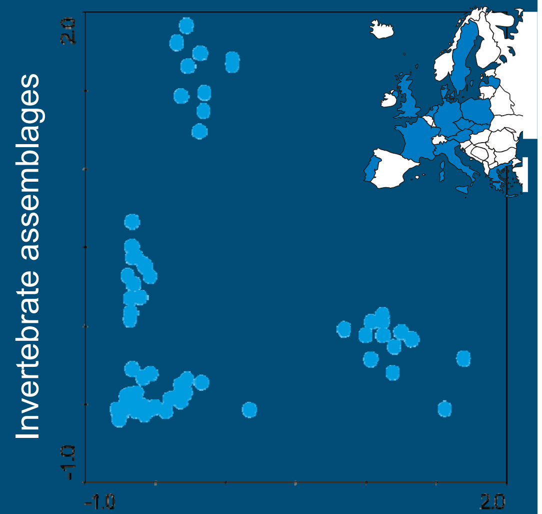
Response of taxonomic groups in streams to gradients in resource and habitat characteristics

Richard K. Johnson
Dept. of Aquatic Sciences and Assessment
SLU, Uppsala

What it's about

- Ecological drivers & scales
- Land use & hydro-morphology
- Response of stream assemblages to resource and habitat gradients
- Multiple-stressor effects on stream invertebrates (special thanks to Colin Townsend)

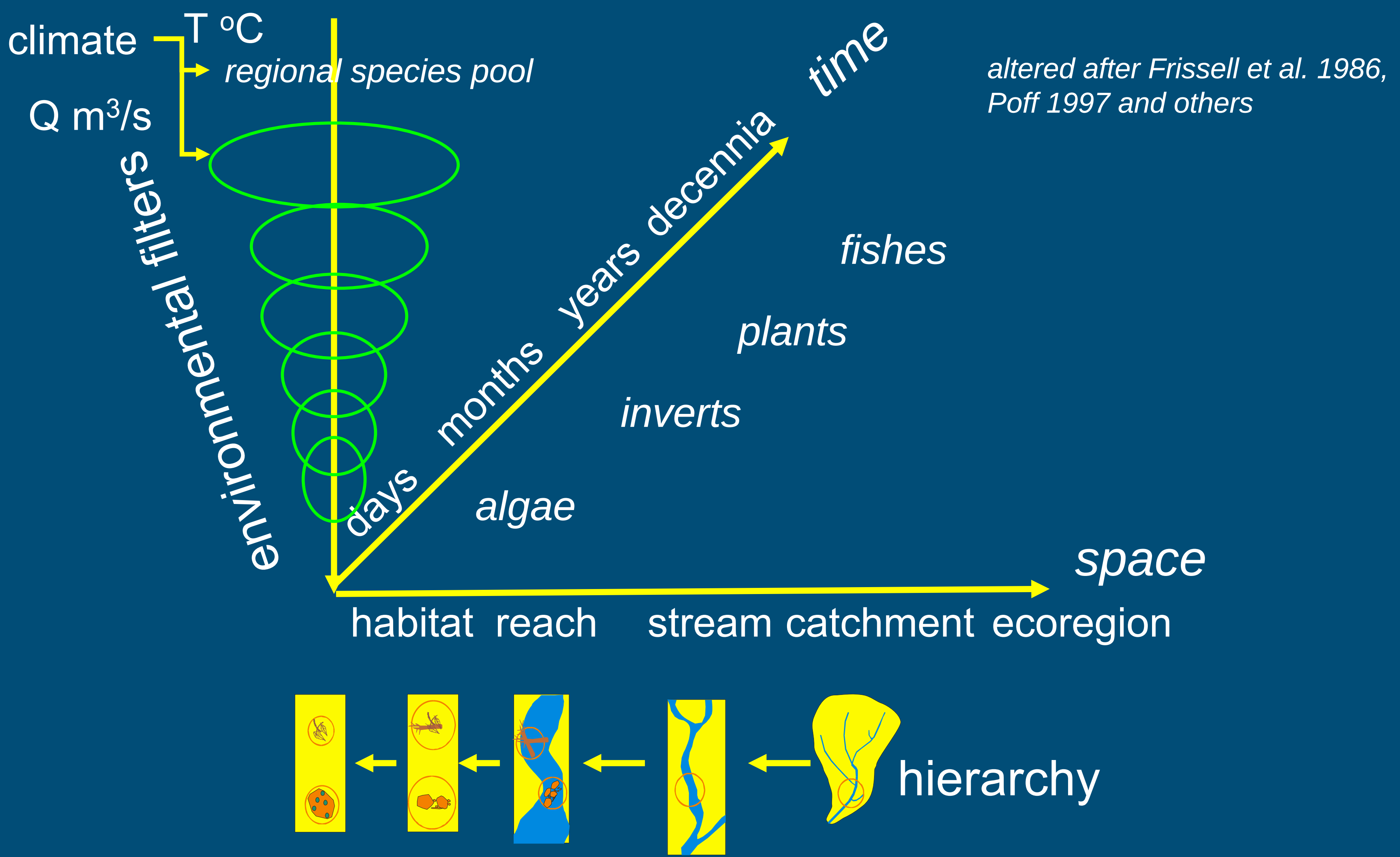
Geographically distinct regions often have their own distinct flora and fauna…



Regional *diversity* is the result of evolutionary history (rates of speciation and extinction), and sets the upper limit of local diversity.

Local *diversity* is constrained by the size of the regional species pool, but often also the size and heterogeneity of the habitat, and the outcome of interactions.

Conceptual models of biological change



Adapted from P. Verdonschot

Birds' (landscape) perspective

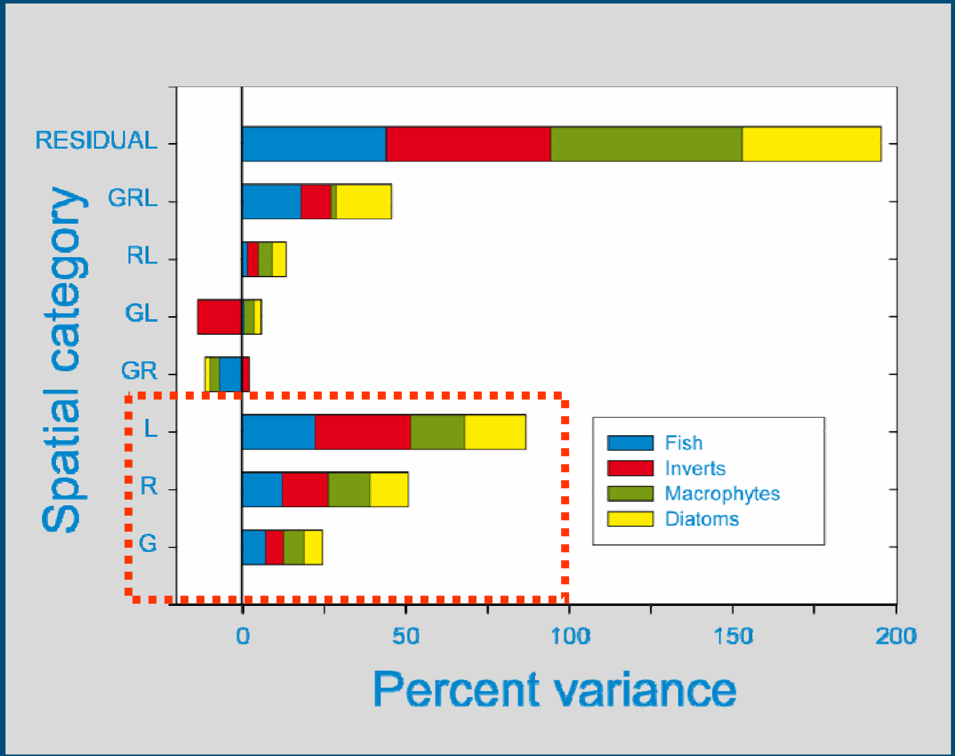
- large scale patterns in vegetation are evident
- spatial scales > 10 km^2
- temporal scales of usually > 10's of years

Bugs' (local) perspective

- individual particles are important
- spatial scales usually $< 1\ m^2$, often cm^2 scale
- temporal scales of hours to years

Predictors of stream assemblages (pCCA)

- VE - 42% (macrophytes) to 58% (diatoms) in lowland streams
- Unique effects:
  - **Geo**; 5% (inverts) to 7% (fish)
  - **Regional**; 12% (diatoms) to 14% (inverts)
  - **Local**; 16% (macrophytes) to 29% (inverts)
- Shared variance; 1% (inverts) to 22% (diatoms)



Johnson et al. 2007 (Freshwater Biology)

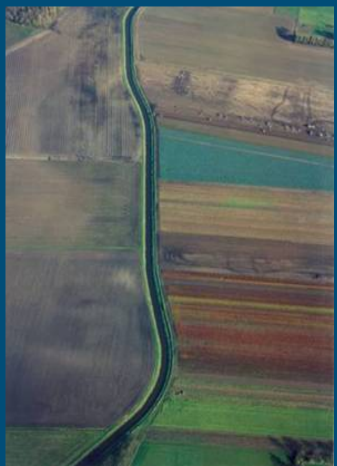
Effects of global change on streams

CC predicts – greater & more intense precipitation

more spates & droughts

intensification agriculture

siltation, scouring



deteriorating

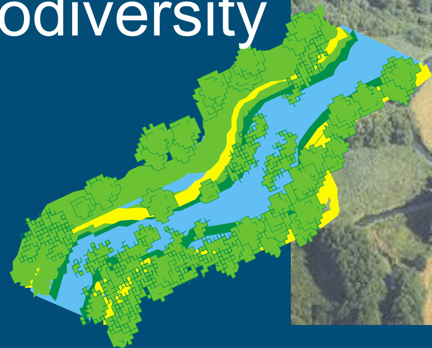
- morphology
- biodiversity

abandoning agriculture

widening buffer strips

improving

- morphology
- biodiversity



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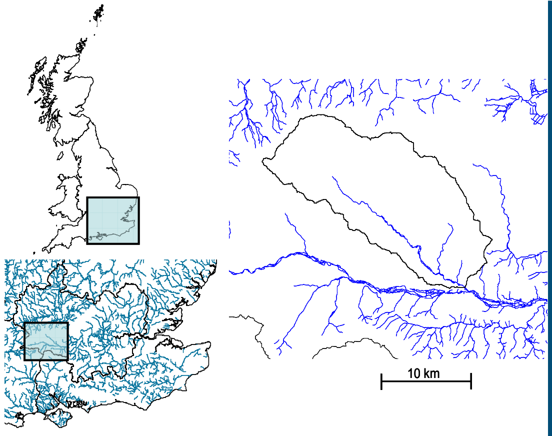
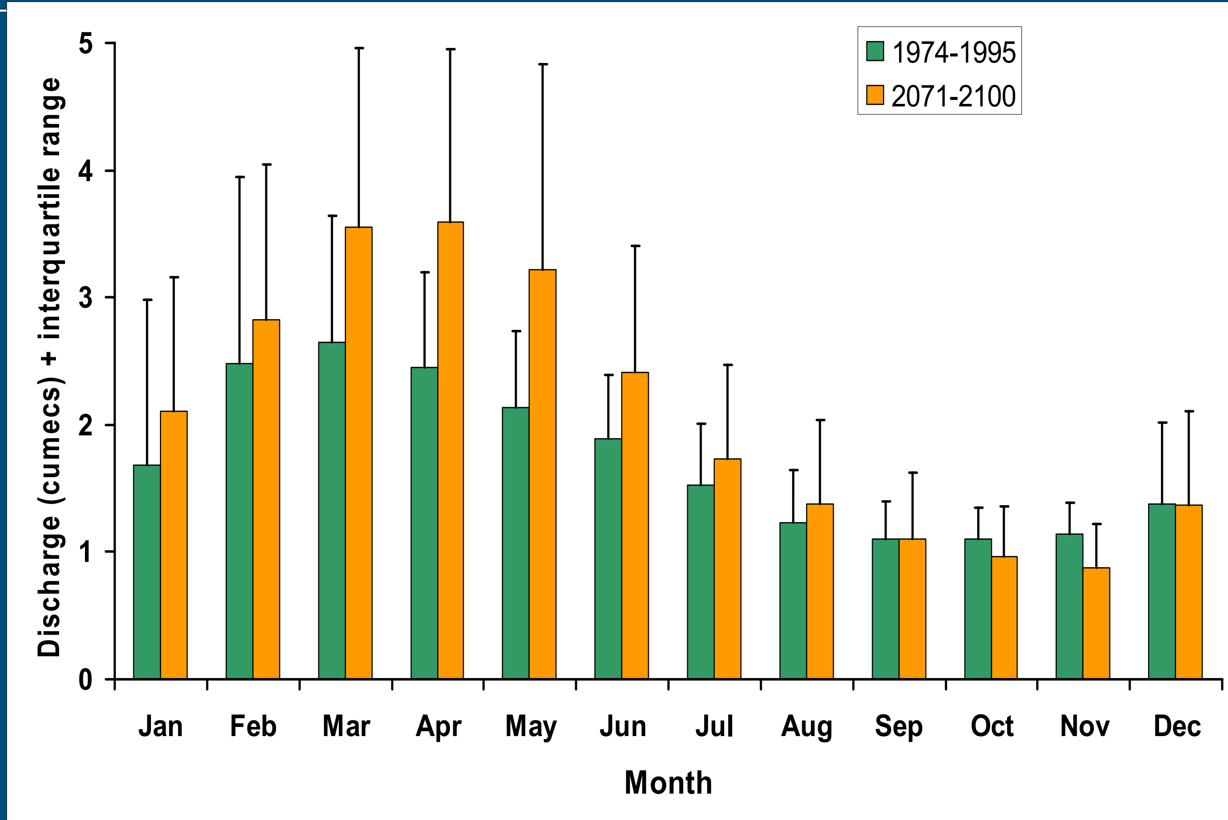
Change , Yes we can: Climate ↔ hydrology ↔ species



Climate model
PRUDENCE B2 med-low
(RCAO HadAM3H model)

Catchment rainfall-runoff model
IHACRES



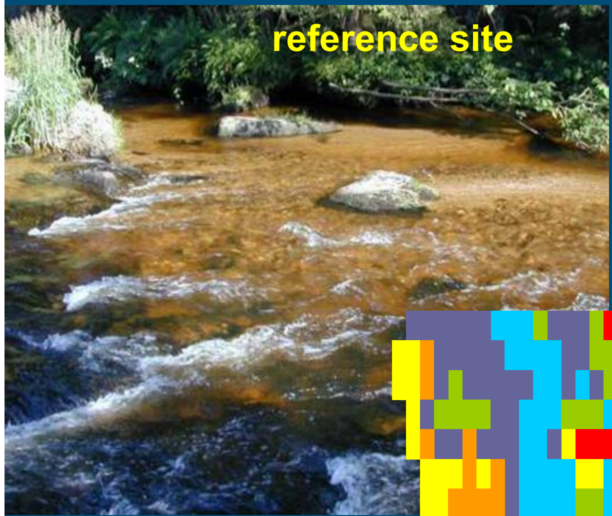
(data CEH)

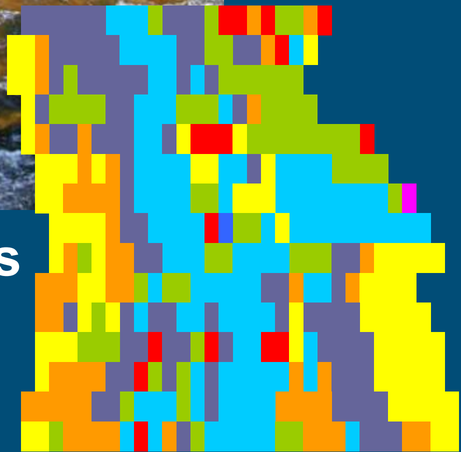
- Catchment model explained 69% of discharge variation
- UK chalk geology: higher winter discharges

Adapted from P. Verdonschot

Euro-limpacs

Change , Yes we can: Land-use ↔ Habitat ↔ species





heterogeneous substratum

homogeneous substratum

(data BOKU)

- Siltation at the disturbed site due to land-use change (drainage)
- Most habitats present at disturbed site, though many < 5%

Adapted from P. Verdonschot

Euro-limpacs

Land-use and hydromorphology - predictors of fish assemblages

46 Fish taxa

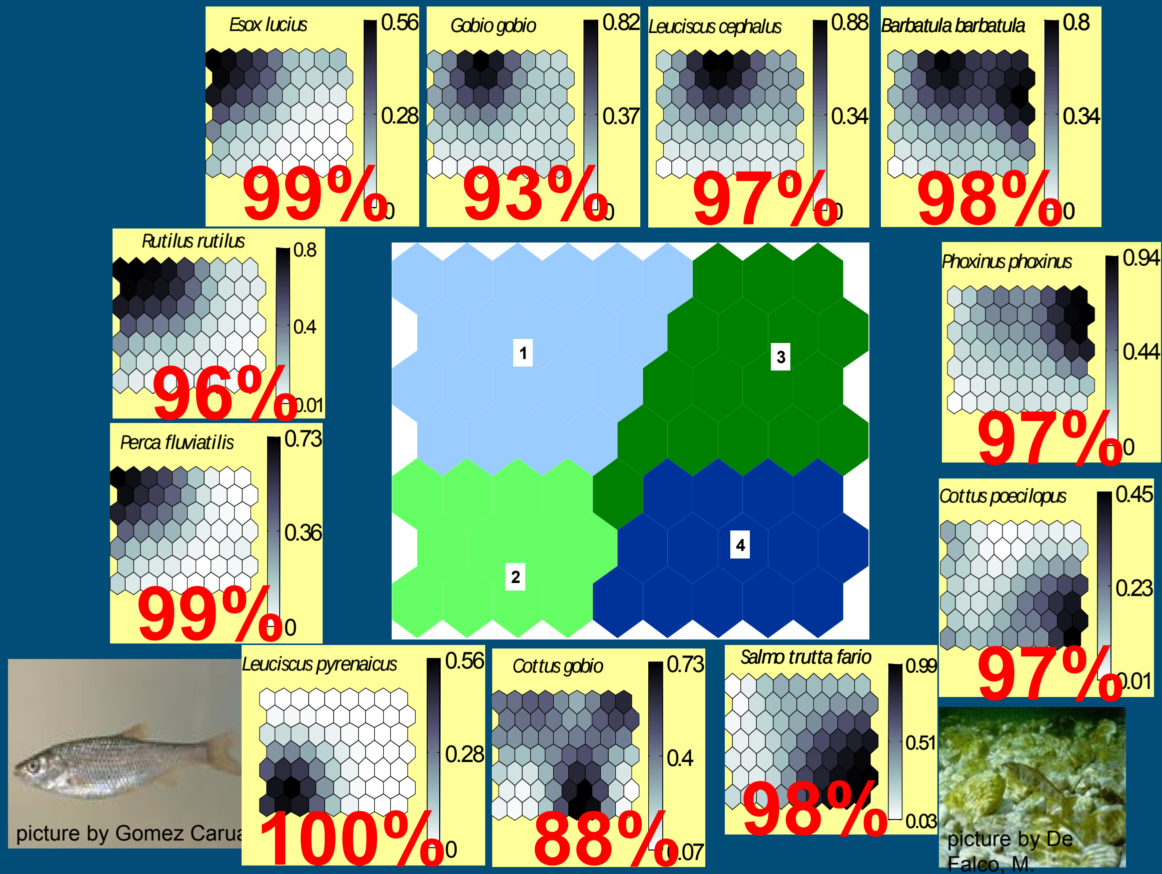
➢11 spp selected

➢Clustering by SOM

(Self Organising Map)

➢Prediction by MLP-BP

(Multi-Layer Perceptron with backpropagation algorithm)



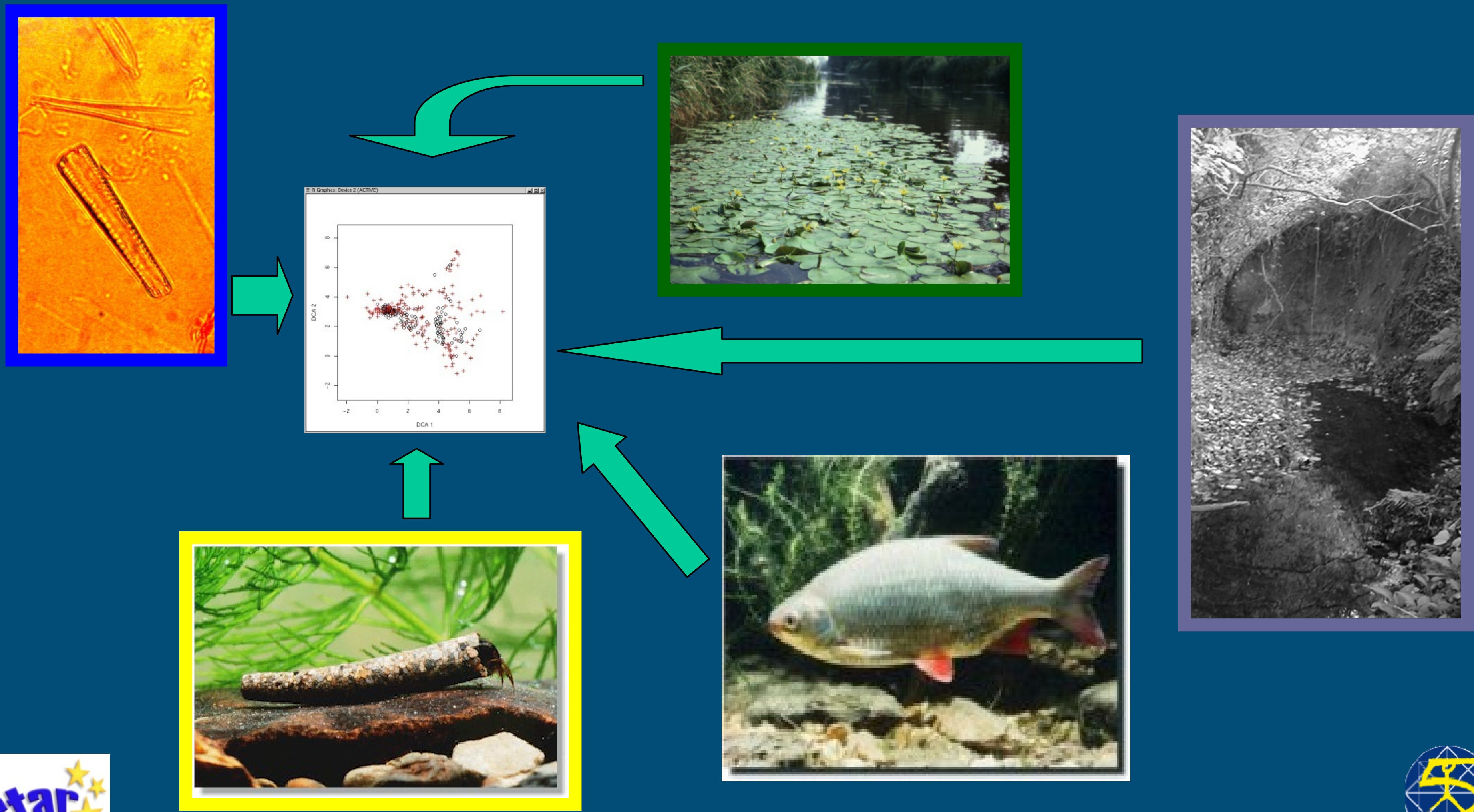
(data CNRS)

- Land-use and hydromorphology were good predictors of fish assemblages
- Climate, land-use and local physical descriptors were species-specific

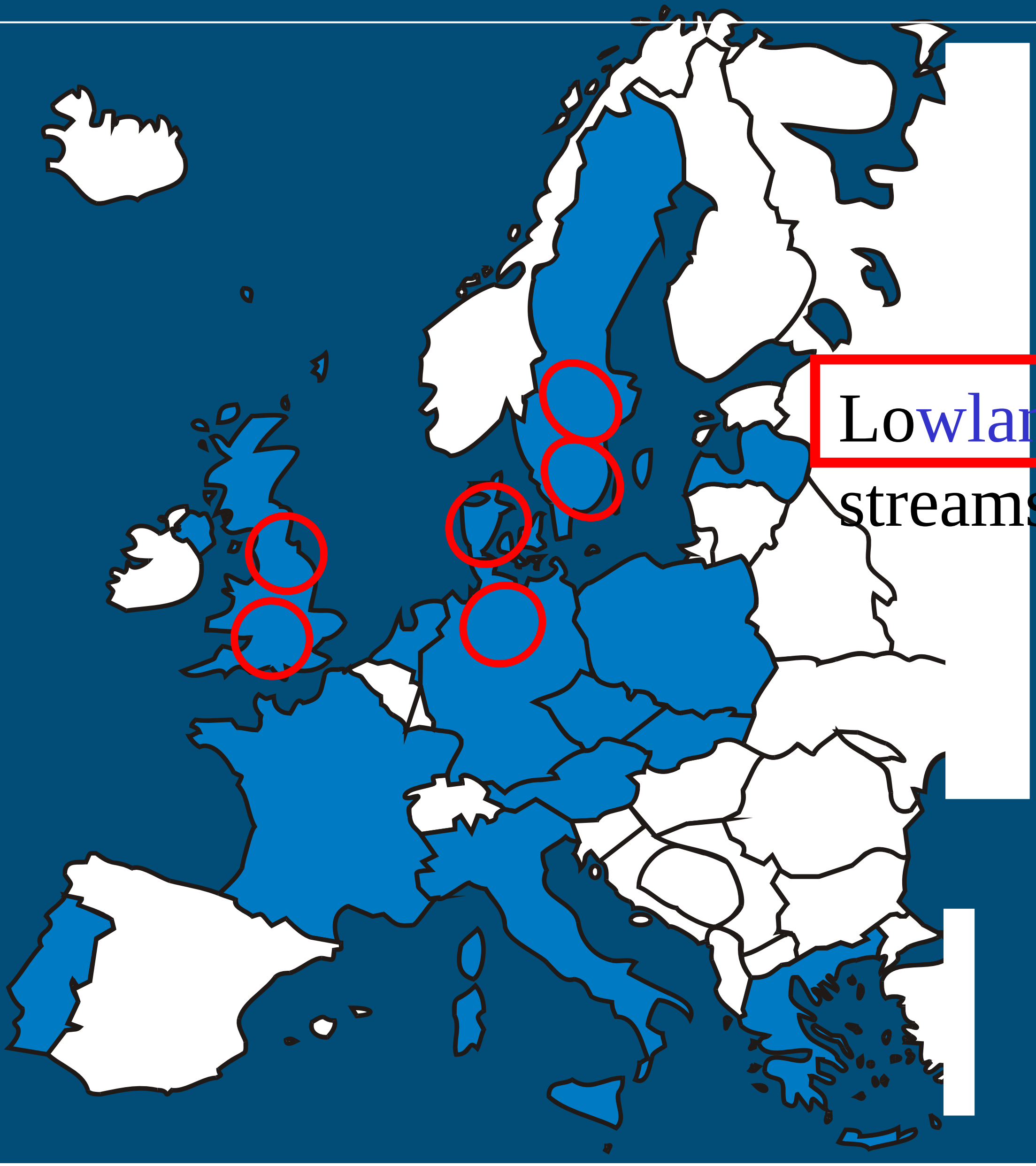
Adapted from P. Verdonschot

Euro-limpacs

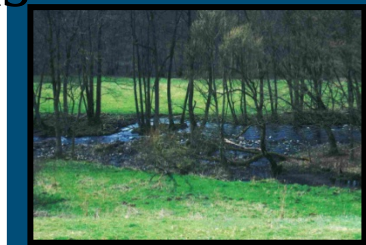
STAR - streams types across Europe



STAR stream types



Lowland
streams



Main stress gradients

Land use

Eutrophication / organic pollution

Hydromorphology

Sampling

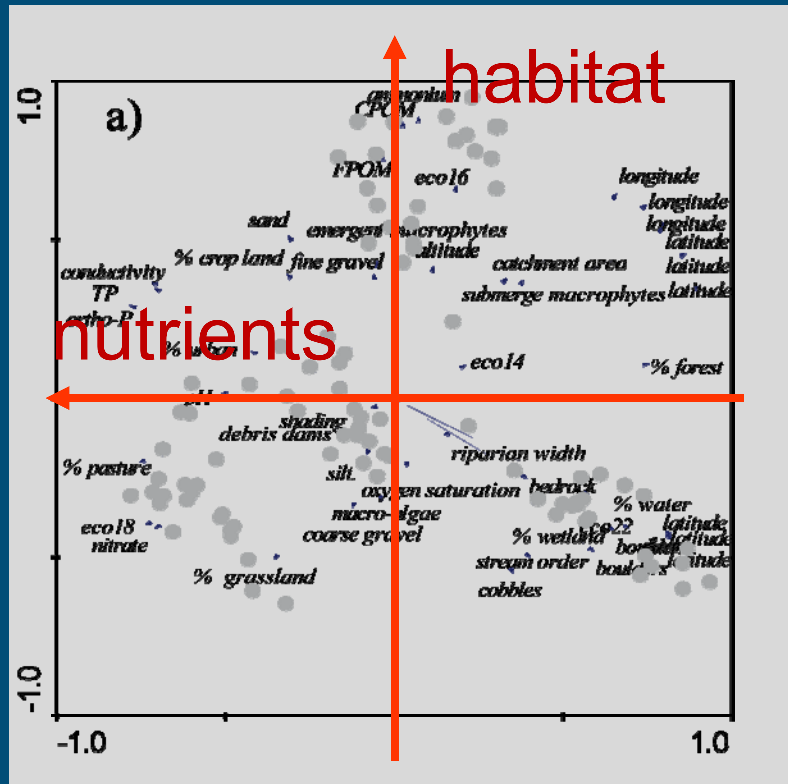
Standardized sampling:

- – **Fish** (electrofishing, 2 runs, 10 x width)
- – **Inverts** (multihabitat, n = 20, composite)
- – **Macrophytes** (100-m stream stretch)
- – **Diatoms** (5 cobbles)

Environmental gradients - lowland streams

48% of variance explained by PC1 and PC2.

- 1st PC: % forest (+); % pasture (-), nutrients (-).
- 2nd PC: CPOM (+); stream order (-), cobble (-).
- **Studied biological response to these two orthogonal gradients**



Analyses

- Regressed measures of diversity (5) and assemblage composition (2) to two gradients (n = 66 streams)
- Three metrics of response models:
  - Precision (coefficient of determination),
  - Sensitivity (magnitude of change, slope),
  - Error (RMSEP)

Response to resource & habitat

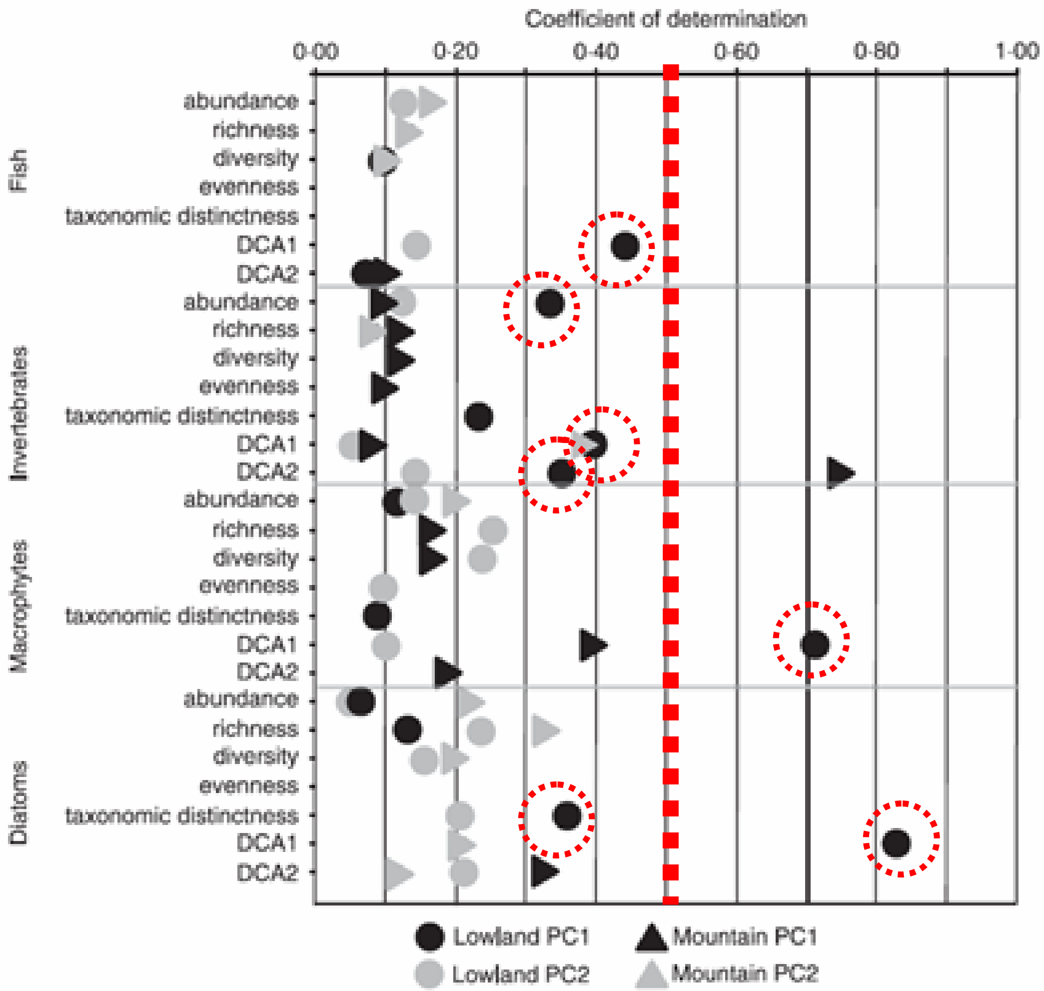
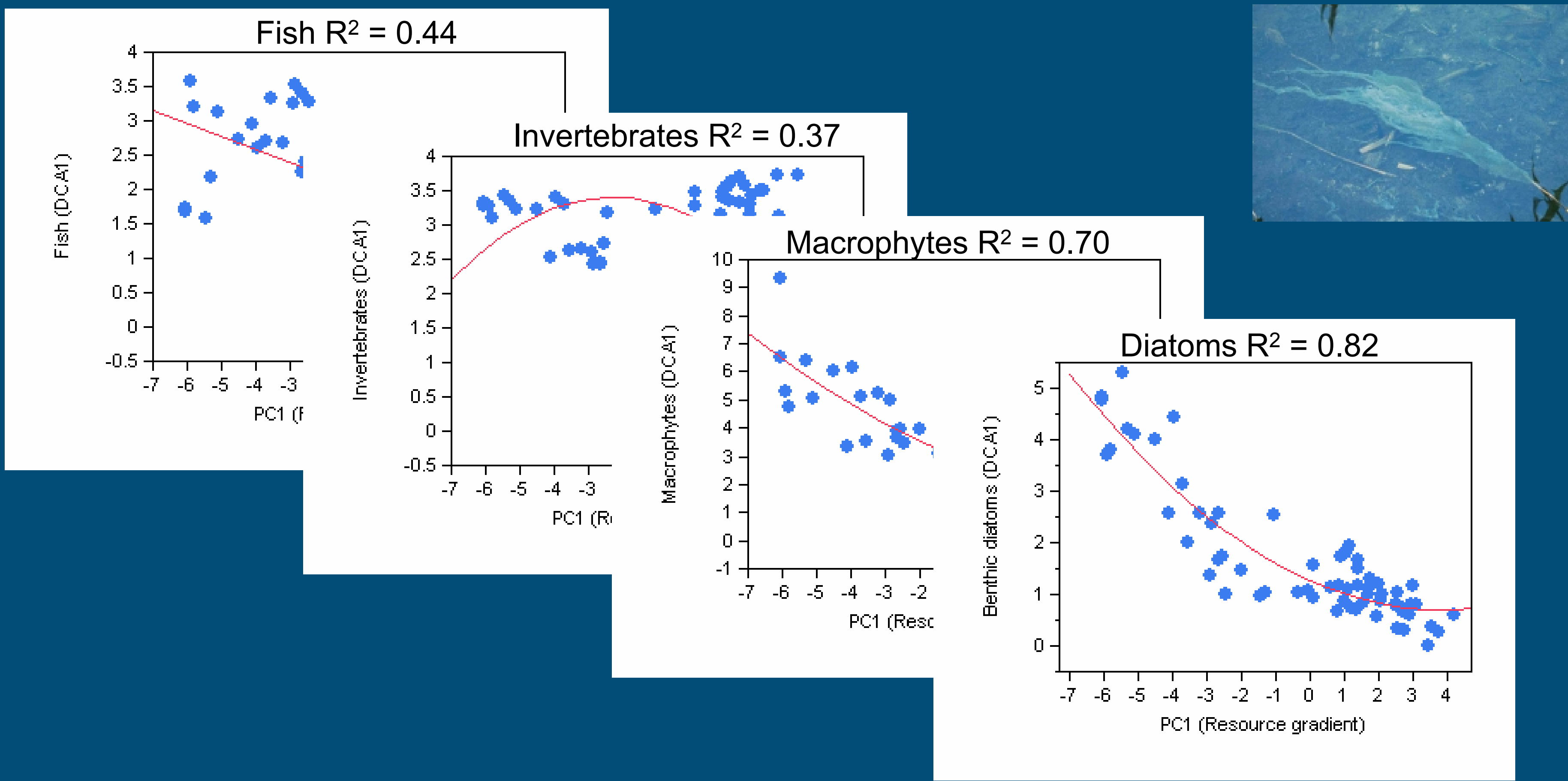


Fig. 4. Coefficients of determination (R^2 values) of diversity and assemblage composition of four taxonomic groups in lowland (n = 66) and mountain (n = 77) streams against two environmental gradient extracted using principal component analysis. Circles show lowland and triangles show mountain streams.

Johnson & Hering 2009 (J. Applied Ecology)

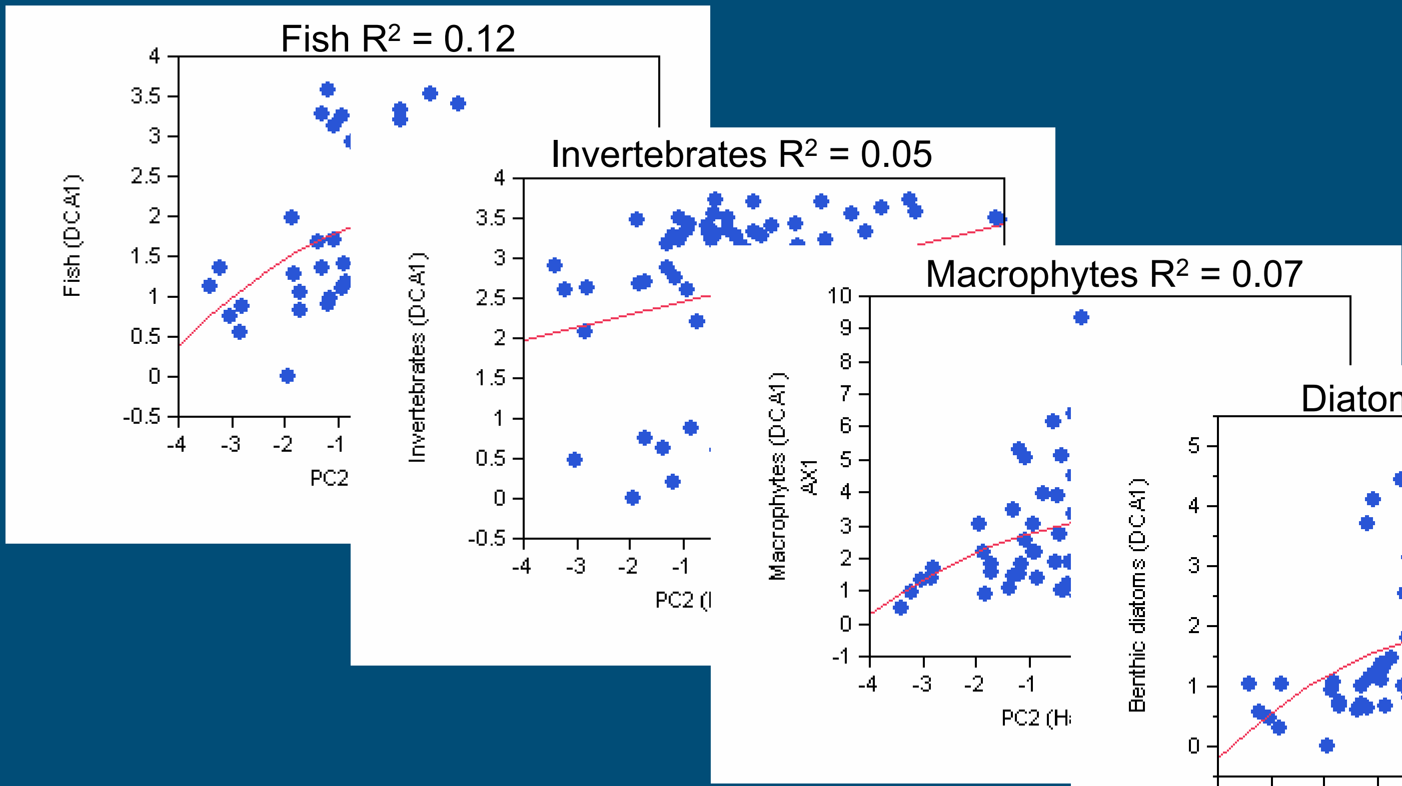
Assemblage response to resource gradient

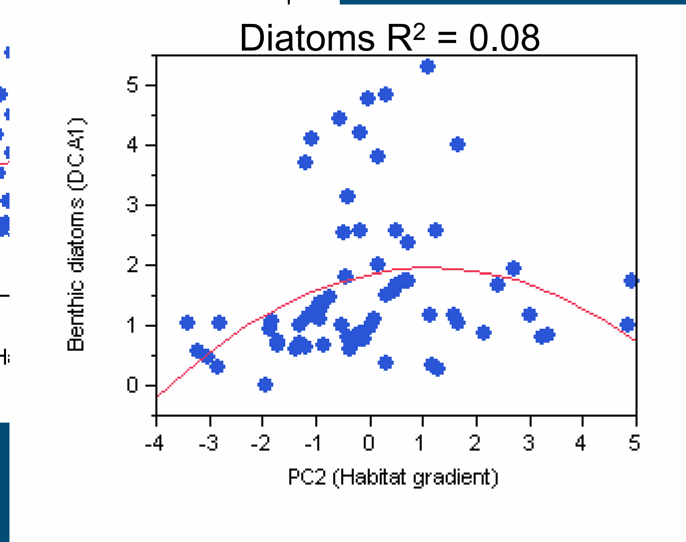


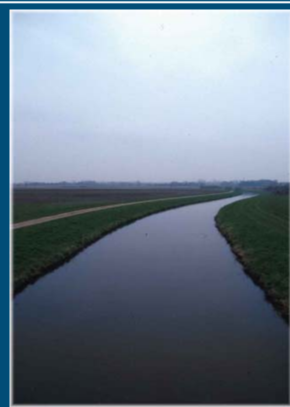
- Responses were species-specific
- Diatom assemblages collapsed at ca 50 µg P/L, invertebrates much higher

Johnson & Hering 2009 (J. Applied Ecology)

Assemblage response to habitat gradient





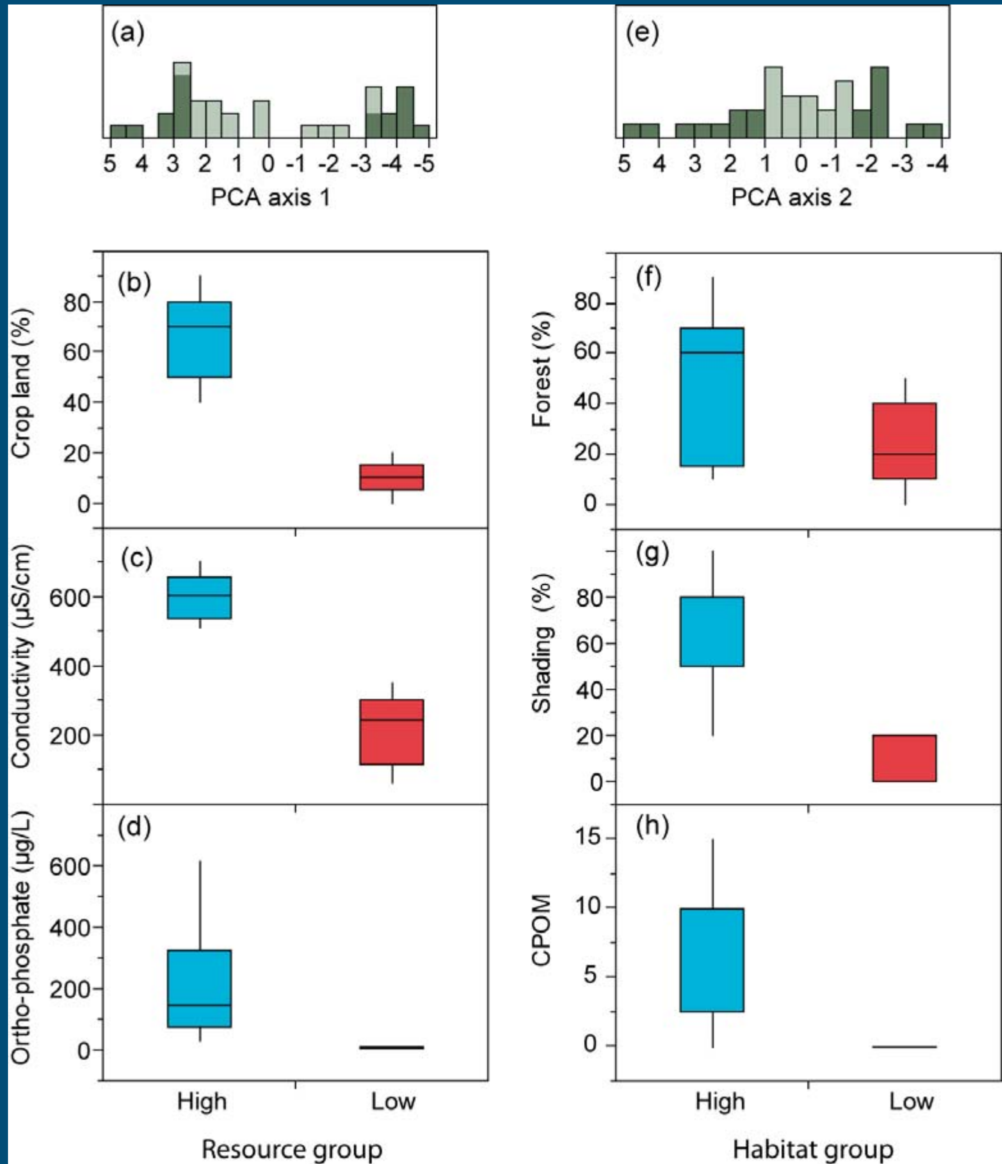


- All groups showed very weak responses to habitat gradient

Johnson & Hering 2009 (J. Applied Ecology)

Not giving up; another approach

PCA used to isolate **high** & **low** resource & habitat groups



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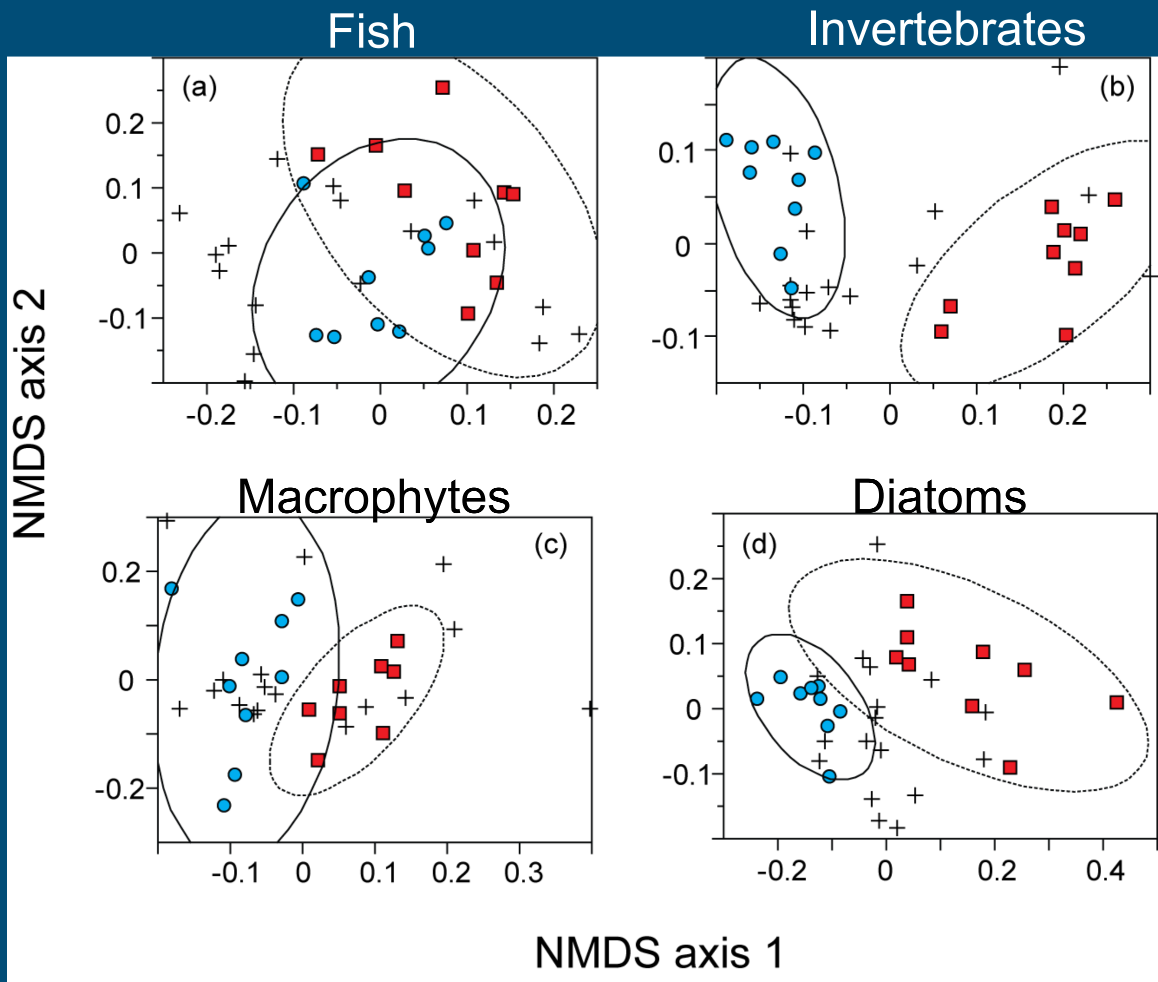
Response to Resource (blue = H, red = L)

- All four groups showed clear differences between H and L resource groups
- ANOSIM – R values between 0.36 (macrophytes) and 0.81 (invertebrates)



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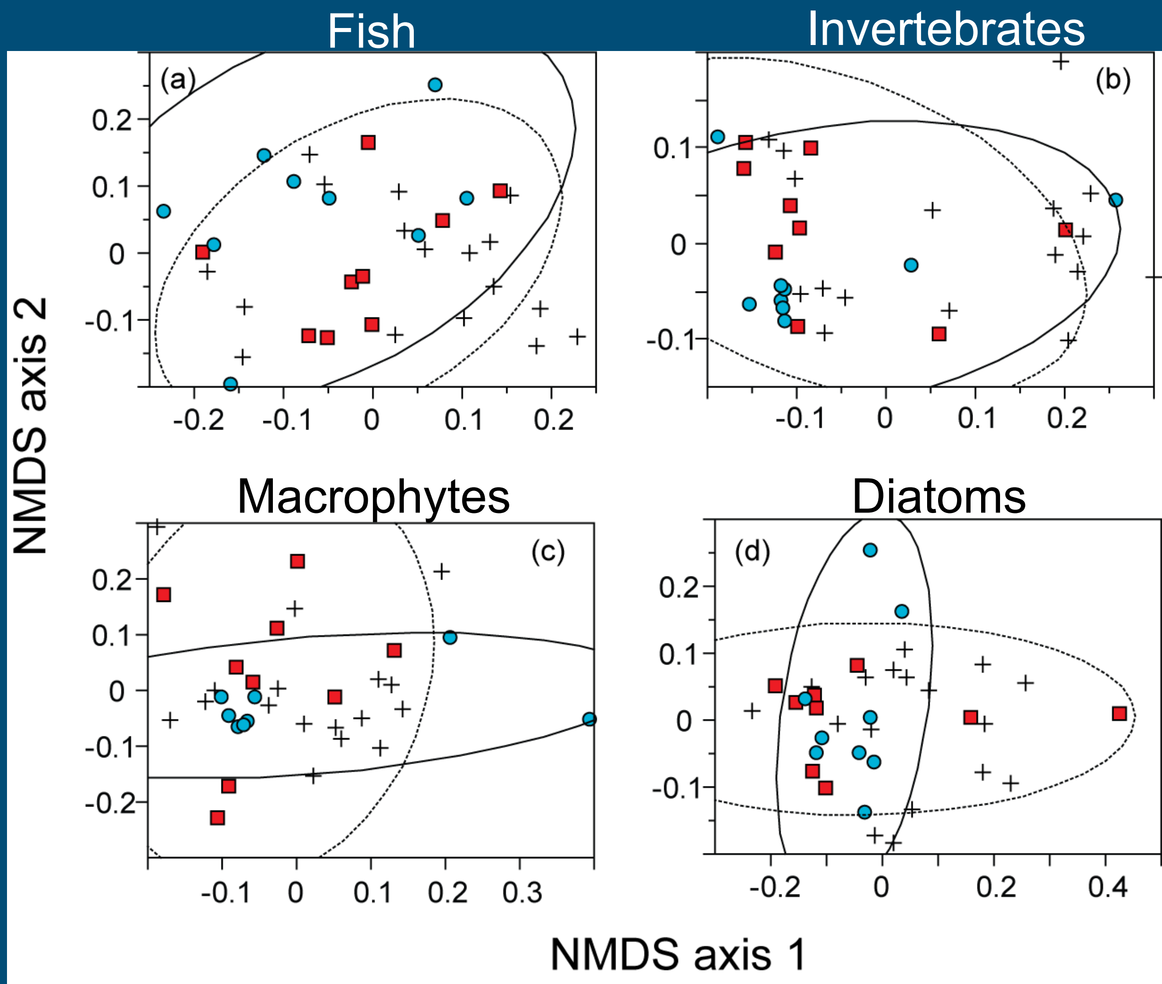
Response to Habitat (blue = H, red = L)

- All four groups showed considerable overlap between H and L habitat quality
- ANOSIM – only fish and invertebrates differed, but R values were low (< 0.20)



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Summary - scale, resource & habitat

- Local factors more important than regional
- Response to resource gradient: diatoms ≥ macrophytes > fish ≈ invertebrates
- Response to habitat gradient: macrophytes ≈ diatoms > fish ≈ invertebrates
- Response trajectories differed between taxonomic group and stressor (nutrients – moderate to strong; hydromorphology – weak)
  BUT...multiple stressors at work?

Multiple stressors the norm not the exception!

- **Simple outcome**: *additive* or *multiplicative* effect of all stressors combined equal to <u>sum</u> or <u>product</u> of individual effects.
- **Complex outcome**: *synergistic* or *antagonistic* combined effect <u>larger</u> or <u>smaller</u> than predicted from single effects.

Adapted from Townsend et al. 2008 (J. Applied Ecology)

Understanding effects of multiple stressors

- *Field survey* - realistic but lacks control
- *Channel experiment* - controlled but realism in question (i.e. appropriate temporal and spatial scale)
- *Reach-scale experiment* - reasonably controlled and reasonably realistic

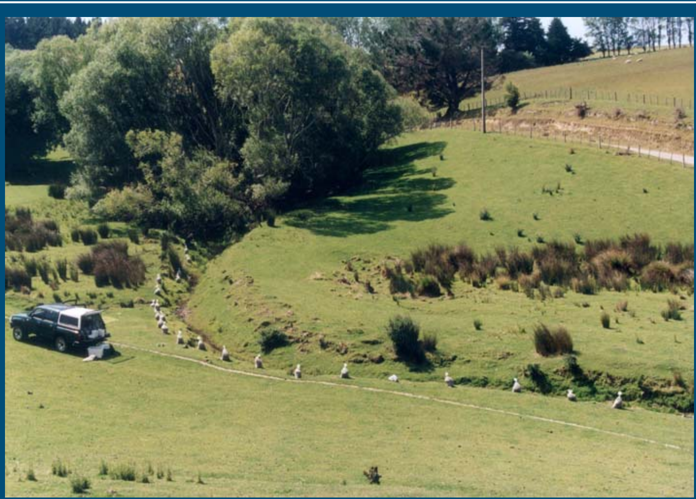
Adapted from Townsend et al. 2008 (J. Applied Ecology)

The survey

- 32 grassland streams in summer
- 2^{nd} order, homogeneous land-use (e.g. tussock grass (least impaired) or pasture with sheep [impaired])
  - % sediment cover (S)
  - $Log_{10}DIN+Log_{10}SRP$ (N)
- All variables normalized and scaled 0-1
- Multivariate models to quantify individual stressor effects and interaction $Y=b_1S + b_2N + b_3SN + b_o$

Adapted from Townsend et al. 2008 (J. Applied Ecology)

The reach-scale experiment



- Nine relatively unimpacted streams (50 m reaches, 5 week experiment)
- Complete factorial design - ambient, intermediate and high levels of both nutrients and sediment
- Repeated measures ANOVA

Adapted from Townsend et al. 2008 (J. Applied Ecology)

The channel experiment

- Eighteen channels
  (18 d experiment)
- Complete factorial design - nutrients and sediment, also normal and **85% reduced discharge**
- ANOVA: important terms are sediment and nutrients and the interactions:

➢ Sediment * Nutrients

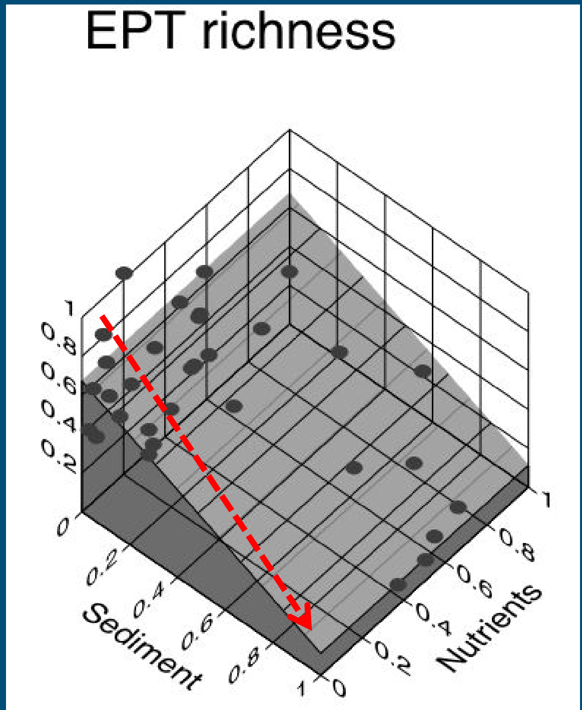
➢ Sediment * Discharge

➢ Nutrients * Discharge

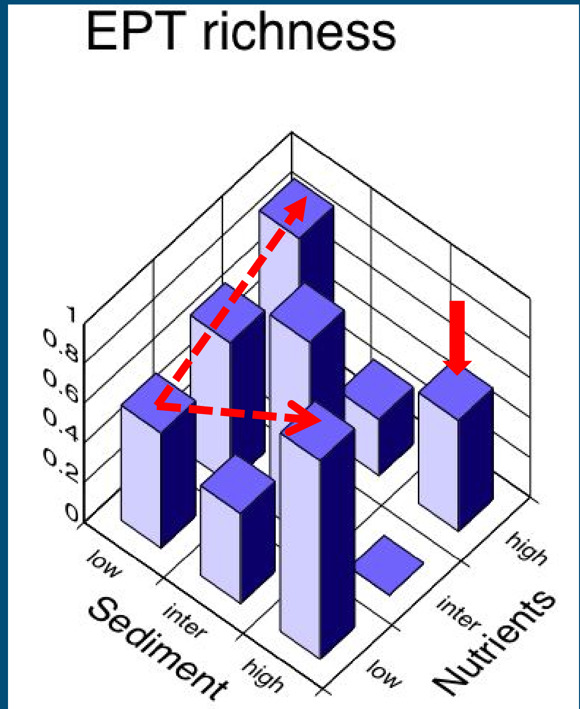
Adapted from Townsend et al. 2008 (J. Applied Ecology)

EPT taxon richness

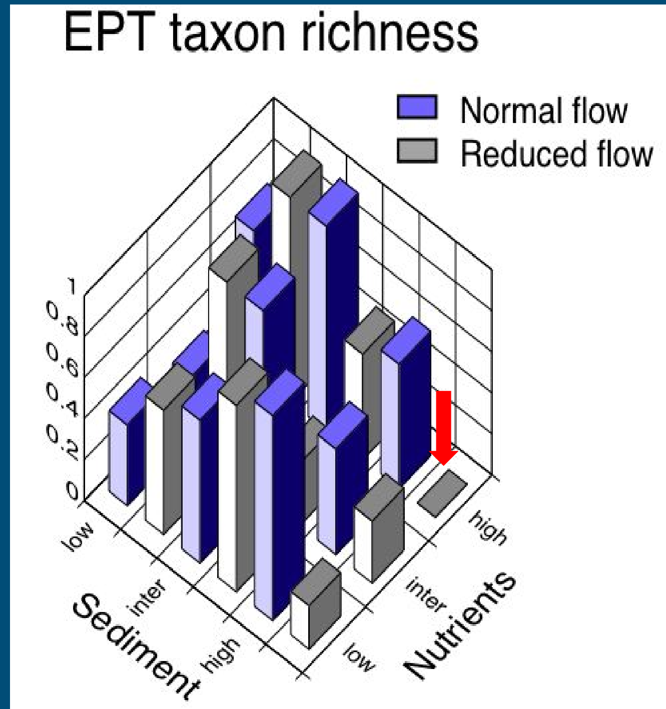
Survey



Reach



Channel



single stressor:
sediment

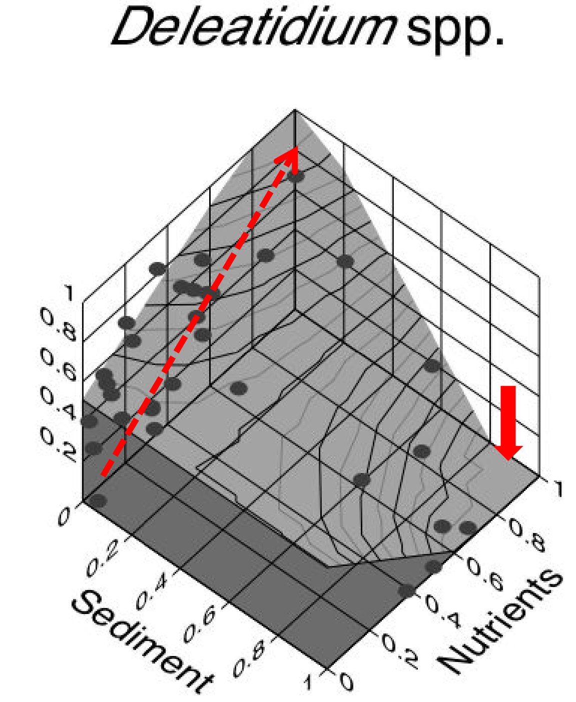
multiple stressors:
sediment*nutrient
antagonism

multiple stressors:
sediment*discharge
antagonism

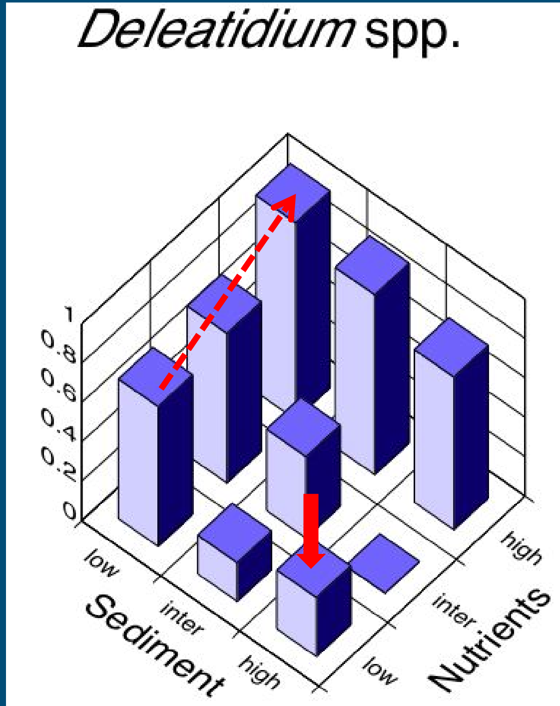
Adapted from Townsend et al. 2008 (J. Applied Ecology)

Mayfly *Deleatidium* spp. (density)

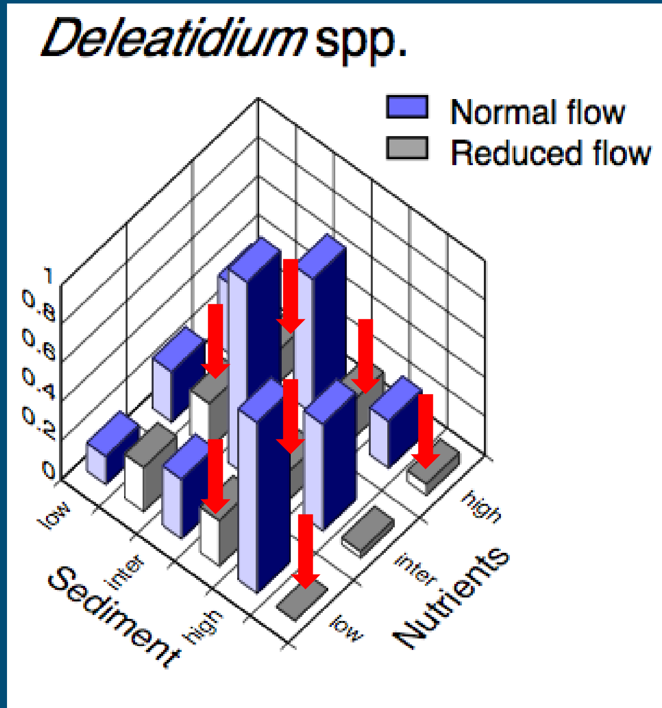
Survey



Reach



Channel



multiple stressors:
nutrient*sediment
antagonism

multiple stressors:
sed and nutrients
multiplicative

multiple stressors:
sediment*discharge
antagonism

Adapted from Townsend et al. 2008 (J. Applied Ecology)

Relative importance of nutrients, sediment and discharge?

	Nutrient effects	Sediment effects	Discharge effects
Survey	4	6	
Reach experiment	5	8	
Channel experiment	8	13	16

Adapted from Townsend et al. 2008 (J. Applied Ecology)

Summary - multiple stressors

- Sediment often more influential than nutrients
  - Abstraction perhaps more important than both
- Surveys and experiments both offer something (not always the same result)
  - Survey - responses confounded by uncontrolled influences?
  - Experiments - scale appropriate?
- Survey and, especially, experiments revealed many complex interactions
  - Managers may get it wrong if multiple stressors act in complex ways

Adapted from Townsend et al. 2008 (J. Applied Ecology)

Focus on nutrients vs hydromorphology

Web of Science®
1980-2009 (22/2)

Timespan=1980-2009.
Databases=SCI-EXPANDED.

stream* and nutrient* = **3839**

stream* and hydromorpho* = **68**

Since acceptance of WFD

Timespan=2000-2009.
Databases=SCI-EXPANDED.

stream* & nutrient* = **2661**

stream* & hydromorpho* = **61**

Hydromorphology alterations of streams

Is there a problem? **Yes**

Is the problem easy to measure? **Not really**

Do we know what to measure? **Nope**

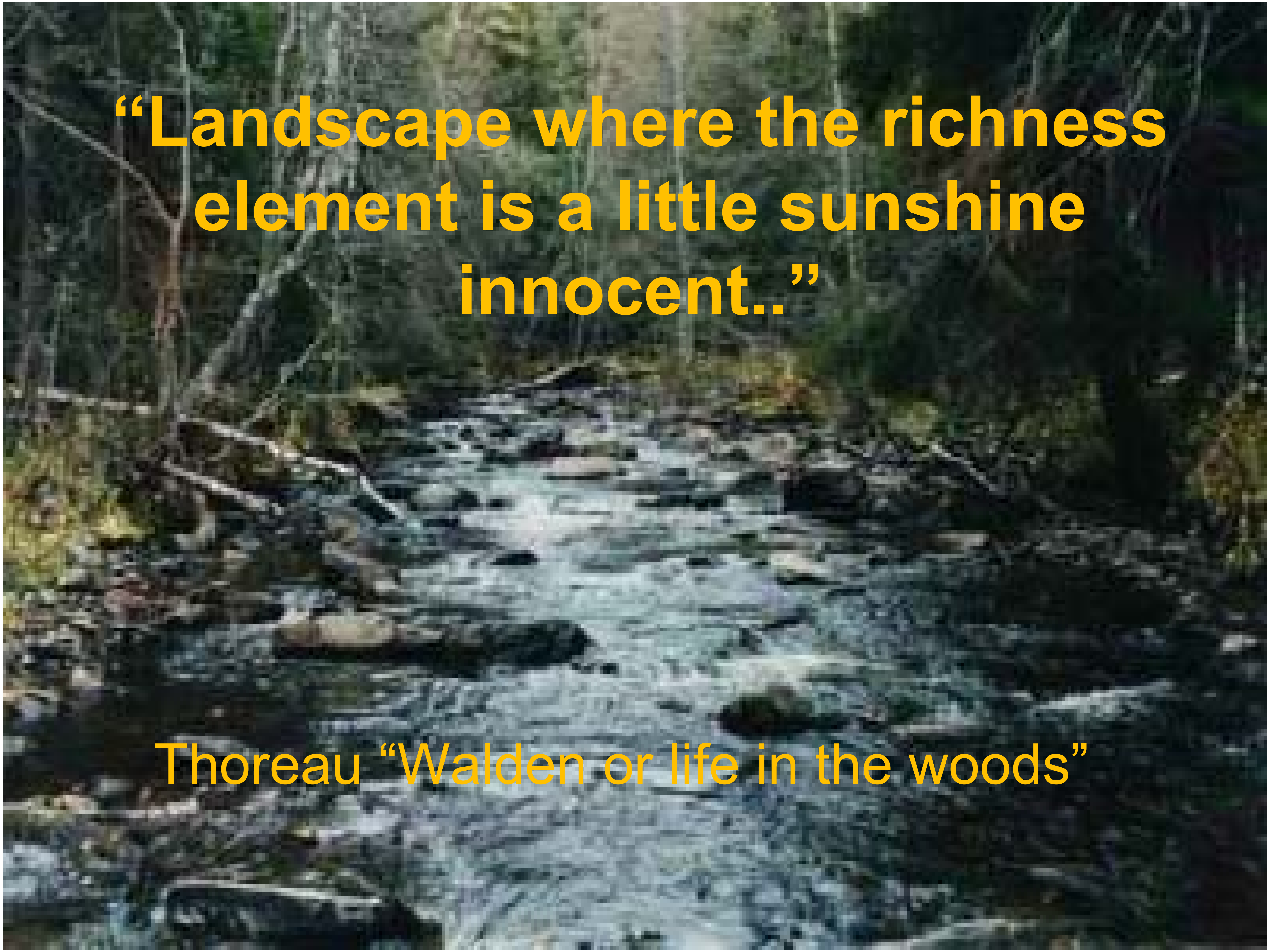
Some questions

- How do we best establish the **reference condition** of streams where present-day analogues are lacking or too few (e.g. lowland streams)?

- Without drastically altering the landscape, is it possible to reconstruct the natural or near natural hydro-geo-morphology and structure and function of streams? How important is **spatial configuration in stream restoration**, e.g. for hydrology, for dispersal and colonization, etc?

- How important are **terra-aquatic linkages** for stream structure and function? Can use of large woody debris in stream restoration replace the function of mature riparian habitats?

- Many streams are affected by **multiple stressors**. Is it possible to separate the effects of multiples stressors on stream systems to best design and recommend management programs?


“Landscape where the richness element is a little sunshine innocent..”
Thoreau “Walden or life in the woods”