Post-Fukushima Nuclear Power Plant Accident

UK Import Radiological Risk Assessment

An assessment of the radiological risk to public health from consuming Japanese food imported into the UK, if the 100 Bq/kg maximum level on radiocaesium for food imported from Japan, was removed

December 2021

Executive Summary

This risk assessment was produced by the Food Standards Agency's (FSA) radiological risk assessment team, in response to a request from Policy colleagues to evaluate the radiological risk[1] to UK public health if import controls were to be removed from foods imported from certain prefectures in Japan (Fukushima, Miyagi, Nagano, Gunma, Ibaraki, Yamanashi, Yamagata, Shizuoka, Niigata) following the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident in 2011.

The import controls in the retained EU Regulation 2016/6[2] impose special conditions governing the import of food from Japan following the FDNPP accident, and these were required to be reviewed by 30 June 2021. They include a maximum level of 100 Bq/kg radiocaesium activity concentration in food which represents a further level of precaution. Radiocaesium in this context refers to caesium 134 (Cs-134) and caesium 137 (Cs-137). As the question addressed by this assessment related to exposure to radiocaesium from ingestion of imported food, the dose from other exposure pathways was not quantitively estimated.

The following question was addressed in the risk assessment:

"What would be the radiological risk to public health from consuming Japanese food imported into the UK, if the 100 Bq/kg maximum level on radiocaesium (i.e., combining Cs-134 and Cs-137) was removed (considering the current activity concentrations in food currently reported in Japan*)?*"

This assessment of risk was based on a model which estimated the committed effective dose (CED) to different age groups, in millisieverts per year (mSv/year),

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[1] Health risk from the consumption of food imported from Japan that is contaminated with low levels of radiocaesium as a result of the FDNPP accident.

[2] EU regulation 284/2012 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station and repealing Implementing Regulation (EU) No 961/2011.

assuming imported food is ingested at reported UK consumption rates (Component A). This assessment also estimated the probability that a commodity exceeding the current 100 Bq/kg level would be imported into the UK if no import controls were in place (Component B). The excess lifetime risk to a member of the UK population of fatal cancers from ingestion of radiocaesium in Japanese imports was also calculated.

Foods produced in the Japanese prefectures affected by the FDNPP accident have been continually monitored for Cs-134 and Cs-137 by the Japanese authorities since the accident in 2011. These monitoring data have been collated and published on the Japanese Government website [MHLW]. Radiocaesium activity concentrations extracted from this data were used for the modelling throughout this risk assessment. The total number of foodstuff samples assayed by the Japanese government since the FDNPP accident was over 1.25 million.

The International Committee on Radiological Protection (ICRP) (ICRP 103, 2007) set out three types of public exposure scenarios. Food imported to the UK from Japan contaminated with radiocaesium following the FDNPP accident is classed as an "existing exposure[3] situation (because of the residual long-term radiocaesium contamination in food). ICRP (2007) recommends the use of reference levels for existing exposure situations in the range from 1 – 20 mSv.

The estimated dose calculated in this risk assessment was compared to the 1 mSv/year at the lower end of the ICRP reference level.

In line with recommendations made by the ICRP, in this assessment the habits of the representative person (RP) were selected to be those of someone who was likely to receive the highest dose, although it is recognised that those habits, while realistic, are likely to be hypothetical and therefore not exhibited by any specific person.

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[3] Existing exposure situations already exist when a decision on regulatory control has to be taken.

Overall, the risk assessment was based on four interconnected components. Components A and B (as introduced above) followed by an estimation of lifetime risk (Component C) and an additional stochastic assessment to further refine the estimated CED (component D).

The original assessment considered the outputs from 3 components (A, B and C) which provided a cautious risk assessment. An additional component (D) was subsequently completed because of recommendations raised on review. This component (D) is attached as Annex 1 to the main report and provides a more refined stochastic mechanistic approach to estimating the CED.

When undertaking the assessment, the results estimated in Component A identified the RP as a top two[4] adult consumer of soft beverages and alcoholic beverages with an estimated annual CED of 0.016 mSv/year, which is about 50 times lower than 1 mSv/year, the lower end of the 1 to 20 mSv/year ICRP reference level for existing exposures (ICRP 103, 2007).

The results of Component B were an estimated 0.18 % mean probability that any individual product imported into the UK would exceed 100 Bq/kg, and less than a 0.003 % mean probability that any individual imported product would exceed the 1,250 Bq/kg limit (the current retained level in EU Regulation 2016/52). This low probability of import indicates that it is unlikely that any individual would regularly consume food containing high activity concentrations of radiocaesium.

The CED (mean bound by 5 % - 95 % confidence intervals) calculated in component D (Annex 1), based on radiocaesium annual ingested activity distributions, Japanese import rates to the UK, demographic data and UK consumption rates, was estimated to be 0.0014 (5×10^{-5} - 7×10^{-3}) mSv/year with controls in place and 0.0016 (3×10^{-5} - 7×10^{-3}) mSv/year when controls had been removed.

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[4] A top two consumer is assumed to consume the two most highly contaminated food groups at a high consumption level (97.5th level consumption) and the remaining food groups at mean consumption levels. Mean radiocaesium activity concentrations were used for this assessment.

Using components A, B and C, the estimated dose for the RP is 0.016 mSv/year, which is 1.6 % of the lower end of the ICRP reference level of 1 mSv – 20 mSv/year for an existing exposure. This result is less than 1 % of the UK average annual dose from natural sources and small compared to the variation in natural background, UK HSA Environmental Radiological assessment Resources. The Japanese monitoring data shows that there were occurrences when products exceeded the 100 Bq/kg limit, however, these were rare (i.e., 1,485 occurrences (0.0013 %) of all measured foodstuff samples (within the scope of this assessment) from the Japanese monitoring data had radiocaesium activity concentrations that exceeded 100 Bq/kg; and 24 occurrences (0.000021 %) that exceeded 1,250 Bq/kg).

There was no significant difference in CED for the RP and all other population groups when the samples that exceeded 100 Bq/kg were removed. The stochastic model (Component D) estimated the highest additional dose to be 5×10^{-4} mSv/year (Annex 1). This indicated that the additional dose and risk if restrictions were lifted would be negligible.

These calculated doses roughly equate to a life time excess risk of fatal cancer of about 1 in million which is negligible compared to the baseline 2018 cancer fatality rate of 25%.

The estimated CED of 0.016 mSv/year to the RP (an adult consumer of alcoholic beverages and soft beverages) is considerably below the 1 – 20 mSv/year ICRP reference level for existing exposures. This has been calculated using the activity concentrations of radiocaesium measured in food samples monitored in Japan, adopting the top two consumption level approach, considering the lifetime risk and the likelihood that a person will receive that dose.

The estimated mean CED from component D of 0.0016 mSv/year and 0.0014 mSv/year (without and with 100 Bq/kg controls in place, respectively) is 10 times lower than the results estimated in component A and the 95% CED is 0.007 mSv/year, which is less than half the CED estimated from component A. These results (from component D) complement and validate the CED calculated in component A by showing that the dose is probably much lower than the deterministic estimate in component A suggests.

Therefore, based on this assessment, the removal of the 100 Bq/kg maximum level on radiocaesium for imported Japanese food would result in a negligible increase in dose and any associated risk to UK consumers.

These results are based on key assumptions and uncertainties which are detailed in the risk assessment.

Abbreviations

- **ARSAC**: Administration of Radioactive Substances Advisory Committee
- **Bq**: Becquerel
- **CED**: Committed effective dose
- **COMARE**: Committee on Medical Aspects of Radiation in the Environment
- **Cs:** Caesium
- **CWG**: COMARE Working Group
- **DNSIYC**: Diet and Nutrition Survey of Infants and Young Children DNSIYC
- **EU**: European Union
- **FDNPP**: Fukushima Daiichi Nuclear Power Plant
- **FSA**: Food Standards Agency
- **ICRP**: The International Commission on Radiological Protection
- **IPF**: Import production factor
- **LNT**: Linear no-threshold
- **LOD**: Limit of detection
- **MAFF**: [The Japanese] Ministry of Agriculture, Forestry and Fisheries
- **MHLW**: The Japanese Governments
- **mSv:** millisievert
- **NDNS**: National Diet and Nutrition Survey
- **NHS**: National Health Service
- **PHE**: Public Heath England (UKHSA)
- **RP**: Representative person
- **TEPCO**: Tokyo Electric Power Company
- **UK**: United Kingdom
- **UNSCEAR**: United Nations Scientific Committee on the Effects of Atomic Radiation

Table of contents

1 Scope

Risk question and scope

Using the FSA risk analysis process, the risk question asked was:

"What would be the radiological risk to the public in the UK if the 100 Bq/kg maximum level on radiocaesium (Caesium-134 (Cs-134) and Caesium-137 (Cs-137)) for food imported from Japan was removed (considering the current levels of activity concentrations in food currently reported in Japan)?*"*

The following details the scope of this risk assessment:

The assessment should determine the risk from food for human consumption produced in specific geographical prefectures (administrative regions) of Japan as listed in Annex II of retained Regulation 2016/6 as amended – namely Fukushima, Miyagi, Nagano, Gunma, Ibaraki, Yamanashi, Yamagata, Shizuoka, Niigata (as shown in Figure 1). This is because these prefectures were within 200 km of the Fukushima Daichii Nuclear Power Plant (FDNPP) and were the most affected by the incident in Japan.

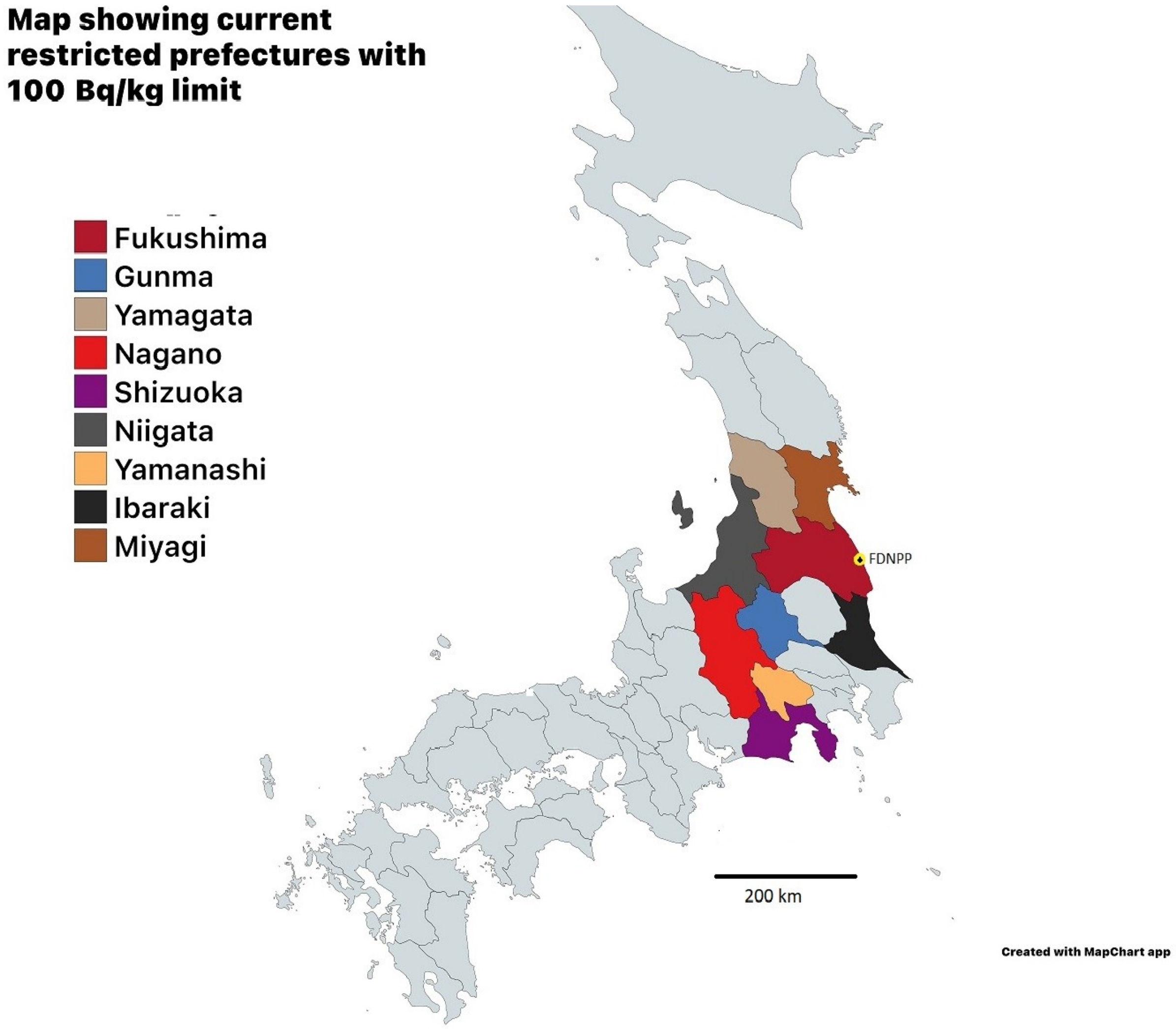

Figure 1 A map showing the current Japanese prefectures for which the 100 Bq/kg limit applies. (Created by FSA using Mapchart).

The only exposure pathway considered in this risk assessment was internal radiation exposure from ingestion of radiocaesium in food and beverages from Japan.

Other exposure scenarios such as external exposure during cooking and handling, skin and oral mucosa exposure and composting were not considered as these were assumed to be negligible and are out of scope of this assessment (but could be assessed at a later stage).

The following were considered out of scope for this risk assessment:

- Fresh meat for human consumption other than domestic bovine (retained Regulation 206/2010, Article 14 provides general conditions on the importation of fresh meat, which is permitted only from countries listed in Annex II, Part 1 and for the commodities listed for that country. In respect of Japan, only domestic bovine is listed in this Annex). This excludes game products such as wild boar meat.

- Animal feed – there are no current controls on feed and no recent monitoring data provided by the MAFF. However, current monitoring of animal products would include contributions made from the animals eating feed so the potential for contaminated animal feed has been included, by proxy, in this assessment.
- Wild meats such as wild boar and game as these are not permitted for import to the UK under current legislation.

2 Introduction

Background

On 11 March 2011, the Great East Japan Earthquake triggered a tsunami which caused an accident at Tokyo Electric Power Company's (TEPCO's) FDNPP in Japan. A loss of electrical power resulted in a large release of several activation and fission radionuclides (Cs-134, Cs-137, Iodine-131 (I-131), Iodine-129, Strontium-90 (Sr-90), Tritium, Plutonium-239, Plutonium-240[5]) (UNSCEAR, 2020). These were released as direct aquatic discharges and atmospheric releases which were deposited on land and the Pacific Ocean. These radionuclides contaminated food and fishery products from affected agricultural areas within Japan and the surrounding marine environment.

Following the accident, and to protect people from consuming potentially highly radiologically contaminated foods, restrictions were put in place to both prevent the marketing of the more contaminated foods in Japan itself and their export to the wider world. In the UK, the conditions of restricting import of foods from Japan has followed the EU regulation 2016/6. This regulation meant that any food produced in Japan could not be imported into the UK if it had a radiocaesium activity concentration exceeding 100 Bq/kg.

In January 2021, the FSA's Risk Assessment Unit was requested by the FSA's Policy team to undertake a risk assessment that would determine "What would be the radiological risk to the public in the UK if the 100 Bq/kg maximum level on radiocaesium (i.e., combined Cs-134 and Cs-137) for food imported from Japan was removed (considering the current levels of activity concentrations in food currently reported in Japan)?"

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[5] Additional radionuclides released with half-life's < 1year were: Xe-133, Sr-89, Ba-140, Te-127^{m}, Te-129^{m}, Te-131^{m}, Ru-103, Zr-95, Ce-141, Ce144, Np-239, Y-90, Pr-143, Nd147, Sb-127, Sb129, Mo-99. (Source Report of Japanese Government to FSA - personal communication).

Data from the Japanese authorities

The Japanese governments have carried out monitoring of food and beverages from immediately after the FDNPP accident in 2011 to the present (May 2021). The aim of the monitoring is to:

- establish provisional regulatory values,
- monitor foods and materials for agricultural production,
- enable restriction of distribution of food with radionuclide concentrations exceeding the regulatory values, and
- establish radionuclide contamination status of affected farmland.

This is to ensure sufficient supply of safe foods distributed across Japan, including foods to be exported.

The FSA was provided with publicly available data focused on radiocaesium activity concentrations in foods from these monitoring activities. The Japanese MAFF informed the FSA that the monitoring sample collection and testing regime mainly focused on the areas suspected of contamination (designated areas that exceeded specified limits of ambient dose rate). This constituted 1,252,017 foodstuffs sample measurements from years 2011 - 2020. Because of the preferential monitoring of foods which were suspected to be contaminated, use of these measurements in this assessment is likely to be cautious and lead to an overestimate of the radiological impact.

Outline

The intention of this risk assessment was to estimate the likely dose the representative person (RP) (explained in more detail in *Section 3*) would receive in the UK from consuming imported foods from Japan using the methods explained further in this report. This estimated dose was then compared with the 1 mSv/year from the lower end of the 1 – 20 mSv/year reference level which is explained further in Section 3.1.3.

The dose an individual may receive is related to both what foods they consume and where that food comes from. The magnitude of individual doses received by members of the UK population who consume food in Japan will also vary considerably. This is due partly to a range in the activity concentration in soil (even over relatively small areas) and the variability in uptake of radioactivity and associated rates for different crops. Radionuclides present in foods produced in Japan, even foods of the same type and grown in the same area, will have a large range in their activity concentrations. In addition, the diets of those eating foods produced in Japan are likely to vary considerably between individuals.

In this risk assessment, the FSA's remit is to give a baseline representation of the risk to the public based on the available evidence of consumers dietary choice. Therefore, the mean activity concentration (*i.e.,* level of radiocaesium in the food) and mean exposure level (*i.e.*, amount of food consumed) was assessed to represent the long term (annual) dose.

While it is recognised that some foods have been found with considerably higher activity concentrations, the amount of food with high radiocaesium activity concentrations may only form a small fraction of the total amount of food produced. Consequently, using the mean activity concentration in this assessment is considered to represent a more realistic long-term average of activity concentrations present in foodstuffs.

In line with guidance issued with respect to assessing doses from consuming foods contaminated with radioactivity from routine discharges (NDAWG PDF, 2008), this assessment considered that some individuals may obtain all a particular food from a single source, noting that it is highly unlikely an individual would do this for a large number of food groups (see Appendix H). To account for this situation, the dose to the RP was estimated assuming that two food groups, that resulted in the highest doses, were ingested at 97.5th percentile consumption rates, while all other food groups were consumed at average consumption rates.

3 Risk Assessment overview

This risk assessment follows the approach as laid down by the Codex Alimentarius and is composed of a hazard identification, hazard characterisation, exposure assessment and risk characterisation.

The RP method used is an agreed approach where a hypothetical individual is representative of the most highly exposed consumers (ICRP, 2006). This individual is a reasonable representation of reality, ensured through use of habits consumption data (described in *Section 3.3.4*). Throughout this assessment, where variability in doses from food may occur, a reasonable cautious approach was adopted.

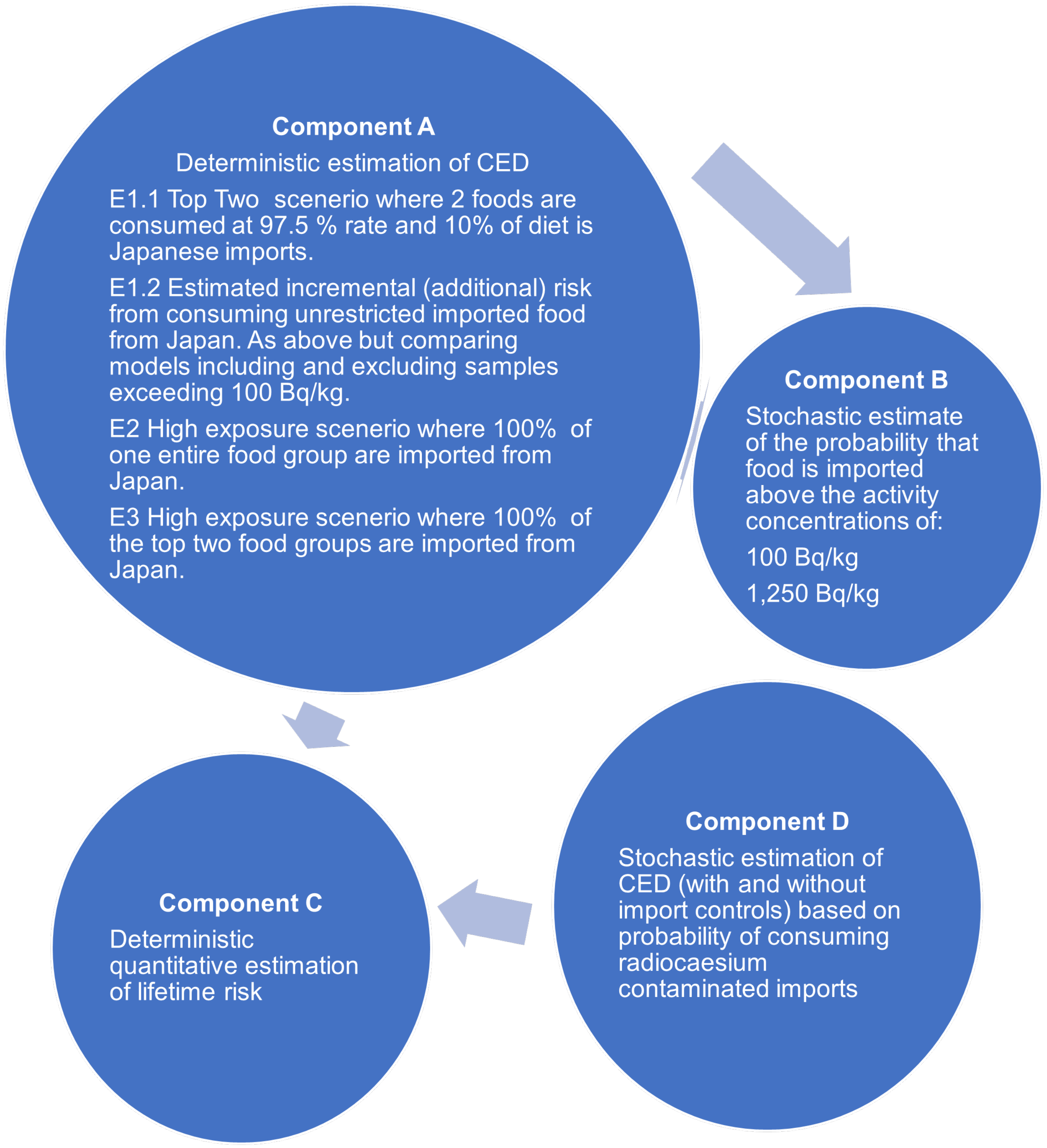
In this risk assessment, the FSA are only considering a single exposure pathway (ingestion of potentially contaminated foodstuffs imported from Japan) and not considering exposure from other sources of radiation. The dose to the RP from consuming imported foodstuffs from Japan will be compared to 1 mSv/year which is at the low end of the ICRP 1 – 20 mSv/year reference level for existing exposures (ICRP 103, 2007) (*Section 3.1.3*).

The exposure assessment firstly considers a cautious estimate which assumes that 10 % (Codex Alimentarius 2011) of a consumer's entire diet is sourced from Japanese imports (Component A, Scenario E1.1), exclusively from the prefectures outlined in *Section 1.1*. Within Component A, there are three other exposure scenarios (E1-3) outlined in the diagram below Fig.2.

Secondly in Component B, an estimate is made of the probability of a product exceeding 100 Bq/kg and/or 1,250 Bq/kg entering the UK from Japan.

The exposure assessment also assesses the difference in committed effective dose (CED) with and without import restrictions both within the deterministic component (A, E1.2) and probabilistic component D and then estimates the lifetime risk (Component C) (Sections 3.5, 3.6).

The main report for this assessment was originally based on 3 components (A, B and C) which provided a cautious risk assessment. An additional component was subsequently completed after the main report because of recommendations raised on review. This component, (D), is attached as an Annex (1) to the main report and provides a stochastic mechanistic approach which looks at the number of people that would be affected by lifting the import restrictions. Component D was based on the annual distribution of radiocaesium activity concentrations within the food groups, demographic data, import rates and UK consumption rates.



Component A

Deterministic estimation of CED

E1.1 Top Two scenerio where 2 foods are consumed at 97.5 % rate and 10% of diet is Japanese imports.

E1.2 Estimated incremental (additional) risk from consuming unrestricted imported food from Japan. As above but comparing models including and excluding samples exceeding 100 Bq/kg.

E2 High exposure scenerio where 100% of one entire food group are imported from Japan.

E3 High exposure scenerio where 100% of the top two food groups are imported from Japan.

Component B

Stochastic estimate of the probability that food is imported above the activity concentrations of:

100 Bq/kg

1,250 Bq/kg

Component D

Stochastic estimation of CED (with and without import controls) based on probability of consuming radiocaesium contaminated imports

Component C

Deterministic quantitative estimation of lifetime risk

Figure 2 Risk assessment components.

Hazard Identification and Characterisation

Radionuclide contamination following the FDNPP accident

It has been 10 years since the FDNPP accident and most radionuclide contamination has since decayed from natural processes. However, there remains a potential health hazard from those radionuclides with a long physical half-life, specifically, Cs-137 with a half-life of 30.1 years and Cs-134 with a half-life of 2.1 years. These radionuclides can be detected in certain foodstuffs produced in Japan and from the surrounding ocean. Both Cs-137 and Cs-134 were released together in approximately the same amounts (*Section 3.1.2*). Although Cs-134 is decaying at a faster rate than Cs-137, it has been used as a fingerprint[6] for contamination by the longer-lived Cs-137.

Cs-134 and Cs-137 are the only radionuclides considered in this risk assessment because there is monitoring evidence that they are still present in Japanese foodstuffs. Other radionuclides that were released may persist but there is little evidence that they are a source of food contamination and hence have not formed part of the routine monitoring programme by the Japanese governments for a number of years.

Source term

The EU Commission Implementation Regulation No 284/2012[7] of 29 March 2012 states that since the Fukushima reactor was stabilised in 2012, I-131 (half-life 8 days) is no longer present, and other radionuclides were not released in significant quantities to be of concern. Therefore, as mentioned earlier, this risk assessment is only concerned with radiocaesium because Cs-134 and Cs-137 may still be present in foodstuffs produced in some regions of Japan and from the surrounding ocean.

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[6] This is standard practice used in the Japanese laboratories where the characteristic high energy photopeak of Cs-134 is used to identify the presence of Cs-137.

[7] EU regulation 284/2012 imposing special conditions governing the import of feed and food originating in or consigned from Japan following the accident at the Fukushima nuclear power station and repealing Implementing Regulation (EU) No 961/2011.

There is some uncertainty regarding how much surface contamination occurred during the FDNPP accident. The FSA has been provided with an estimated source term by the Japanese Government of $1.5\times10^{+16}$ Bq of Cs-137 and $1.8\times10^{+16}$ Bq of Cs-134 being released into the surrounding environment in 2011[8]. The UNSCEAR (2020) report estimates for Cs-137, 6 – $20\times10^{+15}$ Bq were released into the atmosphere of which 5 – $11\times10^{+15}$ Bq (Cs-134 and Cs-137) was deposited into the marine environment in the initial phase and 3.5 - $5.6\times10^{+15}$ Bq (Cs-134 and Cs-137) had been released *via* an aquatic route, directly into the marine environment.

With no further information available, it is assumed in this risk assessment that the retrospective measured values of radiocaesium activity concentrations (combined Cs-134 and Cs-137) in food and beverage samples (in Bq/kg) are representative of the distribution of activity concentrations within the prefectures.

Current control measures

The control measures in retained EU Regulation 2016/6 ‘imposing special conditions governing the import of food from Japan following the Fukushima nuclear power station accident’ are currently in place in the UK. The level is 100 Bq/kg for combined radiocaesium in food and was applied by the EU to maintain consistency with the action levels used internally by Japan. In 2021, the level is still applied to the following prefectures of Japan: Fukushima, Miyagi, Nagano, Gunma, Ibaraki, Yamanashi, Yamagata, Shizuoka, Niigata.

The International Committee on Radiological Protection (ICRP) (2007) set out three types of public exposure scenarios. This situation would be classed as an “existing exposure” for which a reference level of 1 – 20 mSv/year has been set. For comparison, according to Public Health England, the average dose that a member of the UK public is exposed to is about 2.7 mSv/year, which is predominantly natural background radiation.

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[8] Report from Japanese Government to FSA (Internal communication).

Therefore, in this risk assessment calculated doses to the RP are compared against the value of 1 mSv/year because it is the low end of the 1 – 20 mSv/year reference level for existing exposures

Radiocaesium identification and detection

Food produced in Japan can be screened for radiocaesium using gamma detectors because photons from Cs-134 and Cs-137 can be efficiently detected by readily available gamma counting equipment, Gamma-Ray detection with scintillators, Mirion Technologies. The equipment used by Japan's laboratories to test food samples for radiocaesium are germanium detectors and scintillator detectors, Testing Methods for Radioactive Substances in Food, Notice No. 0315 Article 4 of the Department of Food. Safety, March 15, 2012 (PDF). Following a request by the FSA, the Japanese government provided written procedures and quality assurance documents describing the equipment and laboratory methods used in their monitoring programme (see Appendix A). The Japanese laboratory has ISO 17025[9] accreditation.

3.1.1.1 Biokinetics of radiocaesium

Radiocaesium is analogous to potassium and follows a similar metabolic pathway in humans. Radiocaesium can enter the human food chain because it is actively taken up in the biosphere and particularly concentrates in fungi, wild plants and animals, and fishery products such as bottom feeding aquatic species. If these contaminated foods are ingested by humans in high quantities, adverse health effects may result.

In humans, radiocaesium is absorbed from the gut into the blood stream and then distributed into all visceral and muscle tissues exposing the entire body to radiation.

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[9] Guideline for Inspection Work Management" based on Food Sanitation Act, Att.2). (1) Public labs and (2) MHLW registered labs, which mainly perform the domestic monitoring as well as the (3) ISO 17025 accredited labs are registered for export.

From the ICRP model for systemic uptake of radiocaesium (ICRP, 1994), it is assumed to be uniformly distributed in the body and the retention half time[10] is estimated to be 110 days and dependent on many factors such as, cardiac output and extraction, and transfer rates[11] (Leggett, 2011).

Health effects

For radiocaesium and its progeny[12], nuclear decay transformations result in emission of ionising radiation in the form of high energy gamma rays and beta particles. This radiation damages tissue by causing ionising events and the production of free radicals[13] which can result in breakages of chemical bonds in biomolecules such as DNA.

At very high doses (greater than few hundred mSv), radiation can kill cells resulting in the individual showing visible signs that they had been exposed to radiation in days or weeks and high doses of radiation kill large numbers of cells which can result in overt damage to organs and tissues. Such severe acute tissue damage will only occur when the dose received exceeds a threshold level whose value depends on which tissue or organ is exposed. The magnitude of damage caused from these deterministic health effects is proportional to the dose received once the threshold dose is exceeded. As these effects only occur at very high doses, they will not arise as a result of consuming food from Japan and hence are not considered further in this assessment.

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[10] Retention half time is the length of time it takes to eliminate half of the tissue/organ's content by biological processes only, in the absence of radioactive decay.

[11] Extraction and transfer of the radiocaesium from one compartment to another such as blood/tissue and renal clearance.

[12] Cs-137 decays by βeta emission [512Kev] to $Ba137^m$ which emits gamma at about 662 Kev. Cs-134 decays by electron capture and emits βeta particles and gamma rays of average energy 698 KeV.

[13] When Ionising radiation interacts with tissue it deposits it energy and produces oxygen-derived free radicals in the tissue environment; these include hydroxyl radicals (the most damaging), superoxide anion radicals and other oxidants such as hydrogen peroxide.

3.1.1.2 Radiation induced cancers.

Ionising radiation is a known carcinogen and exposure to radiation increases the probability that cancer may develop in the exposed individual. Where doses from exposure to radiation are below the threshold for severe tissue damage the main impact on health is the potential for development of cancer. Within the linear no-threshold (LNT) model[14], the internationally accepted approach to practically manage stochastic risks to health, the probability that cancer develops depends on the magnitude of the dose; a higher dose means a greater risk of cancer. It is the probability of these stochastic effects occurring, expressed in terms of either a committed effective dose (CED) or a lifetime risk , as a result of eating contaminated food for 1 year, that are assessed in this report.

3.1.1.3 Lifetime risk

An approximate estimate of the lifetime risk from radiation exposure can be obtained using the ICRP (2007) value of 5 % per Sv for fatal cancer, which represents an average over all ages and both sexes, as well as applying to a globally-averaged population. Using this value, an annual effective dose of 0.02 mSv corresponds to a risk of fatal cancer of about one in 1 million, although it should be recognised that the numerical values of risk at such low doses are uncertain.

In this assessment, the lifetime risk of excess cancers will be assessed by comparing the estimated CED with the risk from a CED of 0.02 mSv/year.

There are limitations when calculating lifetime risk which are discussed in Section 6.

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[14] ICRP, 2005. Publication 99. Low-dose Extrapolation of Radiation-related Cancer Risk. The LNT model assumes there is no lower threshold at which stochastic health effect begin and assumes a linear relationship between CED and health effects.

Exposure Assessment

To calculate the CEDs, there were four different components which had been developed to explore the exposure assessment using slightly different methods. Component A used 4 different exposure situations. Component B provides an estimate of the probability that a product exceeding 100 Bq/kg and/or 1,250 Bq/kg[15] could enter the UK, from Japan. Component C assesses the lifetime attributable risk. Component D provides an estimation of CED from an annual importation risk assessment. The annual radiocaesium activity consumed by food group was estimated for two different scenarios, 1. no controls on activity concentration, 2. controls where foods with greater than 100 Bq/kg radiocaesium activity concentrations were removed. The difference in dose between controls or no controls was also calculated.

Individual radiation exposure may extend over several years and the activity concentrations for Cs-137 and Cs-134 in foods from Japan will not decrease significantly in the next few years unless farming methods and other practices change. Cs-134 activity concentrations are already relatively low and Cs-137 activity concentrations will continue to slowly decline.

In this section, the hazard (radiocaesium) is combined with the exposure (estimated exposure levels from food ingestion) to assess the potential CED’s, which are then used to estimate the risk of adverse health effects.

The four parameters used in this risk assessment are:

- the total radiocaesium activity concentrations in food,
- the consumption rates of food,
- the import production factor and
- the volume of food imported from Japan.

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[15] The maximum permitted level set in retained EU Regulation 2016/52 which would apply in the EU/UK following a nuclear accident, based on expected consumption for a full local diet. The level of 1,250 Bq/kg was set on the basis of keeping doses below 1 mSv and the 100 Bq/kg level represents a further level of precaution.

These parameters were multiplied to determine a reasonable estimate of the effective dose to the RP, and hence the associated risk.

Data for measured radiocaesium activity concentrations from the Japanese food monitoring programme, consumption data for UK consumers and food volume import data from Japan to the UK were obtained (see Section 3.4). The Import production factor considers the amount of imported food that may be consumed and the ingestion dose co-efficients are constants for specific radiocaesium isotopes that are used to calculate effective doses from radiation.

Component A

The determination of CED to the RP in this risk assessment is dependent on activity concentrations of the food samples measured in the Japanese monitoring programme, the UK consumption rates, the amount of foodstuff imported to the UK and the age dependent dose co-efficient.

As the FSA was provided with the publicly available radiocaesium activity concentrations (Bq/kg) in foodstuffs and beverages, a dose assessment was completed using a deterministic approach within Microsoft Excel. This approach was used due to the low magnitude of CED expected and hence a more time-consuming sensitivity analysis or a statistical approach was not warranted. The equation below (adapted from Codex, 2011) was used for each food group and age group to calculate the annual CED to consumers and identify the RP(s). The critical foods with the highest dose were identified using the rank function in Microsoft Excel.

$$Dose_{ingestion,age} = e(\tau)_{age} \times r_{age} \times f_{\,(food\ group)} \times IPF$$

Where,

$Dose_{ingestion,age}$ = *age related ingested effective dose*[16] *(Sv/year)*

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[16] Effective dose is a unit of prospective dose assessment and the dose quantity used in the International Commission on Radiological Protection (ICRP) system of radiological protection. Committed effective dose [CED] is the sum of the products

$e(\tau)_{age}$ *= age related ingestion dose co-efficient (Sv/Bq) (dose per unit intake)*[17]

r_{age} *= age related consumption rate (Kg/year)*

$f_{(food\ group)}$ *= mean radiocaesium [upper limit of detection (LOD)] activity concentration measured in food group (Bq/Kg).*

IPF = 10 % (0.1) Import production factor: the ratio of the amount of foodstuff imported per year from Japan to the total amount produced annually in the UK (*i.e.,* Fraction of each food group consumed by an individual that was assumed to be imported from Japan) (*Section 3.3.1*).

Mean annual consumption values were used for each food group and mean radiocaesium activity concentrations were used for each food product. Ingestion dose coefficients for each food group are shown in *Table 1*.

In line with best practice, where specific habit data is not present, the top two approach was used to estimate the dose from consuming food obtained from Japan (NDAWG guidance). This approach is widely used in the UK for assessing the impact from routine radioactive discharges into the environment for example, RIFE so, it was considered to be a robust approach to use in this case. In the top two approach, the two foods that were shown to contribute the highest doses, assuming average annual intakes, were assumed to be ingested at the 97.5th percentile rate of that recorded in the national diet surveys (National Diet and Nutrition Survey; NDNS and the Diet and Nutrition Survey of Infants and Young Children; DNSIYC), while all other foods were assumed to be ingested at the average consumption rates from those surveys. This calculation was performed separately for each age group. This approach is likely to represent a cautious estimate of the dose as it is unlikely any individual obtains a significant amount of a large variety of foods from the contaminated area of Japan.

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of the committed organ or tissue equivalent doses and the appropriate tissue weighting factors W_T, where *t* is the integration time in years following the intake. The commitment period is taken to be 50 years for adults, and to age 70 years for children.

[17] Dose coefficients are derived from ICRP119 and defined as committed effective dose per unit acute intake of a radionuclide and takes into account biokinetics, radiation characteristics, yields and energies and its radioactive progeny.

It was highlighted that scenarios may exist whereby an individual consumes all of one particular food product in their diet which has been imported from Japan. To address this, an assessment was conducted to determine the food group that would result in the highest dose to an individual if consumed at a high rate (97.5th percentile) over a year, assuming all of that food consumed came from Japan (i.e., the IPF is equal to 1). Again, mean radiocaesium activity concentrations were used for this assessment.

The incremental (additional) risk, if the restrictions were lifted, was estimated by comparing the results of the doses calculated using the entire data set with those calculated when activity concentrations exceeding 100 Bq/kg were removed.

The following sections describe the parameterisation for each factor.

Estimating the import production factor, IPF

It is highly unlikely that a person's entire diet is consistently comprised of foods imported from Japan. Therefore, in this risk assessment the import production factor (IPF) as recommended by Codex Alimentarius Commission guidelines (Codex, 2011) was applied to the final calculation where it is assumed that approximately 10 % of the diet is imported from Japan. The application of the IPF to the dose calculation accounts for the low probability event that a significant quantity of food consumed by any individual was imported from the areas contaminated by the FDNPP accident. This is most likely an overestimation but has been used as a cautious value. The FSA also made a conservative estimation of the dose if an individual obtained and consumed all (100 %) of any individual food group from the contaminated areas of Japan. In this case, the IPF was assumed to be 1 (*i.e.*, the 100 % scenario A, E-2 and scenario A, E-3).

Applying the dose coefficient, $e(\tau)_{age}$ (Sv/Bq)

Ingestion dose coefficients are a measure of the damaging effects a particular radioactive material can have on the human body if ingested. Ingestion dose coefficients are formulated from background/historic data and the developing knowledge of radiobiology, biokinetics and linear energy transfer of the radionuclides once ingested. Ingestion coefficients are age-specific and defined as the dose per unit intake (DPUI) in Sv/Bq. DPUI of radiocaesium increases with age and is highest in adults (*Table 1*). The dose coefficients for Cs-137 and Cs-134 were obtained from ICRP (2012). In radiation protection, recommendations from the ICRP (2006) state that estimating the dose to members of the population of age 1 year, 10 years and adult at the time of exposure provides adequate information to assess the potential risks to health that a population is exposed to, by accounting for factors such as physiological and habit changes with age. However, the NDNS data includes the dietary habits of all members of the UK population, and hence, is not presented within age range groups as required for this assessment. For this assessment, the NDNS data were therefore grouped into age categories broadly equivalent to those recommended by the ICRP (2006), as shown in *Table 1*, and the appropriate dose coefficient then applied. The pre-natal dose co-efficient was obtained from ICRP 88 (2002).

The entire UK population was assumed to be potentially exposed to imported foodstuffs from Japan. Therefore, the age groups in *Table 1* and their associated consumption habits were considered in the assessment. The age ranges chosen were based on data availability in the NDNS, DNSIYC and the best fit with the ICRP 119 (2012) age dependent dose coefficients.

Table 1: Ingestion Dose coefficients used for the selected age groups.

Age category (years)	**Coefficient used**	**Dose coefficient Cs-134 (mSv/Bq)**	**Dose coefficient Cs-137 (mSv/Bq)**
Adult (16 - less than 70)	Adults	1.90E-05	1.30E-05
Child 3 (10 to less than 16)	Adults	1.90E-05†	1.30E-05
Child 2	10 year old	1.40E-05	1.00E-05*

Age category (years)	**Coefficient used**	**Dose coefficient Cs-134 (mSv/Bq)**	**Dose coefficient Cs-137 (mSv/Bq)**
(5 - less than 10)			
Child 1 (18 months - less than 5)	1 year old	1.60E-05	1.20E-05
Infant (4 months - less than 18 months)	1 year old	1.60E-05	1.20E-05
Woman of childbearing age (16-less than 50) (foetus)	Prenatal child	8.70E-06~	5.70E-06~

*The dose coefficient for the 5-year-old child is slightly lower (9.6E-09 mSv/Bq), therefore the FSA used a cautious value for 10-year-old (1.0E-08 mSv/Bq).

† Where the ICRP 119 value changes from 10 to 15 years the highest value was selected.

~ICRP 88 (2002). Doses to the Embryo and Fetus from Intakes of radionuclides by the mother.

Estimating the mean activity concentration measured in foodstuff, $f_{food\ group}$ (Bq/Kg).

The Japanese governments have monitored foods and beverages for radiocaesium since 2011 (with monitoring and detection methods as described in Section 3.1.4) and these results have been made publicly available on the Japanese MHLW website (accessed 26 March 2021). The food samples tested for radiocaesium were taken from prefectures affected by the FDNPP accident (Fukushima, Miyagi, Nagano, Gunma, Ibaraki, Yamanashi, Yamagata, Shizuoka, Niigata) and represent the Japanese food basket (general food products). The major food products sampled were grains, vegetables, fruit, seafood, beef, milk, infant foods, tea, beverages, cultivated mushrooms and processed foods. Most of the samples were obtained from pre-market locations (93 %) such as farmers and producers and some were collected from shops (post-market, 4 %) the remainder were categorized as produced for sales (1.5 %) unspecified (1 %) or not marketed (less than 1 %).

Data for radiocaesium activity concentrations were obtained from the Japanese MHLW (no date for this reference) for years 2011 to 2020. In the first instance, data for all years (2011 to 2020) were combined into a single dataset. Only data for the prefectures listed in Appendix II of retained Regulation 2016/6[18] were used namely, Fukushima, Gunma, Ibaraki, Miyagi, Nagano, Niigata, Shizuoka, Yamagata, and Yamanashi). The dataset was filtered to include information for month, year, prefecture, food category, food tested, inspection methods, and activity concentrations of Cs-134 (Bq/kg), Cs-137 (Bq/kg) and total radiocaesium (Bq/kg). An additional column was generated to include "food group", where the "food tested" was sorted into one of 35 categories as listed in *Appendix B*. There were no activity concentrations data for the food group 'Yeast', or import data for the food group 'Agar', or import data identified as 'snacks' therefore, subsequent data analysis refers to 33 food groups for component A and 31 for scenario B. (Thirty food groups were used for component D because dried mushrooms were combined with other mushrooms).

Where data for radiocaesium activity concentrations included non-numeric characters, or characters not recognised on a UK keyboard (for example, a text entry such as 'NA' or a Japanese keyboard entry for '１．６' instead of 1.6), these were reviewed by two FSA radiological risk assessors and modified or removed accordingly. Products with insufficient information for classification were classed as out of scope for this risk assessment.

To select the most representative activity concentration data, from the total data available (2011-2020), the effect of remediation, radioactive decay and natural processes needed to be considered. Radiocaesium activity concentrations in foodstuffs were likely to decrease between 2011 – 2020, given that the physical half-lives of Cs-134 and Cs-137 are 2.1 years and 30.1 years, respectively (Dietz, Pachucki, & Land, 1963) and the fact that subsequent, extensive, ongoing remedial

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[18] Food and feed for which sampling and analysis regarding the presence of caesium-134 and caesium-137 are required before export to the Union.

action has been undertaken since the time of the accident which has reduced radiocaesium activity concentrations in agricultural products (IAEA, 2015; UNSCEAR, 2020).

To address yearly variability in measured radiocaesium concentrations in food stuffs (given that such activity concentrations may be unrepresentative due to probable decline since the accident) a parametric survival regression[19] analysis was fitted to both the Cs-134 and Cs-137 activity concentrations data for each food group (using the '*survreg'* function, within the survival package) (Therneau, 2021) using R statistical software (version 4.0.0) (R Core Team, 2020). Survival analysis was selected to assess year-to-year variation in radiocaesium activity concentrations data because it fits probability models to censored data to estimate the maximum likelihood values. Survival models allow incorporation of the upper and lower bounds (section 3.3.3.1) for radiocaesium activity concentrations within a single model and enables estimation of confidence intervals around the fitted values.
Datasets for Cattle and Saltwater fish were too large to run the survival models (944,324 and 81,148 samples, respectively), so a random sample of 25,000 was selected for each group within the analysis. Samples were randomly selected using the '*sample_n'* function, within the dplyr package (Wickham *et al*., 2021). However, taking a sub-sample of the datasets may obscure some subtle trends within the dataset.

The year-on-year comparison showed that for all food groups, the activity concentrations in 2011 and 2012 for both Cs-134 and Cs-137 were statistically significantly higher than years 2013 to 2020. Based on this, the activity concentrations data for 2011 and 2012 were removed from this assessment (see explanation in Appendix E). The years from 2013 - 2020 were included because using a larger dataset increases reliability of the calculation and since there were no significant differences between the years, it was taken to represent the current activity concentrations, although this is recognised to be a cautious approach.

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[19] A statistical technique for examining the relationship between variables using a specified probability distribution (usually a Weibull distribution). An estimate of baseline hazard function and coefficients for covariates can be provided.

The total number of activity concentrations data records used in the final analyses was 1,252,017. The results for the lower and upper bound radiocaesium levels are shown in .

3.1.1.4 Quantifying Less than values / limits of detection (LOD)

To estimate the mean radiocaesium activity concentrations in foodstuff, $[f_{food\ group}]$ the data that were below the limits of detection (LOD) needed to be assigned an appropriate value. The minimum detectable activity using (radiation detection instruments) is the amount of radiation that can be detected with confidence (smallest true quantity value of the measurand[20] that can still be detected with the applied measurement procedure) and is a function of the individual instruments used. From the data and laboratory methods provided by the Japanese monitoring laboratories, it was evident that the detection instruments used (germanium and scintillation detectors) had a wide variation in the LOD.

The LOD is sample specific and related to the sensitivity, detection efficiency and energy resolution of the instrument. Difference in performance can also arise from the nature of the sample (mass and volume), characteristics of the instrument, correction factors, sample count time, calibration, daily variation in background and other applied correction factors. The food monitoring data submitted to the FSA contained a high percentage of values recorded as below the LODs across all the food groups. Specifically, for total radiocaesium data entries, there was a total of 1,079,956 LOD values; for Cs-134 there were 355,253 and for Cs-137 there were 327,132 LOD values (90%[21] of all the data was classed as LOD [total radiocaesium and Cs-137 and Cs-134]). In some cases, only total radiocaesium values were given as less than values (with blank entries for Cs-134 and Cs-137).

To incorporate the data from results below the LOD’s into the risk assessment, FSA risk assessors utilised technical information from Japan and judgement from

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[20] Measurand: An object being measured; a physical quantity or property which is measured.

[21] Some LOD entries were for total radiocaesium only and breakdown of Cs-137 and Cs-134 was not recorded.

published guidance (IAEA, 2004[b]) to assign probable values. As it is unknown if the actual activity of the results below the LOD is 0 or the upper limit, we were unable to qualify these readings with any set degree of certainty and there is no consensus on how to incorporate LOD into statistical models. Therefore, the most conservative approach was used to assign probable values to the reported LOD values. The LOD values were assigned a value equal to the upper LOD in the first instance *i.e.*, a less than value 'less than 25' was assigned an upper limit 25 Bq/kg, and a value of 50 % of the less than value was assigned as the lower LOD (*for example,* a reading of 'less than 25' would have a lower LOD limit value of 12.5 Bq/kg). Where activity concentrations were only provided for total radiocaesium, it was assumed that the activity concentrations were evenly split between Cs-134 and Cs-137.

The mean upper bound activity concentration for Cs-137 and Cs-134 for each food group is illustrated in . The outputs for the calculated mean (upper and lower LOD) radiocaesium activity concentrations are shown in the tables in Appendix F.

The LOD was the most uncertain parameter and is discussed in the sensitivity analysis (see *Section 8*).

3.1.1.5 Food Group Classification

The data were filtered to remove those foods that were considered to be out of scope for this assessment (for example, wild meat products) with the remaining foods being classified into various categories according to the 33 food groups and correlation with available UK consumption data (see).

Food groups were carefully considered based on the typical classes of food regularly imported from Japan and the radiocaesium activity concentrations data available for each food category.

There was occasional difficulty in classifying some samples of food due to lack of data and interpretation ambiguities. (for example, unnamed samples, insufficient information, unknown food category, non-numeric characters). A total of 151 samples were rejected constituting less than 0.02% of the total data. These were excluded from the analyses but would have little effect on the overall outcome of the risk assessment due to their small number.

Estimating the consumption rate, r_{age}(Kg/year)

UK consumption data for each food group were obtained from the NDNS (Bates *et al.*, 2014; 2016; Roberts *et al.*, 2018) for ages 18 months and over. The NDNS data shows three[22] different percentiles of the distribution of consumption across the nation. This allows a basic sensitivity analysis to be carried out between average consumption rates and highly conservative estimates within the exposure populations.

Consumption data for ages 4 to 18 months were obtained from the DNSIYC (DH, 2013).

Food consumption assessments were carried using NDNS or DNSIYC data, depending on the age group being assessed (*Table 1*). Chronic consumption was calculated based upon the daily average calculation, which is the average food intake per day and, therefore, depends on the amounts consumed and the survey length. The mean consumption was calculated using the mean intake for each subject (respondent) during the survey for that food and the mean number of subjects. Consumer-based consumption was used, so the mean is averaged over the number of consumers of the specific food, rather than population-based (where the mean is averaged over all respondents in the survey, regardless of whether they consumed the food or not).

Based upon the activity concentrations data for radiocaesium levels in foods sampled in Japan, some corrections were applied to the consumption data to provide a more realistic dose calculation (Exposure assessment scenario A, *Section 3.3*). Beer and cider were removed from alcoholic beverages as they were not represented in any of the food samples measured for radiocaesium. A dilution factor of 1 % was applied for dry tea food codes, 3 % for dry coffee food codes and 20 % for squash/concentrated

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[22] Mean,97.5% percentiles and max:1) g/day:2) g/kg body weight per day: 3) g/year.

fruit drink food codes. These assumptions were based on expert judgement and data from the products used. However, it is acknowledged that consumers may consume these aforementioned food groups in a different way to that which has been assumed here. For example, people may add more or less tea or coffee to their drinks, similarly with squash drinks. Furthermore, "Water as a diluent for…[23]" food codes were removed from the soft beverages group. It was assumed that these would be tap water food codes and the FSA are only considering soft drinks that would be imported.

The percentile is the value of a variable below which a certain percentage of observation falls. For example, the 97.5th percentile consumption rate is taken to represent the mass of food consumed by 97.5 % of those consuming the food, or to put it another way, only 2.5 % of people who consume that food may eat a greater mass. The 97.5th percentile is used in this assessment to represent a value towards the upper end of the range recognising that, while higher values may be present within a population, they will be exceptionally rare and therefore will not be representative of the vast majority of the general population.

In this exposure assessment, the FSA modelled the CED from a total diet for which consumption of all food groups was assumed. The mean radiocaesium activity concentrations and mean consumption values were used. For the top two approach (see *Section 3.3*) the 97.5th percentile consumption values were used.

Estimation of incremental (additional) dose if the 100 Bq/kg level is removed (E1.2).

Foodstuffs with activity concentrations of 100 Bq/kg and below are currently permitted to be consumed without restriction in the UK. The incremental risk incurred by removing the 100 Bq/kg level was calculated by comparing the CED calculated for the entire dataset with the CED calculated when samples exceeding 100 Bq/kg had

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[23] Water, in this instance, would probably come from a consumer's tap for example, used to dilute squash or boiled to make tea/coffee. Assuming that this water is from the consumer's tap means that it is not imported from Japan.

been removed from the dataset. Microsoft Excel and R were used to create subsets for each food group, for example, Subset A. E1 and calculate the CEDs.

This calculation gives an estimate of the portion of dose due to foodstuffs containing radiocaesium activity concentrations exceeding the current regulatory limits, assuming the same people eat the food in both cases. The assumption that 10% of the RP diets is from Japanese imports was made to enable direct comparison between the two datasets.

To compare the two groups, a Wilcoxon rank sum test[24] was performed for each age group in R to assess whether removing samples exceeding a total radiocaesium activity concentration of 100 Bq/kg had a significant impact on the mean dose or 97.5th percentile dose (using the '*wilcox.test'* function within the stats package) (R Core Team, 2013). This test was done without applying the IPF (*i.e.,* assuming that the total diet is from Japanese imports). The import risk assessment (component D) also looks at the difference with and without import restrictions in place and this is explained in Annex 1.

Sensitivity analyses approach for component A

For the deterministic scenario (A) the sensitivity was tested by varying the parameters of mean food consumption rate and total radiocaesium activity concentration. Specifically, the values for the mean consumption were replaced with a scenario where the consumption is +/- 10 % of the mean consumption rate for each food group, this was repeated by varying the total radiocaesium by +/- 10% in the same way. The mean (baseline) effective dose was compared to the recalculated output from the above scenarios to evaluate the impact.

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[24] A non-parametric Wilcoxon ranked sum test was selected because the Shapiro-Wilk test for normality showed that data were not normally distributed ($p < 0.001$ in all cases). The Wilcoxon ranked sum test is a non-parametric alternative to the paired t-test and compares two related samples to assess whether mean ranks are different from one another.

Component B

Scenario B was conducted using @Risk version 7.6, a Microsoft excel-based Monte Carlo simulation software (Palisade, 2021). The aim of scenario was to estimate the probability that an imported product, entering the UK, will have combined levels of radiocaesium greater than 100 Bq/kg, if the restrictions were lifted.

@Risk modelling parameters

3.1.1.6 Radiocaesium activity concentration for @Risk modelling

The combined Cs-137 and Cs-134 activity concentrations were included in the @Risk model when they exceeded 100 Bq/kg. The 100 Bq/kg value was selected based on the following rationale:

i. 100 Bq/kg is the current level of restriction imposed by the Japanese government for foods [Including beverages][25] consumed within Japan and exported from Japan.[26]

ii. 100 Bq/kg is the current maximum permissible radiocaesium activity concentration in imports of edible foods to the UK imposed by EU (2016/6) legislation and retained in UK legislation.

A second assessment was also conducted to assess the probability that imported products will contain greater than 1,250 Bq/kg of total Cs-134 and Cs-137 activity concentrations (the current retained EU Regulation 2016/52).

The Monte Carlo simulation capability of @Risk encapsulates variability and uncertainty when generating output (for example, probability and/or the percentage likelihood) values.

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[25] All foods mentioned include alcoholic and soft beverages such as Juices, teas, and alcoholic drinks.

[26] https://www.maff.go.jp/e/export/pdf/safety_en_210129.pdf

The probability that an imported product will have combined levels of Cs-134 or Cs-137 greater than 100 Bq/kg (denoted as *D*) is dependent on the volume imported (*A1*), prevalence of contaminated samples above the threshold (*A2*), sensitivity of the export test (*A4*), any decay during transportation (*B*) and any post import testing that may be carried out (*C*), represented by the following equation:

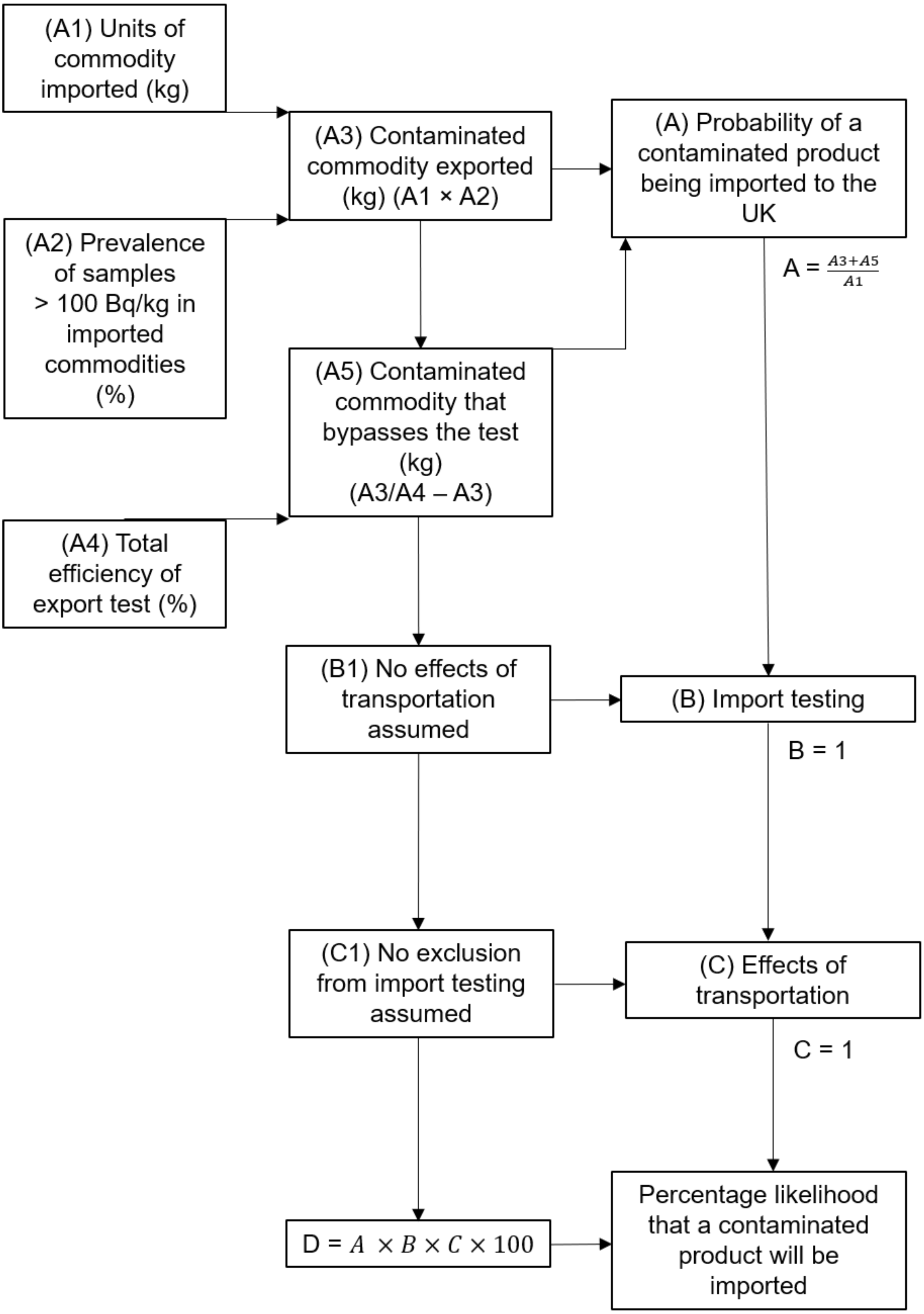
$$D \sim \left(\frac{(A1\ x\ A2) + \left(\frac{A3}{A4 - A3}\right)}{A1} \right) x\ B\ x\ C$$

The risk pathway is shown in Figure 3 and the following sections describe the parameterisation of each step in the pathway.

Data for the upper values for total radiocaesium activity concentrations and the average quantity of imported product (kg) for each commodity was used. It was cautiously assumed that there were no effects of transportation (*i.e.,* not considering radioactive decay in transport (as transport normally occurs within a few months of testing which is a short timescale compared with the half-lives of the radionuclides hence little decay would occur in most food) or any exclusion from import testing at the border, so each of these values was set to one.

Calculations were performed for each foodstuff individually, and for all foodstuffs combined. Convergence ensures that a sufficient number of iterations has been performed. The number of iterations run to achieve convergence for each food group are shown in Tables 3 and 4 and are between 2,900 and 6,000.

Further simulations were conducted to assess the percentage likelihood that imported products will contain greater than 1250 Bq/kg of total Cs-134 and Cs-137 (which is the current legislative value retained EU Regulation 2016/52).


(A1) Units of commodity imported (kg)
(A2) Prevalence of samples > 100 Bq/kg in imported commodities (%)
(A3) Contaminated commodity exported (kg) (A1 × A2)
(A) Probability of a contaminated product being imported to the UK
A = $\frac{A3+A5}{A1}$
(A4) Total efficiency of export test (%)
(A5) Contaminated commodity that bypasses the test (kg) (A3/A4 – A3)
(B1) No effects of transportation assumed
(B) Import testing
B = 1
(C1) No exclusion from import testing assumed
(C) Effects of transportation
C = 1
D = $A \times B \times C \times 100$
Percentage likelihood that a contaminated product will be imported

3.1.1.7 Units of commodity imported, (A1), kg/year

Yearly food import data (kg per year) from 2008 to 2020 were obtained from the Japanese MAFF public database (see *Section 2.2*) to give an appreciation of the foodstuffs that are regularly imported from Japan to the UK. Year-to-year import volumes did not significantly affect the outcome of the model (*Section 3.3.4*) and therefore this selected time frame was deemed sufficient for the analysis. The import data encompassed the whole of the Japanese edible food trade to the UK and were not available by prefecture. Imports only from specific prefectures under consideration have been controlled since 2011.

The HM Revenue and Customs database, accessed 3rd March 2021, for UK imports was used to establish the average rates of edible foods imported from Japan per food group/commodity per year. These were filtered to align with the 31[27] food groups under consideration. An excel summary sheet of the import data was produced (see Appendix D). Previous years' imported kg per year was randomly selected to represent the variability possible in a future year. A discrete distribution with an equal weight per year was used to describe the variability.

There is a possibility of mixing of foods prior to import from Japan. For example, some foods may be imported as a general food so any food produced by those prefectures will be mixed within the total mass of food produced by Japan (for example, rice). Some foods will be a specialist product from those contaminated areas so less mixing may occur prior to import. Therefore, it is not possible to precisely categorize each commodity imported into each food group, and there may be some overlap (for example, where a food is identified as mixed vegetables on import but could be fitted into ready meals or one of the vegetables groups), thus, the import data used was a best approximation of the amount of each food group imported.

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[27] No activity concentrations data were available for 'Yeasts'. The 'Cultivated mushroom' food group was combined with 'Mushroom' food group. 'Snacks' and 'Agar' were removed because of lack of specific import data. This takes the original 35 food groups to 31 food groups.

Prevalence of samples greater than 100 Bq/kg in imported commodities, (A2) (%).

The prevalence of contaminated samples within the commodity *(A2*, Figure 3) was calculated from the available data. The number of total samples and the number of samples greater than 100 Bq/kg in each food group are shown in the histogram below (Figure 4). Due to the large number of samples below 100 Bq/kg compared to the number of samples exceeding 100 Bq/kg, the results are displayed as the square root (n) for illustration purposes only.

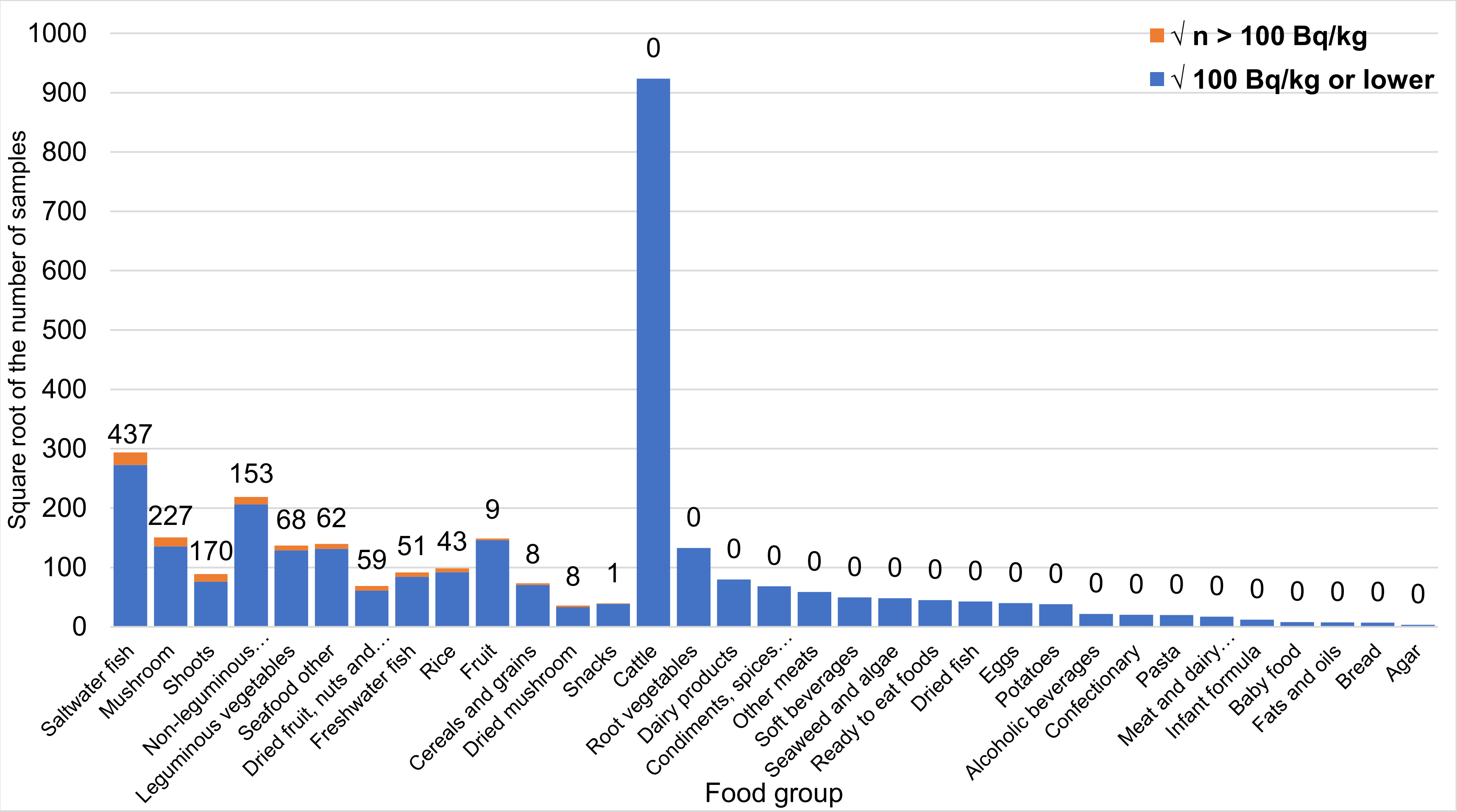

Figure 4: Number (Square root) of samples in each food group and the number of samples exceeding 100 Bq/kg. Note that this is for illustration purposes only.

To address uncertainty regarding the monitoring sample data (i.e., whether measured values are true values) a beta distribution was used. This was based upon the number of successes (those test positive [greater than 100 Bq/kg]) and total number of samples within the import activity concentrations data.

3.1.1.8 Total efficiency of export test (A4) (%).

The assessment in scenario B required the sensitivity/detection efficiency of the detection methodology for radiocaesium by the Japanese MHLW. The probability of a positive result (i.e., exceeding 100 Bq/kg radiocaesium activity concentrations) going undetected can be quantified by using the detection efficiency of the radiation detection instruments. The overall efficiency and sensitivity of gamma spectrometry also depends on other factors such as sample weight, geometry and counting time. It is beyond the scope of this assessment to determine the detection efficiency of instruments used in Japan, so a best estimate was used, derived from IAEA published data and advice from UK Health Security Agency (UK HSA) (formerly Public health England (PHE)). Moreover, since the registered private laboratory has ISO 17025[28] accreditation it was accepted that all the instruments perform to the required standards[29]. The absolute efficiency[30] of germanium detectors was assumed to be 6 % (IAEA, 2004[b]). (An efficiency of 6 % would mean that 6% of photons emitted by the source may not be detected). However, since some of the samples were initially screened with scintillator [31] detectors only, a cautious 25% efficiency was used.

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[28] The laboratories testing radionuclides in food perform quality control as prescribed in the Testing Methods as well as based on the notification of the Ministry of Health, Labour and Welfare (“Guideline for Inspection Work Management” based on Food Sanitation Act, Att.2).
(1) Public labs and (2) MHLW registered labs, which mainly perform the domestic monitoring as well as the (3) ISO 17025 accredited labs are registered for export.

[29] MAFF perform regular QA checks and the Relative efficiency for the Mirion Germanium detectors is 15% or higher.

[30] Absolute efficiency is the ratio of the total number of photons detected to the number of photons emitted by the source.

[31] Scintillator detectors are more efficient than Ge detectors but have poorer energy resolution for the Radiocaesium gamma peaks.

This value was obtained by considering expert advice from UK HSA[32] who suggested that the lowest possible value of efficiency should be used because the amount of effort which goes into optimizing the instruments is unknown. Therefore, a conservative absolute efficiency value of 25% was assumed and from this value the sensitivity of the test was derived and used in the risk assessment for Scenario B.

The number of contaminated products that bypass the test was calculated by summing the number of true positive samples and the number of false negative samples (calculated using the test sensitivity percentage).

Sensitivity analyses method for Component B

The sensitivity analyses for component B assessed the range of the mean, regression coefficient, regression, correlation coefficient and percentage contribution. This considered the variable units of commodity imported each year (Figure 2: *A1*) (due to year-to-year variability) and the prevalence of samples exceeding 100 Bq/kg (*A2*).

Component C - Estimation of lifetime risk

ICRP, in publication 103 (ICRP, 2007), specified a detriment-adjusted nominal risk coefficient of 5 % per Sv that can be used in the calculation of fatal risks after exposure to radiation at low dose rates that are appropriate for the purposes of radiological protection. In this context, detriment includes the lifetime incidence of specific cancers and takes account of the severity of disease in terms of lethality, quality of life and years of life lost. As derived by ICRP, the nominal risk coefficient represents an average value across populations and so accounts for exposure to radiation at all ages and both sexes. This risk coefficient recommended by ICRP was endorsed for use when estimating the lifetime risk to health to members of the UK

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[32] Internal Dosimetry Group, Radiation Hazards and Emergency Department, Public Health England Centre for Radiation, Chemical and Environmental Hazards.

population from exposure to radiation by the Health Protection Agency (HPA) (now UK HSA) in report RCE-12 (HPA 2009).

Thus, there is an internationally accepted assumption (for the purpose of radiation protection) that any dose, no matter how small, has the potential to cause harm, and that an annual dose of 0.01 to 0.02 mSv/year can be broadly equated to an annual risk of death of about one in a million per year (Environment Agency, 2012). Therefore, for the purposes of this assessment, estimated CED's below 0.02 mSv/year will be assumed to have an associated lifetime risk of 1 in a million. The lifetime risk to the UK population will be taken to be the excess cancer mortality rate from ingestion of foods imported from Japan compared to the background cancer mortality rate of about 25 %.

(Deaths, due to all malignant cancers, registered in England and Wales were used to represent the UK mortality rate and obtained from the Office for National Statistics (ons.gov.uk). In 2018 there were 541,589 total deaths in England and Wales. In England (2018) 136,913 deaths were attributable to cancer and about 8445 in Wales (2017 data was used for Wales as 2018 data was not available at the time of this report). This shows that the background rate of death due to all malignant cancers in 2018 was around 25-27%. The national cancer incidence rate for England for 2018 was derived from the NHS cancer database for crude mortality rates for all registered malignant cancers and the data for Wales was extracted from Public Health Wales, Accessed: 28/10/2021)

Component D. Determination of CED using probability of importing radiocaesium contaminated foods

A detailed description of the methodology and sensitivity analyses can be found in Annex 1. Component D was requested after an initial review but had not been developed initially due to time constraints and missing data. It has since been completed and the outcomes used to complement and validate the conclusions from components A, B and C.

In brief, the aim of component D was to calculate the CED to the UK population based on the probability of consuming foods imported from Japan, using a number of available data sets. The annual distribution of activity concentrations of radiocaesium (Cs-134 and Cs-137), measured in foods in Japan, were used along with import rates to the UK from Japan, UK demographic data and UK consumption rates. This was a probabilistic assessment, using distributions reflecting uncertainty or variability

Results were stratified by food group (30 in total) and by age (6 age groups were identified).

The component D model estimated:

- The annual distribution of CED, for the UK population, through consumption of foods imported from Japan, assuming the presence or absence of a 100 Bq/kg level (control).
- The difference in CED between the distributions in the absence or presence of the 100 Bq/kg level (control).

The results from the model are described in detail in Annex 1. In summary, of adult consumers, an estimated mean activity ingested of 98.4 (4, 450)[33] Bq/yr, equating to a CED of 1.6×10^{-3} mSv/year, are consumed in the absence of the 100 Bq/kg controls and 84.8 (2, 450) Bq/yr, equating to a CED of 1.4×10^{-3} mSv/year, when the controls are in place. The mean difference between presence and absence of the controls, for an adult consumer is 33.0 (0, 10^{-13}) Bq/yr which equates to a CED of 5.3×10^{-4} mSv/year.

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[33] 5%-95% range of activity ingested in parentheses.

4 Risk characterisation

Component A

Component A. E1.1 and 1.2 assumed that 10 % (IPF) of the total diet for every mean consumer of each product at mean total radiocaesium activity concentrations comes from Japanese imports. CEDs were calculated for mean and 97.5th percentile consumption rates and RPs identified. E1.1 considered the full dataset of activity concentrations for each food group and in E1.2 CEDs were calculated when activity concentrations exceeding 100 Bq/kg were removed from same datasets. E1.2 also statistically compared the CEDs calculated in this scenario with those for E1.1

The representative person (using upper-bound sampled activity concentrations) is an adult top consumer of soft beverages and alcoholic beverages with a total dose rate of 0.016 mSv/year. Using the lower-bound activity concentrations from sampling, the representative person is an adult top consumer of soft beverages and rice with a total dose rate of 0.0098 mSv/year.

The top two consumers for each age group are shown in Table 2. The highest dose to a consumer (using cautious estimates where there are sampling uncertainties and cautious assumptions on consumption rates) is 0.016 mSv/year, which represents 1.6 % of the 1 mSv/year reference level. A summary of the dose calculations are shown in Appendix G.

Additional incremental dose assessment. (E1.2 and D).

The additional incremental dose estimation was calculated by comparing the above dose for the RP (0.016 mSv/year) with a dose calculated when the samples exceeding 100 Bq/kg were removed from each food group (0.016 mSv/year). The additional incremental dose estimation (i.e., the difference between the two dose estimates) is 0.00020 mSv/year. The RP for this estimate is the same RP as above (adult consumer of soft beverages and alcoholic beverages).

The presence of samples exceeding 100 Bq/kg activity concentrations (in the MHLW data used in this risk assessment) had no significant impact on mean or 97.5th percentile CEDs. This was true for all food and age groups i.e., there was no statistically significant difference between data sets including samples exceeding 100 Bq/kg and datasets for which these samples had been removed. These results are shown in Appendix N and illustrated in Figure. 5.

The additional incremental dose was also estimated using the stochastic method described in Annex 1. The difference in dose was $5.3X10^{-4}$ mSv/year. This result is higher than the deterministic estimation and due to the probabilistic nature and more mechanistic approach of the model where there is a likelihood that values (predicted by the model using distributions of the data) greater than the maximum measured activity concentrations can be randomly selected (explained in Annex 1). The use of total radiocaesium in the probabilistic component rather than individual Cs134 and Cs-137 activity concentrations may also have led to an overestimation of CED.

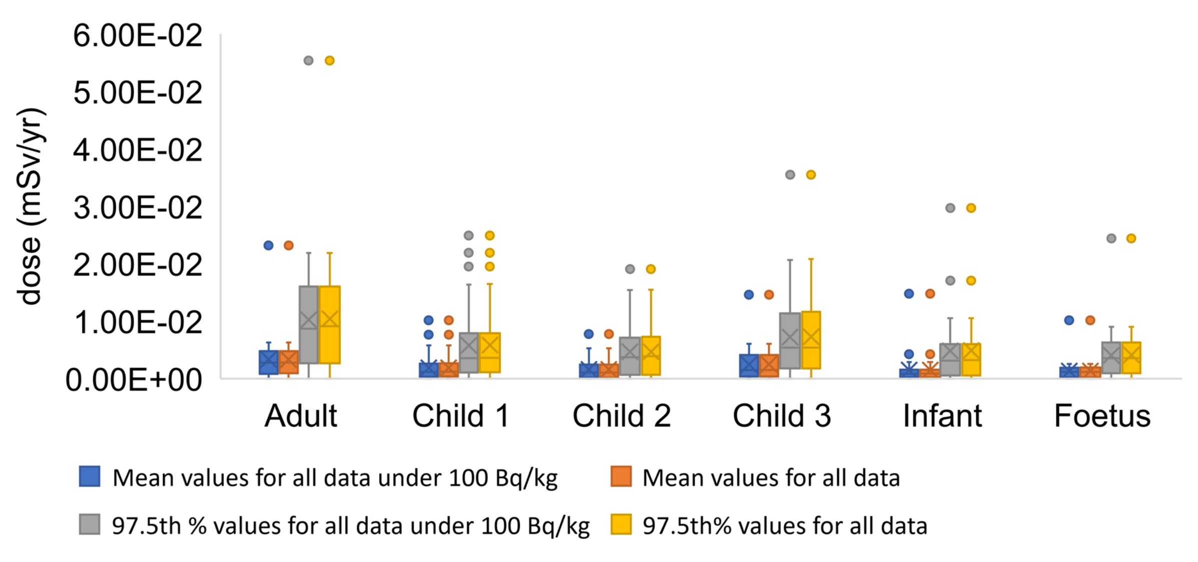

Figure 5. Differences in mean and 97.5th percentile doses from all food groups, for each age group, before and after samples exceeding 100 Bq/kg were removed from the dataset. The boxes show the quantile values, the horizontal line in each box shows the median value, crosses mark the exclusive mean value (excluding the outliers), and outliers are represented by points on the plot.

Table 2. Top two consumers for each age group. Highest CEDs are marked *. Where the top consumer varies between upper- and lower-bound calculations, the top consumer for the upper-bound value is listed first, followed by (U) and the lower-bound consumer thereafter (L). Ages listed refer to consumption data (NDNS age groups).

Age group (yrs)	**Top consumer 1**	**Top consumer 2**	**Lower-bound maximum dose (mSv/year)**	**Upper-bound maximum dose (mSv/year)**
Adult (16 - <70)	Soft beverages	Alcoholic beverages (U) Rice (L)	8.8E-03	-(1.60E-02 (*Highest CEDs)
Child 3 (10 - 16)	Soft beverages	Fruit	6.37E-03	1.18E-02
Child 2 (5 - <10)	Soft beverages	Fruit	4.07E-03	7.51E-03
Child 1 (18m - < 5)	Infant formula	Meat and dairy alternatives	5.07E-03	9.67E-03
Infant (4m - <18m)	Infant formula	Dairy products	3.95E-03	7.66E-03
Foetus [34]	Soft beverages	Rice (L) Alcoholic beverages (U)	3.63E-03	6.56E-03

In scenario A: E2 and E3, it was assumed that the consumption of an entire dietary food group (E2) or two food groups (E3) consisted of imported products from Japan (*i.e.*, 100% dietary intake for that food group comes from imported products from the specified prefectures in section 1.1; IPF = 1). In this case, it was also assumed that an individual would have a high consumption rate for the food group(s) (97.5th percentile consumption rates were used) and none of the remaining food groups were imported from Japan. Under scenario A: E2 the predicted annual CED for the calculated RP (an adult high consumer of soft beverages) was 0.055 mSv/year.

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[34] Intake rates are those of the parent

If two food groups were exclusively consumed at high rates from Japanese imported foods (scenario A. E3), then the top two consumer was an adult consumer of soft beverages and alcoholic beverages. The predicted CED was 0.077 mSv/year. The estimated dose for this scenario across all age categories is shown in H.

Component B

Component B looked at the probability (assuming that the current EU regulatory limits of 1,250 Bq/kg had been removed) that a foodstuff imported from Japan would have an activity concentration that exceeded 100 Bq/kg. The estimated mean probability of a product exceeding 100 Bq/kg for radiocaesium activity concentrations are shown in Table 3. Of the five food groups with an estimated mean likelihood of 2 - 4 % probability that the imported products would exceed 100 Bq/kg, three of those (baby food; fats and oils; bread) contained no actual measured contaminated samples during testing. All three food groups had less than 100 total recorded samples
(Figure 4). The remaining two food groups (shoots; dried fruit, nuts, and seeds), which included measured values exceeding 100 Bq/kg, collectively contributed 0.85 % of the measured values for the total sample data available. These probabilities are therefore based on low sample sizes and uncertainties built into the model regarding test sensitivities.

Eight food groups had a greater than 1 % probability of products exceeding 100 Bq/kg radiocaesium activity concentrations would be imported into the UK (Table 3d and 3e). Three of these food groups (baby food; fats and oils; bread) also had standard deviations that were at least 98 % of the estimated probability (Table 3e and Figure 1 in Appendix I).

When all food groups were combined there was an estimated probability of 0.18 % that a product exceeding 100 Bq/kg of radiocaesium would be imported into the UK. Distributions for each simulation are shown in Appendix J.

The mean estimated probability that a product from one of the food groups exceeding 1,250 Bq/kg for radiocaesium activity concentrations, would be imported into the UK, are shown in Table 4 (distributions for each simulation are shown in Appendix K).

Three food groups had an estimated greater than 1 % probability that products imported to the UK would have activity concentrations that exceed 1,250 Bq/kg radiocaesium (baby food; fats and oils; bread, with estimated probabilities of 2 - 4 %). However, these three food groups did not contain any samples with activity concentrations that exceeded 1,250 Bq/kg during the monitoring process.

Food groups where the estimated probabilities of products exceeding 1,250 Bq/kg radiocaesium activity concentrations were ~ > 0.06 % also had standard deviations that were at least 97% of the estimated mean value (see Appendix I, Figure 2).

The Monte Carlo simulation that assessed the probability that products imported to the UK will have activity concentrations that exceed 1,250 Bq/kg, when combining all food groups, provided a mean value of 0.003 %.

Table 3a. Food groups that were estimated to have <0.01% mean probability (%) that a product with radiocaesium activity concentrations exceeding 100 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.5%**	**Dist**	***N***	**% > 100**
Cattle	5.30E+03	1.50E-04	1.51E-04	6.63E-04	Expon	8.53E+05	0.00E+00
Root vegetables	5.70E+03	7.50E-03	7.60E-03	3.29E-02	Gamma	1.77E+04	0.00E+00

nCon = number of iterations until convergence was achieved, SD = standard deviation, 97.5% = 97.5th percentile value, Dist = distribution of the outputs, n = total number of samples, %>100 = the percentage of actual samples tested that were greater than 100 Bq/kg.

Table 3b. Food groups that were estimated to have <0.1 mean probability (%) that a product with radiocaesium activity concentrations exceeding 100 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**9.75E-01**	**Dist**	***N***	**% > 100**
Dairy products	4.90E+03	2.00E-02	1.89E-02	7.75E-02	Gamma	6.35E+03	0.00E+00
Condiments, spices and preserves	5.80E+03	2.80E-02	2.89E-02	1.28E-01	Expon	4.66E+03	0.00E+00
Other meats	5.60E+03	3.80E-02	3.79E-02	1.66E-01	Expon	3.43E+03	0.00E+00
Soft beverages	5.30E+03	5.40E-02	5.24E-02	2.28E-01	Expon	2.44E+03	0.00E+00
Seaweed and algae	5.80E+03	5.60E-02	5.68E-02	2.40E-01	Gamma	2.32E+03	0.00E+00
Fruit	2.90E+03	6.30E-02	1.99E-02	1.15E-01	Gamma	2.13E+04	4.22E-02
Ready to eat foods	5.30E+03	6.60E-02	6.35E-02	2.75E-01	Gamma	2.02E+03	0.00E+00
Dried fish	5.90E+03	7.60E-02	7.77E-02	3.69E-01	Expon	1.81E+03	0.00E+00
Eggs	6.00E+03	8.50E-02	8.75E-02	3.59E-01	Expon	1.59E+03	0.00E+00
Potatoes	5.70E+03	9.20E-02	9.30E-02	4.01E-01	Expon	1.44E+03	0.00E+00

Table 3c. Food groups that were estimated to have <1 mean probability (%) that a product with radiocaesium activity concentrations exceeding 100 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.5%**	**Dist**	***N***	**% > 100**
Cereals and grains	2900	2.4E-01	7.94E-02	4.50E-01	Lognorm	4.98E+03	1.61E-01
Alcoholic beverages	5600	2.7E-01	2.71E-01	1.18E+00	Gamma	4.79E+02	0.00E+00
Confectionary	5700	3.28E-01	3.29E-01	1.44E+00	Gamma	4.07E+02	0.00E+00
Pasta	5700	3.37E-01	3.39E-01	1.45E+00	Expon	3.92E+02	0.00E+00
Meat and dairy alternatives	5500	4.65E-01	4.60E-01	2.03E+00	Gamma	2.95E+02	0.00E+00
Seafood other	2900	4.84E-01	6.09E-02	6.35E-01	Gamma	1.73E+04	3.58E-01
Leguminous vegetables	2900	5.56E-01	6.60E-02	7.22E-01	Gamma	1.66E+04	4.10E-01
Rice	2900	6.91E-01	1.04E-01	9.50E-01	Gamma	8.48E+03	5.07E-01
Saltwater fish	2900	7.85E-01	3.75E-02	8.70E-01	Normal	7.44E+04	5.88E-01
Infant formula	5800	8.90E-01	8.98E-01	4.05E+00	Gamma	1.47E+02	0.00E+00
Freshwater fish	2900	9.64E-01	1.30E-01	1.27E+00	Weibull	7.15E+03	7.14E-01

Table 3d. Food groups that were estimated to have <2% mean probability (%) that a product with radiocaesium activity concentrations exceeding 100 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**9.75E-01**	**Dist**	***N***	**% > 100**
Non-leguminous green vegetables	2.90E+03	1.04E+00	5.60E-02	1.17E+00	Normal	4.34E+04	7.78E-03
Dried mushroom	2.90E+03	1.08E+00	3.57E-01	2.06E+00	Gamma	1.09E+03	7.32E-01
Mushroom	2.90E+03	1.56E+00	9.90E-02	1.79E+00	Normal	1.99E+04	1.17E-02

Table 3e. Food groups that were estimated to have <4 mean probability (%) that a product with radiocaesium activity concentrations exceeding 100 Bq/kg would be imported in the UK.

Commodity	**nCon**	**Mean**	**SD**	**9.75E-01**	**Dist**	***N***	**% > 100**
Baby food	5.50E+03	2.11E+00	2.08E+00	8.88E+00	Gamma	6.20E+01	0.00E+00
Dried fruit, nuts and seeds	2.90E+03	2.14E+00	2.76E-01	2.78E+00	BetaGeneral	3.74E+03	1.58E+00
Fats and oils	5.70E+03	2.39E+00	2.39E+00	1.05E+01	Expon	5.40E+01	0.00E+00
Bread	5.40E+03	2.62E+00	2.57E+00	1.12E+01	Gamma	4.90E+01	0.00E+00
Shoots	2.90E+03	3.95E+00	3.01E-01	4.61E+00	Normal	5.78E+03	2.94E+00

Table 4a. Food groups that were estimated to have <0.01 mean probability (%) that a product with radiocaesium activity concentrations exceeding 1,250 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.50%**	**Dist**	***N***	**% > 1250**
Cattle	5700	1.55E-04	1.56E-04	6.83E-04	Expon	8.53E+05	0.00E+00
Saltwater fish	2900	3.59E-03	2.53E-03	1.15E-02	Gamma	7.44E+04	1.34E-03
Fruit	5800	6.29E-03	6.36E-03	2.76E-02	Expon	2.13E+04	0.00E+00
Root vegetables	5600	7.68E-03	7.68E-03	3.35E-02	Expon	1.77E+04	0.00E+00
Seafood other	5400	7.77E-03	7.63E-03	3.35E-02	Gamma	1.73E+04	0.00E+00
Leguminous vegetables	5600	7.93E-03	7.94E-03	3.51E-02	Expon	1.66E+04	0.00E+00

nCon = number of iterations until convergence was achieved, SD = standard deviation, 97.5% = 97.5th percentile value, Dist = distribution of the outputs, *n* = total number of samples, %>1250 = the percentage of actual samples tested that were greater than 1250 Bq/kg.

Table 4b. Food groups that were estimated to have <0.1 mean probability (%) that a product with radiocaesium activity concentrations exceeding 1,250 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.50%**	**Dist**	***N***	**% > 1250**
Rice	5500	1.58E-02	1.55E-02	6.68E-02	Gamma	8.48E+03	0.00E+00
Freshwater fish	5500	1.91E-02	1.88E-02	8.05E-02	Gamma	7.15E+03	0.00E+00
Dairy products	5400	2.09E-02	2.04E-02	8.65E-02	Expon	6.35E+03	0.00E+00
Shoots	5700	2.28E-02	2.30E-02	1.01E-01	Expon	5.78E+03	0.00E+00
Cereals and grains	5700	2.72E-02	2.73E-02	1.21E-01	Expon	4.98E+03	0.00E+00
Condiments, spices and preserves	5600	2.86E-02	2.86E-02	1.25E-01	Gamma	4.66E+03	0.00E+00
Dried fruit, nuts, and seeds	5800	3.57E-02	3.62E-02	1.62E-01	Expon	3.74E+03	0.00E+00
Other meats	6300	3.95E-02	4.15E-02	1.80E-01	Expon	3.43E+03	0.00E+00
Mushroom	2900	4.75E-02	1.74E-02	9.40E-02	Gamma	1.99E+04	3.01E-04
Soft beverages	5400	5.45E-02	5.32E-02	2.34E-01	Gamma	2.44E+03	0.00E+00
Non-leguminous green vegetables	2900	5.52E-02	1.31E-02	8.78E-02	Gamma	4.34E+04	3.91E-04
Seaweed and algae	5800	5.68E-02	5.77E-02	2.49E-01	Expon	2.32E+03	0.00E+00
Ready to eat foods	5600	6.65E-02	6.62E-02	2.88E-01	Expon	2.02E+03	0.00E+00
Dried fish	5700	7.60E-02	7.59E-02	2.94E-01	Expon	1.81E+03	0.00E+00
Eggs	5400	8.11E-02	7.88E-02	3.58E-01	Gamma	1.59E+03	0.00E+00
Potatoes	5600	9.52E-02	9.47E-02	4.05E-01	Expon	1.44E+03	0.00E+00

Table 4c. Food groups that were estimated to have <1 mean probability (%) that a product with radiocaesium activity concentrations exceeding 1,250 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.50%**	**Dist**	***N***	**% > 1250**
Dried mushroom	5800	1.23E-01	1.24E-01	5.42E-01	Expon	1.09E+03	0.00E+00
Alcoholic beverages	5500	2.72E-01	2.70E-01	1.16E+00	Expon	4.79E+02	0.00E+00
Confectionary	5500	3.24E-01	3.21E-01	1.42E+00	Expon	4.07E+02	0.00E+00
Pasta	5400	3.34E-01	3.29E-01	1.43E+00	Gamma	3.92E+02	0.00E+00
Meat and dairy alternatives	5500	4.44E-01	4.37E-01	1.95E+00	Gamma	2.95E+02	0.00E+00
Infant formula	5300	8.93E-01	8.69E-01	3.68E+00	Gamma	1.47E+02	0.00E+00

Table 4d. Food groups that were estimated to have <4 mean probability (%) that a product with radiocaesium activity concentrations exceeding 1,250 Bq/kg would be imported to the UK.

Commodity	**nCon**	**Mean**	**SD**	**97.50%**	**Dist**	***N***	**% > 1250**
Baby food	5400	2.06E+00	2.02E+00	8.66E+00	Gamma	6.20E+01	0.00E+00
Fats and oils	5600	2.44E+00	2.42E+00	1.05E+01	Expon	5.40E+01	0.00E+00
Bread	5400	2.58E+00	2.53E+00	1.11E+01	Gamma	4.90E+01	0.00E+00

nCon = number of iterations until convergence was achieved, SD = standard deviation, 97.5% = 97.5th percentile value, Dist = distribution of the outputs, *n* = total number of samples, %>1250 = the percentage of actual samples tested that were greater than 1250 Bq/kg.

Component C - Lifetime risk estimation

In this assessment it was estimated that, should food import restrictions from Japan be lifted, members of the UK population who consumed imported food for 1 year would receive an additional dose of no more than 0.016 mSv. Using the ICRP Risk co-efficient of 5 % per Sv, the lifetime risk of death associated with receiving an effective dose of 0.016 mSv is approximately 10^{-6}, or 1 in a million. (It should be noted that estimation of lifetime risk at low doses is an approximation (section 6). To put this estimated additional risk from consuming foods imported from Japan into context (should import restrictions be lifted), approximately 25 % of all deaths in the UK is due to cancer (all types of malignant cancer). It is therefore concluded that lifting import restrictions on food from Japan would represents a negligible and undetectable yearly increase over the baseline risk to members of the UK population of developing fatal cancer.

Component D - Dose assessment based on the probability of consuming radiocaesium contaminated foods.

The mean CED and associated 5 % - 95 % uncertainty percentile bounds from the probability component D (Annex 1) based on radiocaesium annual activity concentration distributions, Japanese import rates to the UK, demographic data and UK consumption rates were estimated to be $1.4\text{x}10^{-03}$ ($3\text{x}10^{-5-}$ $7\text{x}10^{-3}$) mSv/year with controls and $1.6\text{x}10^{-03}$ ($5\text{x}10^{-5}$, $7\text{x}10^{-3}$) mSv/year without controls.

5 Assumptions

We have made several assumptions in reaching conclusions on the effective dose estimates, and risk modelling for scenarios A to C. In this instance, the assumptions relate to the following:

General assumptions

- The extensive monitoring data provided by Japan is representative of the radiocaesium activity concentrations and is accurate and reliable.
- All the monitoring data are derived from foods and beverages produced solely in Japan. (There may be some instances when foods selected for sampling from the markets within the contaminated prefectures were produced from or mixed with food from other areas.)
- All monitoring data reflect the year in which they are designated on the database and the values are those that were measured at the time of sampling.
- All recorded Cs-137 and Cs-134 activity concentrations originated from the FDNPP accident and there is no background signal resulting from other accidents such as Chernobyl, or due to historical nuclear weapons testing.
- Other radionuclides from the accident (for example, Sr-90) may be present in food but there is scarce measurement data available (UNSCEAR, 2021).
- All monitoring data measured radiocaesium only. The gamma spectroscopy equipment used (Germanium detector) can resolve the gamma energy spectrum of specific radionuclides such as Cs-134 and Cs-137. However, scintillation detectors with lower energy resolution may detect interference photons from other radionuclides with similar energy peaks.
- Foods import data from 2008 to 2020 were evaluated to give an appreciation of the food products that are regularly imported from Japan. The import data

encompassed all of Japanese trade to the UK and could not be filtered by prefecture. Therefore, the risk assessment assumes that all Japanese food imported to the UK comes from the prefectures outlined in Section 1.1. This is likely to be very cautious as a large fraction of the food produced in Japan is likely to come from outside of those areas.

- Wild meats such as boar, game, poultry, and whale meat were excluded as ‘out of scope’ since Regulation 206/2010 only permits cattle meat to be imported from Japan. It is unlikely that other wild foods such as wild mushrooms and Koshiabura[35] (shoot/buds of *Eleuterococcus sciadophylloides*) known to contain relatively high radiocaesium activity concentrations, would be exported to the UK. However, these were included in the assessment for additional caution to account for the possibility that these may be imported to the UK if restrictions were lifted.
- It is assumed that radioactivity from the accident is distributed homogenously throughout each food product.
- It was assumed that no correction for radioactive decay needed to be applied because of the relatively long half-lives. It is recognised that Cs-134 would have decayed since the initial measurements but as this assessment makes use of recent monitoring data (2013-2020) this is accounted for to some extent.
- The import production factor (IPF) is a reasonable estimate of the fraction of each food group that the RP consumes that originates from Japan and it is based on Codex guidelines (Codex 2011).
- The women of childbearing age were grouped into the age range 16-50 according to the availability of food consumption rates. Whereas the Administration of Radioactive Substances Advisory Committee (ARSAC, 2021) guidance notes (2021) for identifying women of childbearing age in relation to radiation protection, recommend an age range of 12-55. This could lead to an overestimation of the dose to the foetus as the consumption rates and dose co-efficients for the 12-16 years olds are lower. There would have

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[35] Koshiabura buds are a speciality wild plant frequently consumed in Japan.

been no impact for the difference between those aged 50 and 55 years as they remained adult consumers.

- It is assumed that the cancer mortality rates for England and Wales in 2018 are representative of the entire UK population, although it is recognised that the mortality rate may be differ in Scotland and N Ireland, however, for the purposes of this risk assessment, a 25% mortality rate is believed to provide a reasonable baseline comparison.

Assumption made regarding the NDNS consumption data

- The NDNS does not include pregnant or breastfeeding women, so the women of child-bearing age group are not necessarily representative of the diet of pregnant women.
- The consumption or exposure estimates made with a small number of consumers may not be accurate. Estimates of the 97.5th percentile based on less than 60 consumers should be treated with extreme caution, as they may not be representative for larger number of consumers. The NDNS data is random and collected by postcode. It is assumed to be representative of region but is sometimes weighted/normalised if there isn’t enough data collected for a particular region.
- There were no import data for infant formulae therefore, baby food was used as a surrogate for this group.
- Food groups such as teas and squash would be diluted and not consumed as imported, therefore a dilution factor was used in the estimates. It was also assumed that the water used as a diluent would come from a consumer’s local water supply and not be imported from Japan.
- It was assumed in scenario B, that there would be no checks at the UK borders. However, the standard 5 % random sanitary and phytosanitary (SPS) checks would still be carried out at the UK border if restrictions were lifted, which may include radiocaesium testing (International Classification of non-tariff measures).

6 Variability and uncertainty

Both variability and uncertainty, where possible, were considered in the model when inputting parameters. To prevent significant underestimation of the doses or risks from variability and uncertainties in the data, reasonably cautious values were used in the assessment.

The variability in this analysis is as follows:

- Variability in the farming practices and the growing season in Japan and time of harvest will have an impact on the amount of food imported as well as total radiocaesium activity concentrations in foods. However, these will not be significant given the data used were measurements taken from the food itself.
- Transfer of radiocaesium in the environment in Japan may vary with changes in food production.
- Imported food commodities can only be based on past data and most likely will vary in the future. The extent of this is unknown and unpredictable. However, those foods that are grown in Japan are those that are compatible with the environment/soil type (*i.e.*, the crops may vary, but not significantly in the foreseeable future).
- There is inherent variability in the types and quantities of foods consumed.
- The assumption that 10 % of the diet, all of which is contaminated with radiocaesium is an uncertainty within the modelling.

The uncertainties in this analysis are as follows:

- There is always inherent uncertainty around consumption behaviours and uncertainties in the NDNS consumption data due to the short survey times (4 days) and may be biased toward people that would respond to surveys. The survey relies on memory recall and people may under report certain food groups for example, those that they consider unhealthy. There are also only 1,000 respondents for the survey, and this may not be representative of all minority populations.

- As discussed in Section 3.4.3, there were uncertainties regarding the LOD and their conversion to numerical values.
- There are inherent uncertainties and variability in the monitoring equipment used and methods of sampling and analysis.
- There are inherent uncertainties within in the statistical methods explained in section 4.1.
- A random sample of 25,000 was taken for Cattle and Saltwater fish food groups in Section 3.3.2, as the datasets were too large to test year-on-year variation (944,324 and 81,148 samples, respectively). There is uncertainty regarding whether subtle trends in the data would have been represented within the random subsamples of the datasets.
- There are uncertainties on whether data from 2013 to 2020 will be representative of activity concentrations in future years.
- The monitoring data from Japan were focused on compliance limits and food safety and may not be fully representative of the situation. The samples were not collected in a randomised fashion but focused on areas that were known to have a high ambient dose rate which could introduce bias towards overestimation of the average activity concentrations.
- Commercial processing of food prior to sale and preparation in the home prior to consumption may lead to a change in the activity concentrations of radionuclides in food for example, a decrease through the preparation of tea leaves.
- As this risk assessment has only assessed radiocaesium exposure through the food chain from imported foodstuffs from Japan (from the specific prefectures see Figure 2), any contribution from external or dermal exposure or inhalation is not considered and is likely to be insignificant.
- Some of the samples had to be eliminated because of incomprehensible descriptions. However, these were only a few compared to the total amount of sample data used in the analyses.

- The assigned age ranges for the age groups used with the consumption data meant that where child's age overlapped with the abutting group *i.e.*, 10-year and 5-year-old child they were assigned a higher dose co-efficient, likely leading to an overestimation of dose. This is related to the variability in human bodies and accounted for by taking a conservative view on appropriate dose coefficient and ingestion rates for individuals within each age band.

- The dose from alcoholic and soft beverages is primarily due to the high reported UK consumption rates of these food groups, rather than particularly high activity concentrations.

- Decay corrections were not applied to account for physical decay processes, which may lead to an overestimation of radiocaesium activity concentrations, especially with Cs-134, because of its shorter half-life of 2.1 years.

- If it is assumed that Cs-134 and Cs-137 were released at the same time and subject to the same dispersion processes, the ratios of Cs-134 and Cs-137 would slowly increase and after 10 years decay, there would be a ratio of 1:21. However, this pattern is not apparent in the individual and mean activity concentrations, and in some food samples where the radiocaesium activity concentrations are low (less than 20 Bq/kg), the Cs-134 activity concentration is similar to that of Cs-137 (*e.g.* for alcoholic beverages: Cs-134 = 3.166 Bq/kg; Cs-137 = 3.098 Bq/kg). The data analysis preserved the relationship between Cs-134 and Cs-137 activity concentrations for each sample. Therefore, it is assumed that the lower-than-expected ratio of Cs-134 to Cs-137 exhibited in this analysis, is a consequence of the way the LODs were processed (*i.e.,* assigning values as the upper LOD) because of the inherent uncertainties around the LOD (Section 3.3.3). The higher-than-expected Cs-134 activity concentrations derived from the monitoring data are likely to lead to an overestimation of the dose.

- Risk of health effects from radiation at very low doses, such as in this assessment, can only be estimated on the basis of observations of exposed population groups at much higher doses. The lifetime risk estimate is extrapolated from observed increases in incidence in an exposed population at higher doses and has not been demonstrated by epidemiological studies at doses below 100 mSv (COMARE, 2007), meaning that the risk may be overestimated. Thus, the estimated risk only provides an indication of the risk to members of the exposed population rather than providing an absolute estimate of the number of people who may experience a negative impact on their health.

- There are acknowledged limitations of calculating the lifetime risk using an average for the whole population i.e the lifetime risk for a young person would be more like 15% per Sv because of the higher intrinsic risk per unit dose and a longer lifespan for the risk to be expressed. There is also uncertainty related to the value of the nominal risk coefficient in relation to members of a dispersed group of individuals of health status. The nominal risk coefficients are derived from whole body exposure to gamma radiation and not from ingestion and thus, the generic ICRP risk values may not be appropriate for both the UK population and pathway (intake). However, this would have little impact on the conclusions because the slight changes in risk would be negligible compared to the 25% baseline cancer incidence.

7 Verification of results

The data processing and output were verified by two FSA radiological risk assessors. Statistical models were independently checked to ensure that they were fit for purpose, in terms of answering the questions posed within the risk assessment. Model outputs were independently quality checked to verify that data had been input correctly and that the outcomes of the model were accurate.

8 Sensitivity Analyses

To demonstrate the robustness of the methodology, the extent to which results for components A, B and D were affected by changes in the parameters used to calculate the CED and probability of a contaminated food entering the UK was assessed.

The results from the sensitivity analyses for scenario A are shown in Appendix L. It was demonstrated that a 10 % reduction or increase in consumption rates or total radiocaesium activity concentration equates to a 10 % change in CED. This indicates that both these variables have an equal contribution to the final calculated CED as the magnitude of change is equivalent if either parameter is altered by the same percentage.

The sensitivity analyses for scenario B assessed the range of the mean, regression coefficient[36], regression[37], correlation coefficient[38] and percentage contribution[39] (see Appendix M). This was conducted using @Risk's built-in sensitivity analysis function. This sensitivity analyses assessed the impact of 2 parameters on the outcome of the model. These parameters were:

i. the number of samples exceeding the level being assessed (*A2*, 100 or 1250 Bq/kg) and
ii. variability in the quantities of imported goods between years (*A1*).

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[36] The regression coefficient for each input variable measures the sensitivity of the output to that particular input distribution.
[37] The overall fit of the regression is measured by the reported fit or R-squared value of the model.
[38] the rank correlation coefficient is calculated between the selected output variable and the samples for each of the input distributions. The higher the correlation between the input and the output, the more significant the input is in determining the output's value.
[39] Contribution to Variance shows the amount of change in the selected output variable attributable to each input.

The variability in import quantities (ii) has no impact on the output of the test, but the number of samples exceeding the level being assessed (i) was the only factor affecting the final output (see Appendix L).

Throughout the risk assessment there were continuous discussions with experts and decision makers and challenging of assumptions to create a risk assessment with optimal sensitivity. At all stages the results were checked against expected outputs and the parameters causing the largest impact on the result were identified. In this risk assessment, the parameter with most uncertainty was the LOD. This was accounted for by assigning the LOD value as the upper-bound and 50 % of the LOD value as the lower-bound. However, it is acknowledged that the true value could lie anywhere in the range below the LOD (section 3.3.3.1).

9 Conclusions

The estimated CED of 0.016 mSv/year to the RP (an adult consumer of alcoholic beverages and soft beverages) is considerably below the 1 - 20mSv/year ICRP reference level for existing exposures. This has been calculated using the activity concentrations of radiocaesium in food samples monitored in Japan, adopting the top two consumption level approach, the probability of consuming Japanese imported food, and the likelihood that a person will receive that dose.

Therefore, based on this assessment, the removal of the 100 Bq/kg maximum level on radiocaesium (i.e. Cs-134 and Cs-137) for imported Japanese food would result in a negligible increase in dose and any associated risk to UK consumers

A CED of 0.016 mSv/year roughly equates to a life time excess risk of fatal cancer of about 1 in a million which is negligible compared to the baseline 2018 cancer fatality rate of 25%.

Using only the additional dose incurred by removing the 100 Bq/kg maximum level, the estimated excess lifetime risk to the UK population is negligible.

Using the probability of consuming Japanese imported food (component D) the mean dose (and 5 % - 95 % confidence intervals) to the RP (adult) was estimated to be $1.6X10^{-03}$ ($5x10^{-5-}$ - $7x10^{-3}$) mSv/year without controls and the associated lifetime risk was negligible. The estimated mean CED from component D of 0.0016 mSv/ year and 0.0014 mSv/year (without and with 100 Bq/kg controls in place) is 10 times lower than the results estimated in component A and the 95% upper range is 0.007 mSv/year, which is less than half the CED estimated from component A. These results from component D, complement and validate the CED calculated in component A by showing that the dose is probably much lower than the deterministic estimate in component A suggests.

Of the food groups that resulted in the highest effective doses to the RP (a top two consumer of alcoholic beverages and soft beverages), scenario B estimated that there was a respective 0.27 % and 0.054 % mean probability of these products being imported and exceeding 100 Bq/kg and 1,250 Bq/kg, respectively.

There is a less than 1 % chance that imported food would exceed either the current restriction level (100 Bq/kg) or the EU food intervention level (1250 Bq/kg) (scenario B, all products combined). Most food that is imported from Japan is unlikely to be contaminated with radiocaesium to any significant degree.

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Appendices

Appendix A: Screening equipment and laboratory methods in Japan

Following a request by the FSA, the Japanese government (MAFF) provided written procedures, confirmation of accreditation and quality assurance documents.

The test methods including the performance of the instruments can be found in the following document.

Testing Methods for Radioactive Substances in Food, Notice No. 0315 Article 4 of the Department of Food Safety, March 15, 2012.

The Japanese laboratories testing radionuclides in food perform quality control as prescribed in the Testing Methods (above) as well as based on the notification of the Ministry of Health, Labour and Welfare (MHLW) document “Guideline for Inspection Work Management” based on Japanese Food Sanitation Act.

Domestic monitoring is mainly performed by (1) Public labs and (2) MHLW registered labs. However, it is the ISO 17025 accredited labs that are registered for monitoring for export.

Appendix B: Food groups identified by the FSA

The activity concentrations data of individually monitored foods were filtered (and out of scope entries such as wild foods were removed, see section 3.3.3 of the risk assessment) and classified into various categories according to 34 food groups (Table 1). These were decided based on commodities imported from Japan and the available respective consumption data.

Table 1. Activity concentrations data classified into the 34 food groups.

Food group	**Examples**
Cereals and grains	Barley, buckwheat, maize/corn, millet, oats, wheat, rye, sorghum flour
Rice	All Rice
Leguminous vegetables	Broad beans, French/green beans, haricot beans, lentils, mange tout, peas, runner beans, soya beans, papri beans, split peas, aduki beans, blackeye beans, black beans, pinto beans, kidney beans, mung beans, butter beans, soya beans, pigeon peas, balor beans, cluster beans, chickpeas, runner beans
Non-leguminous green vegetables	Asparagus, broccoli, Brussel sprouts, cabbage, cauliflower, cucumber, courgette, endive, globe artichoke, kohl rabi, lettuce, marrow, herbs, spinach, salad crops, fennel, chicory, celery, rocket, chard, okra, pak choi, watercress, mustard cress
Root vegetable	Beetroot, carrot, celeriac, l, Jerusalem artichoke, onion, parsnip, radish, swede, turnip, yams, turmeric, salsify, cassava, ginger, sweet potato, butternut squash, pumpkin, garlic
Shoots	Bamboo shoots
Potatoes	Potatoes
Fruit	All fruit except dried
Cattle	All cattle meat incl. cattle offal

Food group	**Examples**
Other meats	All meat except cattle and out of scope, including offal
Eggs	From any birds
Dairy products	Milk, cheese, cultured milk, ice cream
meat and dairy alternatives	Alternatives to meat, milk, and cheese
Mushroom	Mushrooms cultivated and not yet classified
Dried mushroom	Dried or powdered mushrooms
Freshwater fish	All freshwater fish
Saltwater fish	All saltwater fish
Dried fish	All dried seafood
Seafood other	Seafood that does not fall under fish – molluscs, crustacea, cephalopods

Food group	**Examples**
Soft Beverages	Tea, tea (flavoured), coffee, drinking water, juice, cordial, fizzy drinks, smoothies
Alcoholic beverages	Beer, wine, spirits, alcopops, liqueurs, cider
Dried fruit, nuts, and seeds	Nuts, seeds (not spice seeds), dried fruit
Condiments, spices and preserves	spices, seasonings, jam, chutney, honey, pickled products, soy sauce, mustard, mayo, hot sauce, salad dressings, tomato ketchup, etc.
Ready to eat foods	Soups, pasta sauces, sauces, processed foods like ready meals, canned foods etc.
Fats and oils	Fats and oils
Confectionary	Sweets, confectionary, chocolate, Baked goods including cakes, biscuits, wafers, artificial sweeteners, desserts, pudding sweet pies etc.
Pasta	Pasta, noodles
Snacks	Savoury snacks like crisps, popcorn, corn snacks

Food group	Examples
Yeast	Yeast, extracts
Bread	Breads
Seaweed and algae	Seaweeds
Agar	Agar – gelatine to be used as a proxy because agar is not found in the NDNS but is commonly used as a vegetarian gelling agent
Infant formula	Infant formula
Baby food	Baby food

Appendix C: Mean Upper bound radiocaesium (Cs-134/Cs-137) activity concentrations for each food group (Bq/Kg).

Figure 1 illustrates the radiocaesium activity concentrations within each food group for the upper-bound LOD values (section 3.3.3.1).

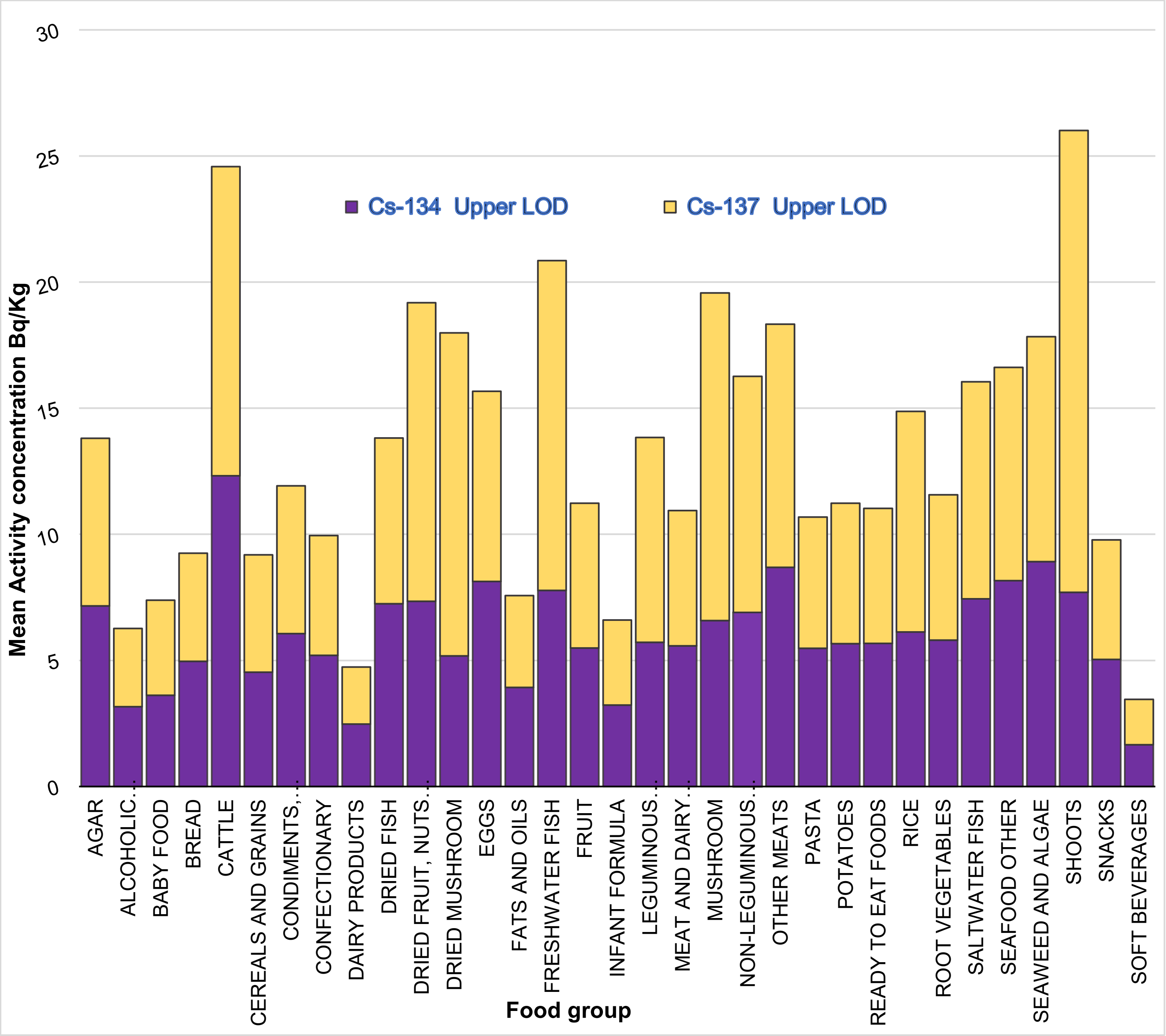

Figure 1. Upper-bound radiocaesium activity concentration for each food group. The blue bars represent Cs-134 activity concentrations and the brown bars, stacked above, represent the Cs-137 activity concentration.

Appendix D: Importation data summary

The UK Import Data from Japan was extracted from Overseas trade data table - UK Trade Info.

This is an HM Revenue and Customs (HMRC) database for UK imports. It was used to establish the average rates of edible foods imported from Japan per food group/commodity for years 2008-2020 (volume of food imported [kg] per year). The data were filtered to align with the 31[40] food groups under consideration.

All UK ports were selected and out of scope items such as live ornamental fish were removed.

Below (Figure 1) is an example of a table produced on the HMRC website for the UK Import Data from Japan. The import data is classified using Harmonized Commodity Description and Coding Systems (HS) which is an international nomenclature system for the classification of products using a six-digit code system.

The six digits can be broken down into three parts. The first two digits (HS2) identify the chapter the goods are classified in, for example*,* 20 = Preparations of vegetables, fruit, nuts, or other parts of plants. The next two digits (HS4) identify groupings within that chapter, for example, 20.03 = Mushroom and truffles preserved. The next two digits (HS6/CN8) are even more specific, for example*,* 200390 = Mushrooms, prepared or preserved otherwise than by vinegar or acetic acid (excl. mushrooms of the genus "Agaricus"). The CN code is the expanded system used within the EU.

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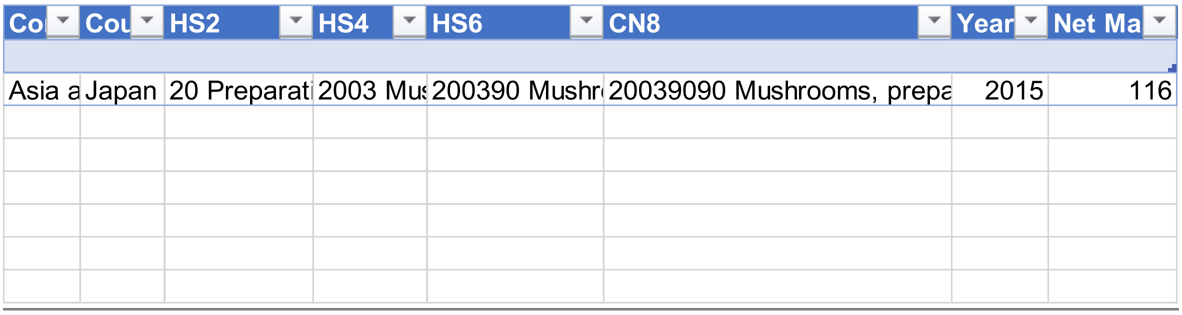
[40] No activity concentrations data were available for 'Yeasts'. The 'Cultivated mushroom' food group was combined with 'Mushroom' food group. 'Snacks' and 'Agar' removed because of lack of specific import data.



Co	Cou	HS2	HS4	HS6	CN8	Year	Net Ma
Asia a	Japan	20 Preparati	2003 Mus	200390 Mushr	20039090 Mushrooms, prepa	2015	116

Figure 1. An example of a typical table downloaded from the HMRC trade website. The data was dependent on selections made.

Table 1 Summary of Imported Japanese food to the UK in Kg per year for each food.

	Yearly Import (Kg)													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Food Group														
Alcoholic beverages	542499	1230102	782812	480750	541041	548216	652561	399924	474110	508139	397658	504855	719877	7782544
Baby food	30996	13011	11178	9570	14092	1345	1075	858	2975	8167	5145	2238	1380	102030
Bread	231883	215984	131776	72096	46796	22398	26006	25804	18386	15260	10838	3872	10334	831433
Cattle							10583	39824	47389	36931	52120	62282	36288	285417
Cereals and grains	28111	118746	86317	82805	55667	55593	67682	124395	87959	98182	127649	134682	40252	1108040
Condiments, spices a	1937239	1780017	2308796	2463321	2423711	3023570	3134011	3736563	4745848	5097173	5414829	5643423	4973382	46681883
Confectionary sugars	66627	94846	54195	31776	20418	46086	55492	59983	68545	15165	82391	84482	100863	780869
Dairy products								12		42			5	59
Dried fish									1300					1300
Dried fruit, nuts and s	138421	143405	265448	248083	116882	108892	155836	80460	102330	99422	75174	93743	42856	1670952
Dried mushroom	872	26	675	1215	709	96		691	3636	2431	1016	2946	1696	16009
Eggs					12									12
Fats and oils	12873	9377	14659	12994	4669	6235	9299	10956	6829	15504	237867	220589	6712	568563
Freshwater fish	2514		21338			64665	220504	651	17024	16256				342952
Fruit	82980	47905	166976	148574	37138	3924	8934	10003	2250	4227	12427	1203	696	527237
Infant formula														0
Leguminous vegetabl	48194	2862	5429	1228	755	489	131	180	467			15960	849	76544
Meat and dairy altern	701533	566677	523373	312797	178235	288368	240714	261619	241283	309611	367781	321240	394194	4707425
Mushroom	92	328	242	344	240			116	700	231	216	127	96	2732
Non-leguminous gree	600691	219771	219596	152725	170855	284220	200498	152333	184159	174319	196995	254250	282519	3092931
Other meats	43543	4742	21999											70284
Pasta	745426	380607	399855	345844	237958	333643	351979	425801	410729	423537	390416	726139	663657	5835591
Potatoes	392	698	12207	4126	4751	5107	421		302	150	529	1128	2333	32144
Ready to eat foods	926797	664280	821740	787959	729810	1222264	1293976	1504945	1972306	2078295	2271586	2405074	2450435	19129467
Rice	77109	34952	47018	107248	92706	61643	129746	190585	326799	743585	404925	463207	433562	3113085
Root vegetables	14152	5170	37342	500	1185	268	3049	2124	1614	3562	4143	6517	4263	83889
Saltwater fish and ca	140450	89680	75094	161367	102890	169439	742632	865807	100837	72460	205396	188626	48725	2963403
Seafood other	62582	58724	48405	8391	1607	58183	54633	99270	46800	50	44190	43510	5000	531345
Seaweed and algae	103639	95813	57102	24172	2652	8029	5622	5650	12349	9001	18451	15022	16799	374301
Shoots (bamboo)	92258	28905	997	1800	22660	11399	43320	9774	15570	22770	27940	44243	21621	343257
Soft beverages juices	322622	696260	186321	155243	306135	248339	116611	118063	519248	1334030	2100615	5340287	1010063	12453837

Appendix E: Removal of years 2011 and 2012 following year-on-year comparison of radiocaesium activity concentrations of foodstuffs.

Analysis of year-to-year variation in Cs-134 and Cs-137 activity concentrations showed that 27 of the 35 food groups had statistically significantly higher levels of Cs-134 and Cs-137 in 2011 and/or 2012 than in subsequent years (21 food groups had higher values in 2011 and 2012 and 7 groups had higher values in one of those years) (Table 1 and Figure 1). Of these 28 food groups, 26 also had larger standard error associated with the fitted values in 2011 and/or 2012. A further five groups did not contain data for years 2011 or 2012.

The only food groups that contained data for 2011 and 2012, where the activity concentrations were found to be greater in subsequent years, were ‘meat and dairy alternatives and ‘pasta’. This provided further justification for the removal of years 2011 and 2012 from the dataset as activity concentrations of radiocaesium in foods produced in 2011 and 2012 is not representative of that in foods produced in recent years, or likely to be produced into the foreseeable future.

Table 1: Fitted log values from parametric survival regression for each food group by year ± 1 standard error.

Food Group	**Radionuclide**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Agar	^{134}Cs	No data	No data	-	2.56 ± 200961920	6.41 ± 502320103	5.46 ± 14695531	5.84 ± 2426999	-	6.47 ± 506705970	-
	^{137}Cs	No data	No data	-	2.32 ± 17561737	5.86 ± 44397060	5.42 ± 5783376	5.36 ± 1999684	-	5.93 ± 44939276	-
Alcoholic beverages	^{134}Cs	No data	No data	0.83 ± 0.04	2.22 ± 0.13	2.5 ± 0.19	2.51 ± 0.19	2.33 ± 0.17	2.19 ± 0.24	2.16 ± 0.18	1.78 ± 0.15
	^{137}Cs	No data	No data	0.89 ± 0.05	2.09 ± 0.13	2.32 ± 0.18	2.25 ± 0.18	2.11 ± 0.16	1.85 ± 0.21	1.95 ± 0.17	1.6 ± 0.14
Baby food	^{134}Cs	No data	No data	0.31 ± 0.1	3.04 ± 1.72	3.1 ± 0.88	2.96 ± 0.63	1.69 ± 0.24	2.85 ± 0.72	2.9 ± 0.4	1.99 ± 0.37
	^{137}Cs	No data	No data	0.33 ± 0.11	2.97 ± 1.74	2.93 ± 0.86	3.04 ± 0.67	1.73 ± 0.25	3.11 ± 0.82	3.02 ± 0.43	2.17 ± 0.42
Bamboo shoots	^{134}Cs	8.89 ± 3.23	49.47 ± 2.28 *	7.24 ± 0.22	5.51 ± 0.13	5.85 ± 0.18	5.11 ± 0.11	2.95 ± 0.08	4.15 ± 0.1	3.99 ± 0.13	4.69 ± 0.16
	^{137}Cs	8.42 ± 4.56	51.98 ± 3.62 *	10.71 ± 0.5	10.07 ± 0.36	9.49 ± 0.43	9.03 ± 0.28	6.96 ± 0.28	9.57 ± 0.34	8.09 ± 0.39	8.59 ± 0.42
Bread	^{134}Cs	No data	No data	3.3 ± 0.35	3.29 ± 0.33	2.5 ± 0.39	3.26 ± 0.31	3.37 ± 0.43	3.77 ± 0.55	4.26 ± 0.42	-
	^{137}Cs	No data	No data	2.78 ± 0.27	2.51 ± 0.23	2.17 ± 0.43	2.72 ± 0.24	2.5 ± 0.32	3.64 ± 0.52	3.73 ± 0.36	-

Food Group	**Radionuclide**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Cattle meat	^{134}Cs	10.18 ± 0.15 *	13.21 ± 0.11 *	8.7 ± 0.05	8.7 ± 0.05	8.66 ± 0.05	8.65 ± 0.06	8.65 ± 0.05	8.63 ± 0.07	8.68 ± 0.05	8.52 ± 0.08
	^{137}Cs	9.67 ± 0.15 *	12.25 ± 0.11 *	8.56 ± 0.05	8.64 ± 0.05	8.61 ± 0.05	8.59 ± 0.06	8.59 ± 0.05	8.57 ± 0.07	8.62 ± 0.05	8.4 ± 0.08
Cereals and grains	^{134}Cs	13.8 ± 0.7 *	14.5 ± 0.49 *	3.15 ± 0.04	2.74 ± 0.05	2.81 ± 0.05	2.91 ± 0.07	2.99 ± 0.08	2.83 ± 0.13	2.83 ± 0.07	2.23 ± 0.07
	^{137}Cs	14 ± 0.8 *	14.4 ± 0.55 *	3.46 ± 0.05	2.67 ± 0.05	2.8 ± 0.06	3 ± 0.08	2.84 ± 0.09	2.68 ± 0.13	2.76 ± 0.07	2.13 ± 0.08
Condiments, spices and preserves	^{134}Cs	10.75 ± 0.77 *	9.61 ± 0.29 *	3.72 ± 0.08	3.89 ± 0.09	3.82 ± 0.09	3.69 ± 0.09	3.53 ± 0.1	3.66 ± 0.14	3.9 ± 0.1	3.8 ± 0.14
	^{137}Cs	11.23 ± 0.85 *	9.83 ± 0.32 *	3.68 ± 0.08	3.76 ± 0.09	3.69 ± 0.09	3.57 ± 0.09	3.35 ± 0.1	3.46 ± 0.14	3.72 ± 0.1	3.62 ± 0.14
Confectionary	^{134}Cs	No data	10.88 ± 1.52 *	3.31 ± 0.16	3.33 ± 0.15	3.25 ± 0.19	3.51 ± 0.22	3.44 ± 0.18	3.64 ± 0.34	3.55 ± 0.29	3.23 ± 0.36
	^{137}Cs	No data	13.17 ± 1.93 *	3.02 ± 0.16	2.96 ± 0.14	2.92 ± 0.18	3.12 ± 0.2	3.12 ± 0.17	3.37 ± 0.34	3.44 ± 0.3	3.37 ± 0.4
Cultivated mushrooms	^{134}Cs	24.09 ± 1.2 *	24.32 ± 0.63 *	4.11 ± 0.09	3.98 ± 0.08	4.18 ± 0.07	3.96 ± 0.07	3.21 ± 0.06	3.55 ± 0.11	3.78 ± 0.07	3.8 ± 0.08
	^{137}Cs	29.34 ± 2 *	28.62 ± 1 *	5.39 ± 0.16	5.49 ± 0.14	6.39 ± 0.15	6.69 ± 0.17	5.81 ± 0.15	7.71 ± 0.31	5.52 ± 0.13	5.82 ± 0.17
Dairy products	^{134}Cs	2.05 ± 0.14 *	2.57 ± 0.07 *	1.11 ± 0.02	1.29 ± 0.03	1.45 ± 0.04	1.53 ± 0.04	1.59 ± 0.04	1.58 ± 0.06	1.84 ± 0.05	1.58 ± 0.07

Food Group	Radionuclide	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	^{137}Cs	1.99 ± 0.12 *	2.53 ± 0.07 *	1.06 ± 0.02	1.2 ± 0.03	1.35 ± 0.03	1.42 ± 0.03	1.48 ± 0.04	1.47 ± 0.06	1.71 ± 0.04	1.48 ± 0.06
Dried fish	^{134}Cs	4.04 ± 0.86	9.15 ± 1.07 *	3.68 ± 0.22	3.26 ± 0.22	3.16 ± 0.24	3.27 ± 0.27	3.46 ± 0.25	4.18 ± 0.43	4.86 ± 0.3	4.81 ± 0.38
	^{137}Cs	4.07 ± 0.81	10.37 ± 1.13 *	3.59 ± 0.2	3.15 ± 0.2	2.98 ± 0.21	3.05 ± 0.23	3.21 ± 0.22	3.87 ± 0.38	4.36 ± 0.25	4.32 ± 0.32
Dried fruit, nuts and seeds	^{134}Cs	15.8 ± 1.02 *	13.91 ± 0.39 *	6.13 ± 0.15	5.23 ± 0.13	5 ± 0.12	3.74 ± 0.11	4.4 ± 0.14	4.22 ± 0.34	4.02 ± 0.11	3.75 ± 0.13
	^{137}Cs	16.79 ± 1.58 *	15.75 ± 0.64 *	8.15 ± 0.29	6.62 ± 0.23	6.75 ± 0.23	4.39 ± 0.18	6.19 ± 0.29	5.01 ± 0.57	5.23 ± 0.21	4.75 ± 0.24
Dried mushrooms	^{134}Cs	41.85 ± 3.97 *	38.02 ± 2.74 *	4.51 ± 0.38	4.33 ± 0.43	3.08 ± 0.26	3.12 ± 0.25	3.1 ± 0.26	2.84 ± 0.32	2.81 ± 0.2	2.63 ± 0.21
	^{137}Cs	59.83 ± 7.23 *	52.48 ± 4.81 *	6.62 ± 0.71	6.72 ± 0.84	5.19 ± 0.55	5.97 ± 0.59	7.92 ± 0.83	7.77 ± 1.12	6.79 ± 0.61	6.15 ± 0.61
Eggs	^{134}Cs	5.03 ± 0.43	7.63 ± 0.22 *	4.68 ± 0.14	4.74 ± 0.15	5.15 ± 0.16	5.32 ± 0.18	5.89 ± 0.22	5.86 ± 0.32	6.05 ± 0.23	5.97 ± 0.28
	^{137}Cs	4.37 ± 0.35	7.02 ± 0.19 *	4.5 ± 0.12	4.51 ± 0.13	4.77 ± 0.14	4.9 ± 0.16	5.48 ± 0.19	5.37 ± 0.28	5.45 ± 0.19	5.41 ± 0.24
Fats and oils	^{134}Cs	6.29 ± 1.57 *	6.18 ± 0.4 *	3.49 ± 0.28	2.3 ± 0.39	2.42 ± 0.23	2.7 ± 0.23	2.54 ± 0.25	2.48 ± 0.33	2.71 ± 0.44	2.74 ± 0.32

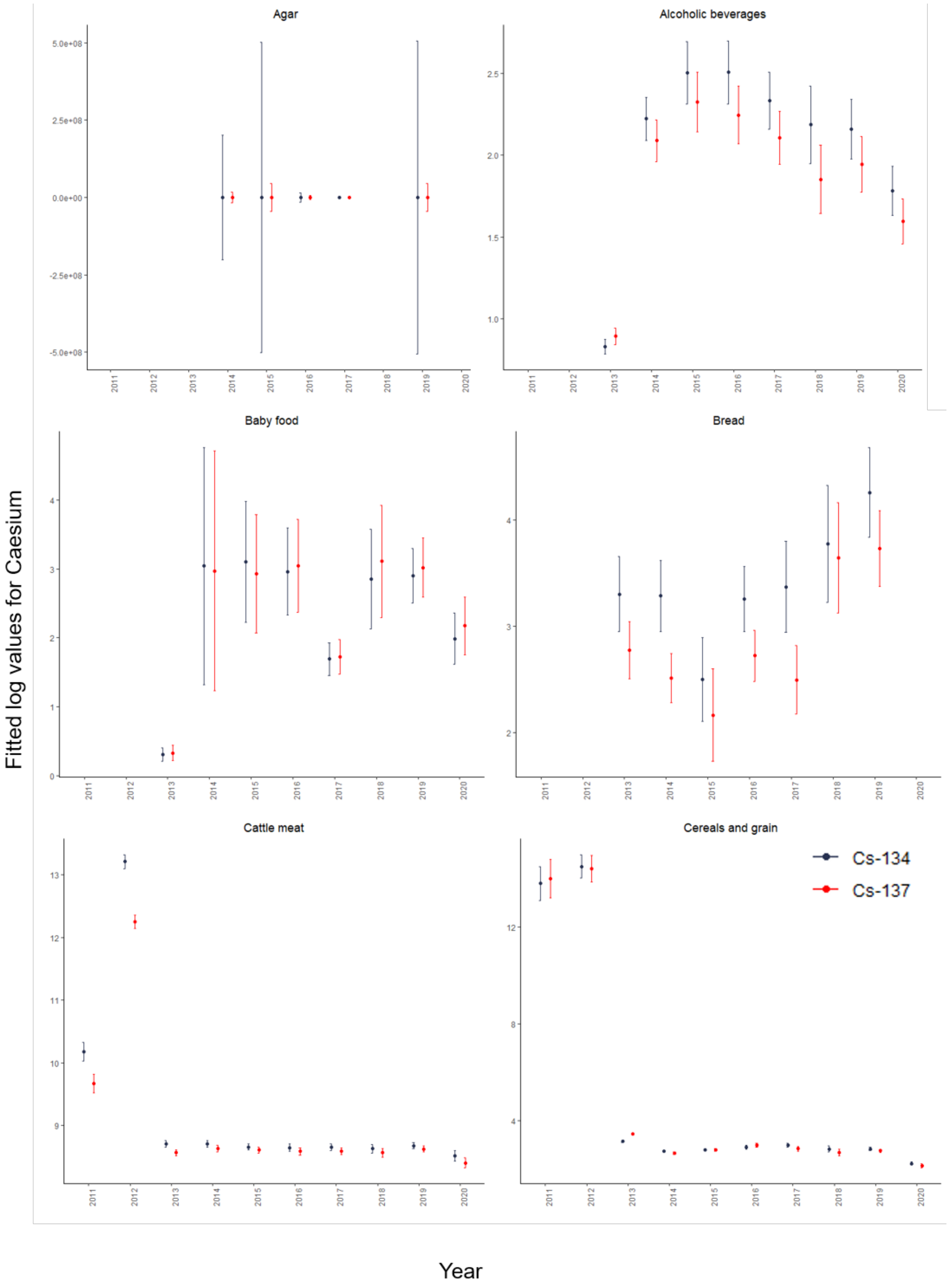
Food Group	Radionuclide	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	^{137}Cs	5.55 ± 1.35 *	5.2 ± 0.33 *	3.09 ± 0.26	1.96 ± 0.31	2.39 ± 0.23	2.33 ± 0.21	2.44 ± 0.25	2.36 ± 0.35	2.68 ± 0.44	2.67 ± 0.35
Freshwater fish	^{134}Cs	21.8 ± 2.06 *	23.44 ± 0.8 *	6.24 ± 0.15	5.36 ± 0.12	4.87 ± 0.11	4.59 ± 0.1	4.8 ± 0.11	4.9 ± 0.12	5.21 ± 0.08	4.74 ± 0.1
	^{137}Cs	25.7 ± 3.6 *	27.42 ± 1.39 *	8.63 ± 0.3	7.85 ± 0.25	7.27 ± 0.25	7.31 ± 0.24	6.92 ± 0.22	7.91 ± 0.28	8.42 ± 0.19	8.83 ± 0.27
Fruit	^{134}Cs	11.23 ± 0.34 *	12.17 ± 0.2 *	3.44 ± 0.03	3.26 ± 0.03	3.28 ± 0.04	3.2 ± 0.04	3.45 ± 0.05	3.46 ± 0.08	3.33 ± 0.05	3.2 ± 0.06
	^{137}Cs	12.21 ± 0.41 *	12.75 ± 0.23 *	3.62 ± 0.04	3.29 ± 0.04	3.4 ± 0.04	3.27 ± 0.05	3.45 ± 0.06	3.42 ± 0.09	3.32 ± 0.05	3.22 ± 0.07
Infant formula	^{134}Cs	No data	No data	1.34 ± 0.32	1.63 ± 0.29	1.38 ± 0.27	2.04 ± 0.3	1.94 ± 0.23	2.45 ± 0.58	2.1 ± 0.24	-
	^{137}Cs	No data	No data	1.41 ± 0.33	1.63 ± 0.29	1.4 ± 0.27	2.23 ± 0.33	2.06 ± 0.24	2.6 ± 0.61	2.16 ± 0.24	-
Leguminous vegetables	^{134}Cs	13.2 ± 0.37 *	12.3 ± 0.28 *	4.8 ± 0.03	3.64 ± 0.03	3.44 ± 0.03	3.34 ± 0.05	3.41 ± 0.07	3.64 ± 0.12	3.57 ± 0.08	3.05 ± 0.09
	^{137}Cs	13.1 ± 0.53 *	12.2 ± 0.4 *	7.17 ± 0.07	4.8 ± 0.05	3.88 ± 0.05	3.77 ± 0.07	3.89 ± 0.11	3.42 ± 0.17	3.57 ± 0.12	3.06 ± 0.13
Meat and dairy alternatives	^{134}Cs	No data	3.35 ± 0.24	2.91 ± 0.27	2.93 ± 0.2	2.86 ± 0.23	3 ± 0.23	3.29 ± 0.3	3.53 ± 0.53	5.94 ± 0.48	4.3 ± 0.57
	^{137}Cs	No data	3.27 ± 0.23	2.81 ± 0.26	2.79 ± 0.19	2.68 ± 0.22	2.86 ± 0.22	3.13 ± 0.28	3.41 ± 0.5	5.66 ± 0.45	4.44 ± 0.59

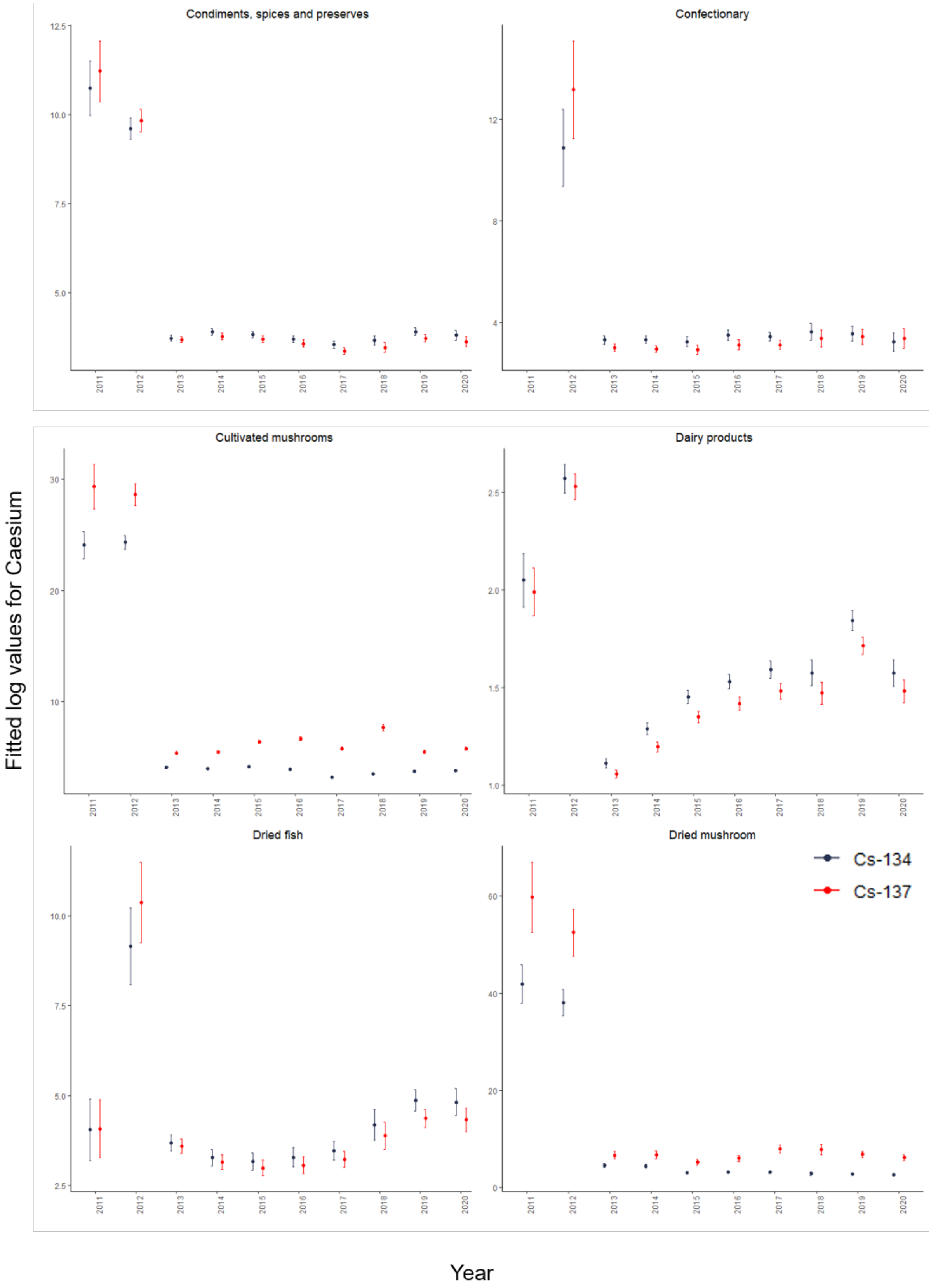
Food Group	Radionuclide	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Meats other than cattle	^{134}Cs	6.52 ± 0.4	6.74 ± 0.21	5.33 ± 0.12	4.64 ± 0.12	5.1 ± 0.14	4.86 ± 0.15	5.31 ± 0.16	5.47 ± 0.25	6.09 ± 0.18	6.24 ± 0.25
	^{137}Cs	6.29 ± 0.42	6.45 ± 0.22	5.4 ± 0.13	4.48 ± 0.12	5.05 ± 0.15	4.86 ± 0.16	5.43 ± 0.18	5.47 ± 0.26	5.95 ± 0.19	6.03 ± 0.26
Mushrooms	^{134}Cs	13.6 ± 0.8 *	10.5 ± 0.36 *	4.54 ± 0.1	4.38 ± 0.1	3.48 ± 0.08	3.88 ± 0.09	3.45 ± 0.09	3.84 ± 0.22	4.13 ± 0.08	3.89 ± 0.12
	^{137}Cs	15.3 ± 1.31 *	11.7 ± 0.58 *	6.25 ± 0.2	5.87 ± 0.19	4.82 ± 0.16	6.43 ± 0.22	5.77 ± 0.21	3.7 ± 0.31	7.87 ± 0.23	7.21 ± 0.32
Non-leguminous green vegetables	^{134}Cs	6.41 ± 0.19 *	8.54 ± 0.12 *	4.05 ± 0.03	3.72 ± 0.03	3.72 ± 0.03	3.75 ± 0.04	3.76 ± 0.04	4.01 ± 0.05	3.8 ± 0.04	3.78 ± 0.05
	^{137}Cs	6.13 ± 0.22 *	8.28 ± 0.14 *	4.12 ± 0.04	3.84 ± 0.04	3.89 ± 0.04	4.04 ± 0.04	4.2 ± 0.05	4.86 ± 0.07	4.36 ± 0.06	4.39 ± 0.07
Pasta	^{134}Cs	No data	3.09 ± 0.48	3.03 ± 0.18	3.18 ± 0.19	3.35 ± 0.23	3.97 ± 0.29	3.06 ± 0.21	3.04 ± 0.35	4 ± 0.19	4.11 ± 0.35
	^{137}Cs	No data	3.8 ± 0.6	2.86 ± 0.18	2.95 ± 0.19	3.43 ± 0.25	3.77 ± 0.29	2.87 ± 0.21	2.96 ± 0.36	3.6 ± 0.19	4.02 ± 0.36
Potatoes	^{134}Cs	7.03 ± 1.12 *	8.53 ± 0.79 *	3.79 ± 0.12	3.22 ± 0.11	3.34 ± 0.13	3.74 ± 0.17	3.87 ± 0.17	3.64 ± 0.18	3.48 ± 0.14	2.82 ± 0.14
	^{137}Cs	7.09 ± 1.18 *	9.05 ± 0.88 *	3.73 ± 0.13	3.09 ± 0.11	3.24 ± 0.13	3.61 ± 0.17	3.86 ± 0.18	3.58 ± 0.18	3.42 ± 0.14	2.78 ± 0.14

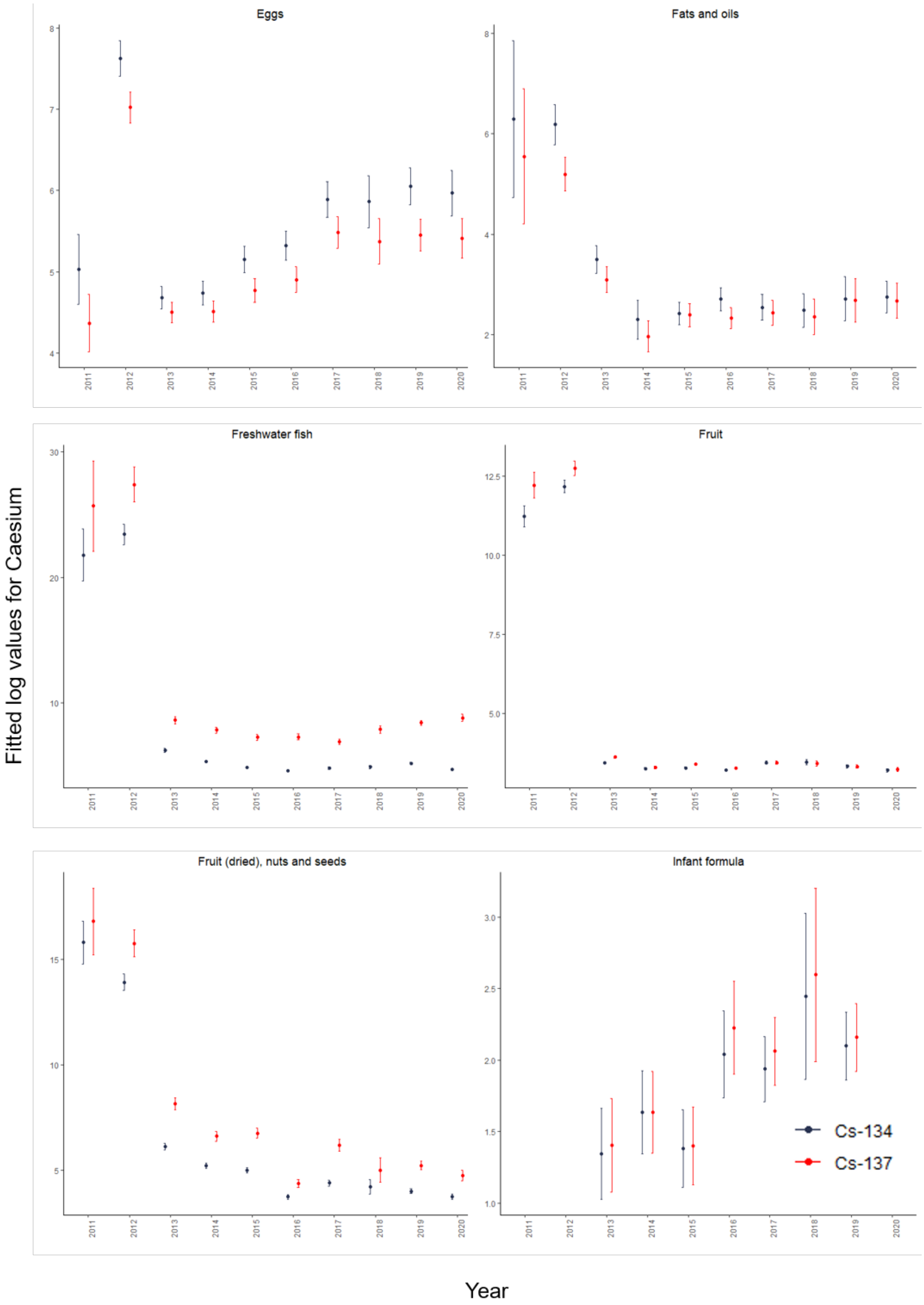
Food Group	Radionuclide	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Ready to eat foods	^{134}Cs	7.7 ± 2 *	5.56 ± 1.23	3.7 ± 0.1	3.66 ± 0.08	3.51 ± 0.09	3.25 ± 0.09	3.09 ± 0.09	3.64 ± 0.17	4.42 ± 0.13	4.33 ± 0.16
	^{137}Cs	7.23 ± 2.12 *	5.32 ± 1.34	3.55 ± 0.11	3.35 ± 0.09	3.32 ± 0.09	3 ± 0.09	2.88 ± 0.09	3.3 ± 0.17	4.12 ± 0.13	4.03 ± 0.17
Rice	^{134}Cs	11.28 ± 0.81 *	9.37 ± 0.55 *	4.73 ± 0.08	2.41 ± 0.06	2.7 ± 0.08	2.05 ± 0.07	1.62 ± 0.06	1.03 ± 0.08	1.78 ± 0.06	4.24 ± 0.1
	^{137}Cs	12.81 ± 1.05 *	10.43 ± 0.7 *	6.02 ± 0.12	2.49 ± 0.07	2.76 ± 0.1	2.17 ± 0.08	1.68 ± 0.07	1.07 ± 0.1	1.83 ± 0.07	4.22 ± 0.11
Root vegetables	^{134}Cs	5.69 ± 0.18 *	6.43 ± 0.1 *	3.63 ± 0.04	3.44 ± 0.04	3.37 ± 0.04	3.52 ± 0.05	3.73 ± 0.06	3.78 ± 0.08	3.48 ± 0.05	3.38 ± 0.06
	^{137}Cs	5.49 ± 0.18 *	6.49 ± 0.1 *	3.63 ± 0.04	3.4 ± 0.04	3.37 ± 0.04	3.49 ± 0.05	3.67 ± 0.06	3.72 ± 0.08	3.48 ± 0.05	3.3 ± 0.06
Saltwater fish	^{134}Cs	17.49 ± 0.77 *	16.14 ± 0.33 *	5.1 ± 0.07	4.35 ± 0.06	4.16 ± 0.06	4.32 ± 0.06	4.65 ± 0.07	4.56 ± 0.09	4.55 ± 0.07	4 ± 0.08
	^{137}Cs	21.11 ± 0.96 *	19.99 ± 0.42 *	6.84 ± 0.09	5.25 ± 0.07	4.66 ± 0.06	4.44 ± 0.07	4.62 ± 0.07	4.47 ± 0.09	4.33 ± 0.07	3.98 ± 0.09
Seafood other than fish	^{134}Cs	8.71 ± 0.53 *	7.81 ± 0.21 *	5.1 ± 0.1	5.11 ± 0.08	4.86 ± 0.08	5.05 ± 0.08	5.14 ± 0.09	5.12 ± 0.12	5.36 ± 0.1	5.23 ± 0.11
	^{137}Cs	9.64 ± 0.61 *	8.55 ± 0.24 *	5.59 ± 0.11	5.4 ± 0.09	5 ± 0.08	4.94 ± 0.08	4.8 ± 0.09	4.81 ± 0.12	4.97 ± 0.09	4.97 ± 0.11
Seaweed and algae	^{134}Cs	6.32 ± 1.56	7.06 ± 0.48 *	2.61 ± 0.2	5.48 ± 0.21	5.52 ± 0.21	5.95 ± 0.24	6.19 ± 0.24	6.24 ± 0.27	5.49 ± 0.26	6.06 ± 0.36

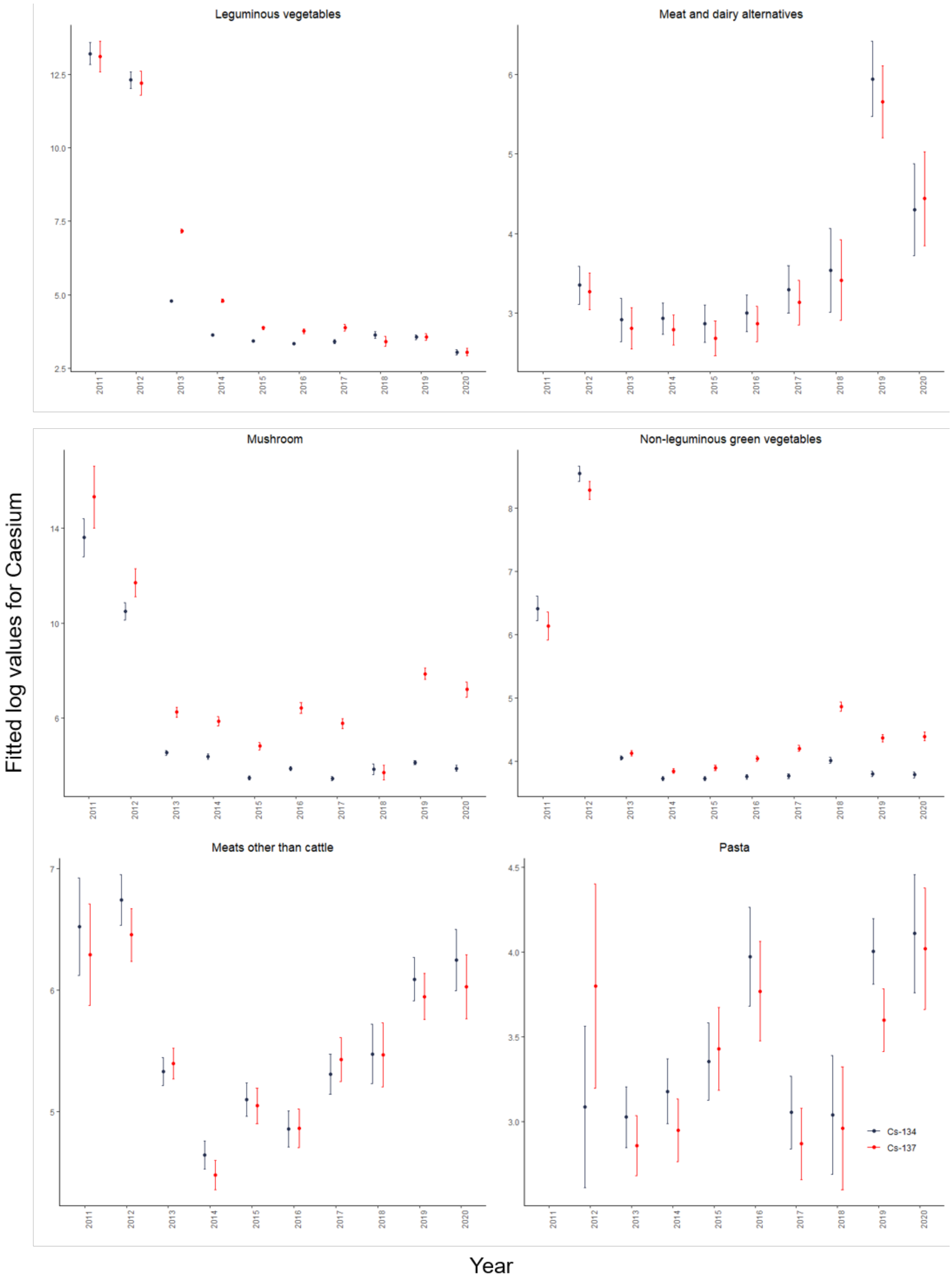
Food Group	Radionuclide	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	^{137}Cs	7.24 ± 1.77	7.34 ± 0.5 *	2.63 ± 0.2	5.55 ± 0.21	5.54 ± 0.21	5.98 ± 0.23	6.16 ± 0.24	6.26 ± 0.27	5.47 ± 0.26	6.01 ± 0.35
Snacks	^{134}Cs	No data	7.64 ± 0.28 *	3.23 ± 0.09	3.21 ± 0.09	3.02 ± 0.08	3.02 ± 0.09	2.96 ± 0.08	3.52 ± 0.13	4.04 ± 0.1	3.66 ± 0.12
	^{137}Cs	No data	6.76 ± 0.29 *	3.01 ± 0.1	2.82 ± 0.09	2.75 ± 0.09	2.7 ± 0.09	2.76 ± 0.09	3.12 ± 0.14	3.77 ± 0.11	3.37 ± 0.13
Soft beverages	^{134}Cs	23.95 ± 2.89 *	18.55 ± 1.09 *	0.58 ± 0.02	0.73 ± 0.04	0.78 ± 0.04	0.87 ± 0.05	0.73 ± 0.04	1.14 ± 0.1	0.73 ± 0.04	0.7 ± 0.06
	^{137}Cs	24.88 ± 3.05 *	20.99 ± 1.25 *	0.64 ± 0.03	0.78 ± 0.04	0.81 ± 0.05	0.89 ± 0.05	0.75 ± 0.04	1.12 ± 0.1	0.75 ± 0.04	0.69 ± 0.06
Wild mushrooms	^{134}Cs	16.14 ± 2.24 *	9.98 ± 0.8 *	4.49 ± 0.14	4.11 ± 0.14	3.97 ± 0.13	3.59 ± 0.11	3.4 ± 0.13	3.99 ± 0.17	3.86 ± 0.13	3.83 ± 0.17
	^{137}Cs	16.93 ± 3.53 *	9.86 ± 1.18 *	5.07 ± 0.23	4.82 ± 0.23	4.6 ± 0.21	4.08 ± 0.18	3.72 ± 0.2	3.63 ± 0.22	5.8 ± 0.28	4.37 ± 0.28

Fitted values for 2011 and 2012 are highlighted in yellow and marked with an asterisk * where they are greater than fitted values for 2013 – 2020.


Fitted log values for Caesium
Agar
5.0e+08
2.5e+08
0.0e+00
-2.5e+08
-5.0e+08
Alcoholic beverages
2.5
2.0
1.5
1.0
Baby food
4
3
2
1
0
Bread
4
3
2
Cattle meat
13
12
11
10
9
Cereals and grain
12
8
4
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Cs-134
Cs-137
Year


Fitted log values for Caesium
Year
Condiments, spices and preserves
12.5
10.0
7.5
5.0
Confectionary
12
8
4
Cultivated mushrooms
30
20
10
Dairy products
2.5
2.0
1.5
1.0
Dried fish
10.0
7.5
5.0
2.5
Dried mushroom
60
40
20
0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Cs-134
Cs-137


Eggs
Fats and oils
Freshwater fish
Fruit
Fruit (dried), nuts and seeds
Infant formula
Fitted log values for Caesium
Year
4
5
6
7
8
2
4
6
8
10
20
30
5.0
7.5
10.0
12.5
5
10
15
1.0
1.5
2.0
2.5
3.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Cs-134
Cs-137


Fitted log values for Caesium
Year
Leguminous vegetables
12.5
10.0
7.5
5.0
2.5
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Meat and dairy alternatives
6
5
4
3
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Mushroom
14
10
6
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Non-leguminous green vegetables
8
7
6
5
4
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Meats other than cattle
7
6
5
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Pasta
4.5
4.0
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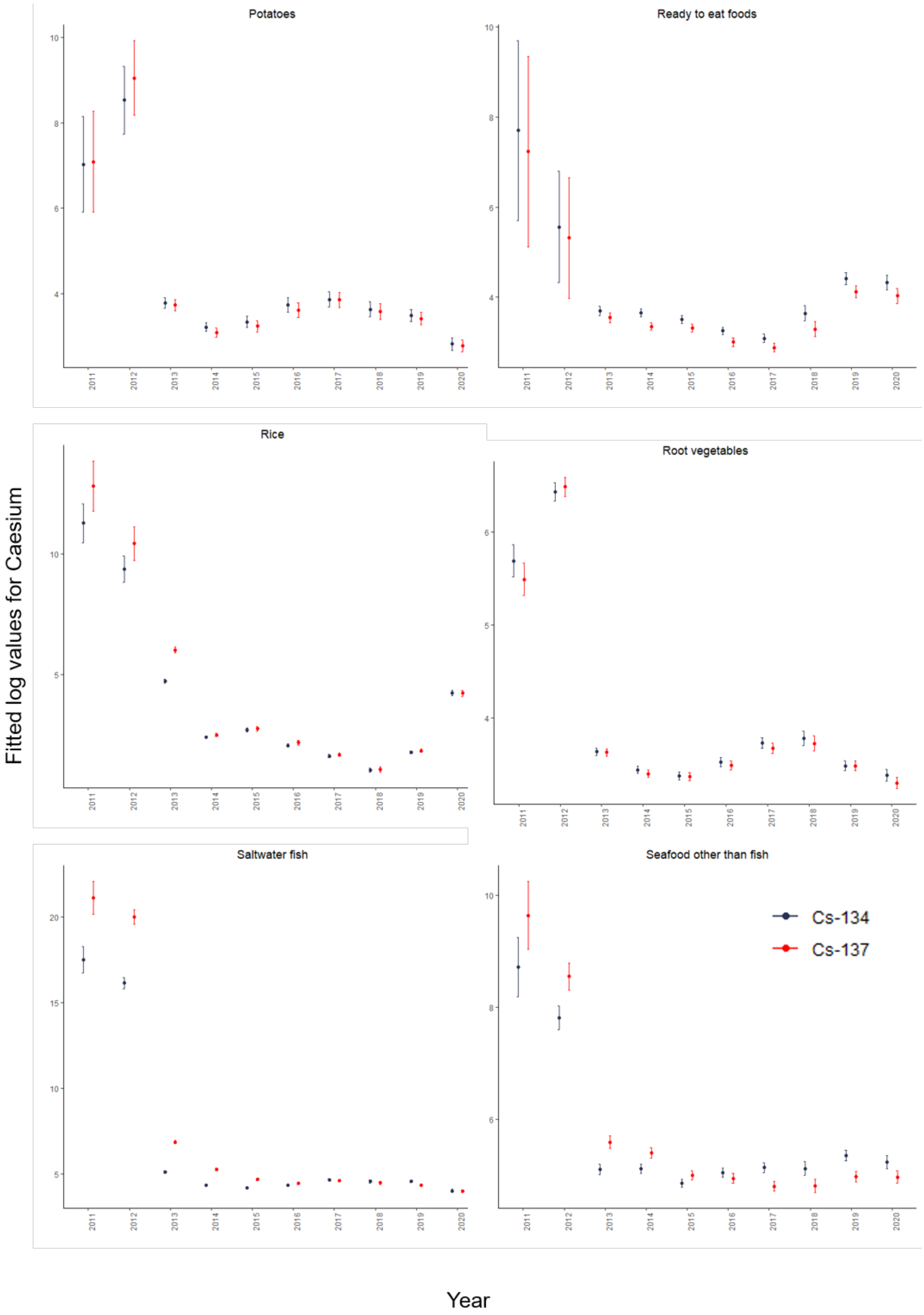
3.0
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Cs-134
Cs-137


Potatoes
Ready to eat foods
Rice
Root vegetables
Saltwater fish
Seafood other than fish
Fitted log values for Caesium
Year
10
8
6
4
5
20
15
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Cs-134
Cs-137

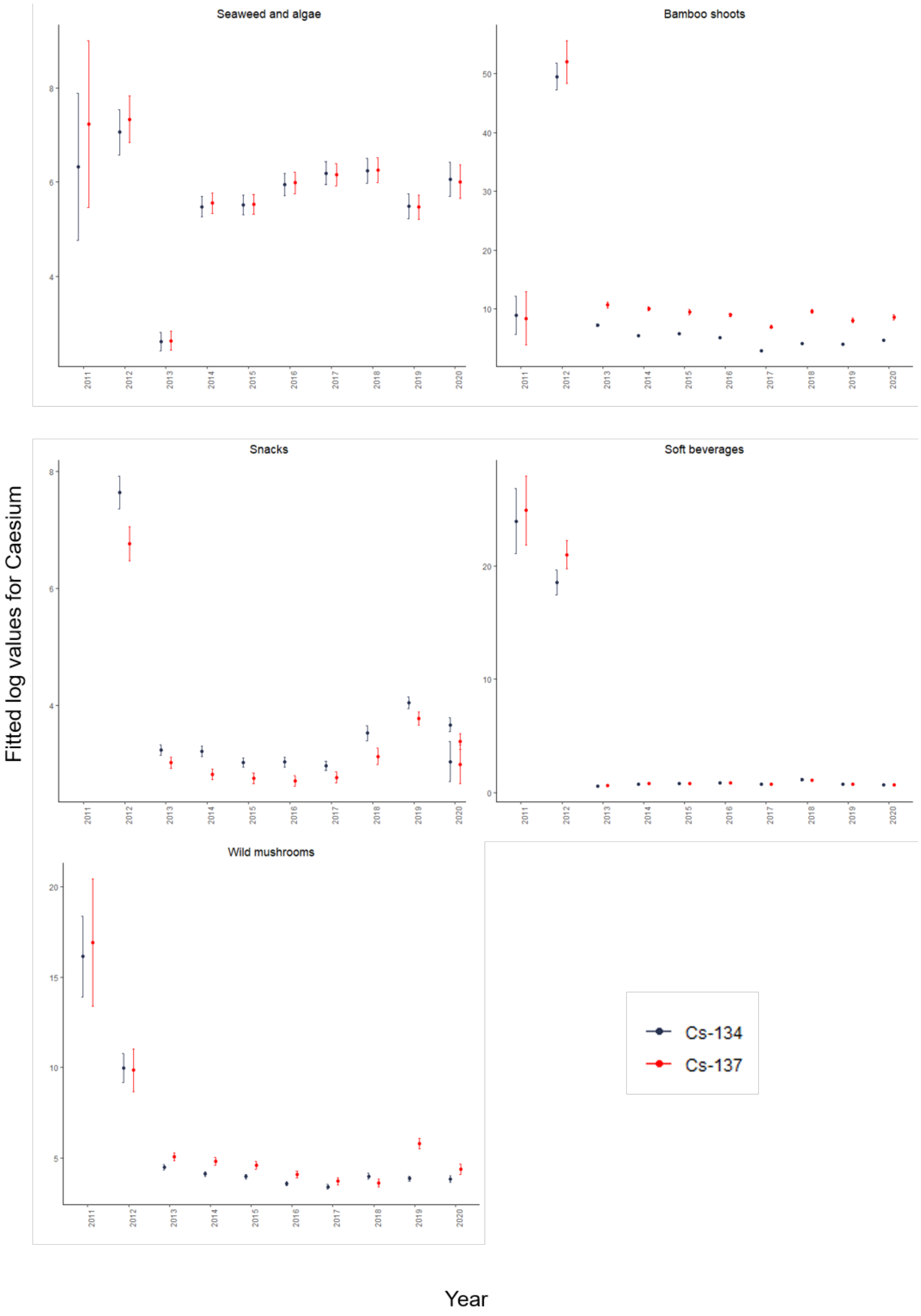


Figure 1: Parametric survival regression model outputs for each food group, comparing Cs-134 (black) and Cs-137 (red) levels by year, from 2011 – 2020. Bar's show ± 1 standard error.

Appendix F: Lower and upper bound radiocaesium activity concentrations for the food groups.

Lower and upper bound Cs-134 and Cs-137 activity concentrations are shown for each food group (Bq/kg) in Tables 1 and 2, respectively.

Table 1. Lower-bound radiocaesium activity concentrations in each food group (Bq/kg).

Food group	Cs-134 (Bq/kg)	Cs-137 (Bq/kg)
Agar	3.58E+00	3.33E+00
Alcoholic beverages	1.58E+00	1.55E+00
Baby food	1.81E+00	1.89E+00
Bread	2.48E+00	2.15E+00
Cattle	6.16E+00	6.13E+00
Cereals and grains	2.37E+00	2.75E+00
Condiments, spices and preserves	3.06E+00	3.09E+00
Confectionary	2.60E+00	2.41E+00
Dairy products	1.24E+00	1.13E+00
Dried fish	3.62E+00	3.31E+00
Dried fruit, nuts, and seeds	4.48E+00	9.85E+00
Dried mushroom	3.23E+00	1.17E+01
Eggs	4.07E+00	3.77E+00
Fats and oils	1.96E+00	1.85E+00
Freshwater fish	4.46E+00	1.12E+01
Fruit	2.83E+00	3.30E+00
Infant formula	1.62E+00	1.68E+00
Leguminous vegetables	3.67E+00	6.71E+00
Meat and dairy alternatives	2.79E+00	2.70E+00
Mushroom	3.77E+00	1.10E+01
Non-leguminous green vegetables	3.30E+00	4.61E+00
Other meats	4.64E+00	6.71E+00
Pasta	2.75E+00	2.63E+00
Potatoes	2.84E+00	2.84E+00
Ready to eat foods	2.86E+00	2.81E+00
Rice	4.03E+00	6.64E+00

Food group	**Cs-134 (Bq/kg)**	**Cs-137 (Bq/kg)**
Root vegetables	2.92E+00	3.00E+00
Saltwater fish	4.19E+00	5.89E+00
Seafood other	4.33E+00	5.01E+00
Seaweed and algae	4.46E+00	4.49E+00
Shoots	4.86E+00	1.65E+01
Snacks	2.55E+00	2.53E+00
Soft beverages	8.49E-01	1.02E+00

Table 2. Upper bound radiocaesium activity concentrations in each food group (Bq/kg).

Food group	**Cs-134 (Bq/kg)**	**Cs-137 (Bq/kg)**
Agar	7.16E+00	6.65E+00
Alcoholic beverages	3.17E+00	3.10E+00
Baby food	3.62E+00	3.77E+00
Bread	4.97E+00	4.29E+00
Cattle	1.23E+01	1.23E+01
Cereals and grains	4.53E+00	4.65E+00
Condiments, spices and preserves	6.06E+00	5.86E+00
Confectionary	5.20E+00	4.75E+00
Dairy products	2.48E+00	2.26E+00
Dried fish	7.24E+00	6.57E+00
Dried fruit, nuts, and seeds	7.34E+00	1.18E+01
Dried mushroom	5.18E+00	1.28E+01
Eggs	8.13E+00	7.54E+00
Fats and oils	3.93E+00	3.65E+00
Freshwater fish	7.78E+00	1.31E+01
Fruit	5.49E+00	5.75E+00
Infant formula	3.23E+00	3.37E+00
Leguminous vegetables	5.71E+00	8.12E+00
Meat and dairy alternatives	5.58E+00	5.37E+00
Mushroom	6.58E+00	1.30E+01
Non-leguminous green vegetables	6.91E+00	9.35E+00
Other meats	8.69E+00	9.64E+00
Pasta	5.48E+00	5.20E+00
Potatoes	5.66E+00	5.57E+00
Ready to eat foods	5.68E+00	5.35E+00
Rice	6.13E+00	8.75E+00
Root vegetables	5.80E+00	5.76E+00
Saltwater fish	7.44E+00	8.60E+00
Seafood other	8.16E+00	8.45E+00
Seaweed and algae	8.92E+00	8.91E+00
Shoots	7.70E+00	1.83E+01
Snacks	5.04E+00	4.74E+00
Soft beverages	1.65E+00	1.80E+00

Appendix G: Dose calculation Summary for Component A.

Summary of dose calculations for component A using IPF 0.1 (10%):

(i) UPPER bound LOD TOP TWO Dose calculation summary

Age group (yrs)	Top two dose (mSv/yr)	Top consumer 1	Top Consumer 2
Adult	1.60E-02	Soft beverages	Alcoholic beverages
Child 1 (18m - < 5)	9.69E-03	Infant formula	Meat and dairy alternatives
Child 2 (5 - <10)	7.54E-03	Soft beverages	Fruit
Child 1 (18m - < 5)	1.18E-03	Soft beverages	Fruit
Infant (4m - <18m)	7.68E-03	Infant formula	Dairy products
Foetus	6.58E-03	Soft beverages	Alcoholic beverages

(ii) LOWER Bound LOD TOP TWO Dose calculation summary.

Age group (yrs)	Top two dose (mSv/yr)	Top consumer 1	Top Consumer 2
Adult	8.80E-03	Soft beverages	Rice
Child 1 (18m - < 5)	5.07E-03	Infant formula	Meat and dairy alternatives
Child 2 (5 - <10)	4.07E-03	Soft beverages	Fruit
Child 1 (18m - < 5)	6.36E-03	Soft beverages	Fruit
Infant (4m - <18m)	3.95E-03	Infant formula	Dairy products
Foetus	3.63E-03	Soft beverages	Rice

Appendix H: Dose calculation for high consumption of individual food groups

Note that the effective doses in Table 1 assumed that 100% of dietary intake (IPF = 1) (doses from scenario E2 and E3) for each food group comes from Japanese imports exclusively from the prefectures listed in Appendix II of retained Regulation 2016/6[18]. The foods were assessed on an individual basis (E2) and for the top two food groups (E3) and consumption assumed to be at the 97.5th percentile. The activity concentrations used in the calculations were the upper-bound values. Altogether, this represented a cautious estimate of CED. It would be unrealistic to assume that more than two food groups would be consumed at this level and therefore no more than two food groups have been added together.

Table 1: Effective Doses (mSv/year) resulting from 97.5th consumption levels for each food group. Calculated using upper-bound radiocaesium activity concentrations.

Food group	**Adult**	**Child 3**	**Child 2**	**Child 1**	**Infant**	**Foetus**
Agar	1.06E-04	1.37E-04	7.18E-05	6.78E-05	1.24E-04	4.29E-05
Alcoholic beverages	1.09E-02	2.25E-03	1.42E-04	2.45E-05	0.00E+00	4.51E-03
Baby food	0.00E+00	0.00E+00	2.12E-03	4.88E-03	8.54E-03	0.00E+00
Bread	5.61E-03	5.36E-03	3.24E-03	2.78E-03	1.68E-03	1.97E-03
Cattle	7.39E-03	5.01E-03	3.16E-03	2.72E-03	2.22E-03	2.73E-03
Cereals and grains	1.70E-03	1.17E-03	7.82E-04	7.02E-04	6.36E-04	6.43E-04
Condiments, spices and preserves	1.15E-03	7.50E-04	5.46E-04	5.54E-04	2.51E-04	4.69E-04
Confectionary	6.34E-03	7.28E-03	5.07E-03	4.40E-03	2.80E-03	2.65E-03
Dairy products	8.27E-03	8.80E-03	6.72E-03	9.75E-03	8.95E-03	3.14E-03
Dried fish	2.01E-03	3.23E-05	3.85E-06	3.82E-04	1.93E-04	0.00E+00

Food group	Adult	Child 3	Child 2	Child 1	Infant	Foetus
Dried fruit, nuts, and seeds	4.06E-03	1.86E-03	1.45E-03	2.24E-03	1.40E-03	1.37E-03
Dried mushroom	1.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.54E-05
Eggs	3.94E-03	2.72E-03	1.84E-03	1.81E-03	1.51E-03	1.77E-03
Fats and oils	1.16E-03	1.17E-03	6.72E-04	5.66E-04	3.37E-04	5.03E-04
Freshwater fish	6.61E-03	3.01E-03	1.77E-03	2.07E-03	0.00E+00	1.12E-03
Fruit	8.93E-03	1.12E-02	8.38E-03	8.92E-03	4.76E-03	3.62E-03
Infant formula	0.00E+00	0.00E+00	0.00E+00	1.25E-02*	1.48E-02*	0.00E+00
Leguminous vegetables	6.38E-03	4.24E-03	2.99E-03	2.66E-03	2.39E-03	2.53E-03
Meat and dairy alternatives	9.22E-03	5.55E-03	4.31E-03	1.10E-02	5.27E-03	3.98E-03
Mushroom	4.15E-03	2.01E-03	0.00E+00	8.00E-04	1.06E-03	1.80E-03
Non-leguminous green vegetables	6.62E-03	3.95E-03	3.02E-03	2.42E-03	2.49E-03	2.77E-03
Other meats	9.34E-03	7.26E-03	4.12E-03	3.52E-03	2.53E-03	3.54E-03
Pasta	5.51E-03	4.06E-03	2.53E-03	2.09E-03	1.66E-03	2.13E-03
Potatoes	7.92E-03	6.79E-03	4.18E-03	3.59E-03	3.26E-03	3.19E-03
Ready to eat foods	1.08E-02	8.82E-03	5.15E-03	4.74E-03	4.27E-03	4.53E-03
Rice	1.30E-02	8.61E-03	5.20E-03	4.39E-03	3.77E-03	5.48E-03
Root vegetables	4.93E-03	2.77E-03	2.00E-03	1.82E-03	2.83E-03	2.02E-03
Saltwater fish	6.34E-03	4.07E-03	2.47E-03	2.20E-03	1.72E-03	2.36E-03

Food group	**Adult**	**Child 3**	**Child 2**	**Child 1**	**Infant**	**Foetus**
Seafood other	3.62E-03	1.57E-03	1.09E-03	6.24E-04	7.15E-04	1.76E-03
Seaweed and algae	1.96E-04	1.23E-04	5.09E-05	0.00E+00	4.01E-05	8.93E-05
Shoots	8.58E-04	3.62E-04	4.22E-05	1.17E-04	1.41E-04	2.15E-04
Snacks	1.56E-03	1.87E-03	9.23E-04	8.07E-04	5.22E-04	5.55E-04
Soft beverages	2.97E-02*	1.91E-02*	1.02E-02*	8.14E-03	4.45E-03	1.31E-02*
Top two	**4.27E-02**	**3.03E-02**	**1.86E-02**	**2.34E-02**	**2.38E-02**	**1.86E-02**

The top two highest dose rates are summed and shown in the last row of the table **in bold**. The highest dose rate coming from one food group for each age category is highlighted in yellow and marked with an asterisk *.

Appendix I: Figures for estimated mean probabilities that imported products will exceed 100 Bq/kg and 1250 Bq/kg (scenario B)

Figures 1 and 2 show the estimated mean probabilities that imported products will exceed 100 Bq/kg and 1250 Bq/kg respectively. Mean probabilities and standard deviations were predicted using the @Risk model implemented for scenario B (Section 4.2).

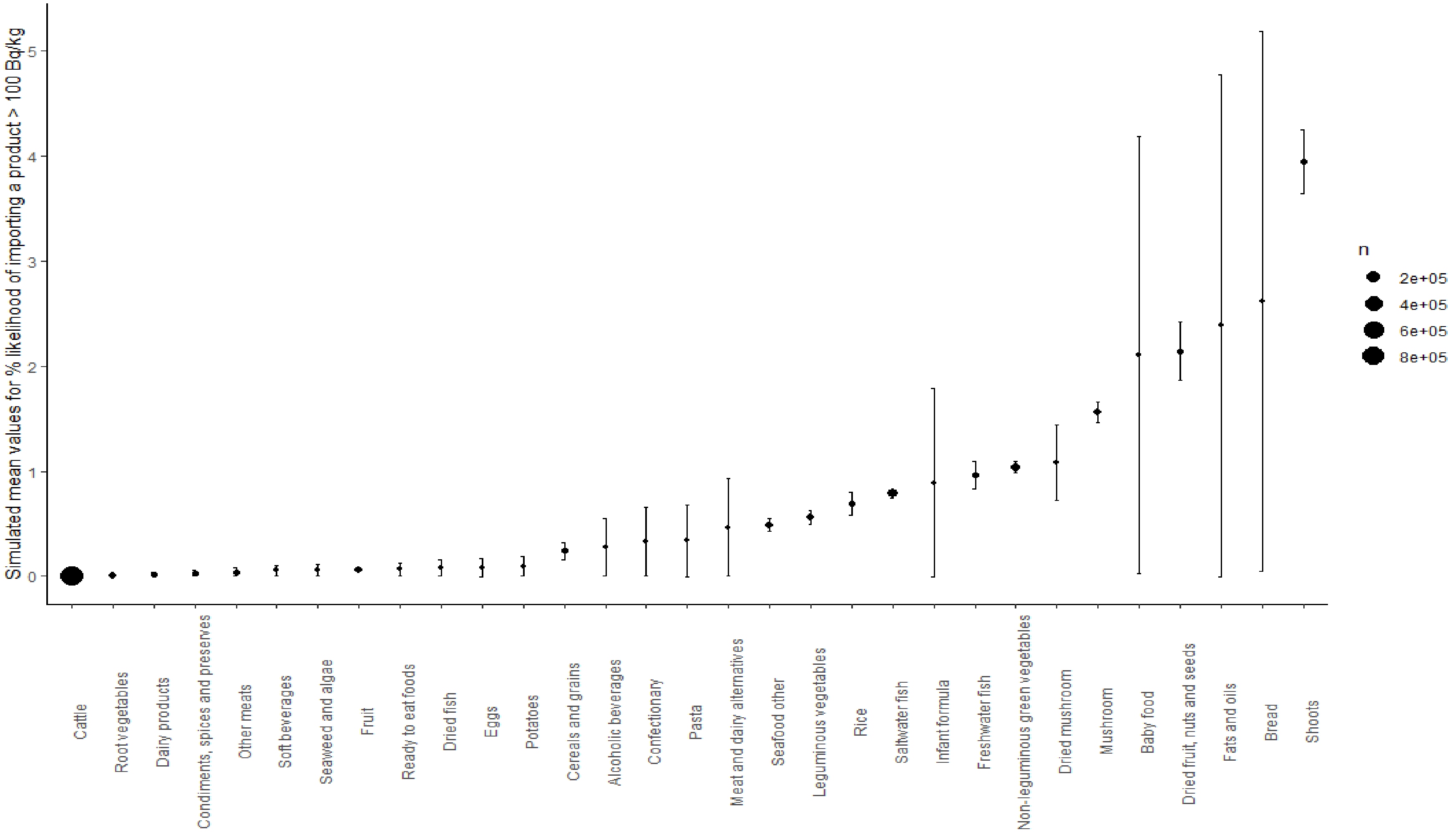


Figure 1: Estimated mean probability values that imported products from each food group will exceed 100 Bq/kg. Error bars show standard deviation. The dot size represents the number of samples tested.

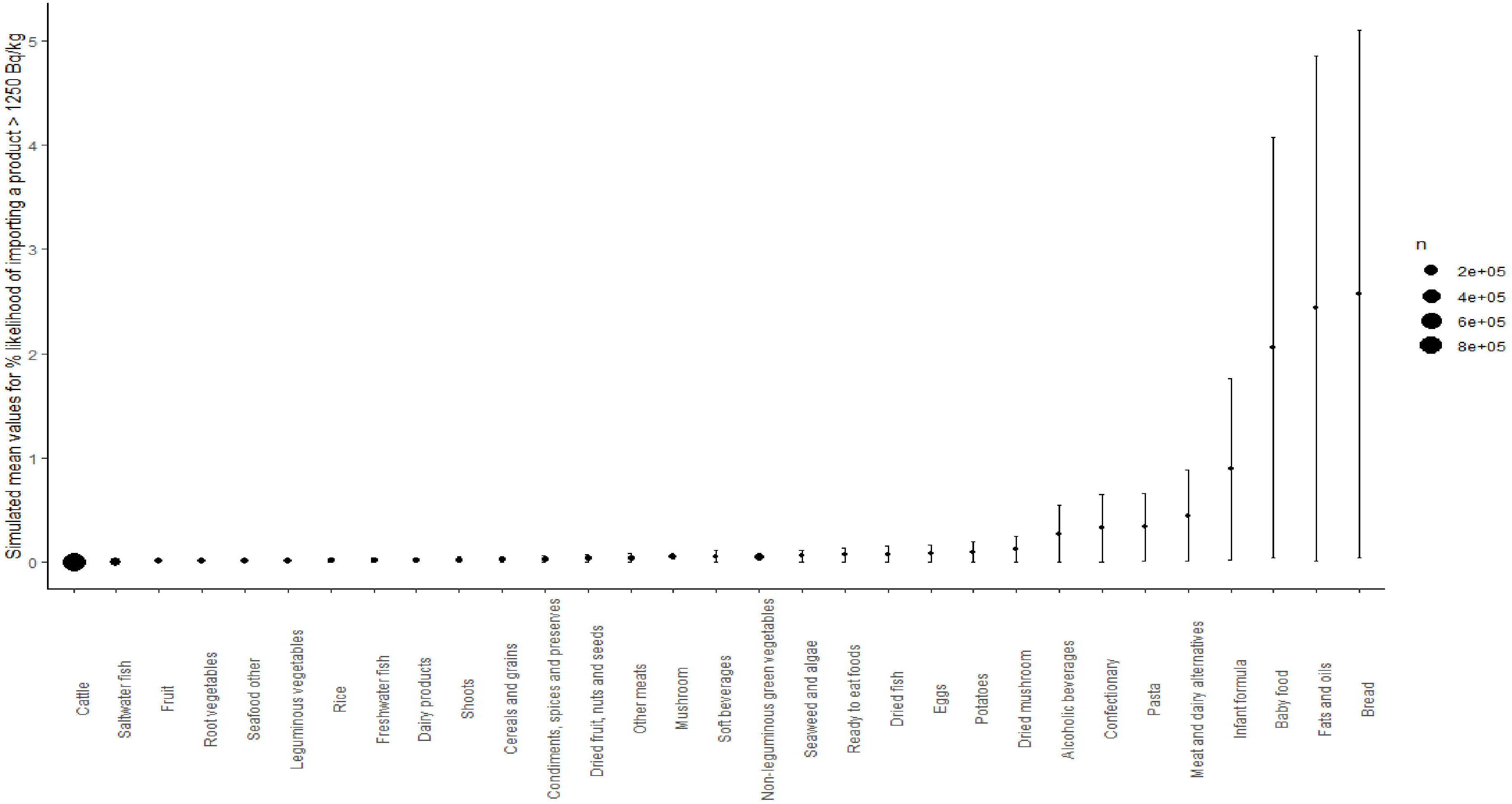
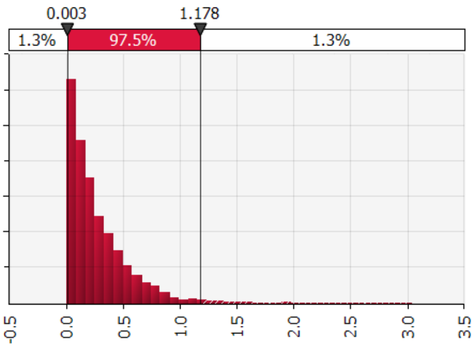


Figure 2: Estimated mean probability values that imported products from each food group will exceed 1250 Bq/kg. Error bars show standard deviation. The dot size represents the number of samples tested.

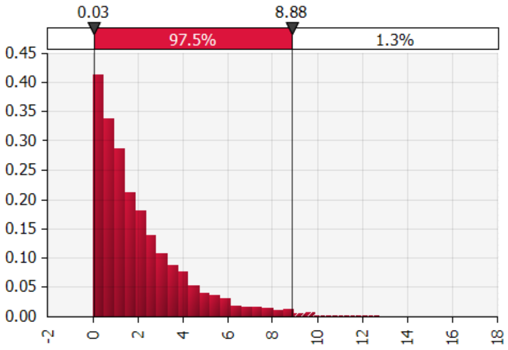
Appendix J: Distributions from Monte Carlo simulations for scenario B - estimating the probability of importing food products exceeding 100 Bq/kg.

Figure 1 shows the full distributions simulated for each food group when estimating the mean probability of a product exceeding 100 Bq/kg for radiocaesium activity concentrations. The graphs show the number of iterations for each outcome (probability value) (y-axis) and their relative probability (%) (x-axis). It is worth noting that distributions vary due to factors including the number of sample data available for each food group and differences in radiocaesium uptake within different food groups.

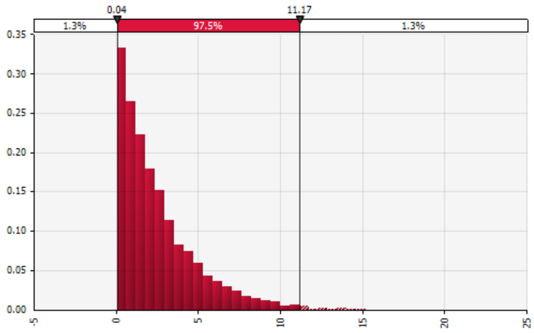
Alcoholic beverages



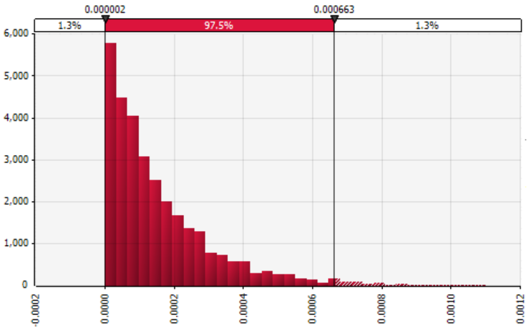
Baby food



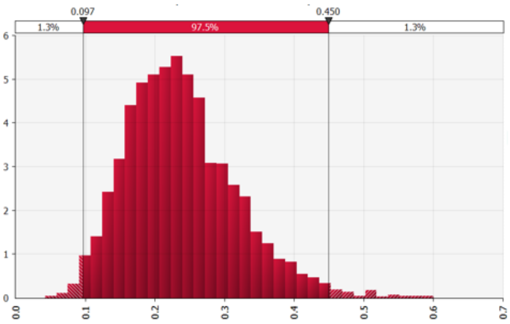
Bread



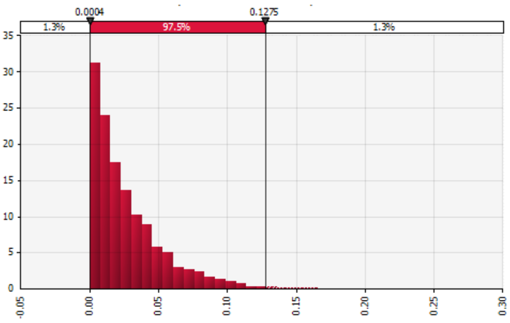
Cattle



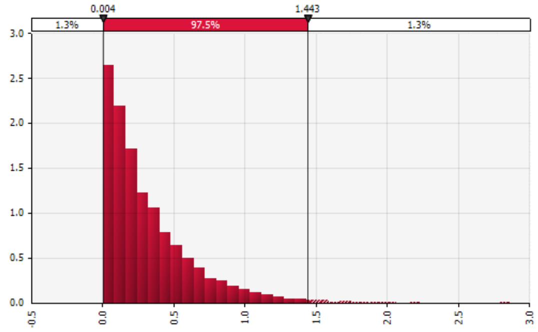
Cereals and grains



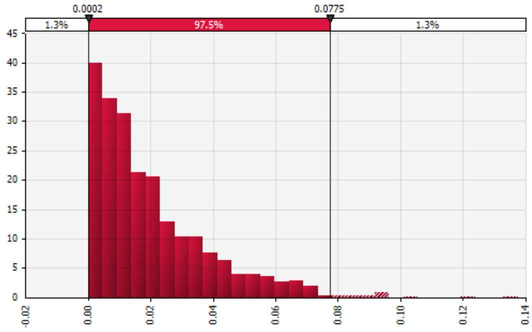
Condiments, spices and preserves



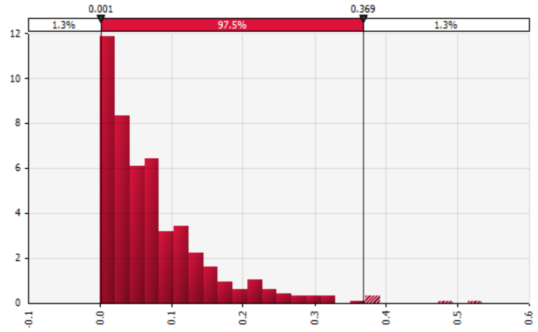
Confectionary



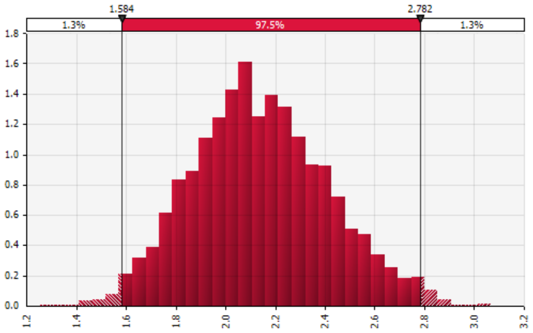
Dairy products



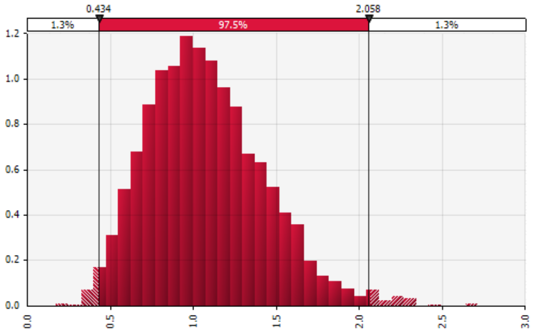
Dried fish



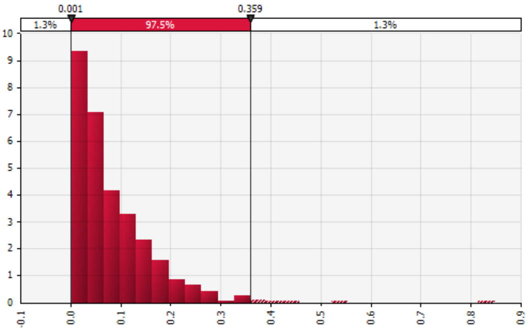
Dried fruit, nuts and seeds



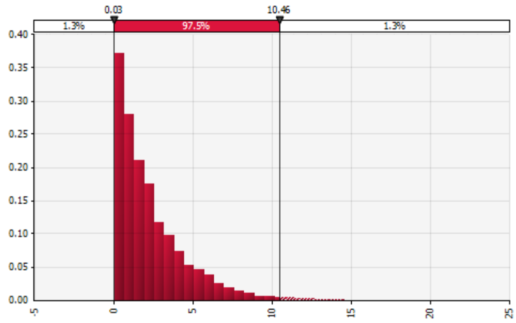
Dried mushroom



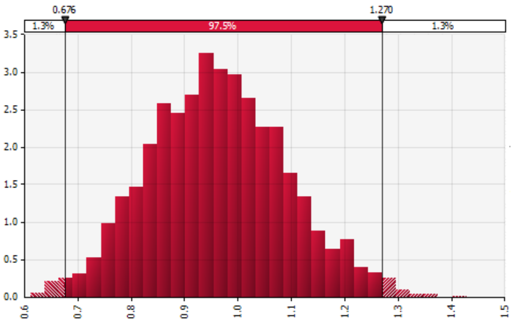
Eggs



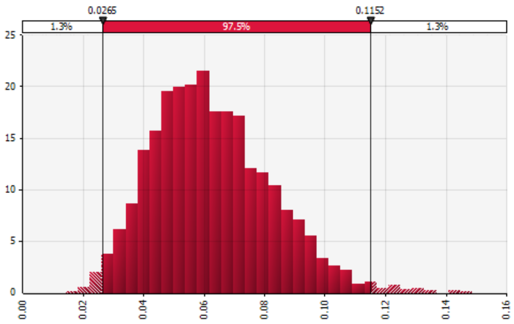
Fats and oils



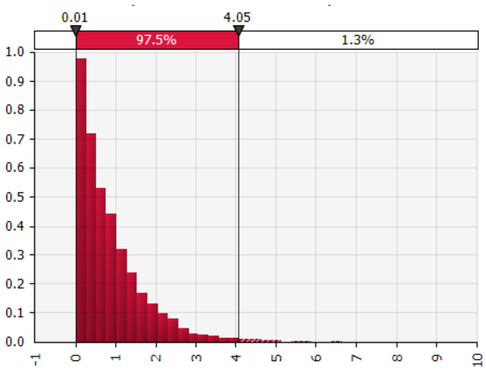
Freshwater fish



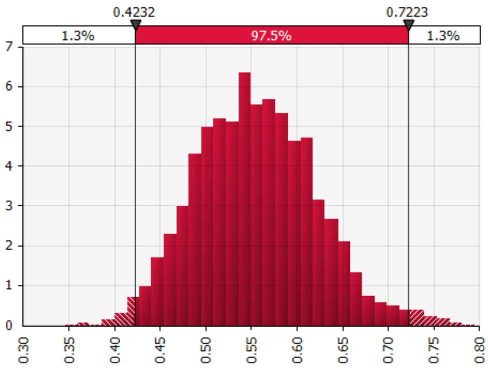
Fruit



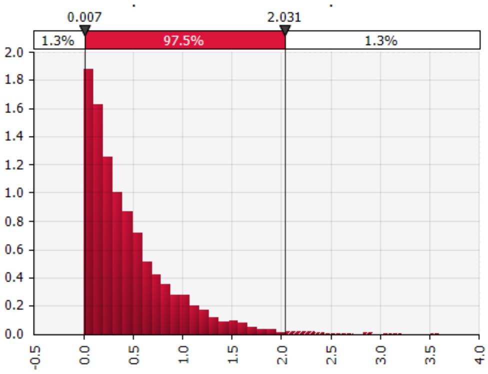
Infant formula



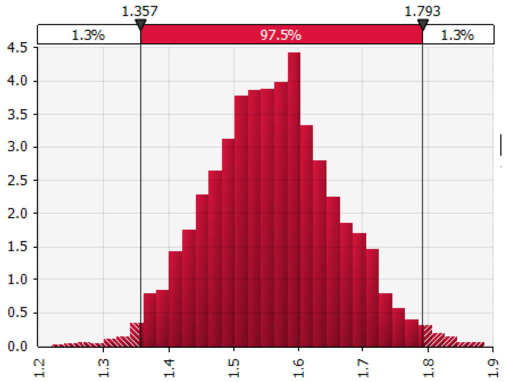
Leguminous vegetables



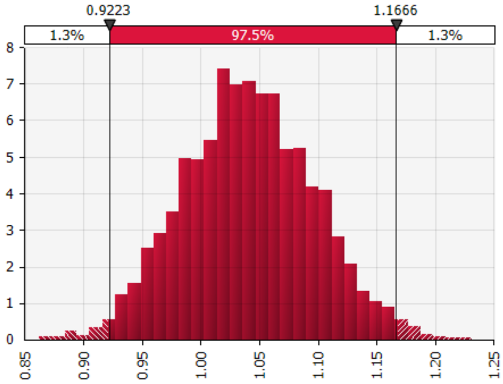
Meat and dairy alternatives



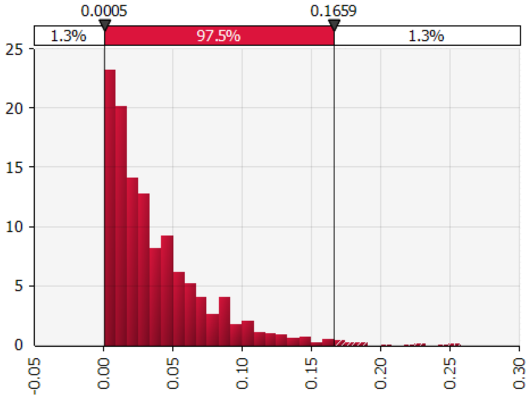
Mushroom



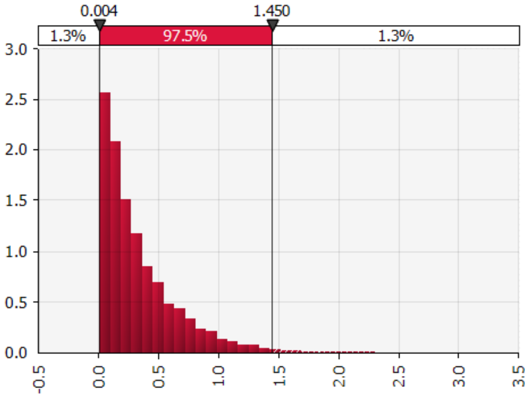
Non-leguminous green vegetables



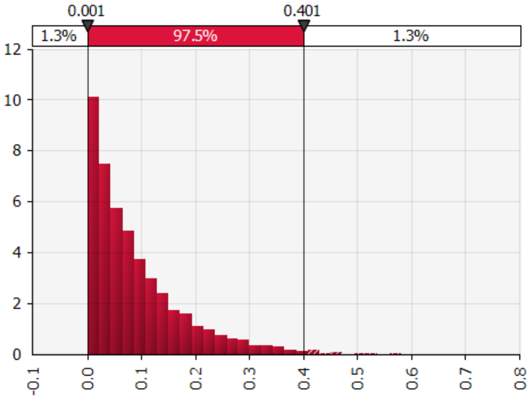
Other meats



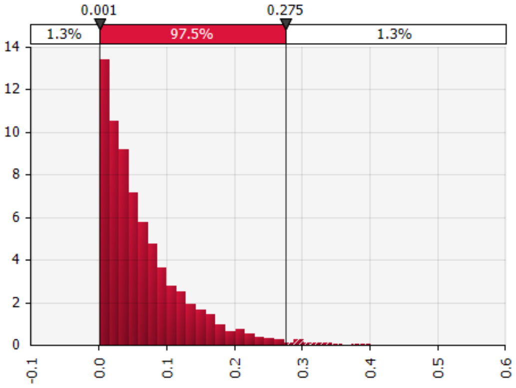
Pasta



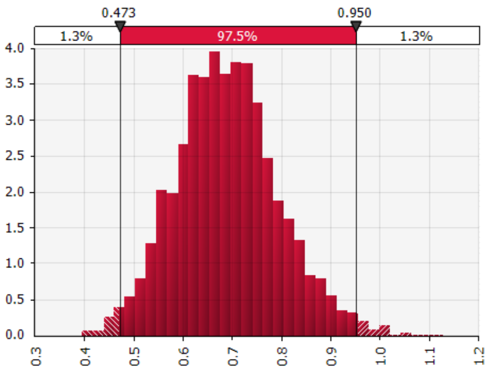
Potatoes



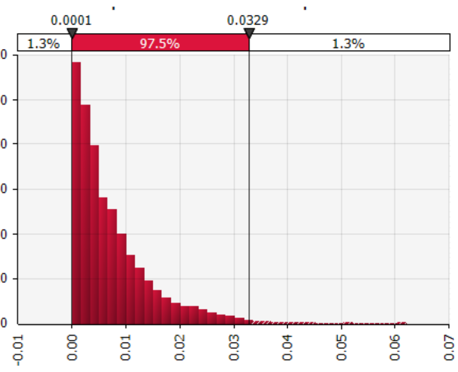
Ready to eat foods



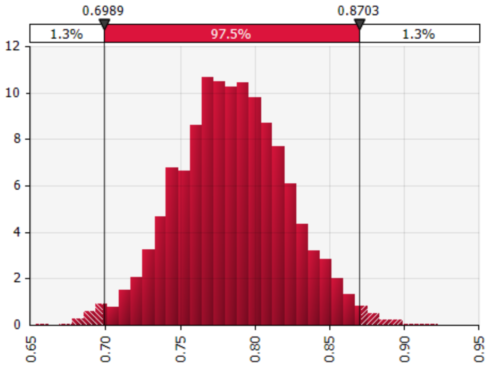
Rice



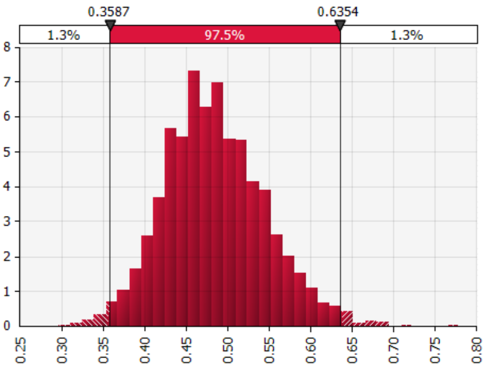
Root vegetables



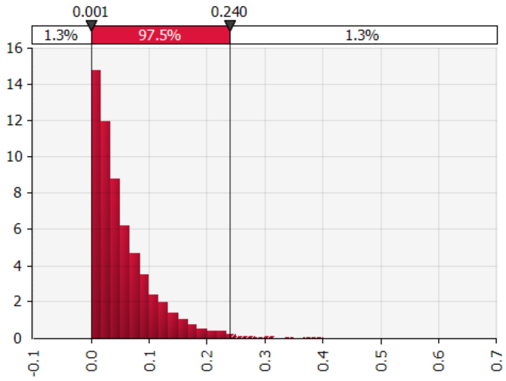
Saltwater fish



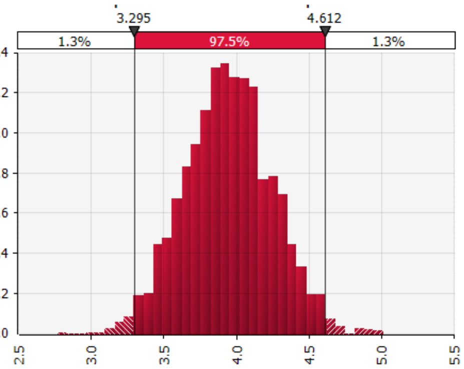
Seafood other



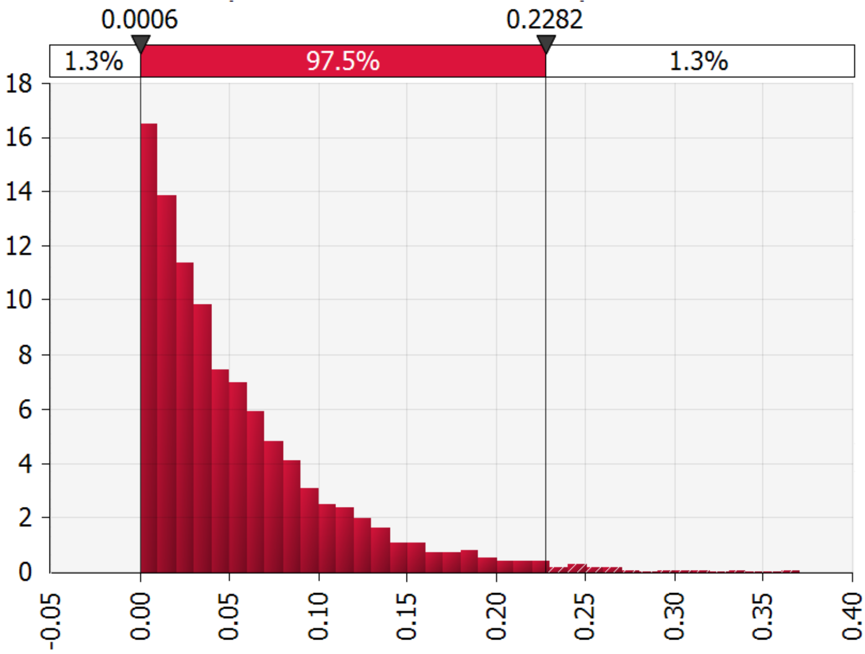
Seaweed and algae



Shoots



Soft beverages



All food groups combined

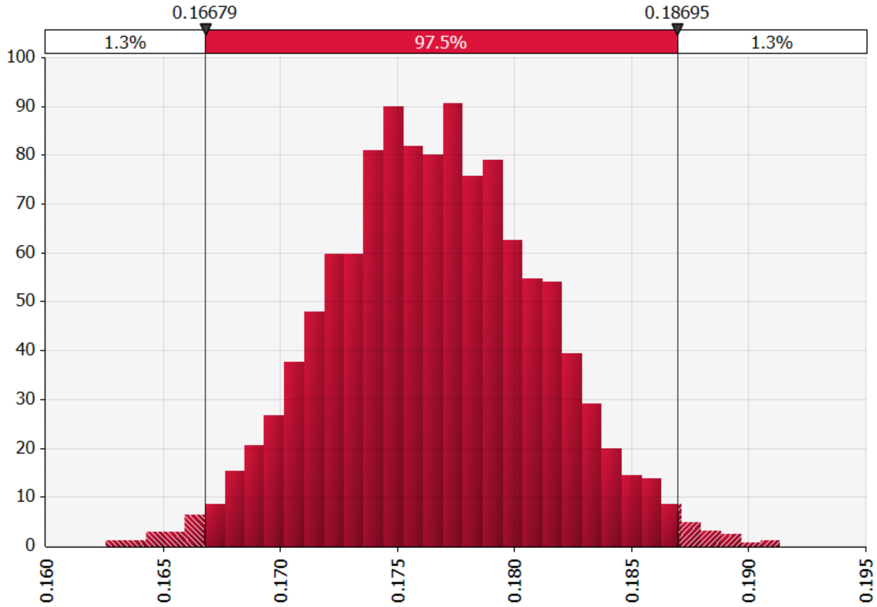
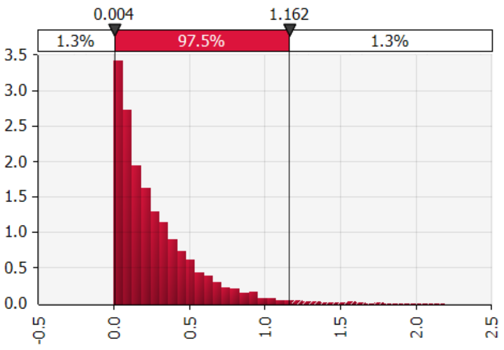


Figure 1. Distributions drawn from Monte Carlo simulations assessing the probability that a product with activity concentrations exceeding 100 Bq/kg will be imported into the UK. Graphs show the 97.5th percentile.

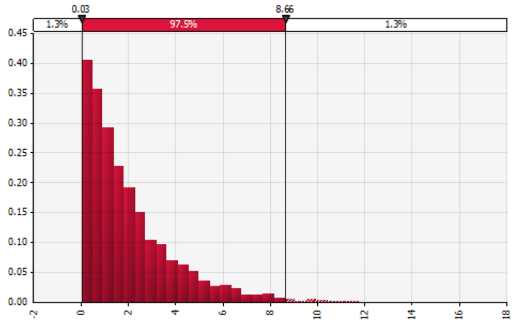
Appendix K: Distributions from Monte Carlo simulations for scenario B - estimating the probability of importing food products exceeding 1,250 Bq/kg.

Figure 1 shows the full distributions simulated for each food group when estimating the mean probability of a product exceeding 1,250 Bq/kg for radiocaesium activity concentrations. The graphs show the number of iterations for each outcome (probability value) (y-axis) and their relative probability (%) (x-axis). It is worth noting that distributions vary due to factors including the number of sample data available for each food group and differences in radiocaesium uptake within different food groups.

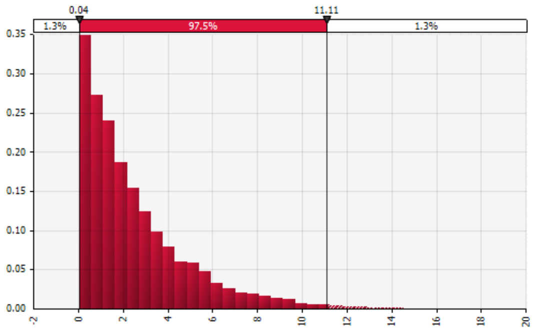
Alcoholic beverages



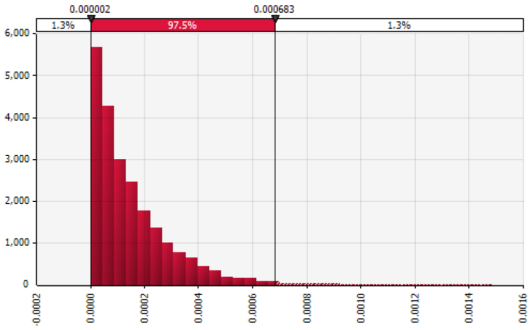
Baby food



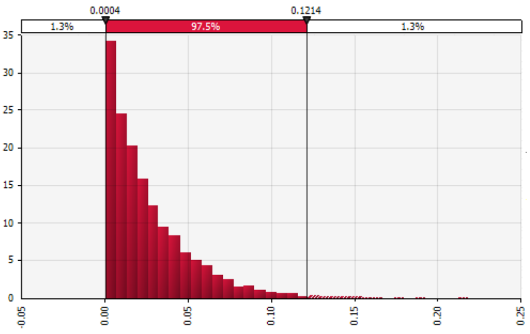
Bread



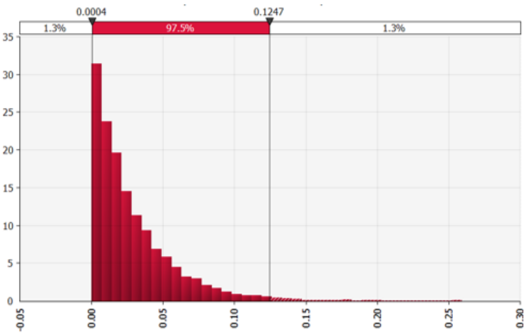
Cattle



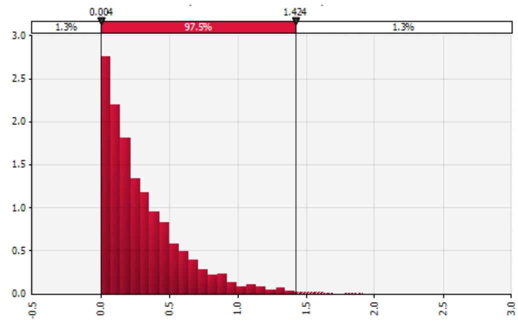
Cereals and grains



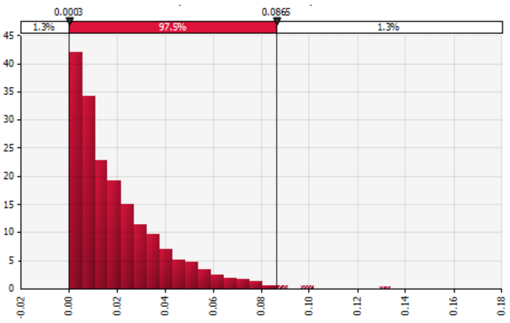
Condiments, spices and preserves



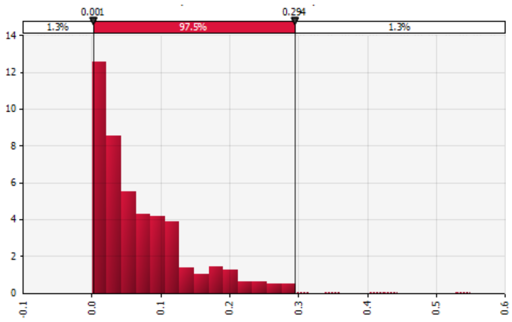
Confectionary



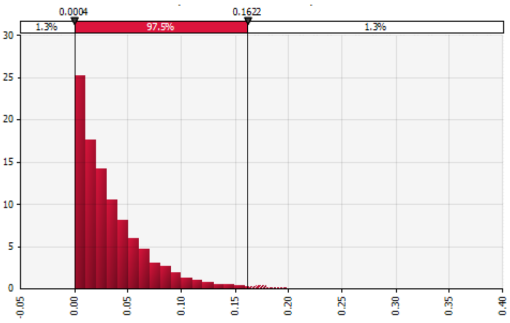
Dairy products



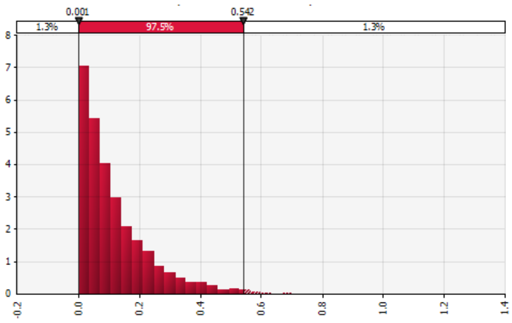
Dried fish



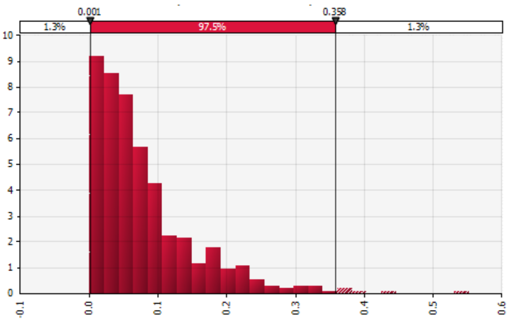
Dried fruit, nuts and seeds



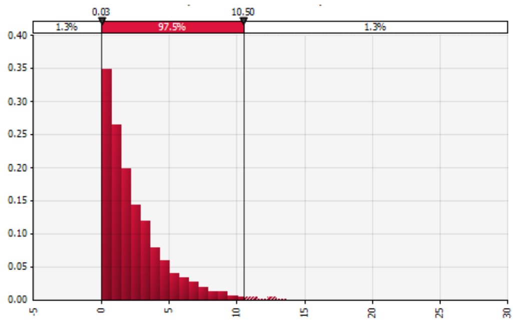
Dried mushroom



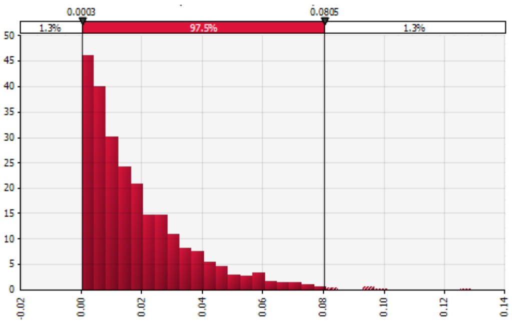
Eggs



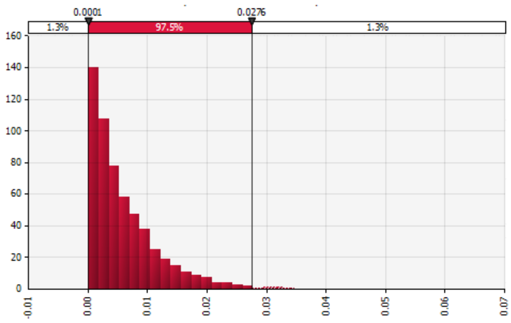
Fats and oils



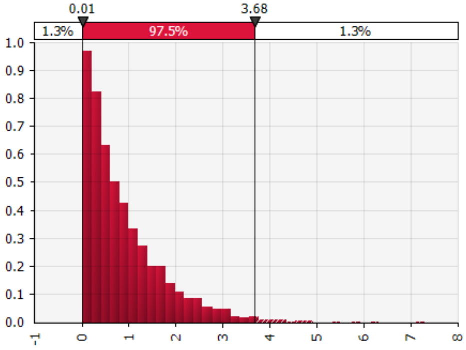
Freshwater fish



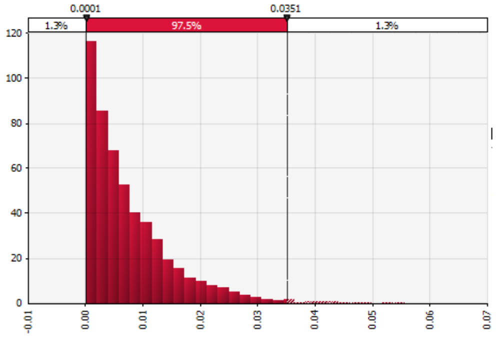
Fruit



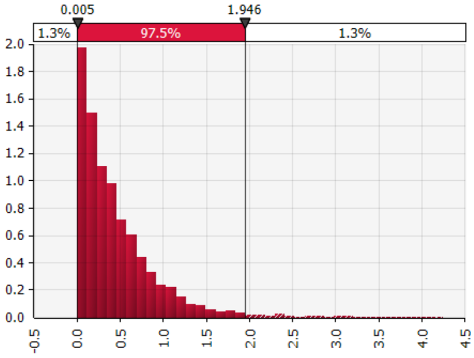
Infant formula



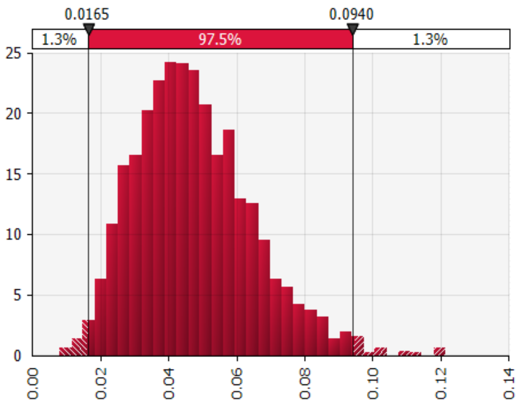
Leguminous vegetables



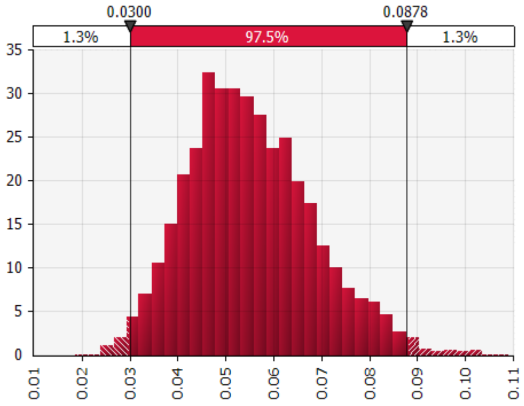
Meat and dairy alternatives



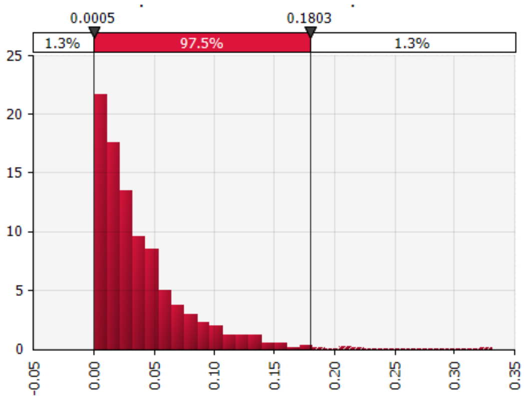
Mushroom



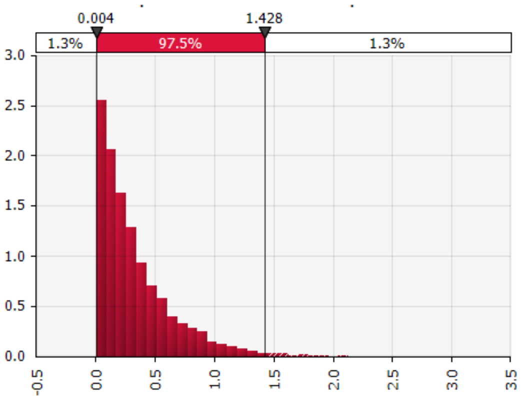
Non-leguminous green vegetables



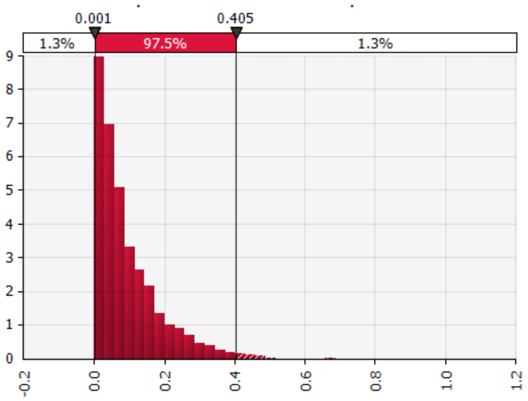
Other meats



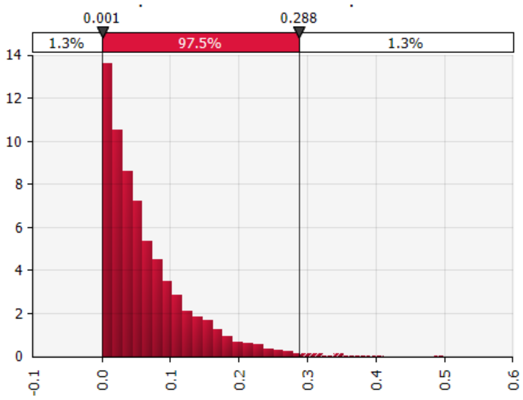
Pasta



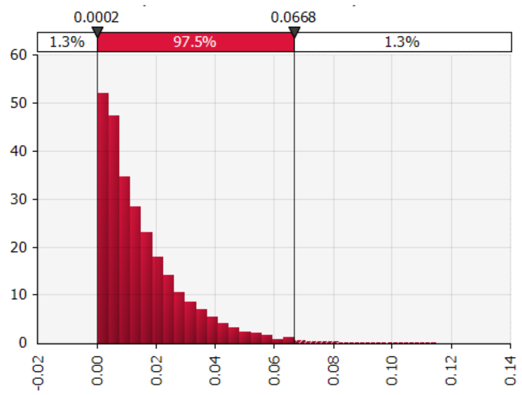
Potatoes



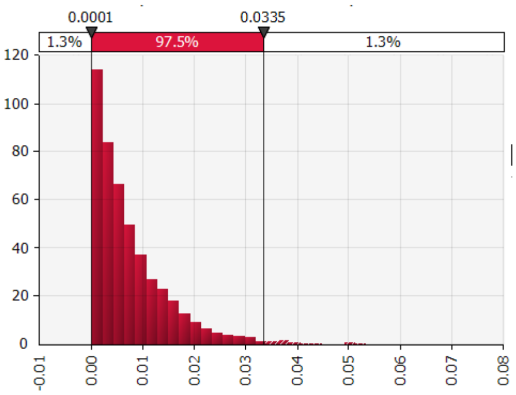
Ready to eat foods



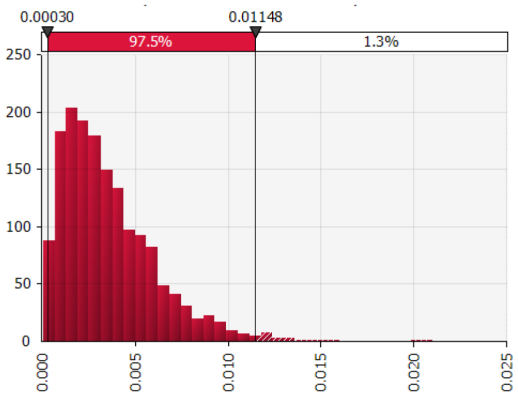
Rice



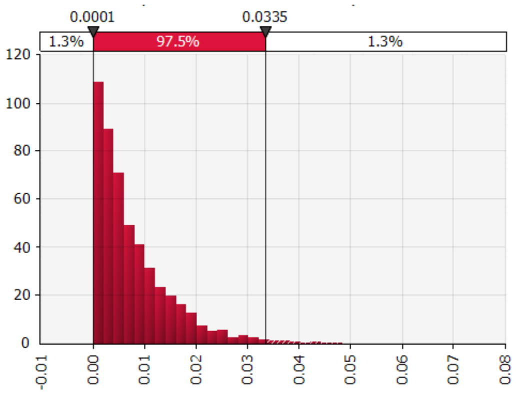
Root vegetables



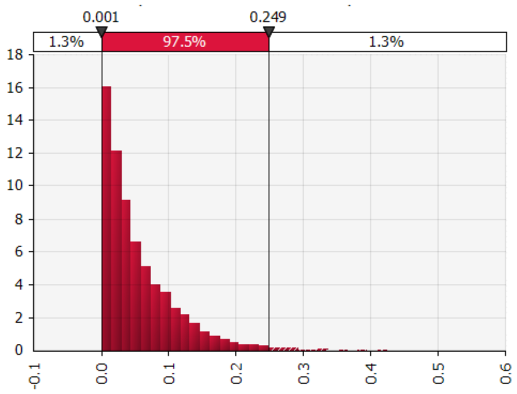
Saltwater fish



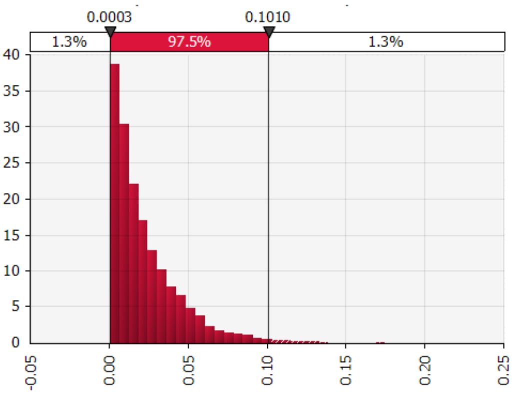
Seafood other



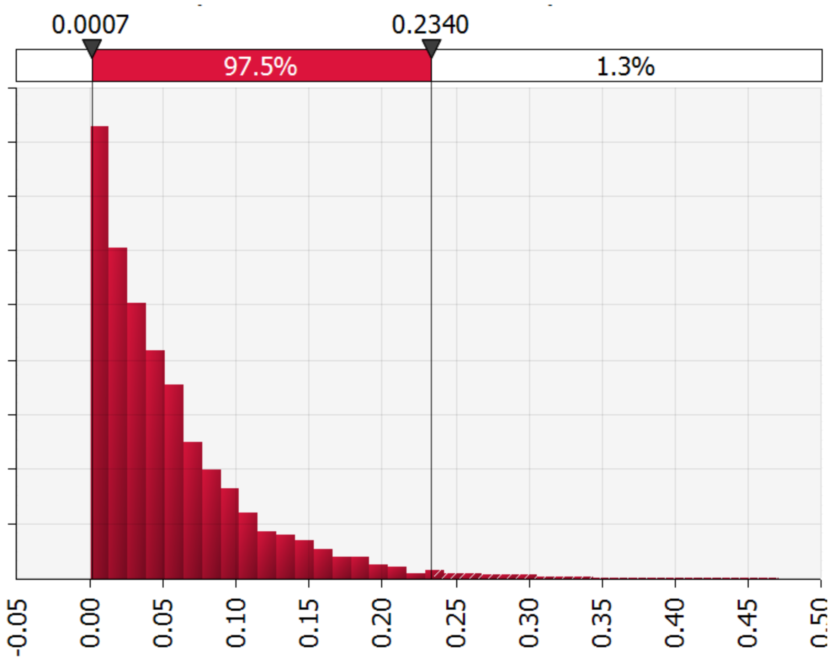
Seaweed and algae



Shoots



Soft beverages



All food groups combined

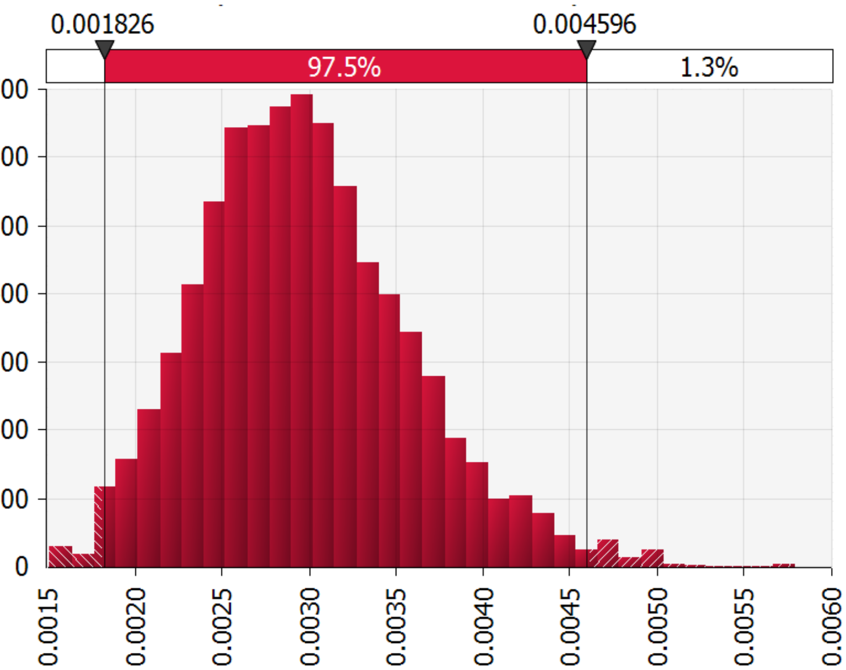


Figure 1. Distributions drawn from Monte Carlo simulations assessing the probability that a product with activity concentrations exceeding 1250 Bq/kg will be imported into the UK. Graphs show the 97.5th percentile.

Appendix L: Sensitivity analysis results for exposure scenario A: dose calculation

For the deterministic sensitivity analyses (for scenario A) the sensitivity was tested by varying the parameters of mean food consumption rate and total radiocaesium activity concentration. To do this, the values for the mean consumption were replaced with a scenario where the consumption is +/- 10 % of the mean consumption rate for each food group. This was repeated by varying the total radiocaesium activity concentration in food by +/- 10 % in the same way. The mean (baseline) CED was compared to the recalculated output from the above scenarios to evaluate the impact. Figure 1 shows the sensitivity analysis for the lower bound consumption levels for each food group. Figure 2 shows the sensitivity analysis for the upper bound consumption levels for each food group. Figure 3 shows the sensitivity analysis for the lower bound radiocaesium values and Figure 4 shows sensitivity analysis for the upper bound radiocaesium activity concentrations.

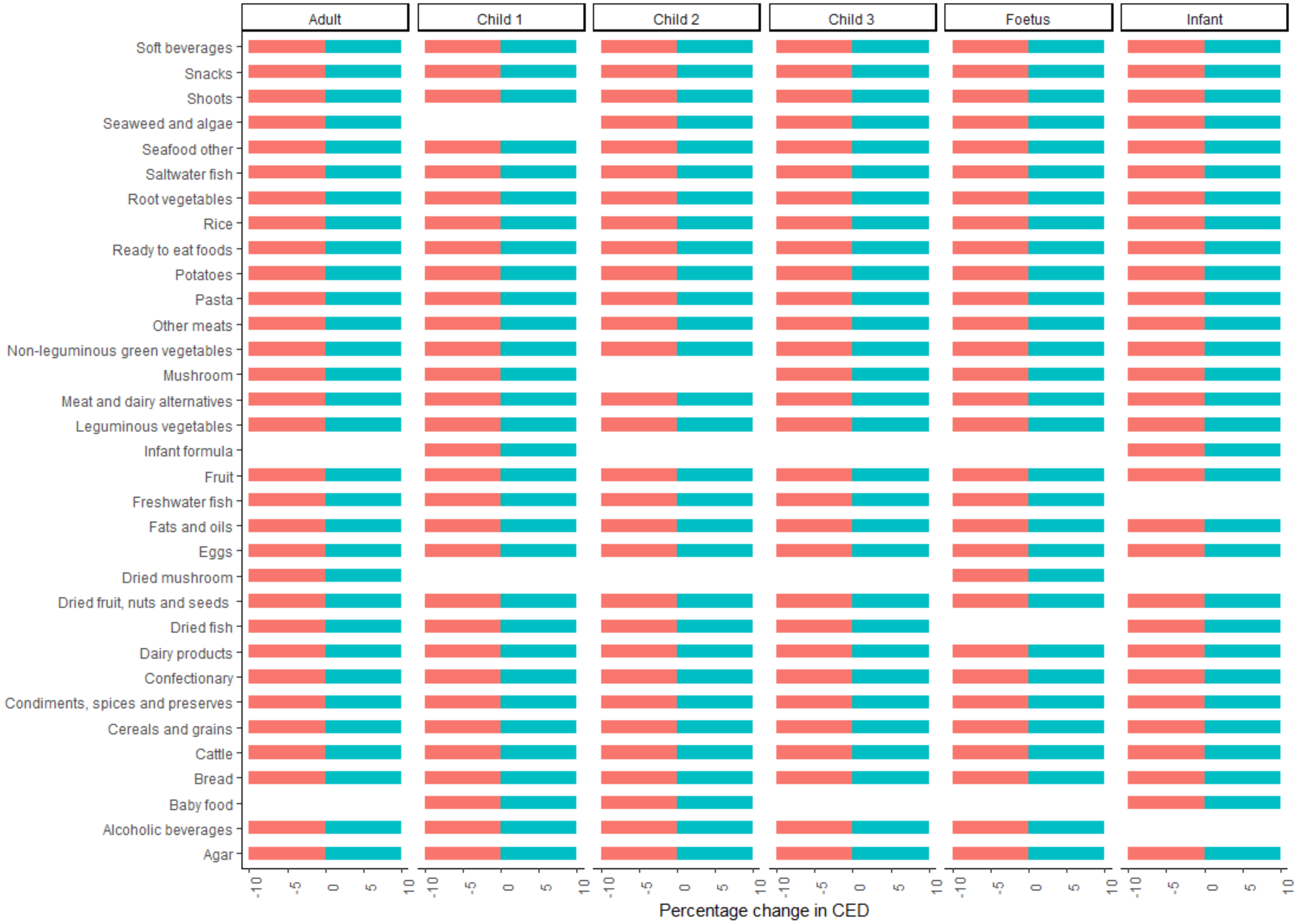


Figure 1. Sensitivity analysis results showing the percentage change in CED values for each food group and age group after 10 % is added to or subtracted from the consumption values for the lower bound radiocaesium activity concentration values. Red bars show percentage change in the mean total CED resulting from subtracting 10 % consumption values. Blue bars show percentage change in the mean total CED resulting from addition of 10 % consumption values.

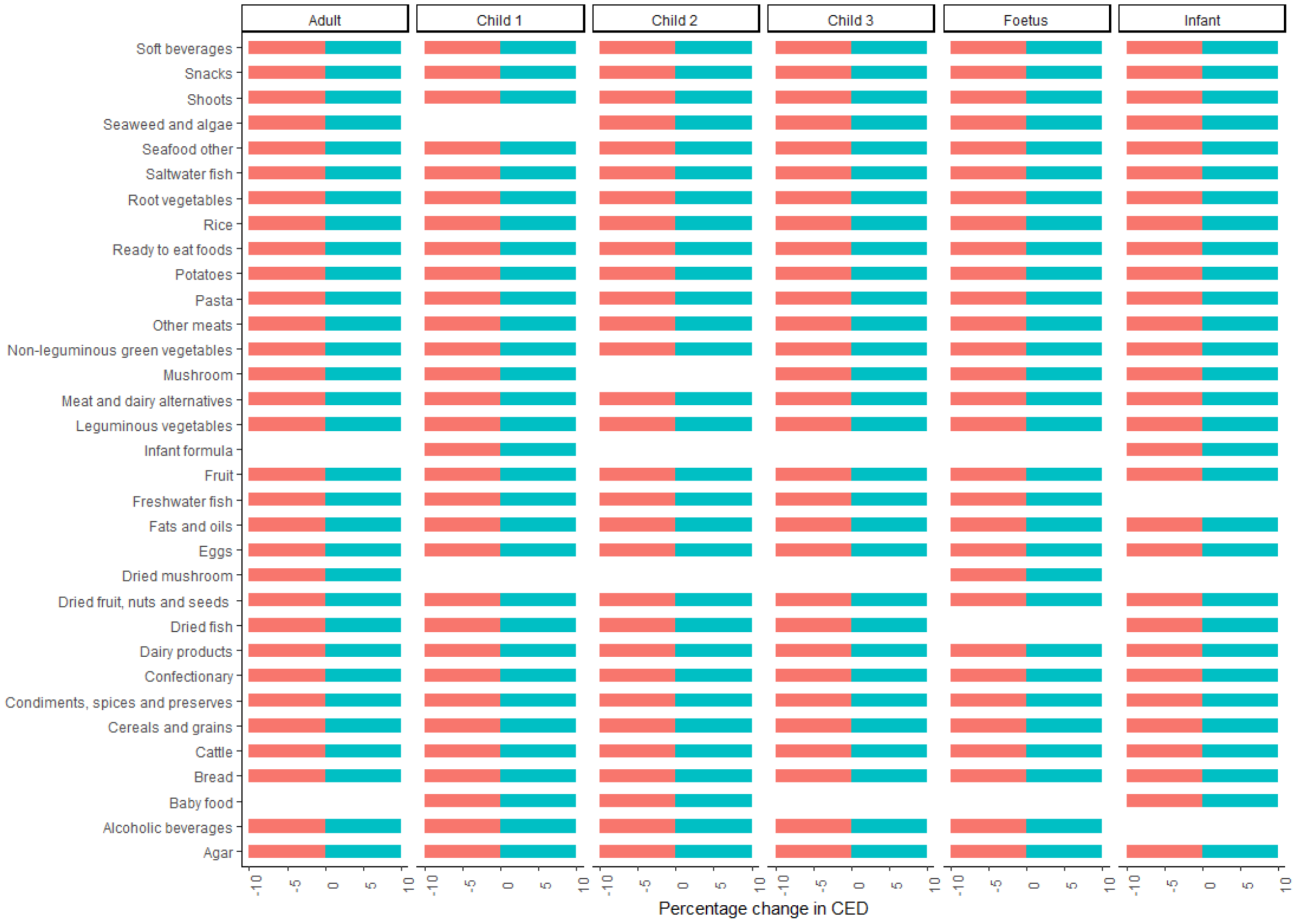


Figure 2. Sensitivity analysis results showing the percentage change in CED values for each food group and age group after 10 % is added to or subtracted from the consumption values for the upper bound radiocaesium activity concentration values. Red bars show percentage change in the mean total CED resulting from subtracting 10 % consumption values. Blue bars show percentage change in the mean total CED resulting from addition of 10 % consumption values.

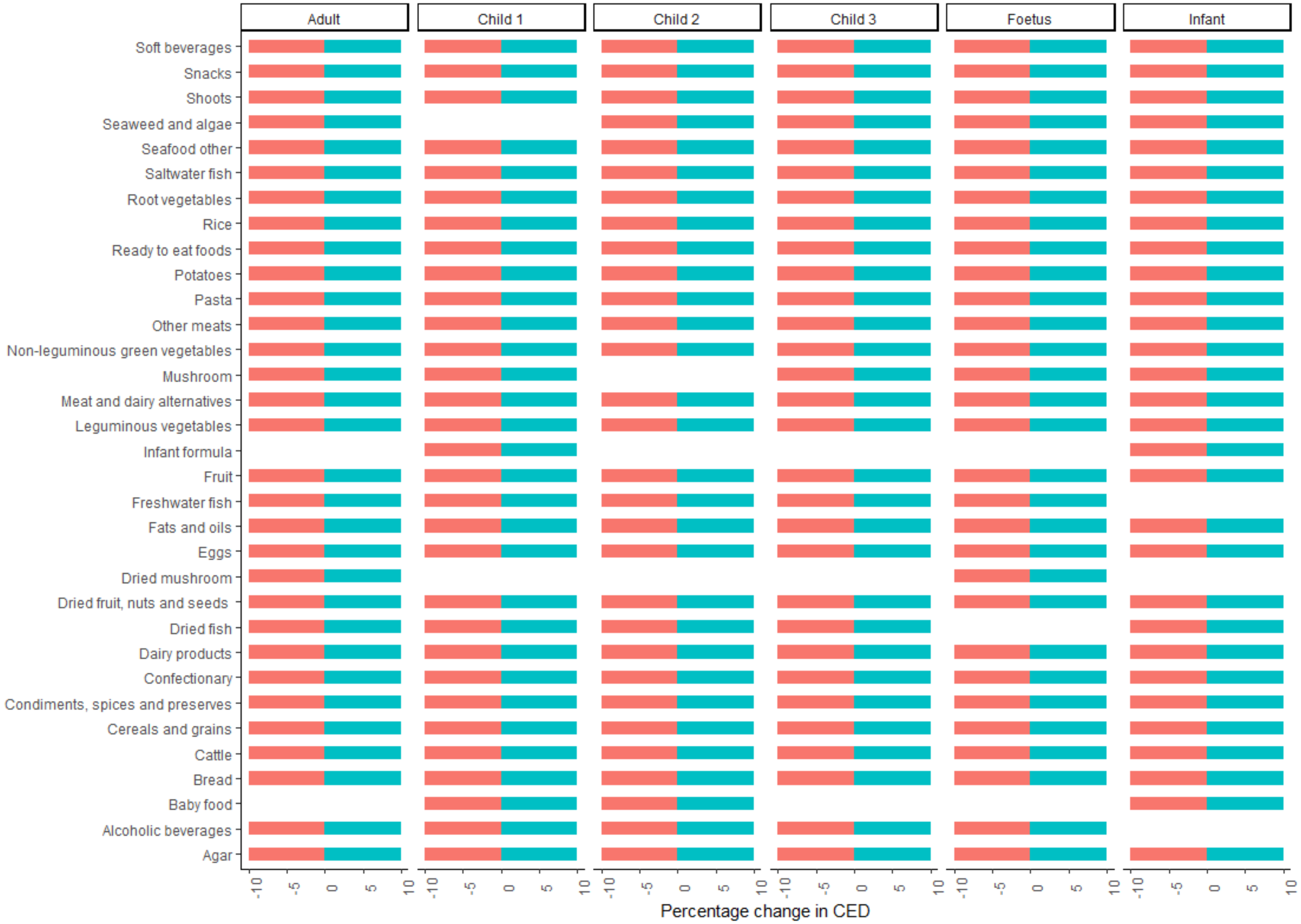


Figure 3. Sensitivity analysis results showing the percentage change in CED values for each food group and age group after 10 % is added to or subtracted from the lower bound radiocaesium activity concentration values. Red bars show percentage change in the mean total CED resulting from subtracting 10% radiocaesium activity concentrations. Blue bars show percentage change in the mean total CED resulting from addition of 10% radiocaesium activity concentrations.

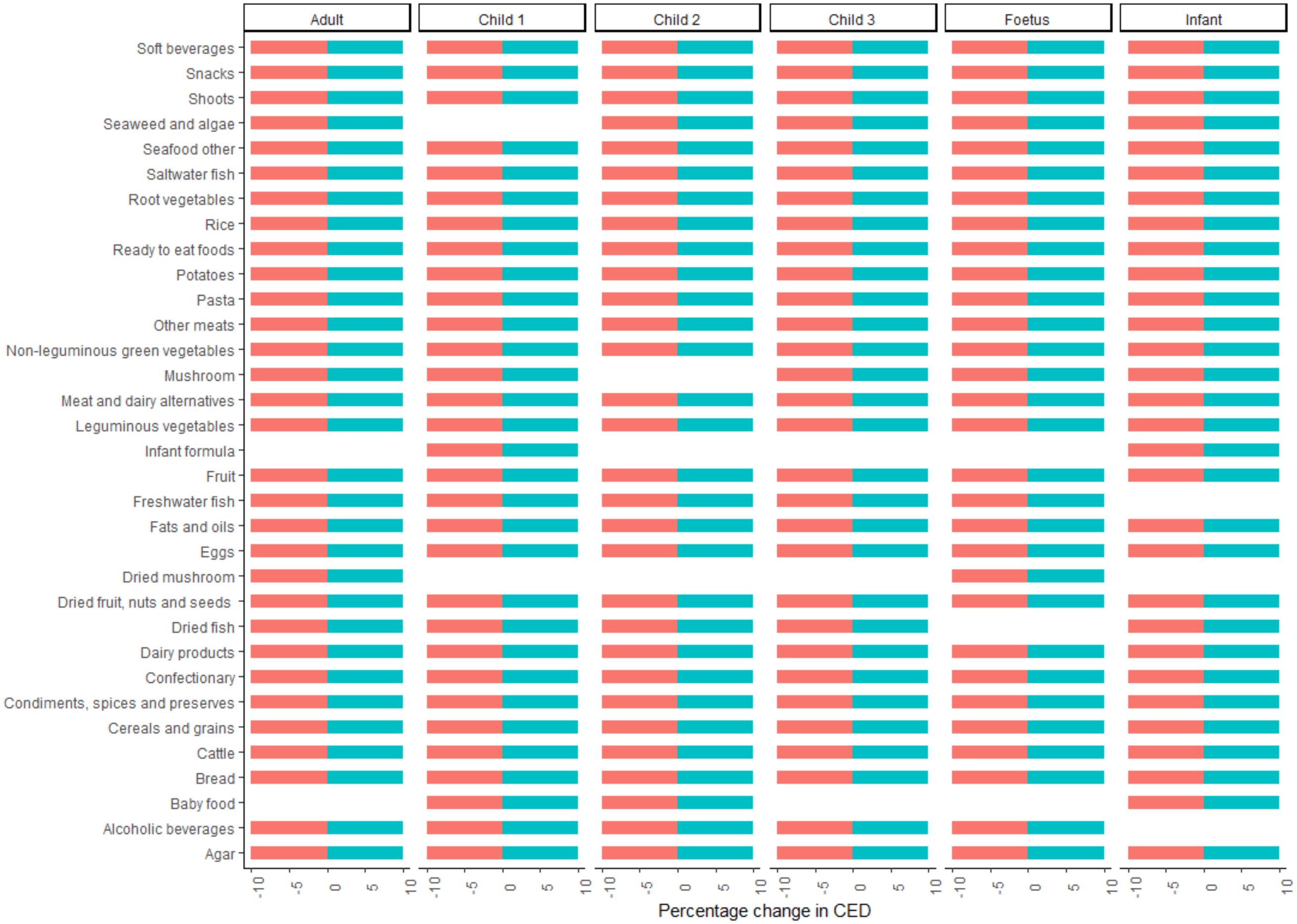


Figure 4. Sensitivity analysis results showing the percentage change in CED values for each food group and age group after 10 % is added to or subtracted from the upper bound radiocaesium activity concentration values. Red bars show percentage change in the mean total CED resulting from subtracting 10 % radiocaesium activity concentrations. Blue bars show percentage change in the mean total CED resulting from addition of 10 % radiocaesium activity concentrations.

Appendix M: Sensitivity analysis results for scenario B using @Risk models

For scenario B, the sensitivity analysis that is built into @Risk software was applied to the results, considering the uncertainty in the units of commodity imported each year (Figure 1 (Appendix A)) (due to year-to-year variability) and the prevalence of samples exceeding 100 Bq/kg (Table 1) or 1,250 Bq/kg (Table 2). The range of the mean, regression coefficient[41], regression[42], correlation coefficient[43] and percentage contribution were extracted[44].

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[41] The regression coefficient for each input variable measures the sensitivity of the output to that particular input distribution.

[42] The overall fit of the regression is measured by the reported fit or R-squared value of the model.

[43] the rank correlation coefficient is calculated between the selected output variable and the samples for each of the input distributions. The higher the correlation between the input and the output, the more significant the input is in determining the output's value.

[44] Contribution to Variance shows the amount of change in the selected output variable attributable to each input.

Table 1. Sensitivity analysis outputs for simulations assessing the percentage likelihood that a product with less than 100 Bq/kg radiocaesium activity concentrations will be imported into the UK.

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Alcoholic beverages	A2	9.04E-01	1	2.77E-01	1	100%
Alcoholic beverages	A1	3.94E-02	0	0.00E+00	0.014	0%
Baby food	A2	6.62E+00	1	2.04E+00	1	100%
Baby food	A1	3.37E-01	0	0.00E+00	0.005	0%
Bread	A2	6.76E+00	1	2.07E+00	1	100%
Bread	A1	1.35E-01	0	0.00E+00	0	0%
Cattle	A2	5.11E-04	1	1.57E-04	1	100%
Cattle	A1	1.61E-05	0	0.00E+00	-0.028	0%
Cereals and grains	A2	2.74E-01	1	7.89E-02	1	100%
Cereals and grains	A1	1.30E-02	0	0.00E+00	0.009	0%
Condiments, spices and preserves	A2	9.78E-02	1	3.01E-02	1	100%
Condiments, spices and preserves	A1	4.16E-03	0	0.00E+00	0.015	0%
Confectionary	A2	1.06E+00	1	3.26E-01	1	100%

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Confectionary	A1	4.95E-02	0	0.00E+00	-0.022	0%
Dairy products	A2	6.94E-02	1	2.09E-02	1	100%
Dairy products	A1	7.29E-03	0	0.00E+00	0.006	0%
Dried fish	A2	2.46E-01	1	7.35E-02	1	100%
Dried fish	A1	0.00E+00	0	0.00E+00	0	0%
Dried fruit, nuts, and seeds	A2	9.52E-01	1	2.72E-01	1	100%
Dried fruit, nuts, and seeds	A1	5.79E-02	0	0.00E+00	-0.013	0%
Dried mushroom	A2	1.30E+00	1	3.75E-01	1	100%
Dried mushroom	A1	6.95E-02	0	0.00E+00	0.021	0%
Eggs	A2	3.14E-01	1	9.26E-02	1	100%
Eggs	A1	0.00E+00	0	0.00E+00	0	0%
Fats and oils	A2	7.56E+00	1	2.33E+00	1	100%
Fats and oils	A1	2.02E-01	0	0.00E+00	-0.017	0%
Freshwater fish	A2	4.61E-01	1	1.31E-01	1	100%
Freshwater fish	A1	2.17E-02	0	0.00E+00	0.015	0%

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Fruit	A2	4.61E-01	1	1.31E-01	1	100%
Fruit	A1	2.17E-02	0	0.00E+00	0.015	0%
Infant formula	A2	2.93E+00	1	8.96E-01	1	100%
Infant formula	A1	1.38E-01	0	0.00E+00	-0.007	0%
Leguminous vegetables	A2	2.35E-01	1	6.66E-02	1	100%
Leguminous vegetables	A1	1.41E-02	0	0.00E+00	-0.012	0%
Meat and dairy alternatives	A2	1.46E+00	1	4.49E-01	1	100%
Meat and dairy alternatives	A1	5.68E-02	0	0.00E+00	0.008	0%
Mushroom	A2	3.84E-01	1	1.10E-01	1	100%
Mushroom	A1	2.16E-02	0	0.00E+00	-0.034	0%
Non-leguminous green vegetables	A2	1.37E-01	1	3.90E-02	1	100%
Non-leguminous green vegetables	A1	6.88E-03	0	0.00E+00	0.006	0%

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Other meats	A2	1.25E-01	1	3.83E-02	1	100%
Other meats	A1	5.61E-03	0	0.00E+00	-0.01	0%
Pasta	A2	1.10E+00	1	3.39E-01	1	100%
Pasta	A1	5.40E-02	0	0.00E+00	-0.004	0%
Potatoes	A2	2.97E-01	1	9.09E-02	1	100%
Potatoes	A1	9.54E-03	0	0.00E+00	0.007	0%
Ready to eat foods	A2	2.20E-01	1	6.76E-02	1	100%
Ready to eat foods	A1	9.24E-03	0	0.00E+00	0.005	0%
Rice	A2	3.72E-01	1	1.06E-01	1	100%
Rice	A1	2.37E-02	0	0.00E+00	0.014	0%
Root vegetables	A2	3.72E-01	1	1.06E-01	1	100%
Root vegetables	A1	2.37E-02	0	0.00E+00	0.014	0%
Saltwater fish	A2	1.30E-01	1	3.72E-02	1	100%
Saltwater fish	A1	5.90E-03	0	0.00E+00	-0.015	0%
Seafood other	A2	2.13E-01	1	6.05E-02	1	100%
Seafood other	A1	1.10E-02	0	0.00E+00	0.001	0%
Seaweed and algae	A2	1.90E-01	1	5.82E-02	1	100%

Commodity	Model component	Range of mean	Regression coefficient	Regression	Correlation coefficient	Contribution (%)
Seaweed and algae	A1	6.50E-03	0	0.00E+00	0.017	0%
Shoots	A2	1.07E+00	1	3.04E-01	1	100%
Shoots	A1	2.65E-02	0	0.00E+00	0.015	0%
Soft beverages	A2	1.76E-01	1	5.44E-02	1	100%
Soft beverages	A1	8.15E-03	0	0.00E+00	0	0%
All products	A2	1.50E-02	1	4.26E-03	1	100%
All products	A1	4.91E-04	0	0.00E+00	-0.025	0%

Table 2. Sensitivity analysis outputs for simulations assessing the percentage likelihood that a product with greater than 1,250 Bq/kg activity concentrations will be imported into the UK.

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Alcoholic beverages	A2	9.07E-01	1	2.78E-01	1	100%
Alcoholic beverages	A1	4.06E-02	0	0.00E+00	-0.003	0%
Baby food	A2	6.84E+00	1	2.09E+00	1	100%
Baby food	A1	1.49E-01	0	0.00E+00	0	0%
Bread	A2	6.84E+00	1	2.09E+00	1	100%
Bread	A1	1.49E-01	0	0.00E+00	0	0%
Cattle	A2	5.29E-04	1	1.61E-04	1	100%
Cattle	A1	1.76E-05	0	0.00E+00	-0.018	0%
Cereals and grains	A2	8.45E-02	1	2.59E-02	1	100%
Cereals and grains	A1	3.71E-03	0	0.00E+00	0.01	0%
Condiments, spices and preserves	A2	9.12E-02	1	2.82E-02	1	100%
Condiments, spices and preserves	A1	4.46E-03	0	0.00E+00	0	0%
Confectionary	A2	9.12E-02	1	2.82E-02	1	100%
Confectionary	A1	4.46E-03	0	0.00E+00	0	0%

Commodity	**Model component**	**Range of mean**	**Regression coefficient**	**Regression**	**Correlation coefficient**	**Contribution (%)**
Dairy products	A2	9.12E-02	1	2.82E-02	1	100%
Dairy products	A1	4.46E-03	0	0.00E+00	0	0%
Dried fish	A2	2.47E-01	1	7.17E-02	1	100%
Dried fish	A1	0.00E+00	0	0.00E+00	0	0%
Dried fruit, nuts, and seeds	A2	1.16E-01	1	3.57E-02	1	100%
Dried fruit, nuts, and seeds	A1	5.23E-03	0	0.00E+00	0.02	0%
Dried mushroom	A2	3.94E-01	1	1.20E-01	1	100%
Dried mushroom	A1	1.37E-02	0	0.00E+00	-0.001	0%
Eggs	A2	2.53E-01	1	7.61E-02	1	100%
Eggs	A1	0.00E+00	0	0.00E+00	0	0%
Fats and oils	A2	7.73E+00	1	2.39E+00	1	100%
Fats and oils	A1	5.51E-01	0	0.00E+00	0.001	0%
Freshwater fish	A2	5.99E-02	1	1.82E-02	1	100%
Freshwater fish	A1	3.98E-03	0	0.00E+00	-0.005	0%
Fruit	A2	1.96E-02	1	5.99E-03	1	100%
Fruit	A1	9.08E-04	0	0.00E+00	0.007	0%
Infant formula	A2	2.83E+00	1	8.67E-01	1	100%

Commodity	Model component	Range of mean	Regression coefficient	Regression	Correlation coefficient	Contribution (%)
Infant formula	A1	1.51E-01	0	0.00E+00	-0.027	0%
Leguminous vegetables	A2	2.66E-02	1	8.19E-03	1	100%
Leguminous vegetables	A1	9.05E-04	0	0.00E+00	-0.007	0%
Meat and dairy alternatives	A2	1.47E+00	1	4.50E-01	1	100%
Meat and dairy alternatives	A1	6.13E-02	0	0.00E+00	-0.018	0%
Mushroom	A2	1.47E+00	1	4.50E-01	1	100%
Mushroom	A1	6.13E-02	0	0.00E+00	-0.018	0%
Non-leguminous green vegetables	A2	1.82E-02	1	5.32E-03	1	100%
Non-leguminous green vegetables	A1	5.52E-04	0	0.00E+00	-0.01	0%
Other meats	A2	1.26E-01	1	3.90E-02	1	100%
Other meats	A1	6.15E-03	0	0.00E+00	-0.002	0%
Pasta	A2	1.26E-01	1	3.90E-02	1	100%
Pasta	A1	6.15E-03	0	0.00E+00	-0.002	0%

Commodity	Model component	Range of mean	Regression coefficient	Regression	Correlation coefficient	Contribution (%)
Potatoes	A2	2.95E-01	1	8.98E-02	1	100%
Potatoes	A1	9.00E-03	0	0.00E+00	-0.005	0%
Ready to eat foods	A2	2.15E-01	1	6.62E-02	1	100%
Ready to eat foods	A1	5.58E-03	0	0.00E+00	-0.008	0%
Rice	A2	2.15E-01	1	6.62E-02	1	100%
Rice	A1	5.58E-03	0	0.00E+00	-0.008	0%
Root vegetables	A2	2.45E-02	1	7.51E-03	1	100%
Root vegetables	A1	9.33E-04	0	0.00E+00	0.013	0%
Saltwater fish	A2	8.68E-03	1	2.58E-03	1	100%
Saltwater fish	A1	3.93E-04	0	0.00E+00	0.031	0%
Seafood other	A2	2.50E-02	1	7.70E-03	1	100%
Seafood other	A1	1.55E-03	0	0.00E+00	0	0%
Seaweed and algae	A2	1.84E-01	1	5.59E-02	1	100%
Seaweed and algae	A1	5.31E-03	0	0.00E+00	-0.01	0%
Shoots	A2	1.79E-01	1	5.49E-02	1	100%
Shoots	A1	5.32E-03	0	0.00E+00	-0.009	0%
Soft beverages	A2	1.79E-01	1	5.49E-02	1	100%
Soft beverages	A1	5.32E-03	0	0.00E+00	-0.009	0%
All products	A2	1.28E-03	1.00E+00	3.70E-04	1.00E+00	100%

Commodity	Model component	Range of mean	Regression coefficient	Regression	Correlation coefficient	Contribution (%)
All products	A1	6.39E-05	0	0.00E+00	0.001	0%

Appendix N: Additional incremental dose calculation

Table 1 shows the Wilcoxon test results comparing CEDs from calculation E1.1 (including all data) to a dataset where the samples exceeding 100 Bq/kg had been removed. Mean and 97.5% doses for each age group were compared.

Table 2 shows mean radiocaesium activity concentrations for each food group when samples exceeding 100 Bq/kg are removed.

Table 1: Wilcoxon test results comparing CEDs from calculation E1.1 (including all data) to a dataset where the samples exceeding 100 Bq/kg had been removed. Mean and 97.5 % CEDs comparisons are shown for each age group.

Age category	**T-test statistic for mean doses**	**T-test statistic for 97.5th percentile values**
Adult	W = 534, p = 0.90	W = 532, p = 0.88
Child 3	W = 534.5, p = 0.90	W = 535.5, p = 0.91
Child 2	W = 537, p = 0.93	W = 533, p = 0.89
Child 1	W = 533.5, p = 0.89	W = 532.5, p = 0.88
Infant	W = 534, p = 0.90	W = 537, p = 0.93
Foetus	W = 536, p = 0.92	W = 538, p = 0.94

Table 2. Mean Radiocaesium activity concentrations (upper LOD) when samples exceeding 100 Bq/kg were removed from the dataset.

Food group	**Cs-134 (Bq/kg)**	**Cs-137 (Bq/kg)**
Agar	7.16E+00	6.65E+00
Alcoholic beverages	3.17E+00	3.10E+00
Baby food	3.62E+00	3.77E+00
Bread	4.97E+00	4.29E+00
Cattle	1.23E+01	1.23E+01
Cereals and grains	4.47E+00	4.54E+00
Condiments, spices and preserves	6.06E+00	5.86E+00

Food group	**Cs-134 (Bq/kg)**	**Cs-137 (Bq/kg)**
Confectionary	5.20E+00	4.75E+00
Dairy products	2.48E+00	2.26E+00
Dried fish	7.24E+00	6.57E+00
Dried fruit, nuts, and seeds	6.86E+00	9.83E+00
Dried mushroom	4.97E+00	1.16E+01
Eggs	8.13E+00	7.54E+00
Fats and oils	3.93E+00	3.65E+00
Freshwater fish	7.50E+00	1.24E+01
Fruit	5.47E+00	5.68E+00
Infant formula	3.23E+00	3.37E+00
Leguminous vegetables	5.54E+00	7.73E+00
Meat and dairy alternatives	5.58E+00	5.37E+00
Mushroom	6.07E+00	9.80E+00
Non-leguminous green vegetables	6.10E+00	6.95E+00
Other meats	8.69E+00	9.64E+00
Pasta	5.48E+00	5.20E+00
Potatoes	5.66E+00	5.57E+00
Ready to eat foods	5.68E+00	5.35E+00
Rice	5.94E+00	8.31E+00
Root vegetables	5.80E+00	5.76E+00
Saltwater fish	7.09E+00	7.78E+00
Seafood other	7.97E+00	8.03E+00
Seaweed and algae	8.92E+00	8.91E+00
Shoots	7.14E+00	1.40E+01
Snacks	5.04E+00	4.66E+00
Soft beverages	1.65E+00	1.80E+00

Post-Fukushima Nuclear Power Station Accident

UK Import Radiological Risk Assessment

Annex 1

December 2021

Annex 1: Component D – National estimate of annual dose to consumers, with and without import controls in place

1. Model overview

Component D is one of four components which have been used to assess the radiological risk to public health from consuming Japanese food imported into the UK, if the 100 Bq/kg maximum level on radiocaesium for food imported from Japan, was removed. Components A, B and C are discussed in detail in the main risk assessment document. Component D was requested after an initial review but had not been developed initially due to time constraints and missing data. It has since been completed and the outcomes used to complement and validate the conclusions from components A, B and C.

The aim of component D was to calculate the committed effective dose (CED) to the UK population based on the probability of consuming foods imported from Japan, using a number of available data sets. Activity concentrations of radiocaesium (Cs-134 and Cs-137), measured in foods in Japan, were used. These data were then sorted into food groups. The final number of food groups run in component D was 30[45] (31 food groups had been identified but it was not possible to get consumption data for dried mushrooms so this group was excluded). The 30 food groups considered in component D were: alcoholic beverages; baby food; bread; cattle; cereals and grains; confectionary; condiments, sauces and preserves (CSP); dairy products; dried fruit, nuts and seeds (DFNS); dried fish; eggs; fats and oils; freshwater fish; fruit; infant formula; leguminous vegetables; meat and dairy alternatives; mushrooms; non-leguminous green vegetables (NLGV); other meats;

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[45] There were 35 food groups in the original risk assessment. 5 food groups were removed for the following reasons: No activity concentrations were available in the sample data for 'Yeast', there was insufficient sample data to provide distributions required for 'Dried mushroom'. There was no import data for 'Algae' and insufficient import data to draw distributions for 'Snacks'. The 'Cultivated mushroom' food group was combined with 'Mushroom' food group to form one 'Mushroom' food group.

pasta; potatoes; ready-to-eat-foods (RTE); rice; root vegetables; saltfish; seafood – other; seaweed and algae; shoots; and soft beverages.

In addition to stratifying by food group, results were also divided into different consumer age intervals to take into account the varying consumption rates of different age groups and also the International Commission on Radiological Protection (ICRP) dose coefficients. The age groups considered in component D were Infant (age 4 to 18 months), Child 1 (age 18 months to 5 years), Child 2 (age 5 to less than 10 years), Child 3 (10 to less than 16 years), Adult (age 16 to less than 70 years) and Women of child-bearing age (age 16 to less than 50 years). This latter group is representative of the potential exposure to a foetus[46]. It is not representative of the exposure of the mother because only the infant dose coefficient is used in the calculations.

The estimation of dose in component D was dependent on: the activity concentrations measured in the food groups; consumption rates for each of the UK population groups for each food group; and the weight of each food group imported to the UK from Japan. This was a probabilistic assessment, using distributions reflecting uncertainty or variability and was based on radiocaesium activity concentration sample data from Japan, UK consumption data, UK imported product volume data and UK population data (values for each population group as a percentage of the total UK population from the Office of National Statistics (ONS)). The risk assessment was implemented in @Risk version 7.6 (Palisade, 2021).

The component D model estimated:

- The annual distribution of CED, for the UK population, through consumption of foods imported from Japan, assuming the presence or absence of a 100 Bq/kg level (control).
- The difference in CED between the distributions in the absence or presence of the 100 Bq/kg level (control).

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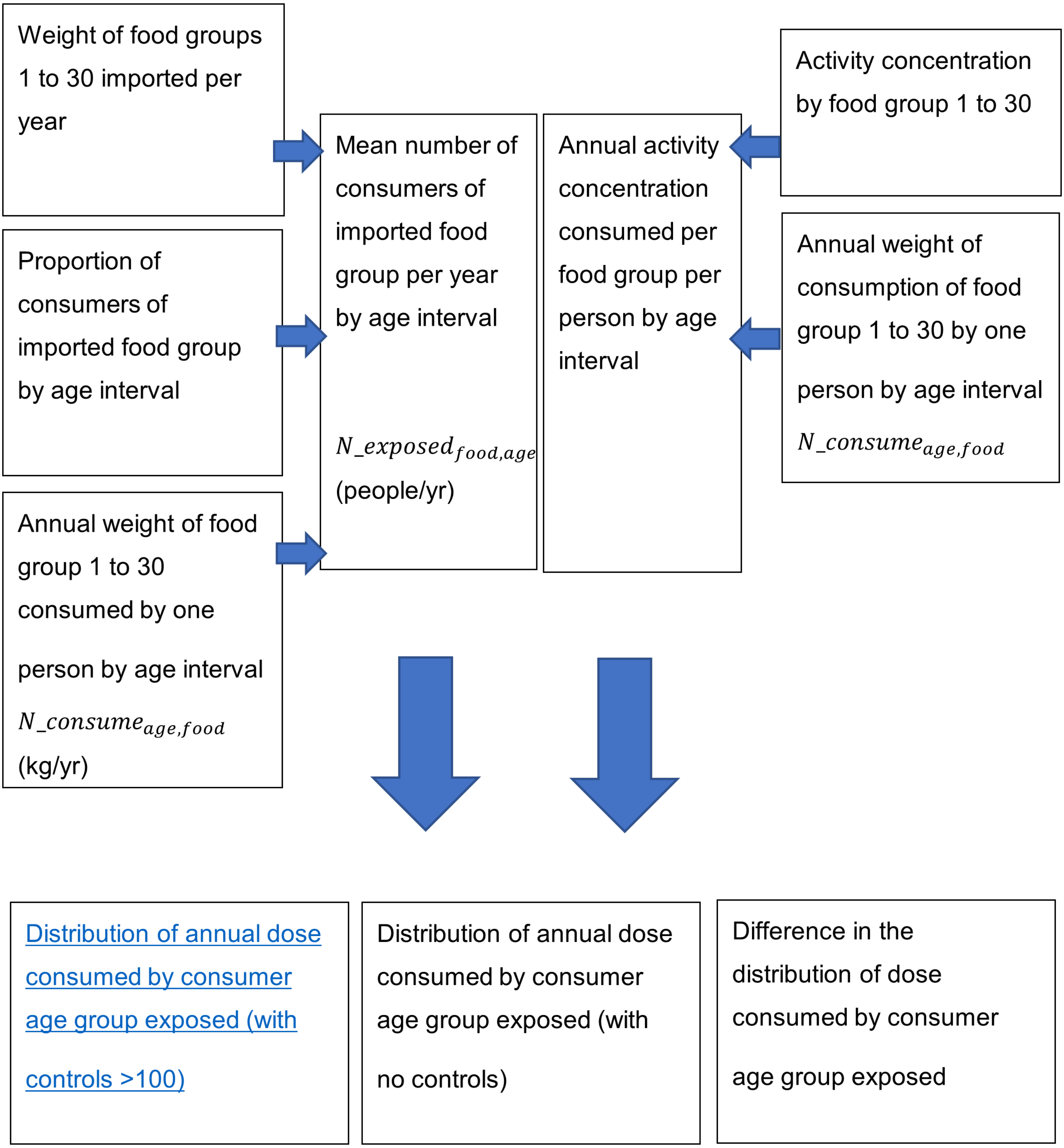
[46] ICRP 88 (2002). Doses to the Embryo and Fetus from Intakes of radionuclides by the mother

The model was run as two separate parts (module 1 and module 2) (Figure 1) where the outputs of module 1 (mean numbers of consumers per food group and annual activity concentration of that food group consumed per person) are used in module 2. The assessment is described in more detail in the relevant sections (2.1, 2.2 and 2.3).

Module 1: Import and consumption of single food group.



Module 2: Annual dose[47] from dietary consumption

Figure 1: Model overview for Component D.

2. Methods

Component D is comprised of two parts: Module 1 and Module 2. Module 1 was run for each food group individually per person and module 2 incorporated all food groups and were combined to represent the diet of an individual. Further detail for modules 1 and 2 is provided in sections 2.1, 2.2 and 2.3.

2.1 Module 1: Estimating the mean number of consumers of imported Japanese food group per year

This part of module 1 estimated the mean number of consumers, by age group (interval), of Japanese food imported into the UK each year. Due to the fact that import data was not available for specific prefectures, the complete import data was used which contributes to the assessment being conservative. Data on the total weight of each food group imported into the UK from Japan was available and was extracted from the Overseas trade data table - UK Trade Info (described in more detail in Appendix D). This imported weight, limits the number of consumers due to the finite amount of each imported food group available. The consumption distributions, based on NDNS and DNSIYC data[48], of each age group for each food group were also taken into account in the module to estimate the number and age of consumers exposed.

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[47] In this diagram dose refers to activity concentrations in Bq/kg consumed which are subsequently converted to mSv/yr using age-specific dose co-efficients.

[48] UK consumption data for each food group were obtained from the NDNS (Bates *et al.*, 2014; 2016; Roberts *et al.*, 2018) for ages 18 months and over. Consumption data for ages 4 – 18 months were obtained from the DNSIYC (DH, 2013).

For each food group, from 1 to 30, the number of consumers exposed to an imported food group, by age interval ($N\_exposed_{food,age}$), is dependent on: the total weight of each food group imported per year (N_import_{food}); the annual weight of consumption of food group by an individual consumer by age interval ($N\_consume_{food,age}$); and the proportion of consumers of imported food group by age interval (P_age).

The estimated weight of any imported food group from Japan for any year in the future was uncertain and described with a Pert distribution using the minimum, most likely[49] and maximum weight of imported food, for each food group, in recent years (defined in Table 1) (kg/yr):

$$N\_import_{food} \sim Pert(minimum, most\ likely, maximum)$$

When estimating how many people in the UK could consume those imports (as weight of consumption is dependent on age), with no further information, the default assumption was that the proportions of consumers for each age group were the same as the proportion of that age in the total UK population (ONS Data Table 2) using point values. For some food groups an exception was made if there was a specific use of a food restricting the age interval of consumers, *for example,* alcohol or baby food. In that instance, the distribution would only use the age groups that would be assumed to consume food from that group and the ratio of the proportions of the age groups was re-calculated.

Due to the high number of kgs imported and therefore considerable number of potential individual consumers for most food groups, the model was run (for all food groups) using a sample of 5,000 consumers selected at random from across the different age groups. For each consumer, their random age (Age) was estimated by the following equation:

$$Age \sim Discrete(\{a\}, \{P\_age\})$$

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[49] The 'most likely' value was estimated using the mean value of the weight of the imported food and fitting the assumed Pert distribution.

Where a is the age group and P_age is the proportion of that age group in the total population, based on ONS data (2019).

The random weight of the food consumed, for an individual consumer, for that food group, from each age group ($N\_consume_{food,age}$) (kg/yr) was then selected from the variable UK consumption distribution based on the NDNS (Bates *et al.*, 2014; 2016; Roberts *et al.*, 2018) and DNSIYC (DH, 2013)[50] data as provided in Table 3. The total weight consumed by those randomly selected 5,000 consumers was then summed as estimated by:

$$N\_exposed5000_{food} = \sum_{1}^{5000} N\_consume_{food,age}$$

The total average (mean) number of consumers exposed through a specific food group was then calculated by the following equation:

$$N\_exposed_{food} = \frac{5000}{N\_exposed5000_{food} \Big/ N\_import_{food}}$$

2.2 Module 1: Estimating the annual activity concentration consumed on the basis of food group per person by age interval

This part of module 1 estimates the annual radiocaesium activity concentration ingested by an individual through food consumption. This is based on the weight of imported food consumed (on a food group basis), per person (on an age group basis) per year.

There was variability associated with both the weight consumed between and within different ages of consumers and the activity concentration of different 1 kg samples of food types. Therefore, for each individual consuming that food, an activity concentration was randomly selected from the distribution for that food and multiplied by the weight of consumption for consumption up to 1 kg, which was randomly selected from the consumption distribution for that age

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[50] These references can be found in the main report.

group, $N\_consume_{food,age}$ (kg/yr). It was assumed that the activity concentrations were homogeneously distributed within all foods.

When the random annual consumption exceeded 1 kg, the value for the number of kgs consumed was rounded to the nearest kg (whole value) and an activity concentration was randomly selected for each kg consumed. This was to reflect the variability of activity per kg in that food group. So, for each iteration, an activity concentration was randomly selected for each kg up to the maximum number of kgs per year of that food group available for consumption ($N\_dose_{C,food,age}$) as shown in the following equation:

$$N\_dose_{C,food,age} = \sum_{N\_consume_{food,age}=1kg}^{N\_consume_{food,age}=maxkg} N\_activity_{food}$$

Where $N\_activity_{food}$ is defined as the activity concentration by food group 1 to 30 (Bq/yr).

The annual activity concentration consumed per food group was estimated for two different control regimes:

- Where C=0, no controls in place on activity concentration, there was no restriction on possible values selected from the distribution of activity concentrations.
- Where C=1, when a sample selected from the distribution was greater than 100 Bq/kg, these samples were removed and replaced with the value of 100. Therefore, no samples were selected that exceeded 100 Bq/kg.
- The difference in the annual activity concentrations consumed by food group, $N\_dose_{2,food,age}$ was estimated from the difference in activity concentrations between no controls and where controls were in place:

$$N\_dose_{2,food,age} = N\_dose_{0,food,age} - N\_dose_{1,food,age}$$

2.3 Module 2: Annual distribution of activity ingested by exposed consumers with ($N\_controls_{age}$) and without ($N\_nocontrols_{age}$) controls in place (kg/yr)

Using the individual food group results from module 1, module 2 calculates the distribution of the ingested activity, and hence, dose from consumption of these food groups, per age group, taking into account what the dose from the total diet could potentially be if the 100 Bq/kg controls were present or absent and to calculate the difference between the two doses. When the controls are present, it is likely that the distribution of the dose will be lower than when the controls are absent, due to the potential presence of foods imported which may have activity concentrations exceeding 100 Bq/kg.

In module 2 the consumption of the food groups is modelled in a tiered approach. The first tier of consumers that is modelled will consume all 30 food types from Japan. However, the quantity of ‘eggs’ imported from Japan is small and finite (import data are available in Appendix D of the main report) and they are all therefore consumed by this first tier. This means the second tier of consumers will consume only 29 food types, until the next food type (‘infant formulae’) runs out. The third tier of consumers will consume 28 food types from Japan, the fourth tier will consume 27 food types from Japan and so on, with the final tier of consumers that only consume ‘condiments, spices and preserves’ (includes soya sauce) from Japan. Note that for all age groups other than adults, the amount of alcohol consumed per year is 0 kg. Similarly, ‘baby food’ is only consumed by infants and ‘infant formulae’ is only consumed by the ‘infants’, ‘Child 1’ and ‘Child 2’ age groups (refer to Table 4 for dietary exclusions).

To implement the tiered approach, the radiological dose that any individual food group can contribute to personal exposure is assumed to be $N_dose_{C,age}$i (where i is the i^{th} food group: i=1, 2, 3…30; C is the control regime, and age is the age group consuming the i^{th} food group). This is calculated on an individual basis and was estimated in Module 1 with the output, a distribution comprised of both uncertainty and variability. This uncertainty was described in Module 2 with a cumulative distribution, using the minimum, maximum and 5th and 95th percentile statistics.

As imported volumes for each food group are finite, there is a threshold on the number of individuals that can consume that food in a year. These thresholds on the number of consumers are denoted by $N_exposed_{food,age}$i (i = 1…30). For simplicity, we have ordered the foods so that $N_exposed_{food,age}$1 < $N_exposed_{food,age}$2 ….< $N_exposed_{food,age}$30. It is also helpful to conceive of a notional $N_exposed_{food,age}$0 such that $N_exposed_{food,age}$0 = 0.

With these definitions in place, it follows that the overall radiological exposure of an individual consumer in component D, of C=0, with no controls in place on activity concentration in the food is given by:

$$\boldsymbol{N\_nocontrols_{age}} = \sum_{i=1}^{i=30} N\_dose_{0,age}\, i$$

And, where C=1, where a selection from the distribution was greater than 100 Bq/kg:

$$\boldsymbol{N\_controls_{age}} = \sum_{i=1}^{30} N\_dose_{1,age} i$$

And where C=2, estimating the difference between no controls and controls:

$$\boldsymbol{N\_difference_{age}} = \sum_{i=1}^{30} N\_dose_{2,age}\, i$$

There are a maximum of $N_exposed_{food,age}$1 individuals in the population who can fall within this top tier of exposure. The 2nd tier of overall radioactive exposure is at a level of:

$$\boldsymbol{N\_nocontrols_{age}} = \sum_{i=2}^{30} N\_dose_{0,age}\, i$$

$$\boldsymbol{N\_controls_{age}} = \sum_{i=2}^{30} N\_dose_{1,age} i$$

$$\boldsymbol{N\_difference_{age}} = \sum_{i=2}^{30} N\_dose_{2,age}\, i$$

and there are a maximum of ($N\_exposed_{food,age}2 - N\_exposed_{food,age}1$) individuals within the 2nd tier. This can be summarised in a single equation covering all 30 tiers of exposure, which is as follows. The exposure at the jth tier is:

$$\boldsymbol{N\_nocontrols_{age}} = \sum_{i=j}^{30} N\_dose_{0,age}\, i$$

$$\boldsymbol{N\_controls_{age}} = \sum_{i=j}^{30} N\_dose_{1,age} i$$

$$\boldsymbol{N\_difference_{age}} = \sum_{i=j}^{30} N\_dose_{2,age}\, i$$

where j=1 denotes the highest tier of potential radiation exposure from the diet, and where j=30 denotes the lowest tier.

The number of consumers within each of the tiers is:

($N\_exposed_{food,age,j}$ - $N\_exposed_{food,age,j-1}$), where $N\_exposed_{food,age,}0 = 0$.

The total number of consumers within any of these tiers of exposure is $N_exposed_{food,age,}$30. Under this pessimistic dietary assumption, all exposure to Fukushima radiocaesium is concentrated within this subset of the UK population. All other members of the population would have zero exposure.

A discrete function was used to randomly select the tier exposure for that iteration where the probability of selecting a tier was equal to the number of individuals exposed $N\_exposed_{food,age}$. For example, due to the number of available imports there are far fewer individuals who can consume all imported products as part of their total diet and this was therefore far less likely to be selected. The most commonly selected individual will be one who consumes condiments, sauces and preserves only. The resulting distribution represents the total uncertainty associated with the annual consumption of an individual UK consumer of a diet including Japanese imported foods in the UK.

In order to convert the value to a dose it was multiplied by the dose coefficient for that age group as detailed in the following section.

2.4 Estimated Committed Effective Dose (CED) (mSv/year) from the activity concentration outputs

The unit output of Bq/kg from Module 2 was converted into the committed effective dose (CED) in units of mSv/year using the following equation.

The ratio of Cs-137 to Cs-134 was assumed to be 1:1 to reflect the pattern seen in the data. This is known to be a cautious approach and likely to overestimate the amount of Cs-134 (refer to assumptions). For example, for the annual CED from the diet, consumed with no controls, would be calculated by:

$$\boldsymbol{Dose\ (mSv) = \ e(\tau)_{age,Cs137} \times \left[\frac{N\_nocontrols_{age}}{2}\right] + e(\tau)_{age,Cs134} \times \left[\frac{N\_nocontrols_{age}}{2}\right]}$$

Where,

$\boldsymbol{e(\tau)_{age}}_{,\mathrm{Cs}137}$ = Age-related dose co-efficient for ingestion of Cs -137

$\boldsymbol{e(\tau)_{age}}_{,\mathrm{Cs}134}$ = Age-related dose co-efficient for ingestion of Cs -134

The age related dose co-efficient are discussed in section 2.5.5. This equation was used for dose conversions from Bq/kg to mSv/year for formulae producing outputs in activity concentration (*i.e.*, $N\_difference_{age}$, $N\_controls_{age}$).

2.5 Parameterisation of Module 1 and 2

2.5.1 Weight of food group 1 to 30 imported per year, N_import_{food} kg/yr)

Annual import data from Japan to the UK (kg/yr) were obtained from HM Revenue and Customs database and attributed to the 30 food groups under consideration.

The annual weight for each food group (kg) varies in each year where recorded and there is therefore uncertainty about the amount that could be imported in the future. This uncertainty was described using a pert distribution using the minimum and maximum values from the import data and generating the most likely value so that the distribution mean equalled the observed import mean weight (Table 1).

For most food groups, the most recent 5 years of data was used to estimate the minimum, mean and maximum imported values. However, in certain cases there were less data available or more years were used where there was relatively higher variability between years for that food group which needed to be captured; these are shown in Table 1.

Table 1: Weight imported for each food group parameter values and distribution used in the risk assessment (kg/year)

Food group	**Distribution and values**
Alcoholic beverages	Pert(397658,502007.95,719877) with a mean of 520927.8kg/yr based on 5 years of trade data
Baby Food	Pert(1380,3584.75,8167) mean 3981 kg/yr based on 5 years trade data
Bread	Pert(3872,12042.5,18386) with a mean of 11738 kg/yr based on 5 years of trade data
Cattle	Pert(36288,44066,62282) with a mean of 45805 kg/yr based on 6 years of trade data
Cereals and grains	Pert(87959,116200,134682) with a mean of 114573.4 kg/yr based on 5 years of trade data
Condiments, spices, preserves	Pert(4745848,5174931,5643423) with a mean of 5174931 kg/yr based on 5 years of trade data
Confectionary	Pert(15165,76426.8,100863) with a mean of 70289.2 kg/yr based on 5 years of trade data
Dairy products	Pert(5,17.75,42) with a mean of 19.67 kg/yr based on 3 years of trade data available
Dried fish	1300 from one year trade data available
Dried food, nuts and seeds	Pert(75174,90962.7,102330) with a mean of 90225.8 kg/yr based on 5 years of trade data
Eggs	12 from one year trade data available
Fats and oils	Pert(6712,85105.55,237867) with a mean of 97500.2 kg/yr based on 5 years of trade data
Freshwater fish	Pert(651,40441.25,220504) with a mean of 63820 kg/yr based on 5 years of trade data
Fruit	Pert(1203,5625.5,12427) with a mean of 6022 kg/yr based on 5 years of trade data
Infant formula	Pert(1380,3584.75,8167) with a mean of 3981kg/yr based on 5 years of trade data

Food group	Distribution and values
Leguminous green vegetables	Pert(131,1019.6,5429) with a mean of 1606.4 kg/yr based on 5 years of trade data
Meat and dairy Alternatives	Pert(352096, 9725, 43764.83) with a mean 326821.8 kg/yr based on 5 years trade
Mushrooms	Pert(96,212,700) mean of 274 kg/yr based on 5 years of trade data
NLGV	Pert(174319,213463.1,282519) with a mean 218448.4 kg/yr based on 5 years trade
Other meats	Pert(4742,23070.75,43543) with a mean of 23428 kg/yr based on 5 years of trade data
Pasta	Pert(390416,480931.05,726139) with a mean of 506713.2 kg/yr based on 5 years of trade data
Potatoes	Pert(150,711.85,2333) with a mean of 888.4 kg/yr based on 5 years of trade data
RTE foods	Pert(1972306,2247623.55,2450435) with a mean of 2235539kg/yr based on 5 years of trade data
Rice	Pert(326799,444027.4,743585) with a mean of 474415.6kg/yr based on 5 years of trade data
Root veg	Pert(1614,3929.5,6517) with a mean of 3974.8 kg/yr based on last 5 years of trade data
Saltwater fish	Pert(48725,122948.8,205396) with a mean of 122948.8 kg/yr based on last 5 years of trade data
Seafood other	Pert(50,36479,99270) with a mean of 40872.69 kg/yr based on last 13 years of trade data due to high variability between years
Seaweed and algae	Pert(5650,12116.7,18451) with a mean of 12094.6 kg/yr based on 5 years of trade data
Shoots	Pert(15570,24689.9,44243) with a mean of 26428.8 kg/yr based on 5 years trade data
Soft beverages	Pert(519248,1626389,5340287) with a mean of 2060849 kg/yr based on 5 years of trade data

2.5.2 Annual weight of consumption of food group 1 to 30 by one person by age interval, $N\_consume_{food,age}$ (kg/yr)

Consumption data for the UK population was based on NDNS and DNSIYC data. Distributions of the variable consumption (from NDNS and DNSIYC) of each food group in the UK, by age interval, were calculated. The known variability was described using a Log normal distribution, based upon observed/recorded consumption data values (Table 2). Where there was limited or no data available on certain food group / age interval combination, assumptions were agreed upon by two radiological risk assessors (details in Table 3).

For example, there are no specific data on the annual consumption distributions for those consumers over 70 years old. The assumption was made that they consumed the same amounts as other adults.

Table 2: Weight of food consumed per UK consumer, by food and by age (kg/yr)

Assumptions made for restricted foods are shown in Table 3.

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Alcoholic beverages	Infant (4 - 18 months)	0
Alcoholic beverages	Child 1 (18 months - <5 years)	0
Alcoholic beverages	Child 2 (5 - <10 years)	0
Alcoholic beverages	Child 3 (10 - <16 years)	0
Alcoholic beverages	Adults (16 - <70 years)	Lognormal (102.29, 468.76)
Alcoholic beverages	Adults (>70 years)	Lognormal (102.29, 468.76)
Alcoholic beverages	Women of childbearing age (16-<50 years)	Lognormal (71.62, 286.16)
Baby food	Infant (4 - 18 months)	Lognormal (41.069, 165.689)
Baby food	Child 1 (18 months - <5 years)	Lognormal (16.13, 94.703)
Baby food	Child 2 (5 - <10 years)	Lognormal (7.283, 48.066)
Bread	Infant (4 - 18 months)	Lognormal (8.772, 25.608)
Bread	Child 1 (18 months - <5 years)	Lognormal (18.012, 42.472)
Bread	Child 2 (5 - <10 years)	Lognormal (25.637, 57.586)
Bread	Child 3 (10 - <16 years)	Lognormal (29.561, 71.412)
Bread	Adults (16 - <70 years)	Lognormal (31.436, 74.802)
Bread	Adults (>70 years)	Lognormal (31.436, 74.802)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Bread	Women of childbearing age (16-<50 years)	Lognormal (26.314, 58.211)
Cattle	Infant (4 - 18 months)	Lognormal (3.598, 12.901)
Cattle	Child 1 (18 months - <5 years)	Lognormal (5.087, 15.805)
Cattle	Child 2 (5 - <10 years)	Lognormal (7.121, 21.384)
Cattle	Child 3 (10 - <16 years)	Lognormal (9.652, 25.465)
Cattle	Adults (16 - <70 years)	Lognormal (13.173, 37.55)
Cattle	Adults (>70 years)	Lognormal (13.173, 37.55)
Cattle	Women of childbearing age (16-<50 years)	Lognormal (10.911, 30.83)
Cereals and grains	Infant (4 - 18 months)	Lognormal (2.207, 8.964)
Cereals and grains	Child 1 (18 months - <5 years)	Lognormal (2.842, 9.886)
Cereals and grains	Child 2 (5 - <10 years)	Lognormal (3.661, 12.872)
Cereals and grains	Child 3 (10 - <16 years)	Lognormal (4, 14.501)
Cereals and grains	Adults (16 - <70 years)	Lognormal (5.132, 20.975)
Cereals and grains	Adults (>70 years)	Lognormal (5.132, 20.975)
Cereals and grains	Women of childbearing age (16-<50 years)	Lognormal (4.203, 17.695)
Condiments, spices, preserves	Infant (4 - 18 months)	Lognormal (0.618, 2.921)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Condiments, spices and preserves	Child 1 (18 months - <5 years)	Lognormal (1.534, 6.44)
Condiments, spices and preserves	Child 2 (5 - <10 years)	Lognormal (1.914, 7.406)
Condiments, spices and preserves	Child 3 (10 - <16 years)	Lognormal (1.786, 7.636)
Condiments, spices and preserves	Adults (16 - <70 years)	Lognormal (2.6, 11.709)
Condiments, spices and preserves	Adults (>70 years)	Lognormal (2.6, 11.709)
Condiments, spices and preserves	Women of childbearing age (16- <50 years)	Lognormal (2.284, 10.613)
Confectionary	Infant (4 - 18 months)	Lognormal (10.022, 39.745)
Confectionary	Child 1 (18 months - <5 years)	Lognormal (20.896, 62.365)
Confectionary	Child 2 (5 - <10 years)	Lognormal (34.68, 83.865)
Confectionary	Child 3 (10 - <16 years)	Lognormal (34.834, 90.137)
Confectionary	Adults (16 - <70 years)	Lognormal (25.19, 78.502)
Confectionary	Adults (>70 years)	Lognormal (25.19, 78.502)
Confectionary	Women of childbearing age (16- <50 years)	Lognormal (23.533, 72.835)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Dairy products	Infant (4 - 18 months)	Lognormal (76.913, 268.241)
Dairy products	Child 1 (18 months - <5 years)	Lognormal (114.461, 292.153)
Dairy products	Child 2 (5 - <10 years)	Lognormal (92.425, 234.554)
Dairy products	Child 3 (10 - <16 years)	Lognormal (79.404, 230.201)
Dairy products	Adults (16 - <70 years)	Lognormal (80.495, 216.485)
Dairy products	Adults (>70 years)	Lognormal (80.495, 216.485)
Dairy products	Women of childbearing age (16-<50 years)	Lognormal (68.898, 182.416)
Dried fish	Infant (4 - 18 months)	Lognormal (1.978, 1.978)
Dried fish	Child 1 (18 months - <5 years)	Lognormal (3.915, 3.915)
Dried fish	Child 2 (5 - <10 years)	Lognormal (0.046, 0.046)
Dried fish	Child 3 (10 - <16 years)	Lognormal (0.289, 0.289)
Dried fish	Adults (16 - <70 years)	Lognormal (4.492, 17.99)
Dried fish	Adults (>70 years)	Lognormal (4.492, 17.99)
Dried fish	Women of childbearing age (16-<50 years)	Lognormal (4.492, 17.99)
Dried food, nuts and seeds	Infant (4 - 18 months)	Lognormal (1.418, 7.384)
Dried food, nuts and seeds	Child 1 (18 months - <5 years)	Lognormal (2.261, 11.827)
Dried food, nuts and seeds	Child 2 (5 - <10 years)	Lognormal (1.697, 8.995)
Dried food, nuts and seeds	Child 3 (10 - <16 years)	Lognormal (1.487, 8.744)

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Dried food, nuts and seeds	Adults (16 - <70 years)	Lognormal (3.218, 19.041)
Dried food, nuts and seeds	Adults (>70 years)	Lognormal (3.218, 19.041)
Dried food, nuts and seeds	Women of childbearing age (16- <50 years)	Lognormal (2.59, 14.425)
Eggs	Infant (4 - 18 months)	Lognormal (2.99, 13.69)
Eggs	Child 1 (18 months - <5 years)	Lognormal (4.055, 16.451)
Eggs	Child 2 (5 - <10 years)	Lognormal (4.528, 19.423)
Eggs	Child 3 (10 - <16 years)	Lognormal (5.149, 21.554)
Eggs	Adults (16 - <70 years)	Lognormal (8.197, 31.218)
Eggs	Adults (>70 years)	Lognormal (8.197, 31.218)
Eggs	Women of childbearing age (16- <50 years)	Lognormal (7.197, 31.208)
Fats and oils	Infant (4 - 18 months)	Lognormal (1.874, 6.284)
Fats and oils	Child 1 (18 months - <5 years)	Lognormal (4.987, 10.553)
Fats and oils	Child 2 (5 - <10 years)	Lognormal (7.496, 14.617)
Fats and oils	Child 3 (10 - <16 years)	Lognormal (8.693, 19.052)
Fats and oils	Adults (16 - <70 years)	Lognormal (8.047, 18.867)
Fats and oils	Adults (>70 years)	Lognormal (8.047, 18.867)
Fats and oils	Women of childbearing age (16- <50 years)	Lognormal (7.311, 18.205)

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Freshwater fish	Infant (4 - 18 months)	Lognormal (10.038, 10.038)
Freshwater fish	Child 1 (18 months - <5 years)	Lognormal (10.038, 10.038)
Freshwater fish	Child 2 (5 - <10 years)	Lognormal (8.092, 10.142)
Freshwater fish	Child 3 (10 - <16 years)	Lognormal (7.711, 13.078)
Freshwater fish	Adults (16 - <70 years)	Lognormal (10.167, 28.668)
Freshwater fish	Adults (>70 years)	Lognormal (10.167, 28.668)
Freshwater fish	Women of childbearing age (16- <50 years)	Lognormal (9.982, 10.95)
Fruit	Infant (4 - 18 months)	Lognormal (18.468, 56.073)
Fruit	Child 1 (18 months - <5 years)	Lognormal (33.891, 105.194)
Fruit	Child 2 (5 - <10 years)	Lognormal (39.242, 115.428)
Fruit	Child 3 (10 - <16 years)	Lognormal (33.991, 116.234)
Fruit	Adults (16 - <70 years)	Lognormal (27.347, 92.487)
Fruit	Adults (>70 years)	Lognormal (27.347, 92.487)
Fruit	Women of childbearing age (16- <50 years)	Lognormal (24.877, 83.319)
Infant formula	Infant (4 - 18 months)	Lognormal (160.094, 322)
Infant formula	Child 1 (18 months - <5 years)	0
Infant formula	Child 2 (5 - <10 years)	0
Infant formula	Child 3 (10 - <16 years)	0

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Infant formula	Adults (16 - <70 years)	0
Infant formula	Adults (>70 years)	0
Infant formula	Women of childbearing age (16- <50 years)	0
Leguminous vegetables	Infant (4 - 18 months)	Lognormal (4.333, 17.15)
Leguminous vegetables	Child 1 (18 months - <5 years)	Lognormal (5.796, 19.103)
Leguminous vegetables	Child 2 (5 - <10 years)	Lognormal (7.934, 25.239)
Leguminous vegetables	Child 3 (10 - <16 years)	Lognormal (7.591, 26.998)
Leguminous vegetables	Adults (16 - <70 years)	Lognormal (11.311, 40.627)
Leguminous vegetables	Adults (>70 years)	Lognormal (11.311, 40.627)
Leguminous vegetables	Women of childbearing age (16- <50 years)	Lognormal (10.08, 36.085)
Meat and dairy alternatives	Infant (4 - 18 months)	Lognormal (9.94, 68.424)
Meat and dairy alternatives	Child 1 (18 months - <5 years)	Lognormal (19.227,142.504)
Meat and dairy alternatives	Child 2 (5 - <10 years)	Lognormal (11.86, 65.354)
Meat and dairy alternatives	Child 3 (10 - <16 years)	Lognormal (10.151,63.012)
Meat and dairy alternatives	Adults (16 - <70 years)	Lognormal (21.681, 104.667)
Meat and dairy alternatives	Adults (>70 years)	Lognormal (21.681, 104.667)
Meat and dairy alternatives	Women of childbearing age (16- <50 years)	Lognormal (18.77, 100.387)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Mushrooms	Infant (4 - 18 months)	Lognormal (1.1, 5.271
Mushrooms	Child 1 (18 months - <5 years)	Lognormal (0.98,3.987)
Mushrooms	Child 2 (5 - <10 years)	Lognormal (1.332, 6.724)
Mushrooms	Child 3 (10 - <16 years)	Lognormal (2.03,8.982)
Mushrooms	Adults (16 - <70 years)	Lognormal (4.729,18.55)
Mushrooms	Adults (>70 years)	Lognormal (4.729,18.55)
Mushrooms	Women of childbearing age (16-<50 years)	Lognormal (4.082, 18.055)
Non leguminous green vegetables	Infant (4 - 18 months)	Lognormal (5.324, 22.903)
Non leguminous green vegetables	Child 1 (18 months - <5 years)	Lognormal (6.892, 22.285)
Non leguminous green vegetables	Child 2 (5 - <10 years)	Lognormal (9.296, 32.613)
Non leguminous green vegetables	Child 3 (10 - <16 years)	Lognormal (9.836, 32.055)
Non leguminous green vegetables	Adults (16 - <70 years)	Lognormal (16.316, 53.692)
Non leguminous green vegetables	Adults (>70 years)	Lognormal (16.316, 53.692)

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Non leguminous green vegetables	Women of childbearing age (16-<50 years)	Lognormal (15.603, 50.136)
Other meats	Infant (4 - 18 months)	Lognormal (5.035, 17.435)
Other meats	Child 1 (18 months - <5 years)	Lognormal (8.842, 24.227)
Other meats	Child 2 (5 - <10 years)	Lognormal (12.991, 33.204)
Other meats	Child 3 (10 - <16 years)	Lognormal (16.197, 43.97)
Other meats	Adults (16 - <70 years)	Lognormal (20.269, 56.565)
Other meats	Adults (>70 years)	Lognormal (20.269, 56.565)
Other meats	Women of childbearing age (16-<50 years)	Lognormal (17.507, 47.829)
Pasta	Infant (4 - 18 months)	Lognormal (6.354, 21.928)
Pasta	Child 1 (18 months - <5 years)	Lognormal (9.349, 27.681)
Pasta	Child 2 (5 - <10 years)	Lognormal (13.043, 38.962)
Pasta	Child 3 (10 - <16 years)	Lognormal (17.318, 46.929)
Pasta	Adults (16 - <70 years)	Lognormal (19.797, 63.665)
Pasta	Adults (>70 years)	Lognormal (19.797, 63.665)
Pasta	Women of childbearing age (16-<50 years)	Lognormal (19.277, 54.659)
Potatoes	Infant (4 - 18 months)	Lognormal (12.445, 40.973)
Potatoes	Child 1 (18 months - <5 years)	Lognormal (16.3, 45.168)

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Potatoes	Child 2 (5 - <10 years)	Lognormal (25.368, 61.289)
Potatoes	Child 3 (10 - <16 years)	Lognormal (30.631, 74.713)
Potatoes	Adults (16 - <70 years)	Lognormal (34.115, 87.076)
Potatoes	Adults (>70 years)	Lognormal (34.115, 87.076)
Potatoes	Women of childbearing age (16- <50 years)	Lognormal (29.541, 78.084)
Ready-to-eat foods	Infant (4 - 18 months)	Lognormal (11.524, 53.762)
Ready-to-eat foods	Child 1 (18 months - <5 years)	Lognormal (18.451, 59.687)
Ready-to-eat foods	Child 2 (5 - <10 years)	Lognormal (24.614, 75.624)
Ready-to-eat foods	Child 3 (10 - <16 years)	Lognormal (33.171, 97.221)
Ready-to-eat foods	Adults (16 - <70 years)	Lognormal (35.473, 118.625)
Ready-to-eat foods	Adults (>70 years)	Lognormal (35.473, 118.625)
Ready-to-eat foods	Women of childbearing age (16- <50 years)	Lognormal (32.307, 110.834)
Rice	Infant (4 - 18 months)	Lognormal (5.351, 26.183)
Rice	Child 1 (18 months - <5 years)	Lognormal (6.308, 30.458)
Rice	Child 2 (5 - <10 years)	Lognormal (9.088, 42.372)
Rice	Child 3 (10 - <16 years)	Lognormal (12.512, 52.887)
Rice	Adults (16 - <70 years)	Lognormal (19.44, 79.875)
Rice	Adults (>70 years)	Lognormal (19.44, 79.875)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Rice	Women of childbearing age (16-<50 years)	Lognormal (18.474, 75.21)
Root vegetables	Infant (4 - 18 months)	Lognormal (10.084, 34.216)
Root vegetables	Child 1 (18 months - <5 years)	Lognormal (5.658, 21.951)
Root vegetables	Child 2 (5 - <10 years)	Lognormal (7.655, 28.22)
Root vegetables	Child 3 (10 - <16 years)	Lognormal (8.098, 29.297)
Root vegetables	Adults (16 - <70 years)	Lognormal (15.084, 52.191)
Root vegetables	Adults (>70 years)	Lognormal (15.084, 52.191)
Root vegetables	Women of childbearing age (16-<50 years)	Lognormal (13.821, 47.477)
Saltwater fish	Infant (4 - 18 months)	Lognormal (3.947, 12.507)
Saltwater fish	Child 1 (18 months - <5 years)	Lognormal (5.569, 15.972)
Saltwater fish	Child 2 (5 - <10 years)	Lognormal (6.872, 20.973)
Saltwater fish	Child 3 (10 - <16 years)	Lognormal (8.503, 26.08)
Saltwater fish	Adults (16 - <70 years)	Lognormal (13.253, 40.599)
Saltwater fish	Adults (>70 years)	Lognormal (13.253, 40.599)
Saltwater fish	Women of childbearing age (16-<50 years)	Lognormal (11.009, 33.709)
Seafood other	Infant (4 - 18 months)	Lognormal (1.229, 5.533)
Seafood other	Child 1 (18 months - <5 years)	Lognormal (1.54, 4.822)

Food group	Age Category	Distribution and values (mean, 97.5th percentile)
Seafood other	Child 2 (5 - <10 years)	Lognormal (2.686, 9.82)
Seafood other	Child 3 (10 - <16 years)	Lognormal (3.041, 10.69)
Seafood other	Adults (16 - <70 years)	Lognormal (6.289, 24.552)
Seafood other	Adults (>70 years)	Lognormal (6.289, 24.552)
Seafood other	Women of childbearing age (16-<50 years)	Lognormal (6.117, 26.521)
Seaweed and algae	Infant (4 - 18 months)	Lognormal (0.104, 0.32)
Seaweed and algae	Child 1 (18 months - <5 years)	Lognormal (0.208, 0.474)
Seaweed and algae	Child 2 (5 - <10 years)	Lognormal (0.208, 0.474)
Seaweed and algae	Child 3 (10 - <16 years)	Lognormal (0.313, 0.856)
Seaweed and algae	Adults (16 - <70 years)	Lognormal (0.368, 1.366)
Seaweed and algae	Adults (>70 years)	Lognormal (0.368, 1.366)
Seaweed and algae	Women of childbearing age (16-<50 years)	Lognormal (0.397, 1.387)
Shoots	Infant (4 - 18 months)	Lognormal (0.00043, 0.071, 0.566) fitted to 2.5th, mean and 99.9th percentile
Shoots	Child 1 (18 months - <5 years)	Lognormal (0.000464, 0.05, 0.739) fitted to 2.5th, mean and 99.9th percentile
Shoots	Child 2 (5 - <10 years)	Lognormal (0.001717, 0.068, 0.181) fitted to 2.5th, mean and 97.5th percentile

Food group	**Age Category**	**Distribution and values (mean, 97.5th percentile)**
Shoots	Child 3 (10 - <16 years)	Lognormal (0.000602, 0.181, 1.179) fitted to 2.5th, mean and 97.5th percentile
Shoots	Adults (16 - <70 years)	Lognormal (0.000803, 0.313, 6.378) fitted to 2.5th, mean and 99.9th percentile
Shoots	Adults (>70 years)	Lognormal (0.000803, 0.313, 6.378) fitted to 2.5th, mean and 99.9th percentile
Shoots	Women of childbearing age (16- <50 years)	Lognormal (0.000783, 0.236, 1.576) fitted to 2.5th, mean and 97.5th percentile
Soft beverages	Infant (4 - 18 months)	Lognormal (0.41, 0.558)
Soft beverages	Child 1 (18 months - <5 years)	Lognormal (0.41, 0.558)
Soft beverages	Child 2 (5 - <10 years)	Lognormal (1.246, 3.763)
Soft beverages	Child 3 (10 - <16 years)	Lognormal (12.24, 44.88)
Soft beverages	Adults (16 - <70 years)	Lognormal (58.911, 217.944)
Soft beverages	Adults (>70 years)	Lognormal (58.911, 217.944)
Soft beverages	Women of childbearing age (16- <50 years)	Lognormal (55.09, 199.508)

Table 3: Exceptions and assumptions for certain food groups

Food group	**Exceptions**	**Assumption**
Alcohol beverages	Only Adult consumption data used	The supply of alcohol to under 18's is not legally permitted
Baby food	Only Infant, Child 1 and Child 2 data used	Only Infant, Child 1 and Child 2 consumption data available
Infant formula	Only Infant consumption data used	Infant formula is only appropriate for infants
Freshwater fish	Child 1 consumption data used for infant	No infant consumption data
Dried fish	Adult consumption data used for women of childbearing age	No consumption data for women of childbearing age (to represent foetal exposure)
Seaweed and algae	Child 2 consumption data used for Child 1	No Child 1 consumption data
Soft beverages	Child 1 consumption data used for infant	No infant consumption data

2.5.3 Proportion of consumers of imported food group by age interval, P_age (%)

The age of UK consumers eating Japanese imported foods is not known and with no further data the default assumption was that the age proportions of consumers were the same as the proportion of that age in the total UK population (ONS Data Table 4) using point values shown in the following Table.

Table 4. Percentage of population in UK by age category (ONS, 2019)

a (age group)	P_age
Infant (4 - 18 months)	0.016
Child 1 (18 months - <5 years)	0.041
Child 2 (5 - <10 years)	0.062
Child 3 (10 - <16 years)	0.070
Adults (16 - <70 years) excluding females (16-<50 years)	0.460
Female (16-<50 years)	0.215
Over 70	0.135

2.5.4 Activity concentration by food group 1 to 30, N _ (Bq/yr)

The activity concentration data from the Japanese Government website (MHLW) (accessed Feb 2021) varied considerably both between food groups and within food groups sampled. This variability has been incorporated into the assessment using a best fitting distribution viewing both the mean of the resulting distribution and the maximum values obtained. Best fitting distributions were first ranked by Akaike's information criterion (AIC[51]). Each distribution fit was inspected by two risk assessors to ensure that the distribution selected was appropriate for the data. In some cases where the suggested distributions were not appropriate for the dataset, particularly when the tails of the distribution were too high or low to encompass the observed data, a cumulative distribution was fitted to the minimum, maximum and percentile observed data. A maximum value 25% higher than the observed maximum value was used as the cut-off point. (This value was based on the assumed detection efficiencies of the instruments used as discussed in the main document section 3.4.2.1.). Distributions for the sampled activity concentrations for each commodity are shown in Table 5.

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[51] AIC is used to evaluate how well a model fits to the data. In this instance, AIC is used to compare multiple distribution fits to the dataset. The distribution with the lowest AIC value indicates a superior model fit.

Table 5: Activity concentration distributions for each commodity, based on sample data provided in the MHLW monitoring data.

Food group	Distribution and values
Alcoholic beverages	Weibull(1.3699,5.8112,RiskShift(0.76593)) truncated at 0
Baby Food	ExtvalueMin(8.306,1.1167) Exponential family, truncated at 0
Bread	Extvalue(7.993,2.1749) Exponential family, truncated at 0
Cattle	Expon(23.178,Shift(1.4)) Exponential family, truncated at 0
Cereals and grains	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Condiments, spices, preserves	Extvalue(9.1268,4.7069) Exponential family truncated at 0
Confectionary	Weibull(2.0003,8.5278,Shift(2.3871)) truncated at 0
Dairy products	Gamma(3.0282,1.6115,Shift(-0.1451)) truncated at 0
Dried fish	Logistic(14.6082,3.3915) truncated at 0
Dried food, nuts and seeds	Loglogistic(0.72596,11.331,2.6351) truncated at 0
Eggs	Logistic(15.7881,2.8469) truncated at 0
Fats and oils	Pearson5(9.0089,55.501,Shift(0.52163)) Inverse Gamma truncated at 0
Freshwater fish	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Fruit	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Infant formula	ExtvalueMin(7.8747,1.826) Exponential family truncated at 0

Food group	Distribution and values
Leguminous green vegetables	Loglogistic (0.83269,8.4946,3.1578) truncated at 0
Meat and dairy alternatives	ExtvalueMin(14.2062,6.7596) Exponential family truncated at 0
Mushrooms	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
NLGV	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Food group	**Distribution and values**
Other meats	ExtvalueMin(19.2791,5.7746) Exponential family truncated at 0
Pasta	Weibull(1.9917,10.33,Shift(1.5646)) truncated at 0
Potatoes	Logistic(9.8555,3.3932) truncated at 0
RTE foods	Lognorm(11.551,5.3608,Shift(-0.59879)) truncated at 0
Rice	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Root veg	Pearson5(7.3849,102.37,Shift(-4.5292)) Inverse gamma truncated at 0
Saltwater fish	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Seafood other	Cumulative distribution fitted to minimum and percentile observed data. Maximum value was +25% higher than observed maximum value.
Seaweed and algae	Logistic(19.1265,2.3681) truncated at 0
Shoots	Lognorm(21.454,24.84,Shift(0.97131)) truncated at 0

Food group	Distribution and values
Soft beverages	Invgauss(3.0018,1.7885,Shift(0.23436)) truncated at 0

2.5.5 Age-related dose co-efficient for ingestion of Cs 137 and 134, $e(\tau)_{age,Cs137}$ and $e(\tau)_{age,Cs134}$

In order to convert the calculated radiocaesium activity concentrations per food group and age, the value is multiplied by the age-related dose co-efficient for ingestion. The dose co-efficients for ingestion of Cs -137 and Cs -134 for each age group are shown in Table 6 (ICRP[52]). These refer to the CED calculation shown in section 2.4. An explanation of dose co-efficients can be found in section 3.3.2 of the main report. This multiplication is done outside of modules 1 and 2 but provides the final dose (mSv/year) for Compartment D.

Table 6: ICRP Dose coefficients by age group (mSv/Bq)

Age group	Dose coefficient Cs-134	Dose coefficient Cs-137
Infant (4 - 18 months)	1.6×10^5	1.2×10^5
Child 1 (18 months - <5 years)	1.6×10^5	1.2×10^5
Child 2 (5 - <10 years)	1.4×10^5	1.0×10^5
Child 3 (10 - <16 years)	1.9×10^5	1.3×10^5
Adults (16 - <70 years) / Females (16-<50)	1.9×10^5	1.3×10^5
Woman of childbearing age (16-<50) (foetus)	8.7×10^6	5.7×10^6

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[52] ICRP, 2012. Compendium of Dose Coefficients based on ICRP Publication 60. ICRP Publication 119. Ann. ICRP Vol 41 supplement 1.

3. Sensitivity Analysis

A multivariate stepwise regression analysis was used to calculate linear regression or sensitivity values for each input parameter represented by a distribution for Module 2 outputs of the annual distribution of activity concentration. This approach is preferred for large numbers of input parameters, as all variables that provide an insignificant contribution are removed from the analysis.

4. Results

Both variability and uncertainty are considered in the model and are represented by 5th and 95th percentiles (within parentheses), which indicate the range within

which 90% of the results lie. The greater the range between the percentiles, the greater the total uncertainty. Model 1 was run for 50,000 iterations using Latin Hypercube sampling to reach convergence. Model 2 converged at approximately

200,000 iterations and was run for 250,000 iterations.

The annual activity consumed per person by age interval, $N\_dose_{c,food,age}$, was estimated for each of the 30 food groups based on the amount consumed and concentration of activity estimated from survey results. The highest estimated mean activity ingested for an adult in the absence of controls was for 1454 Bq/yr from the NLGV food group. Ingested activity estimates for other food groups for adults are provided in Table 7.

Table 7: Estimated single food group activity ingested per year for an adult (or infant where asterisked)[53]

Food group	**No controls** $N\_dose_{0,food,age}$ **(Bq/yr) mean (5th, 95th)**	**Controls** $N\_dose_{1,food,age}$ **(Bq/yr) mean (5th, 95th)**	**Difference** $N\_dose_{2,food,age}$ **(Bq/yr) mean (5th, 95th)**
Alcoholic beverages	619 (59, 2030)	619 (59, 2030)	0
Baby food*	312 (43, 945)	312 (43, 945)	0
Bread	291 (109, 589)	291 (109, 589)	0
Cattle	323 (69, 784)	319 (69,770)	4.3 (0,0)
Cereals and grains	48 (4, 161)	47 (4, 151)	1 (0, 67)
Confectionary	250 (59, 626)	250 (59, 626)	0
Condiments, sauces and preserves (CSP)	31 (2, 103)	31 (2, 103)	0
Dairy products	381 (117, 849)	381 (117, 849)	0
Dried fruit, nuts and seeds (DFNS)	48 (2, 194)	47 (2, 190)	0.6 (0, 0)
Dried fish	62 (7, 199)	62 (7, 199)	0
Eggs	129 (8, 376)	129 (7, 376)	0
Fats and oils	60 (22, 121)	60 (18, 121)	0
Freshwater fish	198 (43, 518)	184 (43, 445)	14 (0, 139)
Fruit	368 (58, 1075)	315 (58, 845)	53 (0, 374)
infant formula*	1096 (523, 1949)[54]	1096 (523, 1949)	0
Leguminous vegetables	123 (19, 348)	123 (19, 347)	0.2 (0)

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[53] These activities are for total radioceasium (Cs-137+Cs-134)

[54] This result takes into account the worst case scenario i.e if an infant exclusively consumes unrestricted Japanese imports for an entire year. However, as this data is taken from module 1 it does not take into account import volumes and it should be noted that there has been no infant formula imported to the UK from Japan in the years 2008-2020,

Food group	No controls $N\_dose_{0,food,age}$ (Bq/yr) mean (5th, 95th)	Controls $N\_dose_{1,food,age}$ (Bq/yr) mean (5th, 95th)	Difference $N\_dose_{2,food,age}$ (Bq/yr) mean (5th, 95th)
Meat and dairy alternatives	230 (9, 817)	230 (9, 817)	0
Mushrooms	144 (5.6, 425)	77 (5.6, 246)	64 (0, 17)
Non-leguminous green vegetables (NLGV)	1454 (40, 11039)	234 (40, 623)	1210 (0, 10477)
Other meats	327 (93, 755)	327 (93, 755)	0
Pasta	212 (46, 546)	212 (46, 546)	0
Potatoes	342 (112, 737)	342 (112, 737)	0
Ready-to-eat-foods (RTE)	387 (79, 1022)	387 (79, 1022)	0
Rice	307 (22, 982)	286 (22, 899)	21 (0, 172)
Root veg	173 (70, 473)	173 (70, 473)	0.01 (0, 0)
Saltwater fish	340 (44, 1651)	205 (44, 517)	130 (0, 1242)
Seafood other	119 (13, 432)	103 (13, 314)	16 (0, 44)
Seaweed and algae	7 (1, 19)	7 (1, 19)	0
Shoots	7 (0.2, 27)	7 (0.2, 27)	0.05 (0, 0)
Soft beverages	187 (29, 535)	187 (29, 535)	0

Using conservative assumptions in compartment D to combine the individual food groups together into a person's annual diet, an estimated average of 2,197,869 people could consume Japanese imported food per year. The top three products consumed were 1) condiments, including soy sauce, 2) shoots and 3) ready-to-eat foods. Of adult consumers, an estimated mean (5th, 95th percentiles) activity of 98.4 (4, 450)[55] Bq/yr, equating to a CED of 1.6×10^{-3} mSv/year, are consumed in the

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[55] 5%-95% range of activity concentrations in parentheses

absence of the 100 Bq/kg controls and 84.8 (2, 450) Bq/yr, equating to a CED 1.3×10^{-3} mSv/year, consumed when the controls are in place.

The difference between the calculated doses in the presence and absence of controls for a representative consumer have been estimated separately. The distribution is extremely skewed with the majority of values being 0, that is, no difference for that consumer for that year, with very infrequent higher values when a food serving is consumed that would have been restricted with controls in place. The mean difference between presence and absence of the controls, for an adult consumer is 33.0 (0, 10^{-13}) Bq/yr which equates to a CED of 5×10^{-4} mSv/year. Results for all age groups are provided in Table 8 (a) as activity concentrations and table 8(b) shows the results converted to CED in mSv/year.

Table 8(a): Estimated annual activity ingested (Bq/yr)[56] for a representative UK consumer by age

Age	$N\_nocontrols_{age}$ **Mean (5th, 95th) Bq/yr**	$N\_controls_{age}$ **Mean (5th, 95th) Bq/yr**	$N\_difference_{age}$ **Mean (5th, 95th) Bq/yr**
Infant (4 – 18 months)	34.0 (1, 140)	29.3 (0.5, 140)	13.3 (0, 1×10^{-14})
Child 1 (18 months - less than 5 years)	57.5 (3, 270)	51.3 (2, 270)	15.8 (0, 1×10^{-13})
Child 2 (5 - less than 10 years)	72.2 (3, 340)	62.3 (2, 340)	21.9 (0, 1×10^{-13})
Child 3 (10 - less than 16 years)	75.8 (3, 400)	66.1 (2, 400)	23.2 (0, 1×10^{-13})
Adults (16 - less than 70 years) excluding females (16-less than 50 years)	100.9 (4, 450)	85.3 (2, 450)	32.9 (0, 1×10^{-12})
Female (16-less than 50 years)	90.4 (4, 440)	77.3 (2, 430)	30.7 (0, 1×10^{-12})

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[56] These activities are for total radiocaesium (Cs-137+Cs-134)

Table 8 (b): Estimated annual dose (mSv/year) for a representative UK consumer by age (Dose conversion from Bq/kg to CED).[57]

Age	$N\_nocontrols_{age}$ **Mean (5th, 95th) (mSv/year)**	$N\_controls_{age}$ **Mean (5th, 95th) (mSv/year)**	$N\_difference_{age}$ **Mean (5th, 95th) (mSv/year)**
Infant (4 - 18 months)	$5x10^{-4}$ ($1x10^{-5}$, $2x10^{-3}$)	$4x10^{-4}$ ($7x10^{-6}$, $2x10^{-3}$)	$2x10^{-4}$ ($1x10^{-19}$)
Child 1 (18 months - less than 5 years)	$8x10^{-4}$ ($4x10^{-5}$, $4x10^{-3}$)	$7x10^{-4}$ ($3x10^{-6}$,$4x10^{-3}$)	$2x10^{-4}$ ($<1x10^{-15}$)
Child 2 (5 - less than 10 years)	$1x10^{-3}$ ($4x10^{-5}$, $5x10^{-3}$)	$1x10^{-3}$ ($3x10^{-5}$, $5x10^{-3}$)	$3x10^{-4}$ ($<1x10^{-18}$)
Child 3 (10 - less than 16 years)	$1x10^{-3}$ ($5x10^{-5}$, $6x10^{-3}$)	$1x10^{-3}$ ($3x10^{-5}$, $6x10^{-3}$)	$4x10^{-4}$ ($<1x10^{-18}$)
Adults (16 - less than 70 years) excluding females (16-<50 years)	$1.6x10^{-3}$ ($6x10^{-5}$, $7x10^{-3}$)	$1.4x10^{-3}$ ($3x10^{-5}$, $7x10^{-3}$)	$5.3x10^{-4}$ ($<1x10^{-18}$)
Female (16-less than 50 years)	$1.5\ x10^{-3}$ ($6x10^{-5}$, $7x10^{-3}$)	$1.2\ x10^{-3}$ ($3x10^{-5}$, $7x10^{-3}$)	$5x10^{-4}$ ($<1x10^{-17}$)
(Foetus) Female (16-less than 50 years)	$6.5.x10^{-4}$ ($3x10^{-5}$, $3x10^{-3}$)	$5.6.x10^{-4}$ ($1x10^{-5}$, $3x10^{-3}$)	$2.2x10^{-4}$ ($<1x10^{-15}$)

The contribution by food group to the difference in annual dietary activity concentration (*i.e.,* dose in the absence of controls minus the dose in the presence of controls) was estimated, the top three contributors to adult dietary dose were NLGV (27%), saltwater fish (16%) and rice (16%). Results were slightly different for

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[57] The mean CED to the adult RP is expressed to 2 SF to assist with comparison with the other components of the risk assessment .

infants due to consumption rates, where the top three were fruit (16%), NLGV (13%) and saltwater fish (11%).

Sensitivity analysis

For Module 2, the top two significant inputs were ranked by regression coefficient for the annual distribution of activity concentration under no controls, controls and the difference in controls as shown in Table 9. It can be seen that the most significant uncertainty for the distribution of total diet activity ingested was from the uncertainty associated with the activity concentration of condiments, sauces and preserves, which includes soya sauce. For the difference between control measures, $N\_difference_{age}$, the uncertainty associated with food groups that have been sampled in Japan with values above 100 Bq/kg were significant, including NLGV, and saltwater fish for adults, and cereals and rice for infants and young children (Child 1).

Table 9: Significant contributing inputs to annual activity ingested

Age	$\boldsymbol{N\_nocontrols_{age}}$	$\boldsymbol{N\_controls_{age}}$	$\boldsymbol{N\_difference_{age}}$
Infant (4 - 18 months)	CSP*, RTE*	CSP, RTE	NLGV*, cereals
Child 1 (18 months - less than 5 years)	CSP, rice	CSP, NLGV	NLGV, rice
Child 2 (5 - less than 10 years)	CSP, RTE	CSP, RTE	NLGV, Saltwater fish
Child 3 (10 - less than 16 years)	CSP, root vegetables	CSP, RTE	NLGV, Saltwater fish
Adults (16 - less than 70 years) excluding females (16-less than 50 years)	CSP, RTE	CSP, RTE	NLGV, Saltwater fish
Female (16-less than 50 years)	CSP, RTE	CSP, RTE	NLGV, Saltwater fish

*Condiments, sauces and preserves - includes soy sauce (CSP);
* Ready-to-eat foods (RTE);
*Non-leguminous green vegetables (NLGV).

5. Discussion and conclusions

Component D, as outlined in this annex is designed to be a supplement to the main assessment to combine the different components of the analysis in order give a single overarching conclusion based on the available evidence.

There are differences in the estimated absolute values of CED estimated between the main report and the probabilistic assessment, which are due to model variation of probabilistic and deterministic approaches and different assumptions required by those approaches. Overall, the results of the probabilistic assessment are a lower absolute value CED than the deterministic assessment. However, the additional incremental dose (if restrictions were lifted) was slightly higher when estimated in the probabilistic assessment.

The probabilistic assessment attempts to estimate the number of consumers affected, estimated as approximately 2.2 million. This seems a high value when considering the total UK population size is approximately 67 million, however, among the food items imported are condiments including soy sauce which are consumed widely and in small serving sizes.

The variability and uncertainties associated with the NLGV food group had the greatest impact on the results, when comparing the difference made by implementing controls. NLGV was shown to have the highest impact on estimated annual activity ingested per adult of the 30 food groups and contributed the most to the overall dietary activity ingested. This is because the NLGV food group included a few measurements of Koshiabura with activity concentrations of up to 12,000 Bq/kg total radiocaesium. By including these sample with high activity concentrations, the assessment predicted a rare but possible occurrence of such values in imported NLGV. Therefore, the results were skewed towards a probability distribution with occasional but very high values at the tail end of the distribution. However, as these samples were from 2013 it may represent a cautious overestimation of dose within this food group, and as discussed in the main report, Koshiabura and other wild plants are not a commodity for import at the present time but were included to a give a cautious estimate of the possible dose if these were to be imported to the UK.

Saltwater fish uncertainty was identified as the second greatest impact on the results and had the second highest food group activity ingested per year for an adult and second highest food group contributor to the overall dietary activity ingested.

The probabilistic assessment also included some rare but high values of activity up to 25% over those that had been recorded to take into account that not all food samples had been tested, and the maximum values might have been missed by the sampling scheme (refer to the method section). Although inclusion of higher maximum values is rare, it resulted in the mean activity concentrations being increased by these unlikely values. This explains the difference in additional incremental dose between the deterministic and stochastic methods with component D accounting for the probability of activity concentrations not observed in the actual measurements. Overall, the probabilistic method of component D is believed to be the more realistic assessment because it takes into account consumption that is restricted by availability of imports and incorporates a more detailed and refined demographic profiles and consumption patterns.

5.1 Uncertainty and variability

The uncertainty and variability within the report have been considered and quantified (where possible) when developing this risk assessment. Table 10 shows the input parameters, and which parameters are associated with quantified variability and uncertainty. Calculated values such as annual distributions will not add to the uncertainty and variability, but the source data used in the model such as sampled data (activity concentrations measured in the food groups; consumption rates for each of the UK population groups for each food group; and the weight of imports) will contain variability and may also contribute to uncertainties if there are data gaps. The inherent variability in the radiocaesium data, import data and consumption data is taken into account by using the range and spread and probability distributions.

As well as variability in the radiocaesium data there is some degree of uncertainty around the limit of detection. Ninety per cent of samples were below the limit of detection. These are all above zero but below the various limits of detection leading to a systematic bias to the upper limit of detection. The large amount of data included in this analysis has reduced this uncertainty but not eliminated it completely. The use of total radiocaesium activity concentration in this model and assuming a 1:1 Cs-134 : Cs-137 ratio has added to the uncertainty and probably overestimated the CED as it is unlikely that Cs-134 will be present in such a high ratio.

Other factors adding to uncertainties are aggregation errors such as the grouping method used to categorise the various food groups and matching the population age groups to the available consumption data and ICRP reference ages.

Rounding consumption values of less than 1kg to whole numbers will lead to uncertainty by overestimating the CED.

There is also uncertainty in the way professional judgement was used to decide on classification of certain foods types within a food group and inherent uncertainty in consumption data, this is discussed in the main report.

Table 10: Input Parameters.

Description	Symbol	Distribution	Units	V/U	Reference
Weight of food group 1 to 30 imported per year	N_import_{food}	Pert	kg/yr	Uncertainty around the mean of the distribution	UK trade info
Proportion of consumers of imported food group by age interval	-	N/A	%	-	ONS
Annual weight of consumption of food group 1 to 30 by one person by age interval	$N\_consume_{food,age}$	Lognormal	kg/yr	Variability in individual consumption and uncertainty due to short sampling window	NDNS
Mean number of consumers of imported food group per year	$N\_exposed_{food,age}$	N/A	People/yr	-	Calculated value
Activity concentration by food group 1 to 30	$N\_activity_{food}$	*	Bq/yr	Variability in annual mean A/C and uncertainty in LOD	Japanese MAFF
Annual activity concentration consumed of food group per person by age interval	$N\_dose_{C,food,age}$	Lognormal	Bq/yr	-	Calculated value
Annual distribution of dose consumed by consumers exposed (with controls >100)	$N\_controls_{age}$	Discrete	Bq/yr	-	Calculated value
Annual distribution of dose consumed by consumers exposed (with no controls)	$N\_nocontrols_{age}$	Discrete	Bq/yr	-	Calculated value
Difference in the distribution of dose consumed by consumers exposed	$N\_difference_{age}$	Discrete	Bq/yr	-	Calculated value

In conclusion, the results from component D (supplementing the main report) show that the estimated CED to the representative person (RP) (adult) is 1.6x10^{-3} mSv/year and the probabilistic estimate of the additional (incremental) dose if restrictions are lifted is 5x10^{-4} mSv/year. This confirms the findings of the main report by providing additional evidence that the CED to the RP is less than 0.02 mSv/year and probably 10 times lower than the 1.6x10^{-2} mSv/year reported in the main risk assessment. This dose is negligible when compared to 1 mSv/year, the lower end of the 1 – 20 mSv/year ICRP reference levels for existing exposures and, although it would represent an increased amount of radiocaesium activity consumed, would not cause any significant radiological risk to the UK population.

5.2 Assumptions

Several assumptions were made during the risk assessment process, these are listed as follows:

- It was assumed that consumers would source their entire diet from Japanese imports, where foods were sufficiently available (this could be limited due to the finite weight of food imported). Therefore, the import production factor (IPF) (used in component A) has not been applied in the probabilistic component D and it was assumed that all of an individual's diet would be comprised of Japanese imports. This may be unrealistic and lead to an overestimation of the estimated dose from component D for an individual. If there were more realistic estimates of the share of the diet from imported food, the imported food would be consumed at a lower level by more people and would lead to an increase in the number exposed. However, the national annual dose would remain unchanged as the reduced average dose would be accompanied by an increase in the number exposed.
- Assumptions were made where consumption data were unavailable (detailed in Table 5) using data available from other age groups.
    - Adults (greater than 70 years) consumed similar amounts to those between 16 and 70.

    - Where data were absent for any age group, the older age group was used. Where data were absent for women of childbearing age, adult data were used.
- It was assumed that the age proportions of consumers were the same as the proportion of the age in the UK population using point values.
- When applying the dose coefficients for the dose calculation a ratio of Cs-134 and Cs-137 was assumed to be 1:1 to reflect the pattern seen in the data. This is recognised to be a cautious approach because Cs-134 has a higher dose coefficient and hence produces a higher dose but it is likely that Cs-134 is present in a lower ratio than Cs1-37. It was agreed by two radiological risk assessors that this approach was most representative of the data provided by the MHLW monitoring data. This is largely due to the FSA's method for data processing of the LOD values (see Section 3.3.3.1).
- The activity concentrations in food groups from 2013 - 2020 are assumed to be representative of future levels, however, the activity concentrations of radiocaesium are likely to reduce in future years due to natural decay process meaning that the use of data from 2013 - 2020 will be an overestimate of future risk.
- Imported foods from Japan vary from year to year and the assessment uses previous years' import data. Results from the assessment could be under- or over-estimates if the amount of food imported were to increase or decrease significantly in future years or the pattern of food groups imported change.
- It is assumed that activity concentrations are distributed uniformly within the food or beverages.