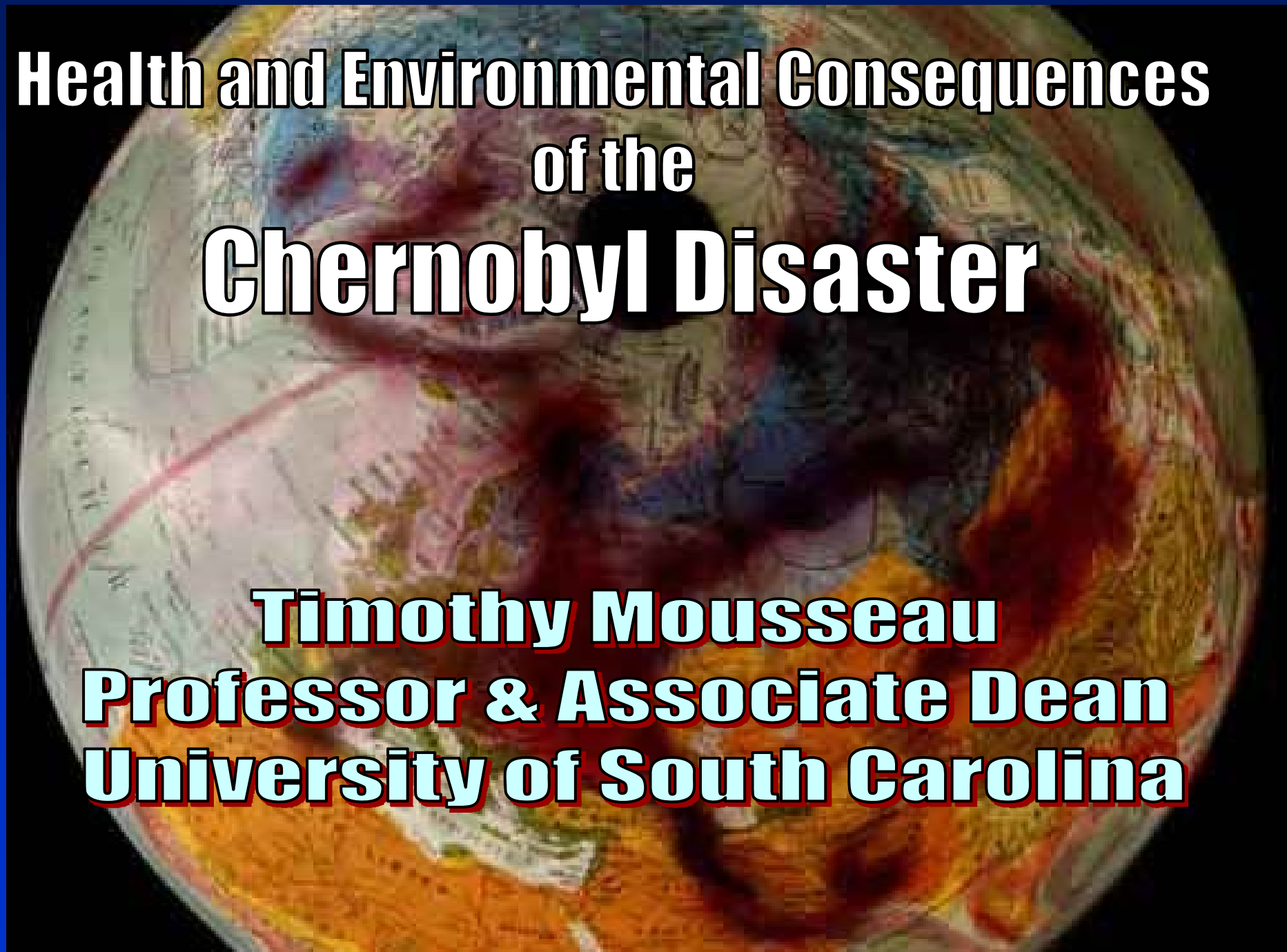
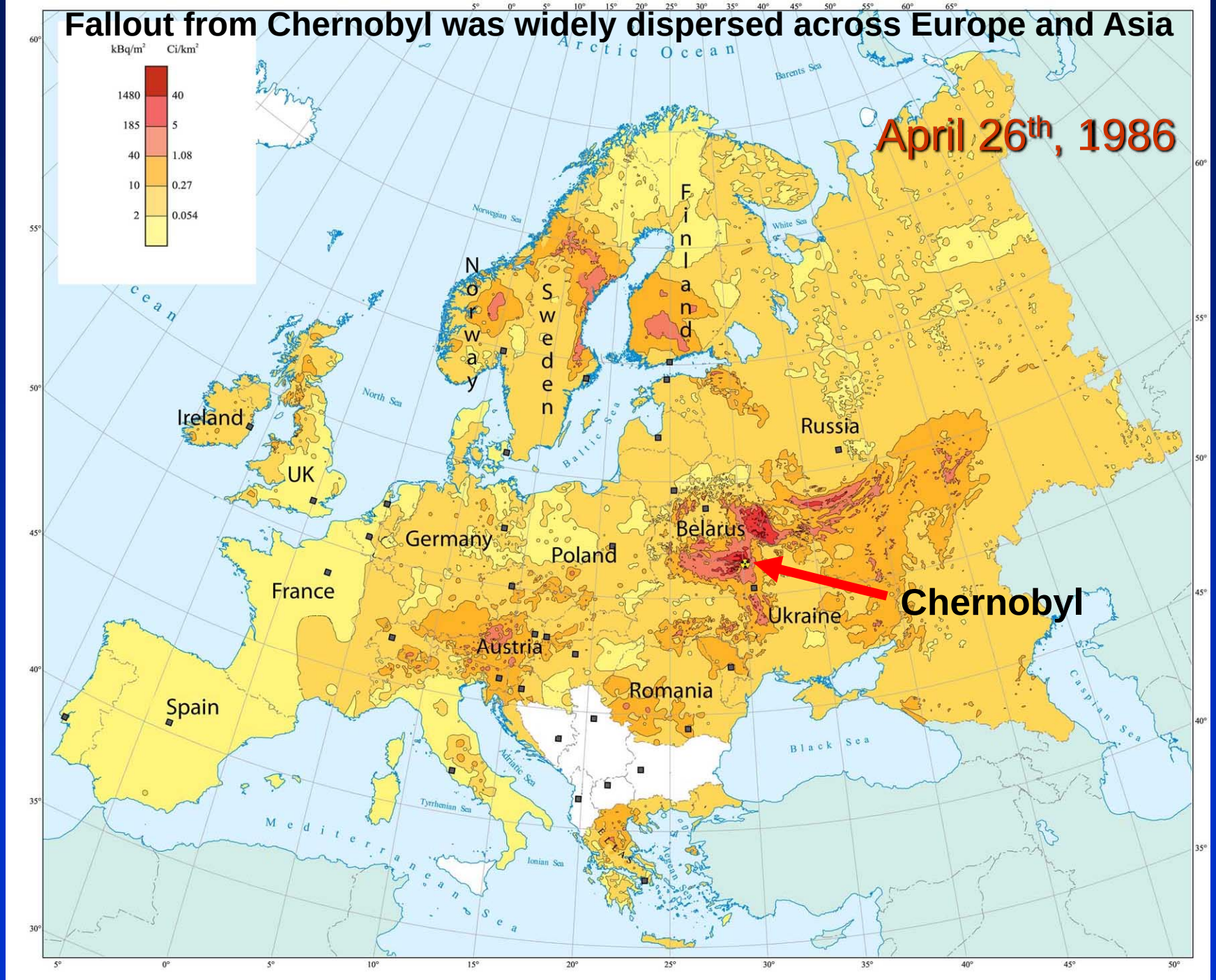


Health and Environmental Consequences of the Chernobyl Disaster

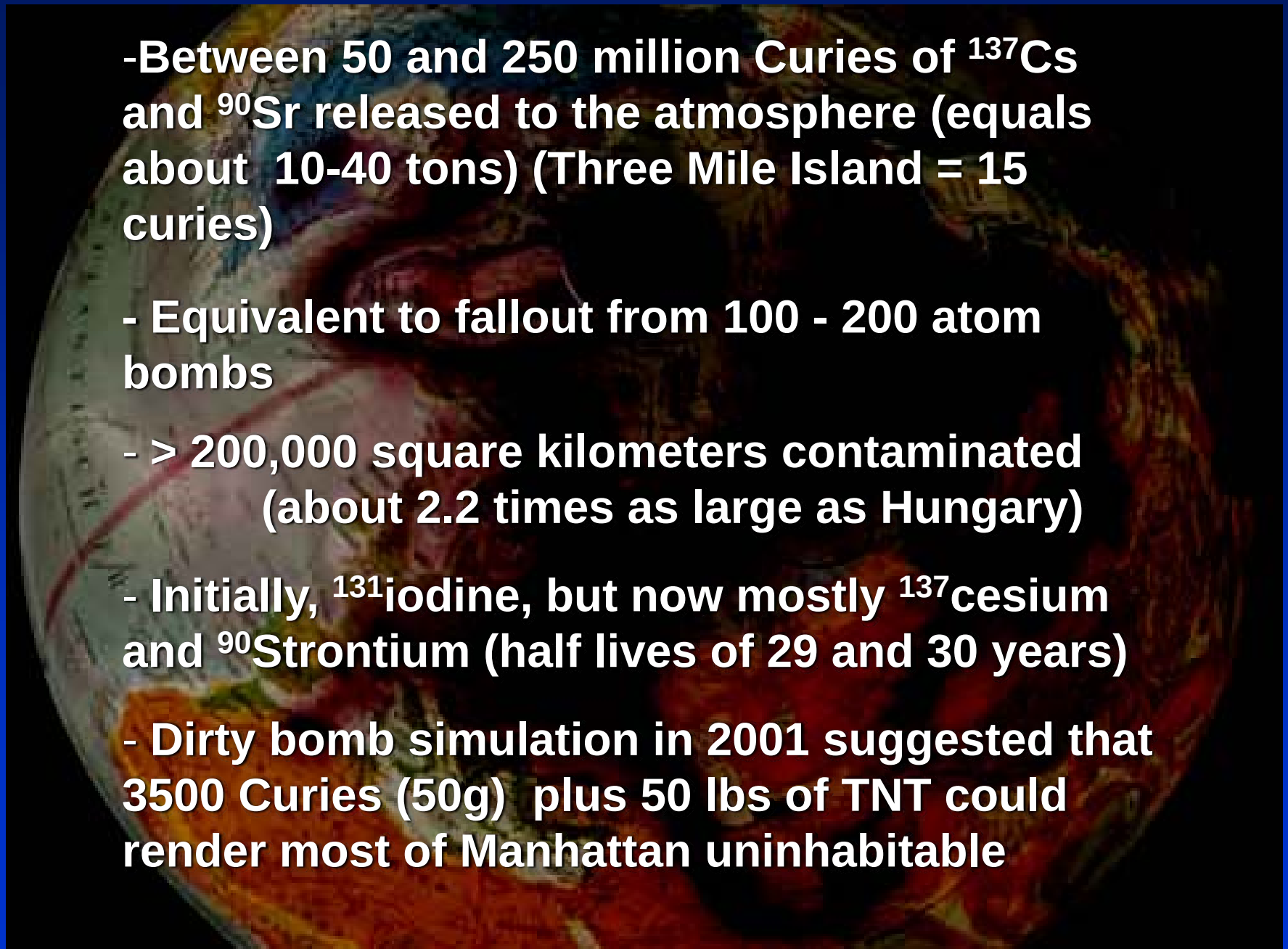
Timothy Mousseau
Professor & Associate Dean
University of South Carolina

Artist’s Rendition of the nuclear fire that burned for 10 days releasing vast quantities for radionuclides into the atmosphere.

Fallout from Chernobyl was widely dispersed across Europe and Asia



Fallout from Chernobyl was widely dispersed across Europe and Asia



-Between 50 and 250 million Curies of ^{137}Cs and ^{90}Sr released to the atmosphere (equals about 10-40 tons) (Three Mile Island = 15 curies)

- Equivalent to fallout from 100 - 200 atom bombs

- > 200,000 square kilometers contaminated (about 2.2 times as large as Hungary)

- Initially, ^{131}iodine, but now mostly ^{137}cesium and ^{90}Strontium (half lives of 29 and 30 years)

- Dirty bomb simulation in 2001 suggested that 3500 Curies (50g) plus 50 lbs of TNT could render most of Manhattan uninhabitable

Chernobyl Nuclear Power Plant

September 1999

Supported by:

US NSF
CRDF
NATO
National Geographic Foundation
CNRS France
Freeman Charitable Trust

Vast regions near the CNPP are obvious ecological disasters.

Red Forest near Chernobyl Reactor

But in some ways, the ecology appears to be returning to “normal”.

Przewalski’s Horses

Chernobyl Area Becomes Wildlife Haven

By DOUGLAS BIRCH
The Associated Press
Thursday, June 7, 2007; 6:45 PM

PARISHEV, Ukraine -- Two decades after an explosion and fire at the Chernobyl nuclear power plant sent clouds of radioactive particles drifting over the fields near her home, Maria Urupa says the wilderness is encroaching. Packs of wolves have eaten two of her dogs, the 73-year-old says, and wild boar trample through her cornfield. And she says fox, rabbits and snakes infest the meadows near her tumbledown cottage.

"I've seen a lot of wild animals here," says Urupa, one of about 300 mostly elderly residents who insist on living in Chernobyl's contaminated evacuation zone.

The return of wildlife to the region near the world's worst nuclear power accident is an apparent paradox that biologists are trying to measure and understand.

Chernobyl in Recovery?

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

Previous Studies of Chernobyl Effects:

- There are no comprehensive studies of long term ecological and environmental effects.
- There have been a number of investigations for cancer effects suggesting significant increases. But these studies are inconclusive given the long latency period of many cancers (consider smoking).
- There have been almost no published studies of non-cancer endpoints.

Why are there so few studies of the health and environmental consequences of Chernobyl fallout?

- Collapse of the Soviet Union resulted in reduced funding for research.
- Widespread perception that consequences were negligible, especially relative to impacts of the economic crisis in Eastern Europe (i.e. UN Chernobyl Forum Report)

Human epidemiological studies have been very difficult because of complications associated with economic depression (i.e. collapse of the Soviet Union), relocation and other stressors (e.g. smoking and alcoholism).

Ukraine:

- **Life expectancy at birth m/f (years): 62/74**

Belarus 64/76

Hungary 69 /77
Slovakia 71/79
Georgia 73/80

USA:

Life expectancy at birth m/f (years): 75/81

Source: WHO

University of South Carolina Chernobyl Research Initiative

Collaboration with:

- **Taras Shevchenko University of Kiev**
- **Ukrainian National Academy of Sciences**
- **Ukrainian National Museum of Natural History**
- **Chernobyl EcoCenter**
- **Institute of Radiobiology, Gomel**
- **University of Paris, France**

University of South Carolina Chernobyl Research Initiative

- **Studies of natural populations of birds, insects, microbes and plants.**
- **Studies of the Children of the Narodichesky region of Ukraine.**

Hypotheses and questions to be addressed:

- **Do low (and high) doses result in elevated mutation rates in natural populations?**
- **Are there phenotypic consequences to elevated mutation rates? (i.e. developmental abnormalities).**
- **Are there fitness consequences to elevated mutation rates? (i.e. survival, reproduction, or disease)**
- **Are there ecosystem consequences as a result of missing or reduced species?**

Animal Models – Provide Clues to Human Populations

Birds don’t usually drink or smoke!

The Barn Swallow,
Hirundo rustica

Exposure to Low-Level Contamination Results in Elevated Mutation Rates in Barn Swallows:

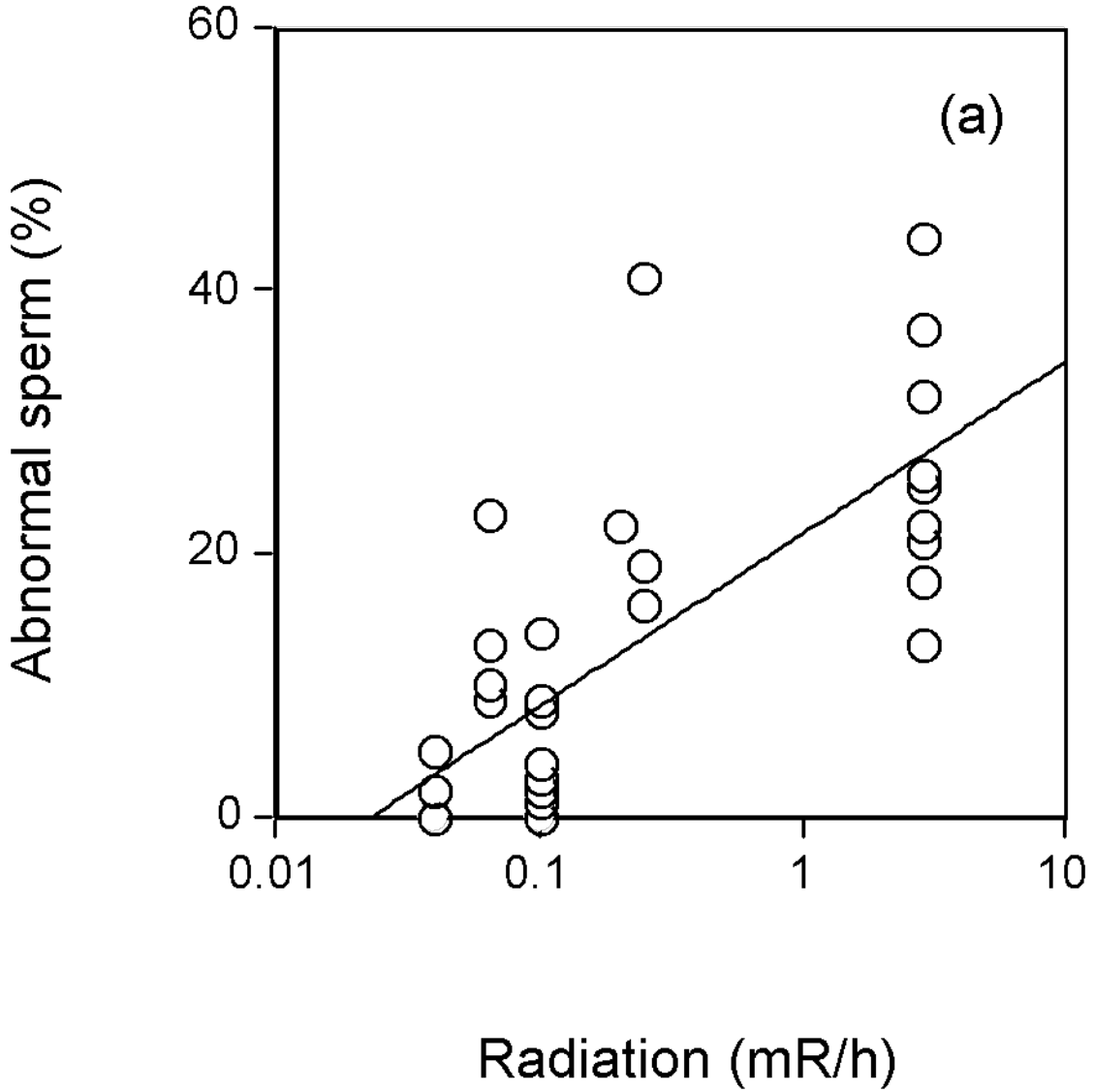
1. Increased mutation rates in microsatellite DNA (2 to 10 times normal).

2. Cell flow cytometry and comet analyses indicate significant increases in variation in nuclear DNA content of red blood cells.

3. Sperm pathology suggests increased genetic damage to germ cells.

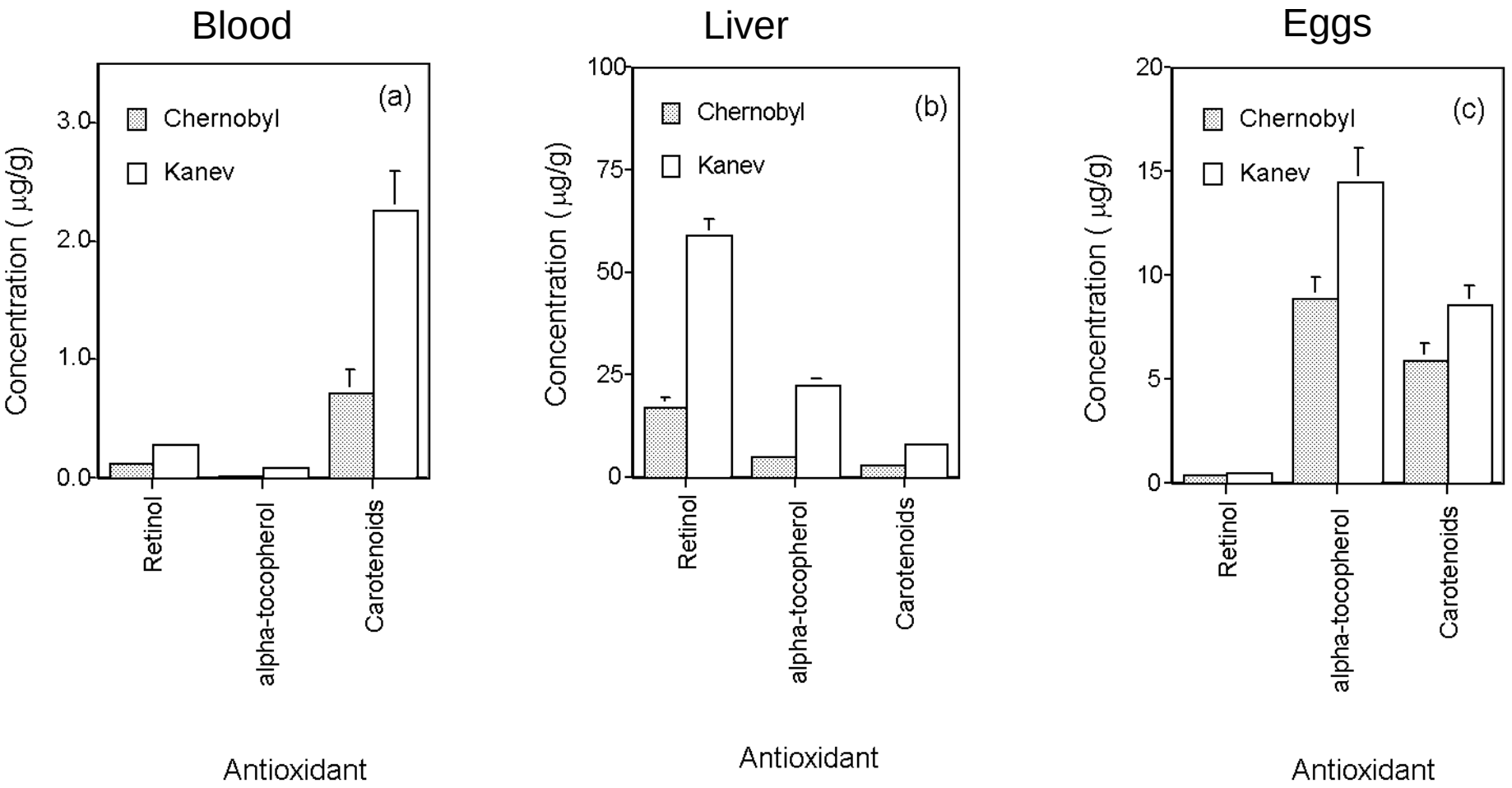
4. Antioxidants appear to provide protection against mutation accumulation.

Male birds from Chernobyl have deformed sperm



Moller, Mousseau & Surai. 2004. Proc. Roy. Soc. Lond. B.

Birds from Chernobyl have reduced levels of antioxidants



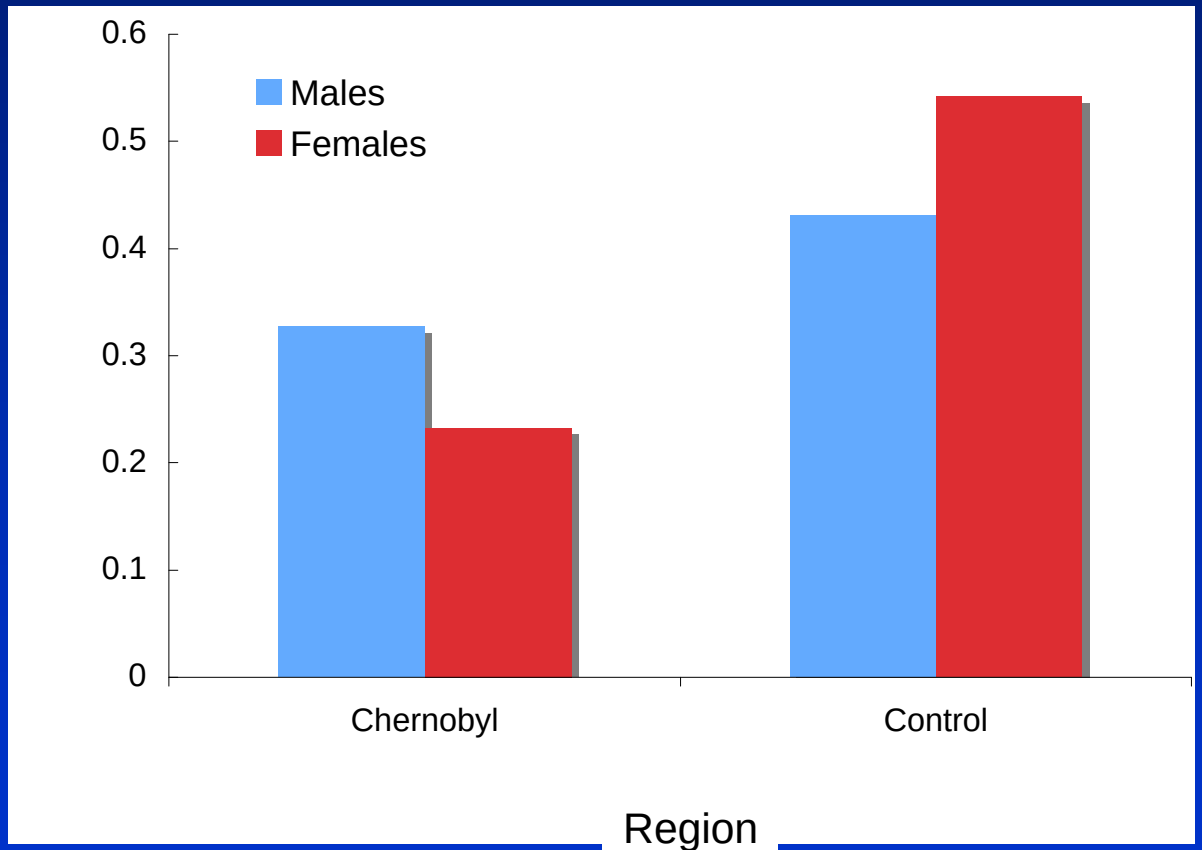
Moller, Mousseau & Surai. 2004. Proc. Roy. Soc. Lond. B.

Mutation and Radiation

24 studies for other species showing elevated mutation rates.

Moller and Mousseau. 2006. Trends in Ecology and Evolution.

Adult survival rate



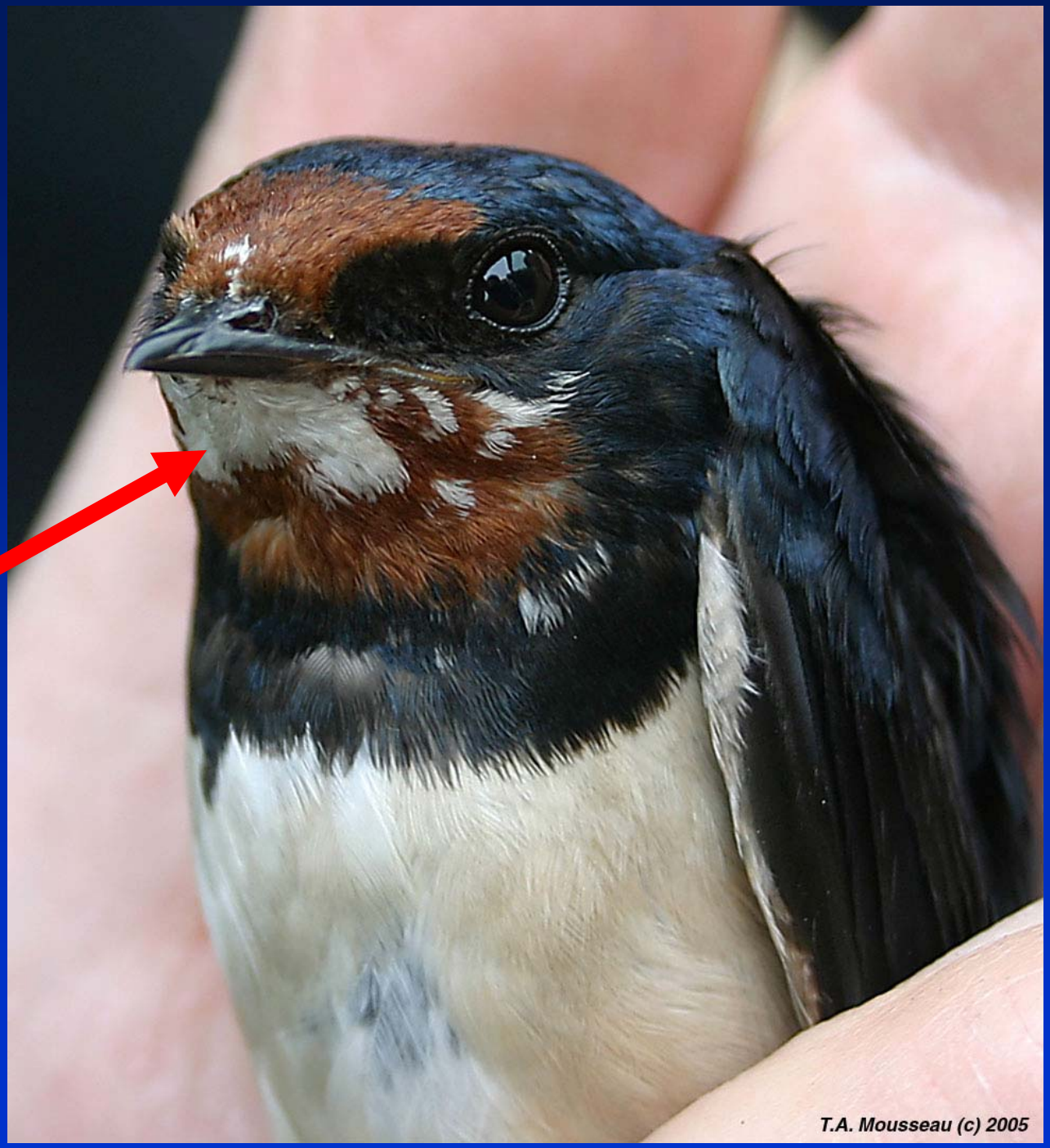
Control sites in Ukraine, Italy, Denmark and Spain

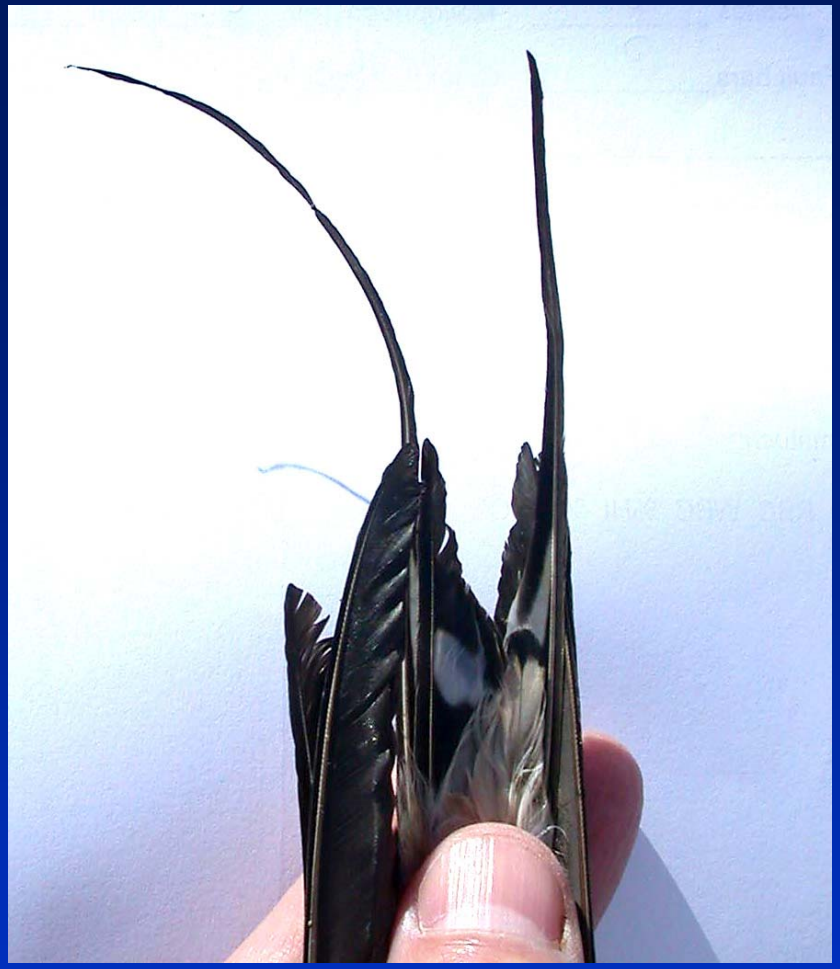
A. P. Møller, T.A. Mousseau, et al., J. Anim. Ecol. 74:1102-1111, 2005

What are the developmental effects of radiation-induced mutations?

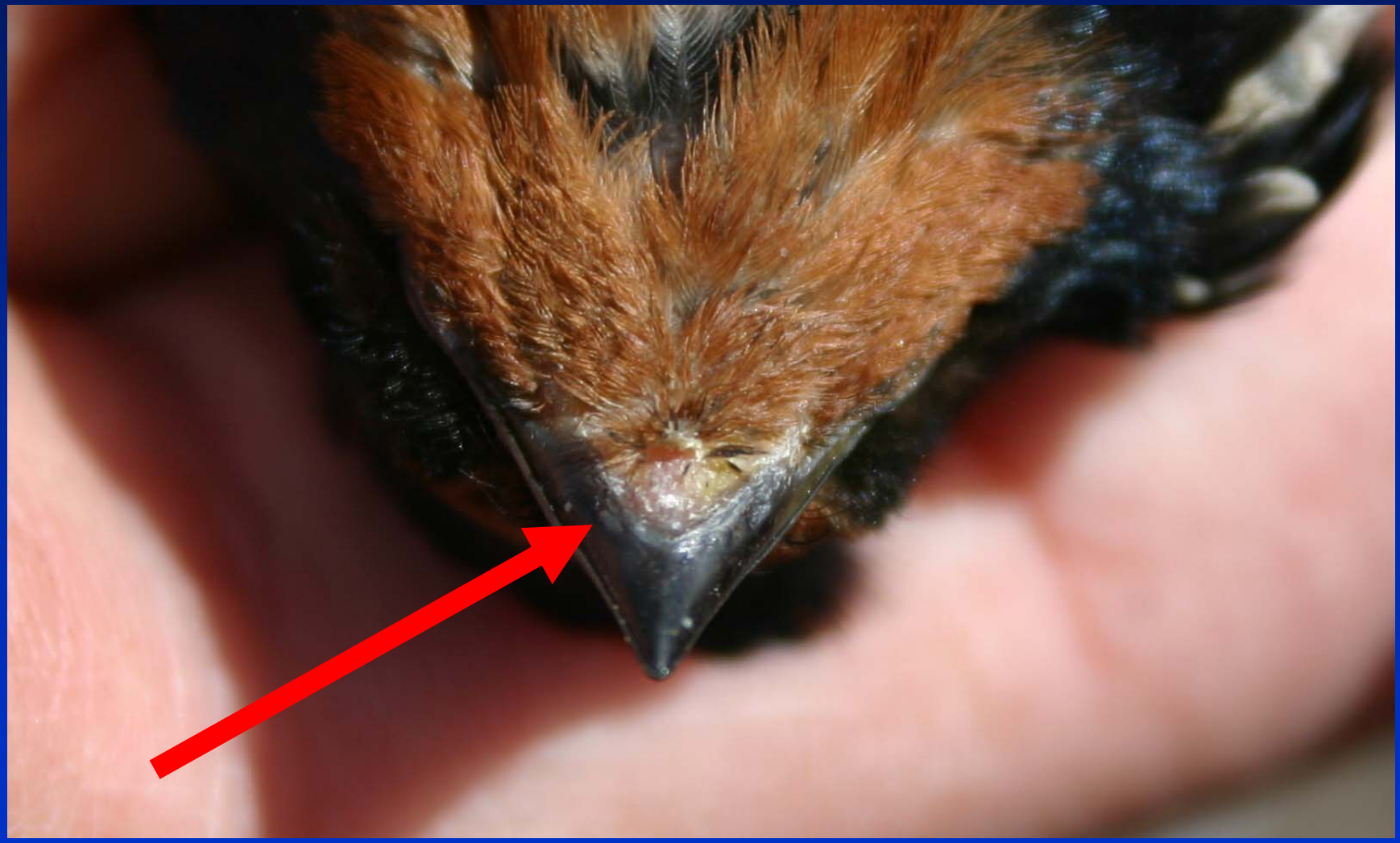
Partially albinistic male swallow (on left). Swallows from Chernobyl region are generally much paler than swallows from other regions.

Moller & Mousseau. 2001. Evolution

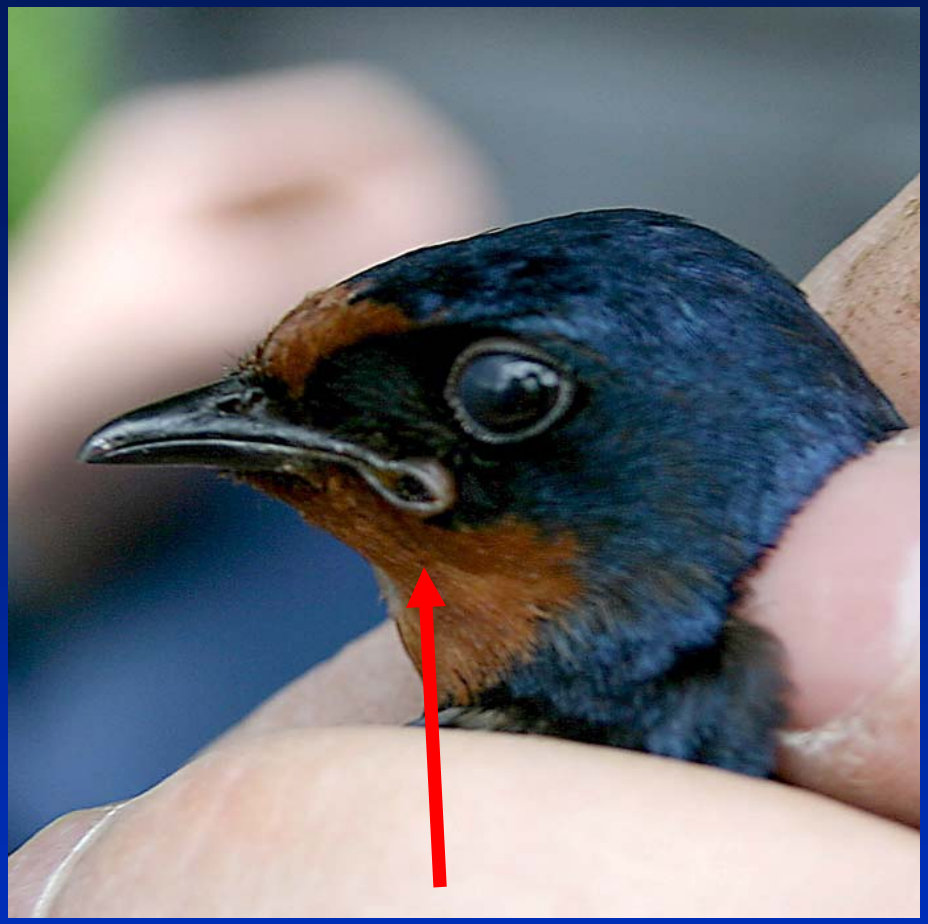

Abnormal coloration
T.A. Mousseau (c) 2005



Bent and asymmetrical tail feathers.



Tumor growth under beak.



Deformed lips

Deformed airsac

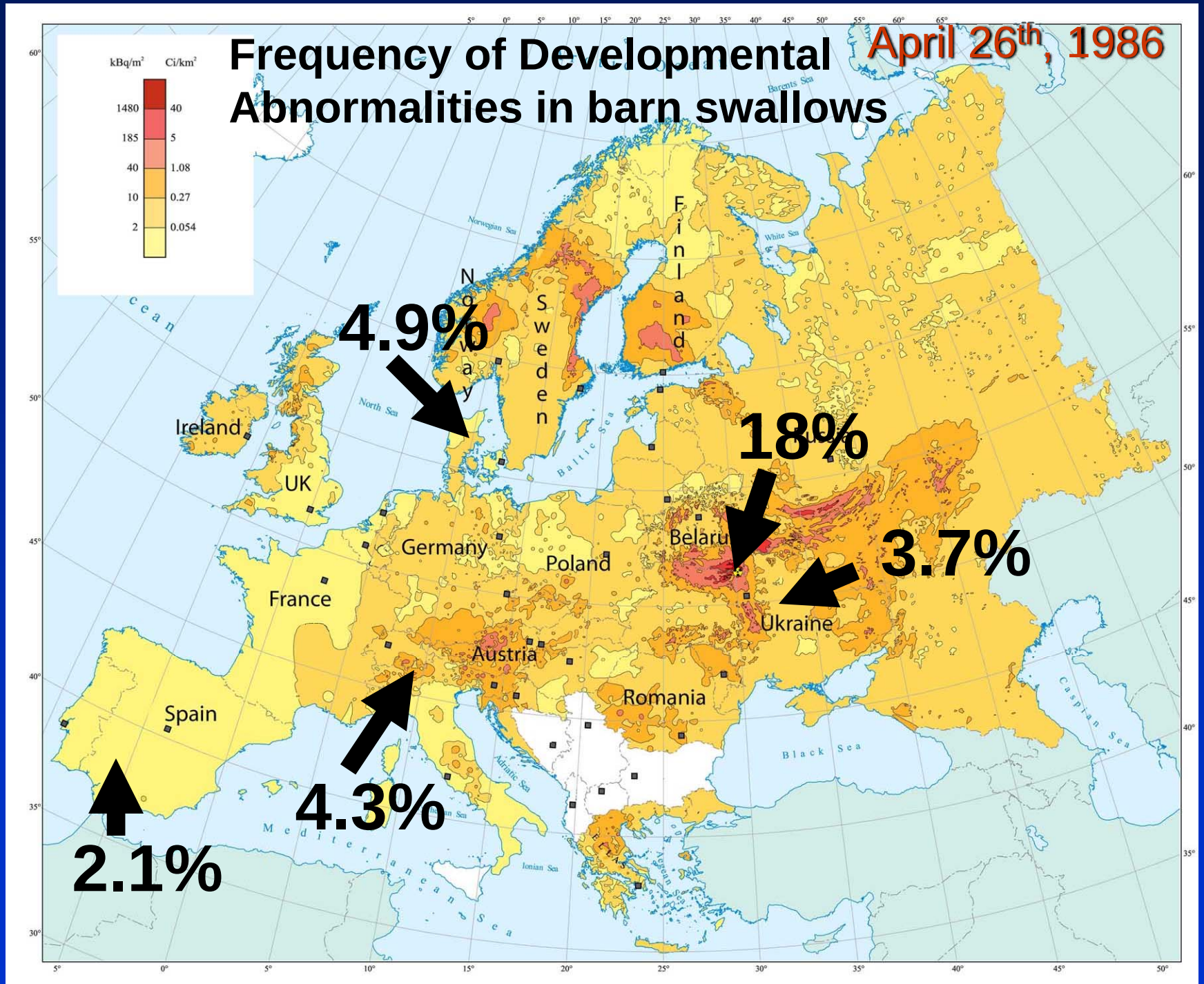
Great tit, *Parus major*

Tumor around eye

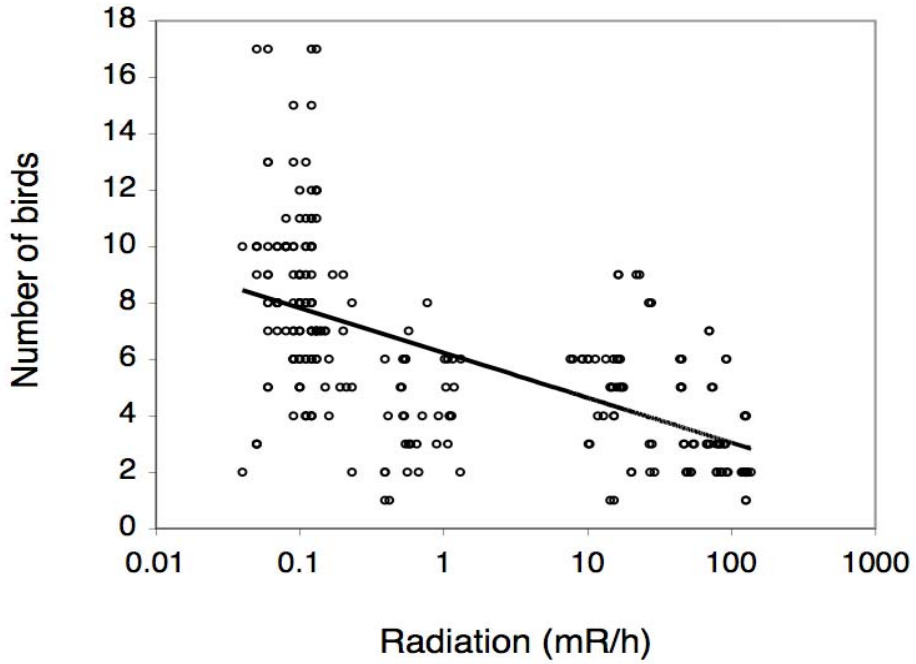
Frequency of abnormalities in Chernobyl and elsewhere

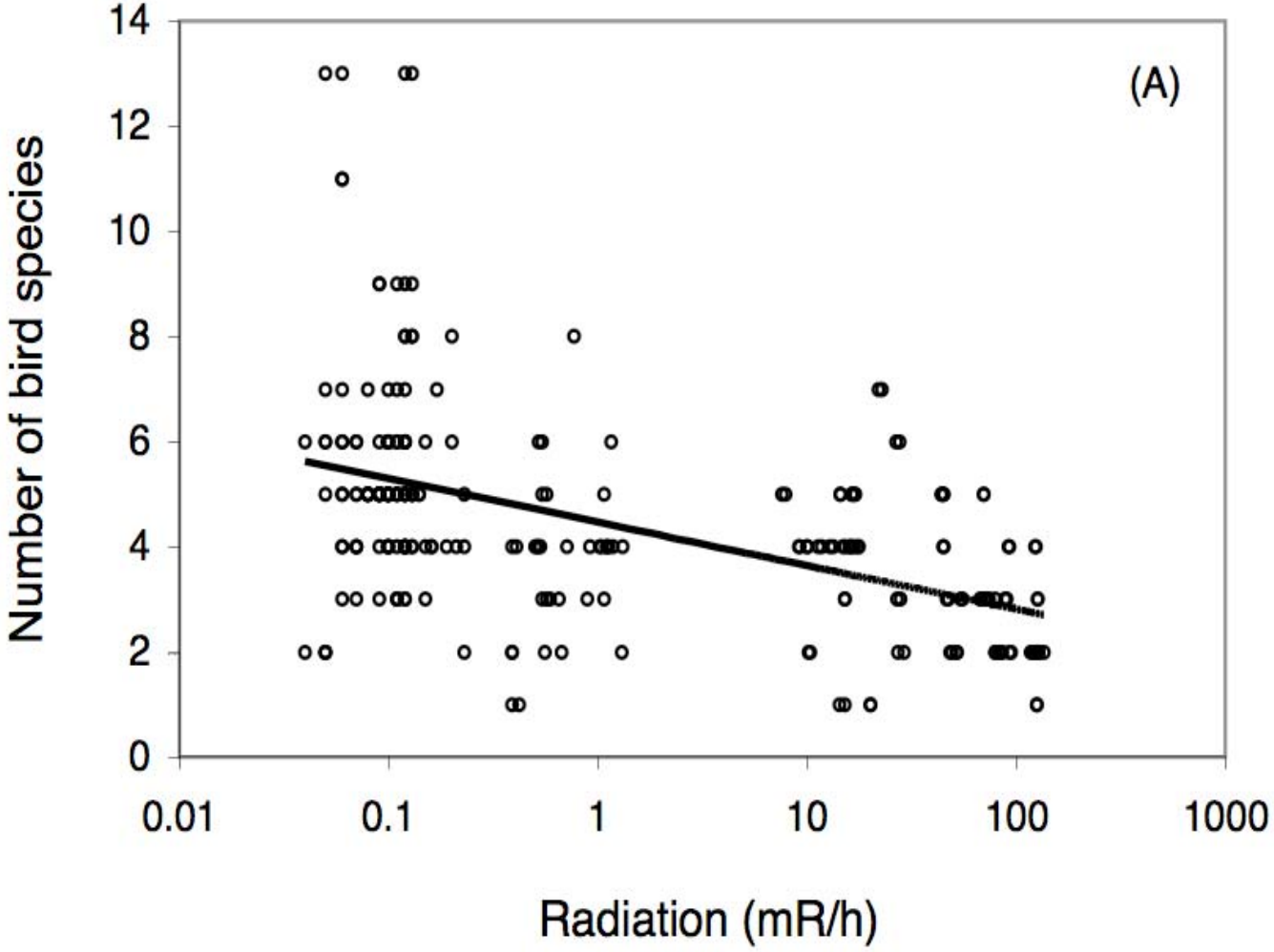
Condition	Chernobyl	Ukrainian control area	Denmark	Spain	Italy
Partial albinism	**13.32 (112)**	**3.75 (20)**	**4.87 (204)**	**1.96 (11)**	**4.06 (65)**
Aberrant coloration of plumage	**0.28 (3)**	0	0	0	0
Red coloration on chest	**0.28 (3)**	0	0	0	0
Blue coloration in red face	**0.19 (2)**	0	0	0	0
Deformed 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
April 26th, 1986
kBq/m² Ci/km²
1480 40
185 5
40 1.08
10 0.27
2 0.054
4.9%
18%
3.7%
4.3%
2.1%
Norway
Sweden
Finland
Ireland
UK
Germany
Poland
Belarus
France
Ukraine
Austria
Romania
Spain
Norwegian Sea
North Sea
Baltic Sea
White Sea
Barents Sea
Black Sea
Caspian Sea
Mediterranean Sea
Adriatic Sea
Ionian Sea
Aegean Sea

Abundance of birds and radiation





Moller & Mousseau. 2007. J. Applied Ecology

Bumblebees, spiders, and butterflies all show declines in abundance with increasing contamination levels.

What about people?

What about people?

- Germline mutations rates are higher, the long term implications are unknown.

• Decreased survival rates

THE ROYAL SOCIETY

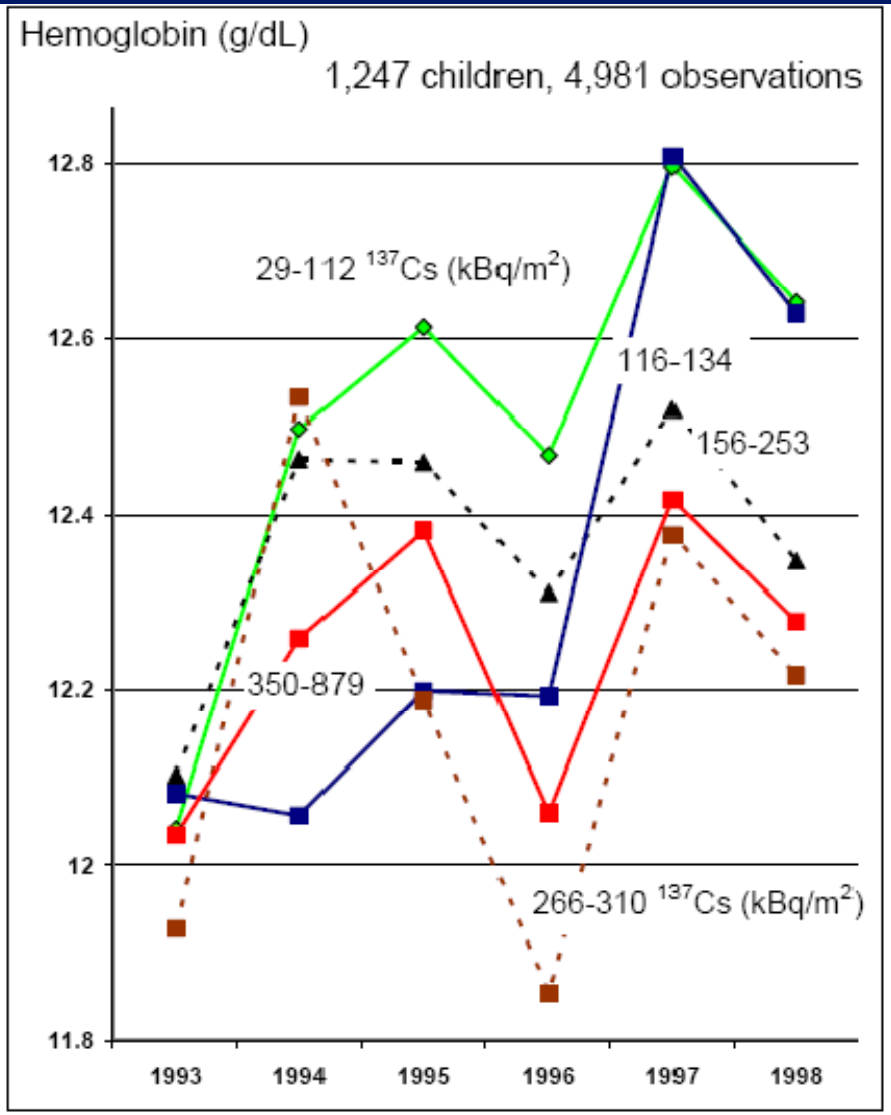
doi 10.1098/rspb.2001.1650

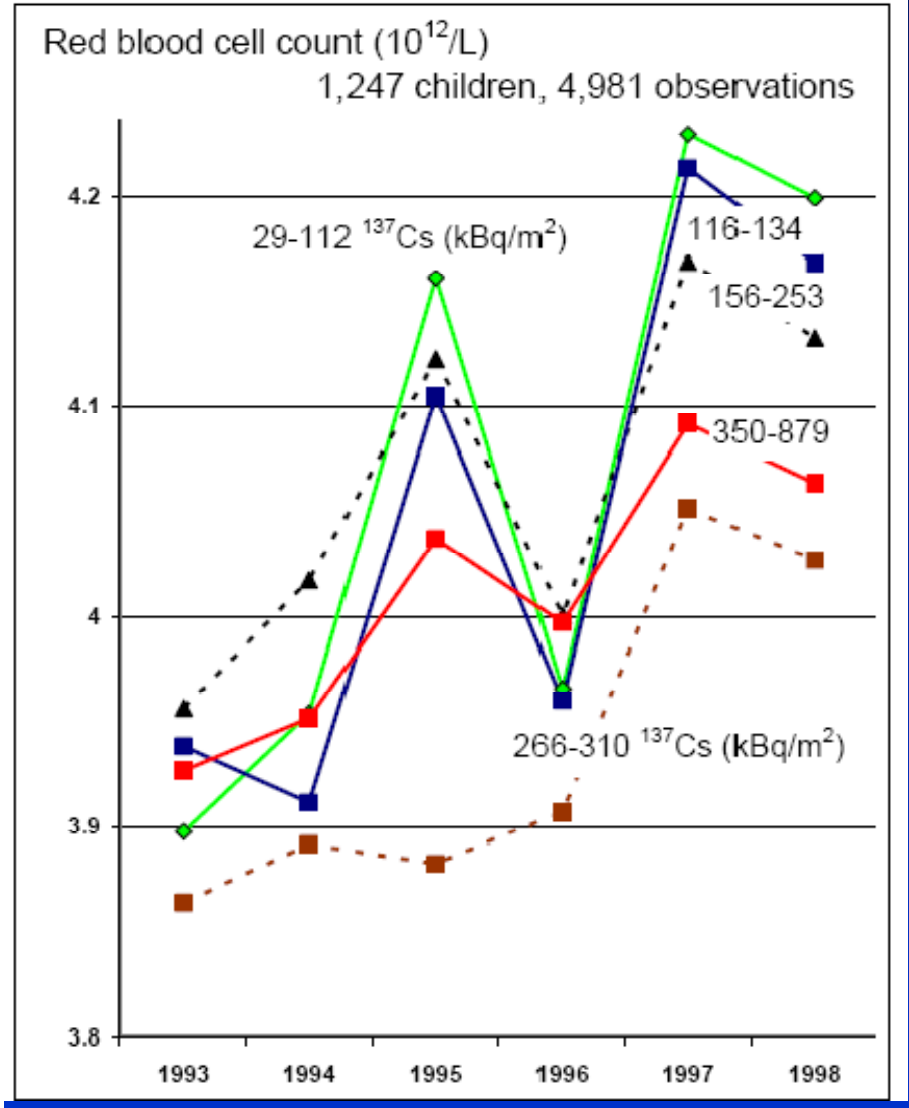
Very high mutation rate in offspring of Chernobyl accident liquidators

H. Sh. Weinberg[1], A. B. Korol[1], V. M. Kirzhner[1], A. Avivi[1], T. Fahima[1], Eviatar Nevo[1]*, S. Shapiro[2], G. Rennert[2], O. Piatak[3], E. I. Stepanova[3] and E. Skvarskaja[3]

[1]*Institute of Evolution, University of Haifa, Haifa 31905, Israel*
[2]*National Kupat Holim Cancer Control Center, Carmel Medical Center and Technion Faculty of Medicine, Haifa 34362, Israel*
[3]*Research Center for Radiation Medicine, Academy of Medical Sciences of Ukraine, Melinkova Street 53, Kiev 254050, Ukraine*

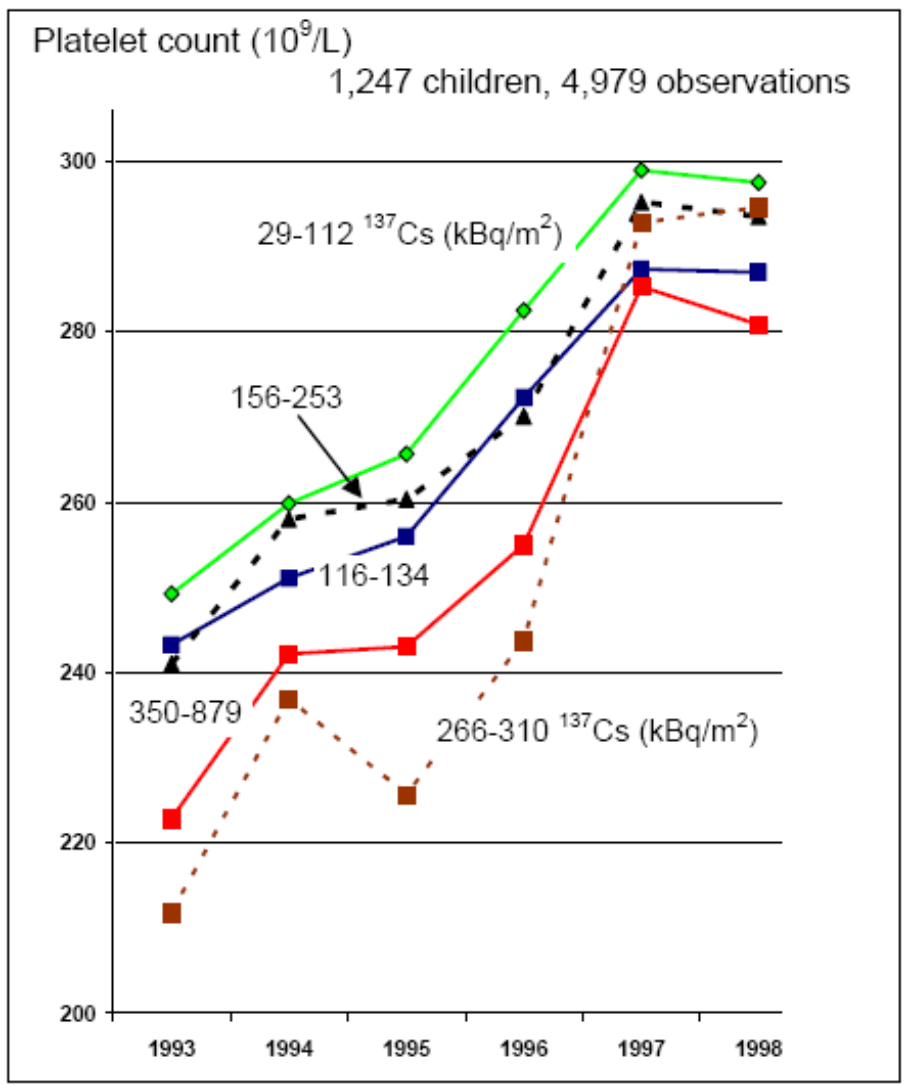
Children of the Narodichesky region

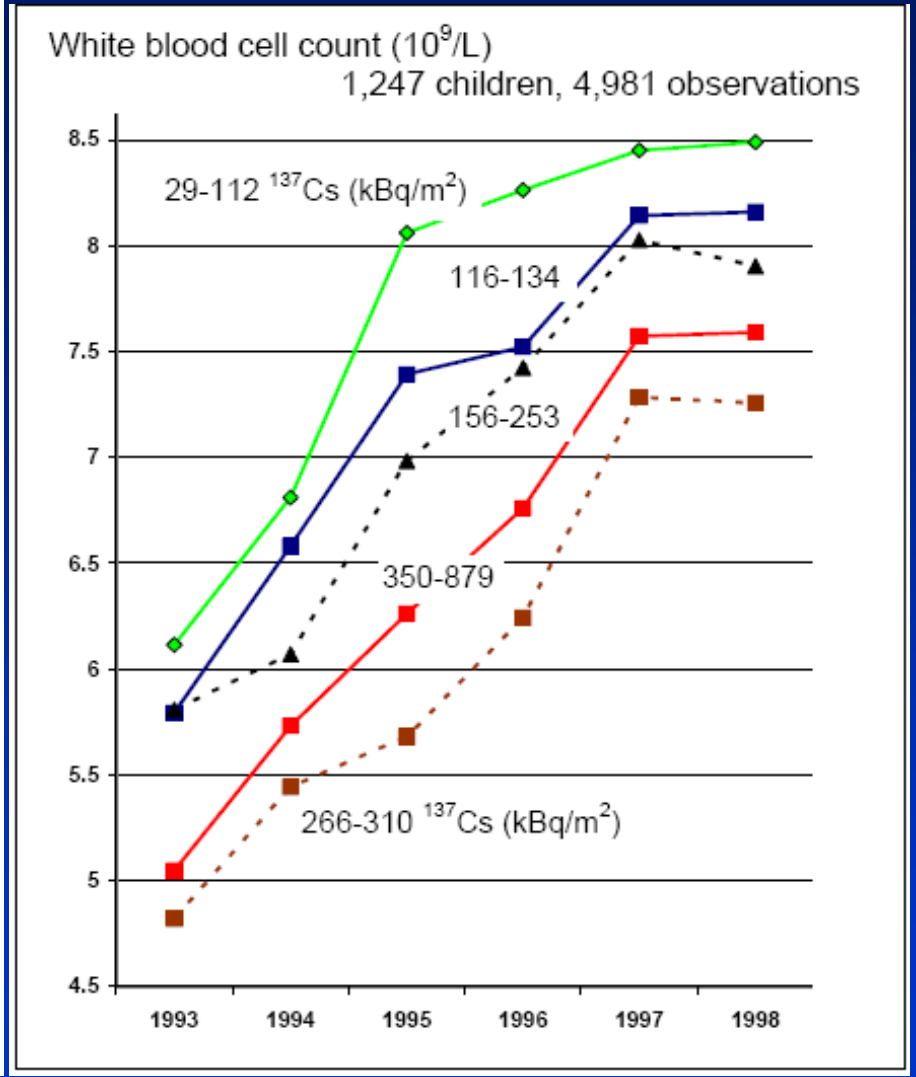




Stepanova, Karmaus, Naboka, Vdovenko, Mousseau, Shestopalov, Drane, Vena, Underhill, & Pastides. 2008. Environmental Health.

Children of the Narodichesky region





Stepanova, Karmaus, Naboka, Vdovenko, Mousseau, Shestopalov, Drane, Vena, Underhill, & Pastides. 2008. Environmental Health

The Children of Naradichy show dramatically impaired pulmonary function.

FEV_1 = Forced expiratory volume

PEF = Peak expiratory flow

FVC = Forced Vital Capacity

MEF_{25} = Maximum expiratory flow at 25% of the exhalation

MEF_{50} = Maximum expiratory flow at 50% of the exhalation

MEF_{75} = Maximum expiratory flow at 75% of the exhalation

Svendsen, Kolpakov, Stepanova, Vdovenko, Naboka, Mousseau, Mohr, Hoel, Karmaus. 2008. Submitted

Conclusions?

- Despite popular unscientific dogma, low-dose radioactive contaminants have significant effects on mutation rates, development, and fitness in animals and humans.

- Are these risks small relative to the potential benefits of nuclear energy? There is insufficient information to draw any conclusions at present.

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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".

Timothy Alexander Mousseau, PhD

Associate Dean for Research and Graduate Education
College of Arts and Sciences

Professor, Department of Biological Sciences

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Most of these papers are available at the author's website: http://cricket.biol.sc.edu/Chernobyl.htm