How can the water fleas of Muskoka point the way to saving the world?





Limnological studies on Lake Mendota (E.A. Birge in 1887)







The beauty (and vulnerability) of our 4000+ hectare Muskoka watersheds







"Survival of the fittest"

"Survival by meeting the challenge"



'I wish it need not have happened in my time,' said Frodo.

'So do I,' said Gandalf, 'and so do all who live to see such times. But that is not for them to decide. All we have to decide is what to do with the time that is given us.'



Cyclomorphosis

"one of the most puzzling aspects of aquatic ecology"

G.E. Hutchinson (1941)

What about coping with new threats?

Sauron's Barad-Dûr tower on earth?

Sudbury, Ontario, Canada

- >100 years of industrial mining
- 6000 square miles of forest damaged , over 100 square miles barren

7000 lakes decimated from acid and metal stress

Are the water fleas doomed?

There may be hope after all The process remains – but at a cost

<u>Acclimation</u>: The process by which an organism becomes accustomed to a new environment (involves physiological changes and occurs at the level of the individual).

Search for the Survival Genes

Unknown Genes are Ecologically Important Genes

Adaptation to Increased Phosphorus

Daphnia's Response to Phosphorus

High P

Daphnia are P-rich herbivores with a somatic C:P ratio around 100

C:P ratios of lakes fluctuate from 100 to 1,000

With Puni Jeyasingh (Oklahoma State Univ.)

Experiments to Measure Gene Responses

1,818 genes (18%) show significant fold change in gene expression

- A: N-glycan biosynthesis
- B: Arachidonic acid metabolism
- C: Glycerolipid metabolism
- D: Fatty acid metabolism
- E: Androgen and estrogene metabolism
- F: Stilbene, courmarine & lignin biosynth.
- G: Purine metabolism
- H: Tryptophan metabolism

Up in LP (900); Down in HP (100) Up in HP; Down in LP Equal change under both No change

Orsini et al., Trends in ecology & evolution, 2013

TRENDS in Ecology & Evolution

Forecasting population genetic responses?

Environmental Problems Requiring Solutions

Samples of tap water from Maywood, California. When residents asked for cleaner water, they were told the water satisfied the Safe Drinking Water Act.

Increasing Frustration with Current Approaches

Low throughput & <u>expensive</u>!

Questionable relevance to actual human risk

Conservative extrapolation defaults

Traditional analog approaches from 1930's

No use of modern biology able to provide <u>knowledge of</u> <u>mechanisms</u>

Questionable ethics for reliance on mammals

Results on Decision Making Process

West Virginia Chemical Leak: crude 4-methylcyclohexanemethanol (MCHM) into the Elk River

1. Because humans may be much more sensitive to the effects of a chemical exposure than rats, a 10-fold "interspecies extrapolation" uncertainty factor was applied. That dropped the value to 82.5 ppm.

2. Because humans differ in their sensitivity to a chemical exposure, another 10-fold "intraspecies extrapolation" uncertainty factor was applied. That dropped the value to 8.25 ppm.

3. Finally, acknowledging that the study in question looked only at lethality, whereas this chemical might well have other health effects short of outright killing you, a third uncertainty factor was applied.

Magically, this factor was set at 8.25-fold, in order to produce the nice round number of 1 ppm as the "safe" level.

Bryan Walsh, senior editor at TIME

A Partial Solution – 21st Century Science

Christopher Portier

What Solution can Daphnia Offer?

- □ A catalog of the effects of all chemicals on gene responses in water flea
- □ Used to monitor the presence of known chemicals, to detect the activities of unknown toxicants
- Used to predict the nature of the chemical effects on animals (including humans), their populations, and on ecosystem functions

Meeting this challenge requires millions of measurements

Birmingham's New Industrial Revolution providing comprehensive and timely solutions

The Vision

To transform environment & health protection by the application of automated higher-throughput biology and OMICS technologies. This breaks artificial barriers between human toxicology and ecotoxicology, by creating a comprehensive database of the effects of all chemicals, advanced materials and their mixtures on biological systems, thereby dramatically reducing uncertainty for industry, policy makers and regulators because of shared knowledge built upon strong scientific principles.

Is This All Possible?

Frequency of 10,216 DE Genes Responding to Different Treatments

Gene Network Reconstruction

B. Pietrzak, D. Becker & M. Wojewodzic

Traditional Product Development and Regulation

Current Timescales for Innovation

Reducing Health and Economic Risks by Reducing Uncertainty

Muskoka's Lakes and Watersheds: a Case Study (starting now!)

What work must be done to protect the Muskoka watersheds?

- 1. Generate the necessary environmental knowledge.
- 2. Marshal the will for environmental action.

Specifically, the needed work includes:

ASSESSMENT – ongoing <u>research and monitoring</u> to select appropriate environmental indicators that reflect what we value, detect changes in conditions and any emerging threats;

OUTREACH – ongoing <u>two-way communication</u> with Muskoka residents and policy makers to solicit advice on and support for preferred solutions;

EVALUATION – ongoing <u>tracking</u> of the status and trends of all environmental threats and of remedial actions;

DIAGNOSTIC – research to <u>understand the causes</u> of environmental deterioration or threats of deterioration;

ACTION – ongoing action to prevent future problems from becoming serious, to remediate problems that are deemed serious, and to conduct follow-up monitoring to determine the success of restorative interventions.

How the work we do might save the watersheds of the world...

Research on the lakes of the Muskoka in the past has shown that solving environmental problems at local scales can help solve severe environmental problems at national and international scales, and we can do so again.

We ought to embrace opportunities to use the knowledge, resources, and volunteer-base in Muskoka to improve risk management of the lakes and watersheds around the world.

"Muskoka residents are not just stakeholders in Muskoka, but what we learn here may be directly applicable to a globally significant resource – the freshwaters in the world's lakes." *Norman Yan on behalf of the FMW*

A New Knowledge-Driven Industry? **Environment Care**

Regulatory Challenges Research & Key Innovations

Discovery & KnowledgeBase

Assessment Applications

Business Performance **Benefits**

Societal **Benefits**

Preventative Sector: Is there a problem? Environmental monitoring and testing new compounds.

Risk

Diagnostics Sector: How does it matter? Assessing bio-resilience of species, populations and ecosystems.

Curative Sector: What are the risks? Assessing the relative costs of taking remedial action versus relying on bio-resilience.

Rehabilitative Sector: How do we intervene? Restoring lost ecosystem services.

Testing the waters

Certainty of death, small chance of success... what are we waiting for?