Assessment of Environmental Impacts from Ionising Radiation following the Fukushima Accident – A review of published works

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16TH INTERNATIONAL CONFERENCE
ON CHEMISTRY AND THE ENVIRONMENT, ICCE, Oslo.
20 June 2017

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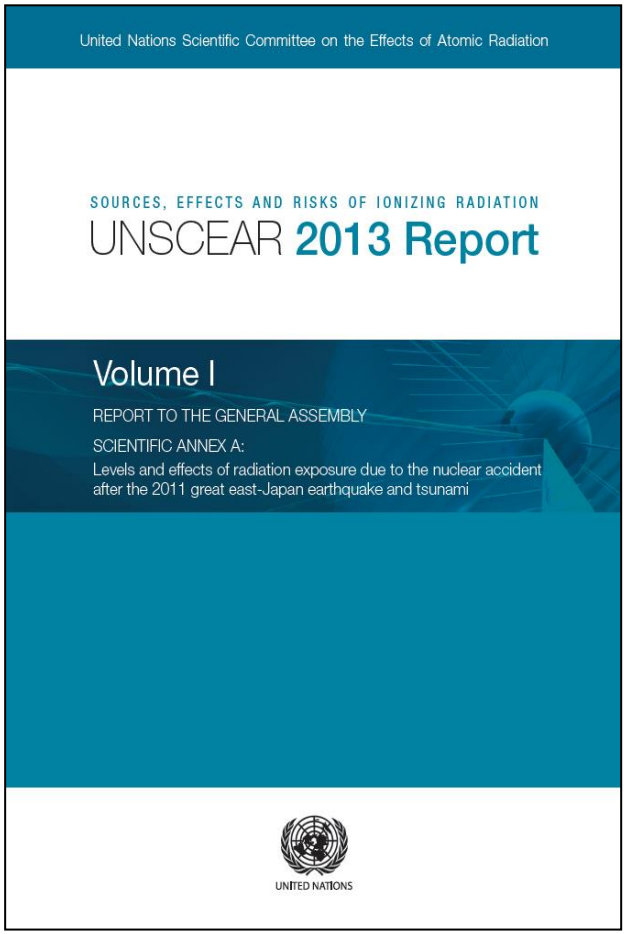
UNSCEAR-2013 Methodology-I

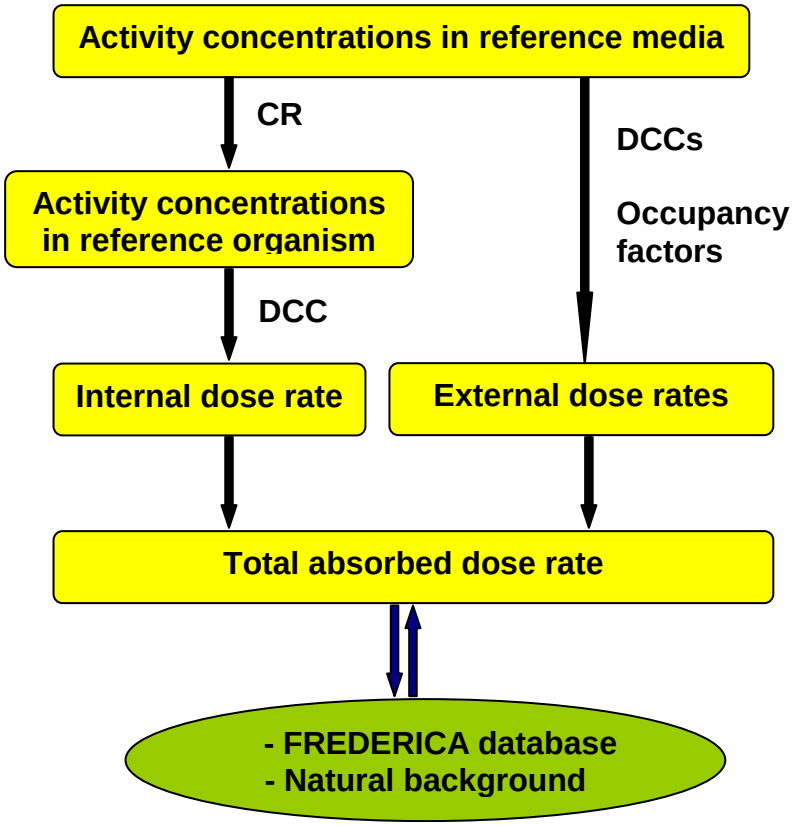
- **The generic methodology has been developed based around Reference organisms and the ERICA integrated Approach**

Table 1. List of organisms selected by UNSCEAR (2008) for assessing exposures

Earthworm/soil invertebrate	Rat/burrowing mammal	Bee/above ground invertebrate
Wildgrass/grasses,herbs and crops	Pine tree/tree	Deer/herbivorous mammal
Duck/bird	Frog/amphibian	Brown Seaweed/macroalgae
Trout/pelagic fish	Flatfish/benthic fish	Crab/crustacean

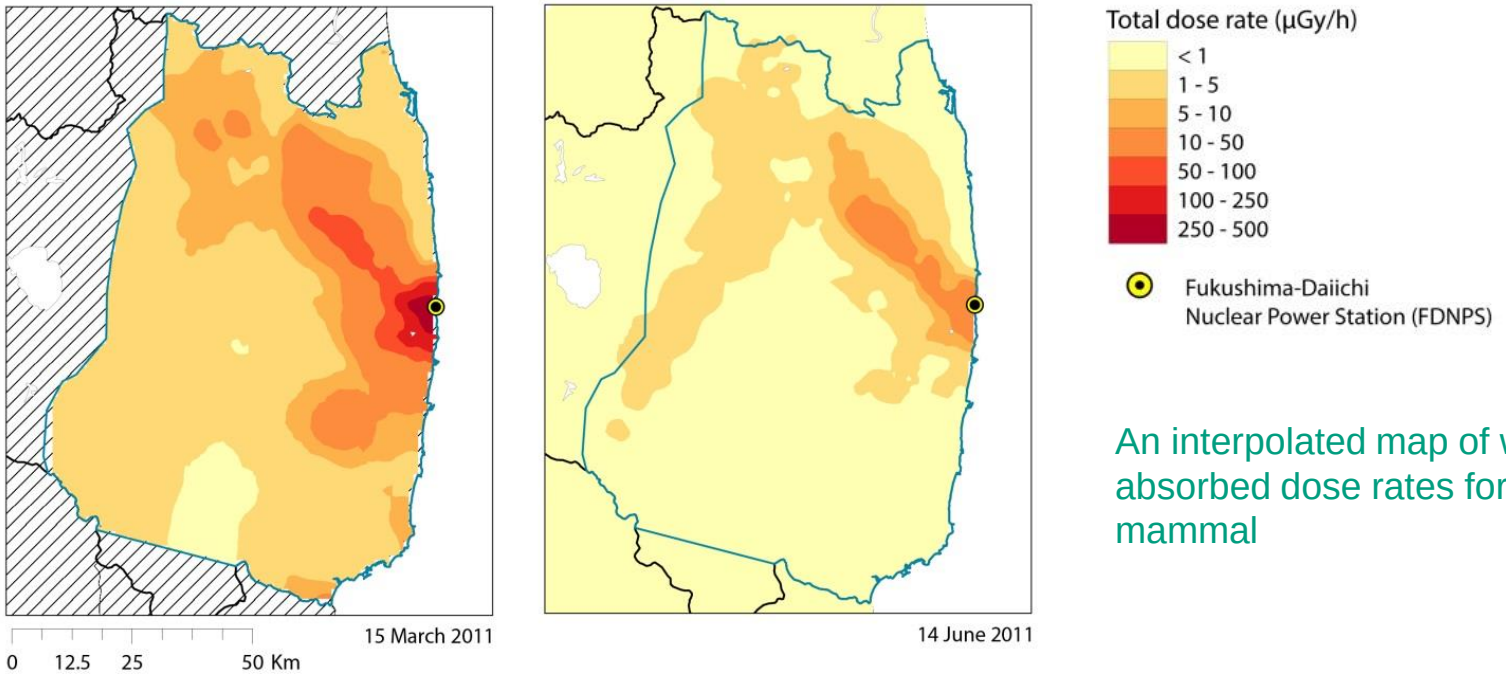


Components within the UNSCEAR assessment



- Modelling transfer through the environment
- Estimating doses to biota from internal and external distributions of radionuclides
- Establishing the significance of the dose-rates received by organisms

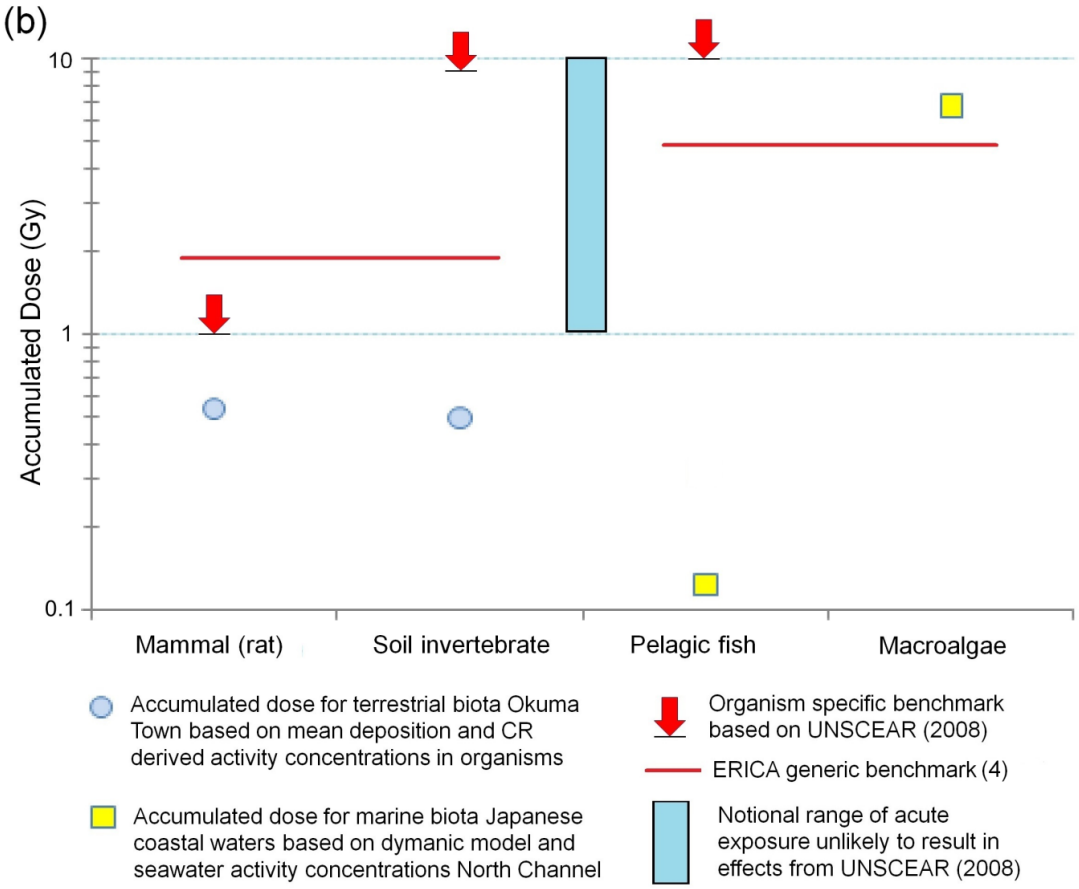
Dose rates in terrestrial ecosystems



An interpolated map of weighted absorbed dose rates for a large mammal

- These dose rates do not include some of the very short-lived radionuclides that were present in fallout from the middle of March 2011. Initial analyses suggest that the primary radionuclides contributing to dose at this time were ^{132}I and ^{132}Te.
- Dose rates to organisms are augmented considerably by including these short-lived radionuclides. For soil dwelling organisms (mammal/rat and soil invertebrate) dose rates, potentially approached 1 mGy/h for a short duration.

Cumulative dose during the first 90 days after the accident in terms of acute exposure benchmarks.



Environmental Science & Technology Letters
Letter
pubs.acs.org/journal/estlcu

Assessment of Fukushima-Derived Radiation Doses and Effects on Wildlife in Japan

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Conclusions from UNSCEAR 2013 Report

- **Intermediate Phase after the accident** : Dose Rates for biota from terrestrial ecosystems may have exceeded the benchmark level of 100 µGy/h for limited periods. However, effects on populations unlikely and expected to be only temporary, because of the short duration of the high exposure levels. Changes in biomarkers for certain biota , especially mammals , cannot be excluded. Calculated doses to marine biota indicate no effect , other than possibly transiently very close to discharge points.

- **Late phase after the accident** : Potential risk for individuals of certain species , especially mammals, may exist in areas with relatively high deposition . Nevertheless, population effects for terrestrial biota are considered unlikely. Estimated exposures for both marine and freshwater biota fall well below the limits where such effects are considered likely.

- The possibility of effects on biota are geographically limited. In areas outside the most contaminated areas, the potential for (population) effects on biota are considered negligible.

REVIEW OF DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT - I

- Exposures derived for non-human biota in recent studies [e.g. F2, K10] generally corresponded closely to the estimates made in the 2013 Fukushima report.
- An exception possibly existed for the marine environment where elevated concentrations in benthic marine fish were found to persist [S4].

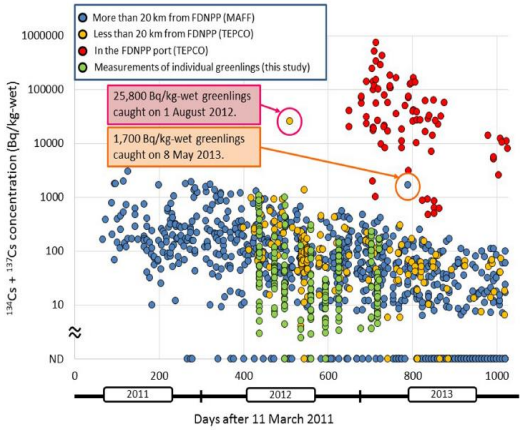


Figure 2 | Temporal trends of radiocesium concentrations ($^{134}Cs + ^{137}Cs$) for greenlings caught within and more than 20 km from the Fukushima Daiichi Nuclear Power Plant (FDNPP) port are shown. Tokyo Electric Power Corporation (TEPCO) has been monitoring marine products within 20 km of the FDNPP since April 2012.

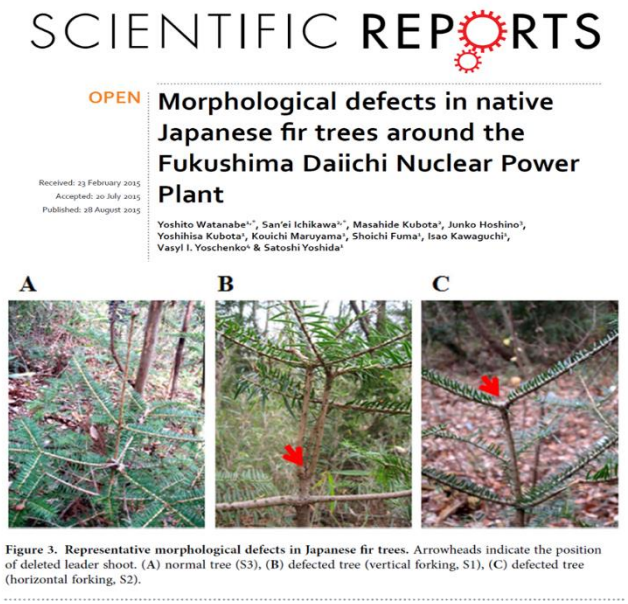
F2: Fujiwara, K., T. Takahashi, P. Nguyen et al. Uptake and retention of radio-caesium in earthworms cultured in soil contaminated by the Fukushima nuclear power plant accident. J Environ Radioact 139: 135-139 (2015).

K10 : Kubota, Y., H. Takahashi, Y. Watanabe et al. Estimation of absorbed radiation dose rates in wild rodents inhabiting a site severely contaminated by the Fukushima Dai-ichi nuclear power plant accident. J Environ Radioact 142: 124-131 (2015).

S4 : Shigenobu, Y., K. Fujimoto, D. Ambe et al. Radiocesium contamination of greenlings (Hexagrammos otakii) off the coast of Fukushima. Sci Rep 4: 6851 (2014).

REVIEW OF DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT - II

- Morphological abnormalities observed in some but not other studies.
  - Matsushima et al. [2015] observed no clear abnormalities in the gonadal tissues of frogs, collected from sites with elevated radionuclide levels



SCIENTIFIC REPORTS

OPEN

Morphological defects in native Japanese fir trees around the Fukushima Daiichi Nuclear Power Plant

Received: 23 February 2015
Accepted: 20 July 2015
Published: 28 August 2015

Yoshito Watanabe[1,*], San'ei Ichikawa[1,*], Masahide Kubota[1], Junko Hoshino[1], Yoshihisa Kubota[1], Kouichi Maruyama[1], Shoichi Fuma[1], Isao Kawaguchi[1], Vasyl I. Yoschenko[1] & Satoshi Yoshida[1]

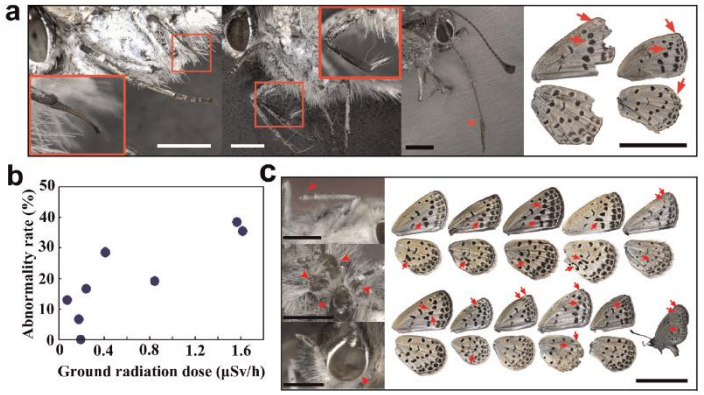
Figure 3. Representative morphological defects in Japanese fir trees. Arrowheads indicate the position of deleted leader shoot. (A) normal tree (S3), (B) defected tree (vertical forking, S1), (C) defected tree (horizontal forking, S2).

- Watanabe et al. [2015] showed that Japanese fir tree populations near FDNPS exhibit a significantly increased number of morphological defects, compared to a control population far from FDNPS.
- Accumulated doses to vegetation in areas with relatively high deposition densities were estimated for the 2013 report. The estimated doses for trees were similar to those at which disturbances in growth, reproduction and morphology of conifers had been observed following the Chernobyl accident.

Matsushima, N., S. Ihara, M. Takase et al. Assessment of radiocesium contamination in frogs 18 months after the Fukushima Daiichi nuclear disaster. Sci Rep 5: 9712 (2015).

REVIEW OF DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT - III

- Further details have been published which add support to some original studies where substantial (population relevant) effects have been observed in the field :
  - Several publications by Mousseau and Møller [e.g. M10] provided additional information on their original studies by, inter alia, presenting more details on the statistical models applied and dismissing the influence of certain confounding factors, such as the effect of the tsunami itself.
  - Several publications [e.g. H7] provided a comprehensive defence of an earlier publication cited in the 2013 Fukushima report concerning the impacts of radionuclide releases on the Pale Grass Blue Butterfly.



a) Representative morphological abnormalities of the field-caught individuals.
(b) Scatter plot of ground radiation dose and abnormality rate of the field-caught adults.
(c) Representative abnormalities in the F1 generation.

M10 : Mousseau, T.A. and A.P. Moller. Genetic and ecological studies of animals in Chernobyl and Fukushima. J Hered 105(5): 704-709 (2014).
H7 : Hiyama, A., C. Nohara, W. Taira et al. The Fukushima nuclear accident and the pale grass blue butterfly: evaluating biological effects of long-term low-dose exposures. BMC Evol Biol 13: 168 (2013).

Journal of Environmental Radioactivity 169-170 (2017) 159–173

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

On the divergences in assessment of environmental impacts from ionising radiation following the Fukushima accident

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ARTICLE INFO

Article history:
Received 24 October 2016
Received in revised form
16 December 2016
Accepted 16 December 2016

Keywords:
Environmental radiological assessment
Fukushima

ABSTRACT

The accident at the Fukushima-Daiichi Nuclear Power Station on March 11, 2011, led to significant contamination of the surrounding terrestrial and marine environments. Whilst impacts on human health remain the primary concern in the aftermath of such an accident, recent years have seen a significant body of work conducted on the assessment of the accident's impacts on both the terrestrial and marine environment. Such assessments have been undertaken at various levels of biological organisation, for different species, using different methodologies and coming, in many cases, to divergent conclusions as to the effects of the accident on the environment. This article provides an overview of the work conducted in relation to the environmental impacts of the Fukushima accident, critically comparing and contrasting methodologies and results with a view towards finding reasons for discrepancies, should they indeed exist. Based on the outcomes of studies conducted to date, it would appear that in order to avoid the fractured and disparate conclusions drawn in the aftermath of previous accidents, radioactive contaminants and their effects can no longer simply be viewed in isolation with respect to the ecosystems these effects may impact. A combination of laboratory based and field studies with a focus on ecosystem functioning and effects could offer the best opportunities for coherence in the interpretation

UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation

DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT ON THE LEVELS AND EFFECTS OF RADIATION EXPOSURE DUE TO THE NUCLEAR ACCIDENT FOLLOWING THE GREAT EAST-JAPAN EARTHQUAKE AND TSUNAMI

paper to guide the Scientific Committee's future programme of work

SCIENCE FOR INFORMED DECISION-MAKING

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Summary and challenges ahead

- Apart from studies reporting severe populations impacts, UNSCEAR's 2013 assessment (on non-human biota) is broadly supported by much of the new information that has since been published.
- There are challenges in relation to how dose-rates are interpreted, and, in particular, whether it is sufficient to focus on endpoints that do not take full account of the complexity of ecosystem interactions.
  - under real conditions, exposure to stressors might potentially trigger non-linear changes in ecosystem function and structure that cannot be predicted from effects on individual organisms.
  - There remains a clear requirement for follow-up studies investigating the dose response at high levels of biological organization (e.g. population) that take due account of biota interactions within ecosystems ➔ **Ecosystem Approach**
  - Field studies, tailored to analyse the impacts of exposure to ionizing radiation on populations of wild organisms interacting under the conditions prevalent within contaminated ecosystems, are required. Such studies would need to be multidisciplinary, involving not just radio-ecologists and radiation specialists but also ecologists, population biologists and geneticists.