Recent Advances in the Application of Radiation Dosimetry to Wild Animal Populations

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Chernobyl + Fukushima Research Initiative
Chernobyl 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.**

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?**

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."

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.

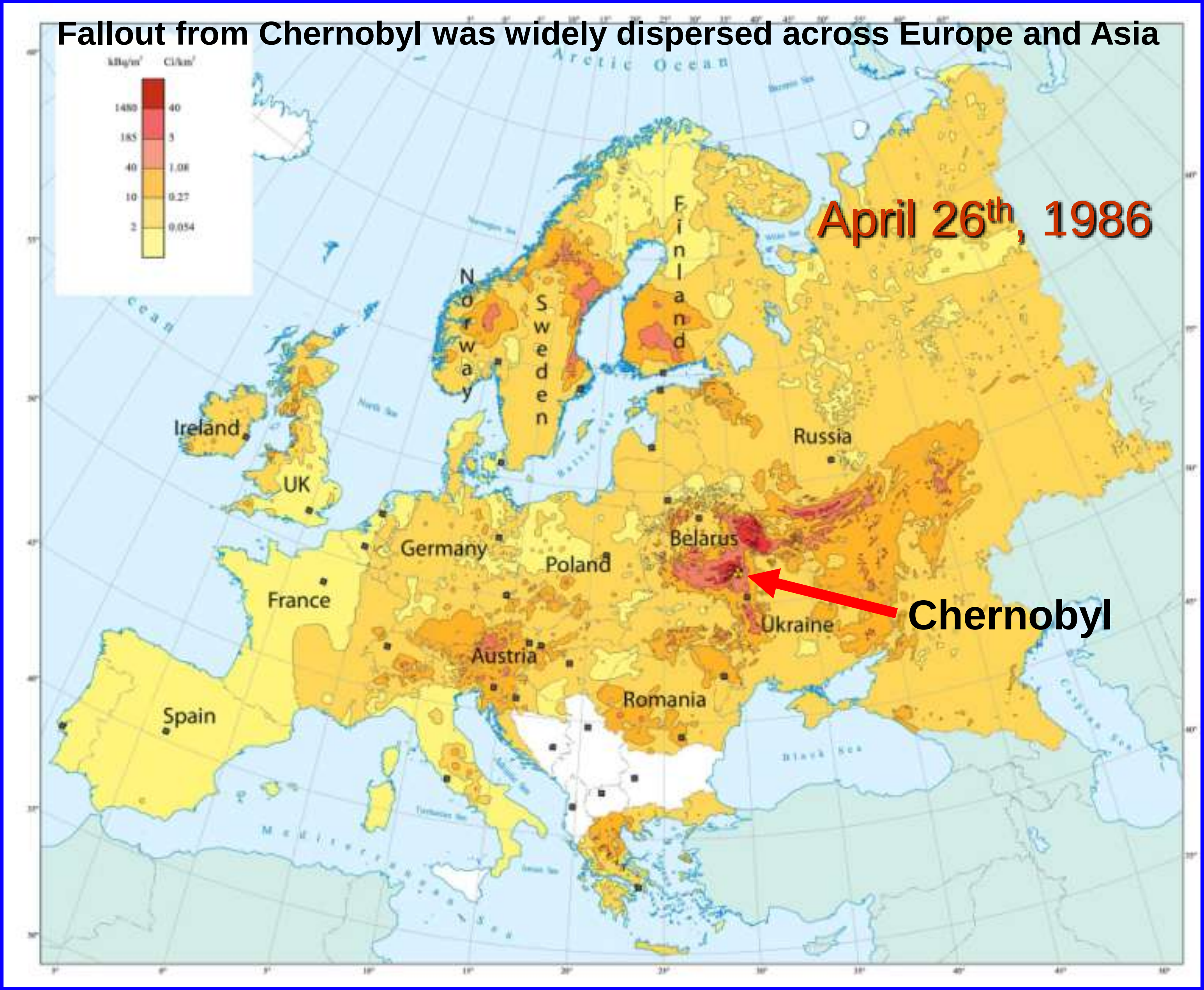
Animal Models – Provide Clues to Human Populations

Birds don't usually drink or smoke!

The Barn Swallow,
Hirundo rustica

Phylopatric

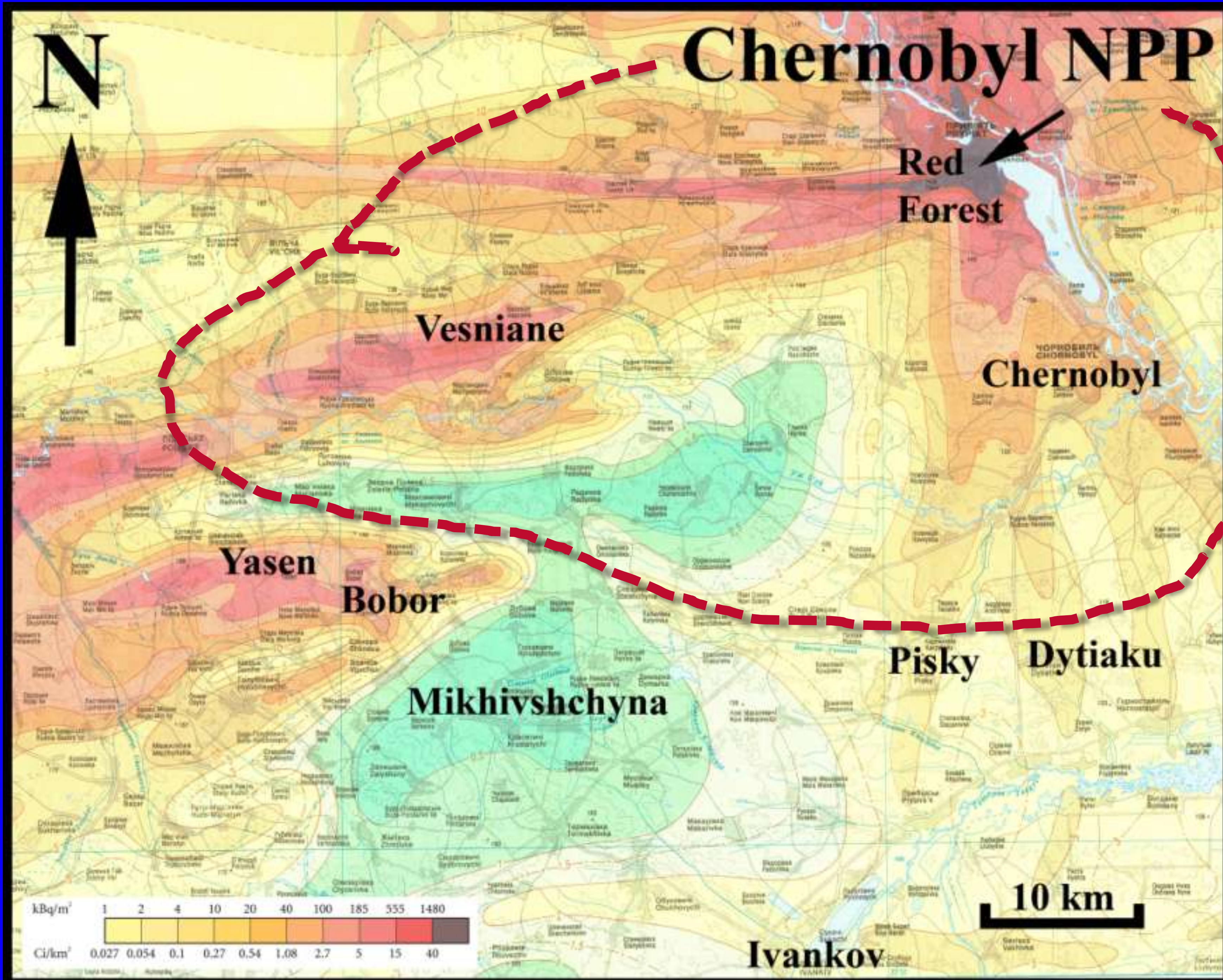
Chernobyl provides a unique opportunity to study impacts of nuclear accidents and the effects of radionuclides in the environment.



Control Populations:

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

- 896 bird and insect surveys from locations in Ukraine and Belarus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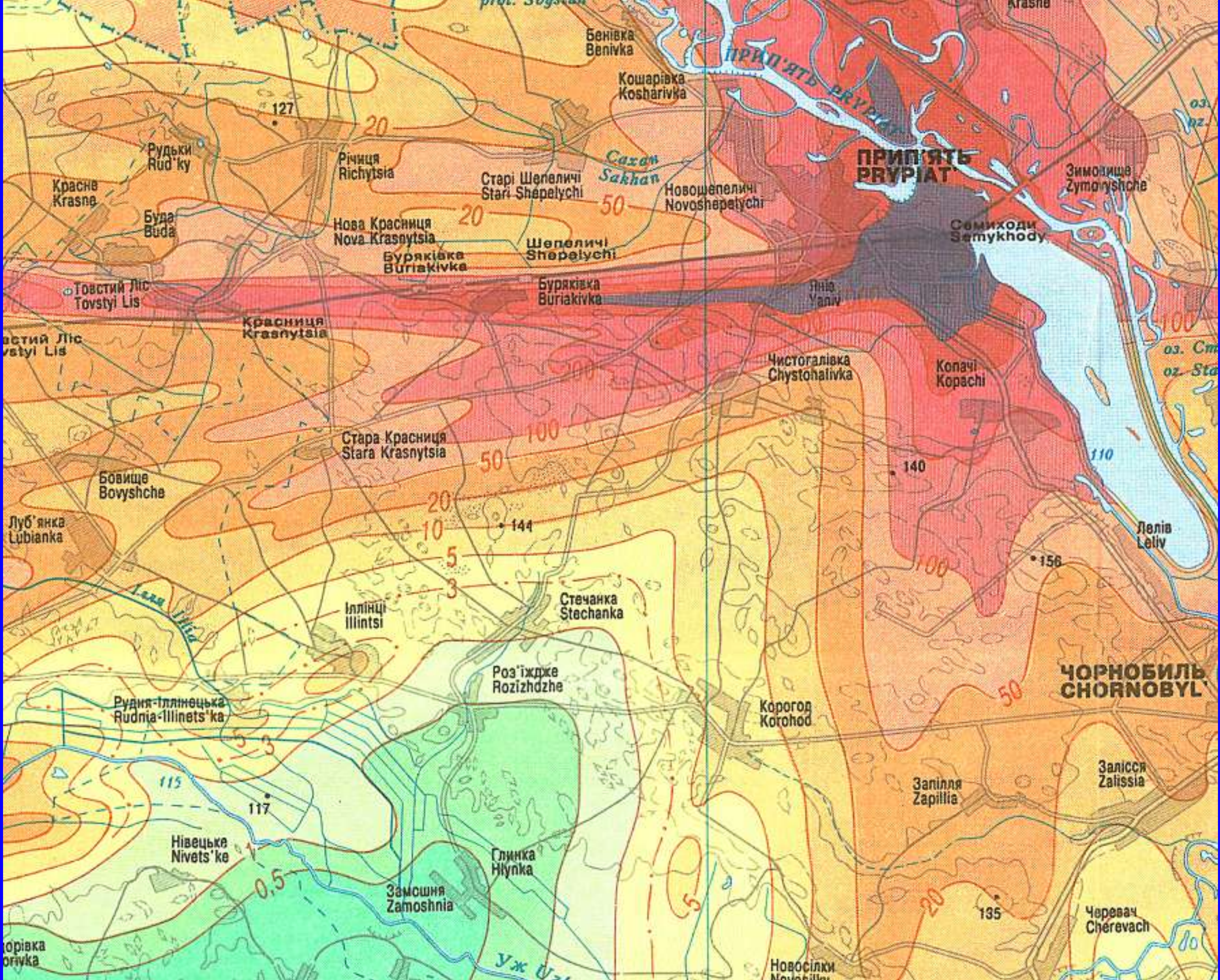
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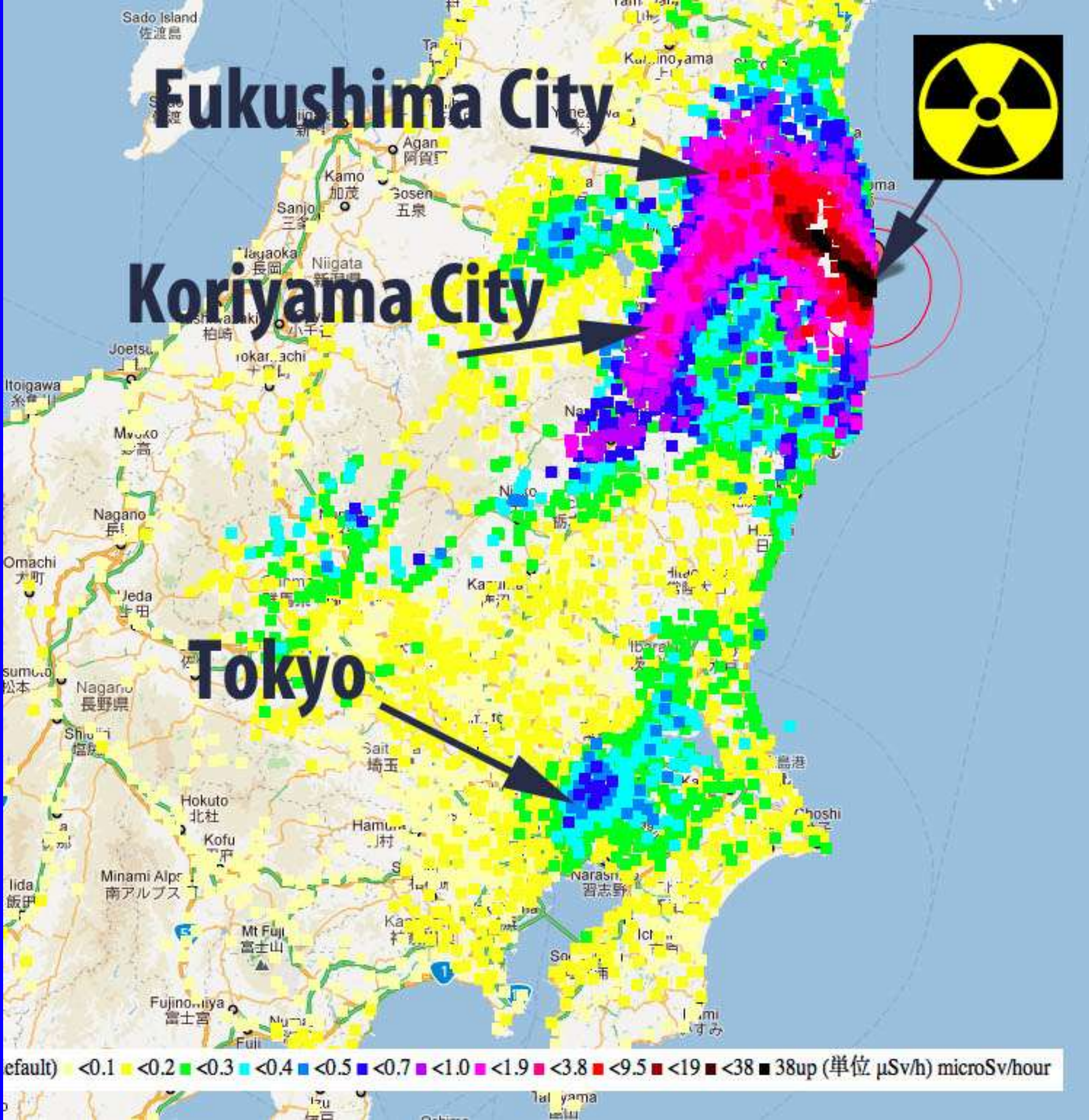
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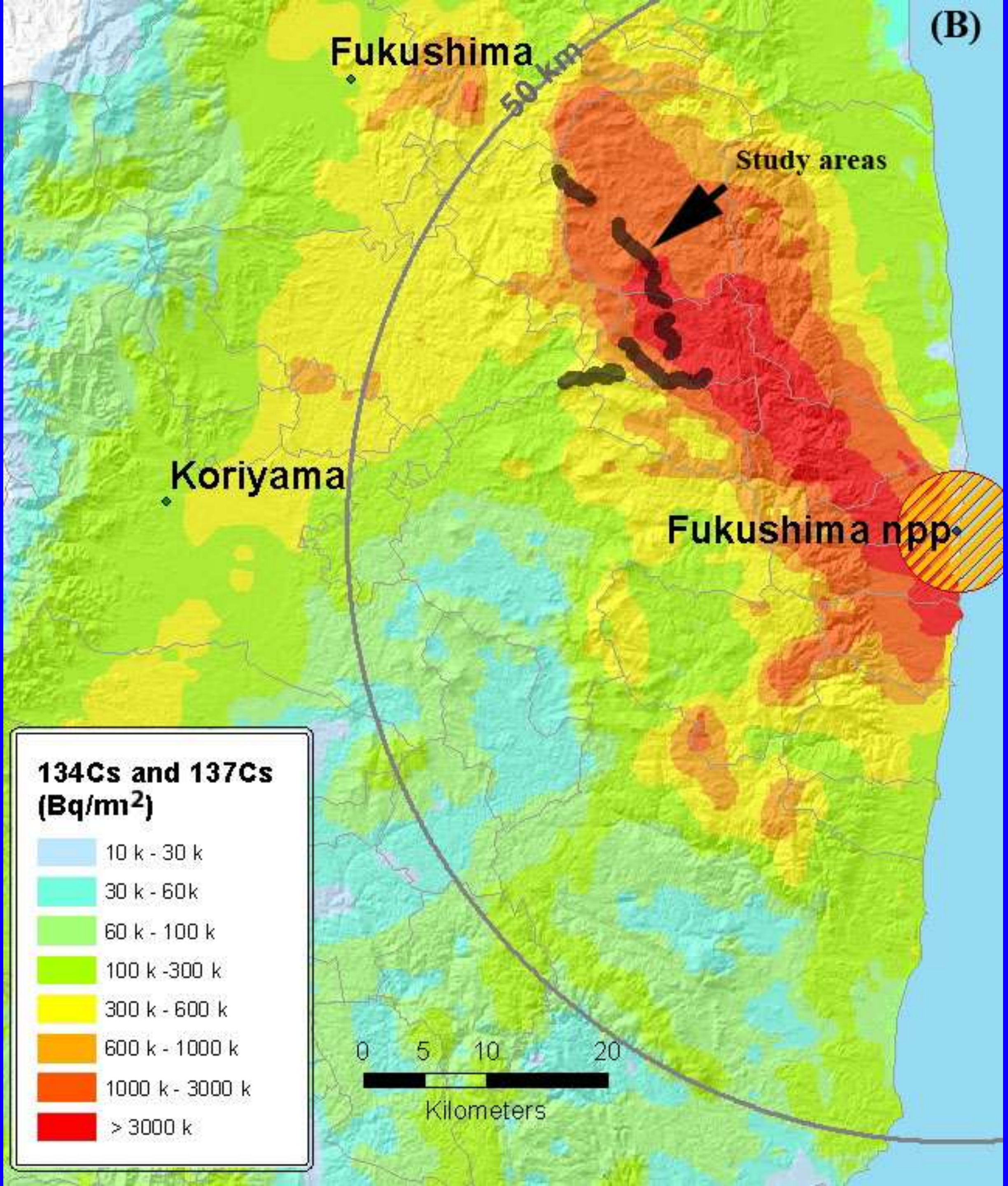
Koriyama City
Tokyo
efault) <0.1 <0.2 <0.3 <0.4 <0.5 <0.7 <1.0 <1.9 <3.8 <9.5 <19 <38 38up (単位 µSv/h) microSv/hour


(B)
Fukushima
50 km
Study areas
Koriyama
Fukushima npp
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(Bq/m2)
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600 k - 1000 k
1000 k - 3000 k
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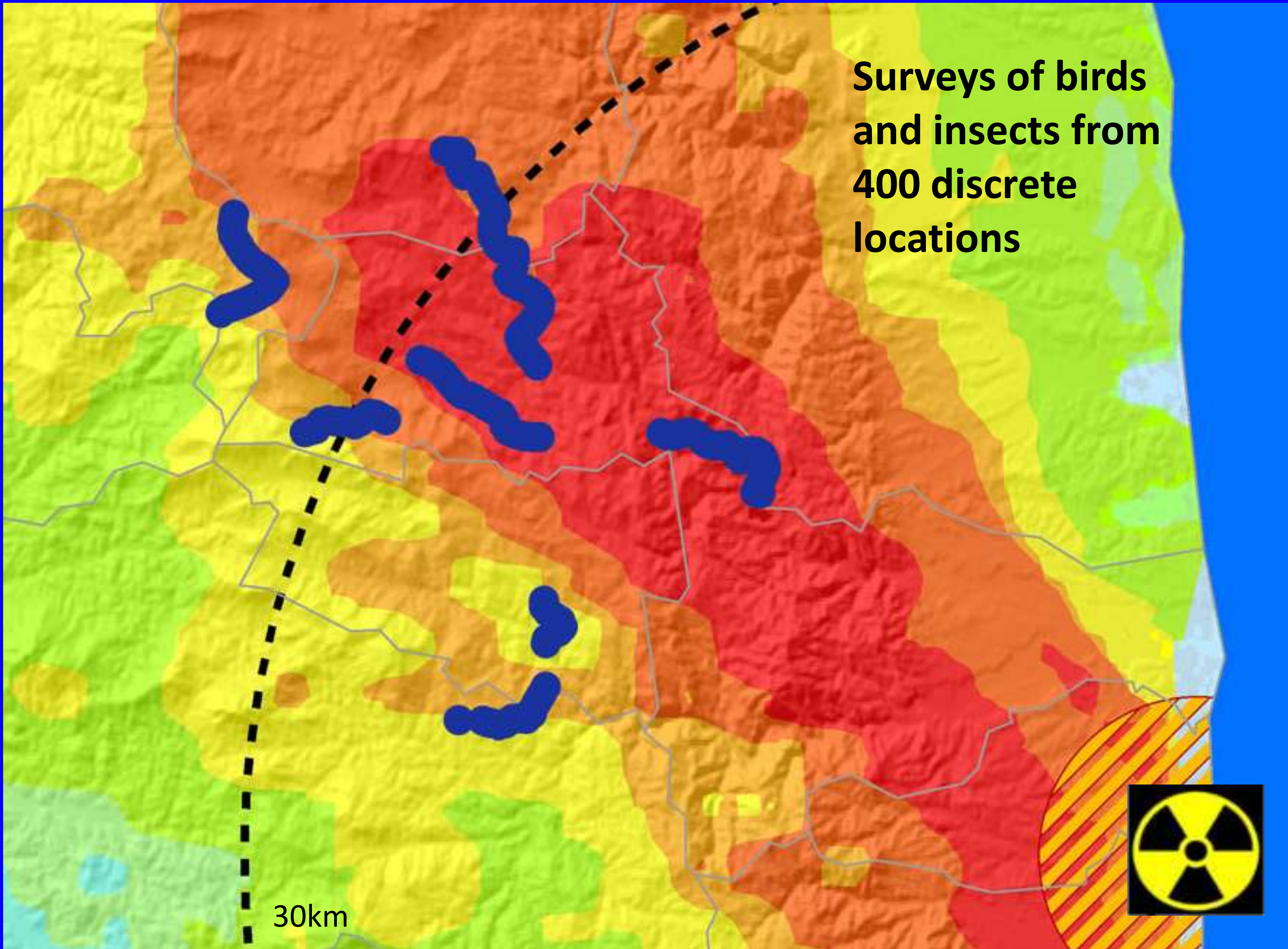
Kilometers


Surveys of birds and insects from 400 discrete locations
30km

Massively Replicated Biotic Inventories
(400 in Fukushima, 896 in Chernobyl)

+

Measures of Multiple Environmental Variables
(e.g. meteorology, hydrology, geology)

+

GIS

+

Field Measures of Residential Radiation Levels

+

Multivariate Statistics

=

Predictive Models of Radiation Effects on Populations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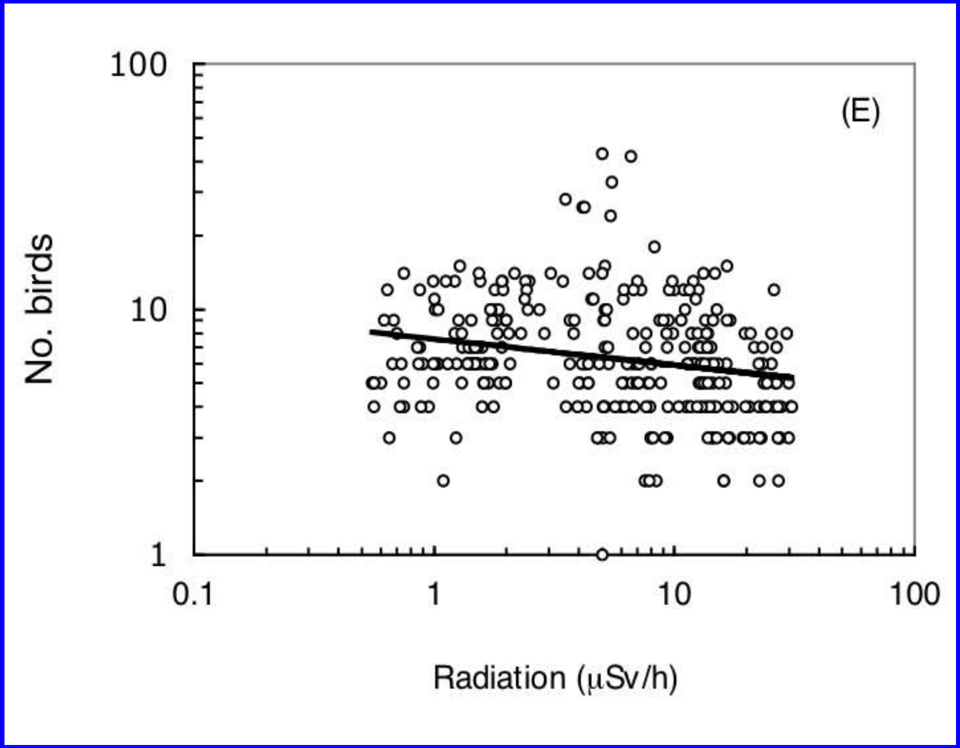
Fukushima



Chernobyl

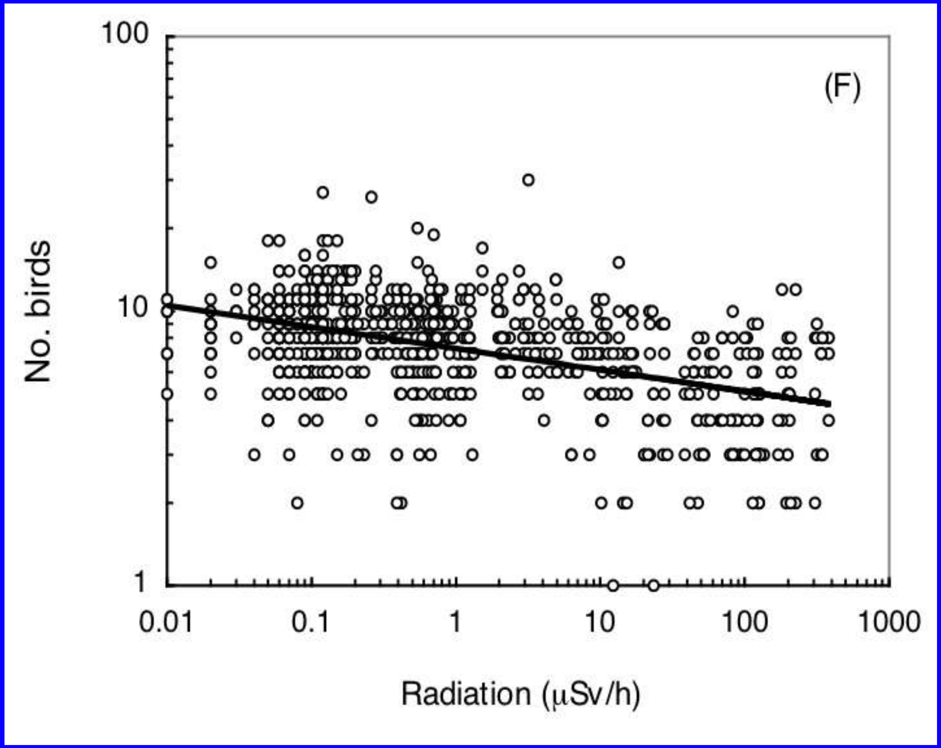


Table 1. Bird abundance in Fukushima and Chernobyl in relation to radiation level.

	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.

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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.
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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.

Residential Background Radiation Measurements as a Proxy for Dose

Advantages:

- Inexpensive, instantaneous, portable, often TBWCD (the best we can do).
- Adequate for comparative ecological studies where interest is in covariance between dependent variable (e.g. genetic damage, tumors) and independent variable (background radiation level).

Disadvantages:

- Coarse relationship with internal and external dose for individuals, leading to conservative estimates of any relationships.

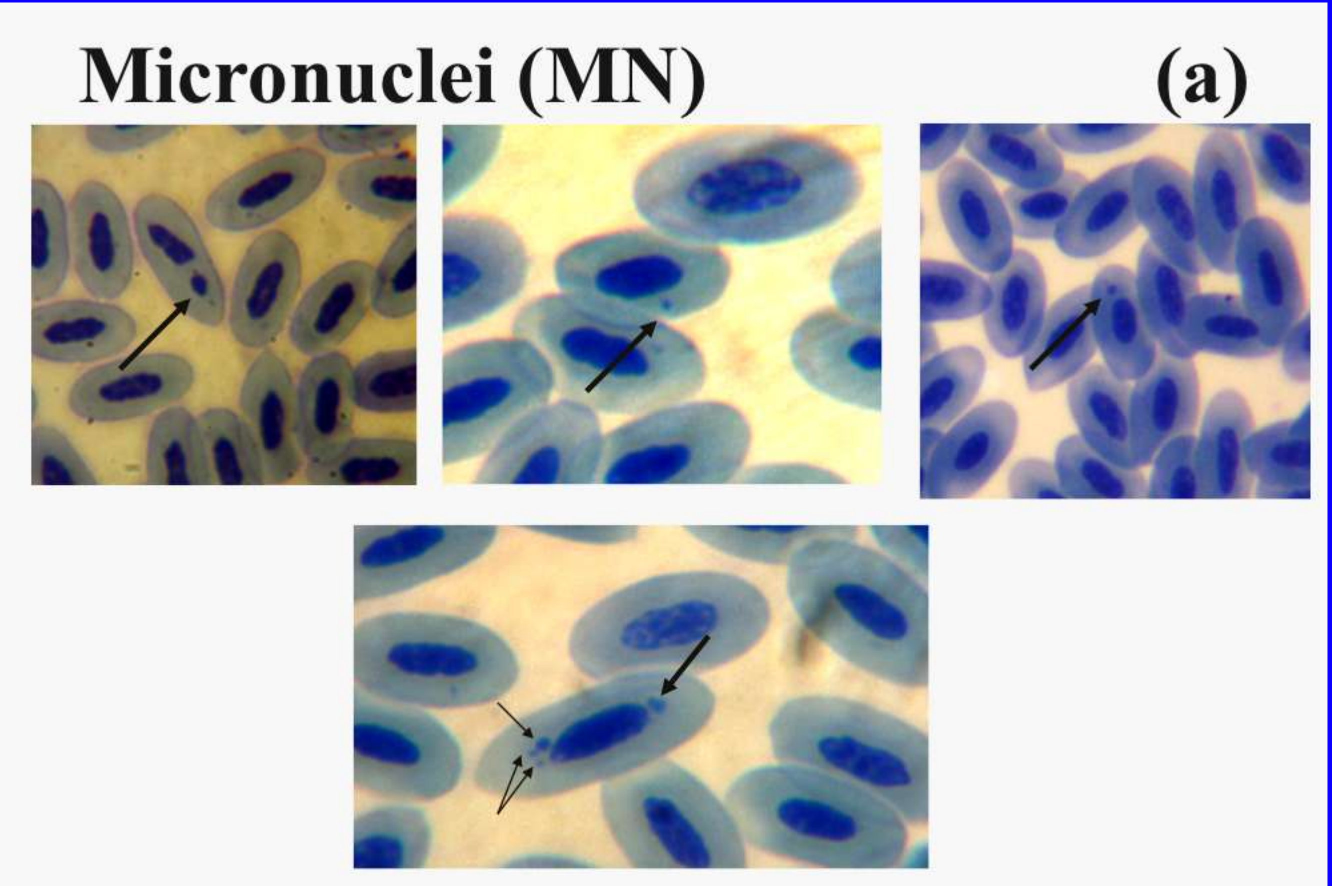
- Missing potentially valuable information concerning variation among individuals in response to exposure.

- Accuracy and precision inadequate for toxicological studies.

- Limited utility for risk assessment.

BIODOSIMETRY:

1) Cytogenetic assays for biodosimetry (e.g. comet, micronuclei counts), microsatellite DNA, DNA sequencing, gene expression profiles, etc.

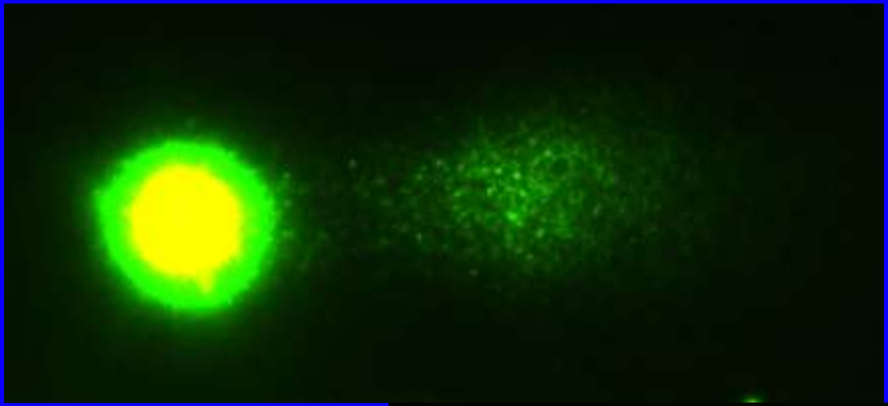


Erythrocyte with 4 MN

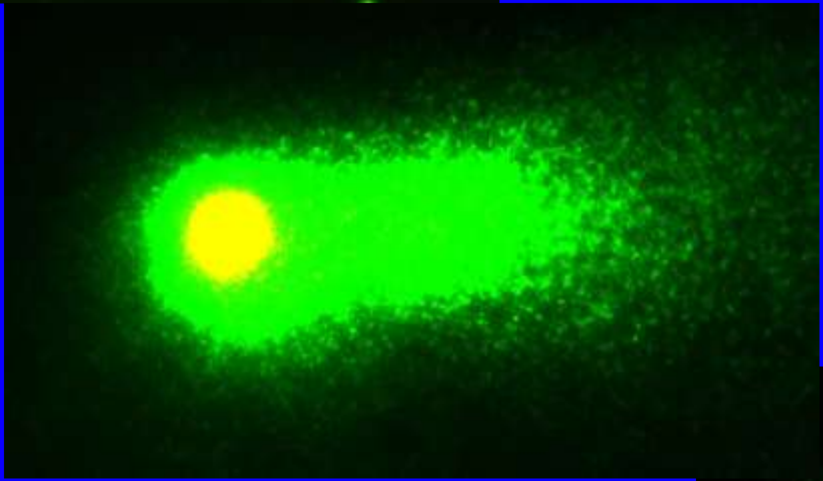
Roskowski, S., T. A. Mousseau and A. P. Møller. 2012. Submitted.

Comet assays of genetic damage to RBCs and sperm

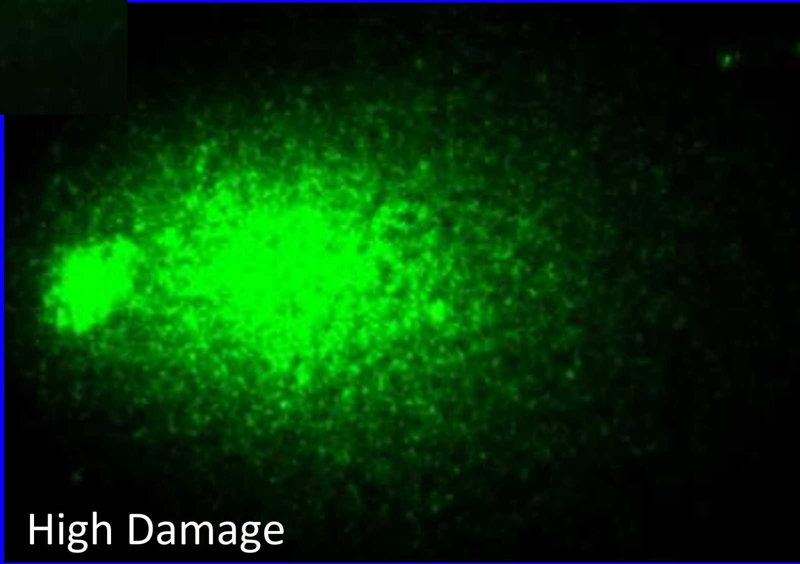
Grasshopper Hemolymph



Low Damage



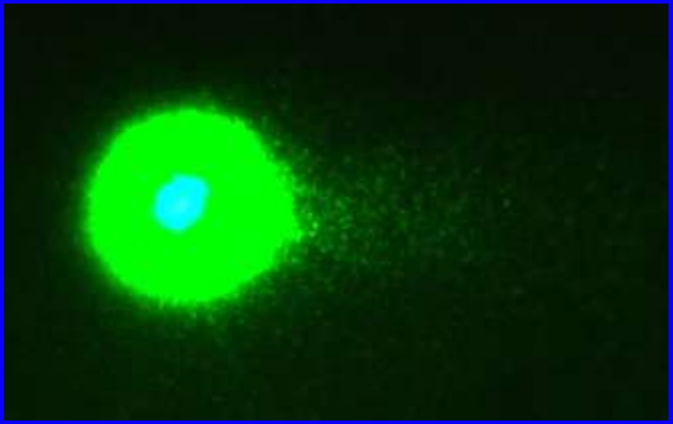
Medium Damage



High Damage

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.

Barn Swallow Sperm



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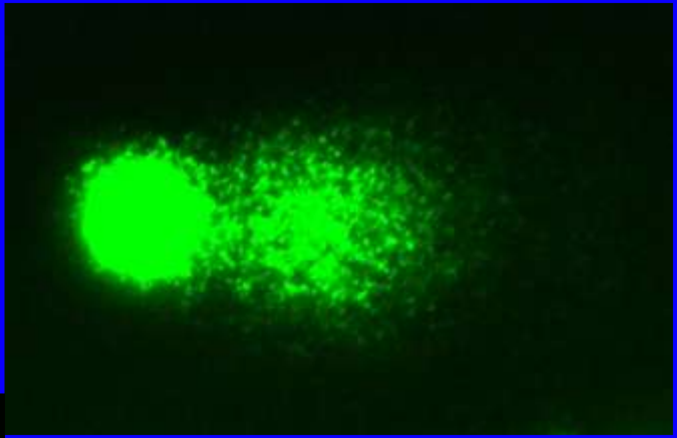
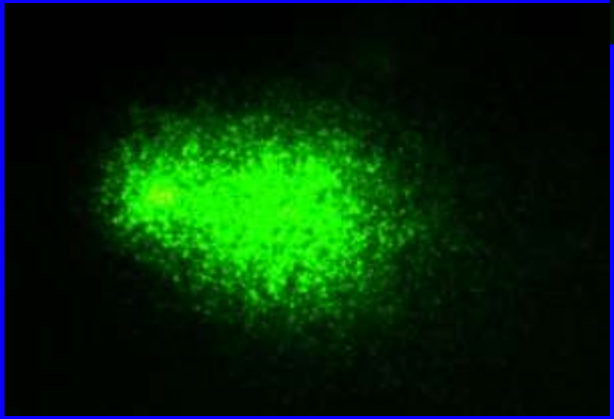
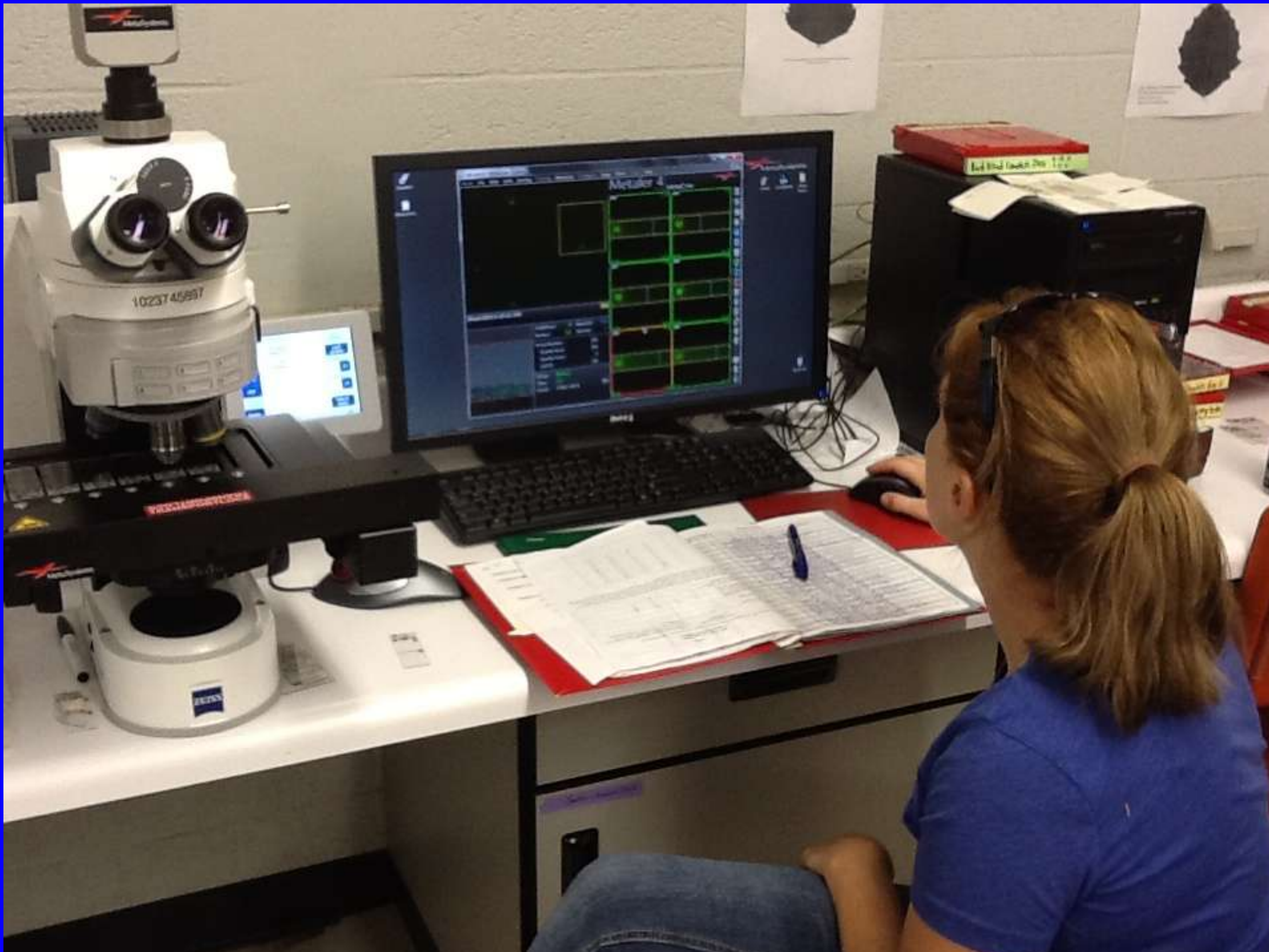


Medium Damage



High Damage

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.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The RABiT: A Rapid Automated Biodosimetry Tool for radiological triage. II. Technological developments

GUY GARTY[1], YOUHUA CHEN[2*], HELEN C. TURNER[3], JIAN ZHANG[2†], OLEKSANDRA V. LYULKO[1], ANTONELLA BERTUCCI[3], YANPING XU[1], HONGLIANG WANG[2], NABIL SIMAAN[2‡], GERHARD RANDERS-PEHRSON[1], Y. LAWRENCE YAO[2], & DAVID J. BRENNER[3]

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Columbia University, New York, NY, USA

Micronuclei and gamma-H2AX Assays.

2 Health Physics February 2010, Volume 98, Number 2

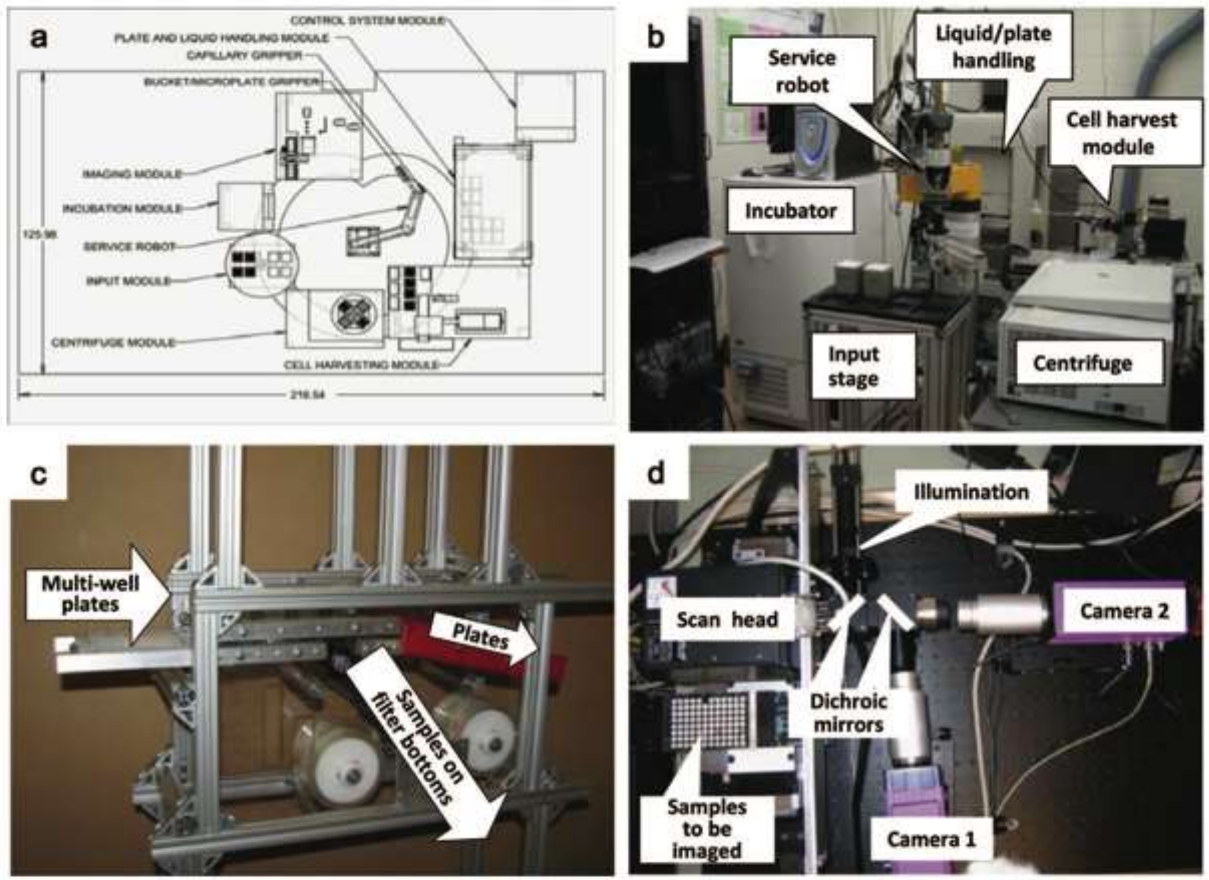
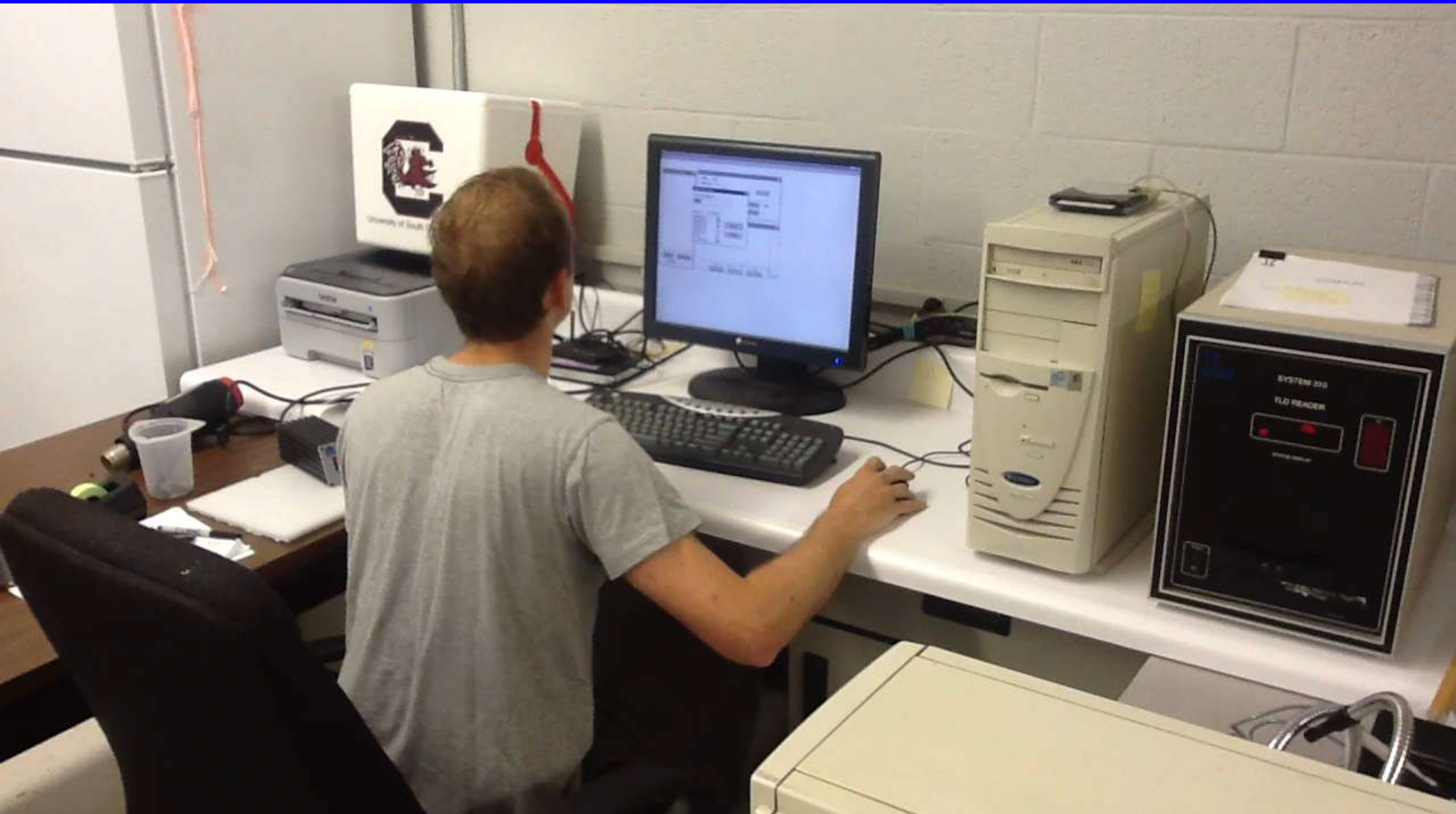
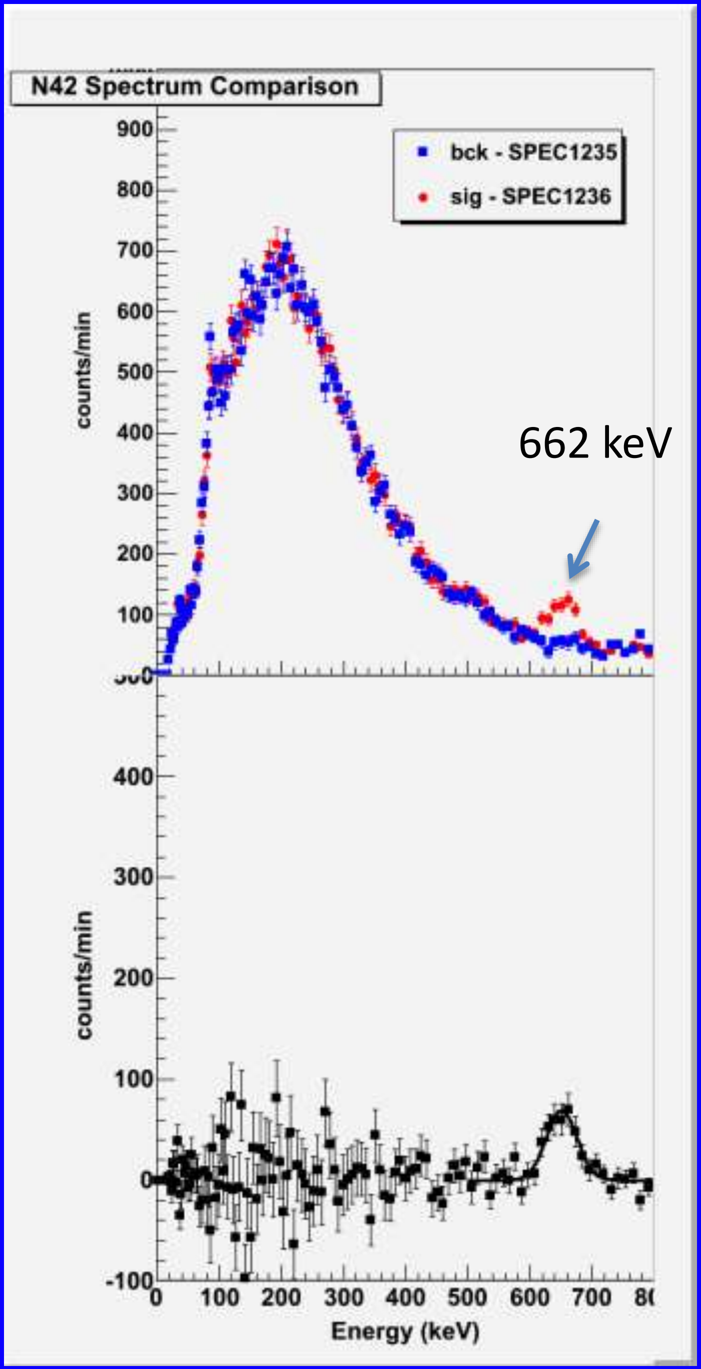


Fig. 2. (a) Schematic of RABIT layout; (b) breadboard prototype; (c) prototype transfer-to-substrate system; (d) prototype imaging system.

TLD Dosimeters to measure radiation dose received by bird is attached to bird leg band.


TLD READER


ANSI
07:31:52
284 gCPS
0 nCPS
0.06 µSv /hr
ID Key:
IND SNM MED
NRM UNC UNK C/B
1.0k
100
10
1.0
Cs137
Cs137
Cs137
0MeV
1MeV
2MeV
3MeV
Acquisition complete in 2 min
Cancel
Erase
-30 s
+30 s
BACK
MENU



N42 Spectrum Comparison
bck - SPEC1235
sig - SPEC1236
counts/min
900
800
700
600
500
400
300
200
100
662 keV
400
300
200
100
0
-100
0
100
200
300
400
500
600
700
Energy (keV)

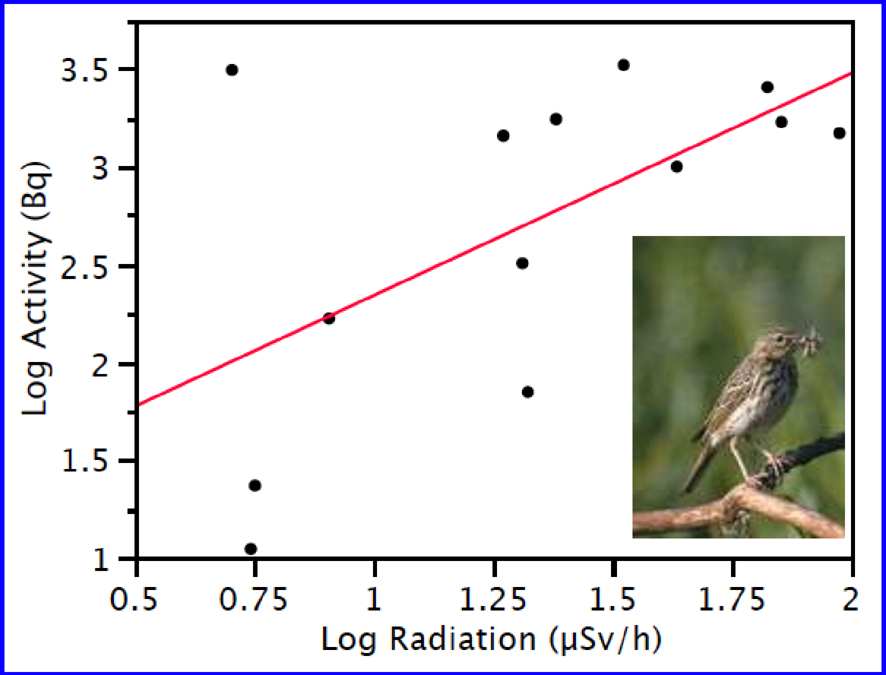
- 0.5 km of mist nets, rotated daily, >2000 birds captured since 2010 (and released).
- 492 birds outfitted with TLD's in May, 2012; 84 recaptured in June (17% recovery rate)

Three Independent Measures of Dose:

1) Residential background radiation levels using field survey meters.

2) External dose using TLD's.

3) Internal dose using whole body counts and gamma spectrometry.



Anthus trivialis; N = 13; **R^2 = 0.36**, **P = 0.031**