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VIEWPOINT

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Fukushima Wildlife Dose Reconstruction Signals Ecological Consequences

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The complexity of the situations surrounding the Fukushima nuclear accident has resulted in considerable uncertainty about the potential environmental consequences. Conjectures appear in News sections of prominent journals,[1] but no environmental risk calculations have been published to ascertain the potential for ecological damage. We reconstructed the radiological dose received by forest and marine biota during the first 30 days of the accident, and comparison with benchmark values considered to be safe for ecosystems or wildlife groups allowed us to assess the ecological risk.

Calculations for forest ecosystems were based on soil samples collected from the zone of greatest atmospheric deposition (Iitate Village area; located 25−45 km northwest of the Fukushima site). Samples were measured on March 31, 2011 under the lead of University of Kyoto, assayed, and posted online.[2] Soil activity concentrations for ^{134}Cs (62 400 Becquerel kg^{-1}) and ^{137}Cs (72 900 Bq kg^{-1}) were considered constant for the 30-day calculations. Short-lived ^{131}I ($T_{1/2}$ = 8 d), was measured in soils at 108 000 Bq kg^{-1} two weeks after the initial deposition of March 15, with back-calculations to the date of deposition estimated at 430 000 Bq kg^{-1}.

Whole-body activity concentrations, $C_{r,o}$, for radionuclide r and organism o, (Bq kg^{-1} fresh weight) were estimated from the soil activity concentrations using default equilibrium concentration ratios, $CR_{r,o}$ (kg dry weight per kg fresh weight with $CR_{r,o} = (C_{r,o})/(C_r^{soil})$ provided in the ERICA[3] tool. Species- and radionuclide-specific dose conversion coefficients ($DCC_{r,o}$; μGy h^{-1} per Bq kg^{-1} fresh weight), tabulated in this same tool,[3] were used to estimate the dose rate absorbed by forest biota. External irradiation from the contaminated environment, as well as radionuclides incorporated within the organisms (from such pathways as root uptake by plants, ingestion and inhalation of radioactive materials by animals) were summed to produce a combined dose rate. All estimations for forest biota were performed under the assumption of no additional atmospheric releases after March 15.

Based on exposure to ^{131}I, ^{134}Cs, and ^{137}Cs, dose rates (mGy d^{-1}) over the first 30 days postaccident were approximately 1 for plants, 1.5 for birds, 2.3 for soil invertebrates, and 3.9 for forest rodents. Other radioisotopes were also measured in the soils ($^{129\,m}$Te, ^{129}Te, ^{132}Te, ^{136}Cs, ^{132}I), and when these isotopes are included in the calculations the total dose rate estimates for the forest biota ranged from 2 to 6 mGy d^{-1}. These values are 10 to 100 times greater than dose rates considered safe for terrestrial ecosystems[4] (Figure 1). They indicate that cytogenetic damages will certainly be measurable; however, changes in reproduction in plants and animals (considered to be the most sensitive endpoint affecting populations) will be difficult to discern against high natural variability.

The lack of a more severe impact to the forest ecosystem is partially due to the accident occurring in late winter, unlike the April 26 accident at Chernobyl. Had the Fukushima accident occurred in midspring, radiosensitive young of many species would have been exposed. The delay in reproduction and rapid decay of ^{131}I will result in bird eggs receiving some 20 mGy d^{-1}, rather than ∼70 mGy d^{-1} if the accident had occurred one month later. However, due to the uncertainties in these initial calculations, a survey of egg hatchability and survival of newborn mammals should be implemented. Moreover, the Fukushima forest zone will be a relevant observatory site for studying adaptation processes to chronic exposures that are 10 to 100× background, a key issue that has yet to be solved from the Chernobyl accident.[5]

In contrast to the forest ecosystem, our analyses indicate that more severe impacts are likely for the coastal ecosystem adjacent to the Fukushima nuclear plant. The marine calculations were performed in a similar manner, except that to include dose from external irradiation by contaminated marine sediments, radionuclide-specific distribution coefficients (K_d; from ERICA[3])

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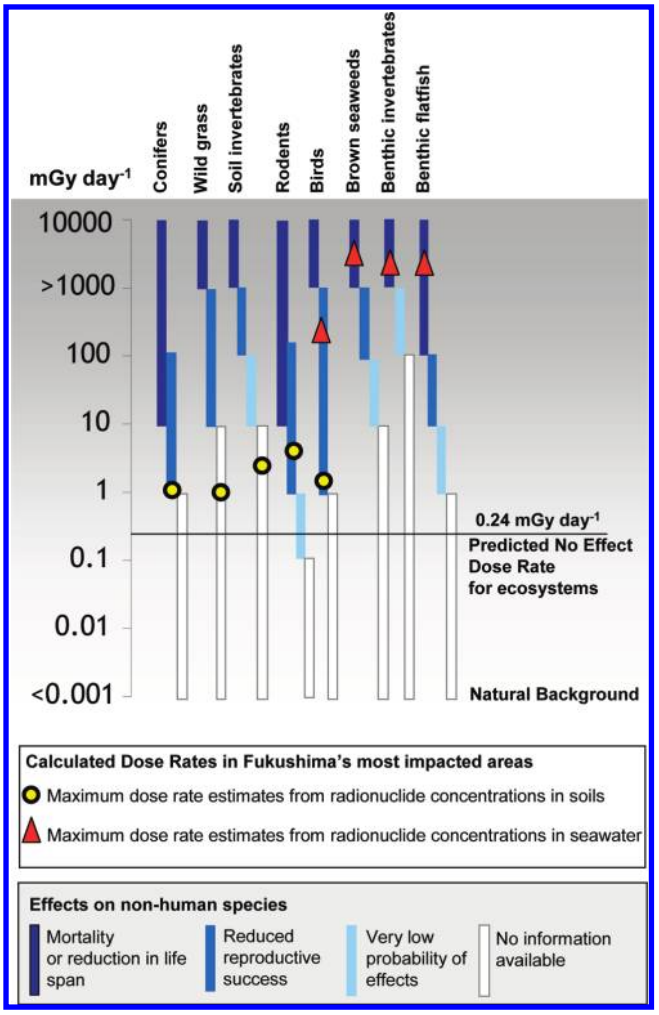

Figure 1. Scale of potential effects in marine wildlife groups and forest biota based on data from ref 4 with indication of dose rates from exposure to ^{131}I, ^{134}Cs, and ^{137}Cs during the first month after the Fukushima accident.

were used to estimate activity concentrations in marine sediments from the activity concentrations reported in seawater, where $K_d^r = (C_r^{sed})/(C_r^{wat})$ (in L kg^{-1}). Seawater concentrations of ^{131}I reached 180 000 Bq L^{-1} on March 30, with an associated 47 000 Bq L^{-1} of ^{137}Cs (measured 330 m offshore). Activity concentrations decreased rapidly with distance due to very high dilution in the seawater (ca. 1/1000, 30 km offshore), and with time: ^{137}Cs decreased by a factor 30 within two weeks and ^{131}I decreased by a factor of 200.

Nonetheless, maximum dose rates for ^{131}I, ^{134}Cs, and ^{137}Cs ranged from 210 to 4600 mGy d^{-1}; the lowest for marine birds and the highest for macroalgae, with intermediate values of 2600 mGy d^{-1} for benthic biota—fish, molluscs, crustaceans. At such high dose rates, marked reproductive effects, and even mortality for the most radiosensitive taxa are predicted for all marine wildlife groups whose life history characteristics confine them to the near-field, contaminant release area. The high dose rates estimated by the models indicate that a field survey is urgently needed to verify radionuclide distributions within the coastal zone, to quantify the role of trophic transfers within food webs, and to determine the extent to which marine sediments will act as a secondary source of radionuclide uptake by biota.[1] All estimations were performed under the assumption of no additional marine releases after the end of March. Actual releases of unknown quantity appear to have continued past this date, thus our dose estimates may be low. Our estimates of dose rates are also under-predictions because they are based on measured data for only a few radioisotopes among the suite of possible radionuclides that composed the actual aquatic source terms (e.g., ^{58}Co, ^{95}Zr, ^{99}Mo, $^{99\ m}$Tc, ^{105}Ru, ^{106}Ru, $^{129\ m}$Te, ^{129}Te, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{132}I, ^{140}Ba, ^{140}La).

For any postaccident ecological impact assessment of the Fukushima accident, great care will be needed in the quantification of radiation dose to biota, consideration of confounding effects (e.g., from the tsunami, complex mixture of toxicants), and careful sampling designs if meaningful results are to be obtained. The contaminated forests and marine ecosystems at Fukushima will be important long-term research sites for studying multigenerational effects from chronic exposures to low doses of radiation; still a controversial topic—25 years after Chernobyl.[5]

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