# Radiobiology and Radioecology--- Sharing Knowledge

**Tom Hinton**

**French Institute of Radiation Protection and Nuclear Safety (IRSN)**

## Japan expands Fukushima evacuation zone. Will residents ever return home?

By Peter Grier, *Staff writer* / April 11, 2011

## Traditional Separation of RB and RE

Radiation Ecologists

Radiation Biologists

Ecosystems

Communities

Populations

Individuals

Tissues

Cells

Molecules

## RADIOECOLOGY

### TRANSPORT AND FATE

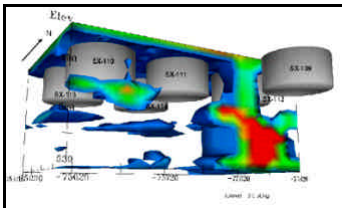
of radionuclides among ecosystem components (soil, air, water, biota)

### EFFECTS

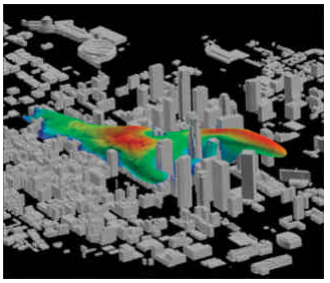
of ionizing radiation on individuals, species, populations, communities, ecosystems

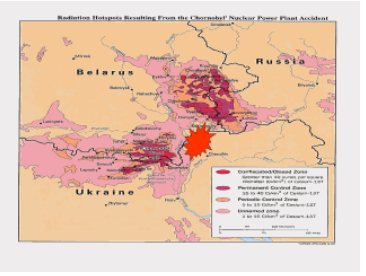
### USE

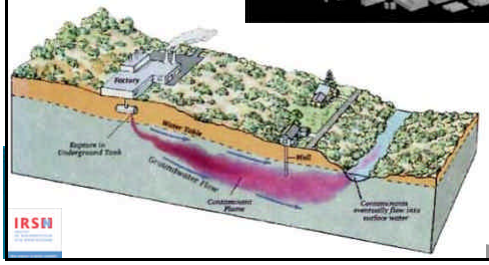
of radionuclides as tracers of chemical, biological or physical processes

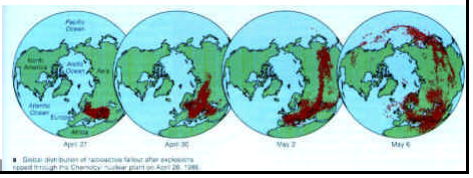


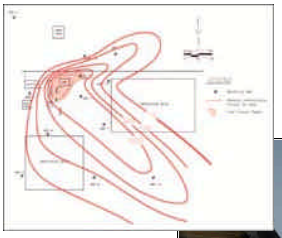
**Contaminant transport, and dispersal with time, are critical components of Radioecology…**





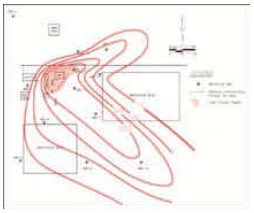



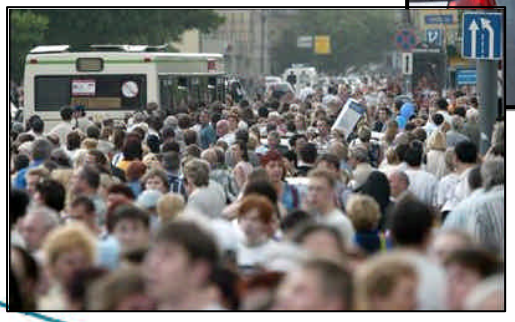



**…small towns…**

…lakes, rivers….

…agricultural areas…





…metropolitan commuter…

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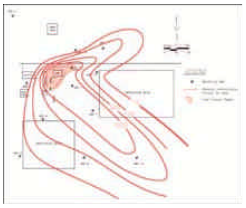
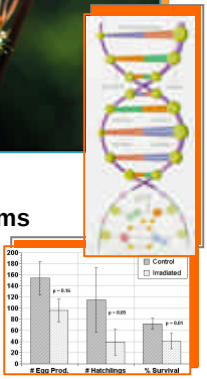


**..how much will go into fish, or the milk of grazing cows..**

The effects component of Radioecology, however, is the aspect most closely aligned with Radiation Biology

## Agenda

- **Contrast radiation effects, as studied in RB vs. RE**
- **Show that the effects paradigm is changing in RE**
- **Present how effects are measured in RE: methods & problems**
- **Give example of how RB and RE benefit from collaboration**



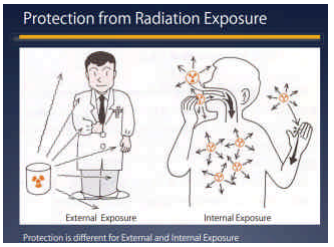
Radiobiology has a well-developed system of dosimetry for humans

**Absorbed Dose**
(Gy = J /kg)

**Equivalent Dose**
(Sv; quality factor for RBE)

**Effective Dose**
(distribution within body)

**Committed Equivalent Dose**
(integrate over time)

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## Epidemiological Studies of Radiation - Induced Cancer Risks

| | Canadian Tuberculosis Patients | Ringworm, Israel Children | UK, Radiation Workers | Japanese Atomic Bomb Survivors |
|---|---|---|---|---|
| Number | 31,701 | 10,834 | 95,217 | 75,991 |
| Setting | Diagnostic | Therapy | Occup. | War |
| Age / Sex | > 10 y (F) | 0 - 15 y (M = F) | 18 - 64 y (92% M) | All (M = F) |
| Organs | Breast, lung | Brain, bone marrow | All | All |
| Doses (Gy) | 0 - 10 | 0 - 6 | 0 - 0.5 | 0 - 4 |

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## Lifetime Probability of a Deleterious Effect

| Detriment | Risk Factor ($mSv^{-1}$) |
|---|---|
| Fatal Cancer | $5.0 \times 10^{-5}$ |
| Genetic Effects | $1.3 \times 10^{-5}$ |
| Non-fatal Cancer | $1.0 \times 10^{-5}$ |
| Total Detriment | $7.3 \times 10^{-5}$ |

## For Nonhuman Biota

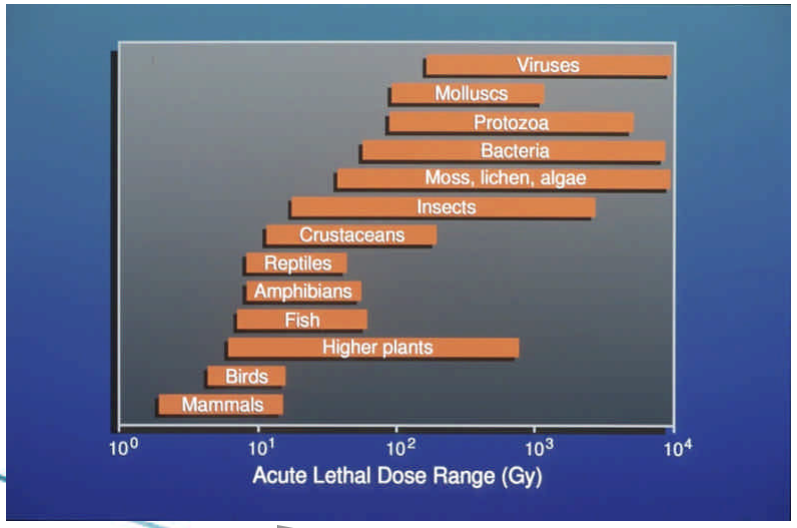
- No specialized units
- No organ distribution factors
- No agreed upon a weighting factors
- Certainly, no risk factors
- No international laws for protecting the environ.
- Not even agreement on endpoint!

# Fundamental Differences In Human and Ecological Risk Analyses

| Type | Unit of Observation | Endpoint | Dose-Response |
|---|---|---|---|
| Human | individual | lifetime cancer risk | relationships established |
| Ecological | varies | varies | not established |

- varies → individual, population, community, ecosystem
- varies → > mortality, < fecundity, sublethal effects
- not established → for chronic, low level exposure to radiation, alone, or mixed with other contaminants

# Organisms vary in their sensitivity to radiation



## The Long-Standing PARADIGM for Protecting Biota from Ionizing Radiation

If man is adequately protected then so is the environment. Explicit radiological limits are not needed for the biota. If dose limits are set to protect humans, then the environment is automatically protected as well.

(ICRP 1977; ICRP 1991; IAEA 1992)

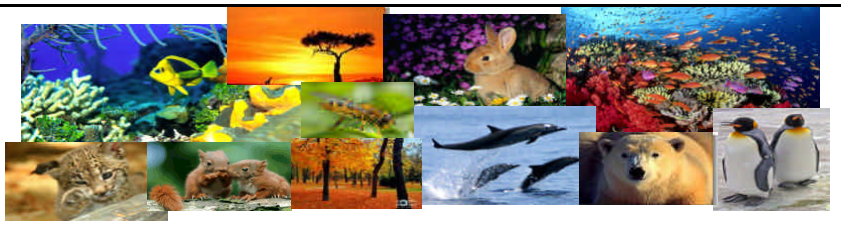
## Problems with Paradigm

Human dominated approach is unacceptable to a growing segment of society

Most importantly, we do not have data to prove that the existing paradigm is true ….

…particularly, for chronic, low level exposures, or with multiple stressors

Generally, we manage non-human biota at the level of populations, rather than individuals



Suggested **DOSE LIMITS** for *maximally exposed individual* that are thought to ensure *protection of the population*

**1 mGy / d** : terrestrial animals

**10 mGy / d**: aquatic animals, terrestrial plants

IAEA (1976, 1992, 1999)

ICRP (1977, 1991)

NCRP (1991)

# Endpoints to estimate radiation effects to non-human biota

**Early Mortality**
***premature death of organism***

**Morbidity**
***reduced physical well being including effects on growth and behavior***

**Reproductive Success**
***reduced fertility and fecundity***

Reproduction is thought to be a more sensitive effect than mortality

These categories of radiation effects are similar to the endpoints that are often used for risk assessments of other environmental stressors, and are relevant to the needs of nature conservation and other forms of environmental protection

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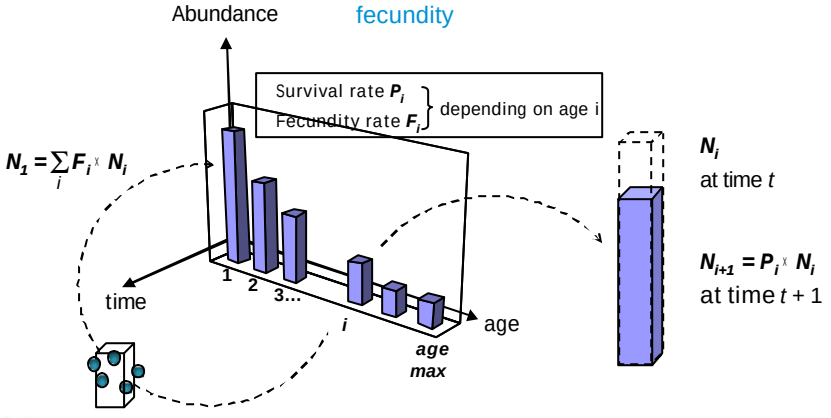
# Endpoints measured among individuals have implications to **population dynamics**

1) Population structured per age classes

2) Cohorts vary over time depending on survival and fecundity




⇨ Modeling population size in number

⇨ Determination of population growth rate

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(F. Alonzo, IRSN)

41 studies that included 28 species and 44 toxicants

Population Growth Rate

52%

Time to reach sexual maturity

Mortality of juveniles

Reduction in number of offspring

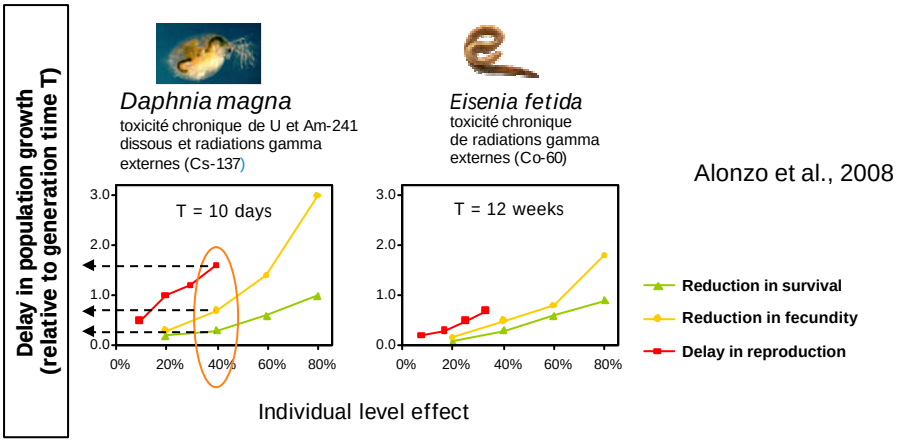
31%

No correlation

Mortality of adults


(Forbes & Calow, 1999)

## Comparison of population sensitivity to changes in different endpoints and different species




Alonzo et al., 2008

⇨ Sensitivity of population depends on individual endpoints

⇨ Sensitivity of population depends on life history strategy of different species

Changes to these

**Operative Environment Categories**

- **Resources** (time, food, space)
- **Biophysical** (temperature, light)
- **Social and Demographic** (dominance, territory, mating structure)
- **Exploitative** (predation, disease)
- **Contaminants** (organics, thermal, radiation)

are filtered through these

**An Organism's Life History Traits**

- **Available Time** (allocated to acquiring mate and resources)
- **Assimilated Resources** (water, energy, nutrients)
- **Reproductive Output** (offspring size, the number of offspring, the frequency of production)

to potentially impact these

**Population Demography**

- **Age- or size-specific birth rate**
- **Probability of mortality**
- **Probability of migration**

(Congdon et al. 2001)

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## Radioecology Advantage: A Data Base of Knowledge on Radiation Effects to Biota

- FREDERICA
- (www.frederica-online.org)

? An online database of literature data to help summarise dose-effect relationships

? FREDERICA can be used on its own; or in conjunction with the ERICA assessment tool (for conducting risk assessments of wildlife exposed to ionising radiation)

(> 1500 references; 26 000 data entries)

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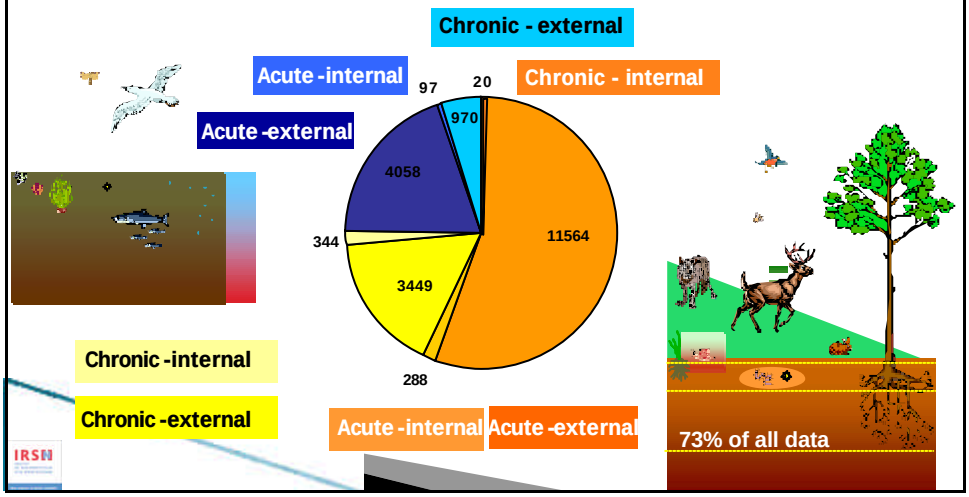
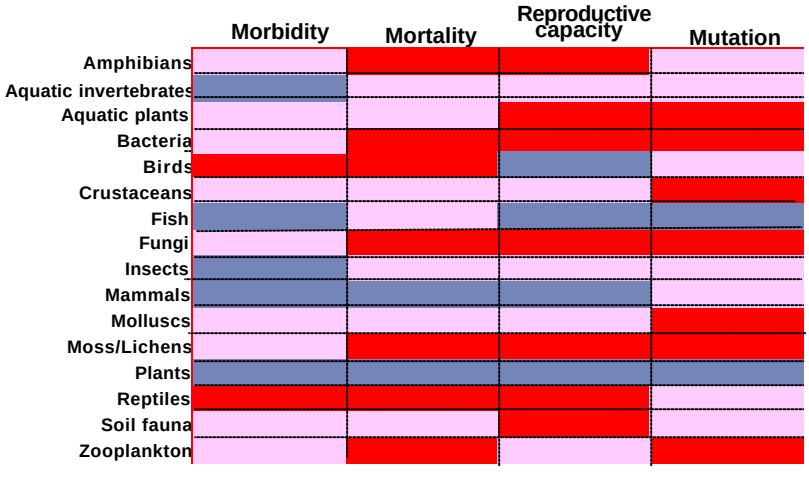
# FREDERICA Database

effects data; per ecosystem
per exposure pathway (external or internal irradiation)
per duration (acute or chronic)




# Data on radiation effects for non-human species

**Chronic effects and ? external irradiation**



## Most research is not directly relevant to responses in nature

**Data Plentiful**

Individual response
Mortality
Acute exposures
External gamma
Laboratory data
Individual exposures

**Least Relevant**

**Data Scarce**

Population response
Reproduction
Chronic exposures
Internal contamination
Field data
Multiple generations

**Most Relevant**

## Responses of Animals to Radiation Are Complicated by:

- other stresses (chemical, physical, biological)
- life cycle stage and physiological condition
- environmental variables

Pika

$LD_{50}$ in captivity: ~ 5.6 Gy
$LD_{50}$ in the wild: ~ 3.8 Gy

(Markham, et al. 1974)

Populations are resilient

Compensating mechanisms exist

Indirect effects often occur that are unpredictable

Blaylock (1969) studies at Oak Ridge
DIRECT EFFECT:
Increased mortality of fish embryos exposed to 4 mGy / d
COMPENSATING MECHANISM:
Fish produced larger brood sizes
NET RESULT:
No effect to population

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## Indirect Effects of Human Abandonment

Pripyat
Abandoned

4 km N of Reactor
50,000 people

135,000 people and 35,000 cattle evacuated

Dozens of towns and villages deserted

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With the removal of humans, wildlife around Chernobyl are flourishing

Russian Boar

48 endangered species listed in the international Red Book of protected animals and plants are now thriving in the Chernobyl Exclusion Zone

Wolves

Prejevalsky Horses

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# Wormwood Forest: A Natural History of Chernobyl

Mary Mycio

Black Stork (with Grey Heron), Schleswig-Holstein, N Germany ©Andreas Schulz-Benick

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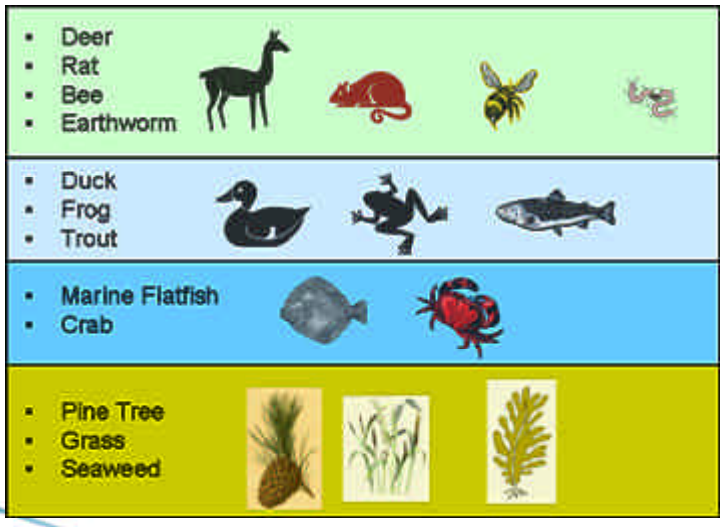
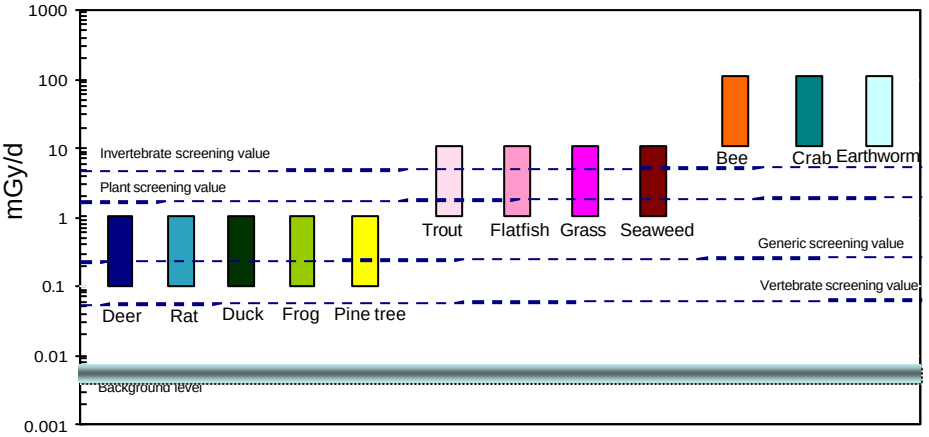
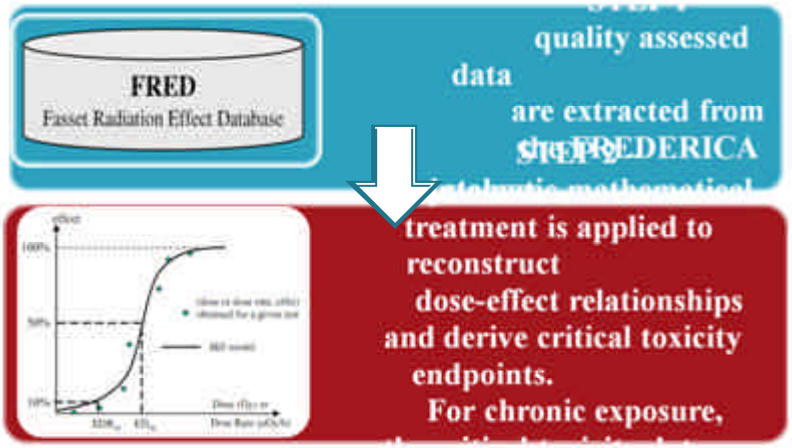
# ICRP Approach: Reference Animals and Plants (RAPs)




# ICRP Derived Consideration Levels



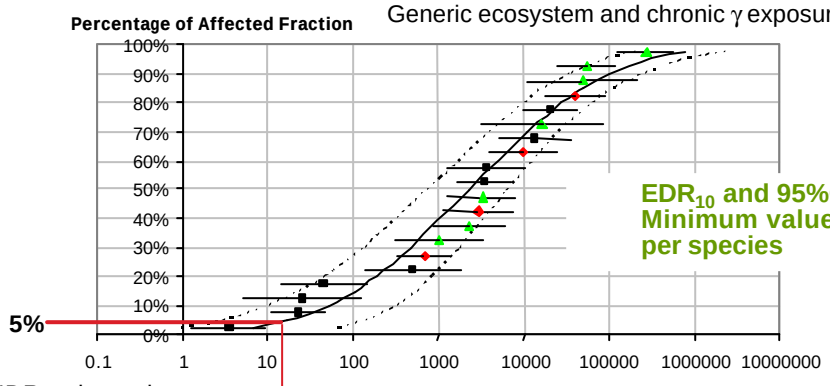
# Alternative approach: Species Sensitivity Distributions




Estimated Dose Rate causing a 10% effect = $EDR_{10}$

# Species Sensitivity Distributions and Predicted-No-Effect-Dose-Rate

Generic ecosystem and chronic γ exposure




$HDR_5$ = hazardous dose rate giving 10% effect to 5% of species)

**$HDR_5$ = 17 µGy/h [2-211]** → **Predicted-No-Effect-Dose-Rate, PNEDR=10 µGy/h**

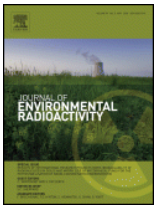
(Safety Factor of 2)

Best-Estimate  Centile 5%  Centile 95%
Vertebrates  Plants  Invertebrates

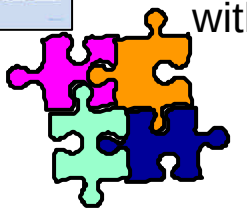
Radiation Biologists

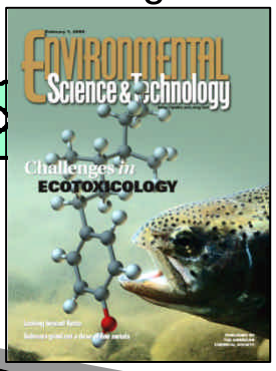
plus

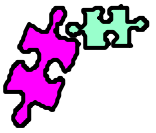
Radiation Ecologists


Fruitful Collaboration with Knowledge Shared!!







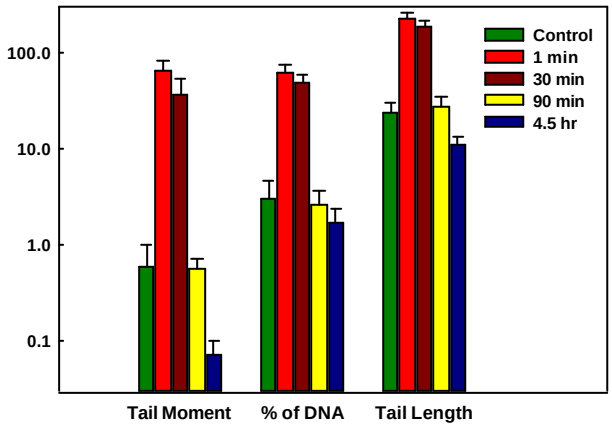
## Examples with Medaka fish

*(Oryzias latipes)*

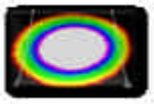
- Widely used in mutagenesis and carcinogenesis studies
- ~ 2 cm in length
- Produce ~ 20 eggs / d
- Easier to maintain than mice
- Transgenic and specialized strains available

# DNA Damage

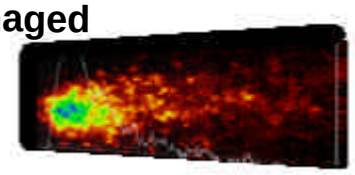
Alkaline Comet Assay

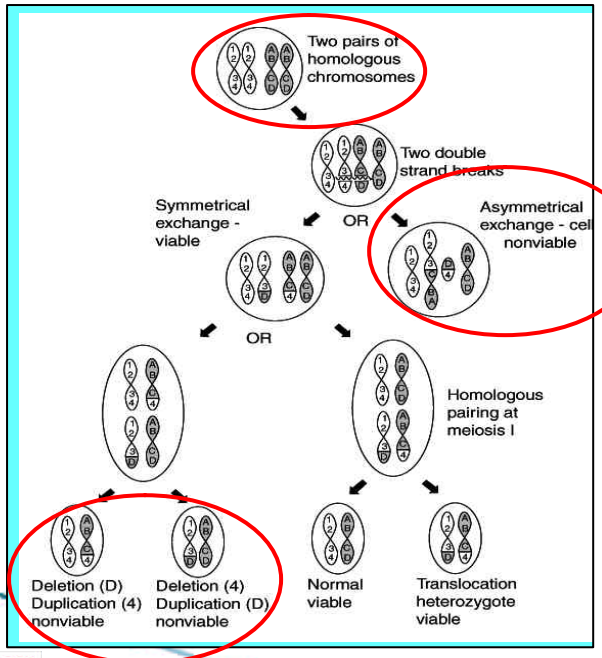



**Normal Cell**



**Damaged Cell**

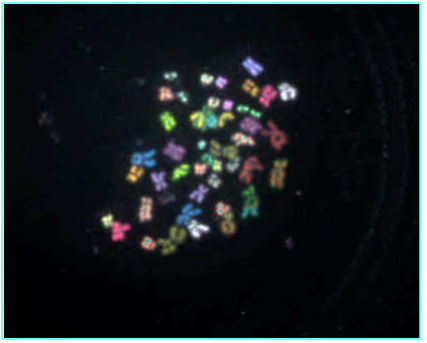




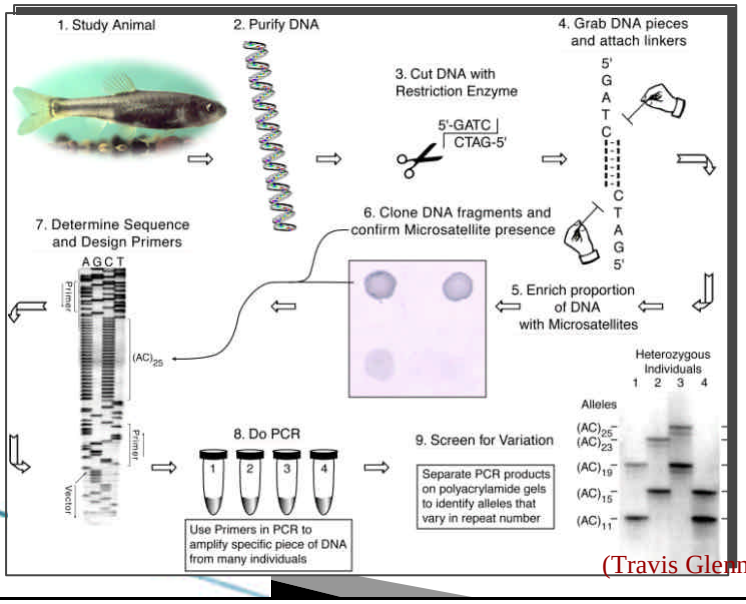

Reciprocal translocations, chromosome aberrations that result in translocation heterozygosity

50 % reduction in reproductive success…thus has implications to POPULATIONS

# Developing chromosome-specific fluorescence in situ hybridization (FISH) probes for medaka

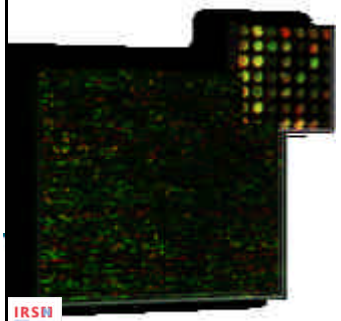
## Mutation Rates in Microsatellite DNA Sequences

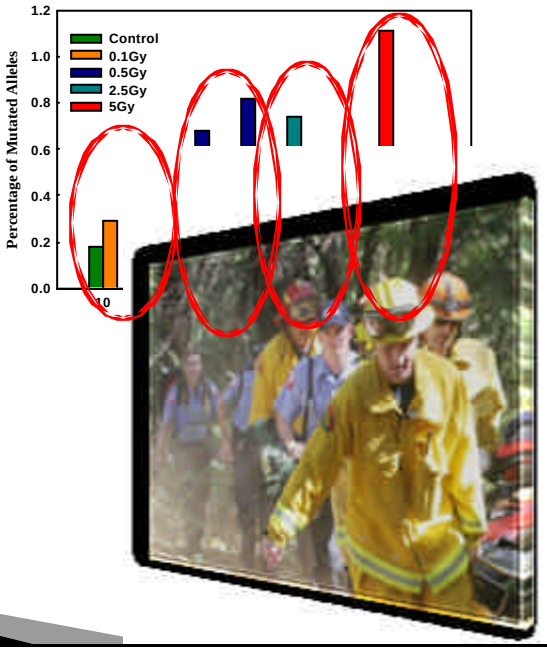



(Travis Glenn, SREL)

with

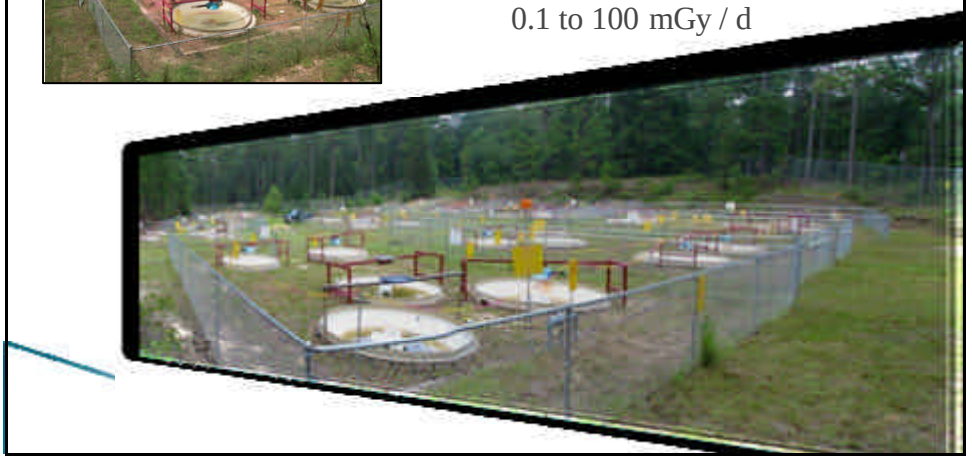
J. Zimbrick, CSU; T. Glenn, SREL






## Low Dose-Rate Irradiation Facility (LoDIF)

- Dose rates from gamma exposures range from 0.1 to 100 mGy / d



Metals Organics Radionuclides

# Summary

Human-centered paradigm in RE is being questioned

Much is known about the effects of ionizing radiation on plant communities and animal populations… but little about chronic, low-level exposures, sub-lethal effects, or exposures to contaminant mixtures…as is also true in RB!

The data and tools developed by RBs can help REs….and vice versa….KNOWLEDGE SHARED addresses both disciplines

More rapid and efficient progress can be accomplished if a collaboration exists among RB and RE

EUROPEAN RADIOECOLOGY ALLIANCE

STAR

STRATEGY FOR ALLIED RADIOECOLOGY

**Alliance Members:**

**IRSN (France)**
**NERC (UK)**
**CIEMAT (Spain)**
**SCK-CEN (Belgium)**
**NRPA (Norway)**
**STUK (Finland)**
**BfS (Germany)**
**SSM (Sweden)**

**www.star-radioecology.org**

A major task within STAR is to develop a Strategic Research Agenda for radioecology

SEVENTH FRAMEWORK PROGRAMME