3.21E+01	0.17	0.3	0.2	73.1	18000	2.19E+02	1.29E+03
160708	2B	6.30E+03	2.54E+01	3.72E+04	8.74E+01	0.17	0.4	0.2	65.1	5400	4.10E+02	2.42E+03
160708	2C	1.22E+04	4.46E+01	7.35E+04	1.58E+02	0.17	0.4	0.2	54.5	3600	6.67E+02	4.00E+03

									Total Activity (Bq)		1.30E+03	7.72E+03
									Total Activity (Bq/m^2)		***6.60E+05***	***3.93E+06***
160708	3A	5.79E+02	3.55E+00	3.48E+03	1.21E+01	0.17	0.6	0.3	111.0	18000	6.42E+01	3.86E+02
160708	3B	1.13E+03	9.16E+00	6.62E+03	3.13E+01	0.17	0.8	0.5	102.0	5400	1.15E+02	6.75E+02
160708	3C	6.51E+02	8.30E+00	3.86E+03	2.86E+01	0.17	1.3	0.7	108.0	3600	7.03E+01	4.16E+02
									Total Activity (Bq)		2.49E+02	1.48E+03
									Total Activity (Bq/m^2)		***1.27E+05***	***7.52E+05***
160607-2	1A	2.04E+01	8.70E-01	1.45E+02	2.74E+00	0.14	4.3	1.9	97.0	18000	1.98E+00	1.41E+01
160607-2	1B	3.07E+02	5.12E+00	2.04E+03	1.82E+01	0.15	1.7	0.9	100.0	5400	3.07E+01	2.04E+02
160607-2	1C	5.20E+03	2.49E+01	3.45E+04	9.21E+01	0.15	0.5	0.3	93.7	3600	4.87E+02	3.23E+03
									Total Activity (Bq)		5.20E+02	3.45E+03
									Total Activity (Bq/m^2)		***2.65E+05***	***1.76E+06***
160607-2	2A	1.15E+03	5.38E+00	7.61E+03	1.95E+01	0.15	0.5	0.3	91.1	18000	1.05E+02	6.93E+02
160607-2	2B	3.76E+03	1.72E+01	2.47E+04	6.19E+01	0.15	0.5	0.3	98.3	5400	3.69E+02	2.43E+03
160607-2	2C	4.10E+03	2.27E+01	2.67E+04	8.34E+01	0.15	0.6	0.3	79.4	3600	3.26E+02	2.12E+03
									Total Activity (Bq)		8.00E+02	5.24E+03
									Total Activity (Bq/m^2)		***4.07E+05***	***2.67E+06***

160607-2	3A	1.61E+03	7.49E+00	1.06E+03	2.70E+01	0.15	0.5	2.5	59.9	18000	9.67E+01	6.34E+01
160607-2	3B	4.35E+03	2.17E+01	2.83E+04	7.81E+01	0.15	0.5	0.3	66.7	5400	2.90E+02	1.88E+03
160607-2	3C	7.45E+03	3.58E+01	4.86E+04	1.31E+02	0.15	0.5	0.3	58.4	3600	4.35E+02	2.84E+03
									Total Activity (Bq)		8.22E+02	4.79E+03
									Total Activity (Bq/m^2)		***4.18E+05***	***2.44E+06***
160715-1	1A	5.48E+01	1.72E+00	3.47E+02	5.59E+00	0.16	3.1	1.6	80.6	10900	4.42E+00	2.80E+01
160715-1	1B	5.20E+01	2.29E+00	3.34E+02	7.84E+00	0.16	4.4	2.3	82.9	5400	4.31E+00	2.77E+01
160715-1	1C	1.33E+02	4.04E+00	7.77E+02	1.34E+01	0.17	3.0	1.7	107.0	3600	1.42E+01	8.31E+01
									Total Activity (Bq)		2.29E+01	1.39E+02
									Total Activity (Bq/m^2)		***1.17E+04***	***7.07E+04***
160715-1	2A	1.57E+01	8.60E-01	9.55E+01	2.56E+00	0.16	5.5	2.7	84.5	15000	1.32E+00	8.07E+00
160715-1	2B	5.20E+01	2.29E+00	3.34E+02	7.84E+00	0.16	4.4	2.3	82.9	5400	4.31E+00	2.77E+01
160715-1	2C	9.69E+02	1.08E+01	5.68E+03	3.77E+01	0.17	1.1	0.7	90.2	3600	8.74E+01	5.12E+02
									Total Activity (Bq)		9.31E+01	5.48E+02
									Total Activity (Bq/m^2)		***4.74E+04***	***2.79E+05***
160715-1	3A	1.12E+02	1.80E+00	6.71E+02	5.93E+00	0.17	1.6	0.9	110.0	15000	1.23E+01	7.38E+01
160715-1	3B	9.60E+02	8.69E+00	5.75E+03	2.98E+01	0.17	0.9	0.5	102.0	5400	9.79E+01	5.87E+02

160715-1	3C	4.47E+03	2.39E+01	2.63E+04	8.30E+01	0.17	0.5	0.3	79.9	3600	3.57E+02	2.10E+03
									Total Activity (Bq)		4.67E+02	2.76E+03
									Total Activity (Bq/m^2)		***2.38E+05***	***1.41E+06***
160428	1A	3.51E+02	3.27E+00	2.07E+03	1.09E+01	0.17	0.9	0.5	108.0	15000	3.80E+01	2.23E+02
160428	1B	4.94E+03	2.06E+01	2.88E+04	7.03E+01	0.17	0.4	0.2	80.6	5400	3.98E+02	2.32E+03
160428	1C	4.16E+03	2.40E+01	2.45E+04	8.40E+01	0.17	0.6	0.3	70.8	3600	2.95E+02	1.73E+03
									Total Activity (Bq)		7.31E+02	4.28E+03
									Total Activity (Bq/m^2)		***3.72E+05***	***2.18E+06***
160428	2A	3.42E+02	3.57E+00	2.01E+03	1.17E+01	0.17	1.0	0.6	64.8	15000	2.21E+01	1.30E+02
160428	2B	2.96E+02	5.41E+00	1.71E+03	1.75E+01	0.17	1.8	1.0	69.9	5400	2.07E+01	1.19E+02
160428	2C	5.54E+03	2.34E+01	3.24E+04	8.18E+01	0.17	0.4	0.3	107.0	3600	5.93E+02	3.47E+03
									Total Activity (Bq)		6.36E+02	3.72E+03
									Total Activity (Bq/m^2)		***3.24E+05***	***1.89E+06***
160428	3A	9.78E+01	1.71E+00	5.78E+02	5.52E+00	0.17	1.7	1.0	109.0	15000	1.07E+01	6.29E+01
160428	3B	1.03E+03	8.07E+00	6.04E+03	2.74E+01	0.17	0.8	0.5	135.0	5400	1.38E+02	8.16E+02
160428	3C	8.00E+03	3.35E+01	4.71E+04	1.17E+02	0.17	0.4	0.2	62.7	3600	5.01E+02	2.95E+03
									Total Activity (Bq)		6.50E+02	3.83E+03

									Total Activity (Bq/m²)		***3.31E+05***	***1.95E+06***
160624	1A	3.18E+02	6.29E+00	1.96E+03	2.04E+01	0.16	2.0	1.0	77.5	4600	2.46E+01	1.52E+02
160624	1B	1.78E+03	1.41E+01	1.12E+04	4.97E+01	0.16	0.8	0.4	63.5	5400	1.13E+02	7.13E+02
160624	1C	1.15E+04	5.16E+01	7.09E+04	1.82E+02	0.16	0.4	0.3	36.5	3600	4.20E+02	2.59E+03
									Total Activity (Bq)		5.58E+02	3.45E+03
									Total Activity (Bq/m²)		***2.84E+05***	***1.76E+06***
160624	2A	8.36E+02	7.41E+00	5.21E+03	2.58E+01	0.16	0.9	0.5	71.4	8500	5.97E+01	3.72E+02
160624	2B	2.52E+03	1.57E+01	1.57E+04	5.52E+01	0.16	0.6	0.4	78.4	5400	1.97E+02	1.23E+03
160624	2C	3.93E+03	2.48E+01	2.41E+04	8.73E+01	0.16	0.6	0.4	61.2	3600	2.40E+02	1.47E+03
									Total Activity (Bq)		4.97E+02	3.08E+03
									Total Activity (Bq/m²)		***2.53E+05***	***1.57E+06***
160624	3A	3.32E+01	1.54E+00	1.78E+02	4.60E+00	0.19	4.6	2.6	70.7	9000	2.35E+00	1.26E+01
160624	3B	3.39E+02	5.57E+00	2.15E+03	1.92E+01	0.16	1.6	0.9	83.7	5400	2.83E+01	1.80E+02
160624	3C	1.88E+03	1.73E+01	1.11E+04	5.97E+01	0.17	0.9	0.5	61.0	3600	1.15E+02	6.76E+02
									Total Activity (Bq)		1.45E+02	8.69E+02
									Total Activity (Bq/m²)		***7.40E+04***	***4.43E+05***
160610-1	1A	5.69E+02	4.61E+00	3.37E+03	1.54E+01	0.17	0.8	0.5	61.0	15000	3.47E+01	2.05E+02

160610-1	1B	4.77E+03	1.93E+01	2.78E+04	6.61E+01	0.17	0.4	0.2	97.2	5400	4.63E+02	2.71E+03
160610-1	1C	6.18E+03	3.31E+01	3.57E+04	1.14E+02	0.17	0.5	0.3	49.0	3600	3.03E+02	1.75E+03
									Total Activity (Bq)		8.01E+02	4.66E+03
									Total Activity (Bq/m^2)		***4.08E+05***	***2.37E+06***
160610-1	2A	5.46E+02	3.74E+00	3.17E+03	1.25E+01	0.17	0.7	0.4	121.0	15000	6.61E+01	3.84E+02
160610-1	2B	2.52E+03	1.03E+01	1.48E+04	3.51E+01	0.17	0.4	0.2	117.0	9000	2.95E+02	1.73E+03
160610-1	2C	3.12E+03	1.77E+01	1.77E+04	5.96E+01	0.18	0.6	0.3	130.0	3600	4.05E+02	2.30E+03
									Total Activity (Bq)		7.66E+02	4.42E+03
									Total Activity (Bq/m^2)		***3.90E+05***	***2.25E+06***
160610-1	3A	6.82E+01	1.40E+00	3.95E+02	4.46E+00	0.17	2.1	1.1	129.0	15000	8.80E+00	5.09E+01
160610-1	3B	1.24E+02	2.36E+00	7.36E+02	7.82E+00	0.17	1.9	1.1	122.0	9000	1.51E+01	8.98E+01
160610-1	3C	4.49E+02	6.95E+00	2.66E+03	2.35E+01	0.17	1.5	0.9	113.0	3600	5.07E+01	3.00E+02
									Total Activity (Bq)		7.47E+01	4.41E+02
									Total Activity (Bq/m2)		***3.80E+04***	***2.25E+05***
160621-3	1A	8.36E+02	4.84E+00	5.15E+03	1.67E+01	0.16	0.6	0.3	102.0	15000	8.53E+01	5.26E+02
160621-3	1B	1.15E+03	7.89E+00	7.09E+03	2.73E+01	0.16	0.7	0.4	74.5	9000	8.55E+01	5.28E+02
160621-3	1C	2.17E+03	1.53E+01	1.32E+04	5.35E+01	0.16	0.7	0.4	113.0	3600	2.45E+02	1.49E+03

									Total Activity (Bq)		4.16E+02	2.55E+03
									Total Activity (Bq/m^2)		***2.12E+05***	***1.30E+06***
160621-3	2A	2.38E+02	2.66E+00	1.47E+03	9.03E+00	0.16	1.1	0.6	102.0	15000	2.43E+01	1.50E+02
160621-3	2B	2.04E+03	9.73E+00	1.25E+04	3.39E+01	0.16	0.5	0.3	98.3	9000	2.00E+02	1.23E+03
160621-3	2C	5.21E+03	2.41E+01	3.16E+04	8.44E+01	0.16	0.5	0.3	99.3	3600	5.17E+02	3.14E+03
									Total Activity (Bq)		7.41E+02	4.52E+03
									Total Activity (Bq/m^2)		***3.78E+05***	***2.30E+06***
160621-3	3A	2.95E+02	3.13E+00	1.85E+03	1.07E+01	0.16	1.1	0.6	92.1	15000	2.72E+01	1.70E+02
160621-3	3B	8.51E+02	8.78E+00	5.38E+03	3.10E+01	0.16	1.0	0.6	41.0	9000	3.49E+01	2.21E+02
160621-3	3C	4.85E+03	3.36E+01	2.97E+04	1.18E+02	0.16	0.7	0.4	41.1	3600	1.99E+02	1.22E+03
									Total Activity (Bq)		2.62E+02	1.61E+03
									Total Activity (Bq/m^2)		***1.33E+05***	***8.21E+05***
160722	1A	6.08E+02	5.31E+00	3.61E+03	1.79E+01	0.17	0.9	0.5	56.7	15000	3.45E+01	2.05E+02
160722	1B	2.24E+03	1.48E+01	1.38E+04	5.18E+01	0.16	0.7	0.4	37.2	9000	8.34E+01	5.12E+02
160722	1C	1.51E+04	6.52E+01	9.28E+04	2.34E+02	0.16	0.4	0.3	31.7	3600	4.79E+02	2.94E+03
									Total Activity (Bq)		5.96E+02	3.66E+03
									Total Activity (Bq/m^2)		***3.04E+05***	***1.86E+06***

160722	2A	7.21E+02	5.19E+00	4.37E+03	1.78E+01	0.16	0.7	0.4	62.9	15000	4.53E+01	2.75E+02
160722	2B	2.45E+03	1.09E+01	1.46E+04	3.77E+01	0.17	0.4	0.3	98.8	9000	2.42E+02	1.44E+03
160722	2C	1.97E+03	1.49E+01	1.20E+04	5.29E+01	0.16	0.8	0.4	103.0	3600	2.03E+02	1.23E+03
									Total Activity (Bq)		4.90E+02	2.95E+03
									Total Activity (Bq/m^2)		***2.50E+05***	***1.50E+06***
160722	3A	6.13E+02	6.23E+00	3.77E+03	2.14E+01	0.16	1.0	0.6	35.4	15000	2.17E+01	1.34E+02
160722	3B	1.96E+03	1.50E+01	1.22E+04	5.31E+01	0.16	0.8	0.4	30.7	9000	6.00E+01	3.75E+02
160722	3C	1.23E+04	6.73E+01	7.60E+04	2.42E+02	0.16	0.5	0.3	22.0	3600	2.70E+02	1.67E+03
									Total Activity (Bq)		3.52E+02	2.18E+03
									Total Activity (Bq/m^2)		***1.79E+05***	***1.11E+06***

OKUMA

Soil		Cs-134 (Bq/kg)		Cs-137 (Bq/kg)		Cs134/Cs137	err/Activity		Dry weight(g)	Live time (s)	Cs-134 in U8	Cs-137 in U8
Date	ID	Activity	Act. err	Activity	Act. err		Cs-134	Cs-137			Bq	Bq
O174	1A-1	3.14E+03	1.19E+01	1.63E+04	3.65E+01	0.19	0.4	0.2	37.9	18000	1.19E+02	6.17E+02
O174	1A-2	1.69E+03	7.78E+01	8.69E+03	2.36E+01	0.19	4.6	0.3	52.2	18000	8.80E+01	4.54E+02

O174	1B-1	1.03E+04	2.93E+01	6.25E+04	1.02E+02	0.17	0.3	0.2	38.1	9000	3.94E+02	2.38E+03
O174	1B-2	8.57E+03	2.29E+01	4.84E+04	7.89E+01	0.18	0.3	0.2	58.5	9000	5.01E+02	2.83E+03
O174	1C-1	1.36E+04	8.32E+01	8.16E+04	2.90E+02	0.17	0.6	0.4	28.1	1800	3.81E+02	2.29E+03
O174	1C-2	1.12E+04	5.41E+02	6.67E+04	1.87E+02	0.17	4.8	0.3	79.0	1800	8.88E+02	5.27E+03
									Total Activity (Bq)		2.37E+03	1.38E+04
									Total Activity (Bq/m^2)		***1.21E+06***	***7.05E+06***
O174	2A	1.70E+03	9.89E+00	8.78E+03	2.96E+01	0.19	0.6	0.3	26.7	18000	4.54E+01	2.34E+02
O174	2B	2.68E+03	1.09E+01	1.54E+04	3.69E+01	0.17	0.4	0.2	107.0	9000	2.87E+02	1.64E+03
O174	2C	2.66E+04	8.03E+01	1.57E+05	2.76E+02	0.17	0.3	0.2	87.2	1800	2.32E+03	1.37E+04
									Total Activity (Bq)		2.65E+03	1.56E+04
									Total Activity (Bq/m^2)		***1.35E+06***	***7.92E+06***
O174	3A	2.93E+03	1.08E+01	1.50E+04	3.28E+01	0.19	0.4	0.2	48.4	18000	1.42E+02	7.27E+02
O174	3B	1.73E+03	1.08E+01	1.04E+04	3.74E+01	0.17	0.6	0.4	64.7	9000	1.12E+02	6.70E+02
O174	3C	2.43E+04	1.28E+02	1.43E+05	4.42E+02	0.17	0.5	0.3	25.0	1800	6.07E+02	3.58E+03

									Total Activity (Bq)		8.60E+02	4.98E+03
									Total Activity (Bq/m^2)		***4.38E+05***	***2.54E+06***
O175	1A	2.09E+02	2.32E+00	1.12E+03	7.09E+00	0.19	1.1	0.6	106.0	18000	2.22E+01	1.19E+02
O175	1B	1.31E+03	8.40E+00	7.65E+03	2.87E+01	0.17	0.6	0.4	86.6	9000	1.13E+02	6.63E+02
O175	1C	5.72E+03	3.81E+01	3.33E+04	1.31E+02	0.17	0.7	0.4	89.3	1800	5.11E+02	2.98E+03
									Total Activity (Bq)		6.46E+02	3.76E+03
									Total Activity (Bq/m^2)		***3.29E+05***	***1.91E+06***
O175	2A	2.17E+03	8.38E+00	1.11E+04	2.57E+01	0.20	0.4	0.2	67.5	18000	1.46E+02	7.47E+02
O175	2B	6.53E+03	2.10E+01	3.84E+04	7.23E+01	0.17	0.3	0.2	59.7	9000	3.90E+02	2.29E+03
O175	2C	5.58E+03	4.53E+01	3.31E+04	1.56E+02	0.17	0.8	0.5	54.8	1800	3.06E+02	1.81E+03
									Total Activity (Bq)		8.41E+02	4.85E+03
									Total Activity (Bq/m^2)		***4.29E+05***	***2.47E+06***
O175	3A	2.27E+02	2.46E+00	1.20E+03	7.43E+00	0.19	1.1	0.6	99.7	18000	2.27E+01	1.20E+02
O175	3B	6.49E+02	5.60E+00	3.64E+03	1.86E+01	0.18	0.9	0.5	101.0	9000	6.55E+01	3.68E+02

O175	3C	4.67E+03	3.59E+01	2.69E+04	1.22E+01	0.17	0.8	0.0	80.6	1800	3.76E+02	2.17E+03
									Total Activity (Bq)		4.64E+02	2.65E+03
									Total Activity (Bq/m^2)		***2.36E+05***	***1.35E+06***
160801	1A	2.13E+02	3.64E+00	1.14E+03	1.05E+01	0.19	1.7	0.9	32.2	18000	6.87E+00	3.66E+01
160801	1B	1.56E+03	1.43E+01	9.23E+03	4.91E+01	0.17	0.9	0.5	21.5	9000	3.35E+01	1.98E+02
160801	1C	1.30E+04	7.01E+01	7.64E+04	2.42E+02	0.17	0.5	0.3	20.4	3600	2.65E+02	1.56E+03
									Total Activity (Bq)		3.05E+02	1.79E+03
									Total Activity (Bq/m2)		***1.55E+05***	***9.14E+05***
160801	2A	1.27E+02	2.85E+00	6.34E+02	7.73E+00	0.20	2.2	1.2	30.0	18000	3.81E+00	1.90E+01
160801	2B	2.95E+02	5.10E+00	1.74E+03	1.70E+01	0.17	1.7	1.0	39.9	9000	1.18E+01	6.93E+01
160801	2C	6.78E+03	4.89E+01	4.10E+04	1.71E+02	0.17	0.7	0.4	20.4	3600	1.38E+02	8.36E+02
									Total Activity (Bq)		1.54E+02	9.25E+02
									Total Activity (Bq/m^2)		***7.83E+04***	***4.71E+05***
160801	3A	1.79E+02	2.96E+00	9.28E+02	8.53E+00	0.19	1.7	0.9	41.3	18000	7.41E+00	3.83E+01

160801	3B	1.15E+03	9.76E+00	6.88E+03	3.35E+01	0.17	0.8	0.5	40.5	9000	4.67E+01	2.79E+02
160801	3C	2.27E+03	2.32E+01	1.36E+04	8.06E+01	0.17	1.0	0.6	35.5	3600	8.05E+01	4.83E+02
									Total Activity (Bq)		1.35E+02	8.00E+02
									Total Activity (Bq/m^2)		***6.86E+04***	***4.07E+05***

Local Soil sample site means with their corresponding database soil sample

Local Soil Cs-137 concentrations (Bq m^{-2})	Map/database Soil Cs-137 concentrations (Bq m^{-2})	Location
139233.3333	99000	Fukushima
223333.3333	330000	Fukushima
142866.6667	330000	Fukushima
1910000	73000	Okuma
5836666.667	2800000	Okuma
597333.3333	73000	Okuma
729333.3333	630000	Namie
1163000	2200000	Namie
1490000	2200000	Namie
2290000	1683745.824	Namie
1615000	1700000	Namie
866000	230000	Namie
2743333.333	2142428.529	Namie
1473666.667	2200000	Namie
1257666.667	2200000	Namie
2974000	4500000	Namie
586566.6667	630000	Namie
1726666.667	1700000	Namie
2350666.667	2142428.529	Namie
7156666.667	4500000	Namie
2006666.667	2700000	Namie
1257666.667	2200000	Namie

APPENDIX E: BOAR DATA

Capture wild boar information

Boar Number	Boar ID	Capture date	Capture location				Sex	Age (weeks)	Weight (kg)
			Place name		Lat.	Lon.			
1	160531-1	May. 31, 2016	Namie	Akougi-Koakuto	37.568932	140.778014	Female	26	N/A
2	160531-2	May. 31, 2016	Namie	Murohara-Hachiryunai	37.500294	140.945460	Male	46	N/A
3	160531-3	May. 31, 2016	Namie	Idekitakawara	37.464554	140.946247	Female	46	N/A
4	160531-4	May. 31, 2016	Namie	Nakasakai	37.479347	140.981908	Female	26	N/A
5	160531-5	May. 31, 2016	Namie	Kiyohashi	37.497798	141.014968	Male	88-106	N/A
6	160603-1	Jun. 3, 2016	Namie	Kazawoe-Minamiosaka	37.491431	140.978599	Male	57-61	N/A
7	160603-A	Jun. 3, 2016	Namie	Tatsuno	37.523055	140.931445	Female	6-9	N/A
8	160603-B	Jun. 3, 2016	Namie	Tatsuno	37.523055	140.931445	Female	6-9	N/A
9	160603-C	Jun. 3, 2016	Namie	Tatsuno	37.523055	140.931445	Male	6-9	N/A
10	160603-D	Jun. 3, 2016	Namie	Tatsuno	37.523055	140.931445	Female	6-9	N/A
11	160603-E	Jun. 3, 2016	Namie	Tatsuno	37.523055	140.931445	Female	127	N/A
12	160607-1	Jun. 7, 2016	Namie	Murohara-Shichisyagu	37.508634	140.931026	Male	46	N/A
13	160607-2	Jun. 7, 2016	Namie	Sakai-Yoshinosaku	37.480354	140.989209	Male	62	N/A
14	160610-1	Jun. 10, 2016	Namie	Akougi-Koakuto	37.568932	140.778014	Male	33-39	30
15	160610-2	Jun. 10, 2016	Namie	Sakai-Matsukiuchi	37.479072	140.979392	Female	26	N/A
16	160610-3	Jun. 10, 2016	Namie	Sakai-Matsukiuchi	37.479072	140.979392	Male	27-31	N/A
17	160617-1	Jun. 17, 2016	Fukushima	Yamada-Onbou	37.704008	140.401985	Female	57-61	51.6
18	160617-2	Jun. 17, 2016	Fukushima	Yamada-Onbou	37.704008	140.401985	Male	21	20.8
19	160621-1	Jun. 21, 2016	Namie	Tsushima-Suikyou	37.581339	140.721047	Female	47-52	27.3
20	160621-2	Jun. 21, 2016	Namie	Minami-Tsushima-Shimohiyada	37.549639	140.796942	Male	33-39	23.3
21	160621-3	Jun. 21, 2016	Namie	Murohara-Sagarifuji	37.510019	140.935489	Male	47-52	35.0

22	160624 Collar	Jun. 24, 2016	Namie	Tatsuno	37.523055	140.931445	Male		
23	160705 Collar	Jul. 5, 2016	Namie	Tatsuno	37.523055	140.931445	Female	127	76.0
24	160708-1	Jul. 8, 2016	Namie	Obori	37.465361	140.943151	Male	less than 5	2.3
25	160715-1	Jul. 15, 2016	Namie	Suenomori	37.491317	140.941102	Male	less than 5	2.8
26	160719-1	Jul. 19, 2016	Namie	Obori	37.465361	140.943151	Female	6-9	7.00
27	160720-1	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	6-9	5.9
28	160720-2	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	6-9	6.8
29	160720-3	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	6-9	6.2
30	160720-4	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Female	6-9	6.3
31	160720-5	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	6-9	6.3
32	160720-6	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Female	6-9	6.8
33	160720-7	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	6-9	5.3
34	160720-8	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Female	6-9	5.8
35	160720-9	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Female	6-9	5.1
36	160720-10	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Male	10	6.3
37	160720-11	Jul. 20, 2016	Fukushima	Yamaguchi-Gohonmatsu	37.761529	140.501009	Female	6-9	4.9
38	160722-1	Jul. 22, 2016	Namie	Murohara-Kamiyachi	37.505422	140.925022	Male	6-9	5.3
39	160722-2	Jul. 22, 2016	Namie	Murohara-Kamiyachi	37.505422	140.925022	Male	6-9	4.2
40	160723-1	Jul. 23, 2016	Katsurao	Katsurao-Noyuki	37.519650	140.816770	Female	21	8
41	160726-1	Jul. 26, 2016	Okuma	Ottozawa-Chuodai	37.415958	141.012303	Female	87	38.7
42	160726-2	Jul. 26, 2016	Okuma	Kumanabedu	37.393036	140.995272	Male	87	69
43	160726-3	Jul. 26, 2016	Okuma	Kumashin-machi	37.400028	140.989244	Male	6-9	9
44	160726-4	Jul. 26, 2016	Okuma	Kumashin-machi	37.400028	140.989244	Female	80	43.6
45	160728-1	Jul. 28, 2016	Katsurao	Katsurao-Kashiwabara	37.528640	140.798470	Female	63-68	34.6
46	160729-1	Jul. 29, 2016	Namie	Minami-Tsushima-Shimohiyada	37.551871	140.788174	Female	145	62.3
47	160801-1	Aug. 1, 2016	Okuma	Kumaasahidai	37.395130	140.973570	Male	62	54.9
48	160801-2	Aug. 1, 2016	Tomioka	Yonomoriminami	37.362790	140.996390	Male	65-58	56.4
49	160801-3	Aug. 1, 2016	Fukushima	Watari-Kouya	37.748730	140.490098	Male	82-86	48

50	160803-1	Aug. 3, 2016	Okuma	Kumanabedu	37.393036	140.995272	Female	125	77.2
51	160803-2	Aug. 3, 2016	Okuma	Kumanabedu	37.393036	140.995272	female	10	9.6
52	160803-3	Aug. 3, 2016	Okuma	Kumanabedu	37.393036	140.995272	Male	10	10.4
53	160804-1	Aug. 4, 2016	Nagasaki	Higashisonogicho-Nakaogo	33.045318	129.976839	Male	56	20
54	160804-2	Aug. 4, 2016	Nagasaki	Higashisonogicho-Nakaogo	33.046058	129.976980	Female	6-9	4.65
55	160805-1	Aug 5. 2016	Nagasaki	Omodakago, Saikai-machi, Saikai city	33.076608	129.685254	Female	21	10.2
56	160805-2	Aug 5. 2016	Nagasaki	Omodakago, Saikai-machi, Saikai city	33.076608	129.685254	Male	less than 5	10.1
57	160805-3	Aug 5. 2016	Nagasaki	Omodakago, Saikai-machi, Saikai city	33.076608	129.685254	Male	less than 5	9.4
58	160806-1	Aug. 6. 2016	Nagasaki	Moriyamacho-Keishino, Isahaya city	32.819950	130.121090	Female	62	19.5
59	160902 K-20	Sep. 02, 2016	Katsurao	Katsurao-Noyuki	37.518804	140.824293	Female	57-61	35.3
60	160902 K-21	Sep. 02, 2016	Katsurao	Katsurao-Noyuki	37.518804	140.824293	Female	63-68	31.7
61	160916	Sep. 16, 2016	Nihonmatsu	Tazawa-Oomori	37.566058	140.672044	Male	N/A	68.9
62	160917-1	Sep. 17, 2016	Nihonmatsu	Tazawa-Maeyama	37.472590	140.648111	Male	N/A	40.8
63	160917-2	Sep. 17, 2016	Nihonmatsu	Tazawa-Machikumi	N/A	N/A	Female	>220	69.2
64	160917-3	Sep. 17, 2016	Nihonmatsu	Tazawa-Myousyouchi	37.560993	140.658546	Female	128-144	52
65	160918-1	Sep. 18. 2016	Fukushima	Watari-Causu	37.744412	140.504675	Female	57-61	45.3
66	160918-2	Sep. 18. 2016	Nihonmatsu	Mobara-Wakabayashi	37.539503	140.628628	Female	N/A	9.8
67	160918-3	Sep. 18. 2016	Nihonmatsu	Mobara	37.536500	140.627664	Male	N/A	16.1
68	160919-1	Sep. 19. 2016	Nihonmatsu	Higashiniidono-Hiraishita	37.534920	140.589073	Female	15	17
69	160919-2	Sep. 19. 2016	Nihonmatsu	Domeki-Nakanouti	37.542977	140.612194	Female	15	8.9
70	160920-1	Sep. 20. 2016	Namie	Idekitakawara	37.465529	140.947112	Male	15	9
71	160920-2	Sep. 20. 2016	Namie	Sakai-Yoshinosaku	37.480354	140.989209	Male	15	11
72	160920-3	Sep. 20. 2016	Namie	Sakai-Yoshinosaku	37.480354	140.989209	Female	15	10.9
73	160920-4	Sep. 20. 2016	Namie	Sakai-Yoshinosaku	37.480354	140.989209	Female	15	9.9
74	160928-1	Sep. 28, 2016	Nihonmatsu	Obama-Kitatsukiyama	37.562445	140.51106	Male	127	N/A
75	161004-1	Oct. 04, 2016	Namie	Murohara-Takidaira	37.506497	140.911872	Female	87	N/A
76	161004-2	Oct. 04, 2016	Namie	Murohara-Takidaira	37.506878	140.916659	Female	87	N/A
77	161004-3	Oct. 04, 2016	Namie	Murohara-Kureki	37.498806	140.931164	Female	89	N/A

78	161004-4	Oct. 04, 2016	Namie	Suenomori-Nitakuo	37.480657	140.940891	Male	15	N/A
79	161004-5	Oct. 04, 2016	Namie	Suenomori-Nitakuo	37.480657	140.940891	Male	15	N/A
80	161004-6	Oct. 04, 2016	Namie	Suenomori-Nitakuo	37.480657	140.940891	Female	15	N/A
81	161004-7	Oct. 04, 2016	Namie	Suenomori-Nitakuo	37.480657	140.940891	Female	15	N/A
82	161012 O-150	Oct. 12, 2016	Okuma	Kumashin-machi	37.400028	140.989244	Female	40	13.4
83	161022-1	Oct. 22, 2016	Nihonmatsu	Tazawa-Kanda	37.547322	140.641809		15	11.3
84	161022-2	Oct. 22, 2016	Nihomatsu	Mobara-Natsui	37.537587	140.654725	Male	26	18.5
85	161022 OT-33	Oct. 22, 2016	Okuma	Ohgawara	37.388383	140.968505	Female	26	13.3
86	161022 OT-34	Oct. 22, 2016	Okuma	Ohgawara	37.388383	140.968505	Male	26	13.1
87	161025 O-174	Oct. 25, 2016	Okuma	Ottozawa-Chuodai	37.414074	140.987373	Male	26	15.2
88	161025 F-92	Oct. 25, 2016	Futaba	Shinzan-Tennoshita	37.443004	141.007252	Female	26	16.4
89	161026 O-175	Oct. 26, 2016	Okuma	Kumashin-machi	37.393047	140.997004	Female	46	49.3
90	161026 O-176	Oct. 26, 2016	Okuma	Kumashin-machi	37.393047	140.997004	Female	26	20.6
91	161026 O-177	Oct. 26, 2016	Okuma	Kumashin-machi	37.393047	140.997004	Male	26	23.1
92	161026 O-178	Oct. 26, 2016	Okuma	Ottozawa-Chuodai	37.414074	140.987373	Female	46	48.5
93	161101-1	Nov. 01, 2016	Namie	Murohara-Machigashira	37.507298	140.932306	Male	26	16.3
94	161101-2	Nov. 01, 2016	Namie	Idekitakawara	37.465529	140.947112	Female	108	42.6
95	161101-3	Nov. 01, 2016	Namie	Sakai-Ishinazaka	37.478359	140.977474	Female	127	47.2
96	161108 GPS	Nov. 08, 2016	Namie	Tsushima-Nishidate	37.561920	140.746675	Male	128-144	115.5
97	161108 GPS	Nov. 08, 2016	Futaba	Nagatsuka-Harada	37.454348	141.002830	Female	32	41.8
98	161111-1	Nov. 11, 2016	Namie	N/A	N/A	N/A	Male	N/A	15.4
99	161111-2	Nov. 11, 2016	Namie	N/A	N/A	N/A	Male	N/A	10.4
100	161111-3	Nov. 11, 2016	Namie	N/A	N/A	N/A	Female	N/A	12.6
101	161111-4	Nov. 11, 2016	Namie	N/A	N/A	N/A	N/A	N/A	N/A
102	161111-5	Nov. 11, 2016	Namie	Idekitakawara	37.465529	140.947112	N/A	N/A	N/A
103	161111-6	Nov. 11, 2016	Namie	N/A	N/A	N/A	N/A	N/A	N/A
104	161117 O-198	Nov. 17, 2016	Okuma	Shimono-Kanayadaira	37.408544	140.975109	Female	N/A	54
105	161126-1 O-205	Nov. 26. 2016	Okuma	Ottozawa-Chuodai	37.416058	140.995227	Female	26	18.5

106	161126-2 GPS	Nov. 26. 2016	Futaba	Kamihatori-Sawairi	37.452980	140.975017	Female	?	31.3
107	161126 F-109	Nov. 26. 2016	Futaba	Shibukawakitasaku	37.470056	140.994922	Male	26	20.2
108	161128-1 O-206	Nov. 28. 2016	Okuma	Shimonogamihara	37.399016	140.971983	Female	26	20.1
109	161128-2 O-207	Nov. 28. 2016	Okuma	Ottozawa-Chuodai	37.416058	140.995227	Male	26	21.2
110	161130-1 O-210 GPS	Nov. 30. 2016	Okuma	Nogamisuwa	37.408318	140.952015	Female	220	88.5
111	161130-2 O-211	Nov. 30. 2016	Okuma	Shimonogamihara	37.399016	140.971983	Female	87	40.2
112	161130-3 O-212	Nov. 30. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Male	26	20.2
113	161130-4 O-213	Nov. 30. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Female	26	16.7
114	161130-5 O-214 GPS	Nov. 30. 2016	Okuma	Ottozawa-Chuodai	37.414074	140.987373	Female	87	55.1
115	161206 O-227 GPS	Dec. 06. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Female	32	42.9
116	161206 O-228	Dec. 06. 2016	Okuma	Kumashin-machi	37.400028	140.989244	Male	26	29
117	161206 O-229	Dec. 06. 2016	Okuma	Kumanabetsu	37.390051	140.998834	Female	46	43.9
118	161206 O-230	Dec. 06. 2016	Okuma	Shimonogamihara	37.399016	140.971983	Male	26	31.6
119	161206 O-231 GPS	Dec. 06. 2016	Okuma	Ottozawa-Chojyahara	37.429225	141.009476	Female	62	39.2
120	161208 O-236	Dec. 08. 2016	Okuma	Ottozawa-Chuodai	37.414074	140.987373	Female	48	48.6
121	161208 O-237	Dec. 08. 2016	Okuma	Kumanabetsu	37.390051	140.998834	Male	22-25	22.1
122	161208 O-238	Dec. 08. 2016	Okuma	Ottozawa-Chojyahara	37.429225	141.009476	Female	87	46
123	161209 O-239	Dec. 09. 2016	Okuma	Shimono-Kanayadaira	37.408544	140.975109	Female	26	25.5
124	161209 O-240	Dec. 09. 2016	Okuma	Shimono-Kanayadaira	37.408544	140.975109	Male	26	22.2
125	161209 O-241GPS	Dec. 09. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Female	??	91.4
126	161209 O-242	Dec. 09. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Male	22-25	19.7
127	161213 PF-26	Dec. 13. 2016	Futaba	Nakanoshibue	37.459737	141.029345	Male	22-25	25.5
128	161213 O-246	Dec. 13. 2016	Okuma	Kuma-Kuma	37.384897	141.009965	Male	27-31	47.1
129	161215 T-1	Dec. 12, 2016	Tochigi	Tochigi-Umesawa	36.439514	139.642847	Female	87	43.4
130	161215 T-2	Dec. 12, 2016	Tochigi	Tochigi-Umesawa	36.439514	139.642847	Male	62	30.3
131	161216 O-247	Dec. 16. 2016	Okuma	Nogami	37.414776	140.944361	Male	145	99.8

132	161216 F-117	Dec. 16. 2016	Futaba	Shibukawakitasaku	37.470056	140.994922	Male	87	88.9
133	170113TB-1	Jan. 13, 2017	Tochigi	Tochigi, Nabeyama	36.448364	139.649656	Female	88-106	31.6
134	170113TB-2	Jan. 13, 2017	Tochigi	Tochigi, Nabeyama	36.448364	139.649656	Female	62	23.3
135	170121 O-266	Jan. 21, 2017	Okuma	Kuma-Kuma	37.384897	141.009965	Female	80-86	62.4
136	170121 O-267	Jan. 21, 2017	Okuma	Kuma-Kuma	37.384897	141.009965	Female	22-25	13.9
137	170123 O-268	Jan. 23, 2017	Okuma	Shimono-Kanayadaira	37.408544	140.975109	Male	26	23.2
138	170125 T-62	Jan. 25, 2017	Tomioka	Oosuge-Kawada	37.371345	141.003753	Female	26	22.3

Boar Cs-137 concentration measurements in bicep femoris

Note: All wild boar samples were measured for Cs-134 at the IER, but the only the Cs-137 data was used in the analysis and T_{ag} calculations.

ID	Capture location	Part	Fresh or Dry	Cs-134 (Bq/kg)		Cs-137 (Bq/kg)		err/Activity		Live time (s)
				Activity	Act. err	Activity	Act. err	Cs-134	Cs-137	
160531-1	Namie	Biceps femoris	Dry	447.98	5.8899	2210.6	18.284	N/A	N/A	N/A
160531-2	Namie	Biceps femoris	Dry	237.68	3.8215	1248.6	12.082	N/A	N/A	N/A
160531-3	Namie	Biceps femoris	Dry	1498	10.02	7538.6	32.144	N/A	N/A	N/A
160531-4	Namie	Biceps femoris	Dry	311.78	5.0365	1712.8	16.379	N/A	N/A	N/A
160603-1	Namie	Biceps femoris	Dry	809.22	11.13	4350.70	36.27	0.014	0.008	10000
160603-B	Namie	Biceps femoris	Fresh	790.80	17.62	3959.70	52.43	0.022	0.013	10000
160603-D	Namie	Biceps femoris	Fresh	681.26	12.16	3535.60	37.47	0.018	0.011	10000
160603-E	Namie	Biceps femoris	Dry	4099.90	29.61	21279.00	97.07	0.007	0.005	10000
160607-1	Namie	Biceps femoris	Dry	3020.5	30.737	15354	92.782	0.010	0.006	10000
160607-2	Namie	Biceps femoris	Dry	1277.3	16.403	6648.5	51.203	0.013	0.008	10000
160610-1	Namie	Biceps femoris	Dry	883.62	13.26	4465.9	41.045	0.015	0.009	10000

160610-2	Namie	Biceps femoris	Dry	1524.2	18.634	8267.7	59.117	0.012	0.007	10000
160610-3	Namie	Biceps femoris	Dry	1346	23.739	7195.9	71.942	0.018	0.010	10000
160617-1	Fukushima	Biceps femoris	Dry	638.30	10.11	3304.20	32.15	0.016	0.010	10000
160617-2	Fukushima	Biceps femoris	Dry	591.15	12.21	3007.60	37.67	0.021	0.013	10000
160621-2	Namie	Biceps femoris	Dry	2319.9	22.249	11765	70.768	0.010	0.006	10000
160621-3	Namie	Biceps femoris	Dry	1063.5	23.107	5668	69.814	0.022	0.012	1000000
160708-1	Namie	Biceps femoris	Dry	488.26	25.382	2524.6	67.184	0.052	0.027	N/A
160715-1	Namie	Biceps femoris	Dry	1141.3	83.739	4591.8	195.73	0.073	0.043	10000
160719-1?	Namie	Biceps femoris	Dry	1953.8	38.072	11099	118.67	0.019	0.011	10000
160719-1?	Namie	Biceps femoris	Dry	3769.5	35.595	19559	111.14	0.009	0.006	10000
160720-1	Fukushima	Biceps femoris	Dry	64.655	11.651	341.78	24.083	0.180	0.070	5000
160720-2	Fukushima	Biceps femoris	Dry	84.17	7.9466	423.94	19.301	0.094	0.046	10000
160720-3	Fukushima	Biceps femoris	Dry	82.749	6.7434	379.96	17.03	0.081	0.045	10000
160720-4	Fukushima	Biceps femoris	Dry	78.72	6.8869	377.94	17.598	0.087	0.047	10000
160720-5	Fukushima	Biceps femoris	Dry	84.744	7.1876	416.47	17.955	0.085	0.043	10000
160720-7	Fukushima	Biceps femoris	Dry	71.205	14.861	309.49	23.929	0.209	0.077	5000
160720-8	Fukushima	Biceps femoris	Dry	94.575	17.958	455.98	31.985	N/A	0.070	N/A
160720-9	Fukushima	Biceps femoris	Dry	61.545	5.7529	327.83	15.143	0.093	0.046	10000
160720-10	Fukushima	Biceps femoris	Dry	56.069	6.4511	307.18	16.698	0.115	0.054	10000
160720-11	Fukushima	Biceps femoris	Dry	160.86	16.685	1027.8	46.012	0.104	0.045	5000
160721-1	N/A	Biceps femoris	Dry	6019.8	18.63	31703	55.969	N/A	0.002	N/A
160722-1	Namie	Biceps femoris	Dry	5596.8	65.686	29576	201.57	0.012	0.007	10000
160722-2	Namie	Biceps femoris	Dry	3493.5	89.387	17785	251.66	0.026	0.014	10000
160726-1	Okuma	Biceps femoris	Dry	3811.1	28.985	19863	94.613	0.008	0.005	10000
160726-3	Okuma	Biceps femoris	Dry	4068.9	40.39	21366	126.09	0.010	0.006	10000
160726-3	Okuma	Biceps femoris	Dry	4068.9	40.390	21366	126.09	0.010	0.006	10000
160726-4	Okuma	Biceps femoris	Dry	4395.9	38.362	23336	120.89	0.009	0.005	10000
160728-1	Katsurao	Biceps femoris	Dry	3829.4	36.291	20142	114.09	0.009	0.006	10000

160801-1	Okuma	Biceps femoris	Dry	2299.4	81.275	12200	248.92	0.035	0.020	1000
160801-2	Tomioka	Biceps femoris	Dry	1596.2	60.092	7856.4	185.07	0.038	0.024	1000
160801-2	Tomioka	Biceps femoris	Dry	1596.2	60.092	7856.4	185.07	0.038	0.024	1000
160801-3	Fukushima	Biceps femoris	Dry	329.65	9.1825	1721.3	27.374	0.028	0.016	10000
160801-3	Fukushima	Biceps femoris	Dry	329.65	9.1825	1721.3	27.374	0.028	0.016	10000
160916-1	N/A	Biceps femoris	Dry	195.6	21.267	1233.7	71.379	0.109	0.058	2000
160917-2	N/A	Biceps femoris	Dry	147.47	11.379	825.93	33.832	0.077	0.041	5000
160917-2	N/A	Rectal content	Dry	125.52	14.632	933.11	51.283	0.117	0.055	2000
160917-3	N/A	Biceps femoris	Dry	391.56	15.242	1938.3	45.259	0.039	N/A	N/A
160918-1	N/A	Biceps femoris	Dry	1088.1	17.988	6014.7	58.582	0.017	0.010	10000
160918-3	N/A	Biceps femoris	Dry	322.3	11.986	1775.1	35.45	0.037	0.020	10000
160919-1	N/A	Biceps femoris	Dry	111.02	5.4509	560.33	15.856	0.049	0.028	10000
160919-2	N/A	Biceps femoris	Dry	N/A	N/A	373.48	32.328	N/A	0.087	5000
160920-1	N/A	Biceps femoris	Dry	14077	127.73	77435	417.92	0.009	0.005	5000
160928-1	N/A	Biceps femoris	Dry	149.97	8.6886	899.66	26.144	0.058	0.029	10000
161004-4	N/A	Biceps femoris	Dry	605.9	16.59	3440	52.237	0.027	0.015	10000
161004-7	N/A	Biceps femoris	Dry	702.87	15.963	3981.5	50.882	0.023	0.013	10000
161012 O-150	Okuma	Biceps femoris	Dry	3683..6	54.867	20887	177	N/A	0.008	N/A
161022-2	N/A	Biceps femoris	Dry	2998.3	29.975	17188	101.76	0.010	0.006	10000
161025 O-174	Okuma	Biceps femoris	Dry	6524.2	57.502	37464	191.28	N/A	0.005	N/A
161025	N/A	Biceps femoris	Dry	787.92	22.805	4664.8	74.352	N/A	0.016	N/A
161026 O-175	Okuma	Biceps femoris	Dry	376.12	7.7899	2118.5	23.968	N/A	0.011	N/A
161026 O-176	Okuma	Biceps femoris	Dry	1173.8	26.046	6986.3	82.123	N/A	0.012	N/A
161026 O-178	Okuma	Biceps femoris	Dry	4346.4	55.831	24824	178.13	N/A	0.007	N/A
161101-3	N/A	Biceps femoris	Dry	569.68	20.47	3311.3	66.694	0.036	0.020	5000
161111-3	N/A	Biceps femoris	Dry	677.13	19.759	3675.9	63.067	0.029	0.017	5000
161126-2 F-110 GPS	N/A	Biceps femoris	Dry	3174.7	43.077	18378	139.09	N/A	N/A	N/A
161130-2	N/A	Biceps femoris	Dry	751.7	22.757	4543.9	71.196	N/A	N/A	N/A

161130-3	N/A	Biceps femoris	Dry	1680	47.175	10034	151.03	N/A	N/A	N/A
161130-4	N/A	Biceps femoris	Dry	2045.3	63.542	12178	202.67	N/A	N/A	N/A
161206 O-229	Okuma	Biceps femoris	Dry	1863.3	59.23	11099	186.17	N/A	N/A	N/A
161206 O-237	Okuma	Biceps femoris	Dry	2730.1	63.849	16030	205.97	N/A	N/A	N/A
161206 O-238	Okuma	Biceps femoris	Dry	2515.2	62.215	15148	201.99	N/A	N/A	N/A
161206 O-239	Okuma	Biceps femoris	Dry	2510.1	58.728	14275	187.91	N/A	N/A	N/A
161208 O-240	Okuma	Biceps femoris	Dry	2089.8	52.364	12500	169.83	N/A	N/A	N/A
161209 O-242	Okuma	Biceps femoris	Dry	1272.3	23.508	7528.6	76.793	N/A	N/A	10000

APPENDIX F: CALCULATED T_{ag} RATIOS

Method 1: Utilizing local soil samples	Method 2: Utilizing database soil samples	Location
0.005965311	0.006905873	Namie
0.003404729	0.001799864	Namie
0.003040069	0.001607091	Namie
0.018296647	0.009672273	Namie
0.010304698	0.006979091	Namie
0.002903275	0.003948636	Namie
0.002765263	0.002627	Namie
0.011335969	0.013123333	Namie
0.009866408	0.011422063	Namie
0.004288578	0.005491432	Namie
0.003846189	0.002576364	Namie
0.002198516	0.001256818	Namie
0.002009276	0.001148636	Namie
0.000849227	0.000561244	Namie
0.007828266	0.007288571	Namie
0.003732011	0.002466444	Namie
0.019849664	0.013443636	Namie
0.011936242	0.008084091	Namie
0.001413216	0.001550577	Namie
0.000313554	0.000498667	Namie
0.009968771	0.007408889	Namie
0.002553936	0.00146	Namie
0.004540174	0.005256032	Namie
0.001368793	0.001300353	Namie
0.023731386	0.033375758	Fukushima
0.021601149	0.030379798	Fukushima
0.001530358	0.001035697	Fukushima
0.001898239	0.001284667	Fukushima
0.001701313	0.001151394	Fukushima
0.001692269	0.001145273	Fukushima
0.001864791	0.00126203	Fukushima
0.001385776	0.000937848	Fukushima
0.002041701	0.001381758	Fukushima

0.001415328	0.000957848	Fukushima
0.001375433	0.000930848	Fukushima
0.00460209	0.003114545	Fukushima
0.012048297	0.005216061	Fukushima
0.003403141	0.007093929	Okuma
0.003660651	0.292684932	Okuma
0.003998172	0.319671233	Okuma
0.020424107	0.167123288	Okuma
0.003657749	0.09570274	Okuma
0.001109162	0.029020548	Okuma
0.004253113	0.009547692	Okuma
0.006418732	0.014409231	Okuma
0.003578584	0.286123288	Okuma

APPENDIX G: ANOVA ANALYSIS

ANOVA analysis of location, age and sex using log-transformed data

```
> Anova(logModel, type = 3)
Anova Table (Type III tests)

Response: log(Cs.137.)
             Sum Sq Df  F value    Pr(>F)    
(Intercept) 278.600  1 371.4732 < 2.2e-16 ***
Location     37.756  2  25.1708 2.065e-08 ***
Age           0.733  2   0.4884    0.6163    
Sex           0.001  1   0.0009    0.9758    
Residuals    39.749 53                       
---
```

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Wednesday, January 25, 2017 at 7:40 PM
To: Anderson,Donovan
Cc: gsi-intex@ml.mlit.go.jp

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