The organismal response to stressors

Eyeing improved risk assessment and sustainability in the Athabasca River Basin

Athabasca University
ATHABASCA RIVER BASIN
RESEARCH INSTITUTE

An eye on the organism studying the stressed organisms

Educational background: animal physiology; aquatic toxicology; environmental science; seafood safety; toxicogenomics (New Zealand, USA, UK, Canada)

Vocational background: Senior Scientist/Group Leader in government research institutes (Norway, NZ); Academic at the University of Canterbury, NZ

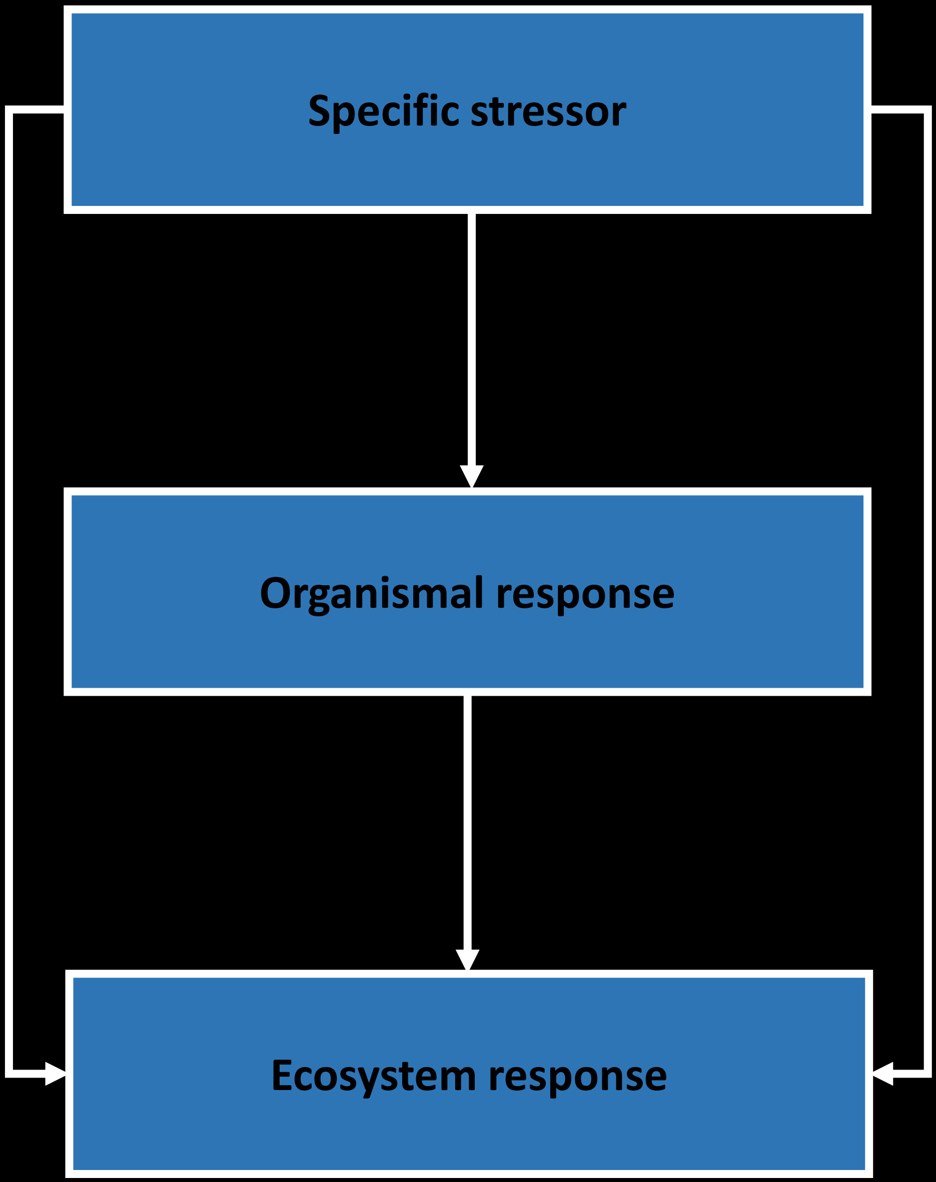
Research interests: aquatic toxicology, environmental physiology

The Athabasca River Basin

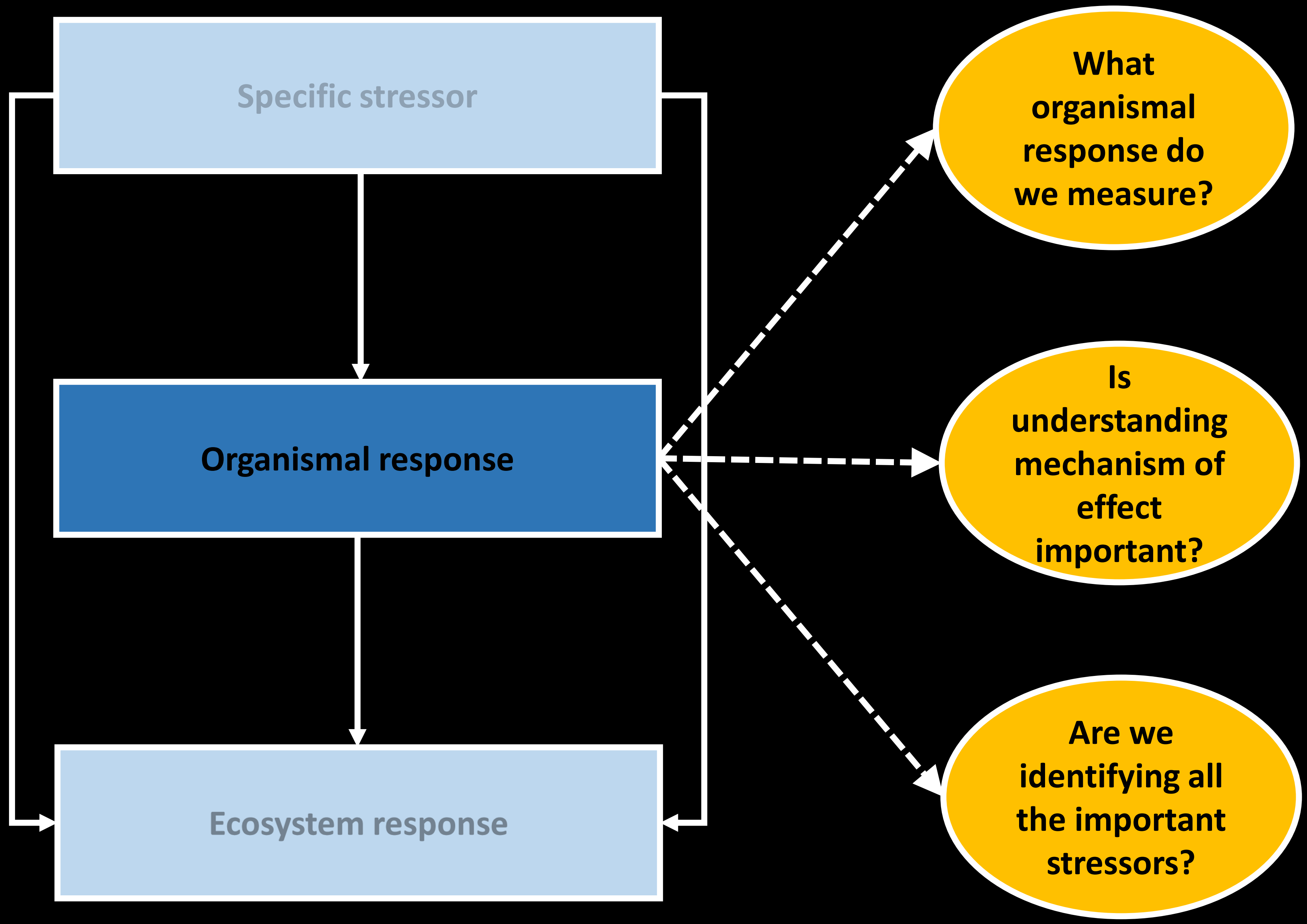
It’s quite big

Complex assortment of stressors that vary spatially and temporally from headwaters to delta

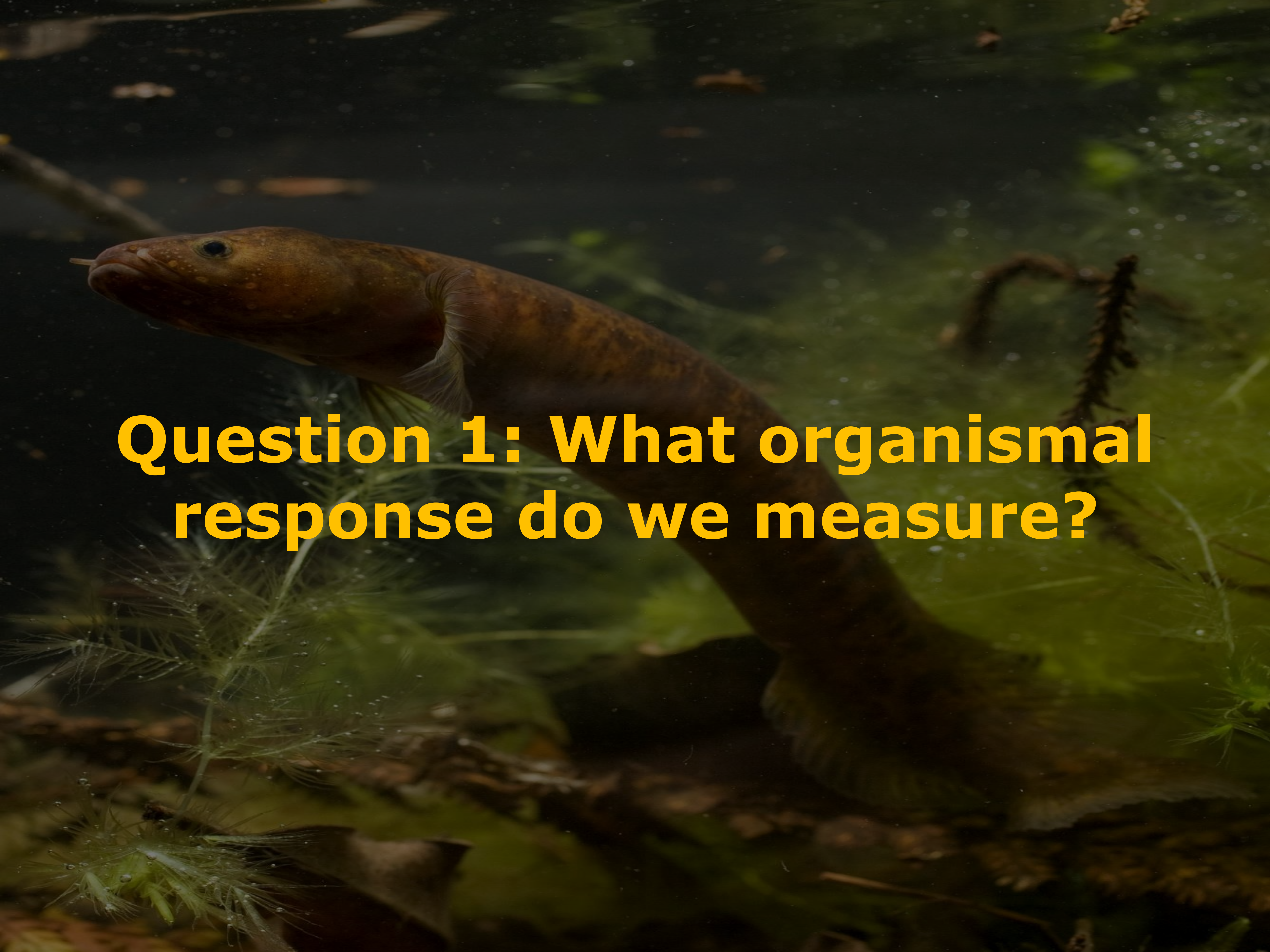
A diverse aquatic fauna that also varies spatially and temporally



Determining environmental risk



Specific stressor
Organismal response
Ecosystem response
What organismal response do we measure?
Is understanding mechanism of effect important?
Are we identifying all the important stressors?



Question 1: What organismal response do we measure?

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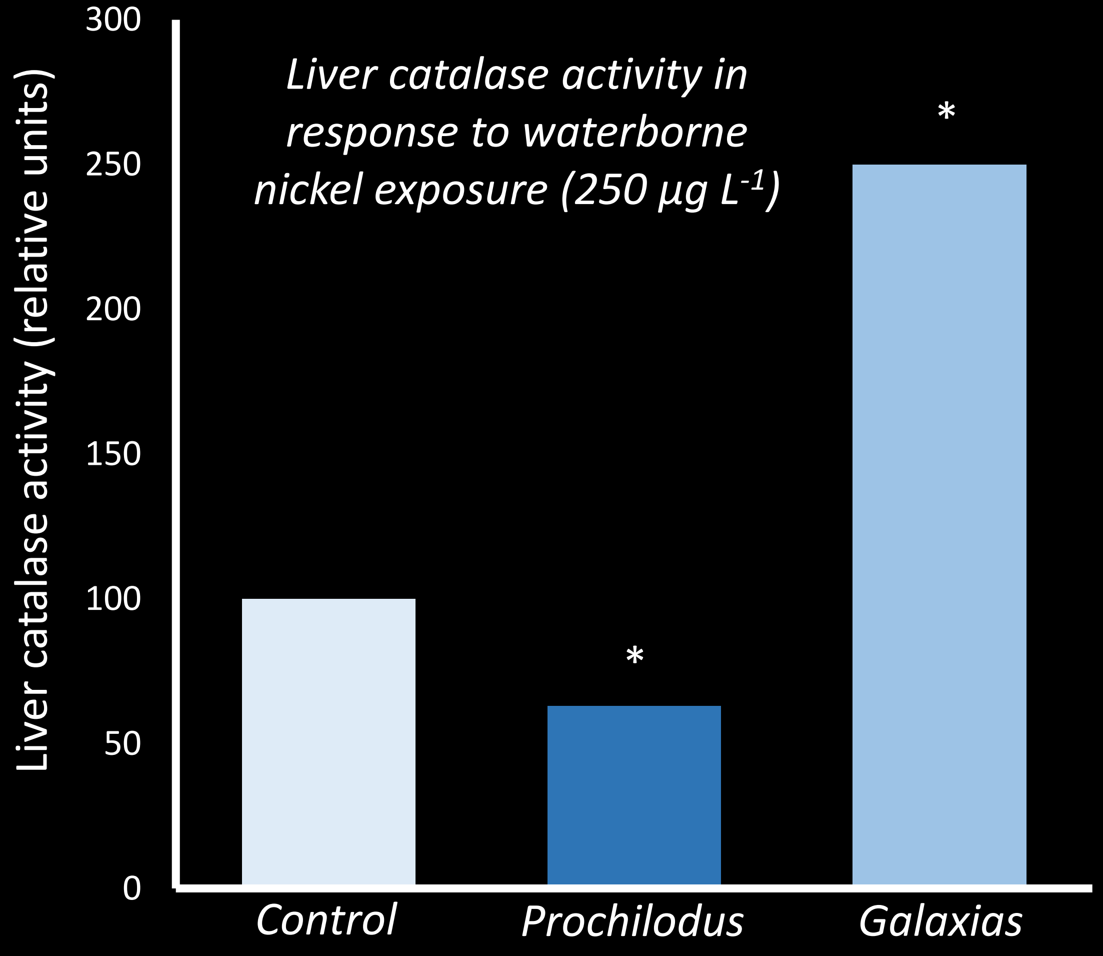
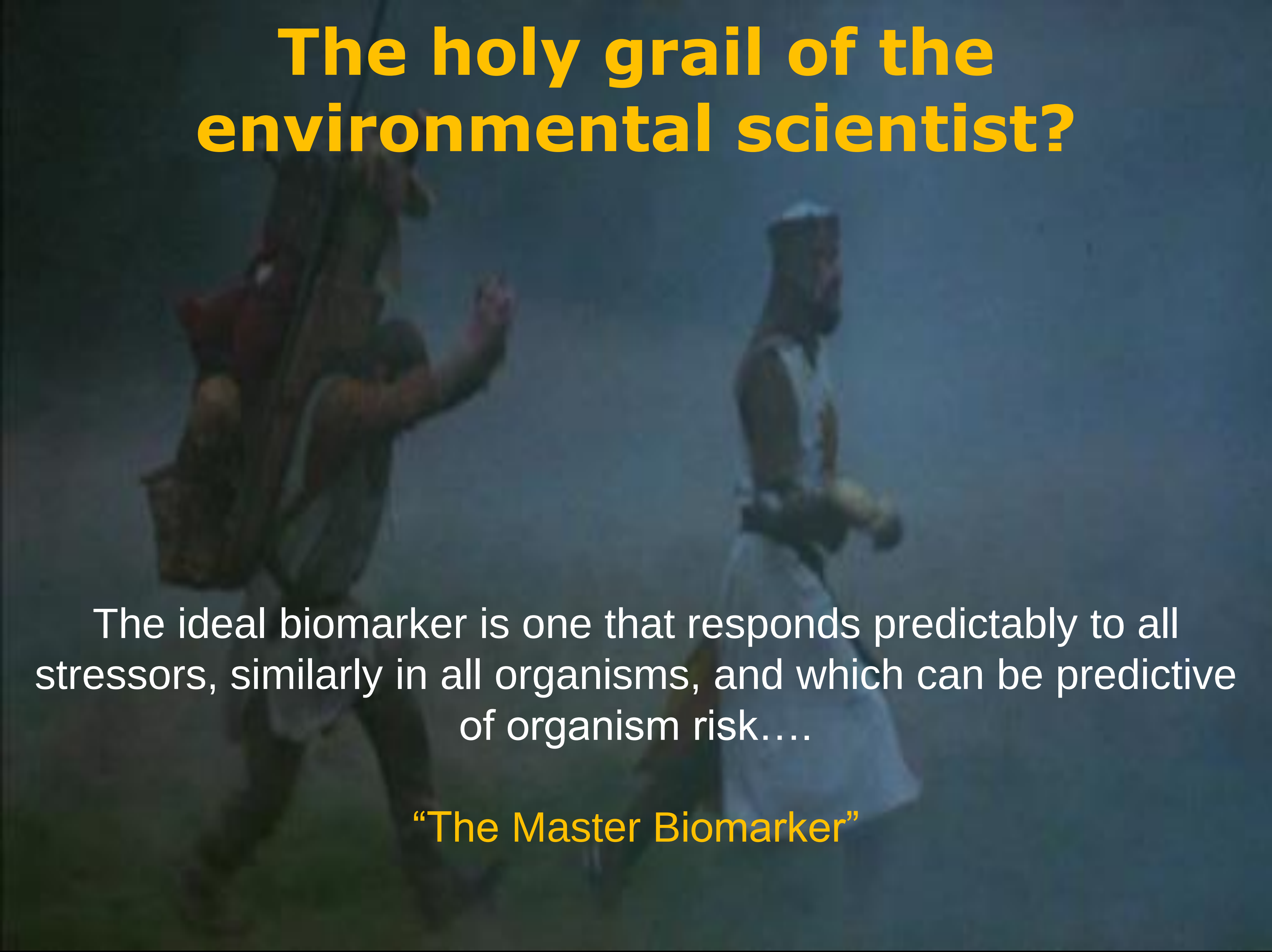
Biomarkers (e.g. activity of detoxification enzymes, condition factors) are useful, but may be variable, and represent a reactive rather than proactive approach to assessing risk



Blewett et al., unpublished; Palermo et al., EES, 116: 19

The holy grail of the environmental scientist?



The ideal biomarker is one that responds predictably to all stressors, similarly in all organisms, and which can be predictive of organism risk….

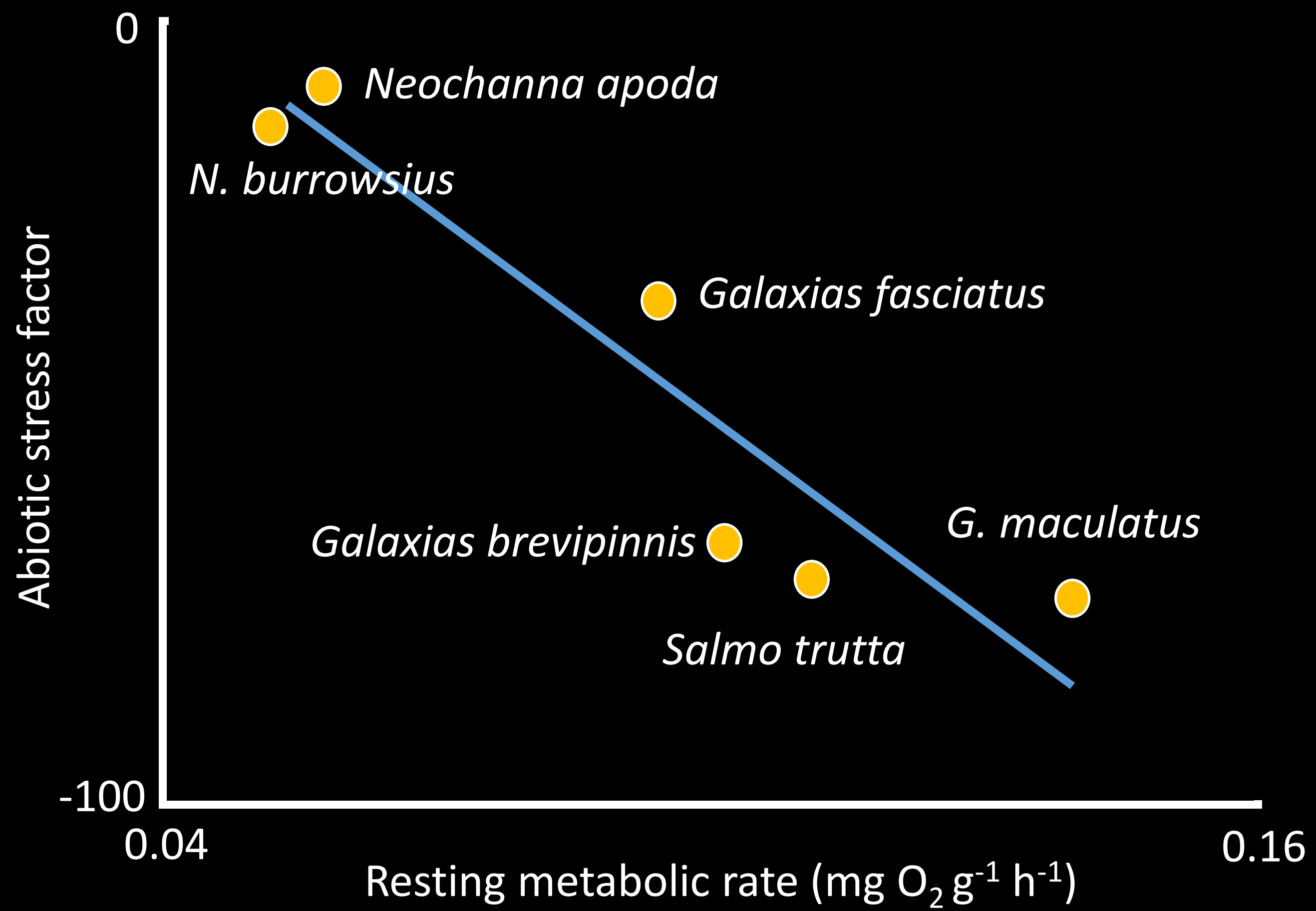
"The Master Biomarker"

Fish in the forest

A study examining forest pool fish populations measuring fish distribution and a number of abiotic stressors (dissolved oxygen, pH etc.)

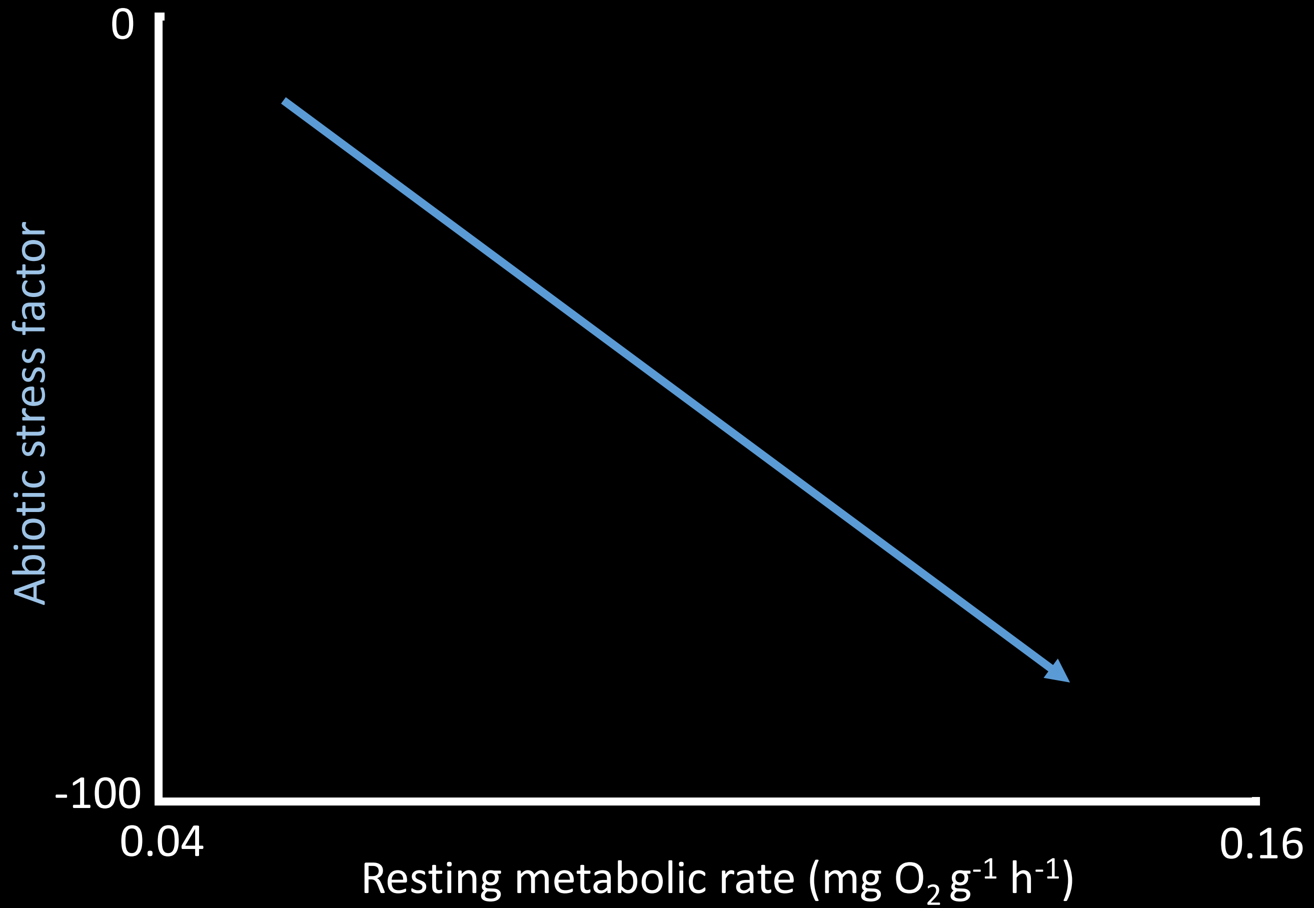
Also measured metabolic rates of fish inhabitants

Is metabolic rate the "master biomarker"?



White et al., unpublished

A caveat…



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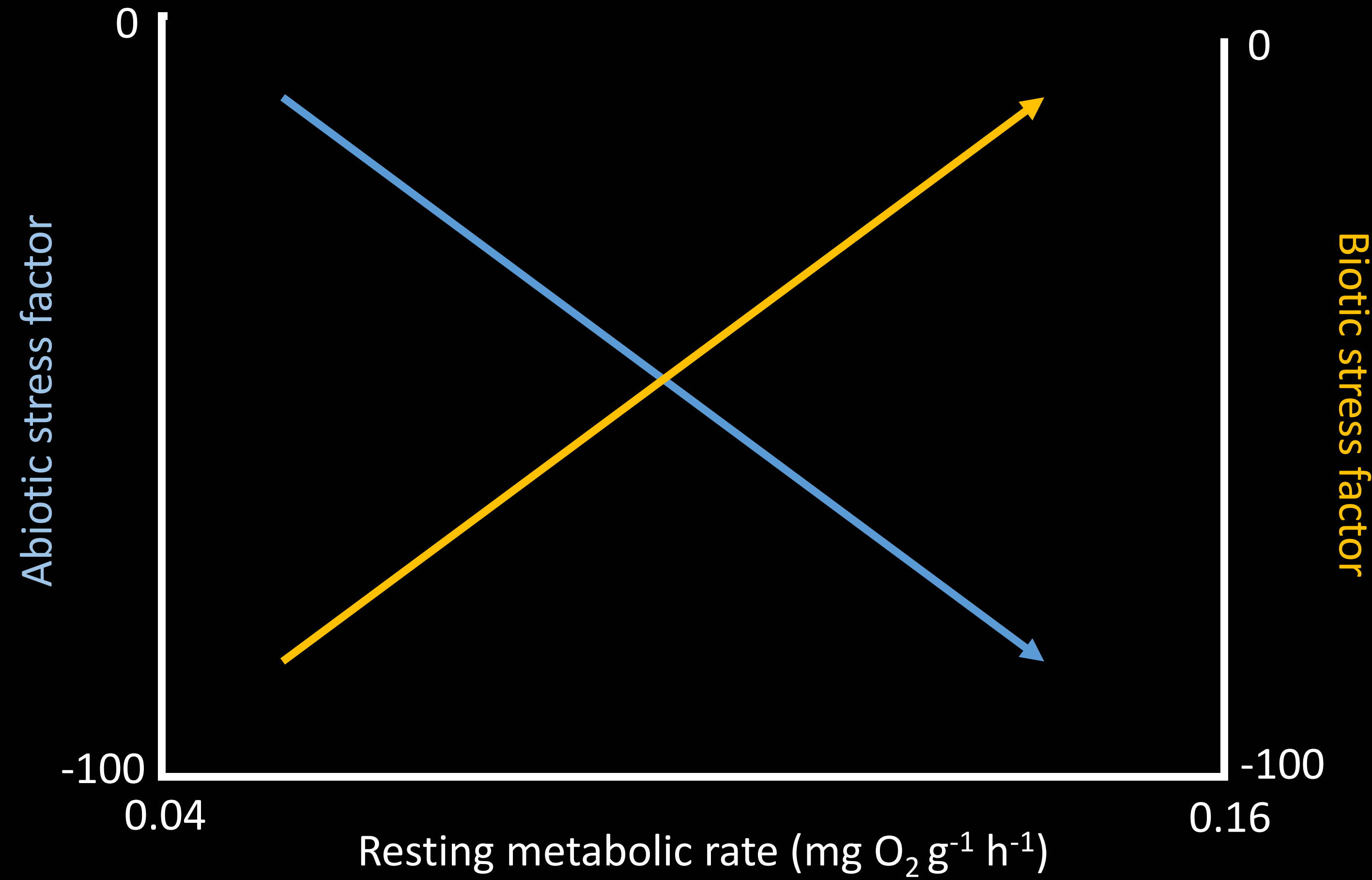

White et al., unpublished

Implications for a sustainable ARB

More research is required to investigate the relationship between metabolic rate and stressors

However, if this relationship holds, then a measurement of inhabitant metabolic rate, might be sufficient to ascertain the stress incurred at a given location

It also will allow prediction of vulnerable species should stressor composition and magnitude change

Question 2: Is understanding mechanism of effect important?

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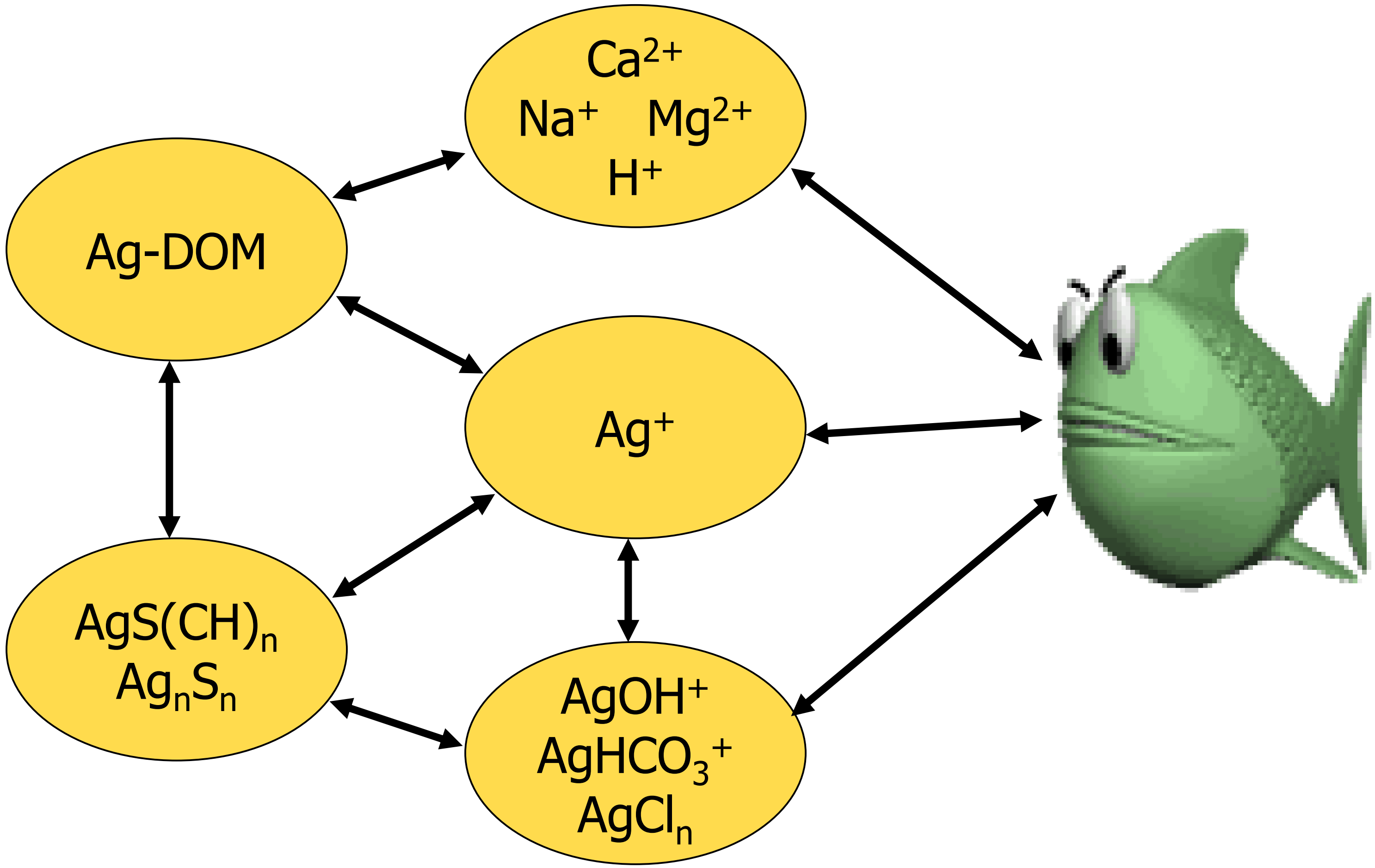
Contaminated ecosystems are complex: multiple different stressors that vary spatially and temporally

Biology is complex: organisms acclimate and adapt

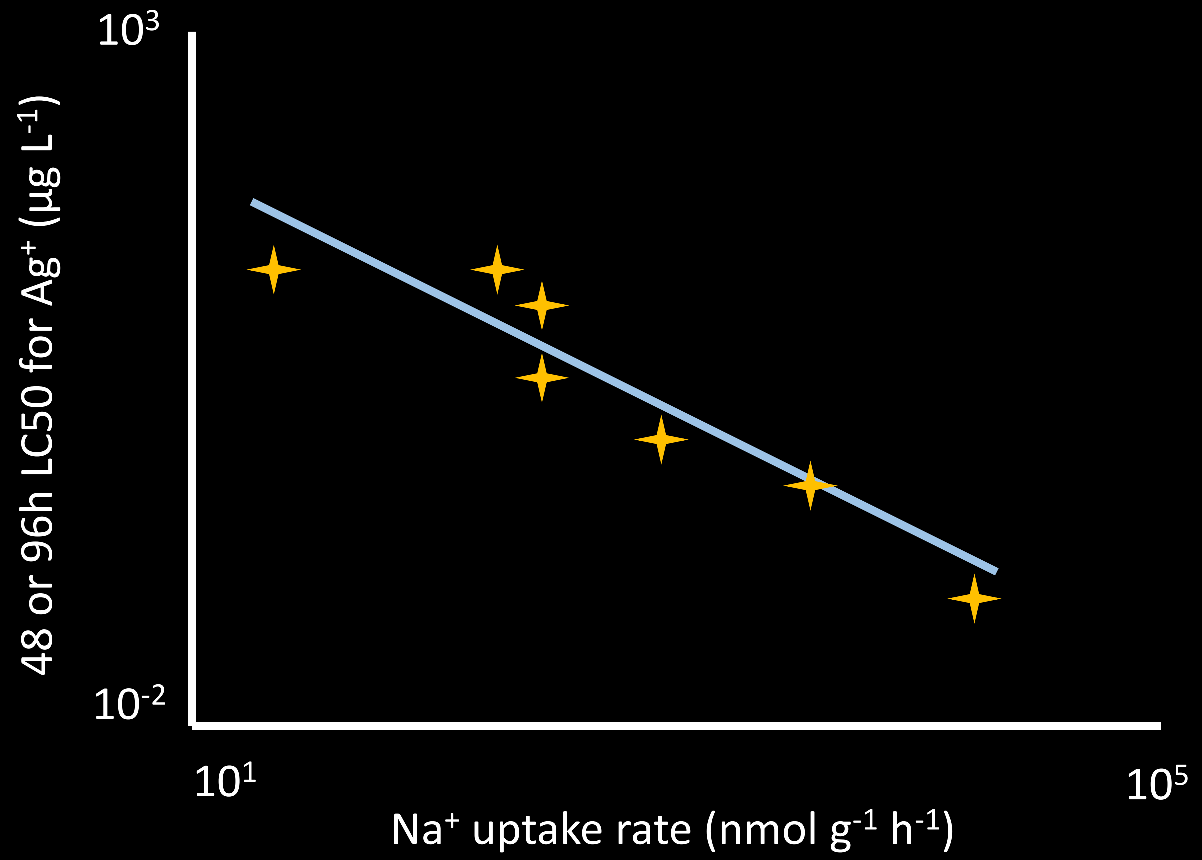
Understanding the mechanisms by which stressors impact biota we can develop predictions as to how stressor mixtures may effect systems, and can predict the impacts of exposure history

The Biotic Ligand Principle



Adapted from Di Toro *et al.* (2001) *ETC*

Sodium influx rate is a strong predictor of sensitivity to some trace metal contaminants



Grosell et al., CBP, 133: 287

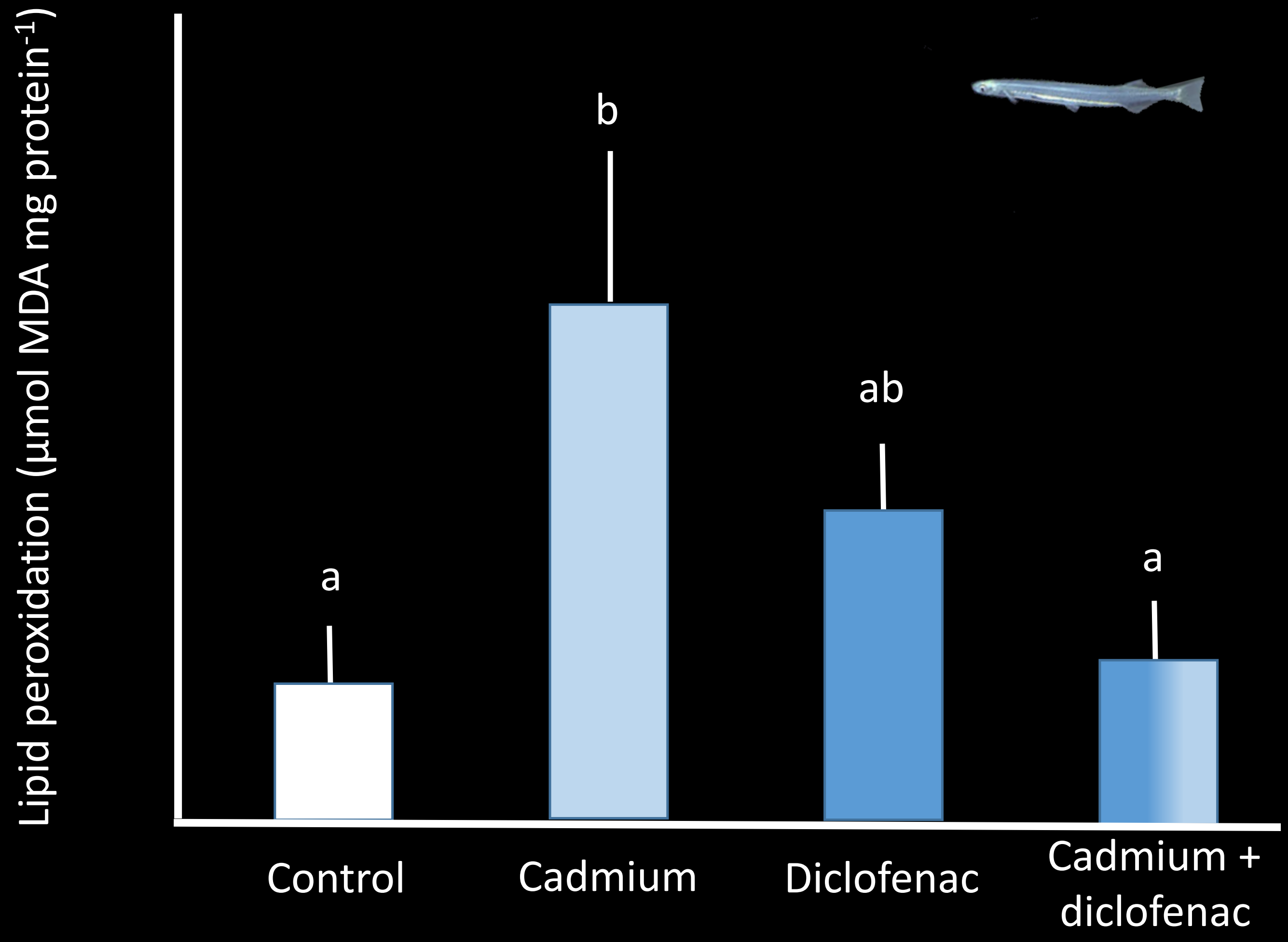
Stressor mixtures

In New Zealand waters two important chemical stressors are the trace metal cadmium, and the pharmaceutical diclofenac:

Cadmium: a contaminant associated with phosphate fertilisers but also naturally high in some NZ regions due to volcanism

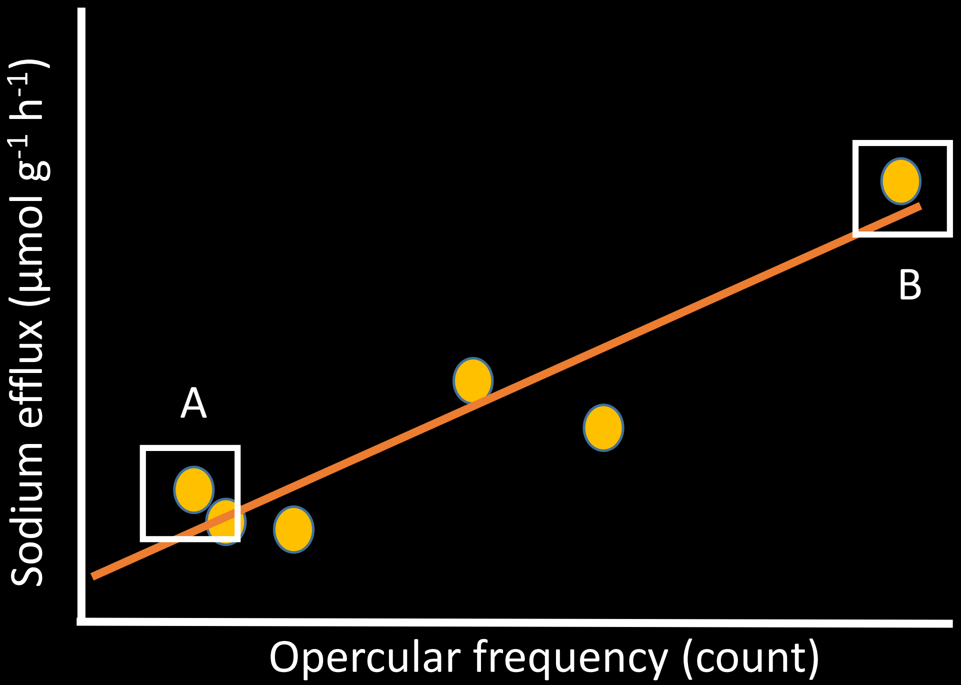
Diclofenac: rapidly increasing in waters worldwide through veterinary and human usage and failure of sewage treatment to remove effectively

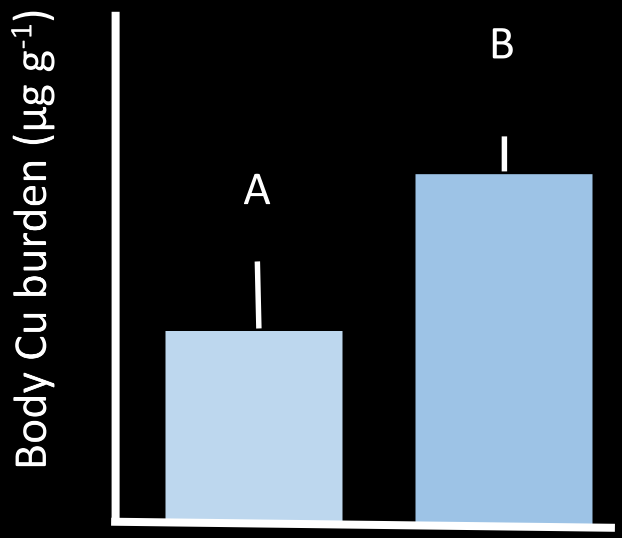
Stressor mixtures



McRae et al., unpublished

Stressor mixtures





Some stressors increase respiration

Respiration increases ion loss

To compensate fish increase ion uptake

Uptake of ion-mimicking toxicants also increases

Harley & Glover, AQT, 147; 41

Implications for a sustainable ARB

A greater understanding of the mechanisms by which stressors impact aquatic biota is important for understanding phenomena such as the impacts of stressor mixtures

In a river basin where multiple stressors vary significantly in time and space, a mechanistic understanding of stressor impacts may provide better prediction of the impacts of environmental change

Question 3: Are we identifying all the important stressors?

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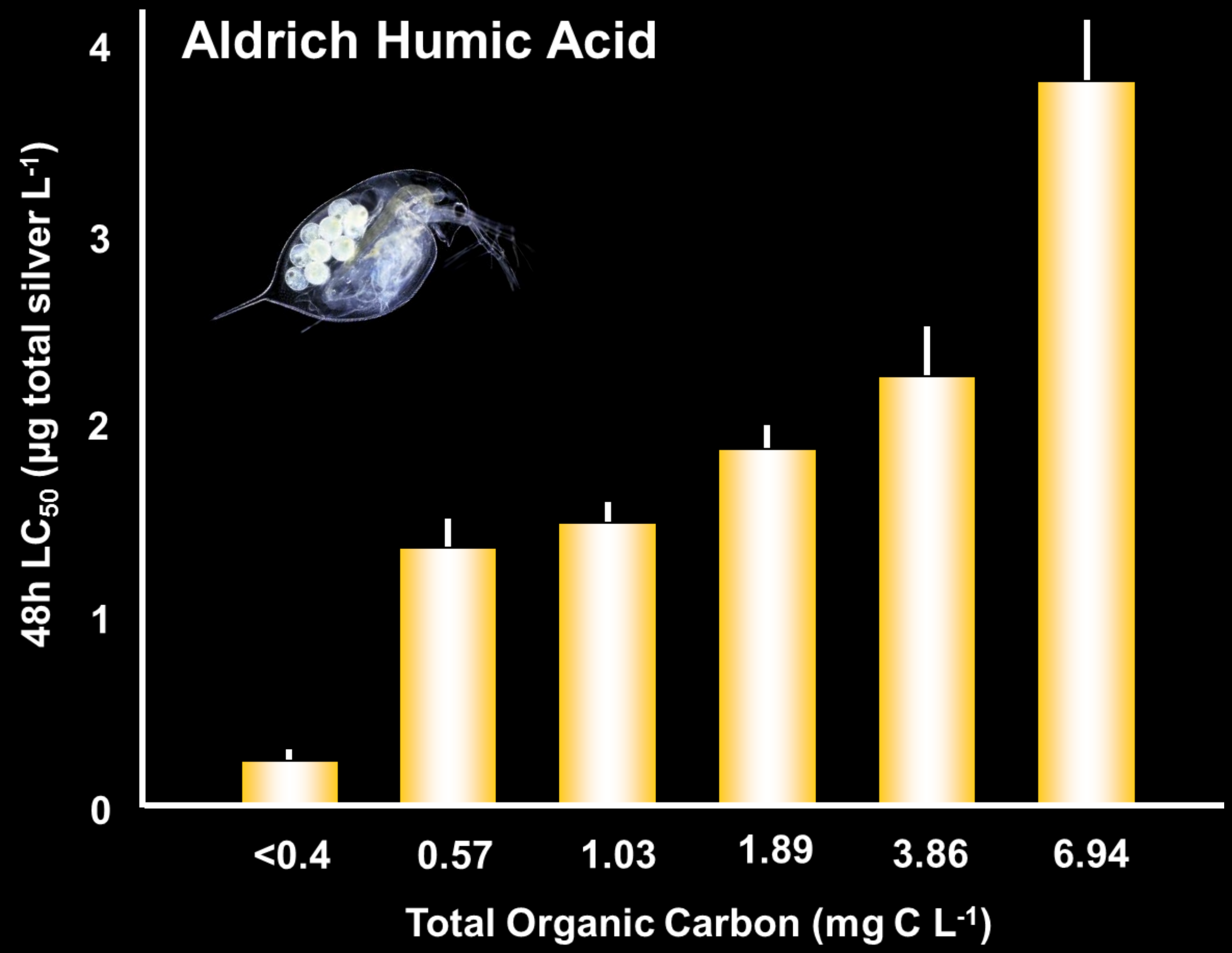
Natural organic matter (NOM; aka dissolved organic carbon, dissolved organic matter, humic substances) has two key characteristics:

Ubiquity: NOM is present to some degree in every natural water

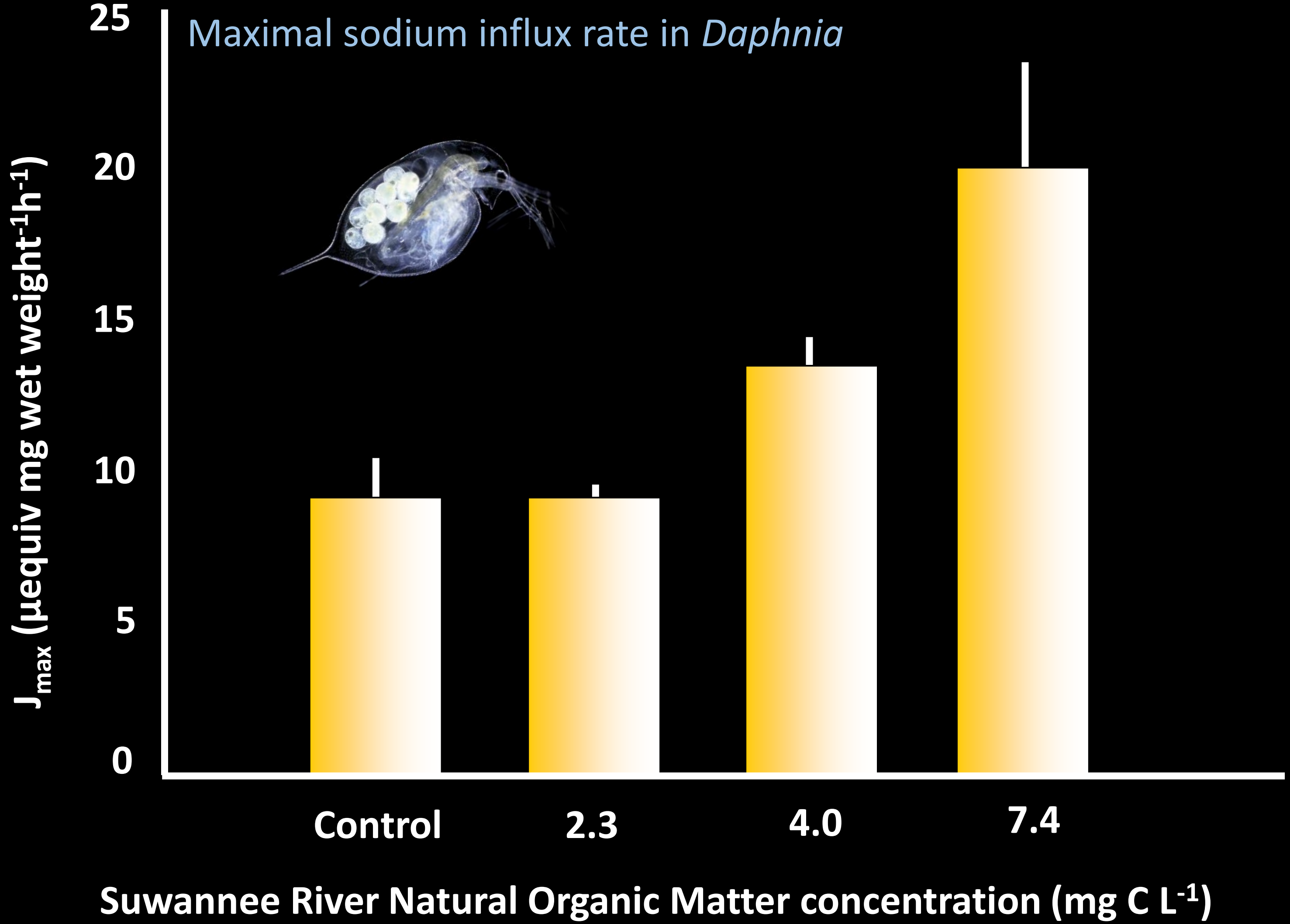
Heterogeneity: NOM varies in every natural water owing to the unique terrestrial and aquatic microbial assemblages that act as sources and modify its chemistry

NOM is a known ameliorator of chemical stressors



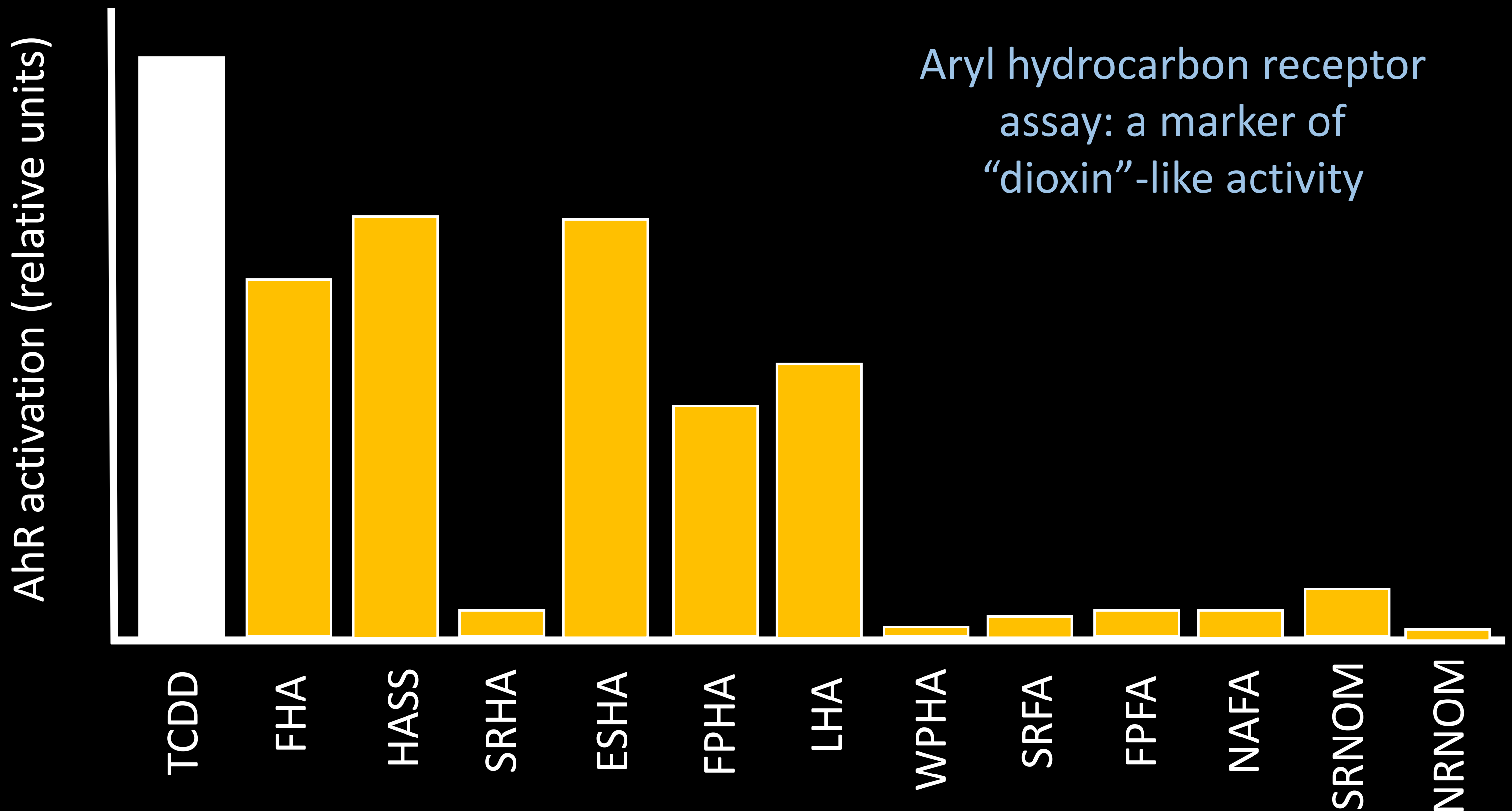
Glover *et al.*, PBZ, 78: 405-416

Direct effects of NOM are less well known

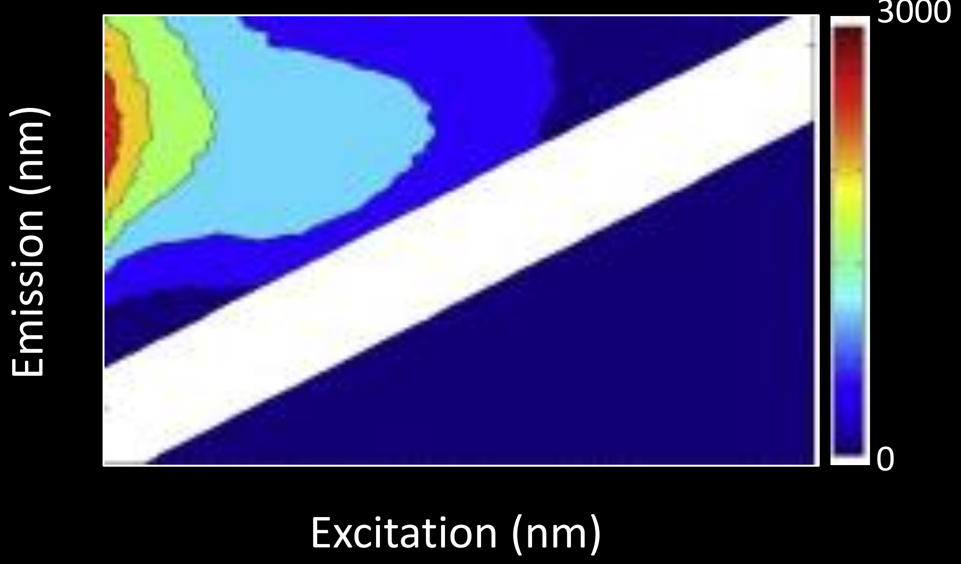


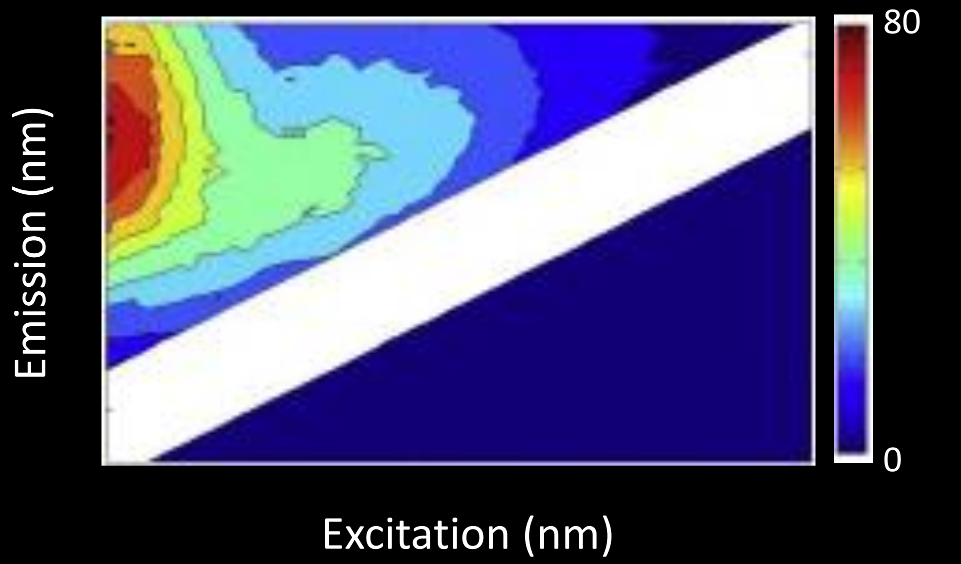
Glover *et al.*, PBZ, 78: 405-416

NOM effects are not restricted to ion transport and vary depending on NOM composition



Steinberg et al., Encyc. Inl. Wat., 747.





Waters of the Athabasca River differ significantly in NOM concentration and composition

Guèguen et al., Chemosphere, 87: 932

Implications for a sustainable ARB

NOM composition and concentration varies throughout the ARB

NOM exerts significant effects on aquatic life, effects that potentially modify the responses of biota to other stressors

Accounting for direct impacts of NOM, may facilitate a better prediction of risk

Conclusions

An improved understanding of organismal responses to stressors will strengthen risk assessment approaches in the ARB enhancing environmental and economic sustainability of this important watershed

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