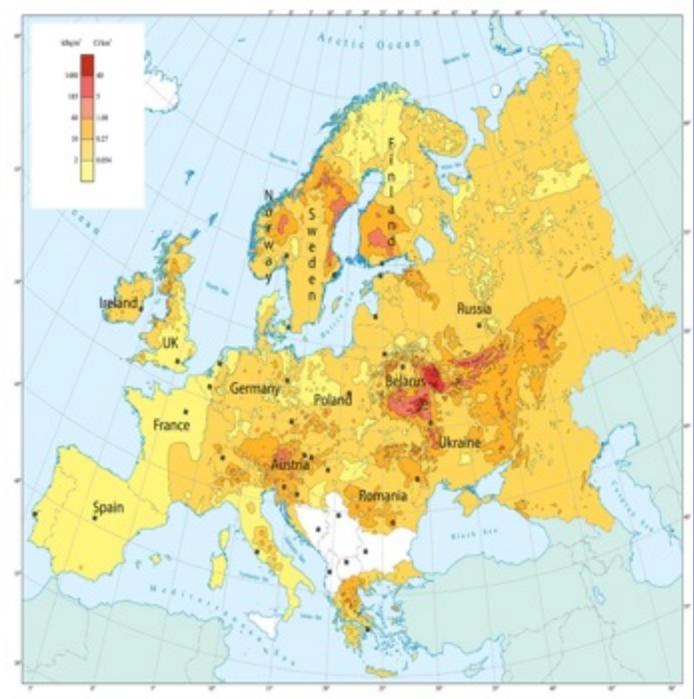
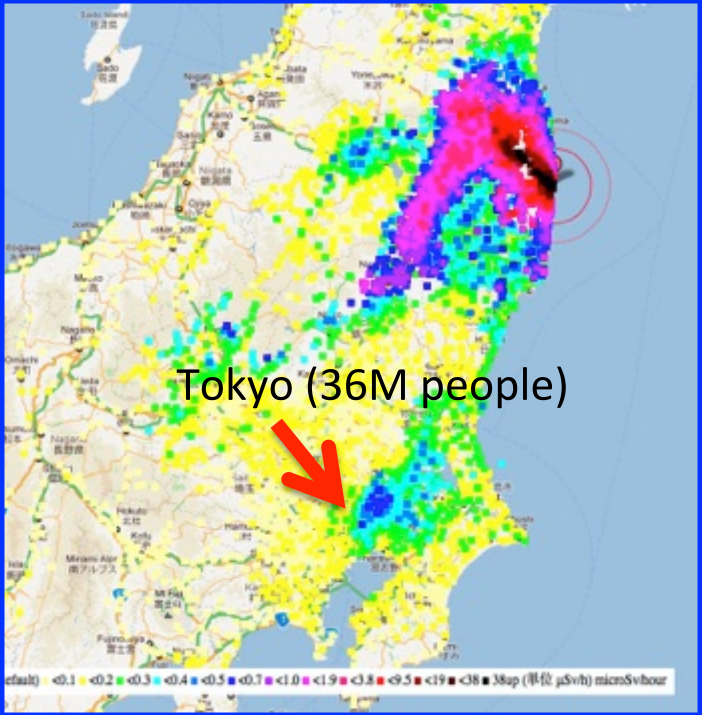
Chernobyl, Fukushima, and Other Hot Places:

Biological Consequences of Radiation in the Environment



Timothy A. Mousseau

University of South Carolina



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<u>A Special Thank You to:</u>
Anders P. Møller, G. Milinevsky, A. Bonisoli-Alquati, T. Mappes, B. Coull, H. Smith, J. Palms, M. Fitzpatrick, P. Nagarkartti, and K. Kawai

Why Study Chernobyl, & Now, Fukushima?

Chernobyl NPP 1986

Fukushima Daiichi NPP 2011

A Brief History of Nuclear Power Plants:

- There have been more than 600 commercial nuclear reactors
- Currently, there are about 430 reactors in 31 countries (100+ in the USA), 72 new reactors are under construction in 15 countries (39 in China; 5 in the USA)
- There have been three major nuclear accidents at commercial NPPs:

  1) Three Mile Island (1979)

  2) Chernobyl (1986)

  3) Fukushima (2011)

- There have been more that 33 serious incidents or accidents at Nuclear Power Plants since 1952
- Given that most NPP's are nearing the end of their design life-span, more accidents are expected…….

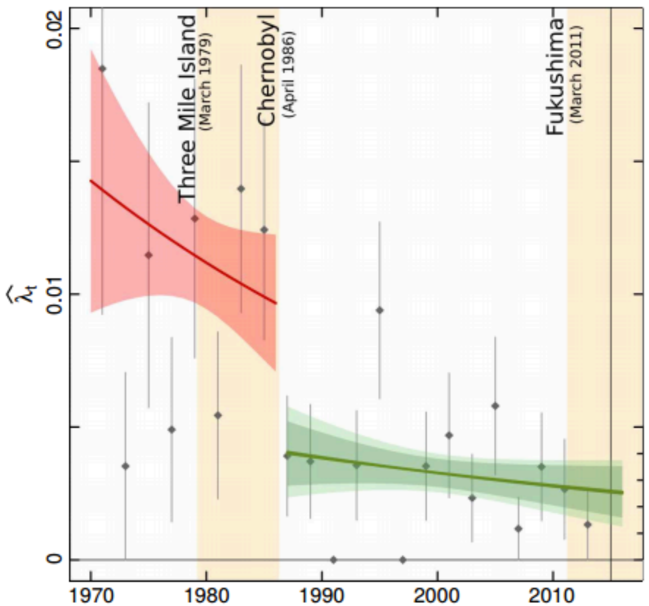
MIT Technology Review

Emerging Technology From the arXiv

April 17, 2015

The Chances of Another Chernobyl Before 2050? 50%, Say Safety Specialists

And there's a 50:50 chance of a Three Mile Island-scale disaster in the next 10 years, according to the largest statistical analysis of nuclear accidents ever undertaken.



The catastrophic disasters at Chernobyl and Fukushima are among the worst humankind has had to deal with. Both were the result of the inability of scientists and engineers to foresee how seemingly small problems can snowball into disasters of almost unimaginable scale.

Wheatley et al. 2015.

Enormous quantities of radioisotopes released as a part of normal operations.

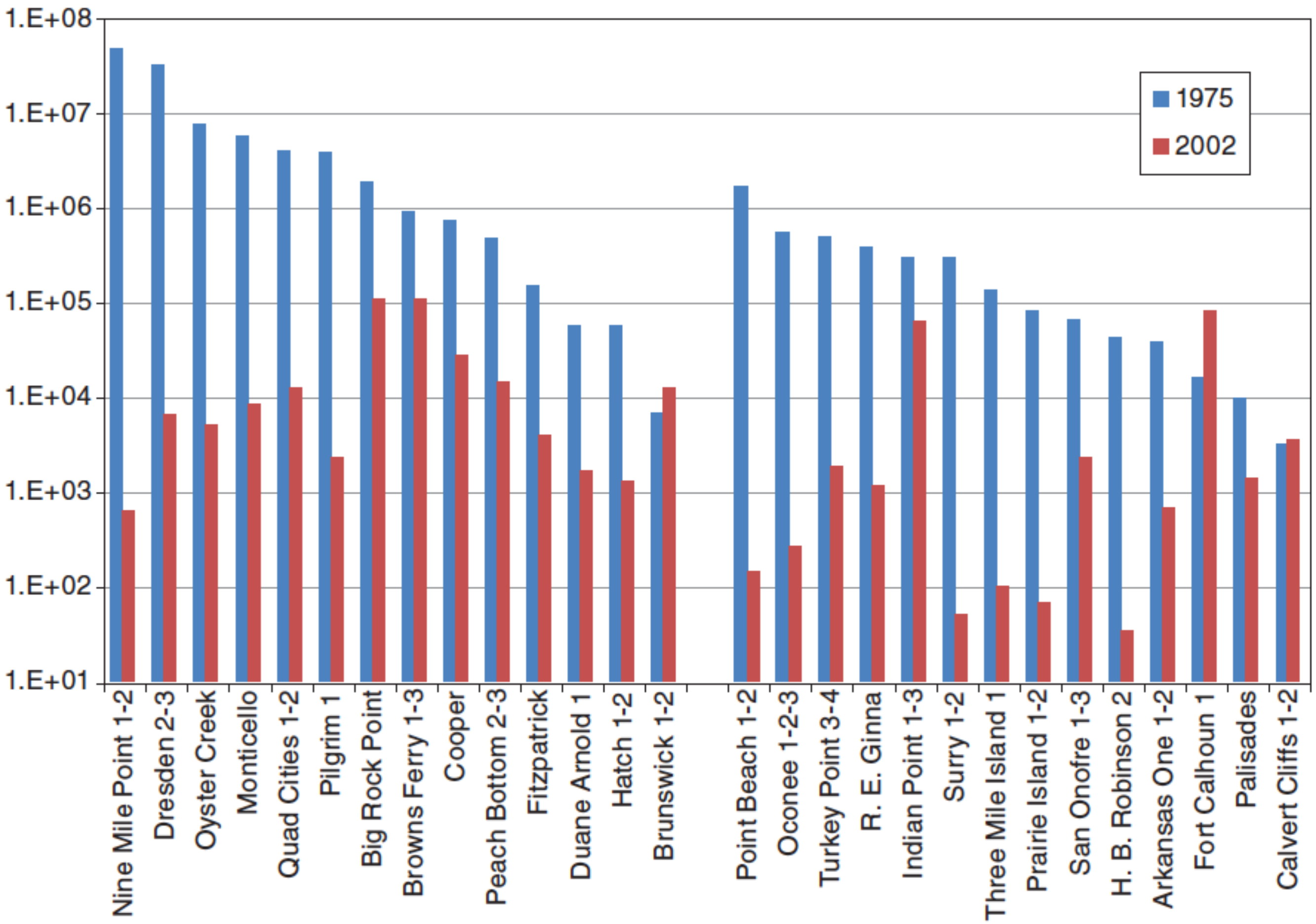


FIGURE 2.5 Comparison of atmospheric releases of noble gases for selected BWRs (left) and PWRs (right) in the United States. The units on the vertical scale are in gigabecquerels (GBq = 0.03 Ci). SOURCE: Data from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Burris, J.E.,..., T. Mousseau, et. al. 2012. Analysis of Cancer Risks in Populations Near Nuclear Facilties: Phase I. **Nuclear and Radiation Studies Board, The National Academies Press,** Washington, D.C., 412pp.

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New Developments Disclosed On Tritium Contamination At Vermont Yankee

Friday, 01/28/11 5:50pm

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John Dillon - Montpelier, Vt.

AP File Photo/Jason R. Henske
A Yankee spokesperson examines a monitoring well in March, 2010.

(Host) There are more developments on radioactive tritium contamination at the Vermont Yankee plant.

The plant disclosed today that another well is contaminated. And, as VPR's John Dillon reports, Yankee also confirmed that it couldn't test for tritium for two weeks.

(Dillon) An underground plume of water laced with tritium has been tracked by Yankee officials and government regulators since about this time last year.

The tritium was traced to leaking underground pipes that Yankee had not previously disclosed existed.

There hadn't been any additional discoveries for months. Until last week. That's when Yankee said it had found another well containing the radioactive isotope.

How many NPP's are leaking tritium? (>37 reported in the last few years)

Also, each plant has enormous quantities of spent fuel on site.

ELSEVIER

Journal of Environmental Radioactivity

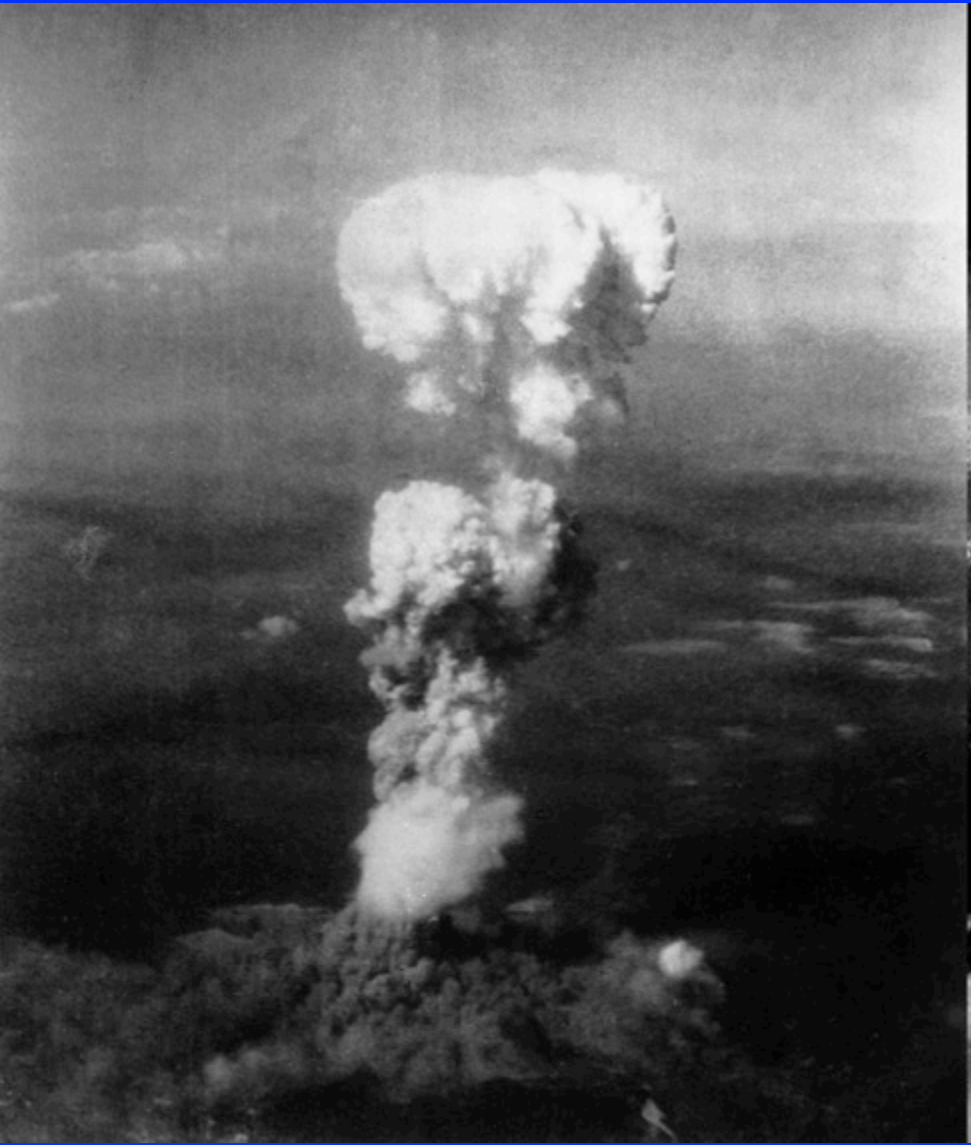
Volume 133, July 2014, Pages 10–17

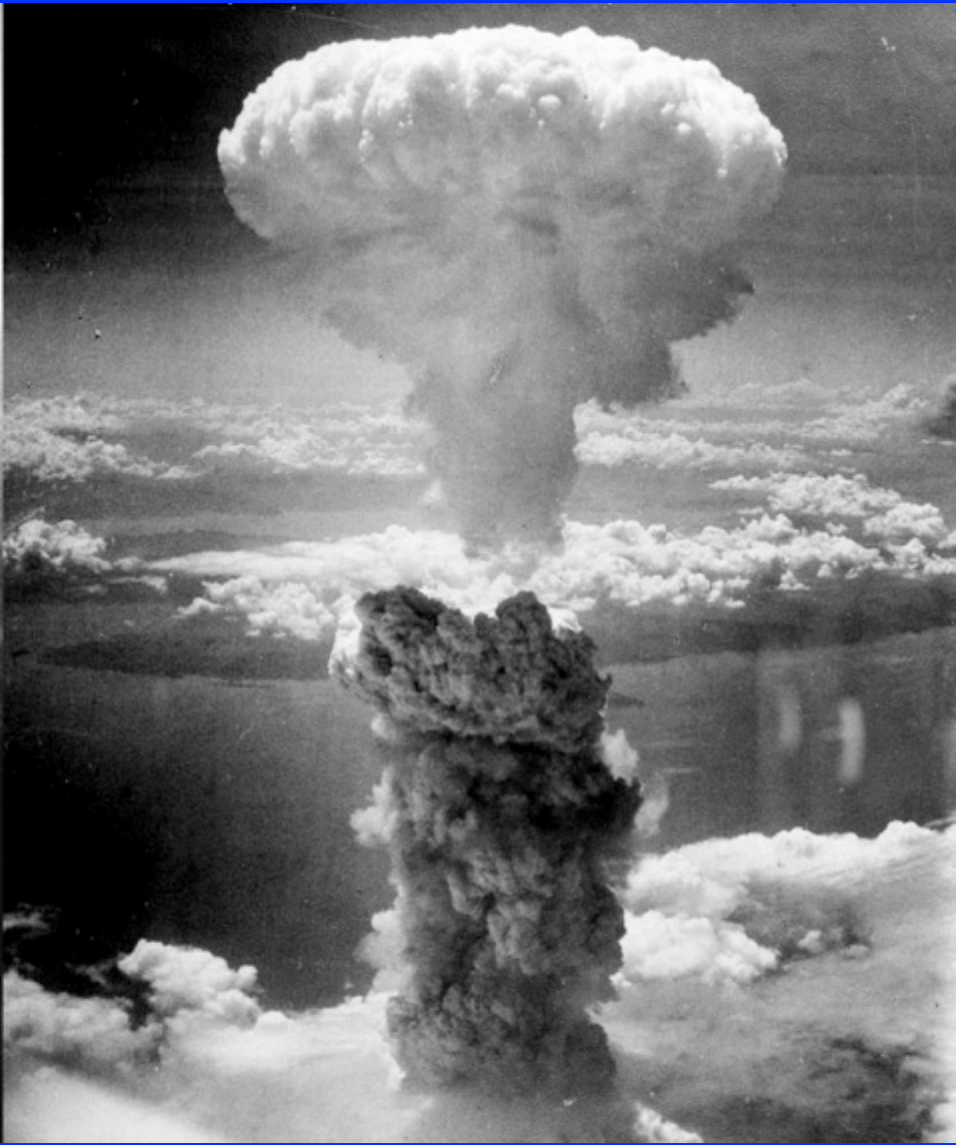
Environmental Radioactivity: Implications for Human and Environmental Health - International Symposium at Plymouth University, UK

A hypothesis to explain childhood cancers near nuclear power plants

Ian Fairlie

Atomic Bombs at Nagasaki and Hiroshima





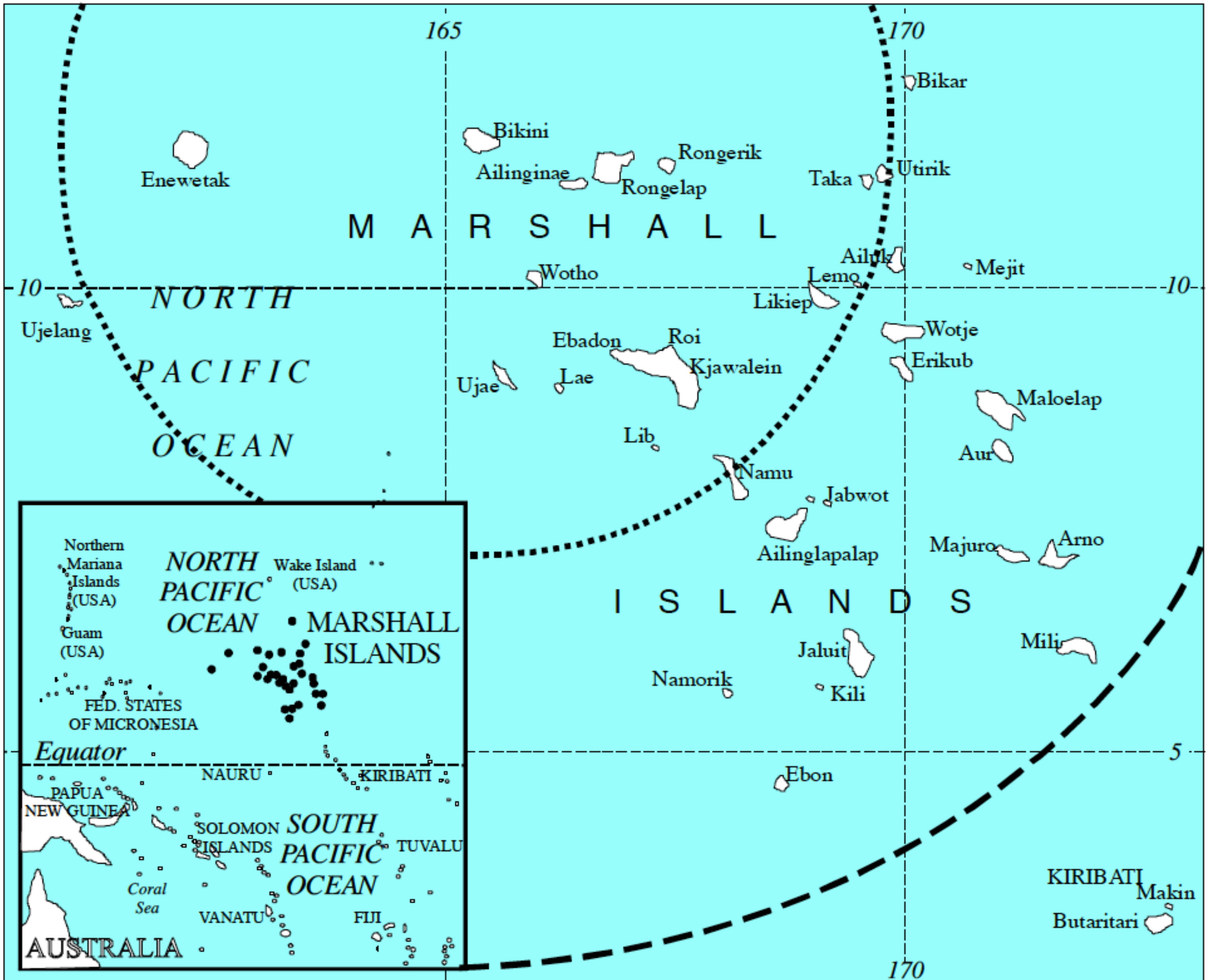


Figure XII. Bikini and Enewetak test sites.

The inner dotted circle indicates a distance of 500 km, the outer dashed circle 1,000 km from the test sites.

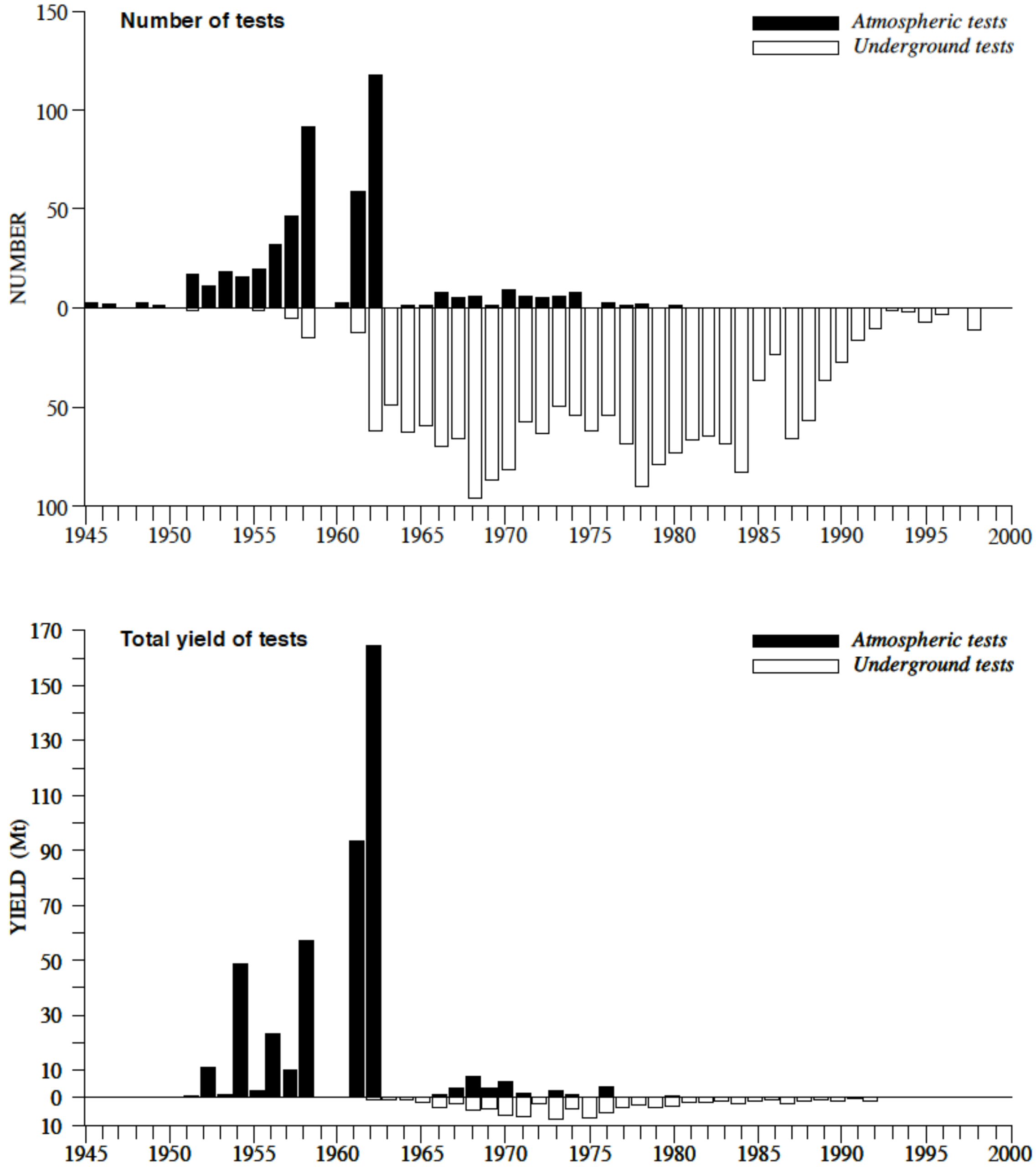


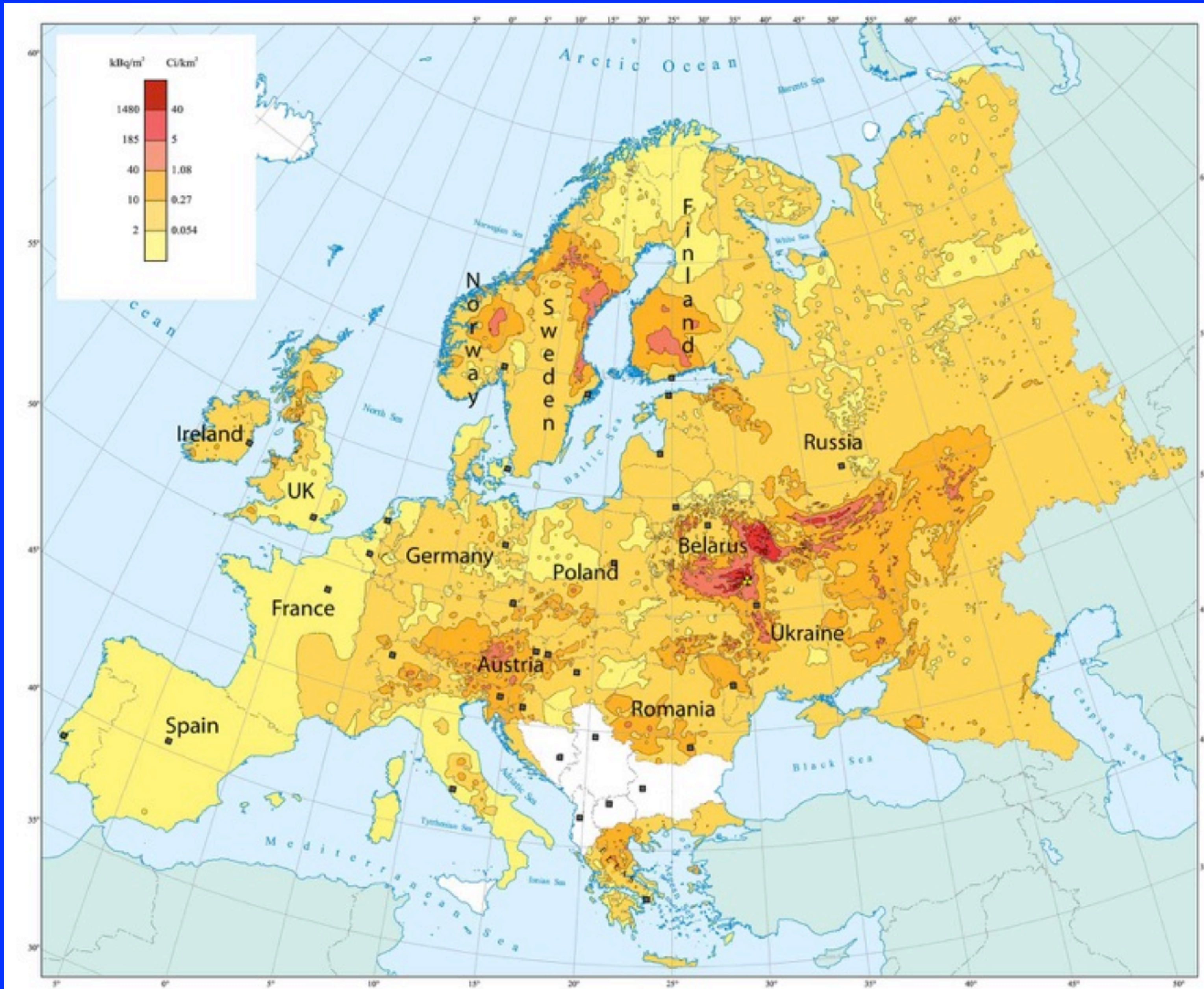
Figure I. Tests of nuclear weapons in the atmosphere and underground.

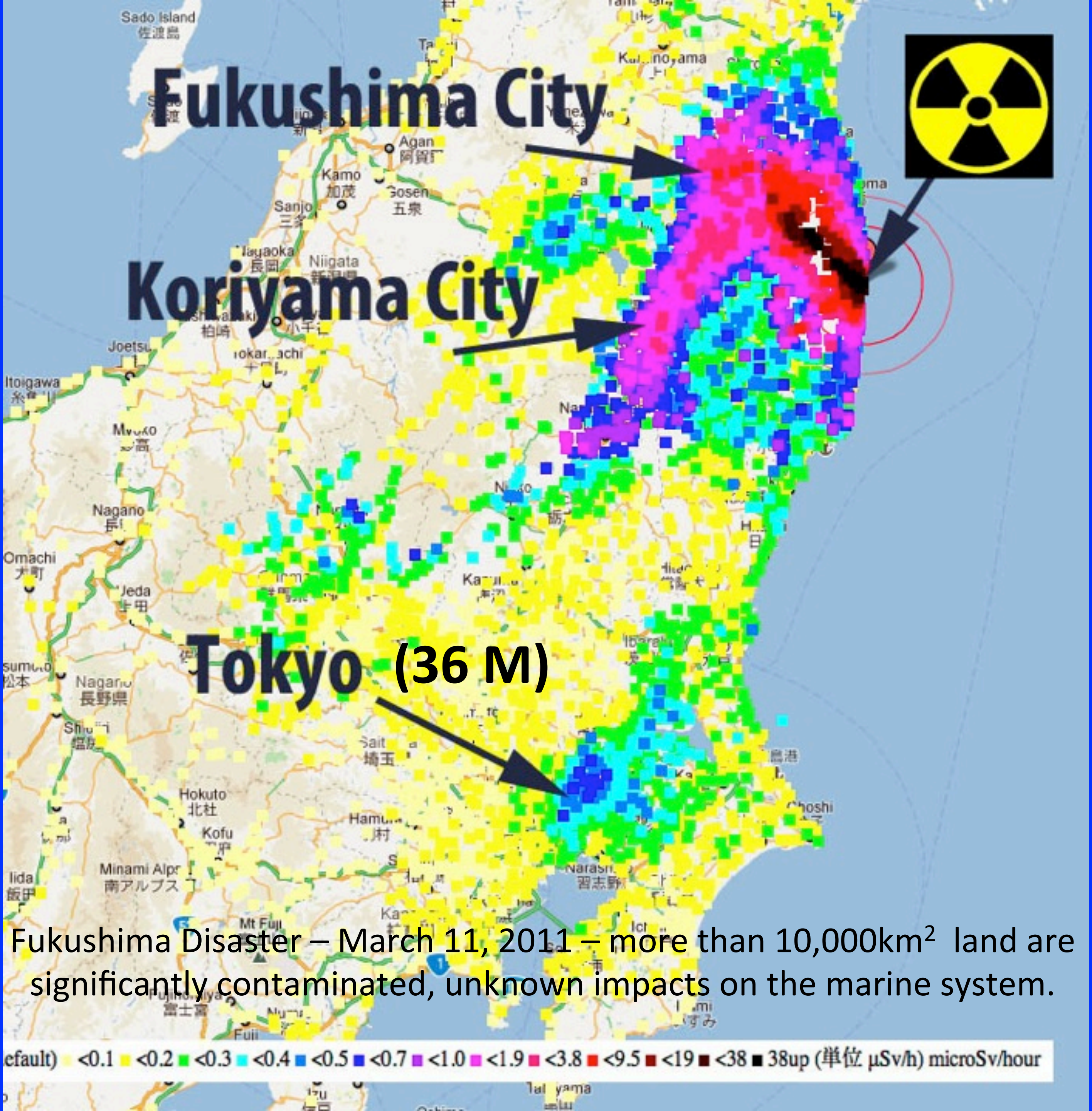
1193 atmospheric
1517 underground
2710 total

UNSCEAR 2000

Chernobyl disaster – April 26, 1986 – nuclear fire burned for 10 days

- More than 200,000 km^2 significantly contaminated land or abut half the land area of Japan





Fukushima Disaster – March 11, 2011 – more than 10,000km^2 land are significantly contaminated, unknown impacts on the marine system.

The UN Chernobyl Forum Report (IAEA, 2006: p137):

". . . the populations of many plants and animals have expanded, and the present environmental conditions have had a positive impact on the biota in the Chernobyl Exclusion Zone."

Human morbidities primarily the result of psychological stress....

(and other environmental factors, e.g. smoking, alcohol)

UNSCEAR 2013

Report to the UN General Assembly – April 2014

4. Radiation exposures and effects on non-human biota

"Exposures of both marine and terrestrial non-human biota following the *[Fukushima]* accident were, in general, **too low for acute effects to be observed**……."

"(b) …..Any radiation effects would be restricted to a limited area where the deposition of radioactive material was greatest; beyond that area, **the potential for effects on biota is insignificant**."

Note: This report was released April, 2014, more than a year after several papers were published showing impacts to birds and insects.

IAEA ignores all the recent Chernobyl and Fukushima research!

IAEA

4.5. RADIOLOGICAL CONSEQUENCES FOR NON-HUMAN BIOTA

No observations of direct radiation induced effects in plants and animals have been reported although limited observational studies were conducted in the period immediately after the accident. There are limitations in the available methodologies for assessing radiological consequences but, based on previous experience and the levels of radionuclides present in the environment, it is unlikely that there would be any major radiological consequences for biota populations or ecosystems as a consequence of the accident.

The Fukushima Daiichi Accident

But….

- No rigorous, empirical scientific data in support of these statements.

- Ignored growing body of empirical data demonstrating injuries to individuals, populations, and the ecosystem resulting from these disasters.

Chernobyl Research Initiative

Chernobyl + Fukushima Research Initiative

- **Began in 2000 by T.A. Mousseau (South Carolina) and A.P.** Møller (France).
- **Research in Fukushima beginning July 2011**
- **Studies of natural populations of birds, insects, microbes, mammals, and plants.**
- **Studies of the Children of the Narodichesky region of Ukraine.**
- **More than 35 research expeditions to Chernobyl, and 14 expeditions to Fukushima.**
- **More than 80 scientific publications related to low-dose radiation effects (Most available at http://cricket.biol.sc.edu)**
- **We are *independent* evolutionary biologists; our primary interest is in documenting adaptation and impacts of elevated mutation rates on population processes. We are not activists.**

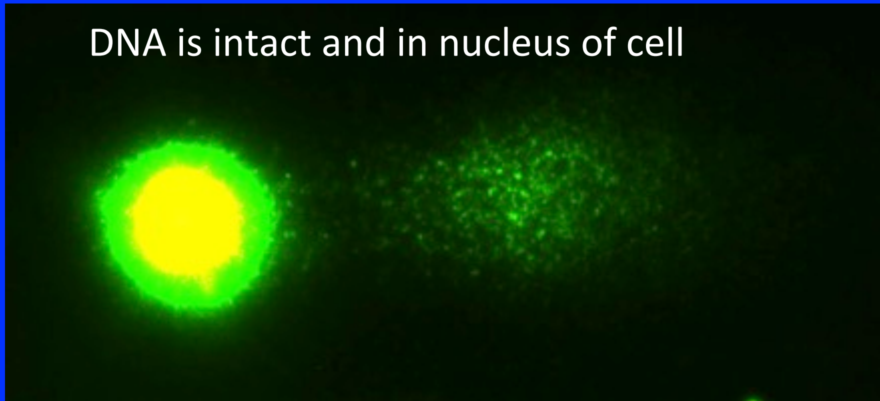
Hypotheses and questions addressed:

- Do low (and high) doses result in measureable, elevated mutation rates in natural populations?
- Are there phenotypic consequences to elevated mutation rates? (i.e. teratology).
- Are there fitness consequences to elevated mutation rates? (i.e. survival, reproduction, or disease).
- Is there evidence for adaptation?
- Are there effects on population abundances and biodiversity?
- Are there ecosystem consequences?

Estimating Mutation Rates

- Microsatellite DNA markers
- Comet assays for single and double strand break rates
- Micronuclei frequency
- Sperm morphological damage as a proxy for genetic damage
- Future: - Gene expression profiles
  - Whole genome scans for de novo mutation rate estimates.

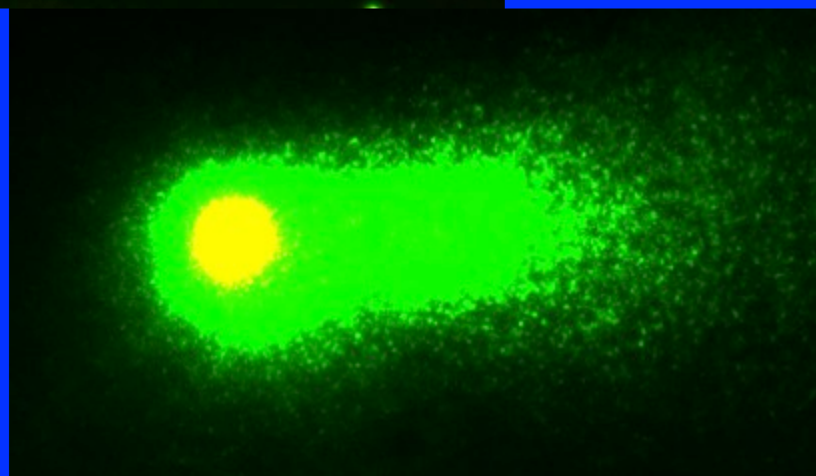
Comet assays of genetic damage to chromosomes



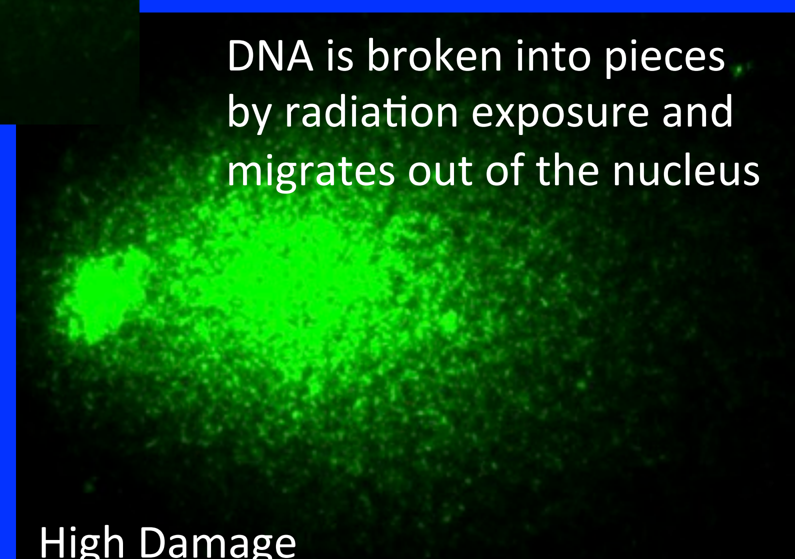
Low Damage

Grasshopper Hemolymph

(Chernobyl)



Medium Damage



Beasley, D.A.E., A. Bonisoli-Alquati, S.M. Welch, A. P. Møller, T.A. Mousseau. 2013. Effects of parental radiation exposure on developmental instability in grasshoppers (*Chorthippus albomarginatus*). **Journal of Evolutionary Biology**, in press.

SCIENTIFIC REPORTS

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SUBJECT AREAS:
ECOLOGICAL GENETICS
EVOLUTIONARY GENETICS

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Strong effects of ionizing radiation from Chernobyl on mutation rates

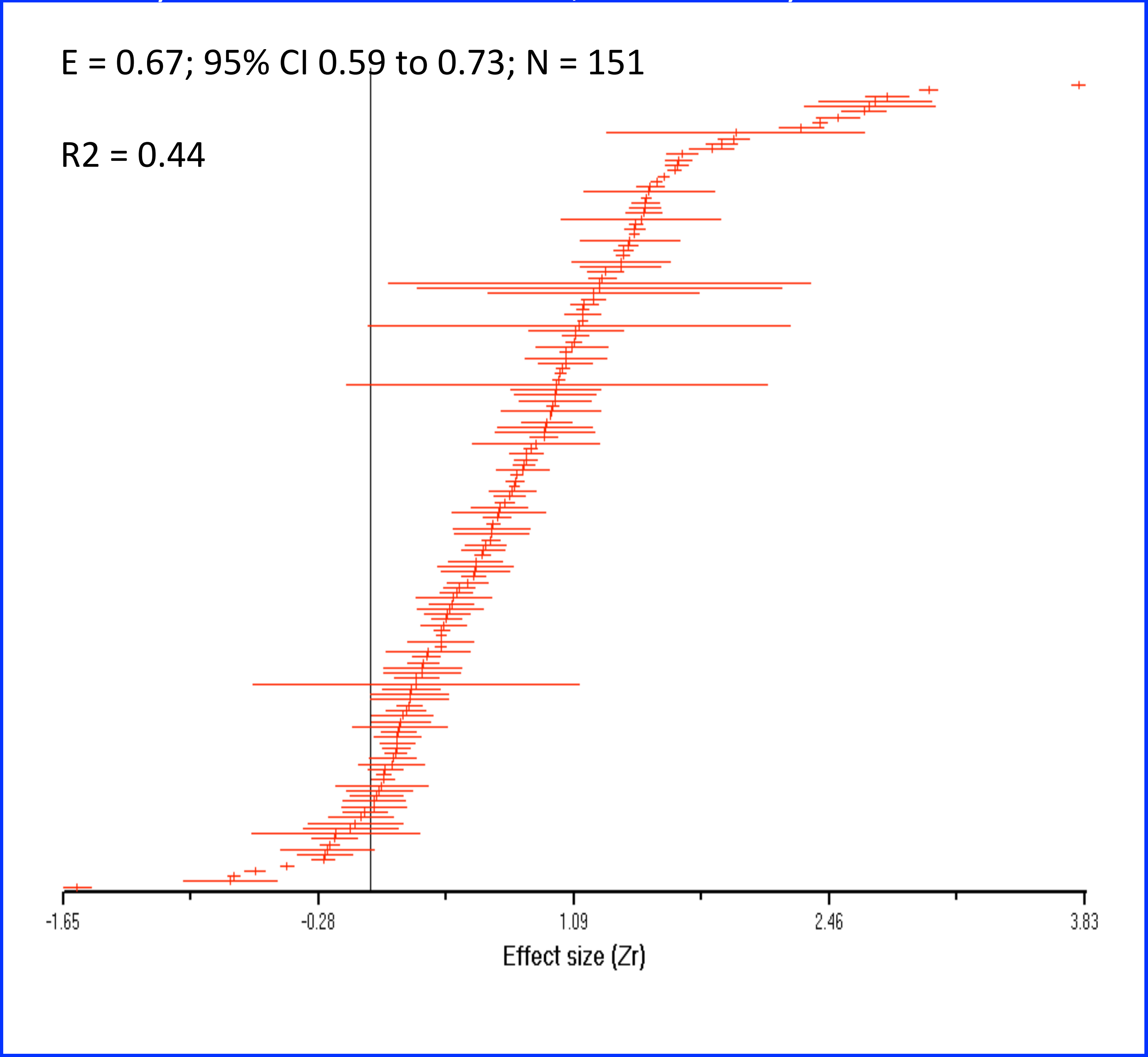
Anders Pape Møller[1] & Timothy A. Mousseau[2]

[1]Laboratoire d'Ecologie, Systématique et Evolution, CNRS UMR 8079, Université Paris-Sud, Bâtiment 362, F-91405 Orsay Cedex, France, [2]Department of Biological Sciences, University of South Carolina, Columbia SC 29208, USA.

Correspondence and requests for materials should be addressed to A.P.M. (anders.moller@u-psud.fr)

In this paper we use a meta-analysis to examine the relationship between radiation and mutation rates in Chernobyl across 45 published studies, covering 30 species. Overall effect size of radiation on mutation rates estimated as Pearson's product-moment correlation coefficient was very large ($E = 0.67$; 95% confidence intervals (CI) 0.59 to 0.73), accounting for 44.3% of the total variance in an unstructured random-effects model. Fail-safe calculations reflecting the number of unpublished null results needed to eliminate this average effect size showed the extreme robustness of this finding (Rosenberg's method: 4135 at $p = 0.05$). Indirect tests did not provide any evidence of publication bias. The effect of radiation on mutations varied among taxa, with plants showing a larger effect than animals. Humans were shown to have intermediate sensitivity of mutations to radiation compared to other species. Effect size did not decrease over time, providing no evidence for an improvement in environmental conditions. The surprisingly high mean effect size suggests a strong impact of radioactive contamination on individual fitness in current and future generations, with potentially significant population-level consequences, even beyond the area contaminated with radioactive material.

Chernobyl: Radiation and Mutation, a Meta-Analysis

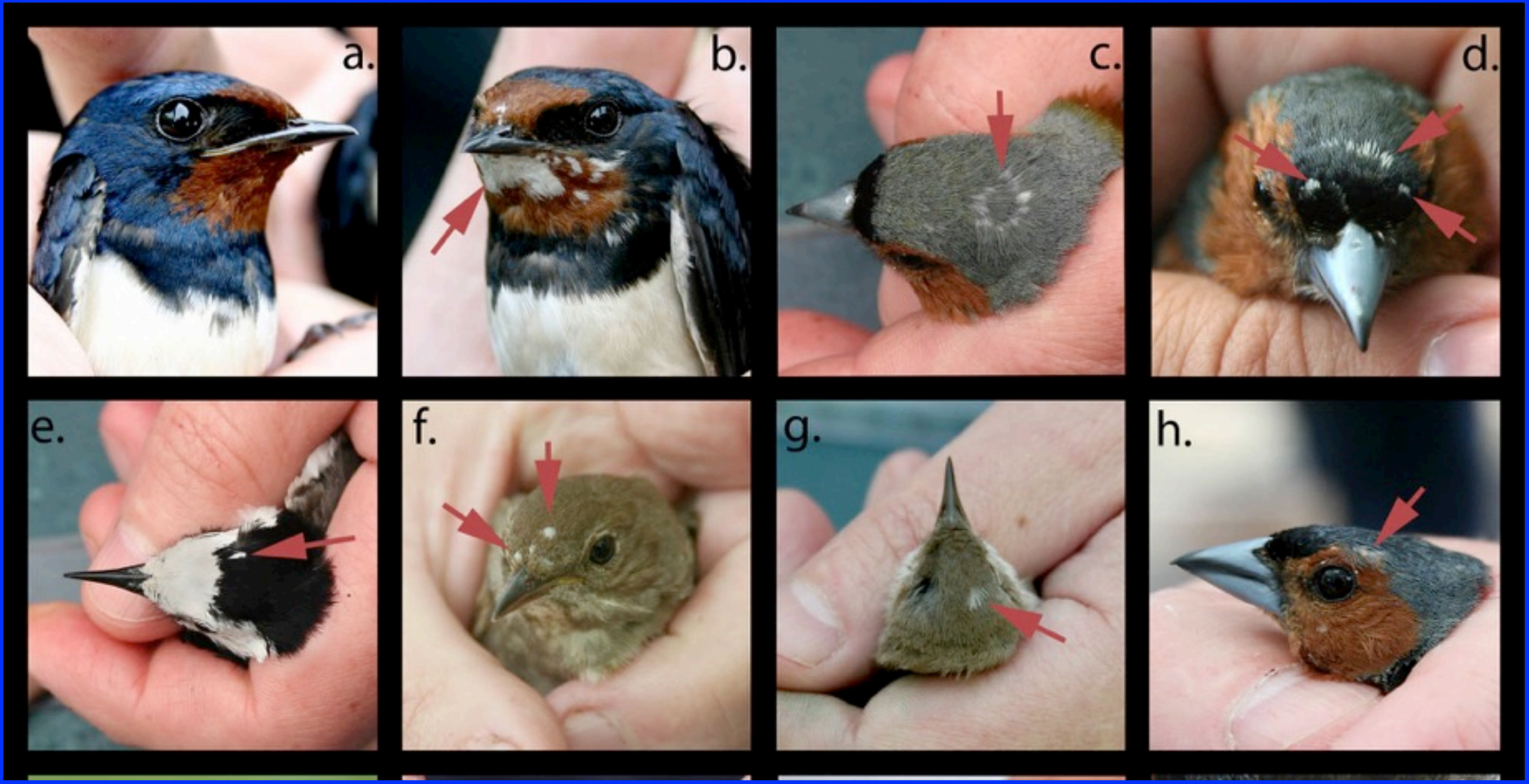


A. P. Møller, T. A. Mousseau. 2015. Strong effects of ionizing radiation on mutation rates from Chernobyl. Nature Scientific Reports .

What are the Consequences of Increased Mutation Rates for Plants and Animals Living in Radioactive Regions of Chernobyl and Fukushima?

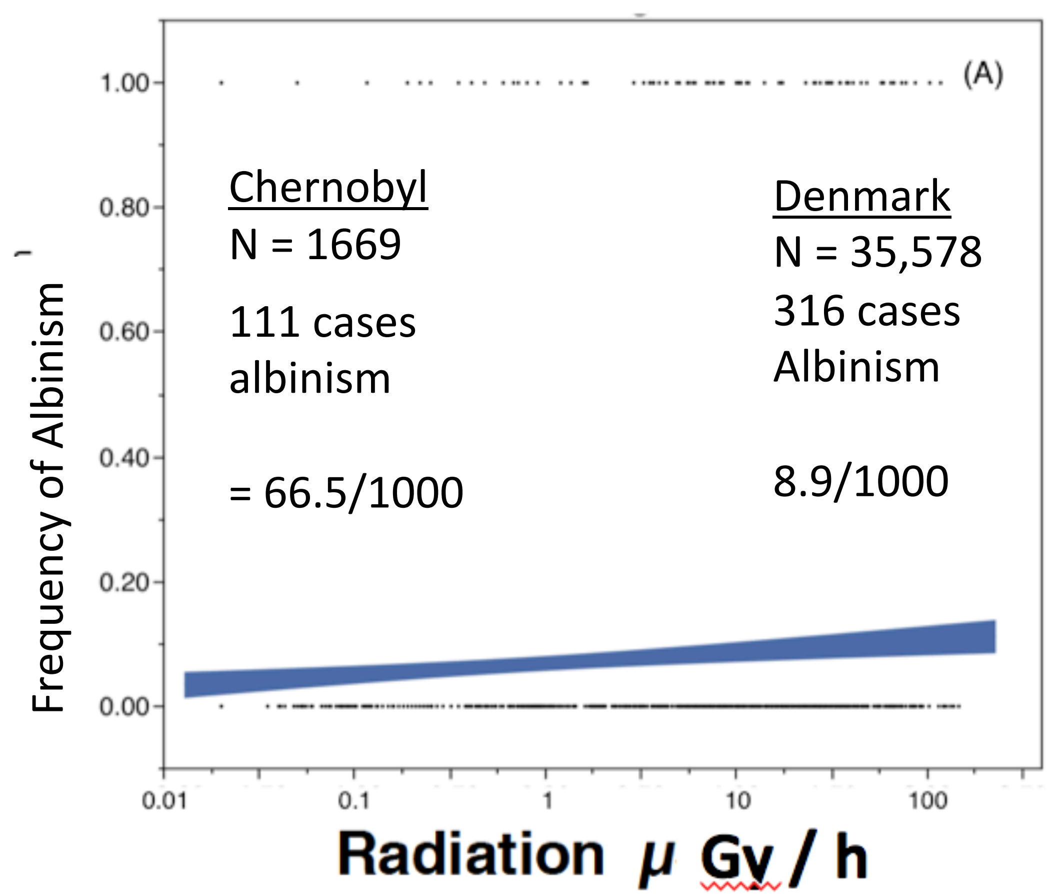
Abnormal coloration

Partial albinos are much more frequent in Chernobyl



Møller, A.P., A. Bonisoli-Alquati, and T.A. Mousseau. 2013. High frequencies of albinism and tumors in free-living birds at Chernobyl. **Mutation Research**.

Chernobyl Birds Show High Levels of Partial Albinism ("White Spots")



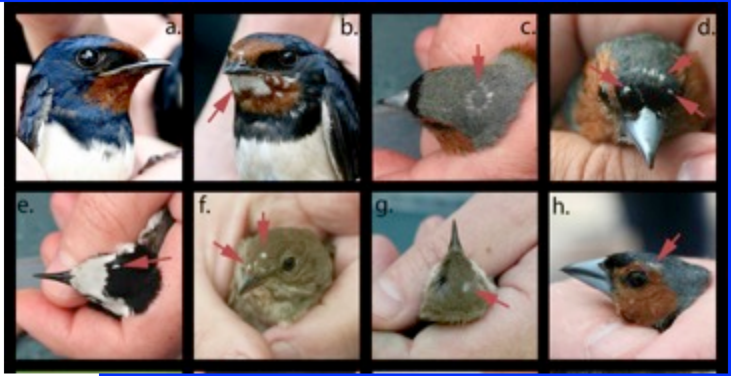


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Table 1
Nominal logistic regression models of albinism and tumours in relation to background radiation and species. R^2 was 0.20 and 0.06 for the two models. Odds ratios and their 95% confidence interval are also shown.

Variable	Chi-square	d.f.	*P*	Estimate (SE)	Odds ratio	95% CI for odds ratio
Albinism						
Species	146.97	61	<0.0001			
Radiation	33.82	1	<0.0001	0.660 (0.120)	0.309	0.162, 0.577
Tumours						
Radiation	15.06	1	0.0001	0.722 (0.210)	0.061	0.011, 0.271


Fukushima barn swallow
Albinistic feathers
白化した羽

15 partial albinos reported from Fukushima region by the Wild Bird Society of Japan in 2012-13

White spots on Fukushima cow

Bird Sperm swimming performance is impaired in radioactive areas of Chernobyl.

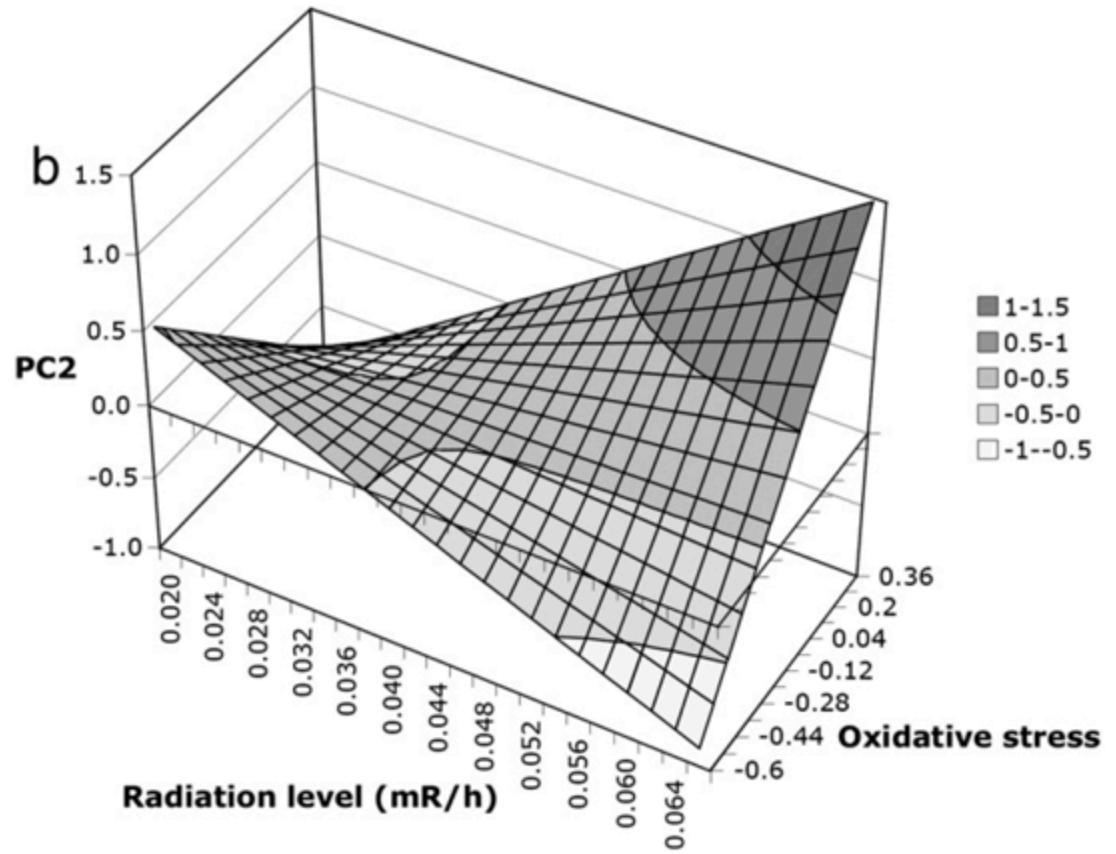
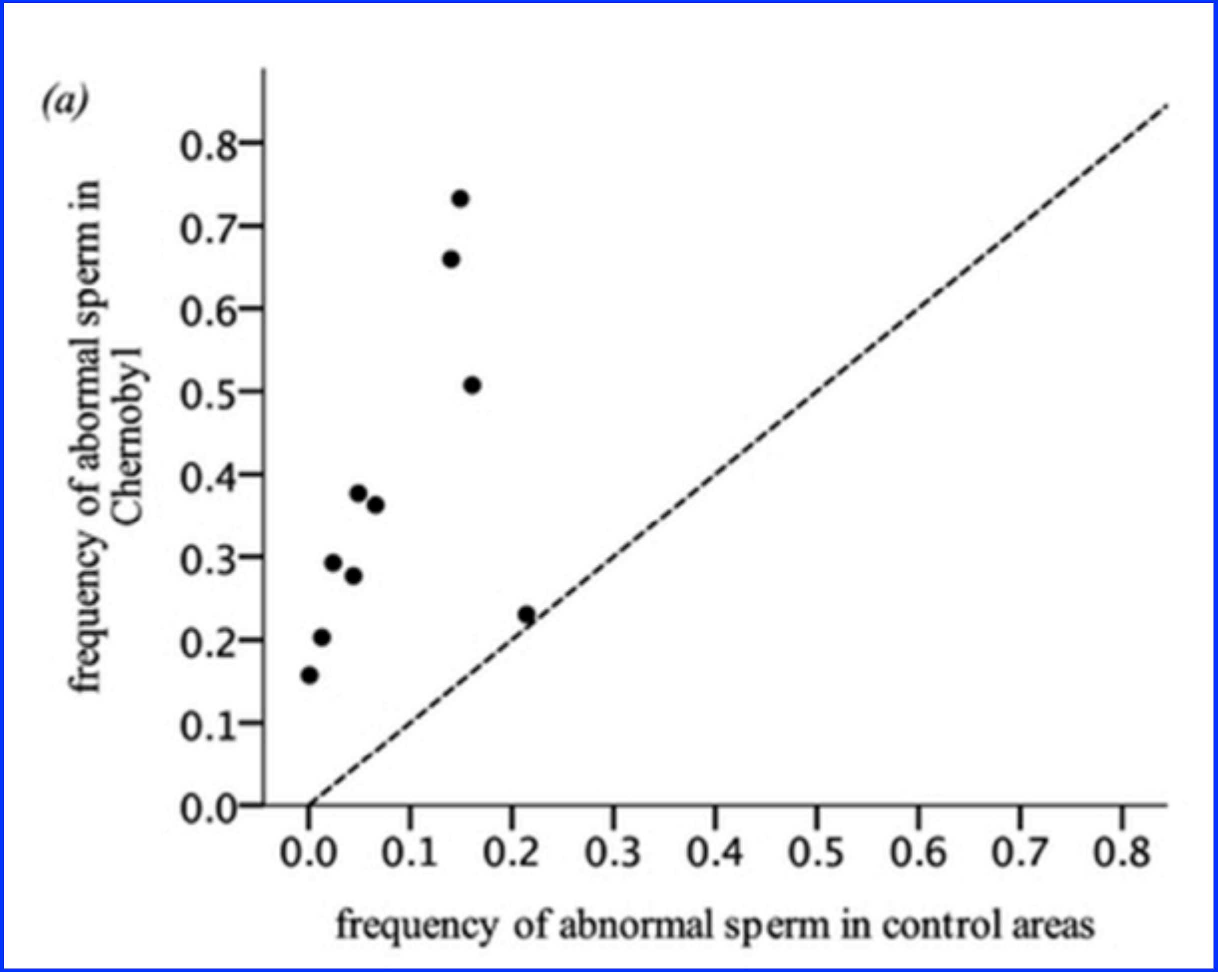


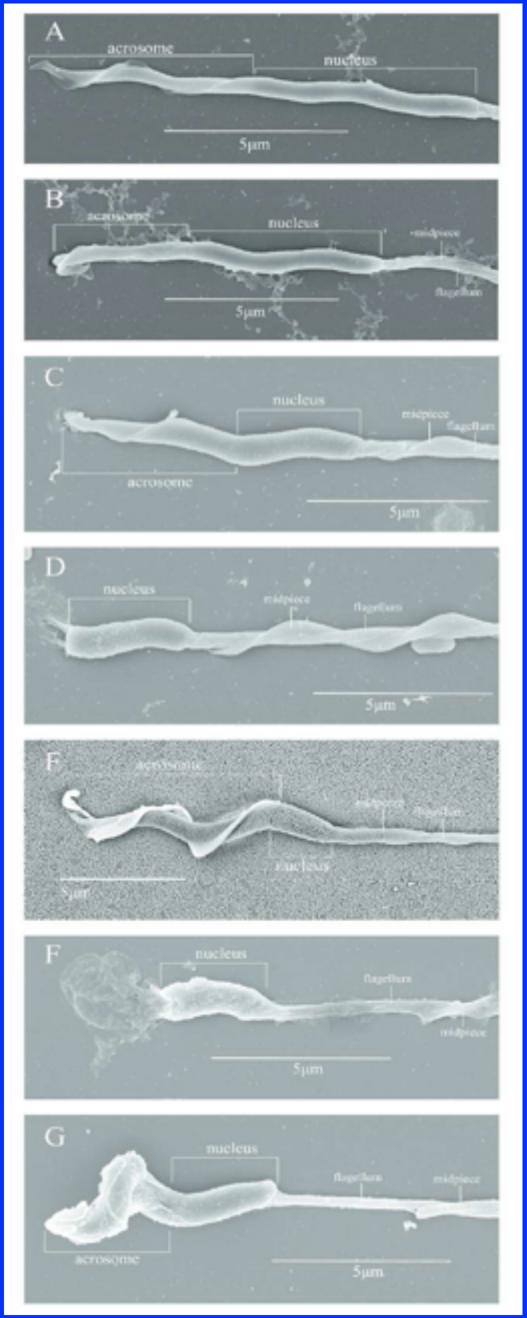
Fig. 3. Relationship between the PC2 scores, background radiation level and oxidative stress in the plasma. In panel (a), individual values of those individuals for which we could determine both TAC and ROMs levels are shown (n = 65). In panel (b), a surface was interpolated based on the coefficients for the effects of background radiation level, oxidative stress levels and the interaction between the two in the best-fit model. The

Bonisoli-Alquati, A., A.P. Møller., G. Rudolfsen, N. Saino, M. Caprioli, S. Ostermiller, T.A. Mousseau. 2011. The effects of radiation on sperm swimming behavior depend on plasma oxidative status in the barn swallow (Hirundo rustica). Comparative Biochemistry and Physiology – Part A – Molecular & Integrative Physiology, 159(2): 105-112. DOI: 10.1016/j.cbpa.2011.01.018

Frequency of abnormal sperm in 10 Chernobyl bird species.

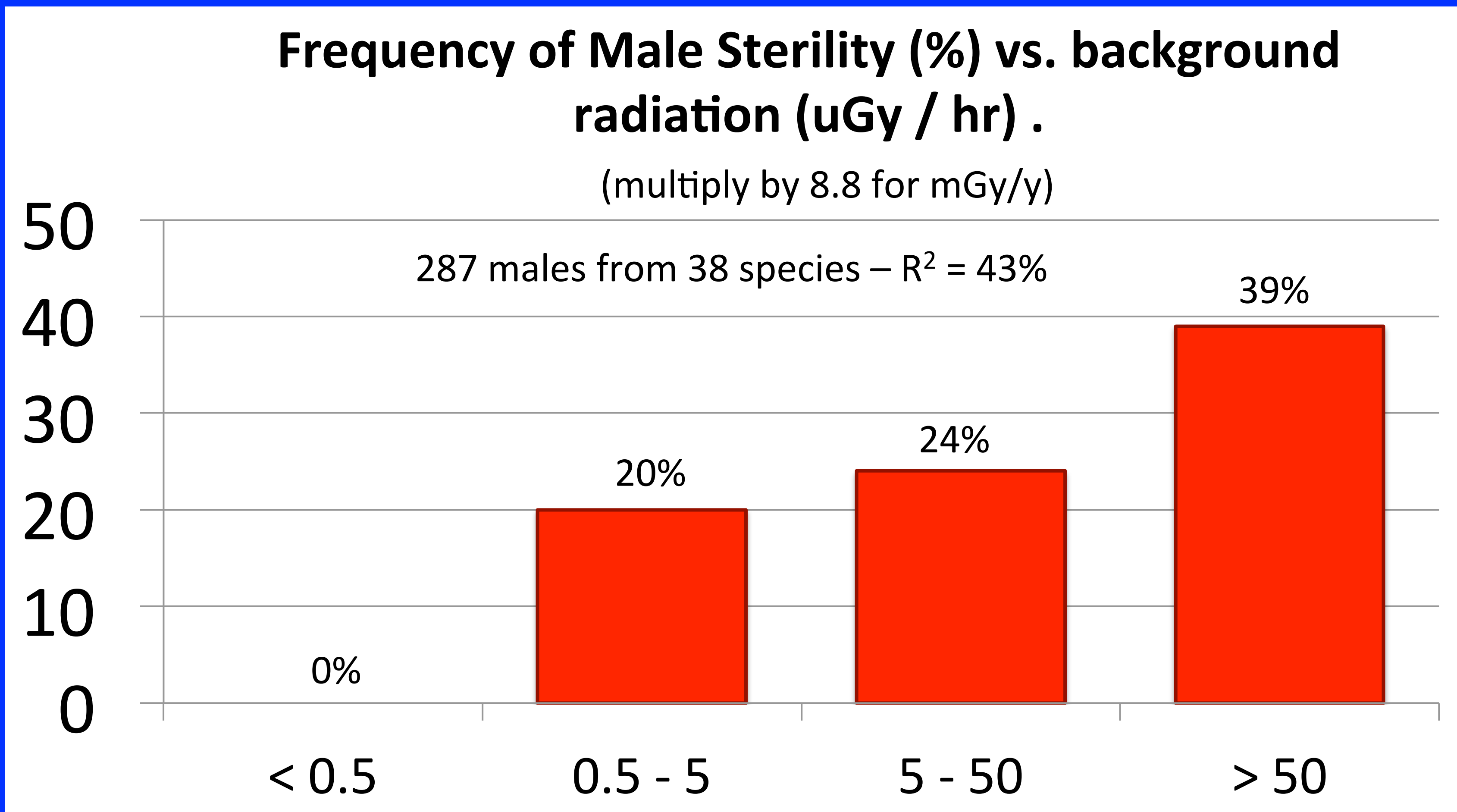
- Nine out of 10 species have much higher rates of abnormalities in Chernobyl





Hermosell, Laskemoen, Rowe, Møller, Mousseau, Albrecht & Lifjeld. 2013. Biology Letters of the Royal Society.

Proportion of male birds with no sperm Or only dead sperm in Chernobyl.



Moller, Rudolfsen, Bonisoli-Alquati, & Mousseau. 2014.

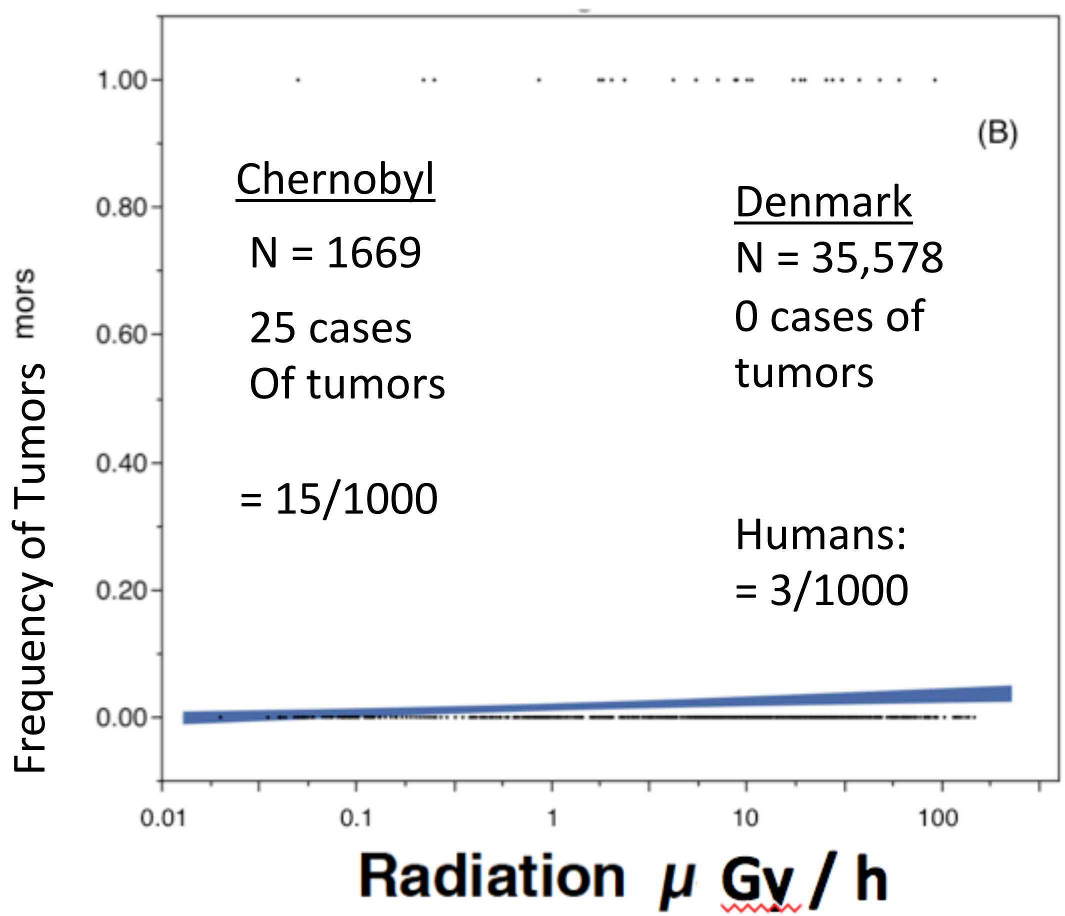
Tumors and other developmental abnormalities

Møller, A.P., A. Bonisoli-Alquati, and T.A. Mousseau. 2013. High frequencies of albinism and tumors in free-living birds at Chernobyl. **Mutation Research**.

Great tit, *Parus major*

Tumor around eye

Chernobyl Birds Have Significantly Higher Rates of Tumors



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原爆白内障

放射線によって目の中の水晶体(レンズ)の後ろ中心部が白くにごり、視力が低下する症状です。被爆して数か月から数年後に多発しました。

A-bomb Cataracts

Radiation can cause the center posterior part of the lens to become white and cloudy, leading to loss of sight. Cataracts occurred several months to several years after exposure.

原爆白内障患者の目

1966(昭和41)年4月撮影 広島大学医学部眼科教室提供

爆心地から820メートルで被爆し、
両眼に白濁があります。
写真の中央にある黒い部分が原爆白内障によるにごりです。

The eye of an A-bomb cataract patient

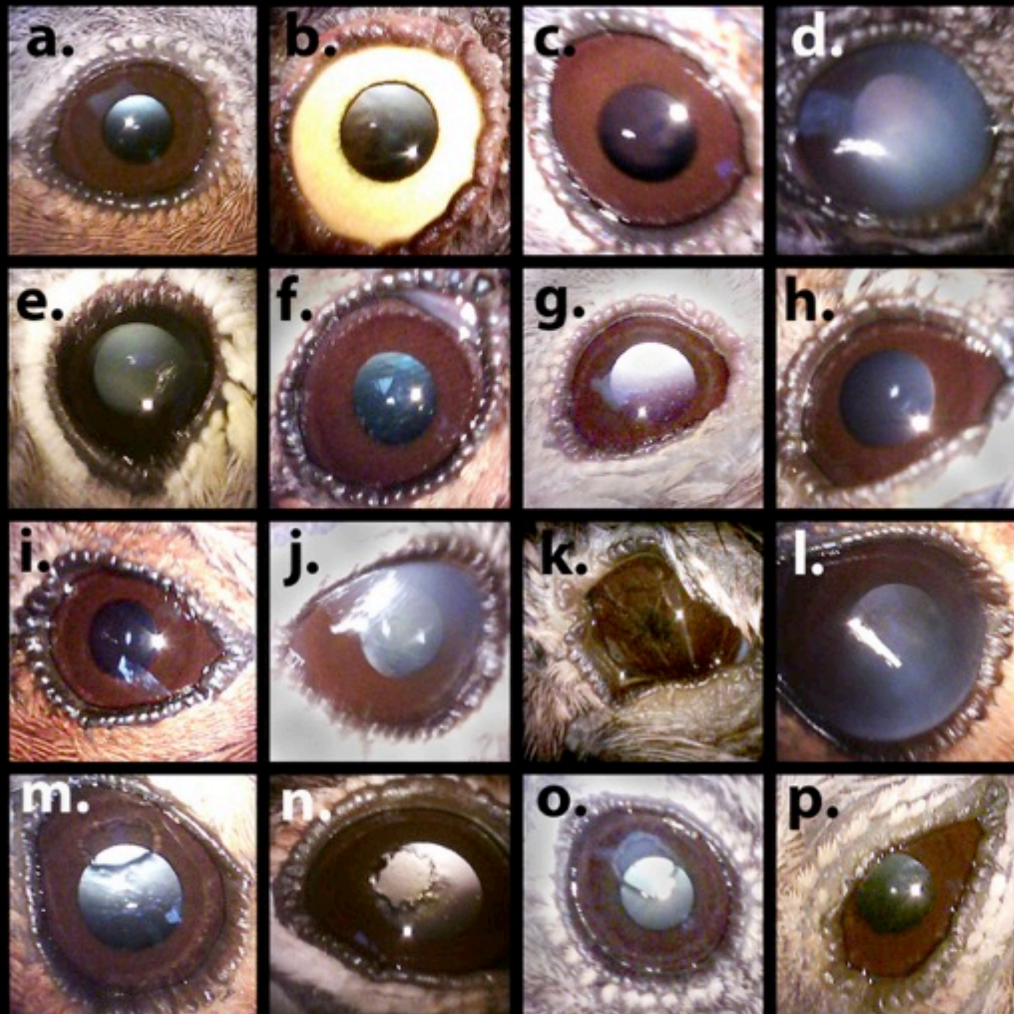
Taken in April 1966

Courtesy of the Department of Ophthalmology, Faculty of Medicine, Hiroshima University

The patient was exposed 820m from the hypocenter and had white cloudiness in both eyes.
The dark area in the center of this photo is the cloudiness caused by an A-bomb cataract.

Cataracts & Deformities

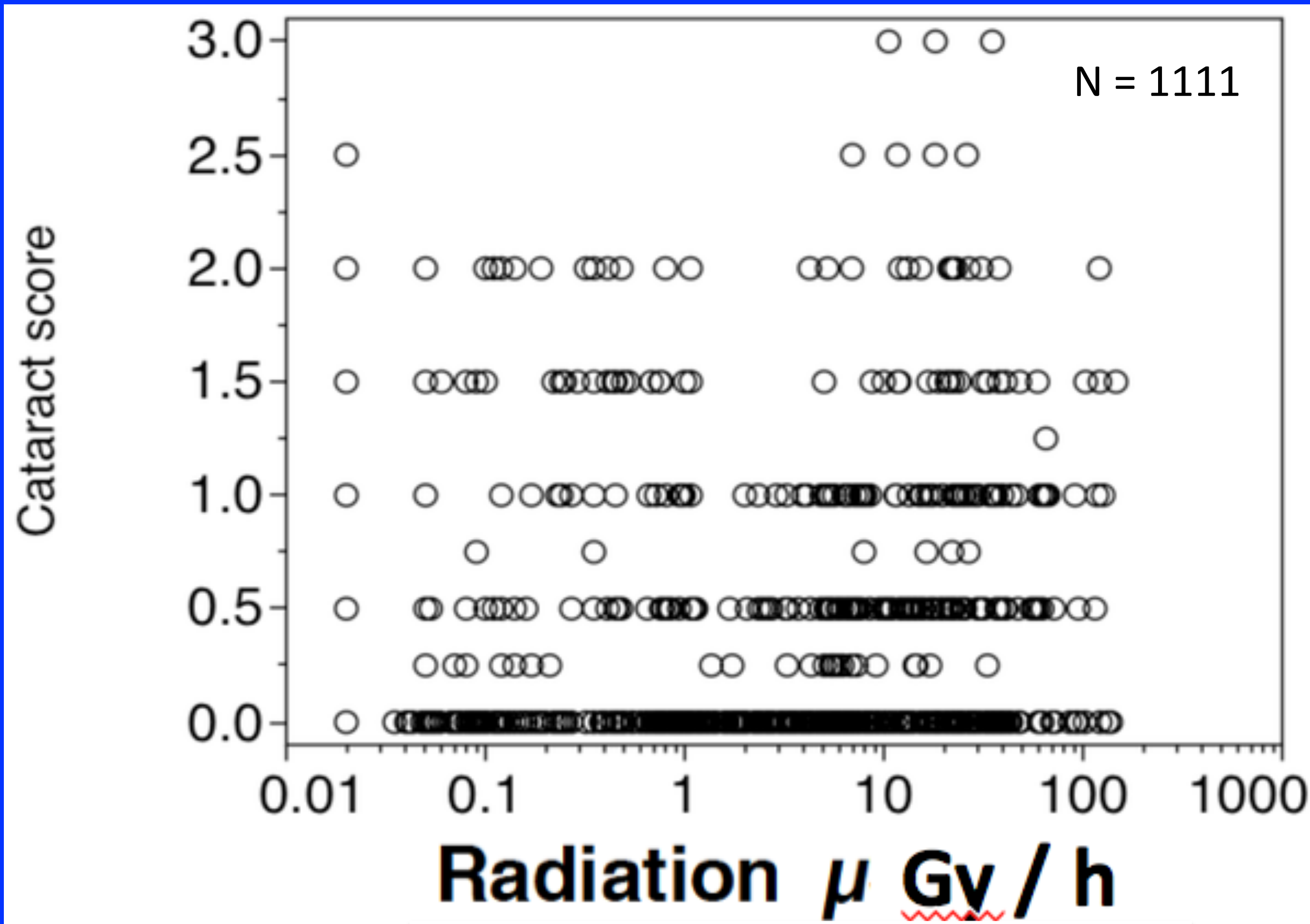
Bird Eyes of Chernobyl



(a.) Black cap, (*Sylvia atricapilla*), normal. (b.) Barred warbler, (*Sylvia nisoria*), normal. (c.) Black cap, (*Syvia atricapilla*), very slight haze in cornea. (d.) Barn swallow (*Hirundo rustica*), significant haze on cornea. (e.) Chiffchaff (*Phylloscopus collybita*), slight haze on cornea. (f.) Chiffchaff , (*Phylloscopus collybita*), significant haze on cornea. (g.) Spotted fly catcher, (*Muscicapa striata*), partial haze on cornea. (h.) Chaffinch (*Fringilla coelebs*), slight haze on cornea. (i.) Chaffinch (*Fringilla coelebs*), clear eye but deformed eye lids. (j.) Tree pipet (*Anthus trivialis*), significant opacity of cornea. (k.) Barn swallow (*Hirundo rustica*), highly deformed eye lids and iris. (l.) Robin (*Erithacus rubecula*), significant haze on cornea. (m.) Robin (*Erithacus rubecula*), tear in cornea. (n.) Whinchat (*Saxicola rubetra*), tear on cornea. (o.) Spotted flycatcher (*Muscicapa striata*), tear on cornea (p.) Chiffchaff (*Phylloscopus collybita*), deformed eye lids, haze on cornea.

All photos captured using an EyeQuick Digital Ophthalmoscope Camera.

Further information can be found at http://cricket.biol.sc.edu/chernobyl/



Chernobyl Birds

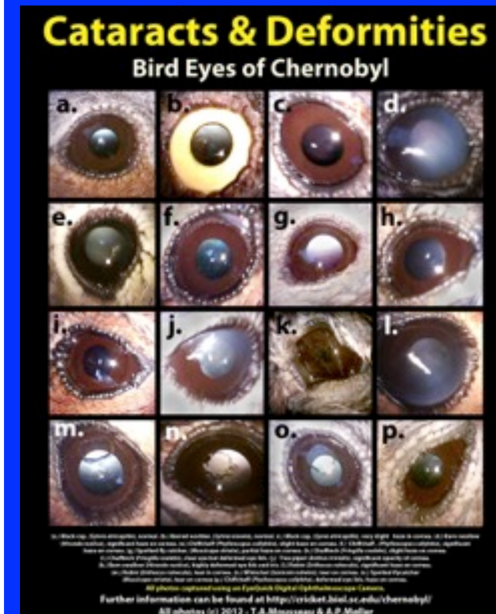


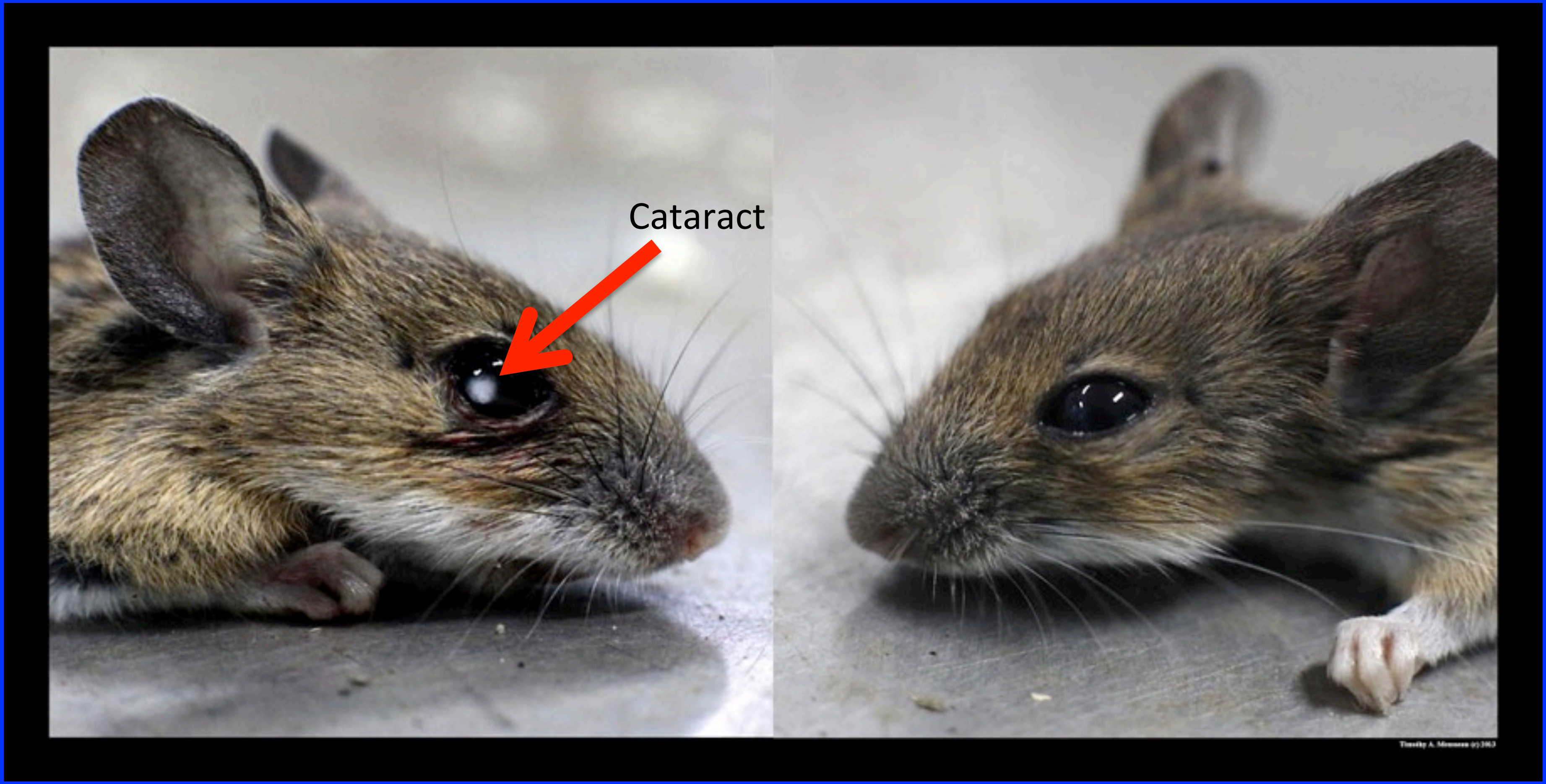
Table 1. Mixed model of cataracts in relation to species (random factor) and radiation. The random species effect accounted for a variance ratio of 0.0955 and 8.71% of the total variance.

Variable	d.f.	*F*	*P*	Estimate (SE)
Intercept	48.66, 1074		< 0.0001	
log Radiation	1, 1074	89.63	< 0.0001	0.131 (0.014)

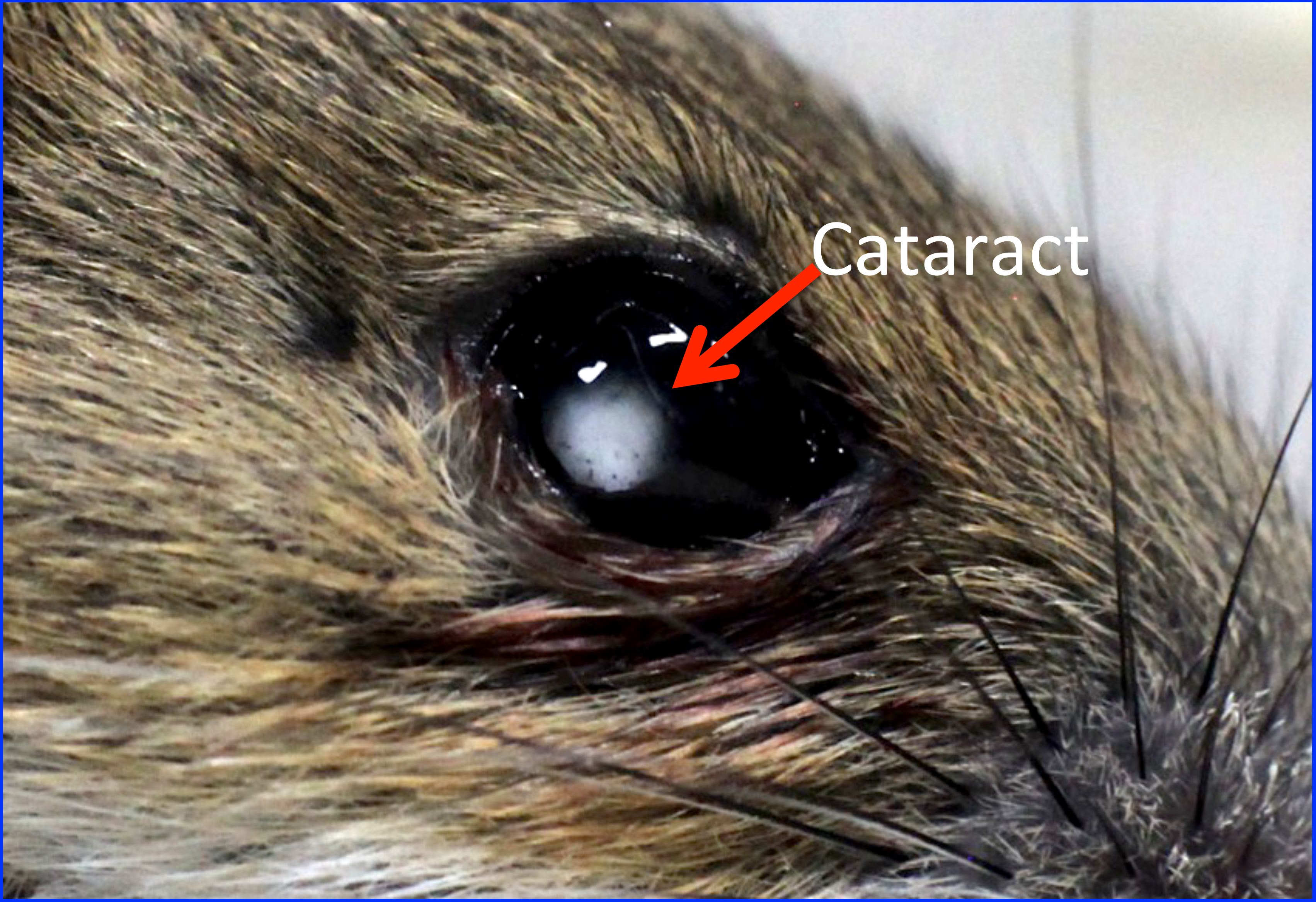
Mousseau, T.A., and A.P. Møller. 2013. Elevated frequencies of cataracts in birds from Chernobyl. **PLoS ONE**.

PLOS ONE

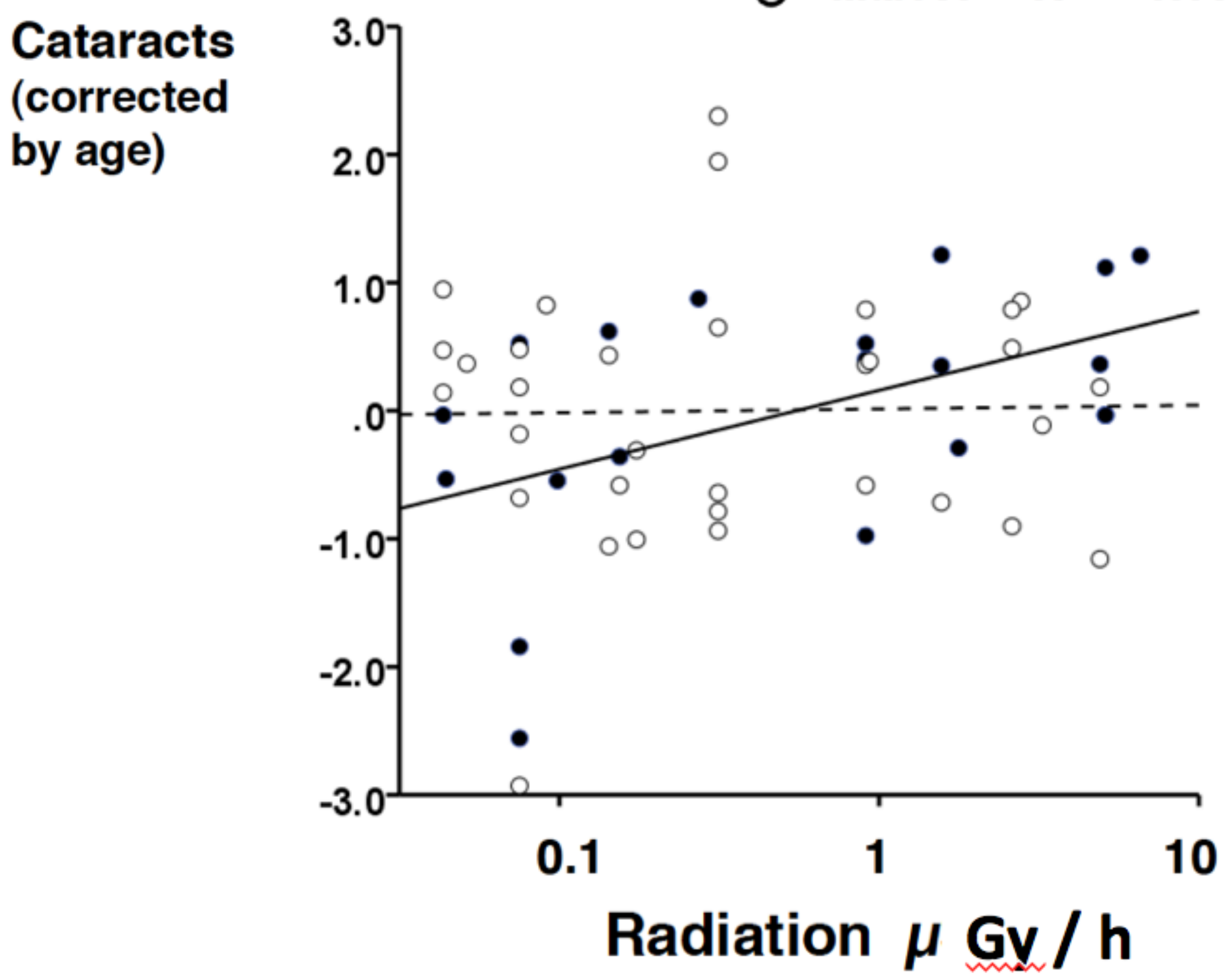
Cataract in Chernobyl mouse



Mousseau, Mappes, Boratynsji, and Moller. 2013. unpublished data.


Cataract

Chernobyl Voles - 2013



Mappes, Mousseau, Boratynsji, and Moller. 2013. unpublished data.

Mental Retardation Following *In Utero* Exposure to the Atomic Bombs of Hiroshima and Nagasaki[1]

William J. Blot, Ph.D., and Robert W. Miller, M.D.

ABSTRACT—The prevalence of mental retardation in children tested at 17 years of age who had been exposed *in utero* to the atomic bombs of Hiroshima and Nagasaki was studied in relation to the most recent estimate of radiation dose received. Significant increases at doses greater than 50 rads in Hiroshima and 200 in Nagasaki were found, with the risk of mental retardation generally rising directly with increasing dose. The lower dose-effect in Hiroshima may have been due to irradiation by neutrons which were virtually absent in Nagasaki.

INDEX TERMS: Mental Deficiency • Radiations, Injurious Effects, embryonal, fetal

Radiology 106:617–619, March 1973

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Page last updated at 09:05 GMT, Saturday, 5 February 2011

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Chernobyl birds are small brained

By Matt Walker
Editor, Earth News

Marsh warblers are one of the species affected

Birds living around the site of the Chernobyl nuclear accident have 5% smaller brains, an effect directly linked to lingering background radiation.

Smaller brained birds die younger and appear to have lower "IQs".

Moller, Mousseau, et al. 2011. PLoS One

Birds from “hot” regions of Chernobyl have significantly smaller brains.

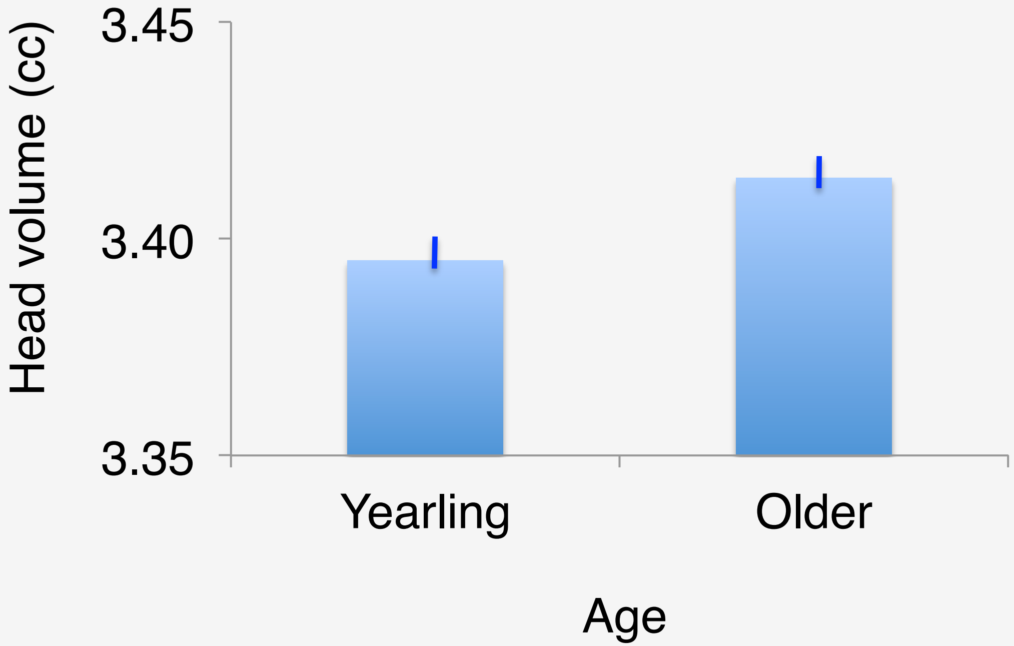
	Sum of squares	df	F	P	Slope (SE)
Species	1.008	32	13.93	<0.0001	
Radiation [Species]	0.146	33	1.96	0.0015	
Body mass	0.011	1	4.94	0.027	0.140 (0.063)
Keel length	0.008	1	3.59	0.059	0.177 (0.094
Error	1.013	448			

The model had the statistics $F_{67,448} = 171.15$, $r^2 = 0.96$, $P < 0.0001$.
doi:10.1371/journal.pone.0016862.t001

Møller AP, Bonisoli-Alquati A, Rudolfsen G, Mousseau TA (2011) Chernobyl Birds Have Smaller Brains. PLoS ONE 6(2): e16862. doi:10.1371/journal.pone.0016862
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0016862

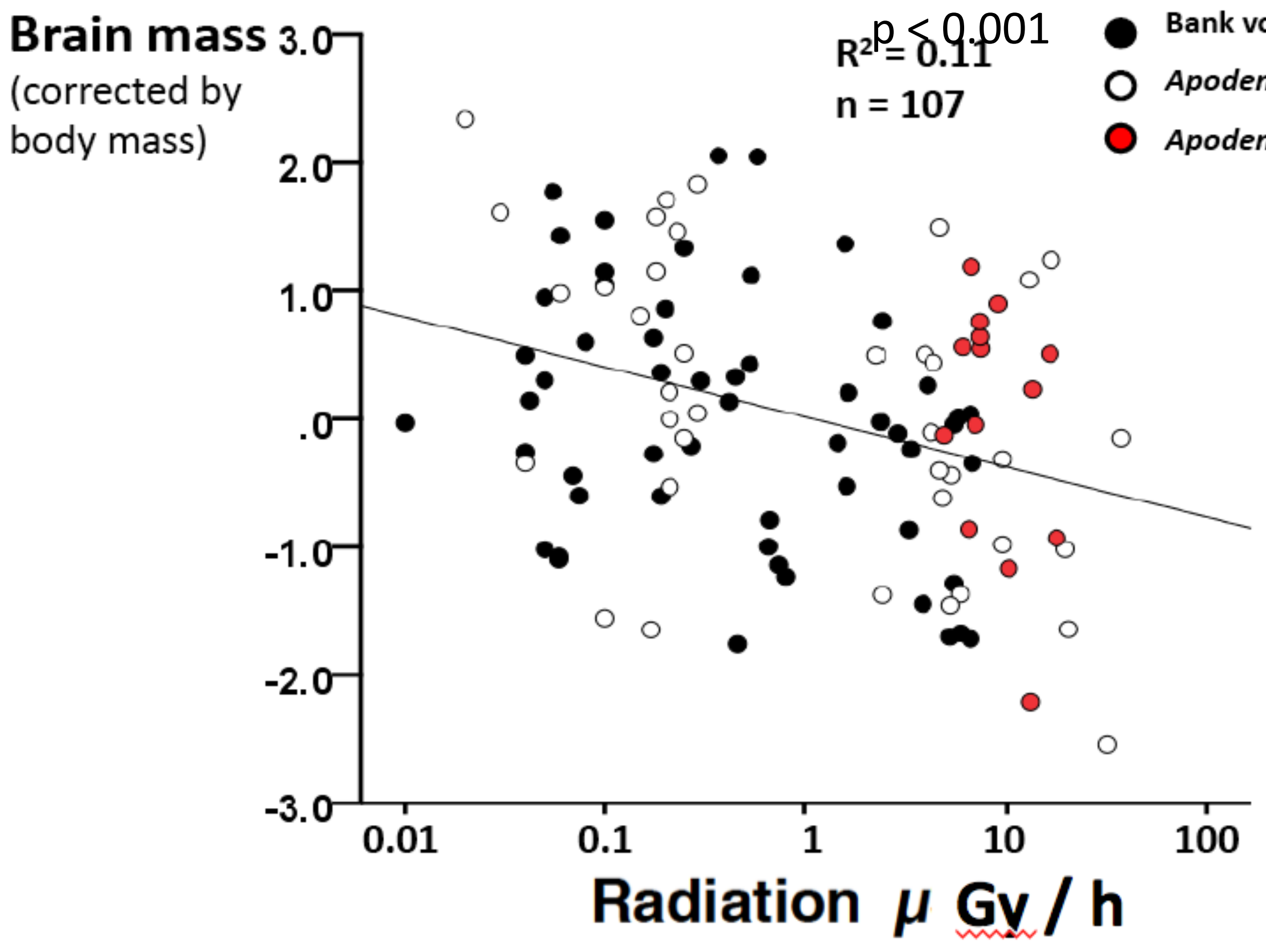
Selection against small heads

F = 9.92, df = 1,284, P = 0.0018



(Møller et al., PLoS One 6(2):e16862, 2011)

Rodents from Chernobyl and Fukushima show smaller brains in radioactive areas



Firebug

Pyrrhocoris apterus

"Facemask Bug"

Mutant Firebugs from Chernobyl

Mousseau & Møller. 2013..

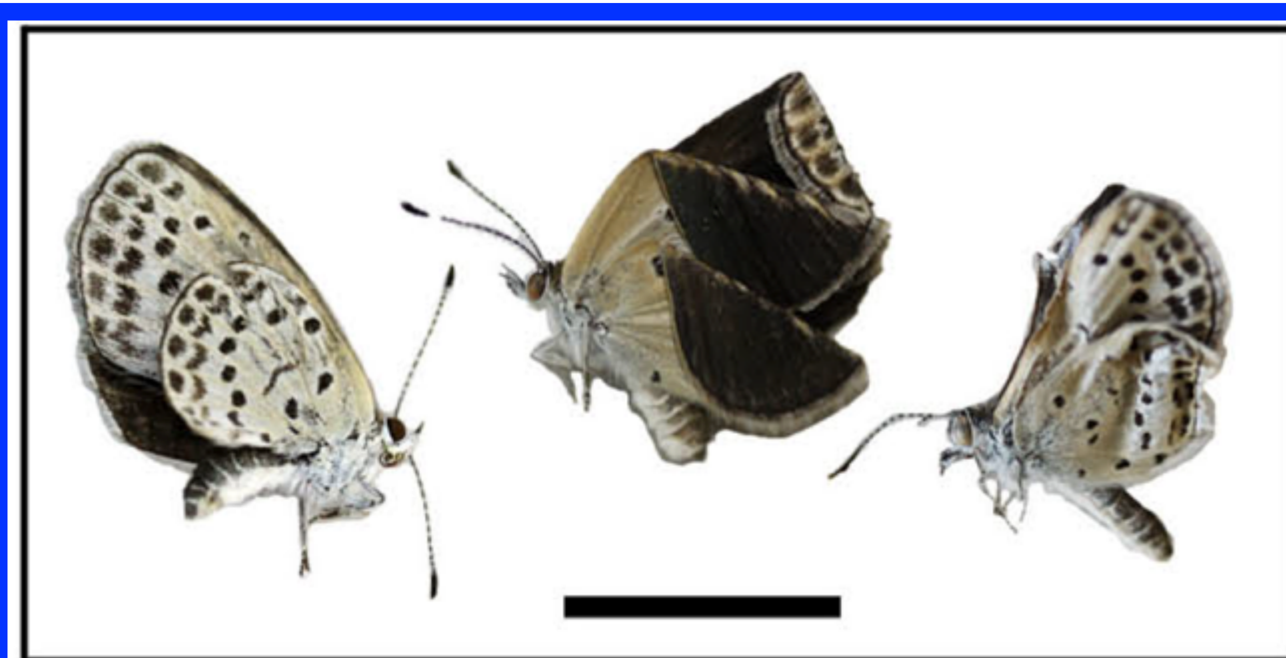
SCIENTIFIC REPORTS

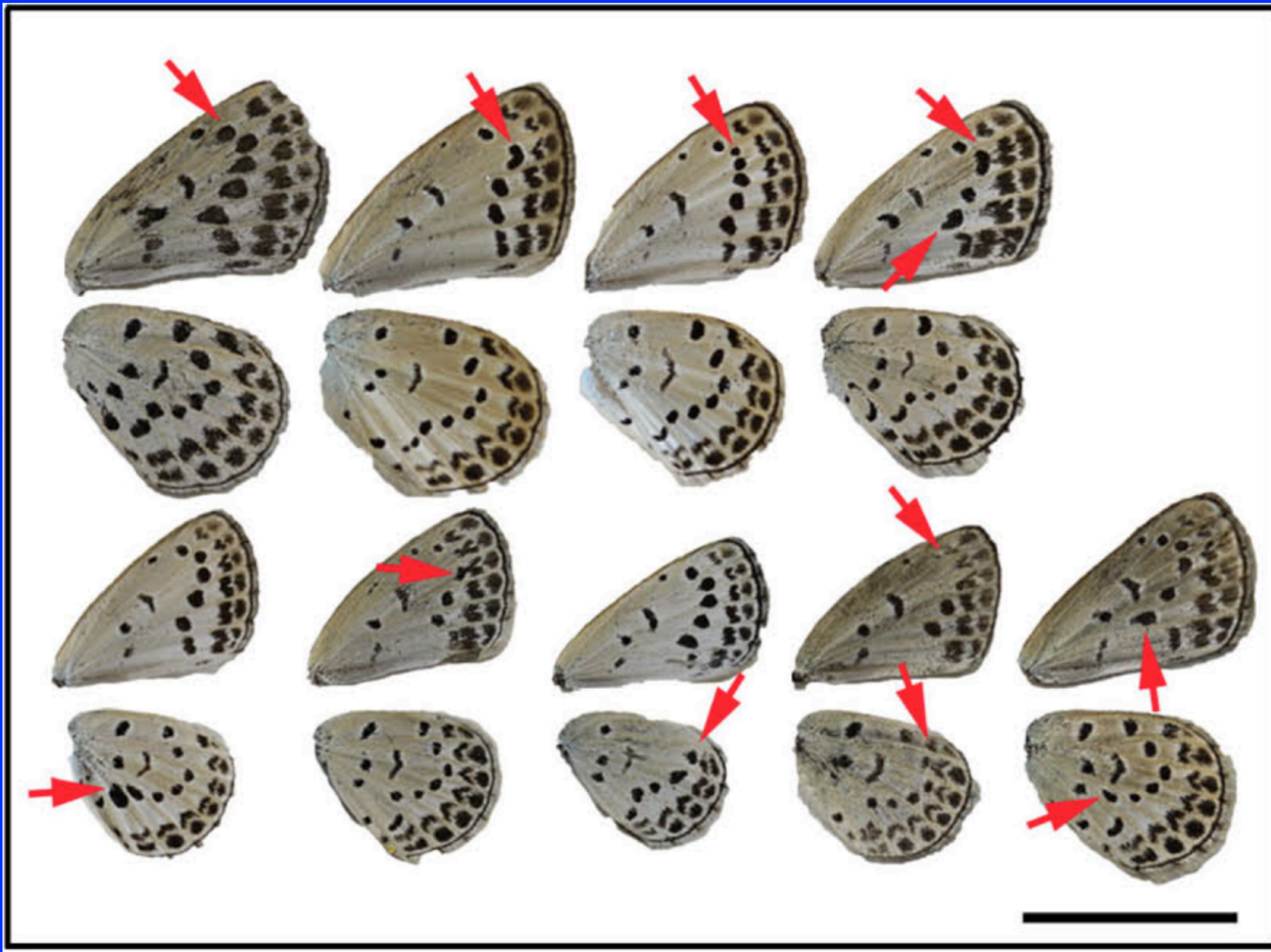
OPEN

The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly

SUBJECT AREAS:
ENVIRONMENTAL SCIENCES
ECOLOGY
BIODIVERSITY

Atsuki Hiyama[1]*, Chiyo Nohara[1]*, Seira Kinjo[1], Wataru Taira[1], Shinichi Gima[2], Akira Tanahara[2] & Joji M. Otaki[1]

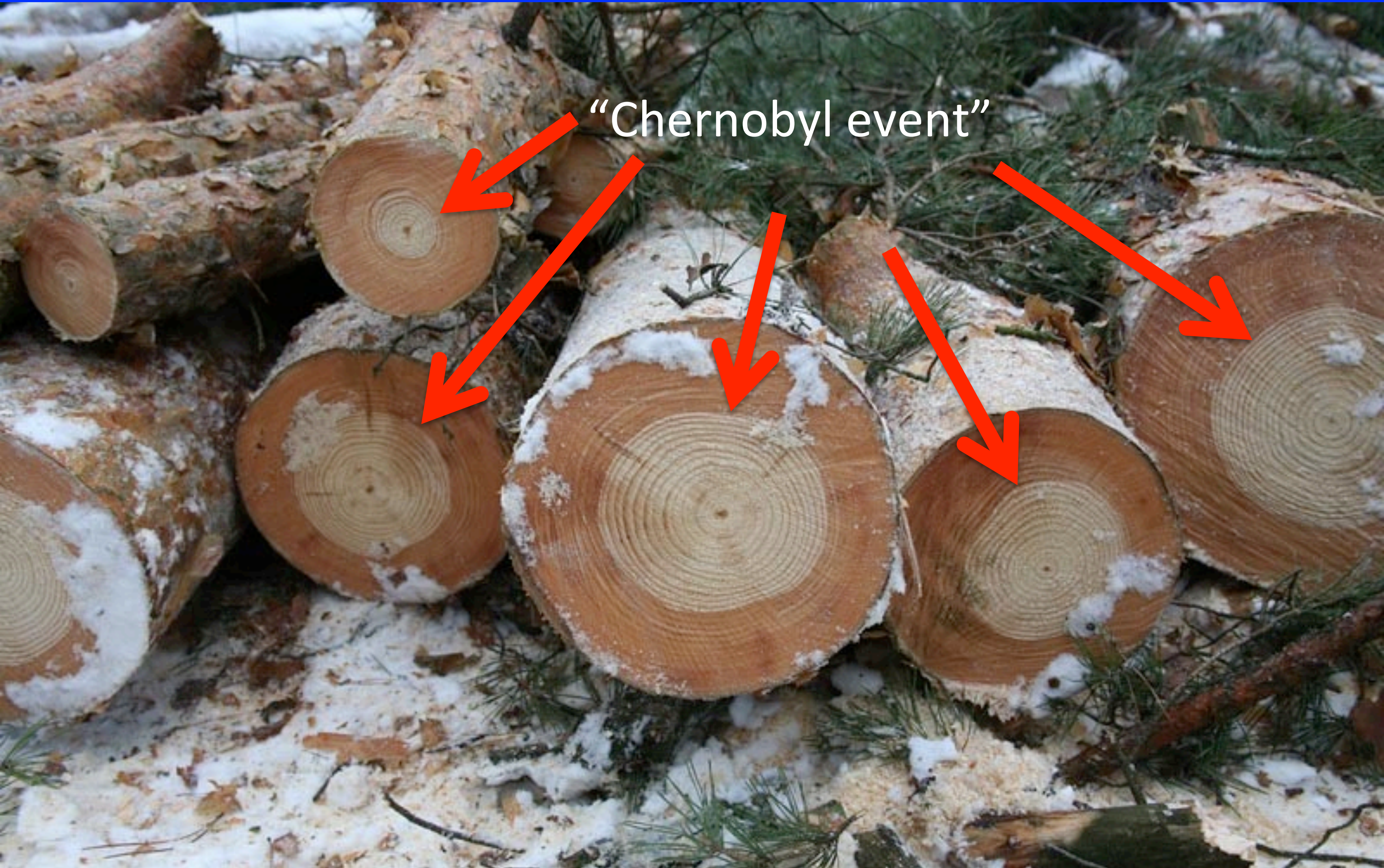




Abnormal Scots pine trees (*Pinus sylvestris*) from Chernobyl.

Mousseau, T.A., S.M. Welch, I. Chizhevsky, O. Bondarenko, G. Milinevsky, D. Tedeschi, A. Bonisoli-Alquati, and Møller, A.P., 2013. Tree rings reveal extent of exposure to radiation in Scots pine, Pinus sylvestris. **Trees – Structure and Function**, DOI 10.1007/s00468-013-0891-z

Radiation and tree growth



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: 18 August 2015

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

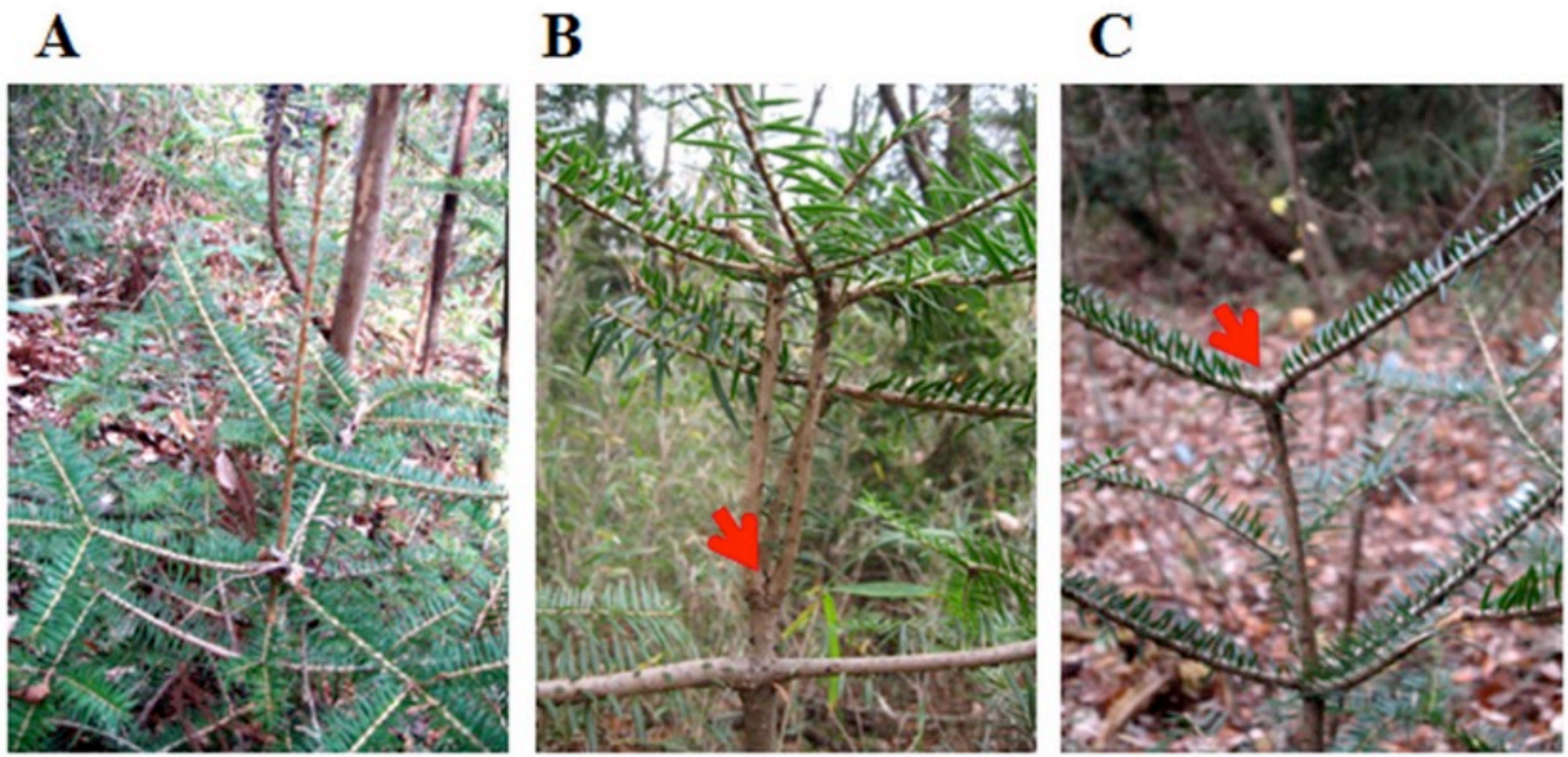


Figure 3. Representative morphological defects in Japanese fir trees. Arrowheads indicate the position of deleted leader shoot. (**A**) normal tree (S3), (**B**) defected tree (vertical forking, S1), (**C**) defected tree (horizontal forking, S2).

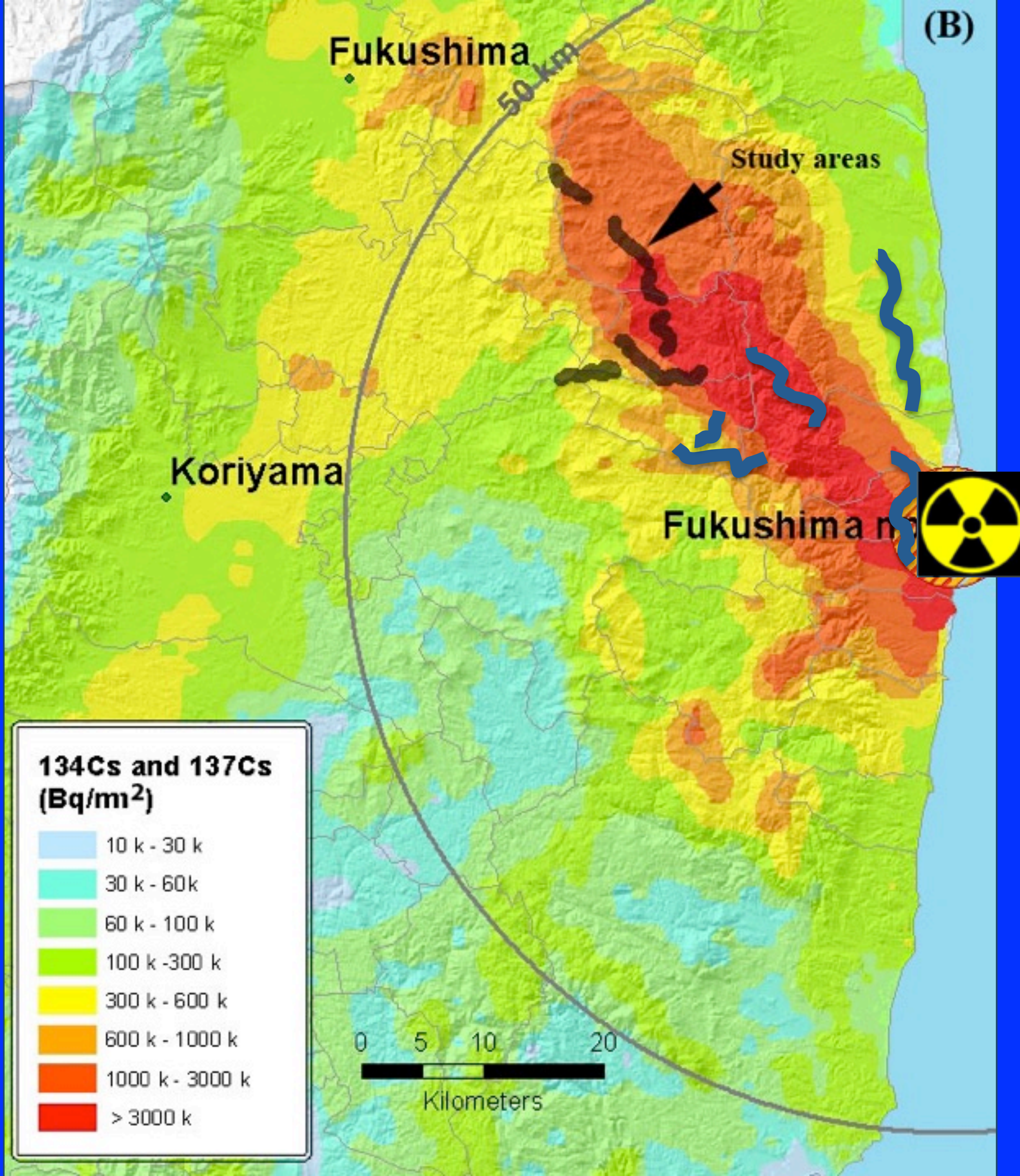
How is Animal Abundance and Diversity Affected by Radiation?

Most of our research includes areas of the highest contamination in addition to control areas. Patchiness of deposition permits disentanglement of radiation, distance from source, and other environmental factors that influence abundance and biodiversity.

- 896 bird and insect surveys from about 300 locations in Ukraine and Belarus

Control Populations:

- Italy (Milan)
- Spain (Badajoz)
- Denmark (Aalborg)
- Ukraine



Surveys of birds and insects from 400 discrete locations, 1500 inventories in total to date.

Massively Replicated Biotic Inventories

(1500 in Fukushima, 896 in Chernobyl)

+

Measures of Multiple Environmental Variables

(e.g. meteorology, hydrology, geology, plant community, Habitat type,
land use history, plant coverage amount and type, altitude,
meteorological conditions, time, date, distance to nearest water source, etc)

+

Field Measures of Residential Radiation Levels

+

GIS

+

Multivariate Statistics

=

Predictive Models of Radiation Effects on Populations

Recent studies of radiation effects on abundance

Journal of Applied Ecology 2007 **44**, 909–919

Determinants of interspecific variation in population declines of birds after exposure to radiation at Chernobyl

A. P. MØLLER* and T. A. MOUSSEAU†

*Laboratoire de Parasitologie Evolutive, CNRS UMR 7103, Université Pierre et Marie Curie, Bât. A, 7ème étage, 7 quai St Bernard, Case 237, F-75252 Paris Cedex 05, France; and †Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA

Ecological Indicators 11 (2011) 424–430

Contents lists available at ScienceDirect

Ecological Indicators

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

Original article

Efficiency of bio-indicators for low-level radiation under field conditions

Anders Pape Møller[a,b,*], Timothy A. Mousseau[c]

[a] Laboratoire d'Ecologie, Systématique et Evolution, CNRS UMR 8079, Université Paris-Sud, Bâtiment 362, F-91405 Orsay Cedex, France
[b] Center for Advanced Study, Drammensveien 78, NO-0271 Oslo, Norway
[c] Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA

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ABSTRACT

Relatively little is known about biological consequences of natural variation in background radiation, and variation in exposure due to nuclear accidents, or even the long term consequences to human health stemming from the over-use of nuclear medicine and imaging technologies (i.e. CAT scans). This realization emphasizes the need for assessment and quantification of biological effects of radiation on living organisms. Here we report the results of an environmental analysis based on extensive censuses of abundance of nine animal taxa (spiders, dragonflies, grasshoppers, bumblebees, butterflies, amphibians, reptiles, birds, mammals) around Chernobyl in Ukraine and Belarus during 2006–2009. Background levels of radiation explained 1.5–26.5% of the variance in abundance of these nine taxa, birds and mammals having the strongest effects, accounting for a difference of a factor 18 among taxa. These effects were retained in analyses that accounted for potentially confounding effects. Effect size estimated as the amount of variance in abundance explained by background level of radiation was highly consistent among years, with weaker effects in years with low density. Effect sizes were greater in taxa with longer natal dispersal distances and in taxa with higher population density. These results are consistent with the hypotheses that costs of dispersal (i.e. survival) were accentuated under conditions of radioactive contamination, or that high density allowed detection of radiation effects. This suggests that standard breeding bird censuses can be used as an informative bio-indicator for the effects of radiation on abundance of animals.

1. Introduction

The biological consequences of natural variation in background radiation levels remain largely unexplored. The average annual worldwide radiation dose is around 2.4 mSv, with a typical range

radioactive material. These include at least three in the former Soviet Union, Three Mile Island in the US and nuclear test sites in the US, Russia, Algeria, China, India, Australia, and the Pacific. To date, the single largest radiation accident is that at Chernobyl on 26 April 1986 that resulted in the emission of at least 9.35×10^3

biology letters

Biol. Lett. (2007) **3**, 483–486
doi:10.1098/rsbl.2007.0226
Published online 14 August 2007

Community ecology

Species richness and abundance of forest birds in relation to radiation at Chernobyl

A. P. Møller[1,*] and T. A. Mousseau[2]

[1]Laboratoire de Parasitologie Evolutive, CNRS UMR 7103, Université Pierre et Marie Curie, Bâtiment A, 7ème étage, 7 quai St Bernard, Case 237, 75252 Paris Cedex 05, France
[2]Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA
*Author for correspondence (amoller@snv.jussieu.fr).

The effects of low-level radiation on the abundance of animals are poorly known, as are the effects on ecosystems and their functioning.

Since 1990, we have collected information suggesting a reduced and continuously declining abundance of birds in the most contaminated areas. This prompted us to conduct standard censuses in relation to local levels of radiation.

During May to June 2006, we censused breeding birds using standard point count census (Møller 1983; Bibby *et al.* 2005), while simultaneously recording levels of background radiation at these forest sites. Species richness and abundance of animals can be affected by numerous environmental factors other than radiation, and, therefore, we controlled statistically for a range of potentially confounding variables that could affect our assessment of the relationship between species richness and abundance of animals and the level of background radiation by including variables reflecting habitat, soil type, weather and several other factors in the statistical models. Most radiation around Chernobyl is currently in the top-most layer of the soil (Shestopalov 1996; European Union 1998), where soil invertebrates are abundant. Therefore, we predicted that the abundance of bird

J Ornithol (2009) 150:239–246
DOI 10.1007/s10336-008-0343-5

ORIGINAL ARTICLE

Reduced abundance of raptors in radioactively contaminated areas near Chernobyl

Anders Pape Møller · Timothy A. Mousseau

Biological Conservation 144 (2011) 2787–2798

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Review

Conservation consequences of Chernobyl and other nuclear accidents

A.P. Møller[a,*], T.A. Mousseau[b]

[a] Laboratoire d'Ecologie, Systématique et Evolution, CNRS UMR 8079, Université Paris-Sud, Bâtiment 362, F-91405 Orsay Cedex, France
[b] Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA

J Ornithol
DOI 10.1007/s10336-015-1173-x

REVIEW

Ecological differences in response of bird species to radioactivity from Chernobyl and Fukushima

A. P. Møller · T. A. Mousseau · I. Nishiumi · K. Ueda

SCIENTIFIC REPORTS

OPEN

SUBJECT AREAS:
ECOLOGICAL EPIDEMIOLOGY
ECOPHYSIOLOGY

Abundance and genetic damage of barn swallows from Fukushima

A. Bonisoli-Alquati[1], K. Koyama[2], D. J. Tedeschi[3], W. Kitamura[4], H. Sukuzi[5], S. Ostermiller[1], E. Arai[6], A. P. Møller[7] & T. A. Mousseau[1]

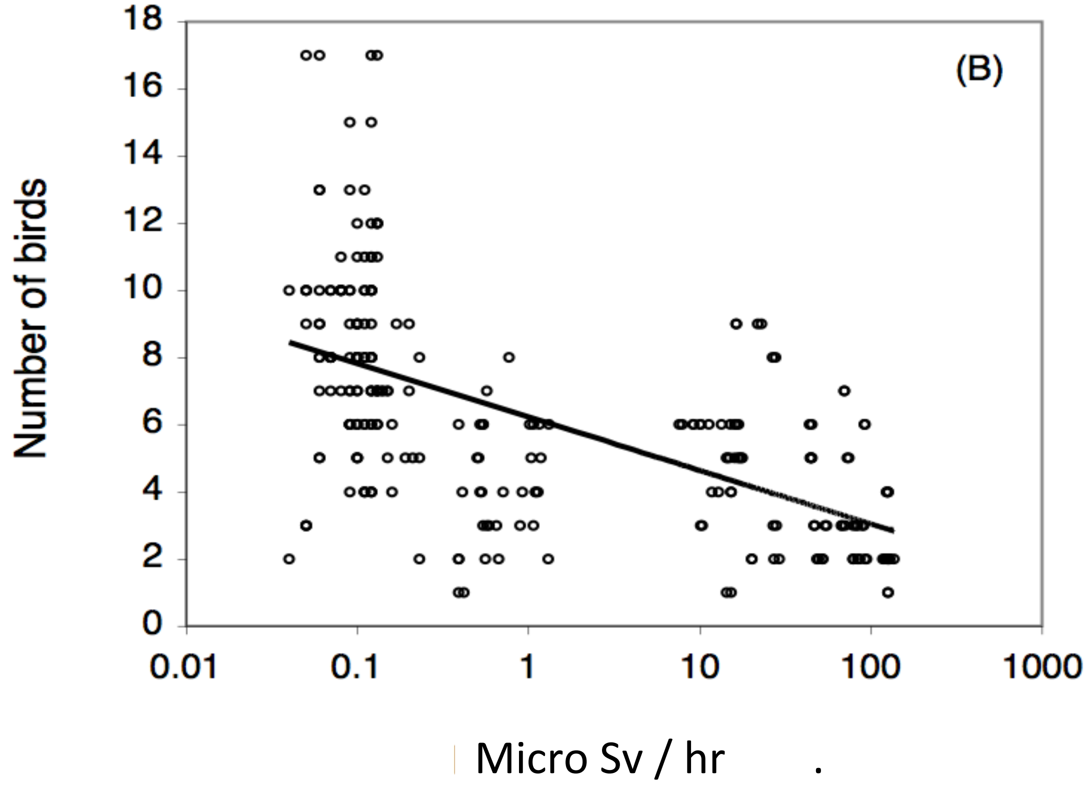
J Ornithol
DOI 10.1007/s10336-015-1197-2

REVIEW

Cumulative effects of radioactivity from Fukushima on the abundance and biodiversity of birds

A. P. Møller[1] · I. Nishiumi[2] · T. A. Mousseau[3,4]

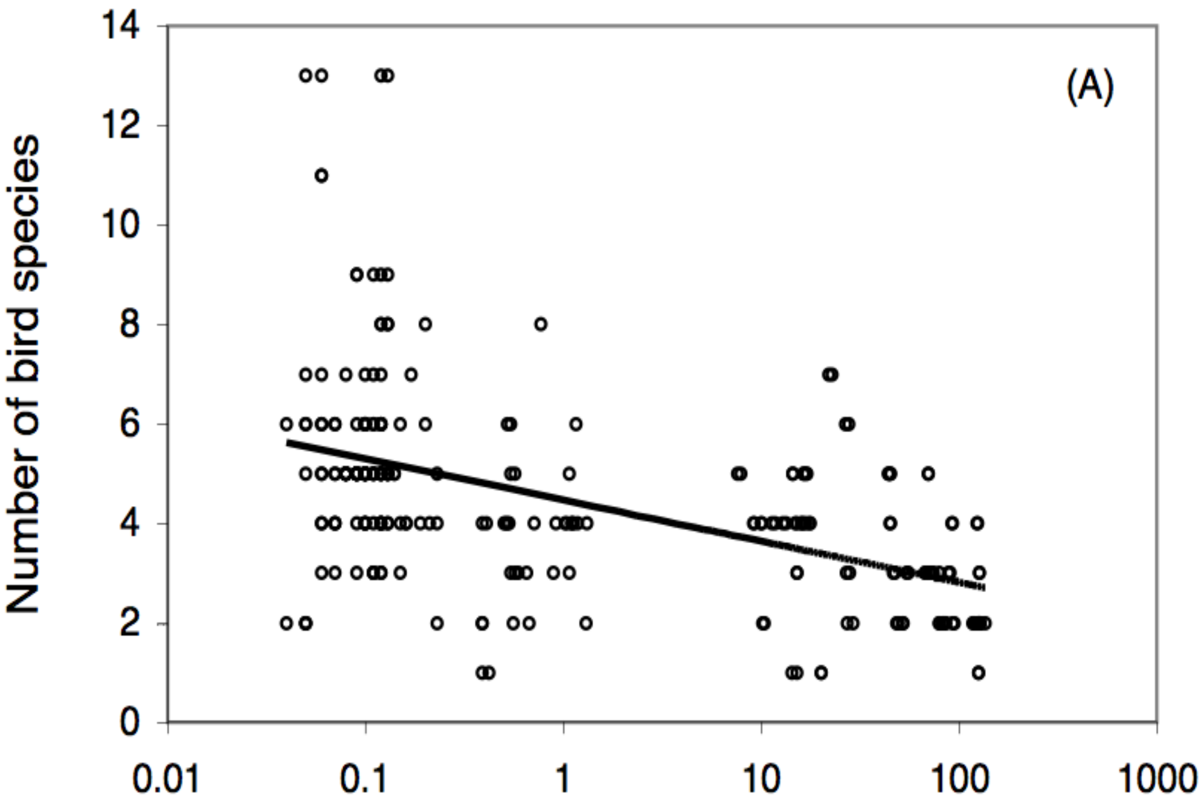
Abundance of birds depressed by more than 66%



Moller & Mousseau. 2007. Biology Letters of the Royal Society
Moller & Mousseau. 2010. Ecological Indicators.

Bird Biodiversity depressed by more than 50%

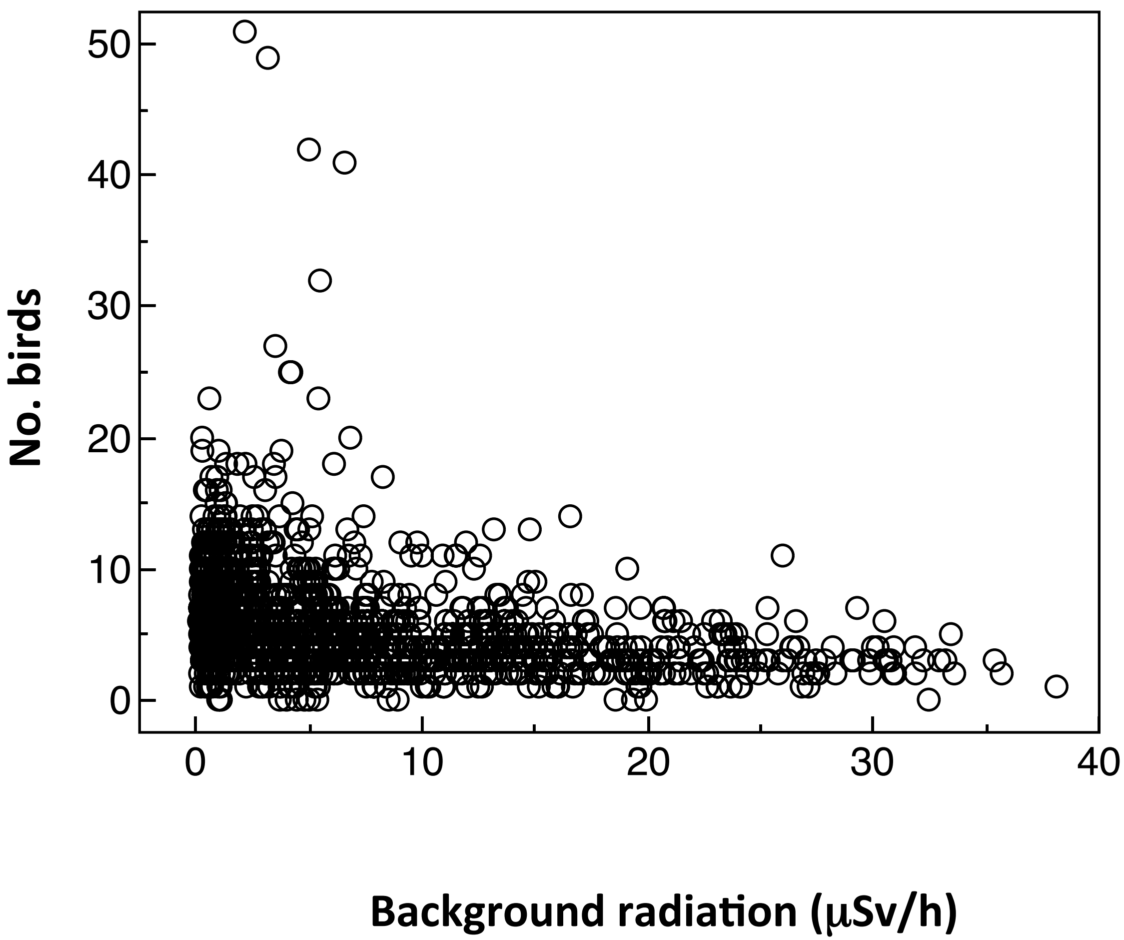
Long distance migrants and brightly colored birds are most affected



Micro Sv / hr .

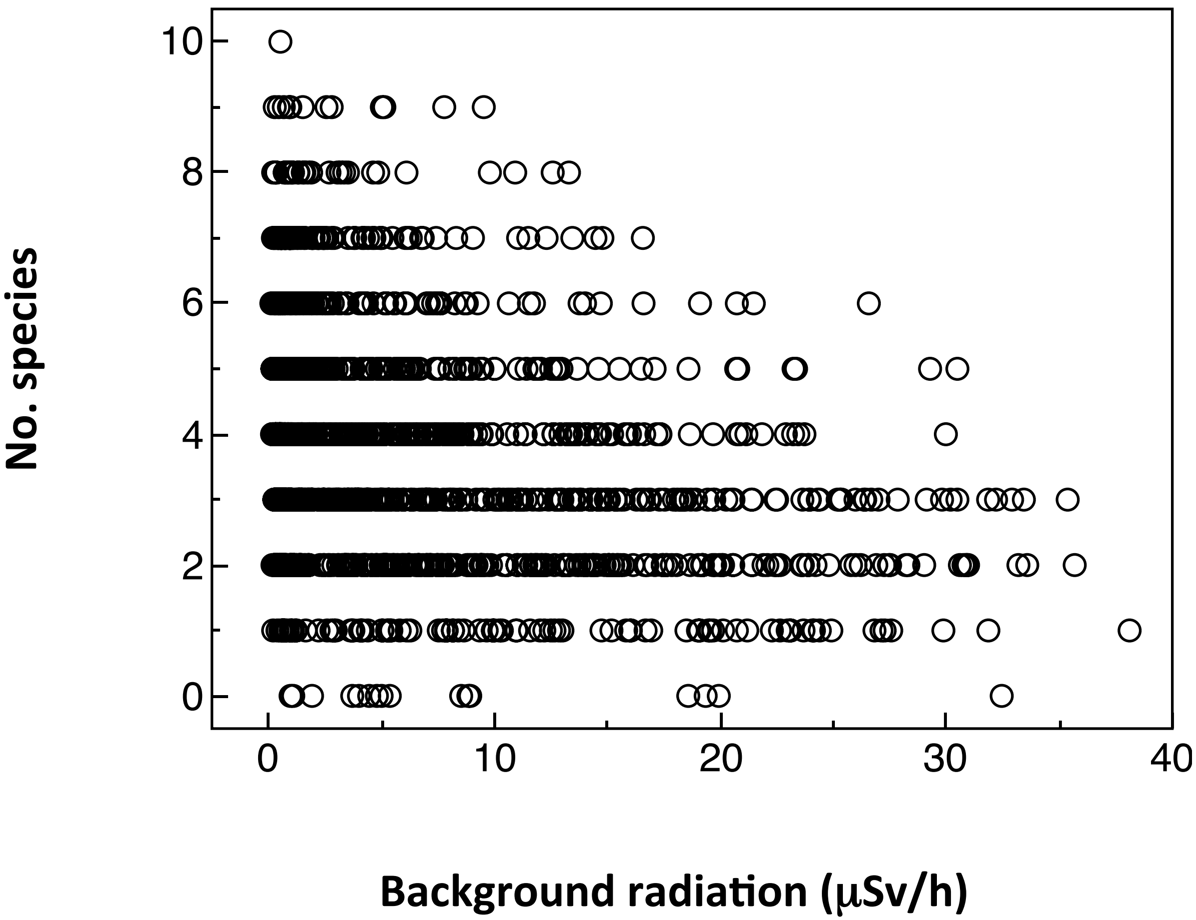
Moller & Mousseau. 2007. J. Applied Ecology

Abundance and radiation – Fukushima Birds 2011-14



$\chi^2 = 241.93, P < 0.0001$

Species richness and radiation - Fukushima Birds 2011-14



$\chi^2 = 100.30$, $P < 0.0001$

“cold” site - < 0.6 usv/h

Hot Site – about 30 usv/h

What does this all mean?

- Contrary to governmental reports, there is now an abundance of information demonstrating consequences (i.e. injury) to individuals, populations, species, and ecosystem function stemming from the low dose radiation due to the Chernobyl and Fukushima disasters.

Major Findings from studies of Wildlife in Chernobyl:

1) Most organisms studied show significantly increased rates of genetic damage in direct proportion to the level of exposure to radioactive contaminants
2) Many organisms show increased rates of deformities and developmental abnormalities in direct proportion to contamination levels
3) Many organisms show reduced fertility rates…..
4) Many organisms show reduced life spans……
5) Many organisms show reduced population sizes…..
6) Biodiversity is significantly decreased…… many species locally extinct.

More speculative, but potentially larger impact:

7) Mutations are passed from one generation to the next, and show signs of accumulating over time.
8) Mutations are migrating out of affected areas into populations that are not exposed (collateral damage).

What is the solution? Create huge piles of radioactive dirt?

What should be done?

- We are calling for funding of in international scientific effort to fully document the range of biological consequences related to low-dose-rate radiation in the environment.
- Such an effort must be led by independent scientists who are committed to a rigorous, unbiased analysis of the present situation with the goal of predicting long term impacts.

Publications, photos and press coverage

- http://cricket.biol.sc.edu/chernobyl/Chernobyl_Research_Initiative/Publications.html