Chernobyl, Fukushima, and Other Hot Places

Timothy A. Mousseau[1] & Anders P. Møller[2]
Andrea Bonisoli-Alquati[1]
Gennadi Milinevski[3]

[1] University of South Carolina
[2] CNRS, France
[3] Taras Shevchenko University of Kyiv

Sponsored by:

The Samuel Freeman Charitable Trust,
USC College of Arts & Sciences,
USC Office of Research, CNRS (France),
Fulbright Foundation, Qiagen GmbH, National Science Foundation,
National Institutes of Health, National Geographic Society, CRDF, NATO

Chernobyl + Fukushima Research Initiative

- **Began in 2000 by T.A. Mousseau and A.P.** Møller
- **Studies of natural populations of birds, insects, microbes and plants.**
- **Studies of the Children of the Narodichesky region of Ukraine.**
- **As evolutionary biologists, mainly interested in documenting adaptation and impacts of elevated mutation rates on population processes.**

Scientific Publications by the Chernobyl Research Initiative (Moller, Mousseau, et al.) since 2001: http://cricket.biol.sc.edu/chernobyl/

1. Møller, A.P., I. Nishiumi, H. Suzuki, K. Ueda, and T.A. Mousseau. 2013. Differences in effects of radiation on abundance of animals in Fukushima and Chernobyl. **Ecological Indicators**, in press.
2. Mousseau, T.A., Møller, A.P. 2012. Chernobyl and Fukushima: Differences and Similarities, a biological perspective. **Asian Perspective**, in press.
3. Svendsen, E.R., J.R. Runkle, V.R. Dhara, S. Lin, M. Naboka, T. Mousseau, C. Bennett. 2012. Epidemiological lessons learned from environmental public health disasters: Chernobyl, the World Trade Center, Bhopal, and Graniteville, South Carolina. **International Journal of Environmental Research and Public Health**, 9 (doi:10.3390/ijerph90x00x), in press.
4. Møller, A.P. and T.A. Mousseau. 2012. The effects of natural variation in background radioactivity on humans, animals and other organisms. **Biological Reviews**, in press.
5. Møller, A.P., F. Barnier, and T.A. Mousseau. 2012. Ecosystem effects 25 years after Chernobyl: pollinators, fruit set, and recruitment. **Oecologia**, in press.
6. Beasley, D.A.E., A. Bonisoli-Alquati, S.M. Welch, A. P. Møller, T.A. Mousseau. Effects of parental radiation exposure on developmental instability in grasshoppers (Chorthippus albomarginatus). **Journal of Evolutionary Biology**, in press.
7. Møller, A.P., A. Hagiwara, S. Matsui, S. Kasahara, K. Kawatsu, I. Nishiumi, H. Suzuki, K. Ueda, and T.A. Mousseau. 2012. Abundance of birds in Fukushima as judged from Chernobyl. **Environmental Pollution**, 164:36-39.
8. Møller, A.P., A. Bonisoli-Alquati, G. Rudolfsen, T.A. Mousseau. Elevated mortality among birds in Chernobyl as judged from biased sex and age ratios. **PLoS One**, 7(4):e35223.
9. Møller, A. P., and T.A. Mousseau. 2011. Conservation consequences of Chernobyl and other nuclear accidents. **Biological Conservation**, 144:2787-2798.
10. Mousseau, T.A. and A.P. Møller. 2011. Landscape portrait: A look at the impacts of radioactive contaminants on Chernobyl's wildlife. **Bulletin of the Atomic Scientists.** 67(2): 38-46. (DOI: 10.1177/0096340211399747)
11. Redchuk, T.A., A.I. Rozhok, O.W. Zhuk, I. A. Kozeretska, and T.A. Mousseau. 2012. DNA Methylation in Drosophila melanogaster may depend on lineage heterogeneity. **Cytology and Genetics,** ISSN 0095-4527; 46:58-61.
12. Galvan, I., T.A. Mousseau, and A.P. Møller. 2011. Bird population declines due to radiation exposure at Chernobyl are stronger in species with pheomelanin-based coloration. **Oecologia** 165(4): 827-835 (DOI 10.1007/s00422-010-1860-5)
13. Balbontín, J., F. de Lope, I. G. Hermosell, T. A. Mousseau and A. P. Møller. 2011. Determinants of age-dependent change in a secondary sexual character. **Journal of Evolutionary Biology** 24(2): 440-448. DOI: 10.1111/j.1420-9101.2010.02183.x
14. Møller, A.P. and T.A. Mousseau. 2011. Ten ecological and evolutionary questions about Chernobyl. **Bulletin of the Chernobyl Zone.** In press.
15. 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
16. Møller, A. P., & T.A. Mousseau. 2011. Efficiency of bio-indicators for low-level radiation under field conditions. **Ecological Indicators**, 11 (2): 424-430. DOI: 10.1016.j.ecolind.2010.06.013
17. Møller, A.P., A. Bonisoli-Alquati, G. Rudolfsen, and T.A. Mousseau. 2011. Chernobyl birds have smaller brains. **Public Library of Science – One**, 6(2): Art. No. e16862. DOI: 10.1371/journal.pone.0016862
18. **Serga, S.V., A.I. Rozhok, O.V. Protsenko**, I.A. Kozeretska, and T.A. Mousseau. 2010. Spiroplasma in natural populations of *Drosophila melanogaster* from Ukraine. **Drosophila Information Service,** 93: 148-154.
19. Møller, A.P., J. Erritzoe, F. Karadas, and T. A. Mousseau. 2010. Historical mutation rates predict susceptibility to radiation in Chernobyl birds. **Journal of Evolutionary Biology,** 23(10): 2132-2142. DOI: 10.1111/j.1420-9101.2010.02074.x
20. Bonisoli-Alquati, A., , **A. Voris,** T. A. Mousseau, A. P. Møller, N. Saino, and M. Wyatt. 2010. DNA damage in barn swallows (*Hirundo rustica*) from the Chernobyl region detected by the use of the Comet assay. **Comparative Biochemistry and Physiology C- Toxicology & Pharmacology** 151: 271-277.
21. Bonisoli-Alquati, A., T. A. Mousseau, A. P. Møller, M. Caprioli, and N. Saino. 2010. Increased oxidative stress in barn swallows from the Chernobyl region. **Comparative Biochemistry and Physiology**. **Part A: Molecular & Integrative Physiology,** 155: 205-210.
22. Czirjak, G.A., A.P. Møller, T.A. Mousseau, P. Heeb. 2010. Microorganisms associated with feathers of barn swallows in radioactively contaminated areas around Chernobyl. **Microbial Ecology** 60(2): 373-380.
23. E.R. Svendsen, I.E. Kolpakov, Y.I. Stepanova, V.Y. Vdovenko, M.V. Naboka, T.A. Mousseau, L.C. Mohr, D.G. Hoel, W.J.J. Karmaus. 2010. ^{137}Cesium exposure and spirometry measures in Ukrainian children affected by the Chernobyl nuclear incident. **Environmental Health Perspectives**, 118: 720-725 .
24. Møller, A.P., and T.A. Mousseau. 2009. Reduced abundance of insects and spiders linked to radiation at Chernobyl 20 years after the accident. **Biology Letters of the Royal Society** 5(3): 356-359.
25. Kravets, A.P., Mousseau, T.A., Litvinchuk, A.V., Ostermiller, S. 2010. Association of P-Mobile element activity and DNA methylation pattern changes in conditions of Drosophila melanogaster prolonged irradiation. **Cytology and Genetics** 44(4): 217-220.
26. Kravets A.P, T.A. Musse (T.A. Mousseau), Omel'chenko1 Zh. A., Vengjen G.S. 2010. Dynamics of hybrid dysgenesis frequency in *Drosophila melanogaster* in controlled terms of protracted radiation exposure. **Cytology and Genetics**, 44(4): 262.
27. Kravets A.P, T.A. Musse (T.A. Mousseau), Omel'chenko1 Zh. A., Vengjen G.S. 2010. Dynamics of hybrid dysgenesis frequency in *Drosophila melanogaster* in controlled terms of protracted radiation exposure. **Cytology and Genetics**, 44(3): 144-148.
28. Kravets A.P., Mousseau T.A., Litvinchuk A.V., Ostermiller S., Vengzhen G.S. and D.M. Grodzinskiy. 2010. Wheat plant DNA methylation pattern changes at chronic seed γ- irradiation. **Cytology and Genetics**, 44(5): 276-279.
29. Kravets A.P., T.A. Mousseau, Omel'chenko1 Zh. A. 2010. Transformation of dose dependences of P-mobile element activity following acute and chronic radiation. **Radiation Biology & Radioecology**, in press (in Russian).
30. Gaschak, S., M. Bondarkov, Ju. Makluk, **A. Maksimenko, V. Martynenko,** I. Chizhevsky, and T.A. Mousseau. 2009. Assessment of radionuclide export from Chernobyl zone via birds 18 years following the accident. Radioprotection 44(5): 849-852.
31. Stepanova, E., W. Karmaus, M. Naboka, V. Vdovenko, T. Mousseau, V. Shestopalov, J. Vena, E. Svendsen, D. Underhill, and H. Pastides. 2008. Exposure from the Chernobyl accident had adverse effects on erythrocytes, leukocytes, and, platelets in children in the Narodichesky region, Ukraine. A 6-year follow-up study. **Environmental Health**, 7:21.
32. Kozeretska, I.A., **A.V. Protsenko, E.S. Afanas'eva**, S.R. Rushkovskii, A.I. Chuba, T.A. Mousseau, and A.P. Møller. 2008. Mutation processes in natural populations of *Drosophila melanogaster* and *Hirundo rustica* from radiation-contaminated regions of Ukraine. **Cytology and Genetics** 42(4) : 267-271.
33. Møller, A. P., T.A Mousseau. 2008. Reduced abundance of raptors in radioactively contaminated areas near Chernobyl. **Journal of Ornithology**, 150(1):239-246.
34. Møller, A. P., T.A. Mousseau and G. Rudolfsen. 2008. Females affect sperm swimming performance : a field experiment with barn swallows *Hirundo rustica*. **Behavioral Ecology** 19(6):1343-1350.
35. Møller, A. P., F. Karadas, & T. A. Mousseau. 2008. Antioxidants in eggs of great tits Parus major from Chernobyl and hatching success. **J. Comp. Physiol. B. 178:735-743.**
36. Gashak, S.P., Y.A. Maklyuk, **A.M. Maksimenko**, V.M. Maksimenko, V.I. Martinenko, I.V. Chizhevsky, M.D. Bondarkov, T.A. Mousseau. 2008. The features of radioactive contamination of small birds in Chernobyl Zone in 2003-2005. **Radiobiology and Radioecology** 48: 27-47.(Russian).
37. Møller, A. P., T. A. Mousseau, **C. Lynn,** S. Ostermiller, and G. Rudolfsen. 2008. Impaired swimming behavior and morphology of sperm from barn swallows *Hirundo rustica* in Chernobyl. **Mutation Research**, Genetic Toxicology and Environmental Mutagenesis, **650:210-216.**
38. Møller, A. P., T. A. Mousseau, F. de Lope and N. Saino. 2008. Anecdotes and empirical research in Chernobyl. **Biology Letters, 4:65-66**.
39. A.P. Møller, T.A Mousseau. 2007. Species richness and abundance of forest birds in relation to radiation at Chernobyl. **Biology Letters of the Royal Society**, 3: 483-486.
40. A.P. Møller, T.A Mousseau. 2007. Determinants of interspecific variation in population declines of birds after exposure to radiation at Chernobyl. **Journal of Applied Ecology**, 44: 909-919.
41. A.P. Møller, T.A Mousseau . 2007. Birds prefer to breed in sites with low radioactivity in Chernobyl. **Proceedings of the Royal Society**, 274:1443-1448.
42. A.P. Møller, T.A. Mousseau, F. de Lope, and N. Saino. 2007. Elevated frequency of abnormalities in barn swallows from Chernobyl. **Biology Letters of the Royal Society,** 3: 414-417.
43. O.V. Tsyusko, M.B. Peters, C. Hagen, T.D. Tuberville, T.A. Mousseau, A.P. Møller and T.C. Glenn. 2007. Microsatellite markers isolated from barn swallows (Hirundo rustica). **Molecular Ecology Notes**, 7: 833-835.
44. A. P. Møller, T. A. Mousseau. 2006. Biological consequences of Chernobyl: 20 years after the disaster. **Trends in Ecology and Evolution**, 21: 200-207.
45. A. P. Møller, K. A. Hobson, T. A. Mousseau and A. M. Peklo. 2006. Chernobyl as a population sink for barn swallows: Tracking dispersal using stable isotope profiles. **Ecological Applications**, 16:1696-1705.
46. A. P. Møller, T. A. Mousseau, G. Milinevsky, A. Peklo, E. Pysanets and T. Szép. 2005. Condition, reproduction and survival of barn swallows from Chernobyl. **Journal of Animal Ecology,** 74: 1102-1111.
47. Møller, A. P., Surai, P., and T. A. Mousseau. 2004. Antioxidants, radiation and mutations in barn swallows from Chernobyl. **Proceedings of the Royal Society, London**, 272: 247-252.
48. Shestopalov, V., M. Naboka, E. Stepanova, E. Skvarska, T. Mousseau, and Y.Serkis. 2004. Risk assessment of morbidity under conditions with different levels of radionuclides and heavy metals. **Bulletin of the Chernobyl Zone** 24(2): 40-47. (In Ukrainian).
49. Møller, A. P., and T. A. Mousseau. 2003. Mutation and sexual selection: A test using barn swallows from Chernobyl. **Evolution**, 57: 2139-2146.
50. Møller, A. P. and T. A. Mousseau . 2001. Albinism and phenotype of barn swallows *Hirundo rustica* from Chernobyl. **Evolution**, 55 (10): 2097-2104.

Major Findings from studies of Wildlife in Chernobyl and Fukushima:

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.
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 (i.e. population bystander effects).

Animal Models – Provide Clues to Human Populations

Birds don't usually drink, smoke or get depressed!

The Barn Swallow,
Hirundo rustica

Phylopatric

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?**

Massively Replicated Biotic Inventories
(700 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

+

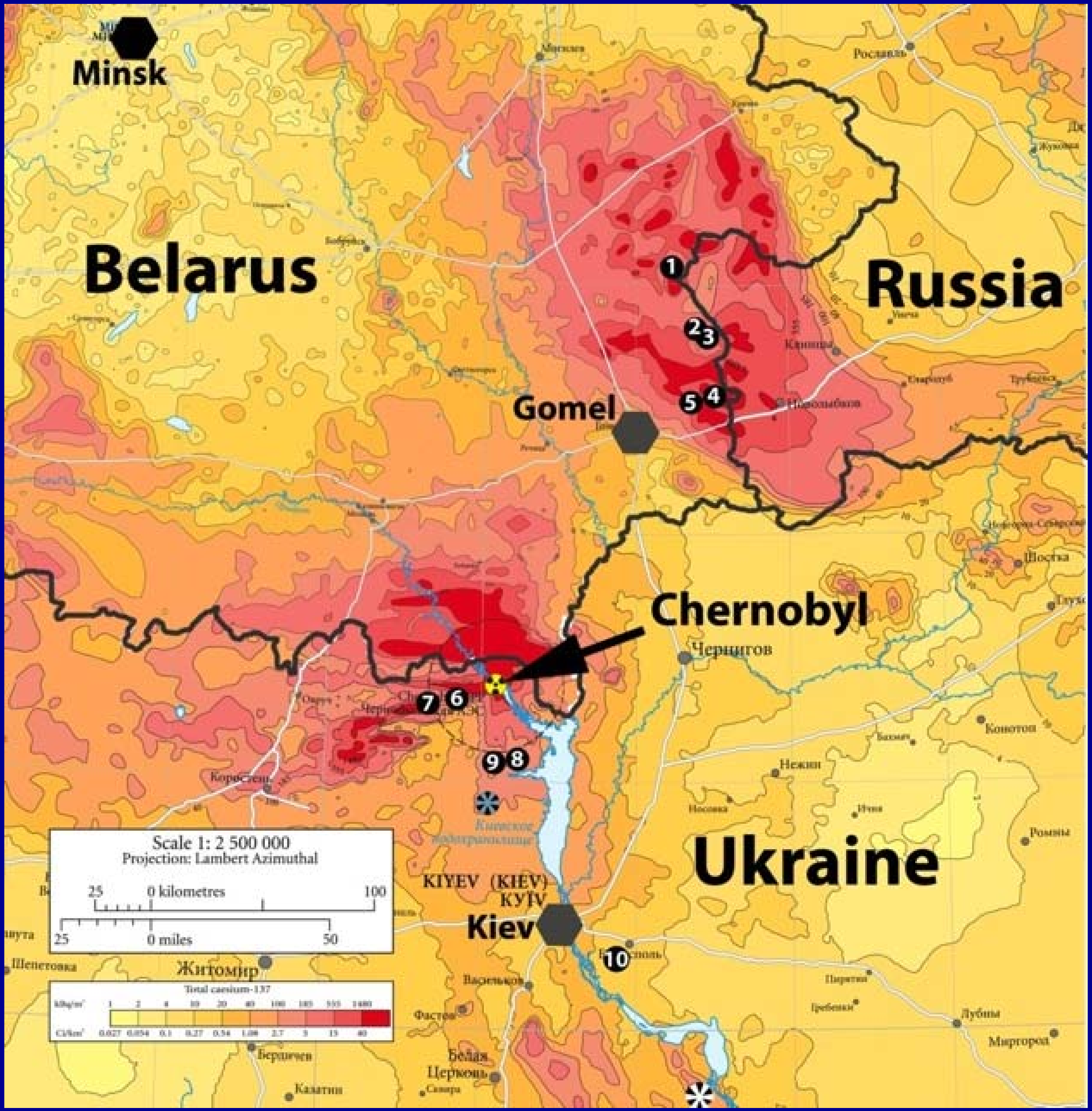
GIS

+

Multivariate Statistics

=

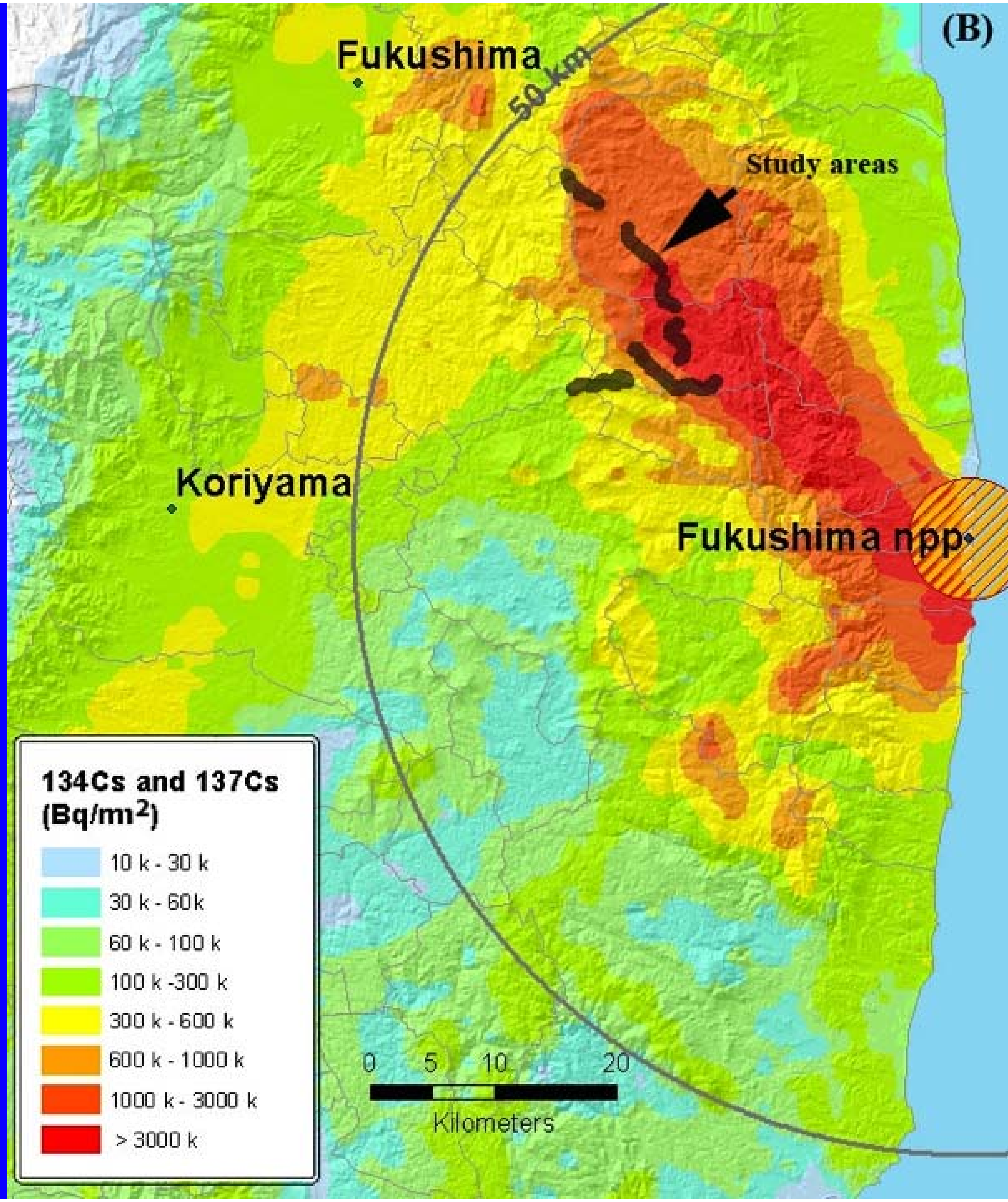
Predictive Models of Radiation Effects on Populations

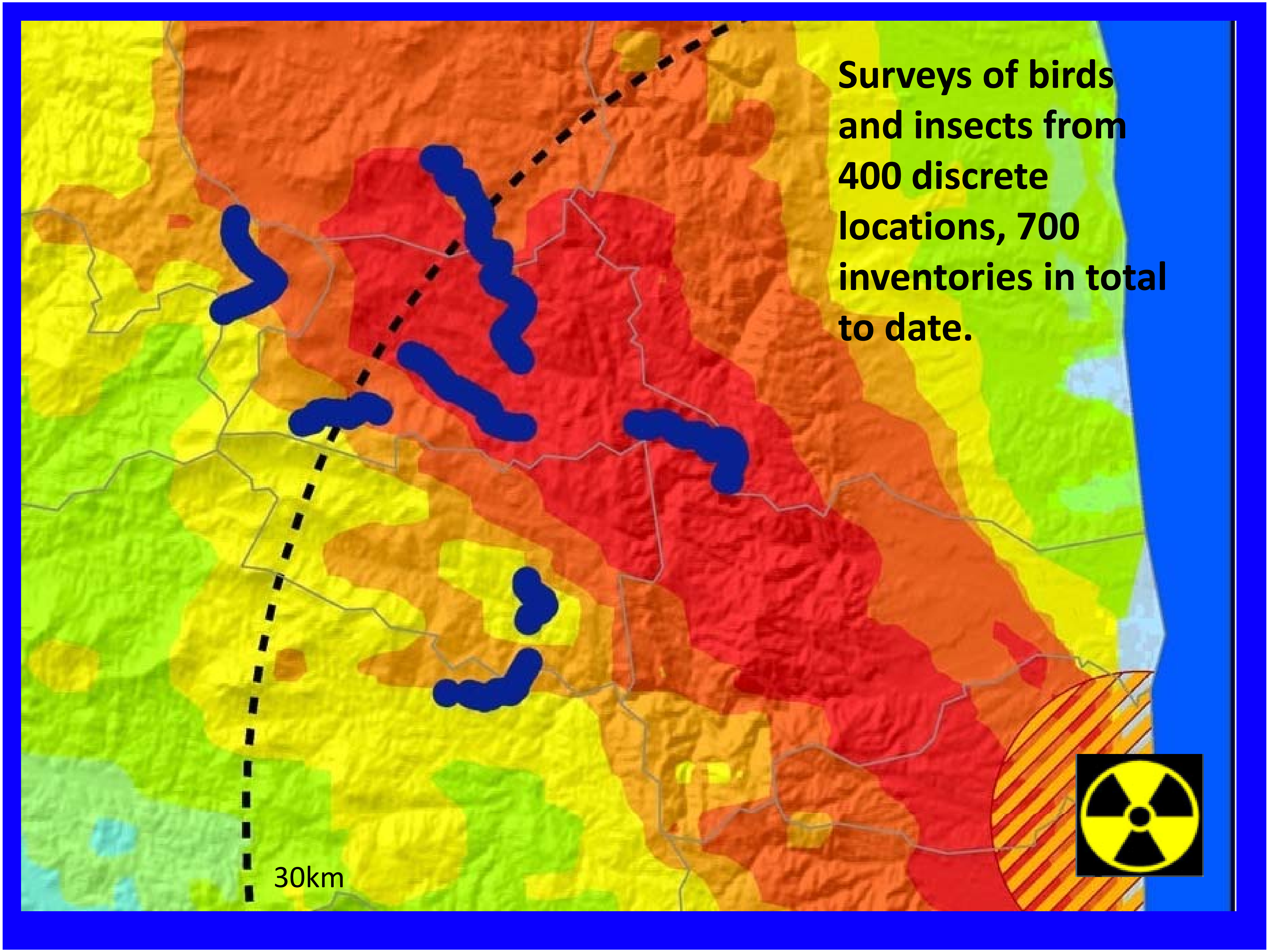


896 bird and insect surveys from locations in Ukraine and Belarus

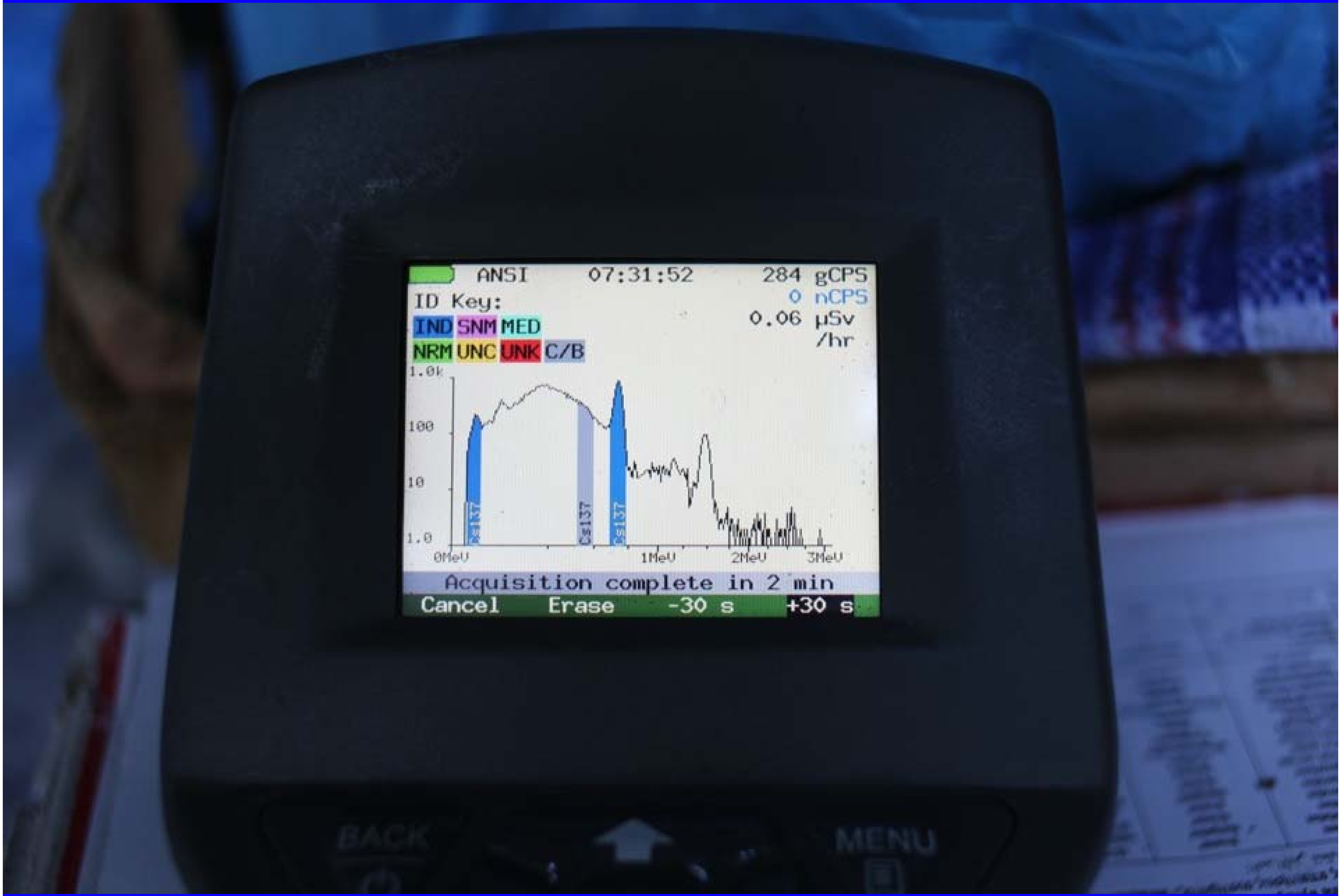
Control Populations:

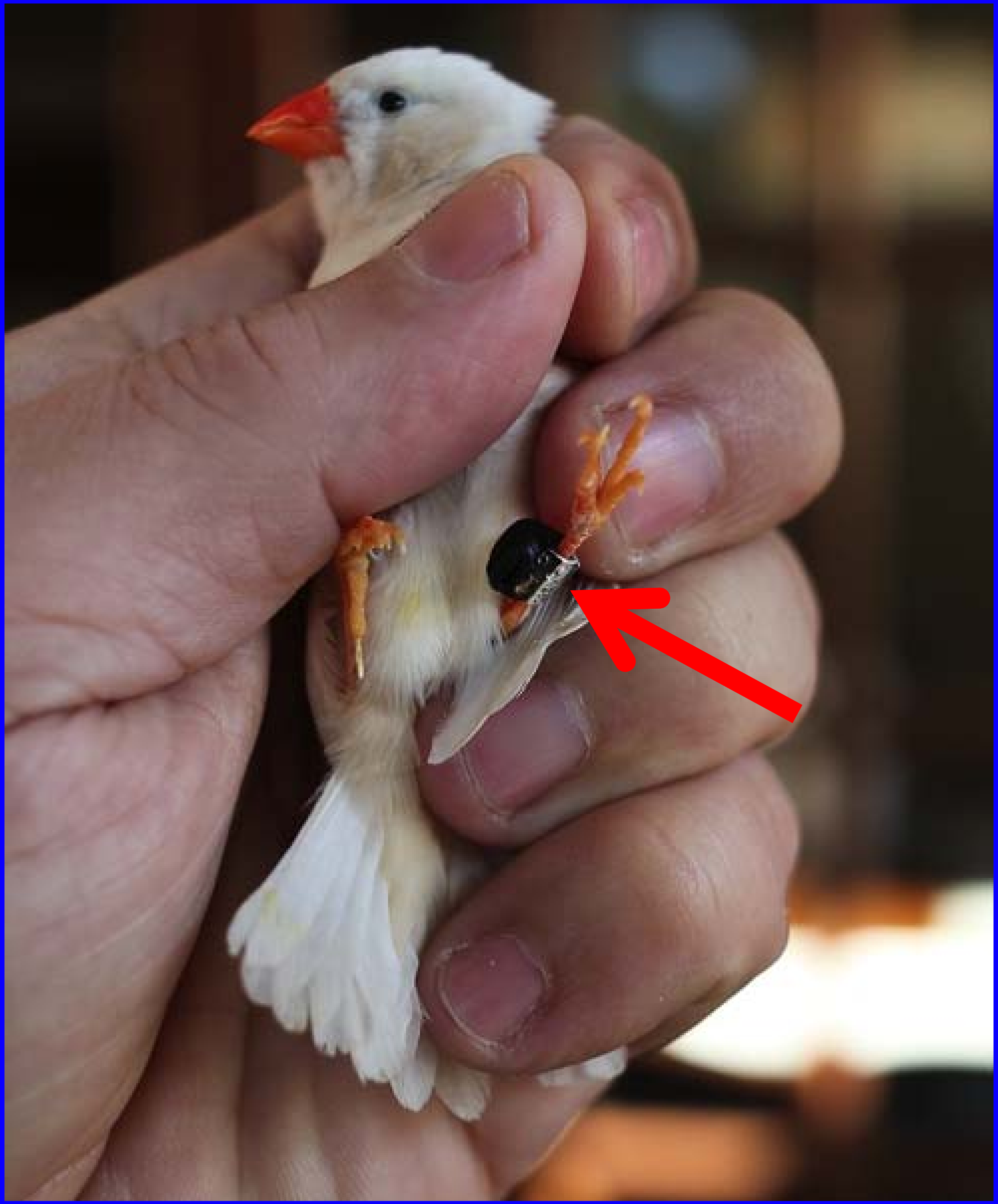
- Italy (Milan)
- Spain (Badajoz)
- Denmark (Aalborg)
- Ukraine (Borispil)


(B)
Fukushima
50 km
Study areas
Koriyama
Fukushima npp
134Cs and 137Cs
(Bq/m2)
10 k - 30 k
30 k - 60 k
60 k - 100 k
100 k -300 k
300 k - 600 k
600 k - 1000 k
1000 k - 3000 k
> 3000 k
0 5 10 20
Kilometers

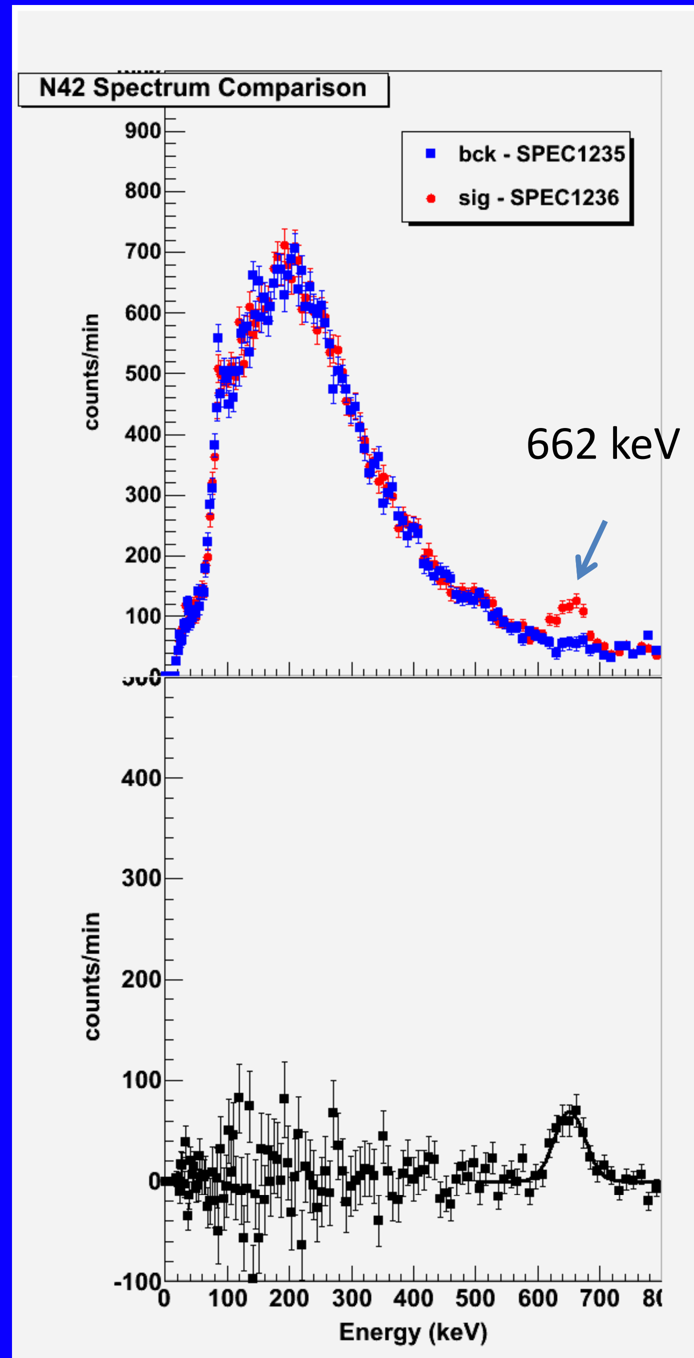

Surveys of birds and insects from 400 discrete locations, 700 inventories in total to date.
30km

“Radioactive Robin” with Jeremy Wade and Tim Mousseau near Chernobyl cooling pond.


ANSI 07:31:52 284 gCPS
0 nCPS
0.06 µSv /hr
ID Key:
IND SNM MED
NRM UNC UNK C/B
Cs137
Cs137
Cs137
0MeV 1MeV 2MeV 3MeV
Acquisition complete in 2 min
Cancel Erase -30 s +30 s
BACK
MENU

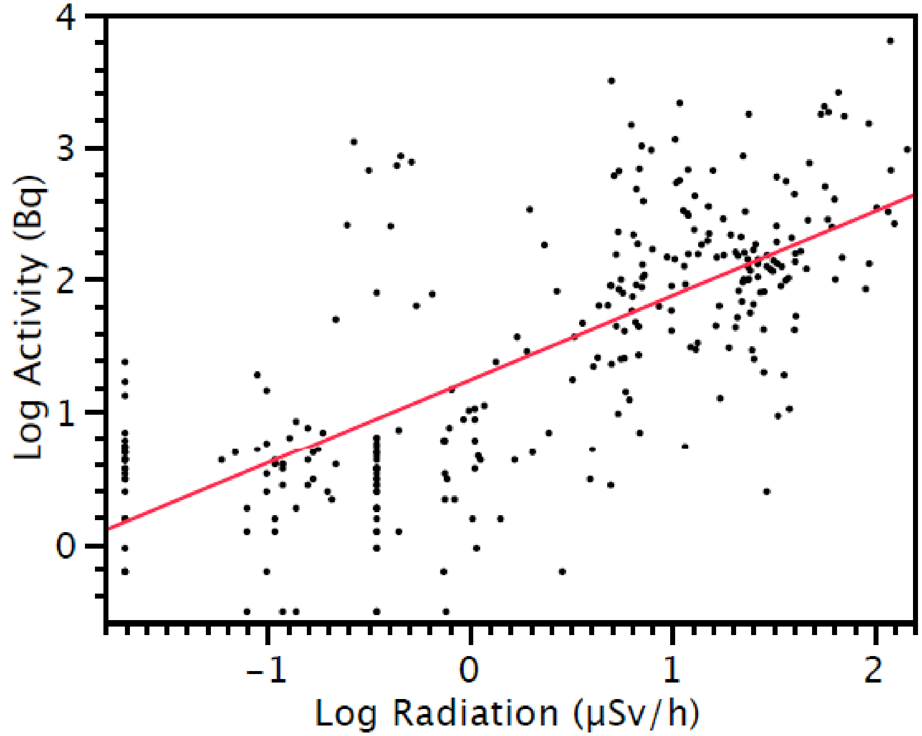


"TLD" dosimeters to measure external radiation dose received by bird is attached to bird leg band.



N42 Spectrum Comparison
bck - SPEC1235
sig - SPEC1236
662 keV
counts/min
counts/min
Energy (keV)

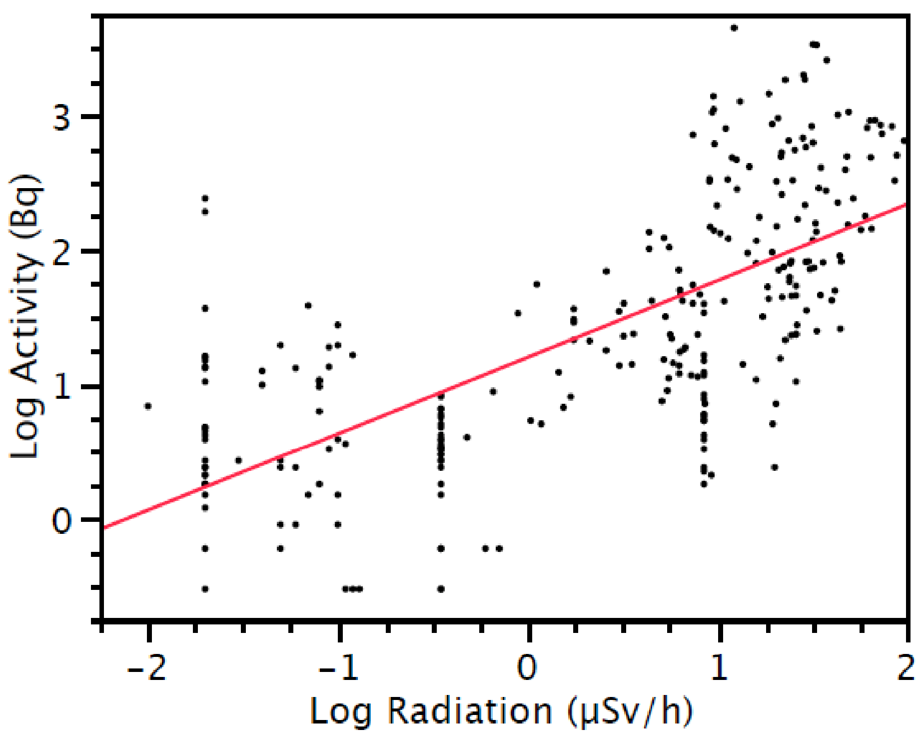
Activity vs Environmental Measurements



May

N = 307; slope = 0.63 (0.03 SE);

$t_{306} = 18.66; P < 0.0001; R^2 = 0.53$

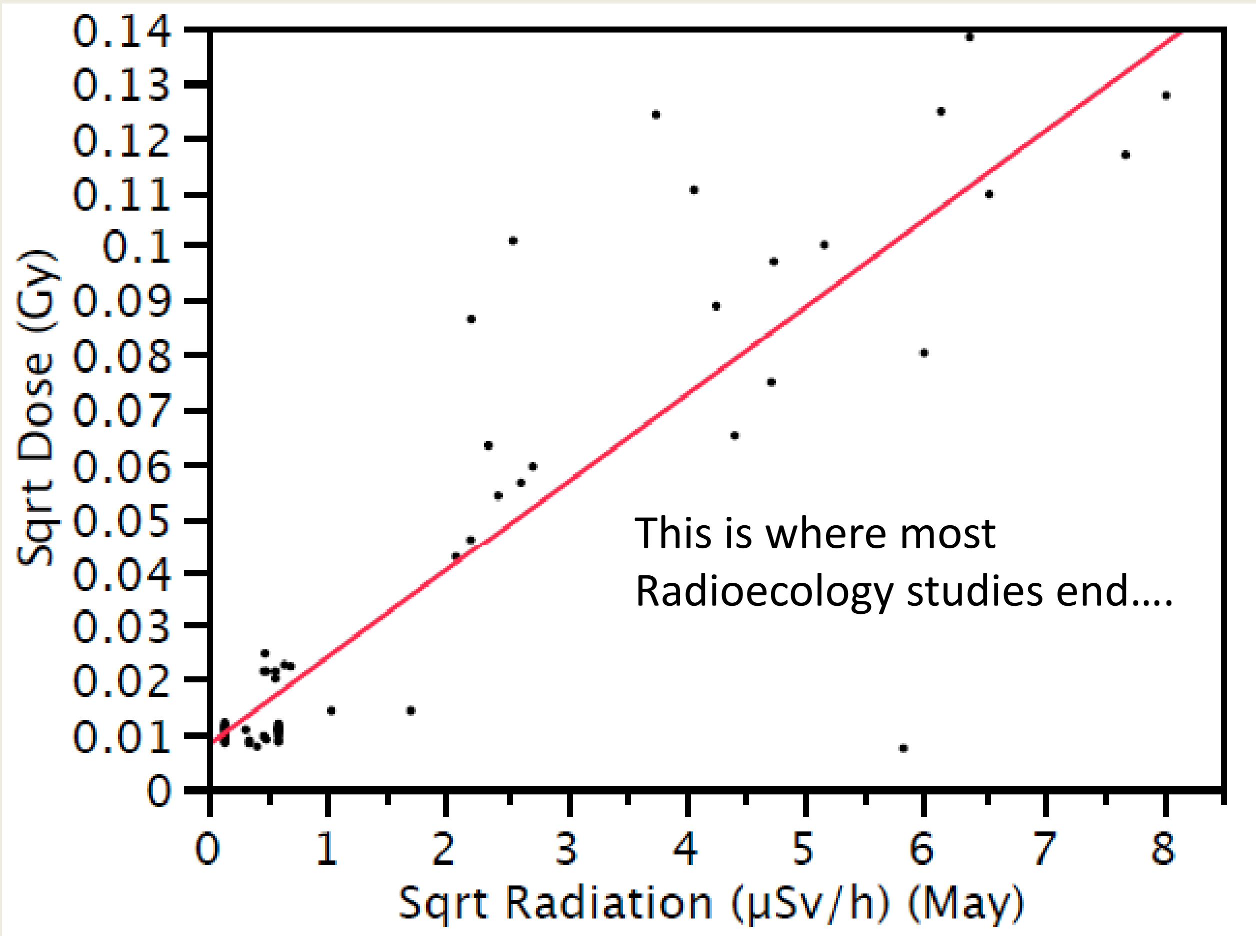


June

N = 279; slope = 0.57 (0.03 SE);

$t_{278} = 15.52; P < 0.0001; R^2 = 0.47$

External Dose Correlates with Radiation at First Capture



N = 75; slope = 0.016 (0.001 SE);

t_{74} = 16.42; P < 0.0001; R^2 = 0.79

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….

But:

No quantitative data in support of this position and it avoids the primary question of whether or not there are injuries to populations and the ecosystem as a result of radioactive contaminants.

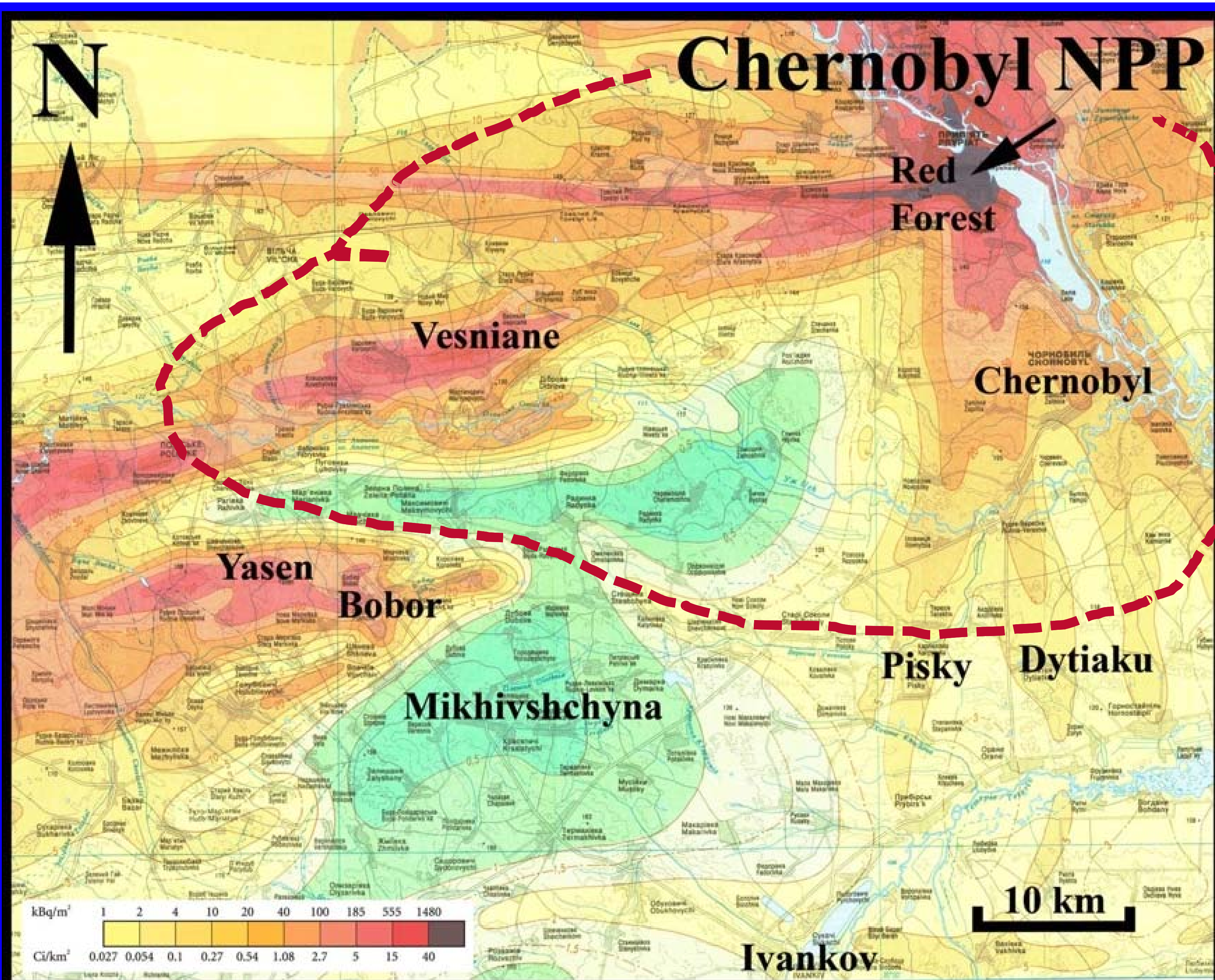

T.A.Mousseau (c) 2012

Chernobyl in Recovery?

The return of plants, animals and people give the appearance that health and environmental consequences of radioactive contaminants are negligible.

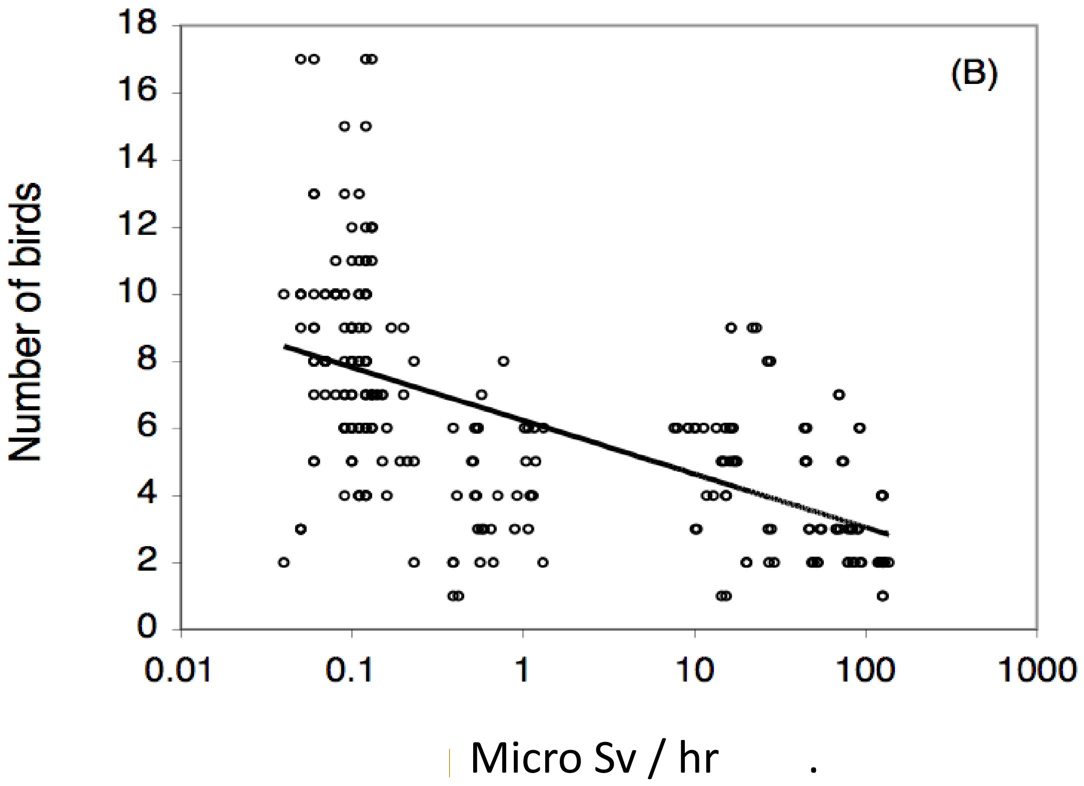
Is this correct?

In 2005, no data available to accept or refute this hypothesis.



Chernobyl NPP
N
Red Forest
Vesniane
Chernobyl
Yasen
Bobor
Pisky
Dytiaku
Mikhivshchyna
Ivankov
10 km
kBq/m²: 1, 2, 4, 10, 20, 40, 100, 185, 555, 1480
Ci/km²: 0.027, 0.054, 0.1, 0.27, 0.54, 1.08, 2.7, 5, 15, 40

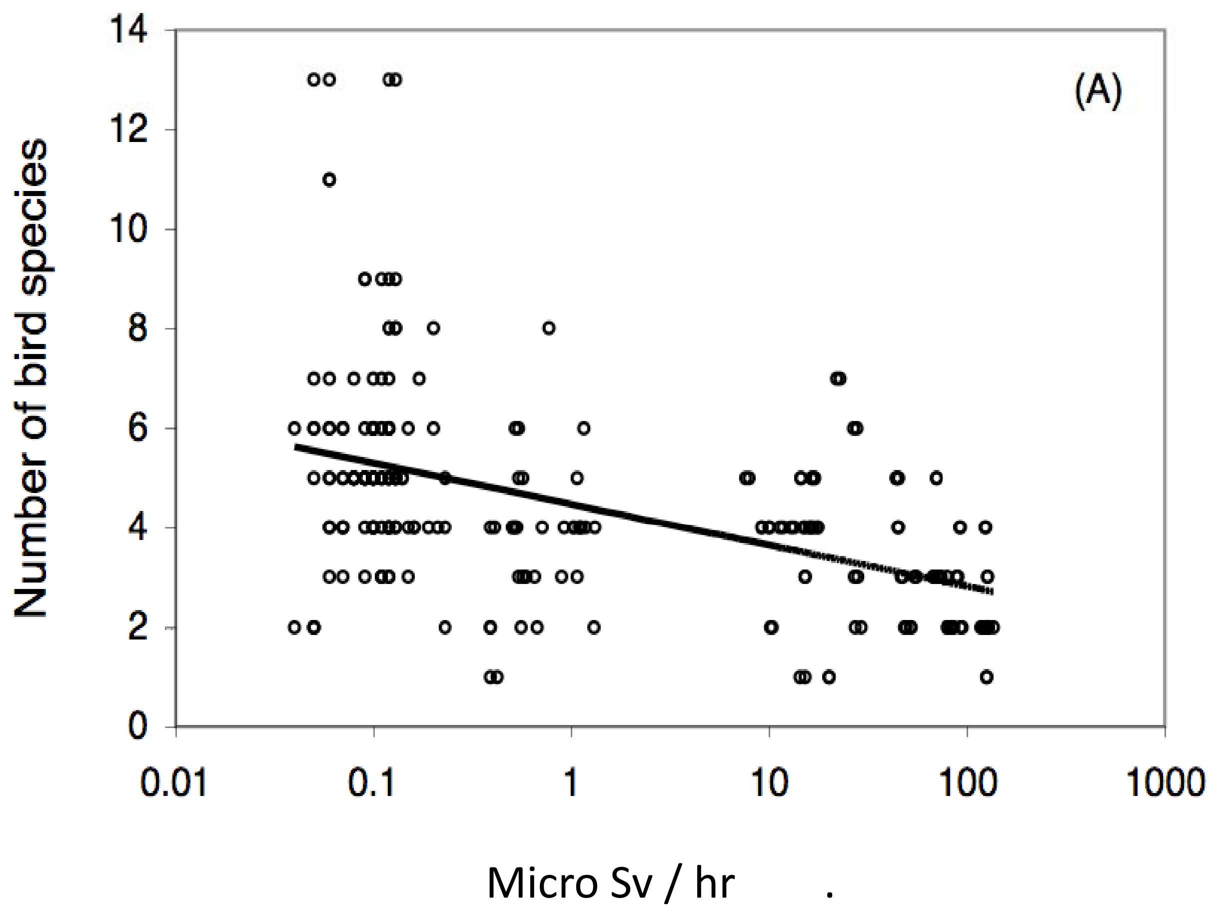
Abundance of birds depressed by more than 66%



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

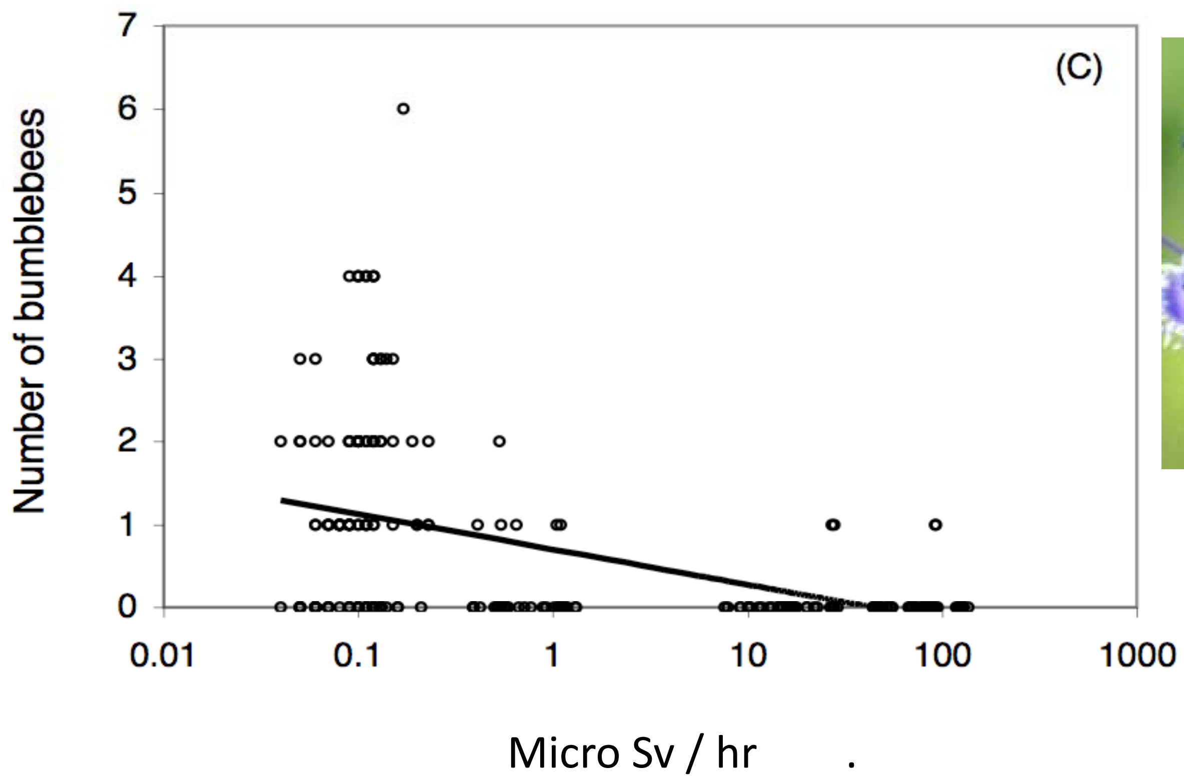
Biodiversity depressed by more than 50%

Long distance migrants and brightly colored birds are most affected



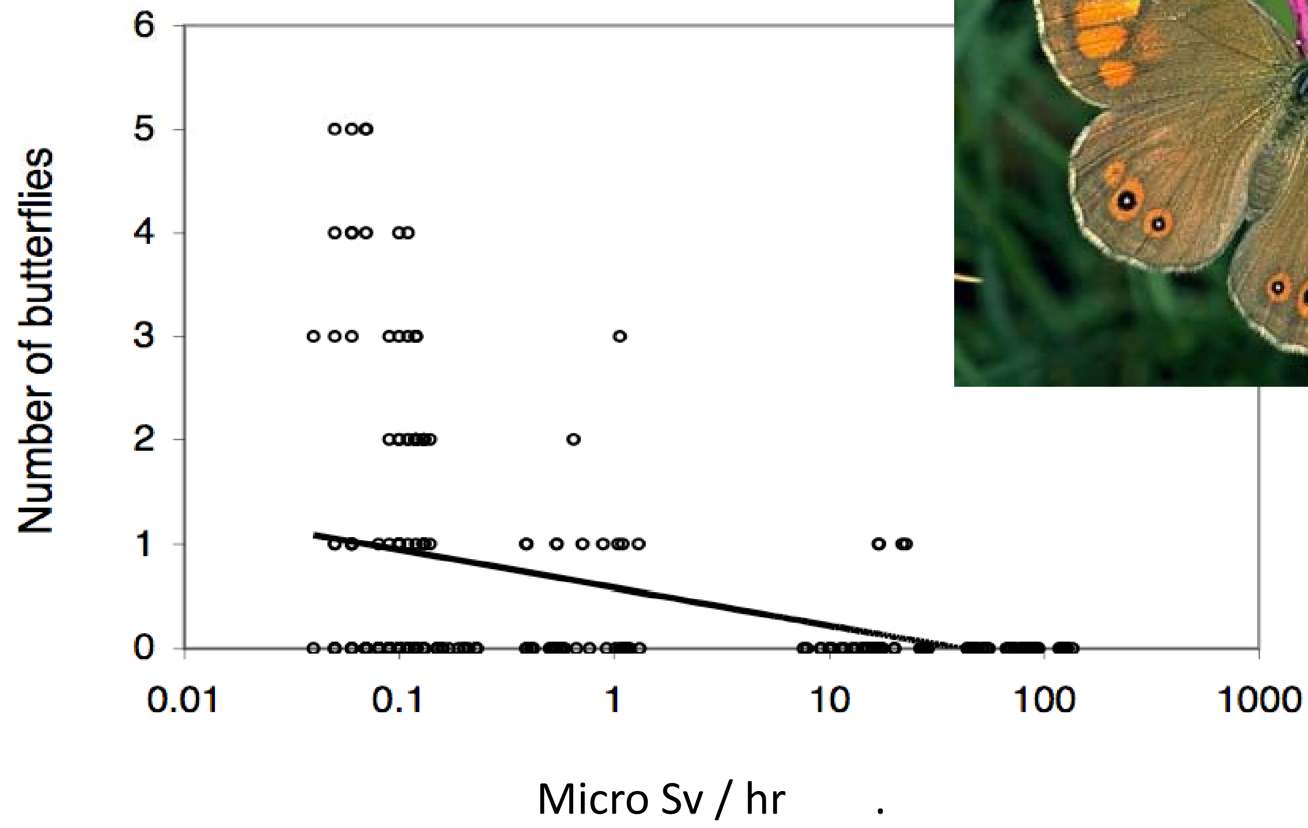
Moller & Mousseau. 2007. J. Applied Ecology

Abundance of bumblebees and radiation



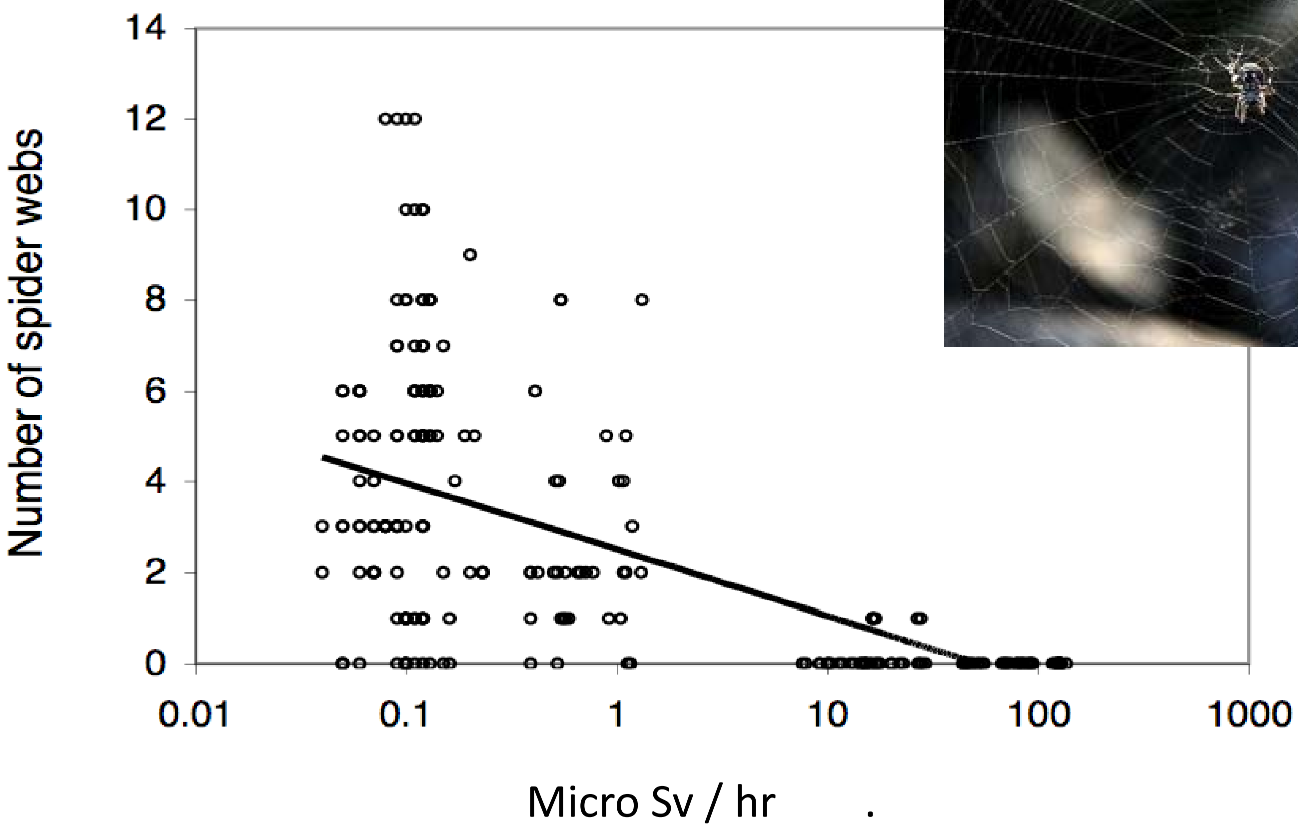
Moller & Mousseau. 2009. Biology Letters of the Royal Society

Abundance of butterflies and radiation

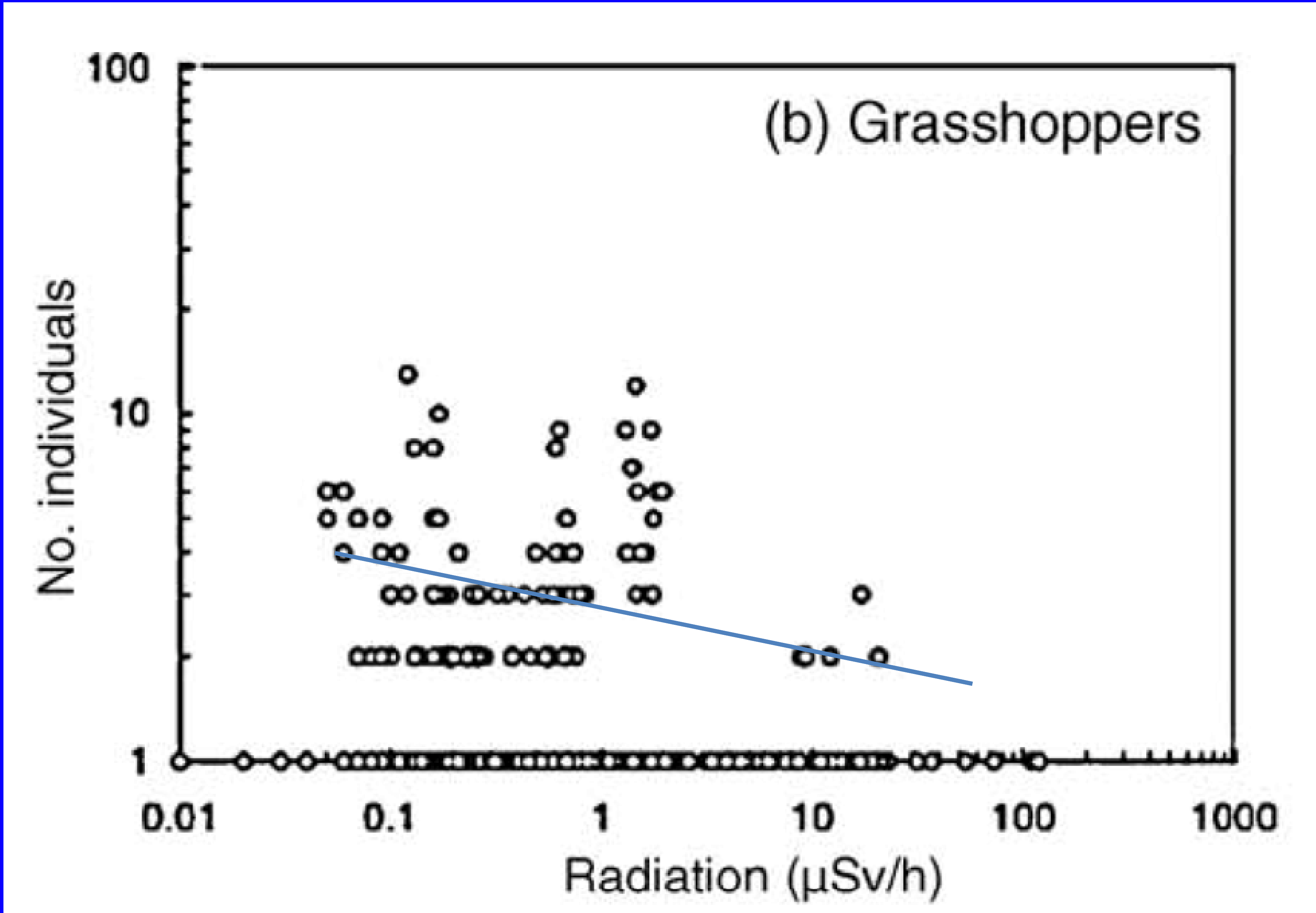


Moller & Mousseau. 2009. Biology Letters of the Royal Society

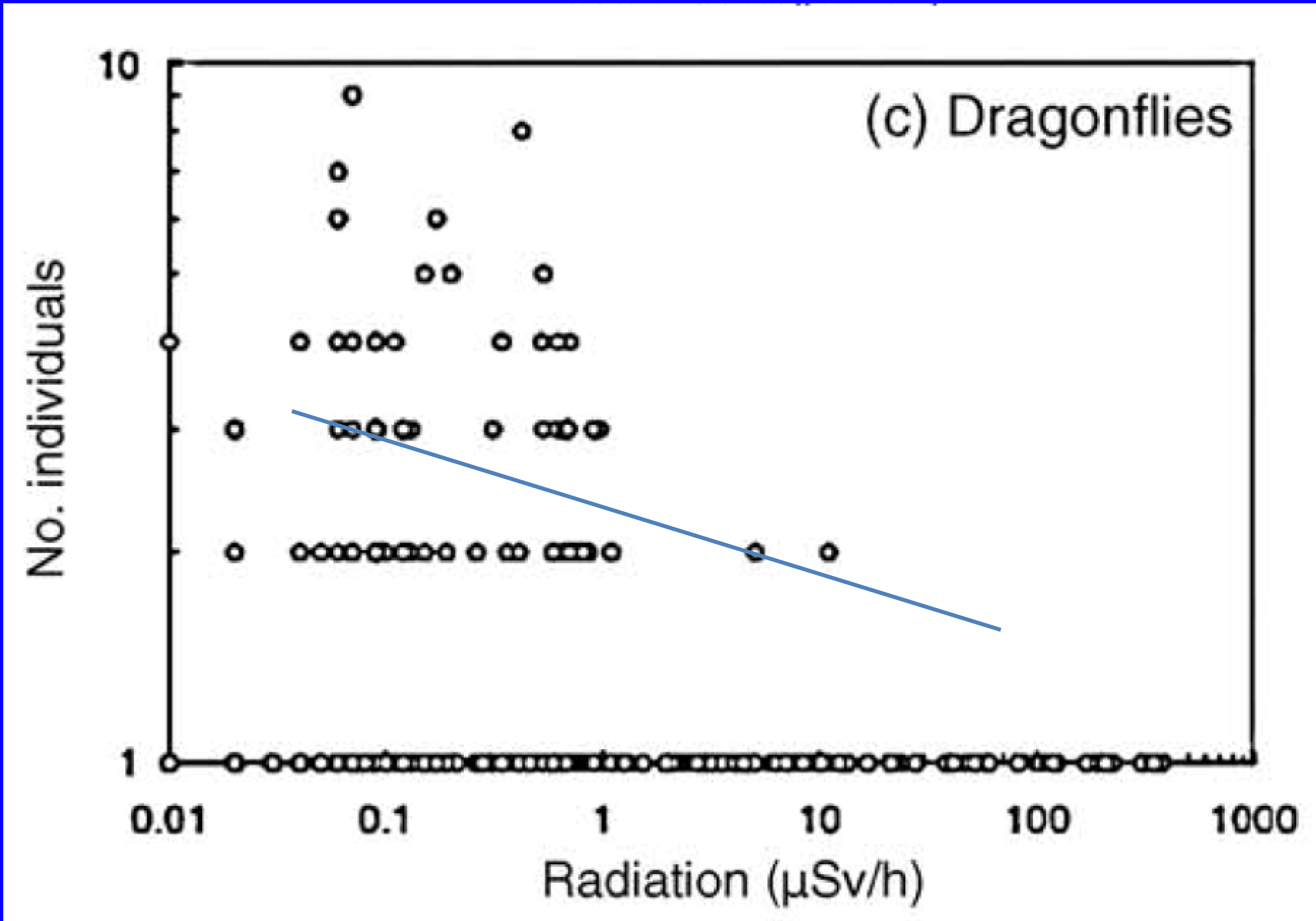
Abundance of spiders and radiation



Moller & Mousseau. 2009. Biology Letters of the Royal Society



Moller and Mousseau. 2010. Ecological Indicators.
Mousseau and Moller. 2011. Bulletin of the Atomic Scientists.

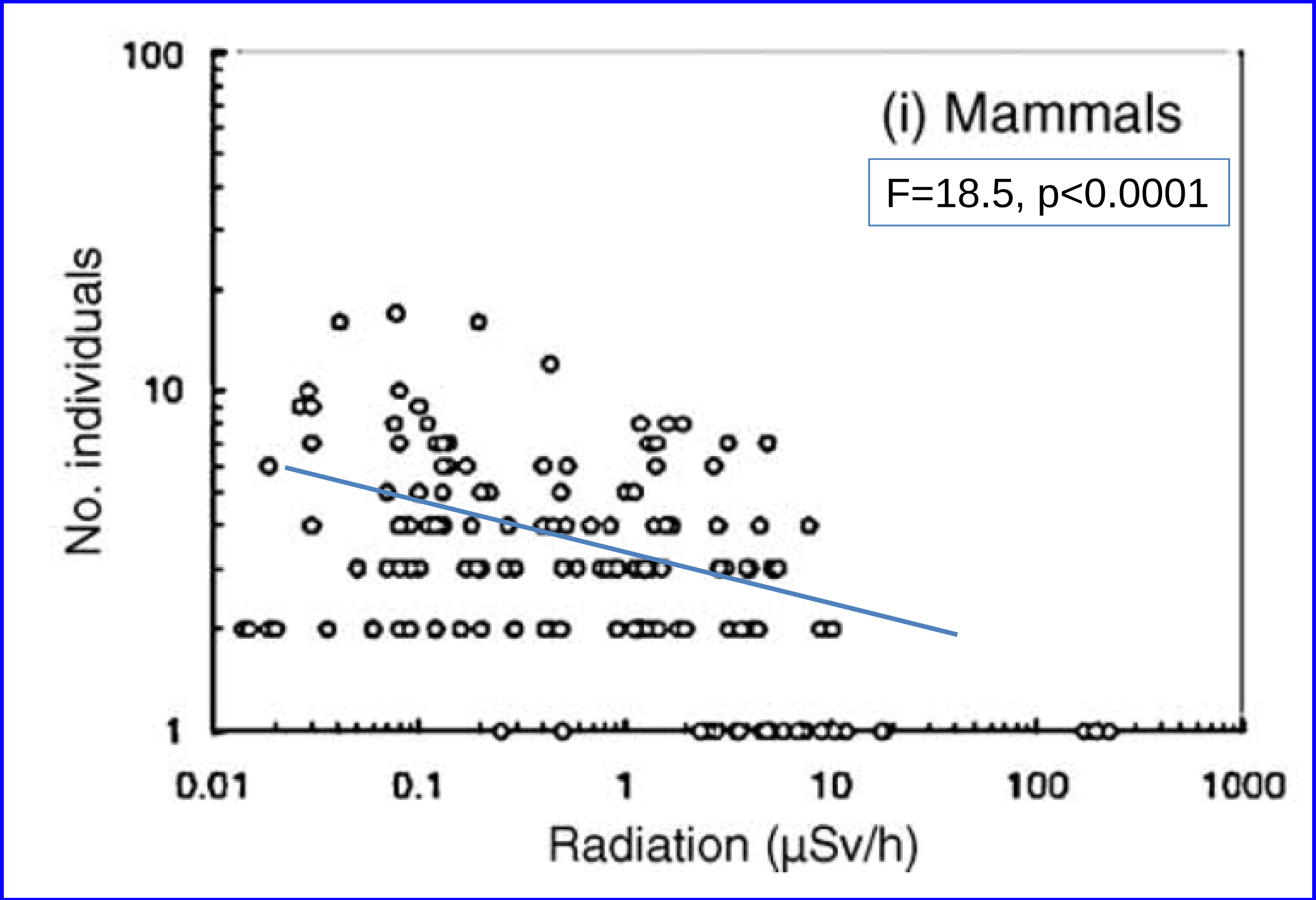


Moller and Mousseau. 2010. Ecological Indicators.
Mousseau and Moller. 2011. Bulletin of the Atomic Scientists.


STAINLESS STEEL
12"
STAINLESS
STEEL RULER

Interspecific interactions

Mammals show significant declines in areas of high contamination.



Moller and Mousseau. 2010. Ecological Indicators.
Mousseau and Moller. 2011. Bulletin of the Atomic Scientists.

BBC NEWS

WATCH One-Minute World News

News Front Page

Africa
Americas
Asia-Pacific
Europe
Middle East
South Asia
UK
Business
Health
Science/Nature
Technology
Entertainment
Also in the news

Video and Audio

Have Your Say
In Pictures
Country Profiles
Special Reports

RELATED BBC SITES

Last Updated: Tuesday, 14 August 2007, 23:38 GMT 00:38 UK

E-mail this to a friend   Printable version

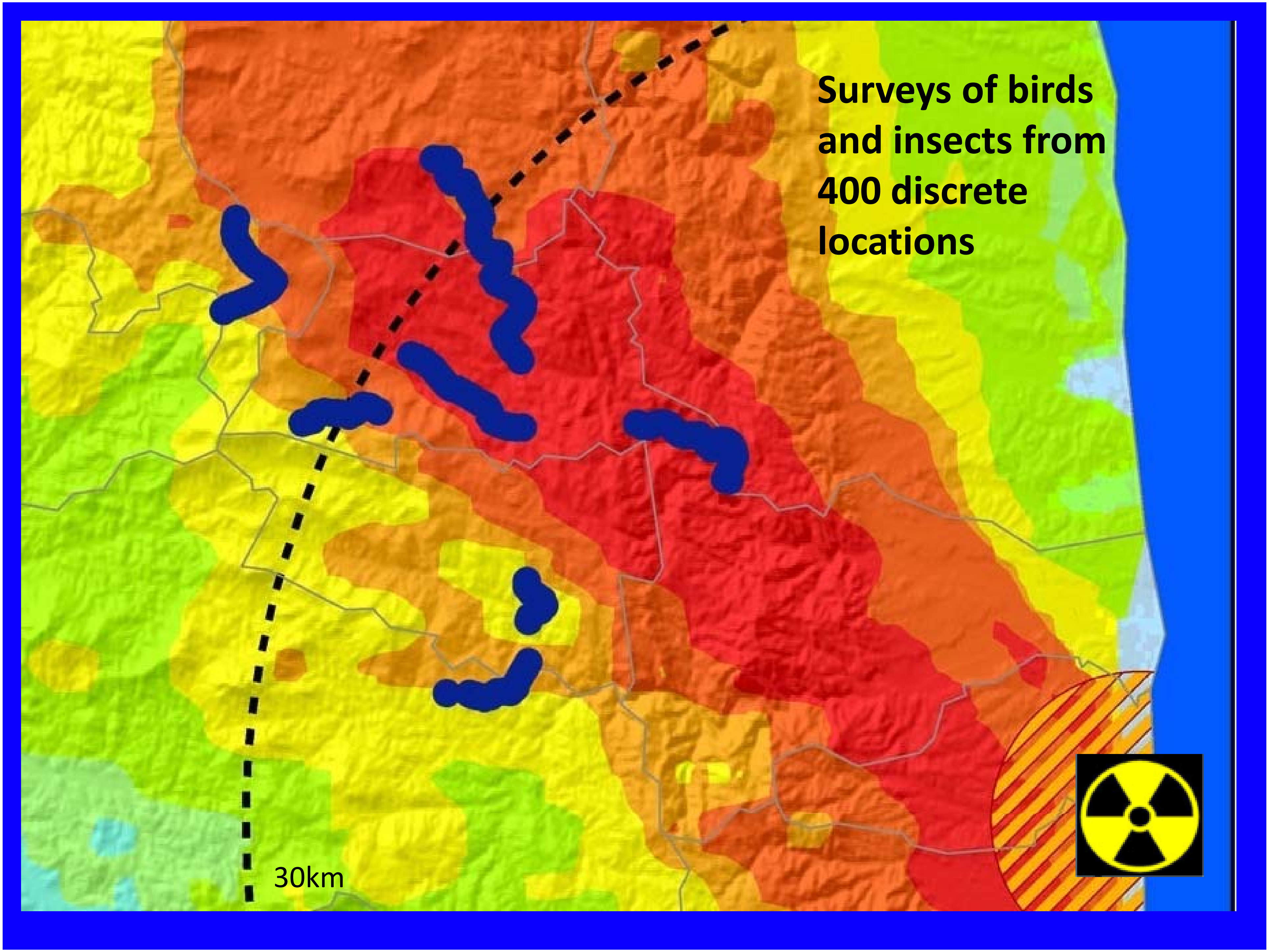
Chernobyl 'not a wildlife haven'

By Mark Kinver
Science and nature reporter, BBC News

The idea that the exclusion zone around the Chernobyl nuclear power plant has created a wildlife haven is not scientifically justified, a study says.

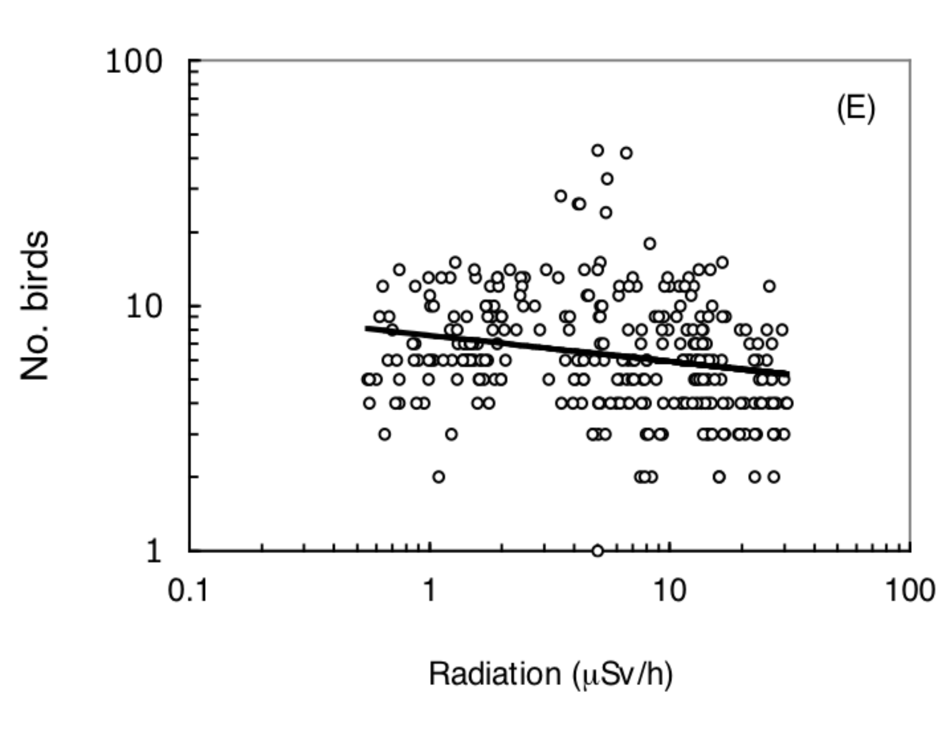
Recent studies said rare species had thrived despite raised radiation levels as a result of no human activity.

But scientists who assessed the 1986 disaster's impact on birds said the ecological effects were "considerably greater than previously assumed".


Surveys of birds
and insects from
400 discrete
locations
30km

Fukushima 2011

Chernobyl 2006-09



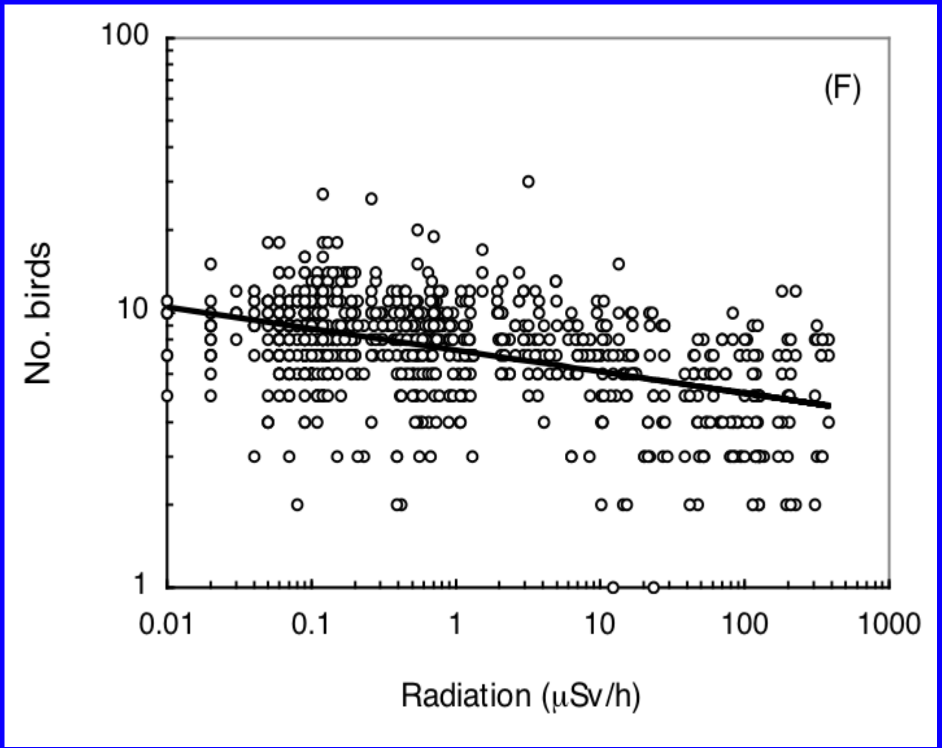


Table 1. Bird abundance in Fukushima and Chernobyl in relation to radiation level.

	SS	d.f.	*F*	*P*	Estimate (SE)
Fukushima:					
No. bird individuals	0.775	1, 298	14.89	0.0001	-0.105 (0.027)
Chernobyl:					
No. bird individuals	6.973	1, 896	256.89	< 0.0001	-0.078 (0.005)

A.P. Møller, A. Hagiwara, S. Kasahara, S. Matsui, I. Nishiumi, H. Suzuki, K. Ueda and T. A. Mousseau. 2012. Environmental Pollution.

The Economist

Radiation and evolution

Surviving fallout

Birds can evolve to cope with the lingering effects of nuclear incidents

Mar 3rd 2012 | from the print edition

And the raven, never flitting, still is sitting

THE disaster last year at the Fukushima Dai-ichi nuclear power plant, caused by an earthquake and tsunami, scored seven on the International Nuclear and Radiological Event Scale (INES). No worse rating exists. Radiation is harmful to living things, yet the long-term effects of persistently high levels of background radiation on ecosystems are poorly understood. With this in mind, a team led by Timothy Mousseau of the University of South Carolina and Anders Moller of the University of Paris-Sud set out to compare bird species dwelling near the Fukushima plant with those living at the site of another nuclear incident that scored a seven on the INES: the Ukrainian town of Chernobyl, where disaster struck in 1986. Remarkably, they found that some species seem to develop a tolerance for radioactivity over time.

Can organisms evolve adaptations to cope with nuclear fallout?

Table 1
Species richness of birds and abundance of different animal taxa in Fukushima and Chernobyl in relation to radiation level.

	Sum of squares	d.f.	*F*	*P*	Estimate (SE)
Fukushima					
No. bird individuals	0.775	1, 298	14.89	0.0001	−0.105 (0.027)
No. bird species	0.181	1, 298	6.77	0.010	−0.051 (0.020)
No. bumblebees	0.001	1, 298	0.16	0.69	0
No. butterflies	4.553	1, 298	37.18	<0.0001	−0.254 (0.042)
No. cicadas	0.208	1, 298	19.24	<0.0001	−0.054 (0.012)
No. dragonflies	0.127	1, 298	0.87	0.35	0
No. grasshoppers	0.004	1, 298	0.22	0.64	0
No. spiders	0.636	1, 298	14.12	0.0002	+0.095 (0.025)
Chernobyl					
No. mammals	3.669	1, 159	57.28	<0.0001	−0.182 (0.024)
No. bird individuals	6.973	1, 896	256.89	<0.0001	−0.078 (0.005)
No. bird species	4.124	1, 896	172.85	<0.0001	−0.060 (0.005)
No. reptiles	0.093	1, 896	24.14	<0.0001	−0.009 (0.002)
No. amphibians	0.196	1, 896	14.22	0.0002	−0.005 (0.001)
No. bumblebees	1.595	1, 896	55.71	<0.0001	−0.037 (0.005)
No. butterflies	2.153	1, 896	57.63	<0.0001	−0.043 (0.006)
No. dragonflies	1.195	1, 402	34.58	<0.0001	−0.049 (0.008)
No. grasshoppers	0.891	1, 372	13.58	0.0003	−0.071 (0.019)
No. spiders	5.738	1, 896	81.94	<0.0001	−0.071 (0.008)

Major Findings from studies of Wildlife in Chernobyl and Fukushima:

1) Most organisms studied show significantly increased rates of genetic damage in 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…..

1) Biodiversity is significantly decreased…… many species locally extinct.

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."

New Results:

The question of whether or not abundances of some species (e.g. those subject to hunting) are higher inside the zone is moot. There is now very strong evidence that population abundances and biodiversity are negatively impacted in proportion to level of radioactive contamination levels.

BIOLOGICAL REVIEWS

Cambridge Philosophical Society

Biol. Rev. (2012), pp. 000–000.
doi: 10.1111/j.1469-185X.2012.00249.x

The effects of natural variation in background radioactivity on humans, animals and other organisms

Anders P. Møller[1,*] and 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*

ABSTRACT

Natural levels of radioactivity on the Earth vary by more than a thousand-fold; this spatial heterogeneity may suffice to create heterogeneous effects on physiology, mutation and selection. We review the literature on the relationship between variation in natural levels of radioactivity and evolution. First, we consider the effects of natural levels of radiation on mutations, DNA repair and genetics. A total of 46 studies with 373 effect size estimates revealed a small, but highly significant mean effect that was independent of adjustment for publication bias. Second, we found different mean effect sizes when studies were based on broad categories like physiology, immunology and disease frequency; mean weighted effect sizes were larger for studies of plants than animals, and larger in studies conducted in areas with higher levels of radiation. Third, these negative effects of radiation on mutations, immunology and life history are inconsistent with a general role of hormetic positive effects of radiation on living organisms. Fourth, we reviewed studies of radiation resistance among taxa. These studies suggest that current levels of natural radioactivity may affect mutational input and thereby the genetic constitution and composition of natural populations. Susceptibility to radiation varied among taxa, and several studies provided evidence of differences in susceptibility among populations or strains. Crucially, however, these studies are few and scattered, suggesting that a concerted effort to address this lack of research should be made.

Key words: adaptation, cancer, disease, DNA repair, hormesis, mutation, radioactivity, radio-resistance, radio-tolerance.

Table 2. Mean effect sizes weighted by sample size, their confidence intervals, number of studies, heterogeneity (Q_T) among studies (global test) or among categories, degrees of freedom (d.f.) for the heterogeneity test and probability (P) for this heterogeneity test for different groupings of the data set listed in Table 1

Category	Mean effect size	Bootstrap 95% confidence interval	No. studies	Q_T	d.f.	P
All studies	0.093	0.039, 0.171	66	952.41	65	<0.0001
Animals	0.089	0.071, 0.108	57	39.45	1	<0.0001
Plants	0.749	0.570, 0.878	9	—	—	—
Immunology	0.451	0.018, 0.750	3	70.86	4	<0.0001
Physiology	0.278	−0.029, 0.767	4	—	—	—
Mutation	0.177	0.059, 0.376	31	—	—	—
Disease	0.054	0.004, 0.124	19	—	—	—
Morphology	−0.005	−0.049, 0.006	6	—	—	—
Cancer	0.057	−0.017, 0.158	11	1.49	1	0.22
Other diseases	0.026	0.010, 0.063	8	—	—	—
Confounding variables not controlled	0.056	−0.079, 0.199	17	2.08	1	0.15
Confounding variables controlled	0.098	0.041, 0.184	49	—	—	—

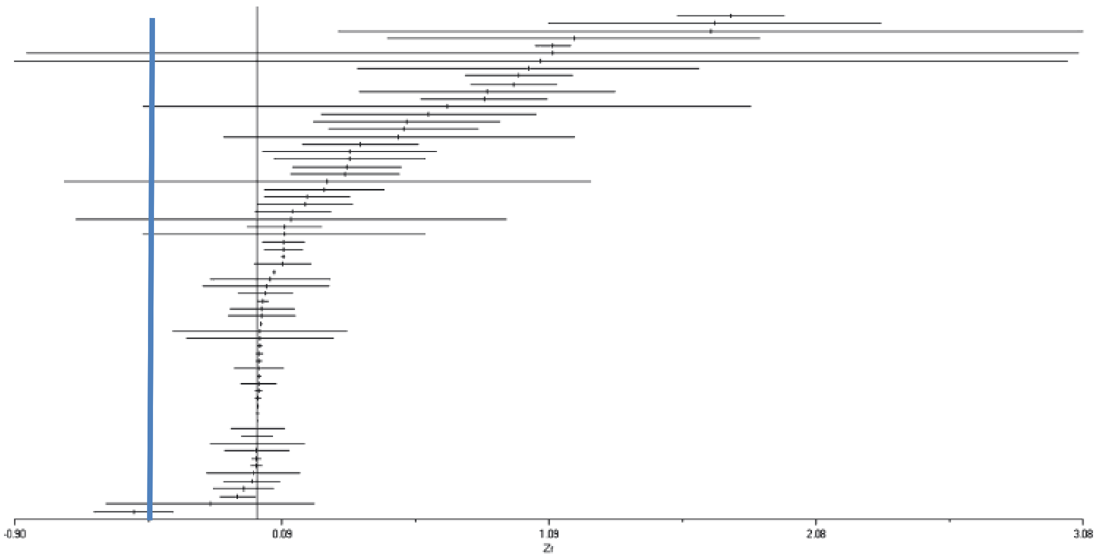


Fig. 1. Plot of the 66 effect size estimates of the relationship between level of natural background radiation and biological response variables, ordered by increasing effect size. Effect sizes are z-transformed Pearson product-moment correlation coefficient estimates (Z_r), shown here with 95% confidence intervals. Vertical line indicates overall mean effect size of 0.093.

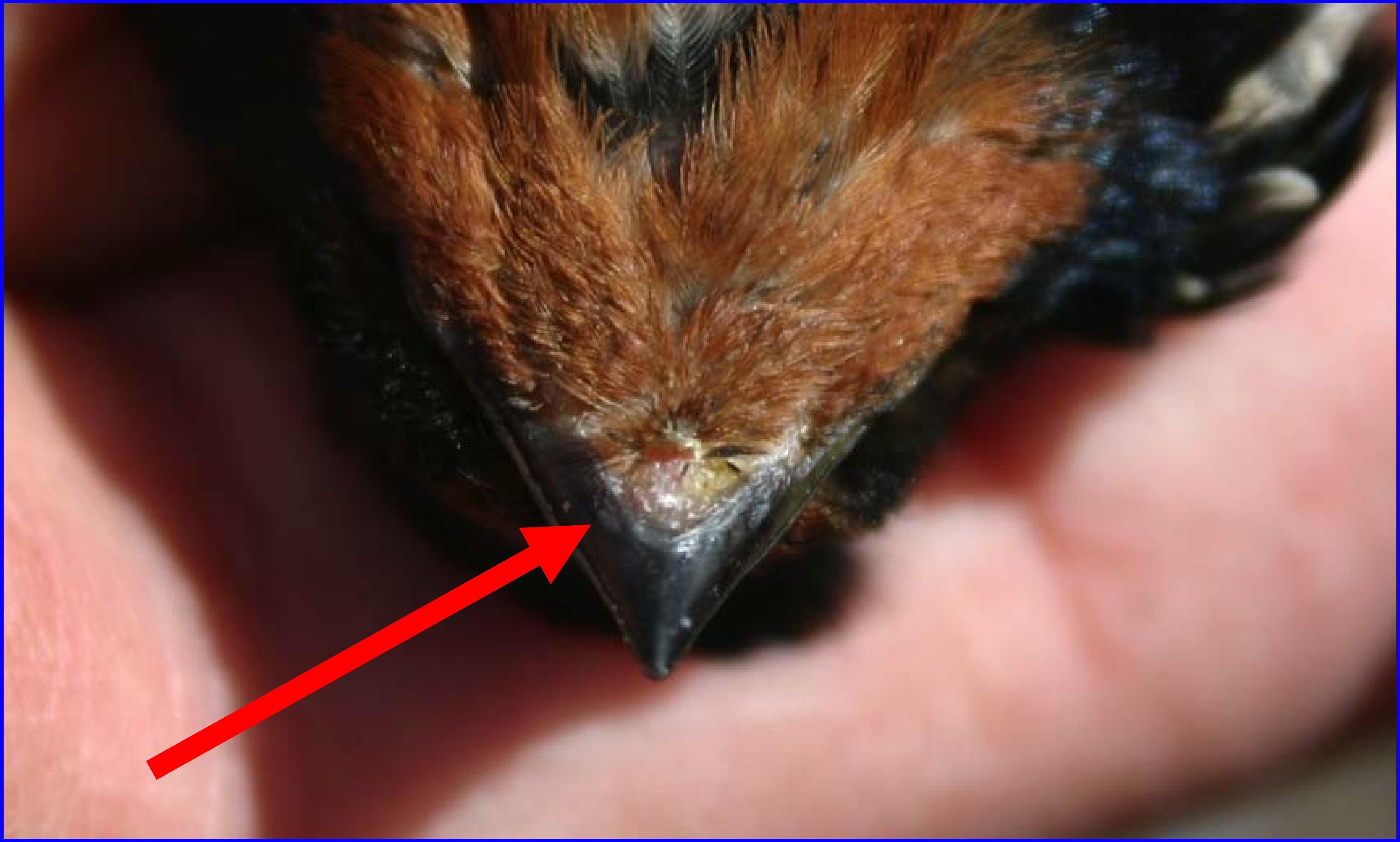
What are the developmental effects of radiation-induced mutations?

Partially albinistic male swallow (on left). Swallows from Chernobyl region are generally much paler than swallows from other regions.

Moller & Mousseau. 2001. Evolution

Abnormal coloration

Bent and asymmetrical tail feathers.



Tumor growth under beak.

Deformed lips

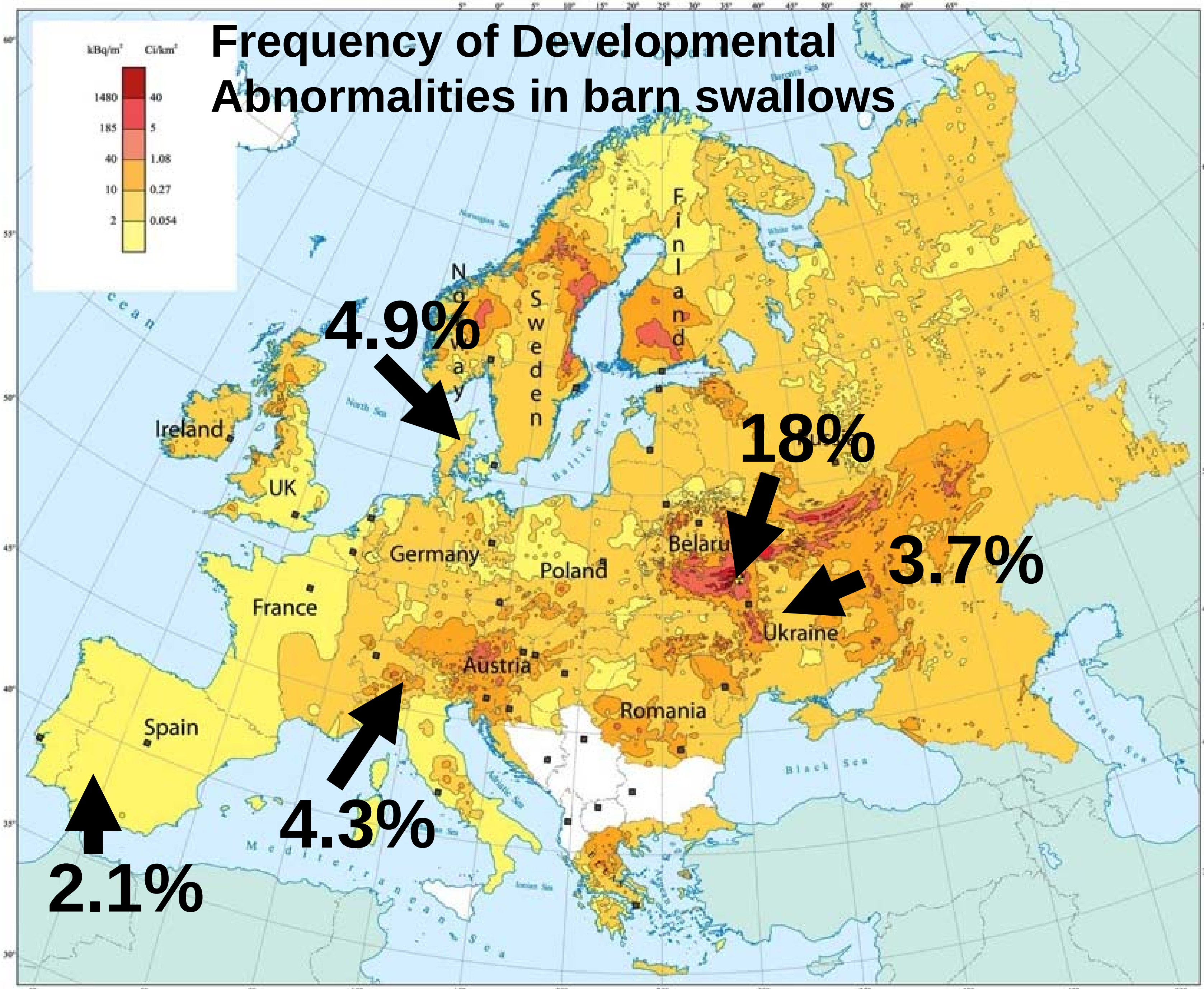
Deformed airsac

Frequency of abnormalities in Chernobyl and elsewhere

Condition	Chernobyl	Ukrainian control area	Denmark	Spain	Italy
Partial albinism	**13.32 (112)**	**3.75 (20)**	**4.87 (204)**	**1.96 (11)**	**4.06 (65)**
Aberrant coloration of plumage	**0.28 (3)**	0	0	0	0
Red coloration on chest	**0.28 (3)**	0	0	0	0
Blue coloration in red face	**0.19 (2)**	0	0	0	0
Deformed toes	**0.76 (8)**	0	0	**0.18 (1)**	**0.06 (1)**
Deformed beak	**0.38 (4)**	0	0	0	0
Tail feathers with non-fused barbs	**0.57 (6)**	0	0	0	0
Bent tail feathers	**0.19 (2)**	0	0	0	0
Tumours	**0.66 (7)**	0	0	0	**0.19 (3)**
Deformed air-sacks	**0.09 (1)**	0	0	0	0
Deformed eyes	**0.19 (2)**	0	0	0	0
N	841	534	4198	562	1601

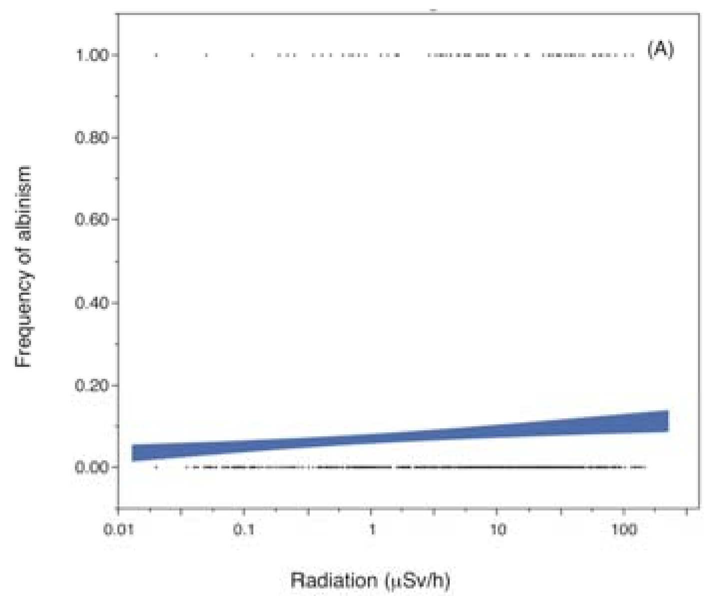
A. P. Møller, T.A. Mousseau, et al., Biol. Lett. 3:414-417, 2007

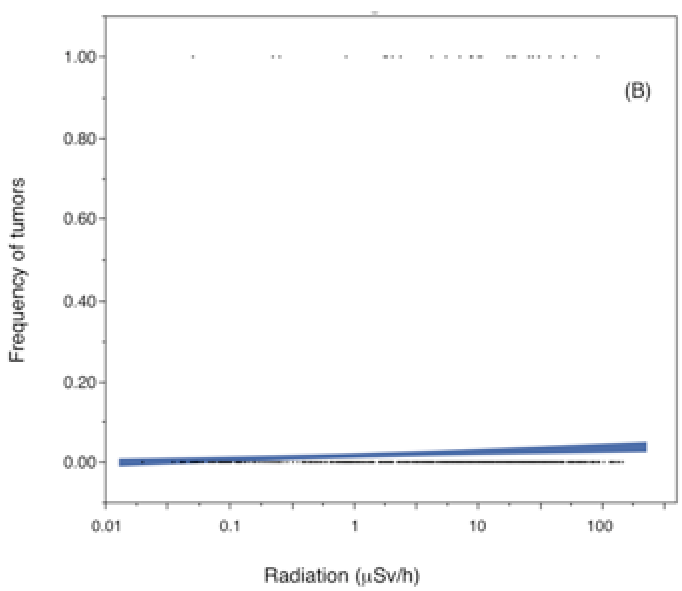
Frequency of Developmental Abnormalities in barn swallows



Great tit, *Parus major*

Tumor around eye


(A)
Frequency of albinism
1.00
0.80
0.60
0.40
0.20
0.00
0.01
0.1
1
10
100
Radiation (μSv/h)


(B)
Frequency of tumors
1.00
0.80
0.60
0.40
0.20
0.00
0.01
0.1
1
10
100
Radiation (μSv/h)


a.
b.
c.
d.
e.
f.
g.
h.
i.
j.
k.
l.
m.
n.
o.
p.
q.
r.
s.
t.
u.
v.
w.
x.

BBC

News | Sport | Weather | Travel | TV | R

EARTH NEWS

REPORTING LIFE ON EARTH

- Earth News
- Contact us
- Who we are

Related BBC sites

- Earth Explorers
- Wildlife Finder
- BBC News
- Weather

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

E-mail this to a friend   Printable version

Chernobyl birds are small brained

By Matt Walker
Editor, Earth News

Marsh warblers are one of the species affected

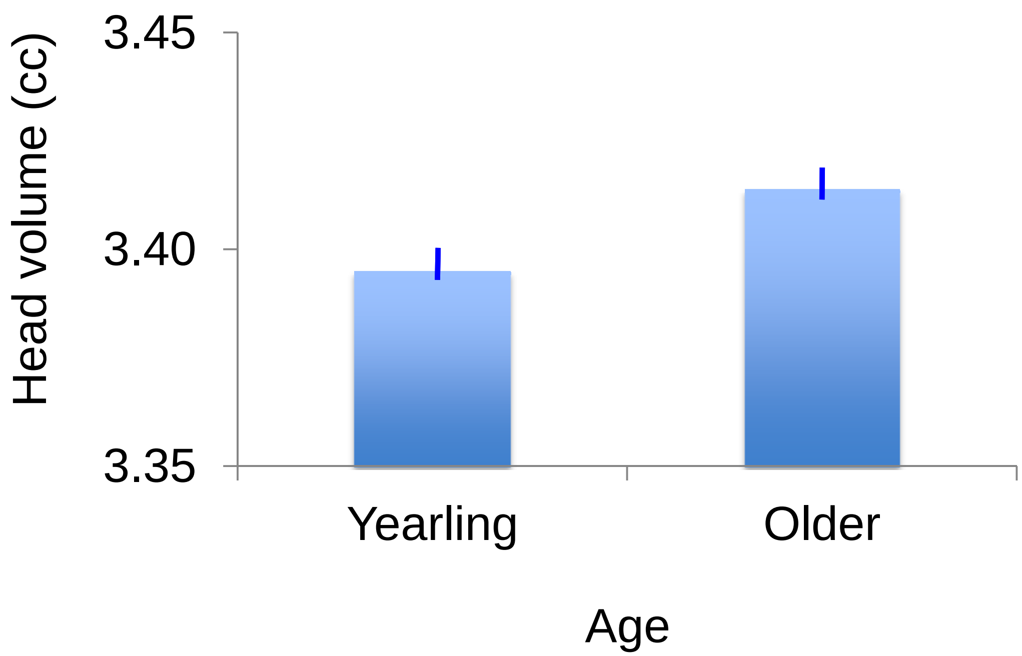
Birds living around the site of the Chernobyl nuclear accident have 5% smaller brains, an effect directly linked to lingering background radiation.

Moller, Mousseau, et al. 2011. PLoS One

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

Selection against small heads

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



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

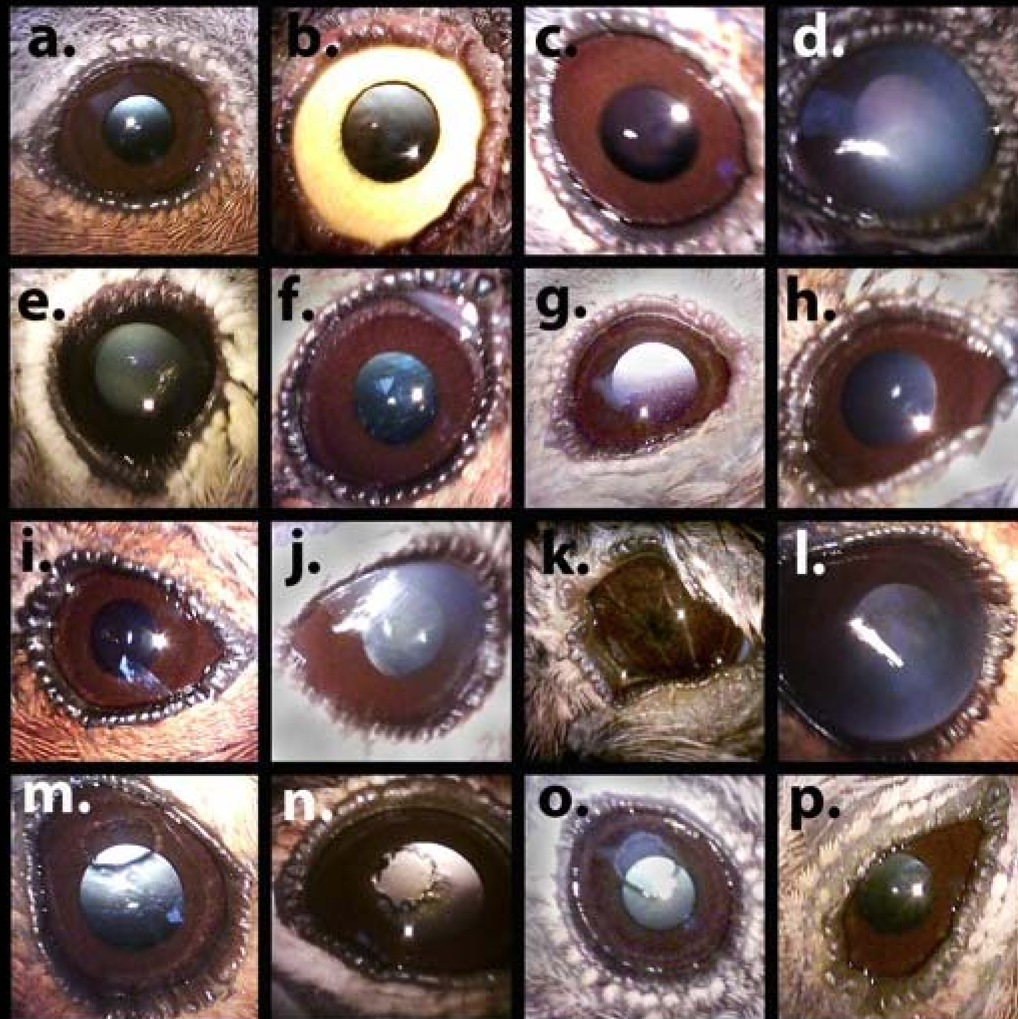

Stunted Chernobyl Pines - T.A. Mousseau (c) 2012


Chernobyl Pines - T.A. Mousseau (c) 2012

Mutant Firebugs from Chernobyl

Cataracts & Deformities

Bird Eyes of Chernobyl

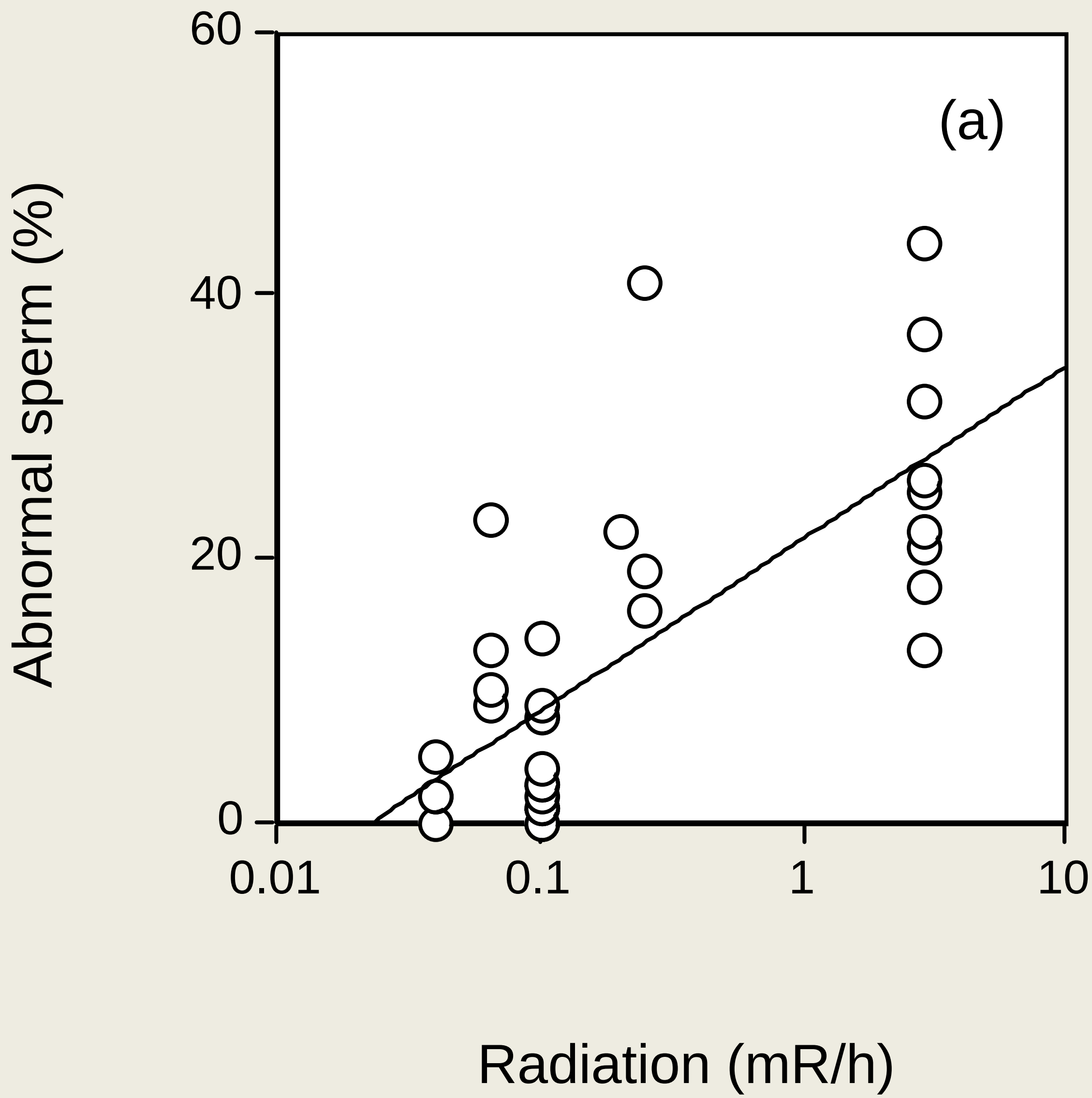


(a.) Black cap, (*Sylvia atricapilla*), normal. (b.) Barred warbler, (*Sylvia nisoria*), normal. (c.) Black cap, (*Syvia atricapilla*), very slight haze in cornea. (d.) Barn swallow (*Hirundo rustica*), significant haze on cornea. (e.) Chiffchaff (*Phylloscopus collybita*), slight haze on cornea. (f.) 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/

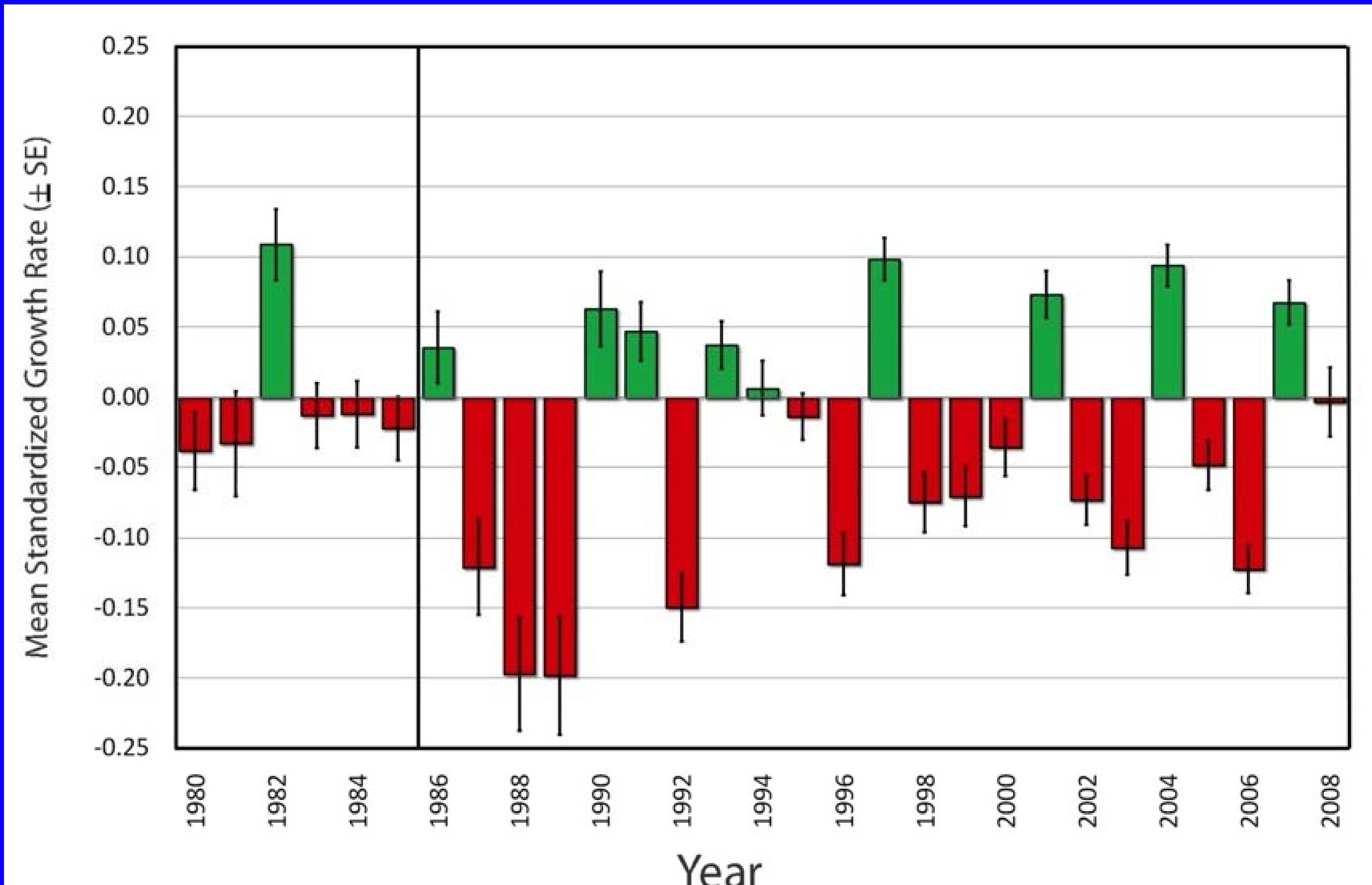
Frequency of abnormal sperm is directly related to background radiation levels.



Moller, Mousseau & Surai. 2005. Proc. Roy. Soc. Lond. B.

Radiation and tree rings

Standardized tree growth rate



Vast regions near the CNPP are obvious ecological disasters.

T.A.Mousseau © 2002

Red Forest near Chernobyl Reactor

Note lack of decomposition