Dr Guy Woodward
(Queen Mary University of London)

"Tales from the riverbank: separating myths from reality"

The overarching (but declining) influence of organic pollution....habitat as the new bottleneck?

As water quality improves, second-order effects, such as habitat quality, come into play.

First fix the **medium**, then the **matrix**...

Habitat loss, fragmentation and simplification

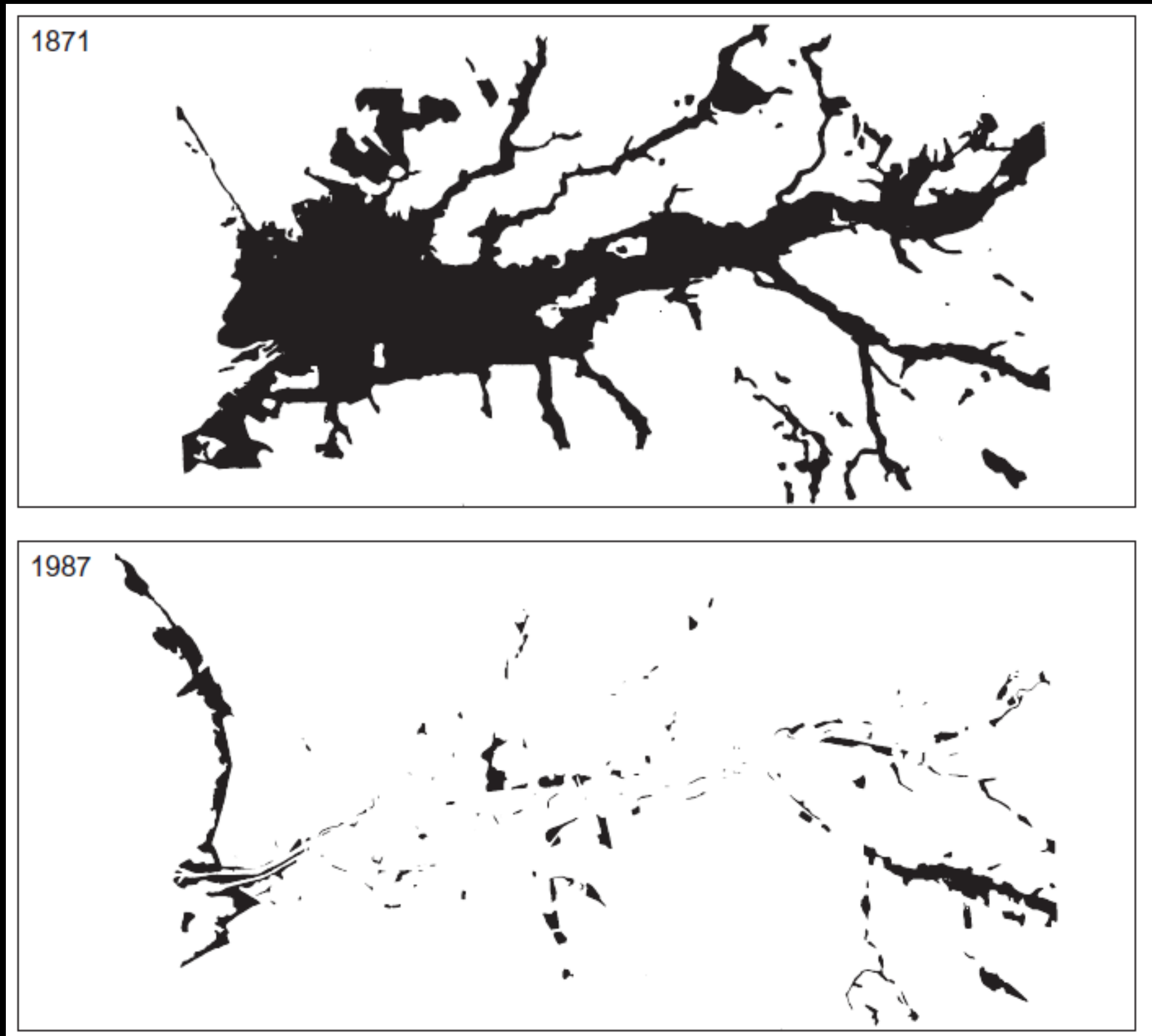
The Haywain – John Constable ,1821.......and the 21st Century version

A changing world-view....and a growing desire to restore habitats

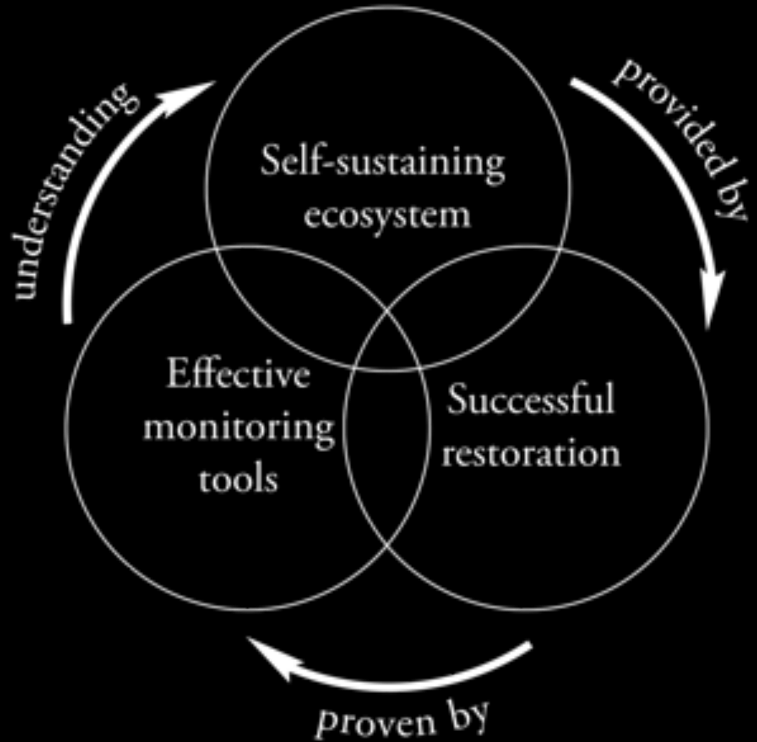
W. Gloeckner "Summer" 1972

Agricultural landscape

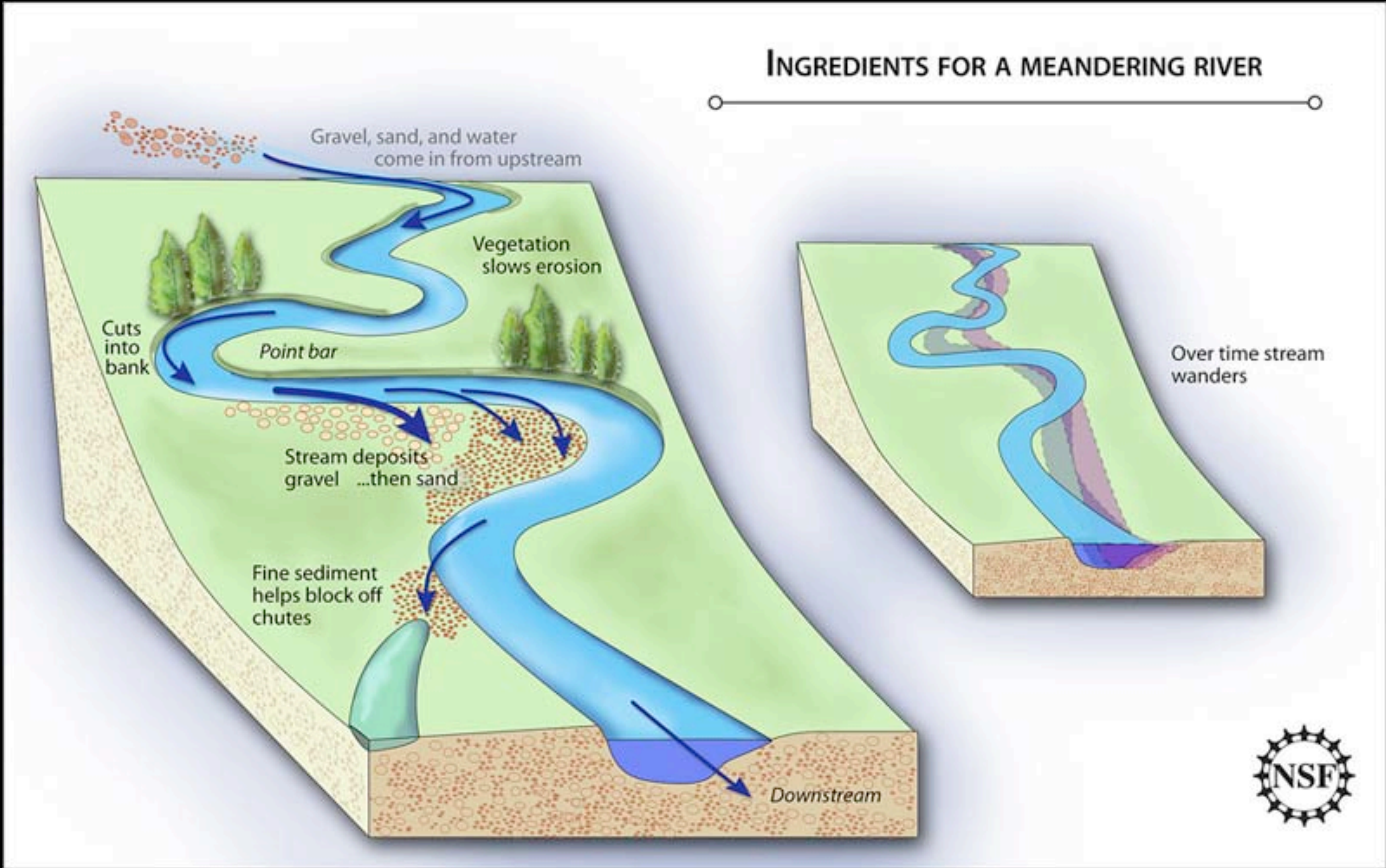
The same old story....habitat loss, fragmentation and simplification



The "virtuous circle" of restoration



What should a river look like....and how does this affect it biology?



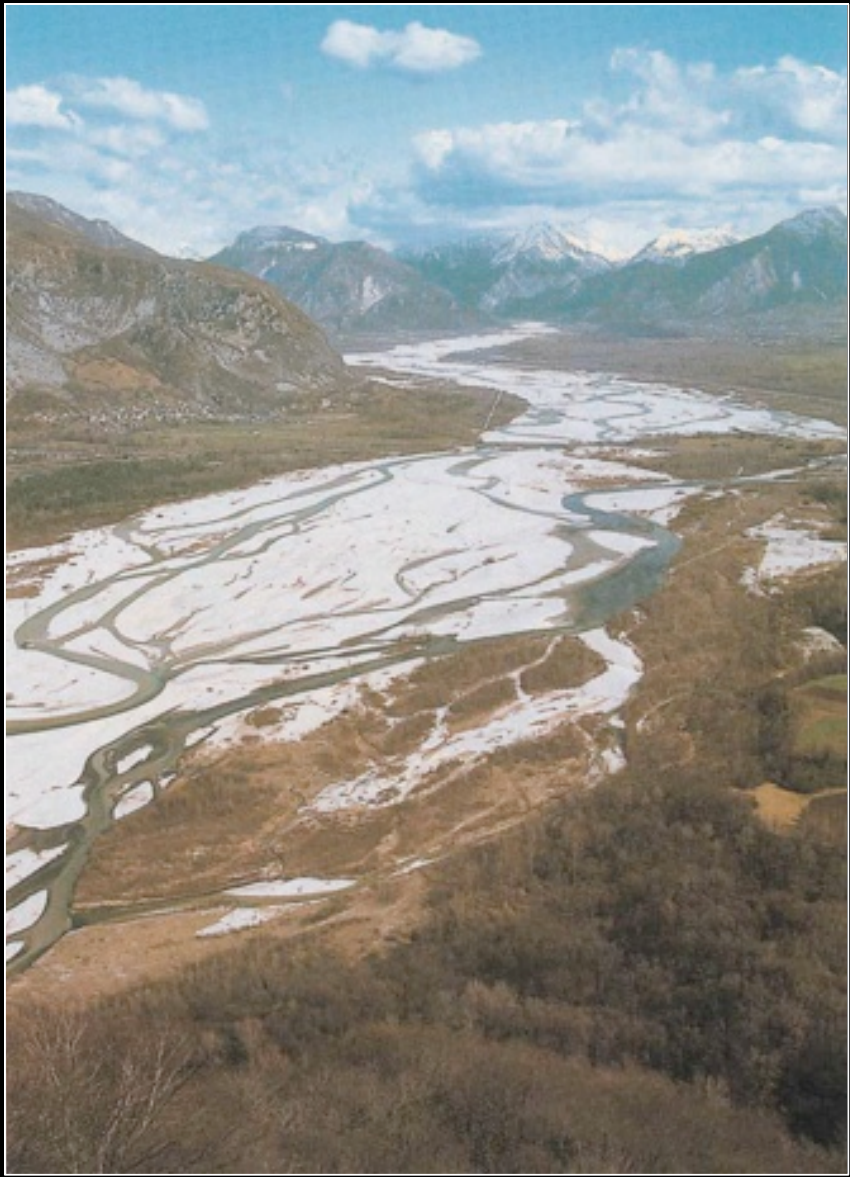
Restoration – or gardening?
Goals need to be clearly-defined and measurable

Before we can fix something, we need to understand how it works...

...and we need to measure if the "symptoms" respond to our "cures" (or not)

Is this really river restoration?

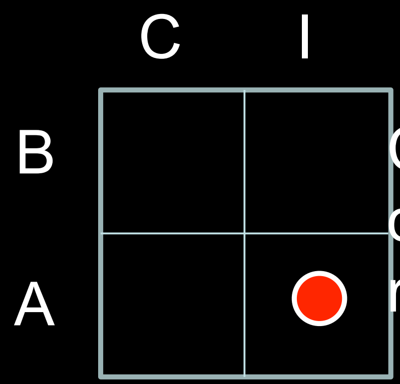
Model systems and the comparative approach



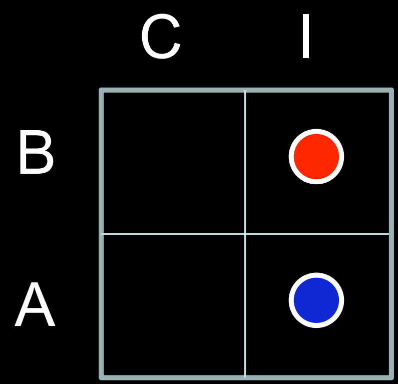
The Tagliamento - an aspirational target but unachievable for most rivers...we need more replicated, paired BACI-style approaches to test in situ ***responses*** to restoration

From pie-in-the-sky optimism towards an evidence-based approach

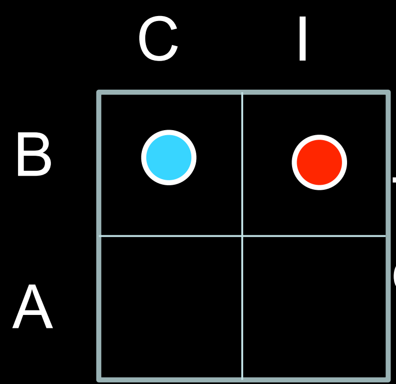
Developing the evidence base – Before-After-Control-Impact studies...and the need for long-term monitoring



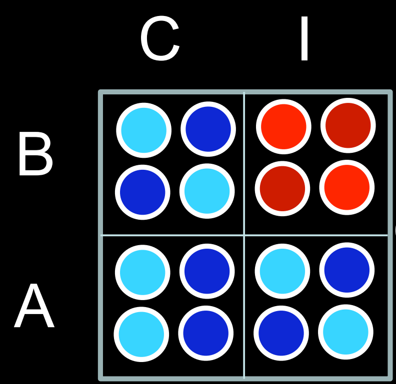
Cannot demonstrate restoration



Spatially confounded



Temporally confounded



Can demonstrate restoration

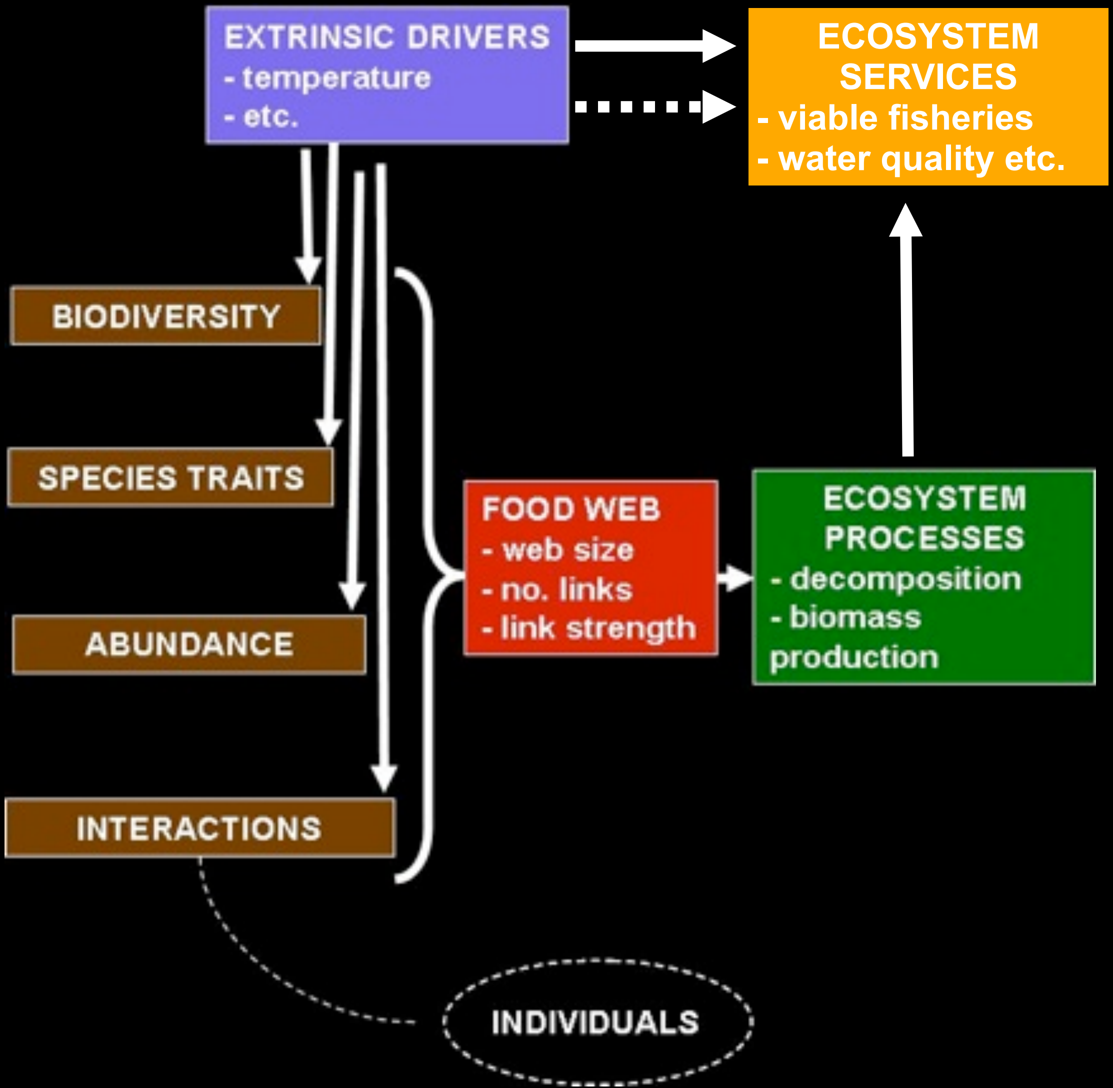
(not always achievable in practice)

The desired goals – maintenance of healthy fisheries and a diverse biota – but what are the drivers?

Interactions within the biota and between the biota and environment must be considered.

e.g. trout depend on terrestrial subsidies and in-stream biota – and can have strong top-down effects on the latter (but not the former).

The next step: linking structure to function



Biodiversity loss has a food web context

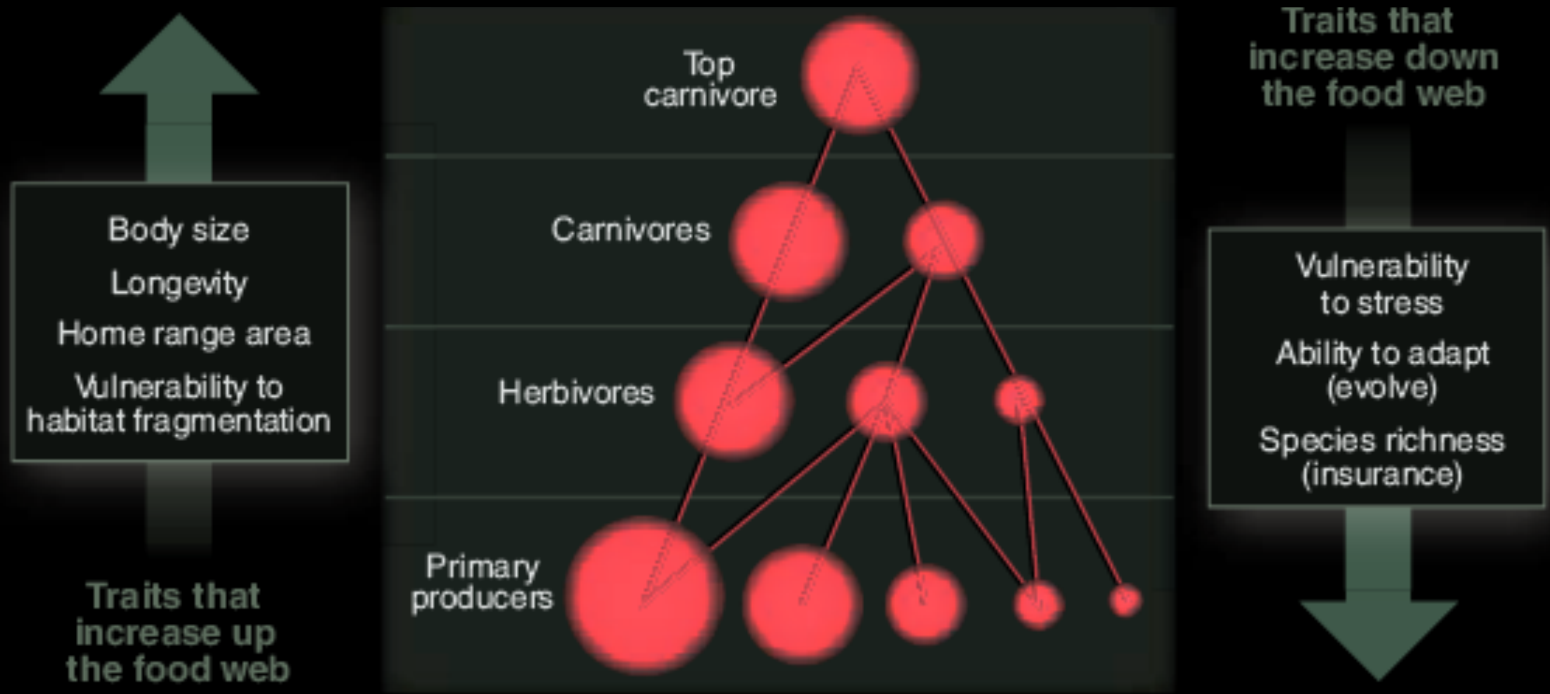

ECOLOGY

SCIENCE VOL 306 12 NOVEMBER 2004

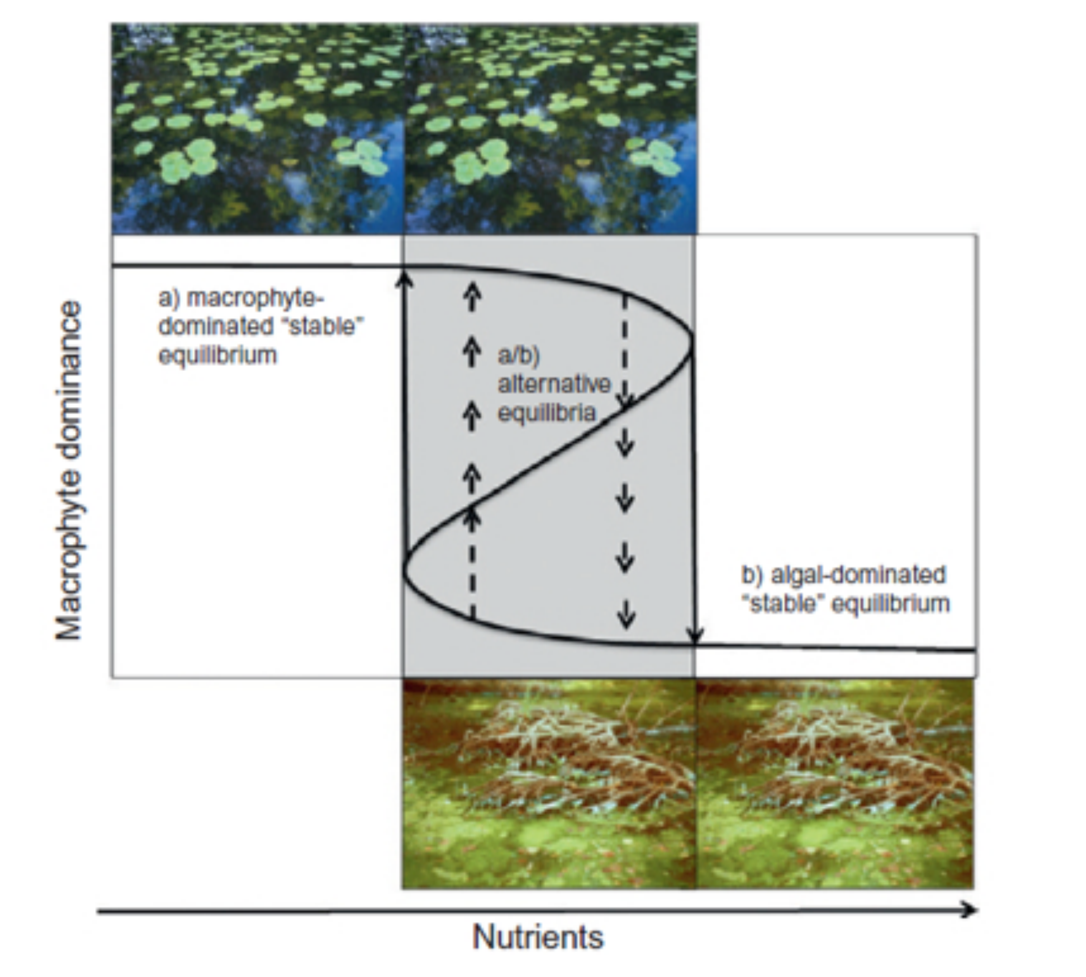
How Extinction Patterns Affect Ecosystems

David Raffaelli

"…effects of biodiversity loss… will depend largely on the order in which species are lost, which in turn is determined by the susceptibilities of ecosystems to different types of stresses"



Beyond the physico-chemical template – the role of biotic interactions



Alternative ecosystem states may exist despite **<u>IDENTICAL</u>** environmental conditions – due to food web effects

Can we find some simple means of understanding (and predicting) these complex systems?

Ecological tools at our disposal – none are perfect, so we need to combine them – river restoration has largely failed in this regard

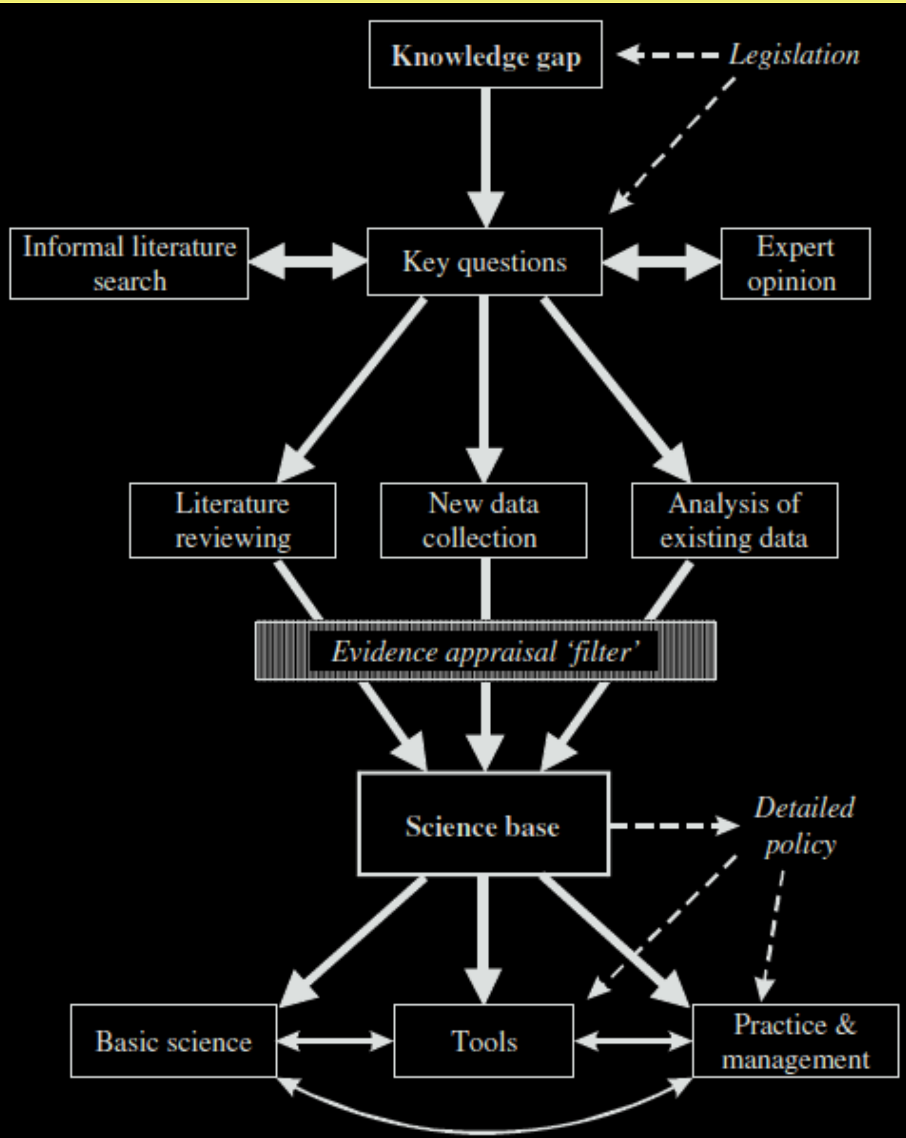
	Pros	**Cons**
Surveys	Realism	Inferential, confounded
Field experiments	Some realism	Often small-scale
Modeling	Predictive	Limited realism, lack of data
Lab experiments	High control	Limited realism, small-scale

Trade-off : "Replication – Realism – Control"

River restoration can be employed as LARGE SCALE, LONG-TERM, REPLICATED experimental manipulations – unfortunately we often end up with patchy case-study data and an inability to link to cause and effect.

The Assumption: "If you build it, they will come…."

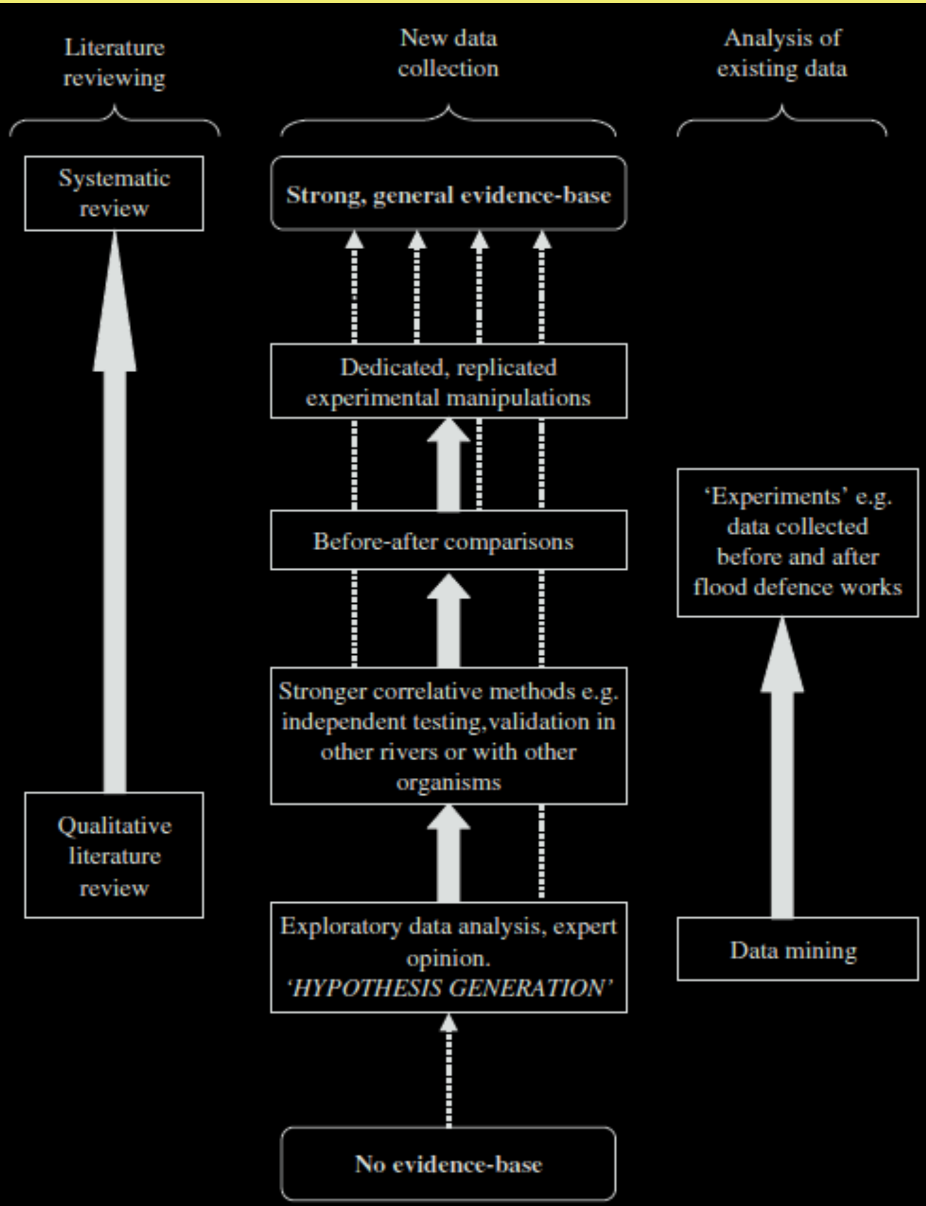
Knowledge - understanding - prediction



Science in the real world – from knowledge gap, to understanding, to management

(Vaughan *et al* 2009)

Parallel approaches - linking ecology to the physical habitat



Habitat-biota links in rivers are still poorly understood – yet this is what we are trying to restore.

Co-ordinated multi-pronged approach is needed to improve evidence base and mechanistic understanding

(Vaughan *et al* 2009)

Employing a BACI approach across multiple sites in collaboration with multiple end-users (Murray Thompson PhD study...in process)

Replicated reach-scale BACI studies across rivers

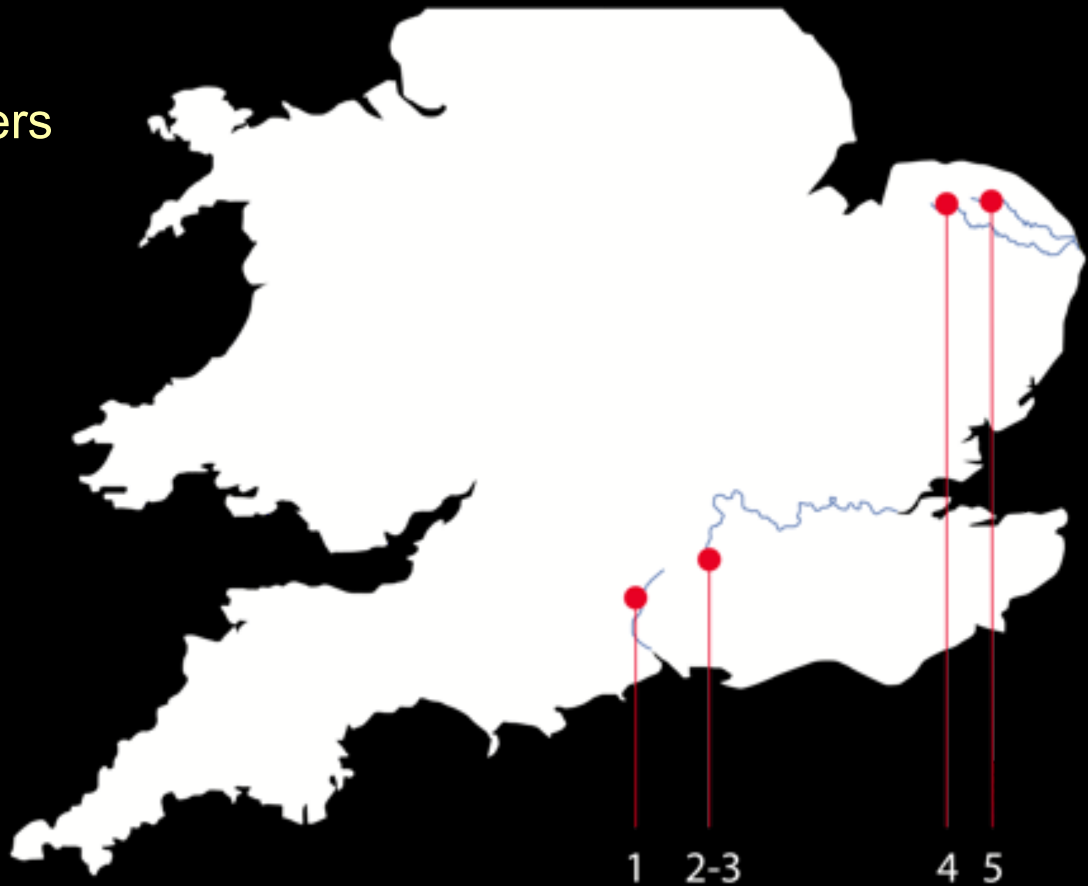
1. The Test

2. The Loddon

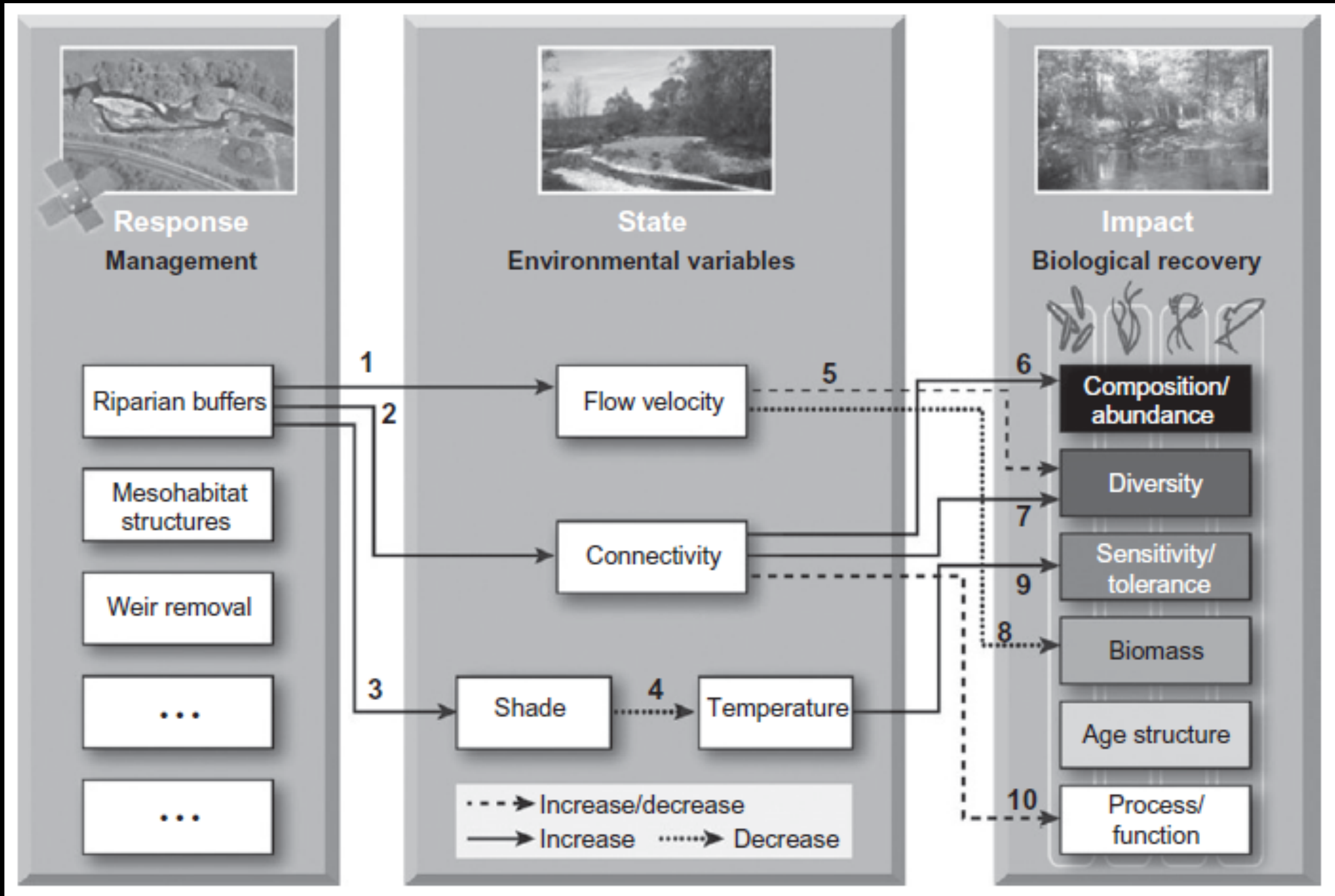
3. The Lyde

4. The Bure

5. The Wensum



Developing a more integrated conceptual framework (Feld et al 2011 Adv Ecol. Res. 44)



Prioritising biotic measures...from structure to function

Biomass (*B*) and body mass (*M*)

Numerical abundance (*N*)

Diversity (species richness, *S*, is not the only measure!!)

Feeding links (introducing interactions) (*L*)

Functional attributes (*F*) (e.g. ecosystem process rates)

The most important ecological measures have often been ignored in restoration schemes

Different combinations can address different questions (and require different expertise)

N + M + B + S + L + F: The "Rolls-Royce" can address multiple questions relating to energy flux, community stability, functioning, redundancy & "emergent properties"

N + M + S + L: food web dynamics & stability

N + M (B = NM): community energy flux, size spectra

B + S + F: weighting of key functional species

S + F: functional diversity

S: .....relatively little!

Collecting the data…

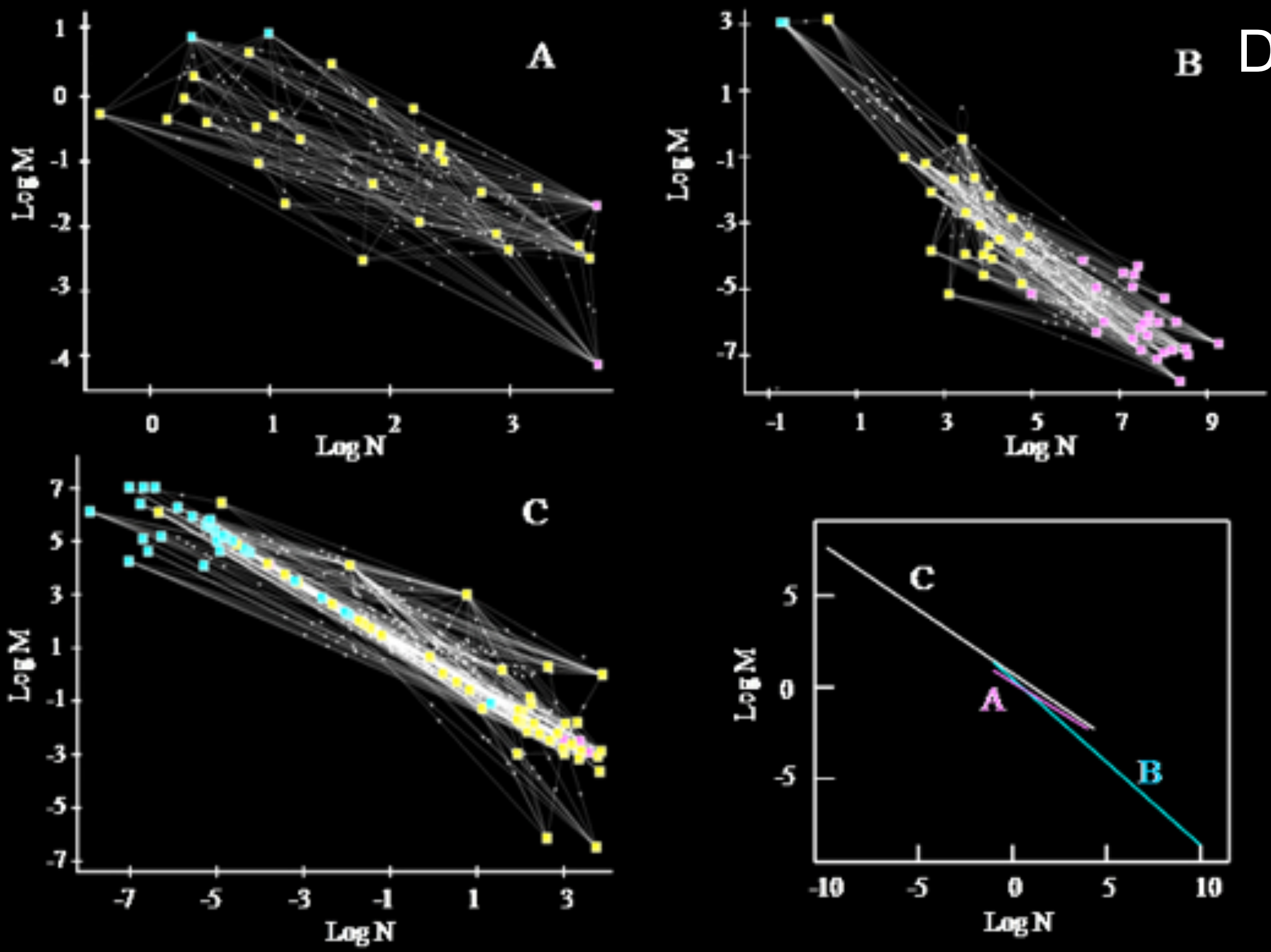
Stones scrapes: algal community

Hess sampler: invertebrates

Electrofishing between stop nets

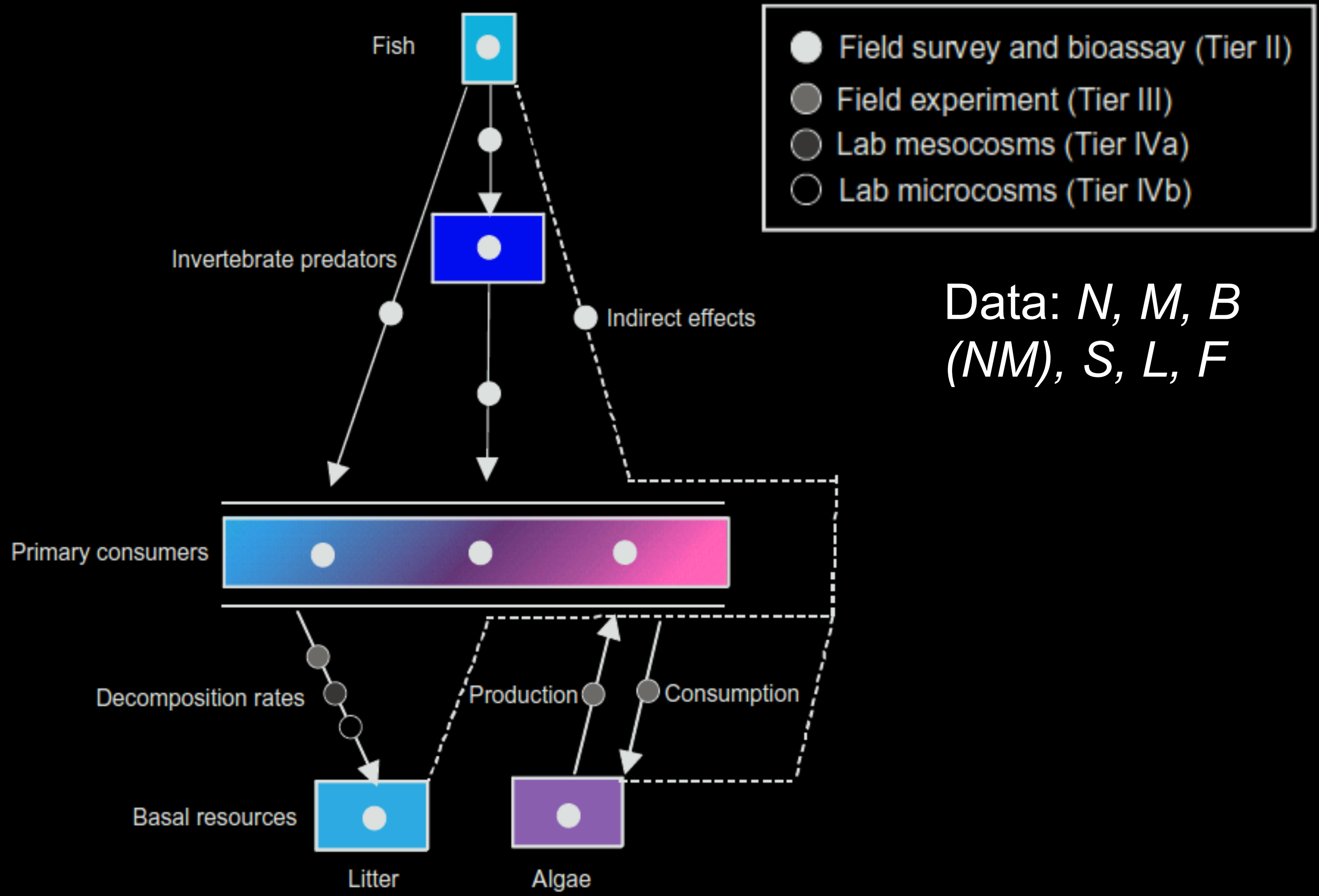
Analysing the data: even complex systems can be predictable

Data: *N, M, S, L*



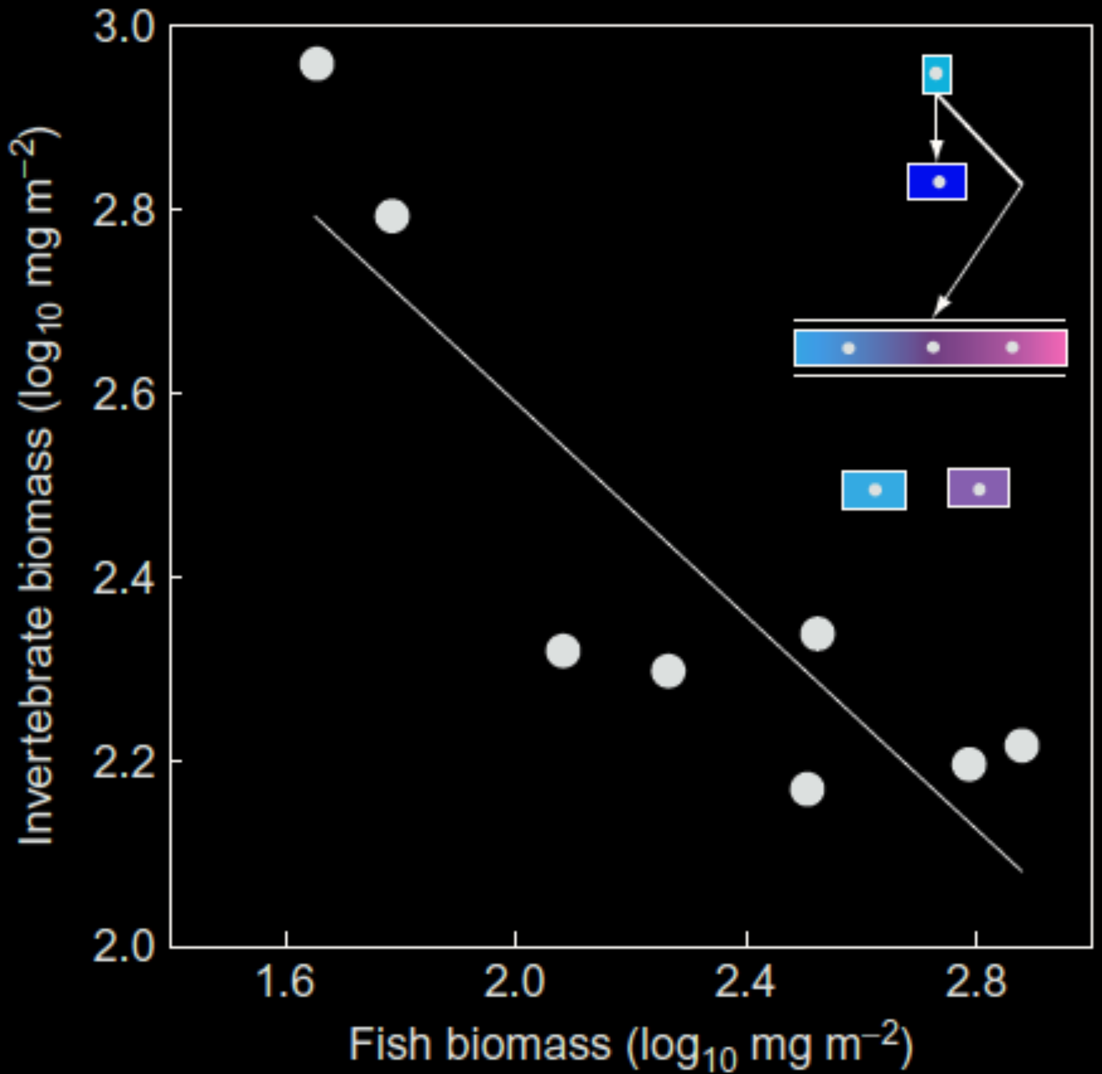
Woodward et al. (2005) *Trends in Ecology & Evolution*

Linking structure to function: a multitiered approach (Hladyz et al 2011 Adv Ecol. Res. Vol 44)



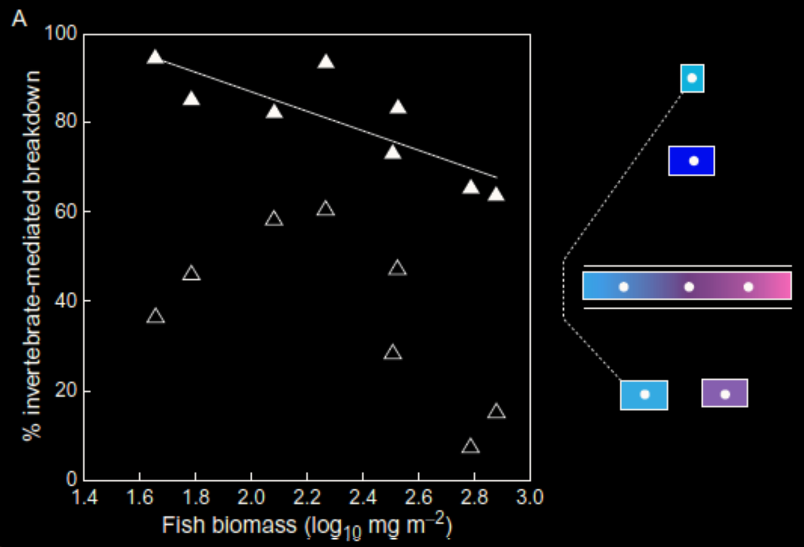
Data: *N, M, B (NM), S, L, F*

Top-down effects across streams – fish v invertebrates



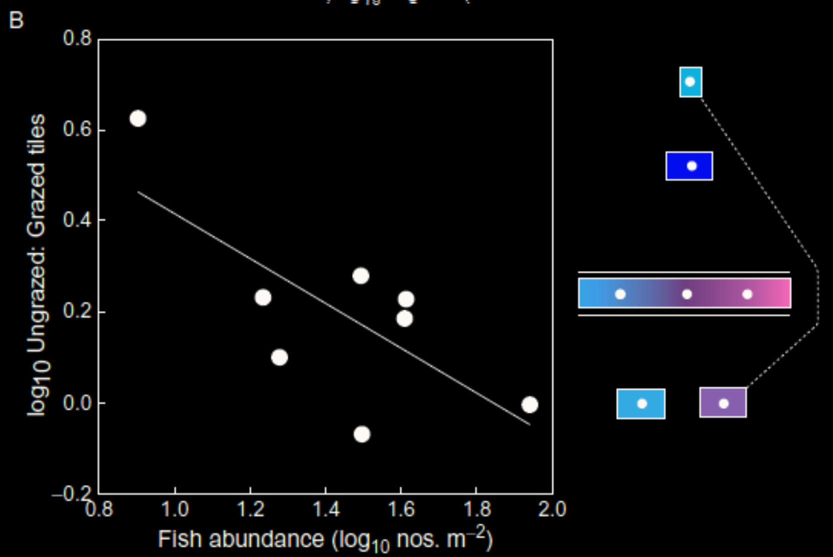
Data: *B, (S)*

Indirect (food web) effects of fish on functioning



Reduced litter breakdown rates

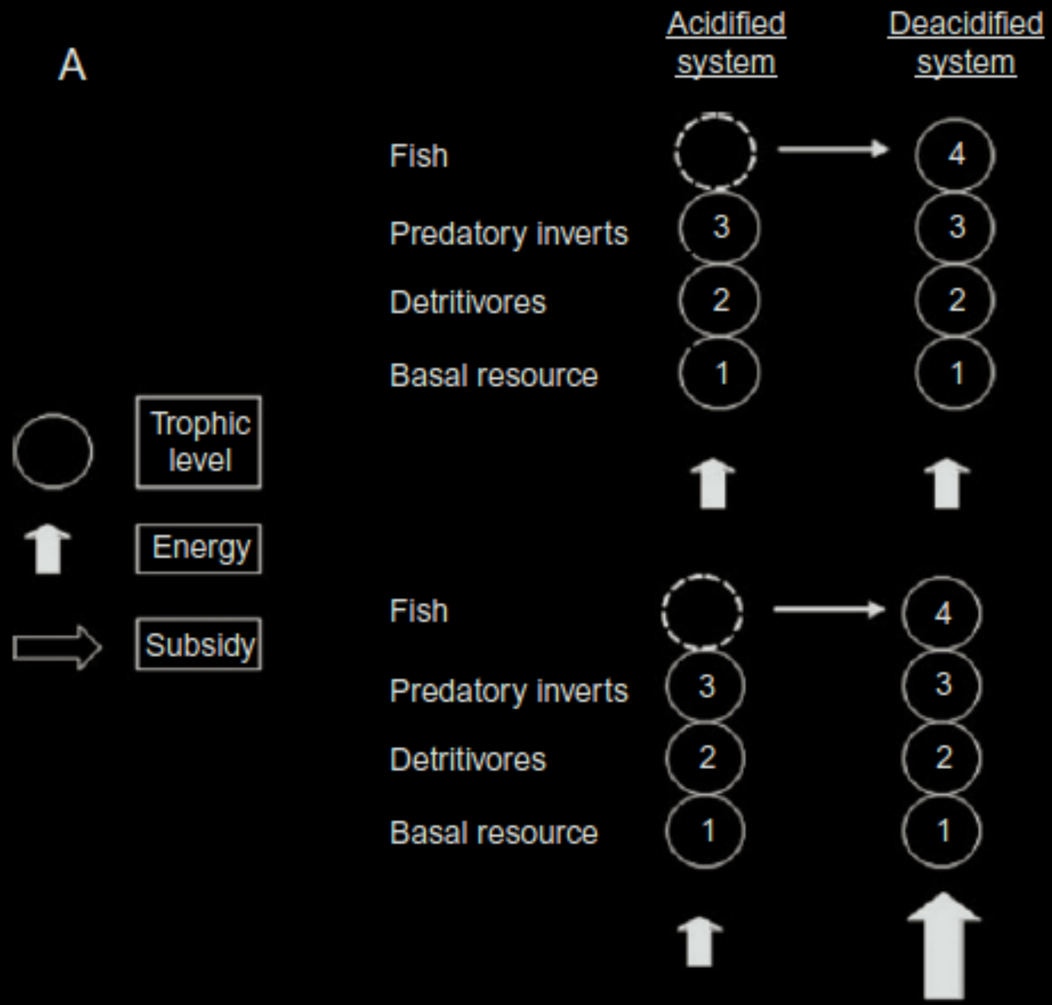
Data: *B, F*



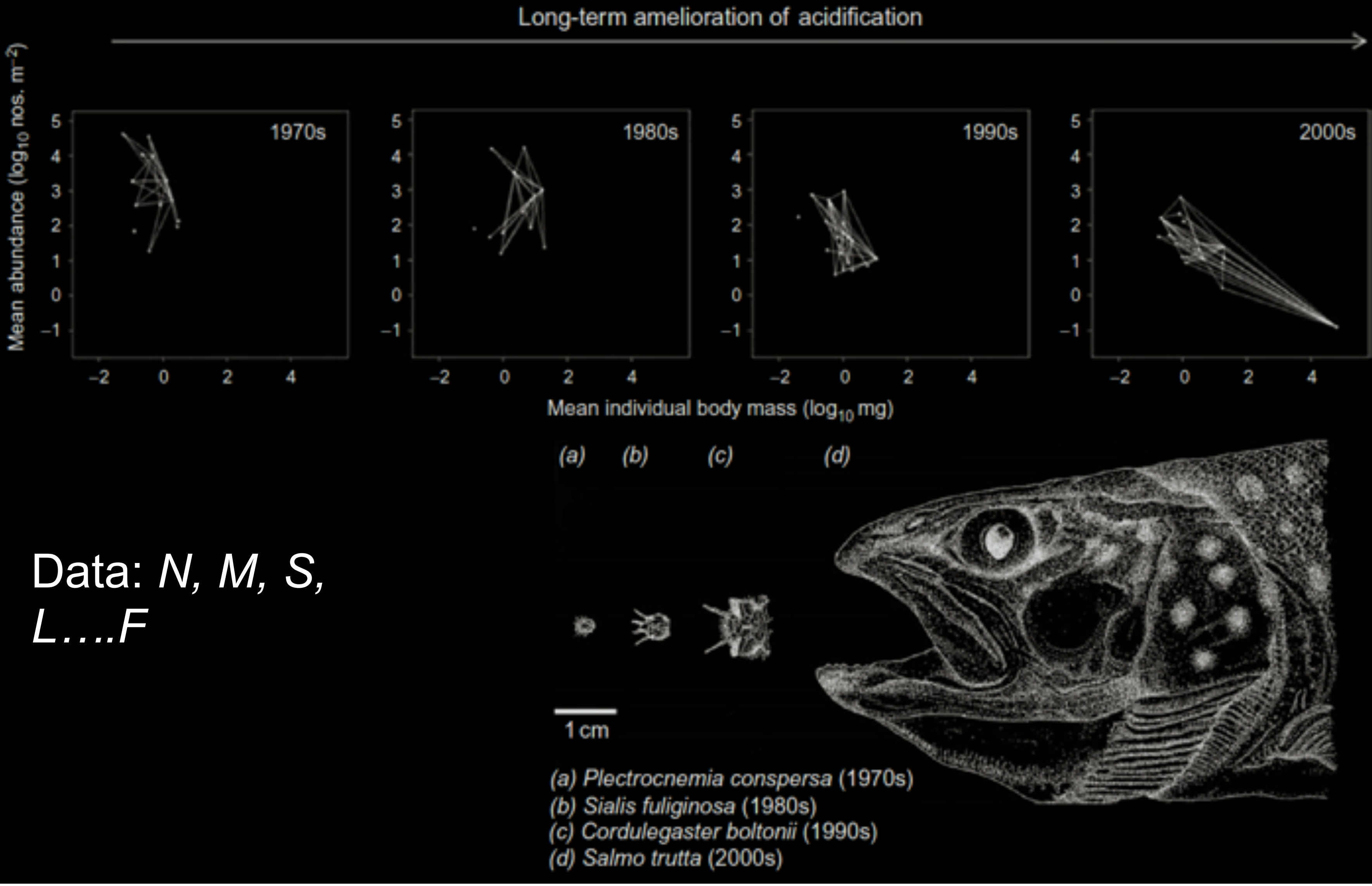
Reduced control on algal production

Data: *N, F*

Hypothesis-driven biomonitoring and assessment: acidification and chemical recovery (“restoration of the medium”)

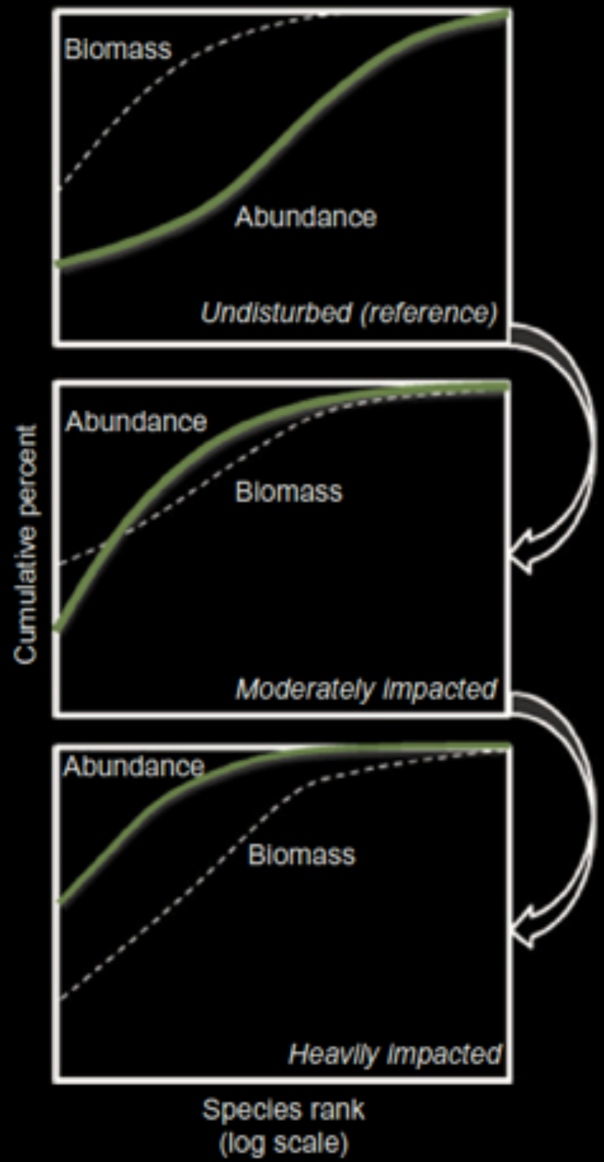


Long-term biological recovery from acidification...similar approaches can be adopted in restoration studies



Data: *N, M, S, L….F*

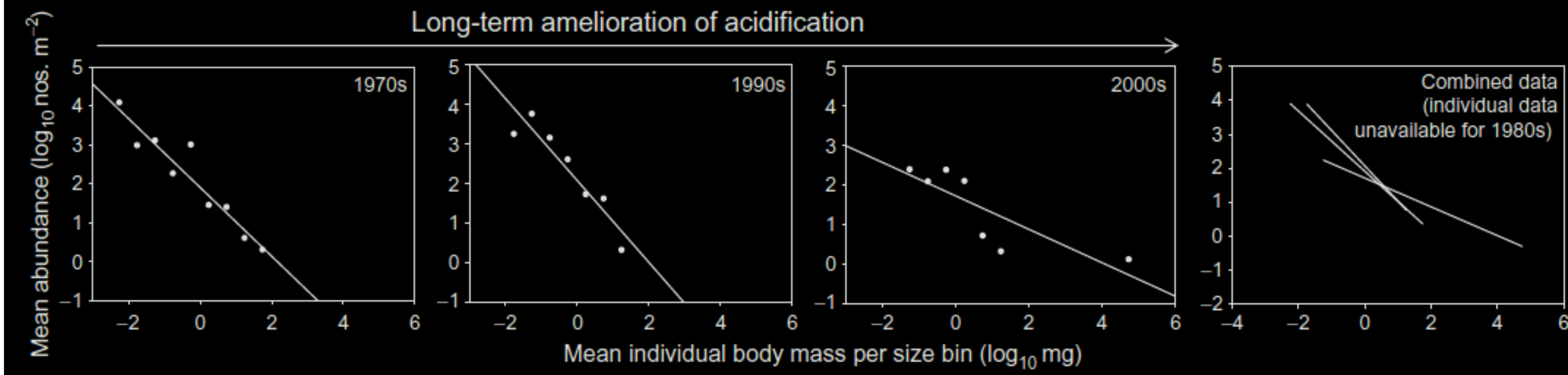
Escaping the curse of the Latin binomial?



Data: *N*, *B*, *(S)*

Taxonomic-free approaches have a long history in marine ecology...they have potential for studying impacts of environmental change (inc. restoration) in freshwaters...e.g., AB curves form a link from structure to function

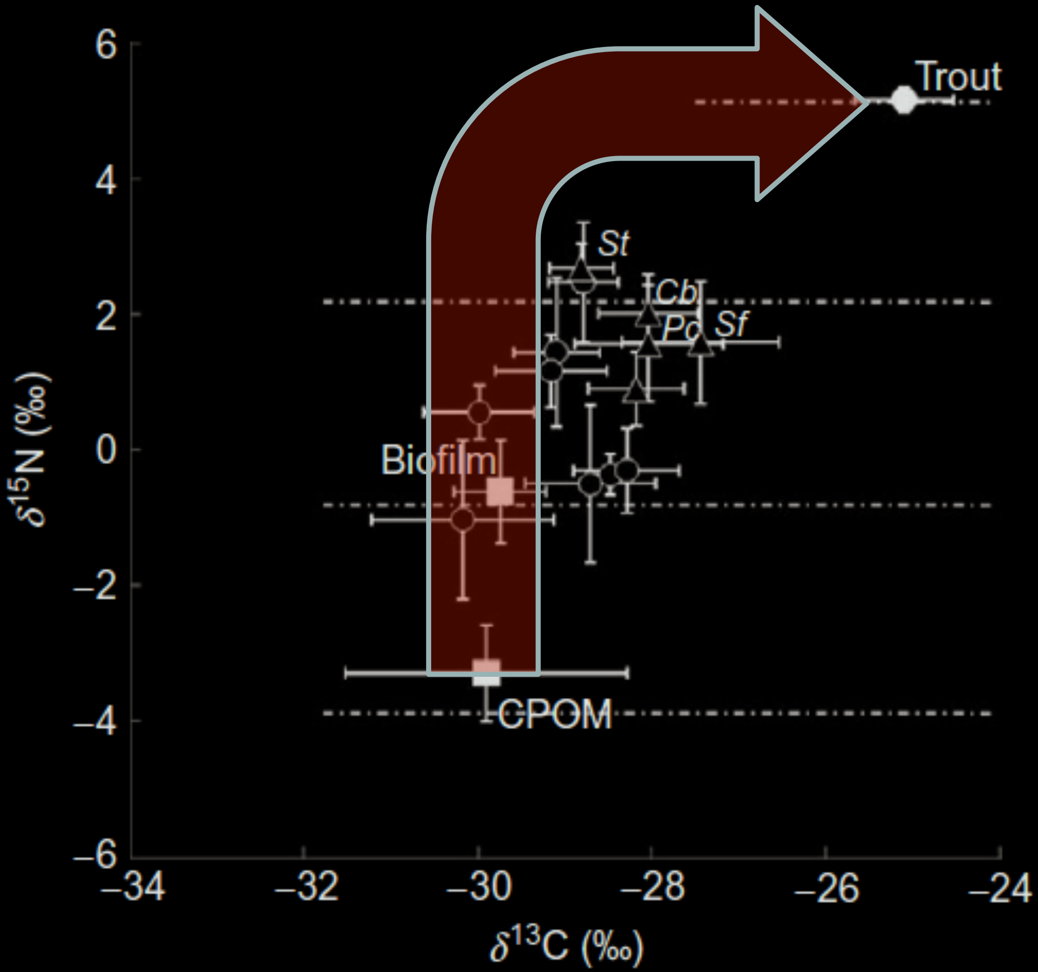
Impacts of the return of trout on community size structure



Data: *N, M….F*

No detailed taxonomic data needed here – yet dramatic changes in "food web" triggered by fish predators are clear

Stable isotope analysis provides broad-brush views of trophic structure (implicit structure-function link)

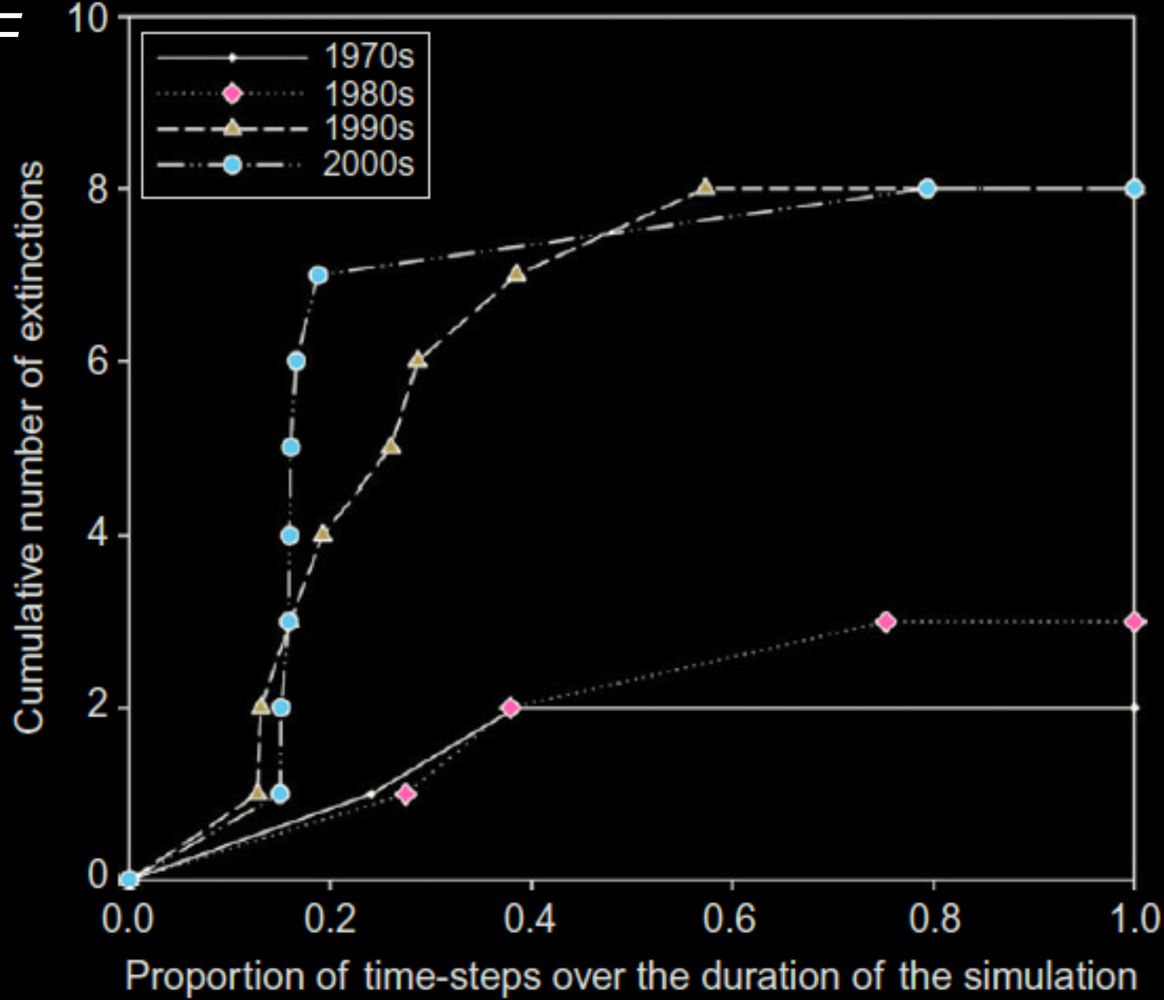


Data: *S, (L)…F*

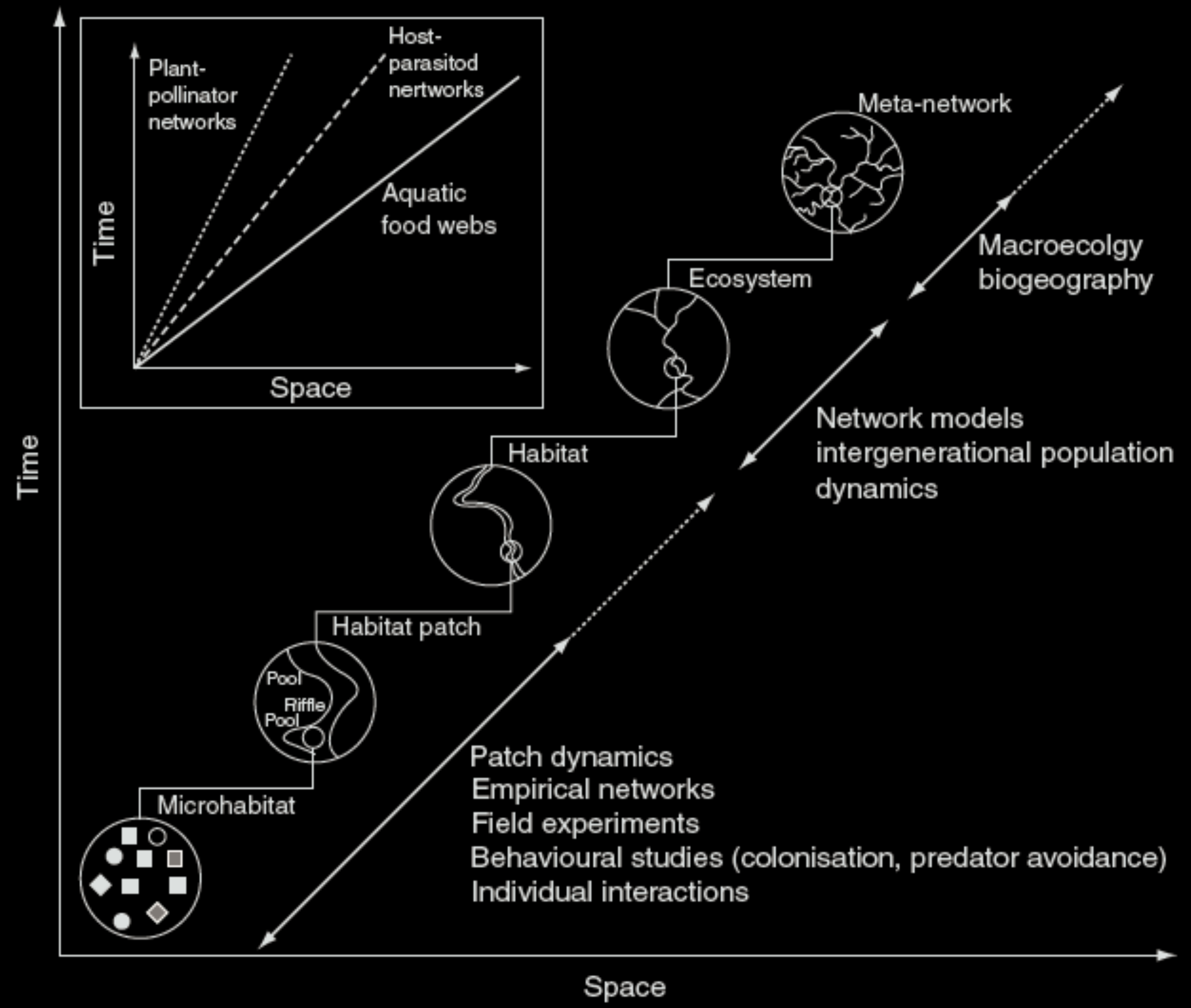
Many stream food webs are detrital-based and size structured (among consumers) – with key implications for restoration

Top predators (e.g. trout) influence community stability (a high-level functional property)

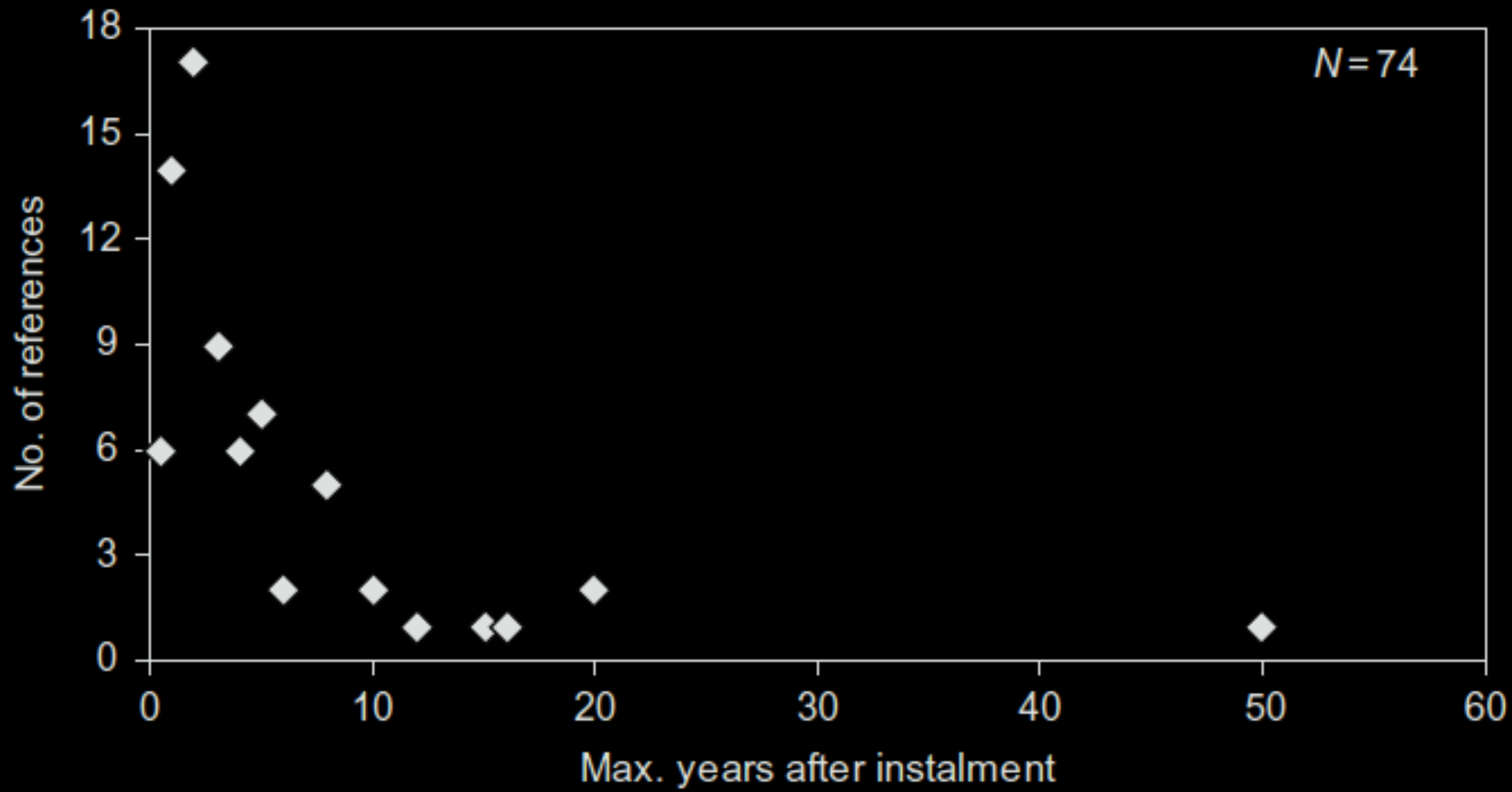
Data: *N, M, S, L….F*



A question of scale – over time and space



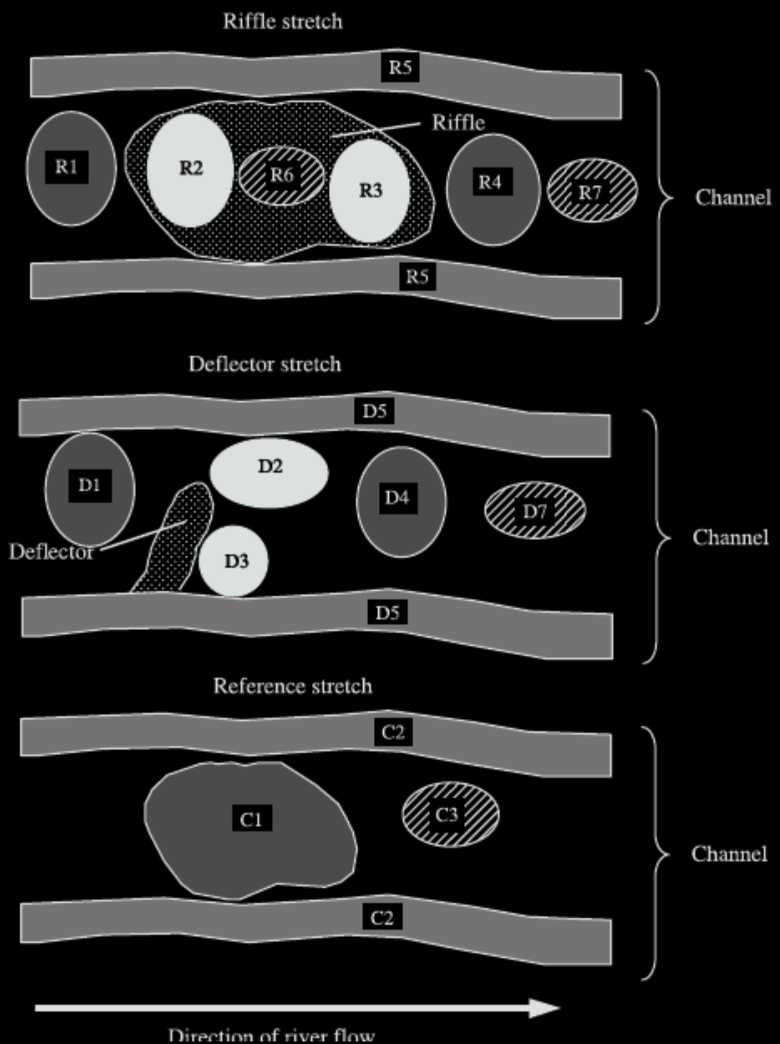
Long-term (re)assessment of restoration is rare – but critically important (Feld et al 2011)



"Habitat-by-numbers" – small-scale modification

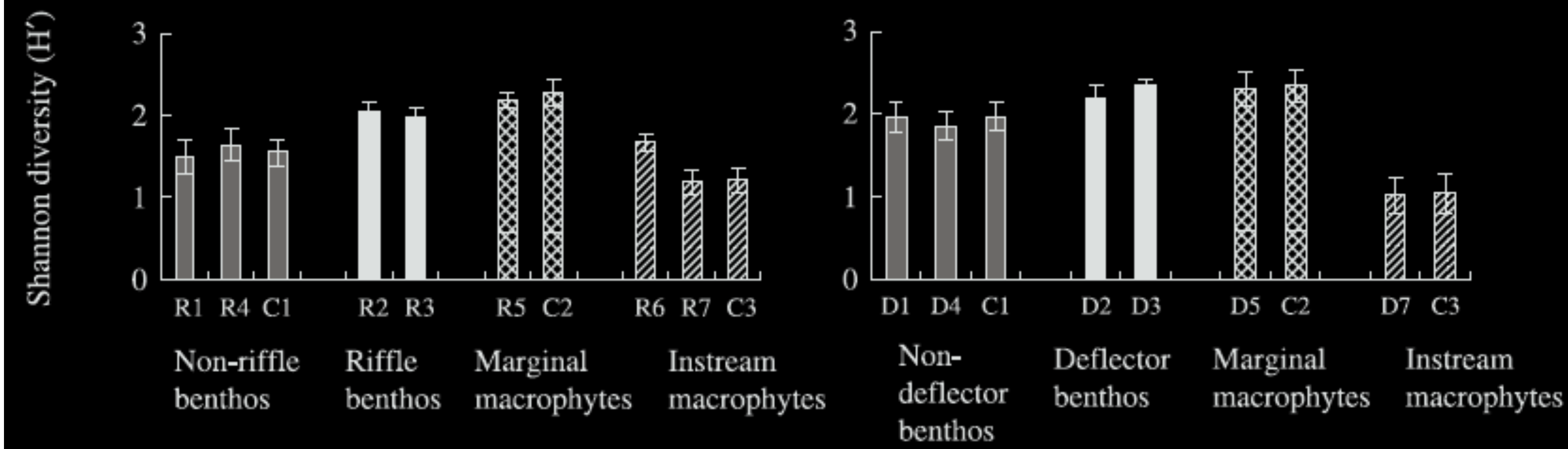
Isolated small-scale approaches unlikely to have lasting and meaningful biological benefits....need to scale-up over time and space

Harrison et al (2004)....small scale restoration produced no detectable benefits



A comparative study (C-I) found no evidence of small-scale flow modification on invertebrates (or fishes) – suggesting a far bigger scale is needed

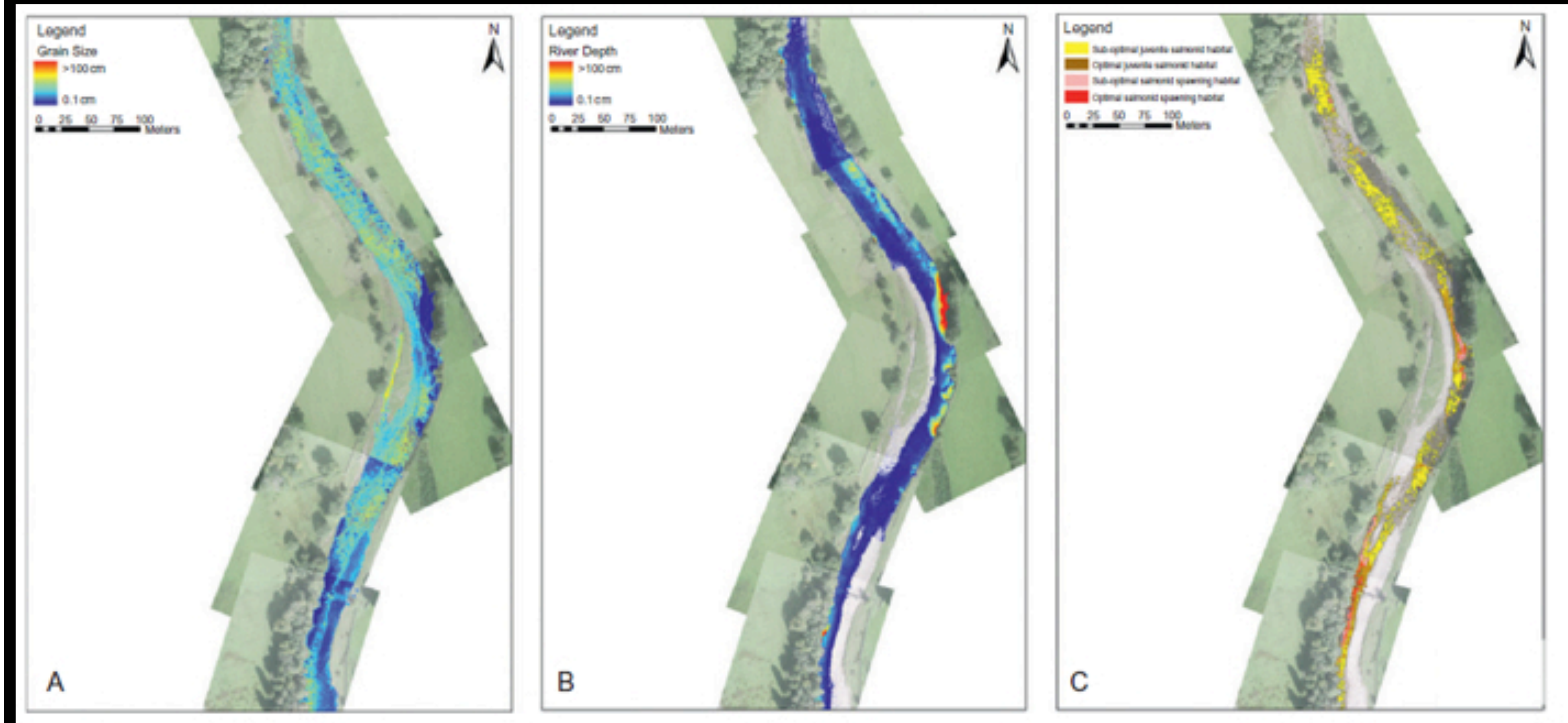
Harrison et al (2004)....small scale restoration produced no detectable benefits



Data: *N, S*

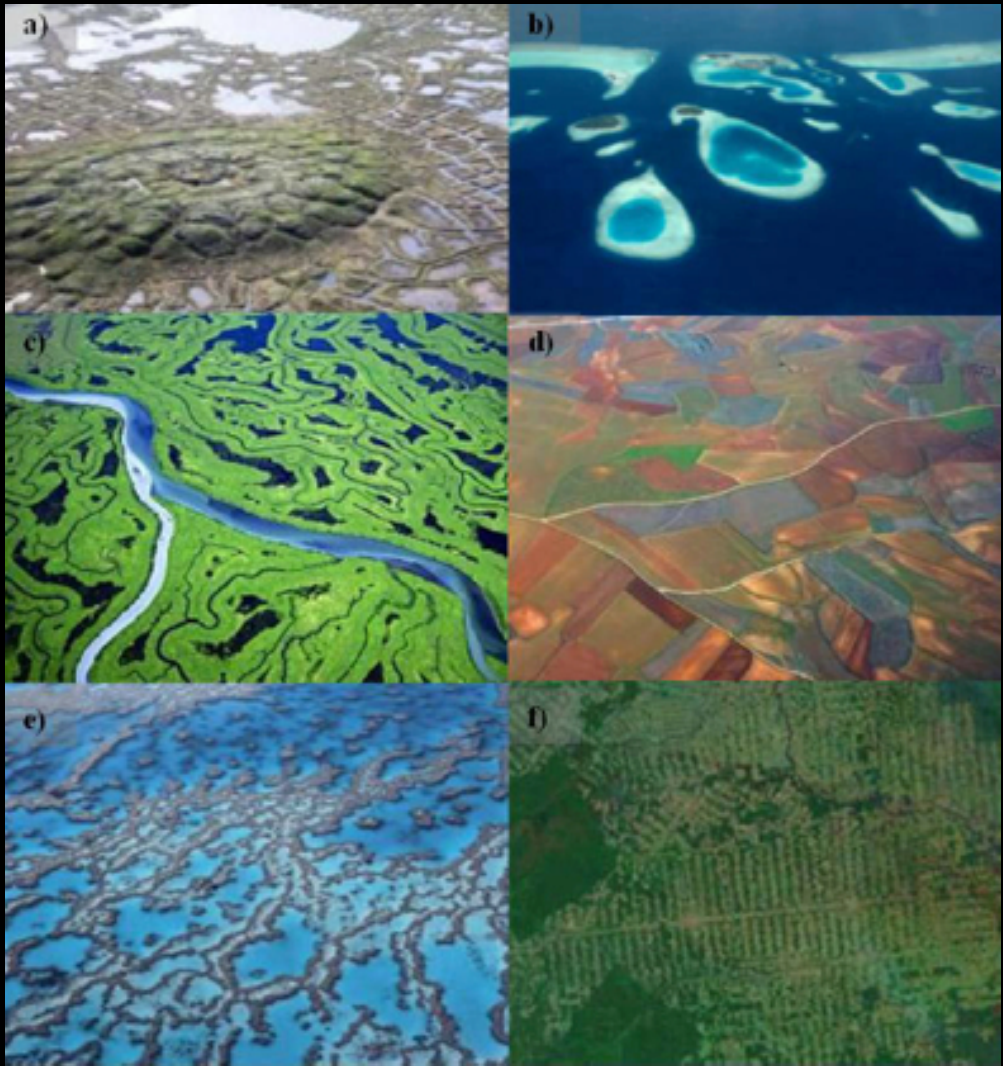
Diversity did not respond to restoration...suggestion that "soft-engineering" by emergent macrophytes could be a cheaper, simpler solution

The bigger picture?
Can remote sensing predict habitat quality?



Can fish habitat be assessed rapidly from the air....?
(Friberg et al 2011 Adv. Ecol. Res. 44)

Natural and anthropogenic habitat fragmentation

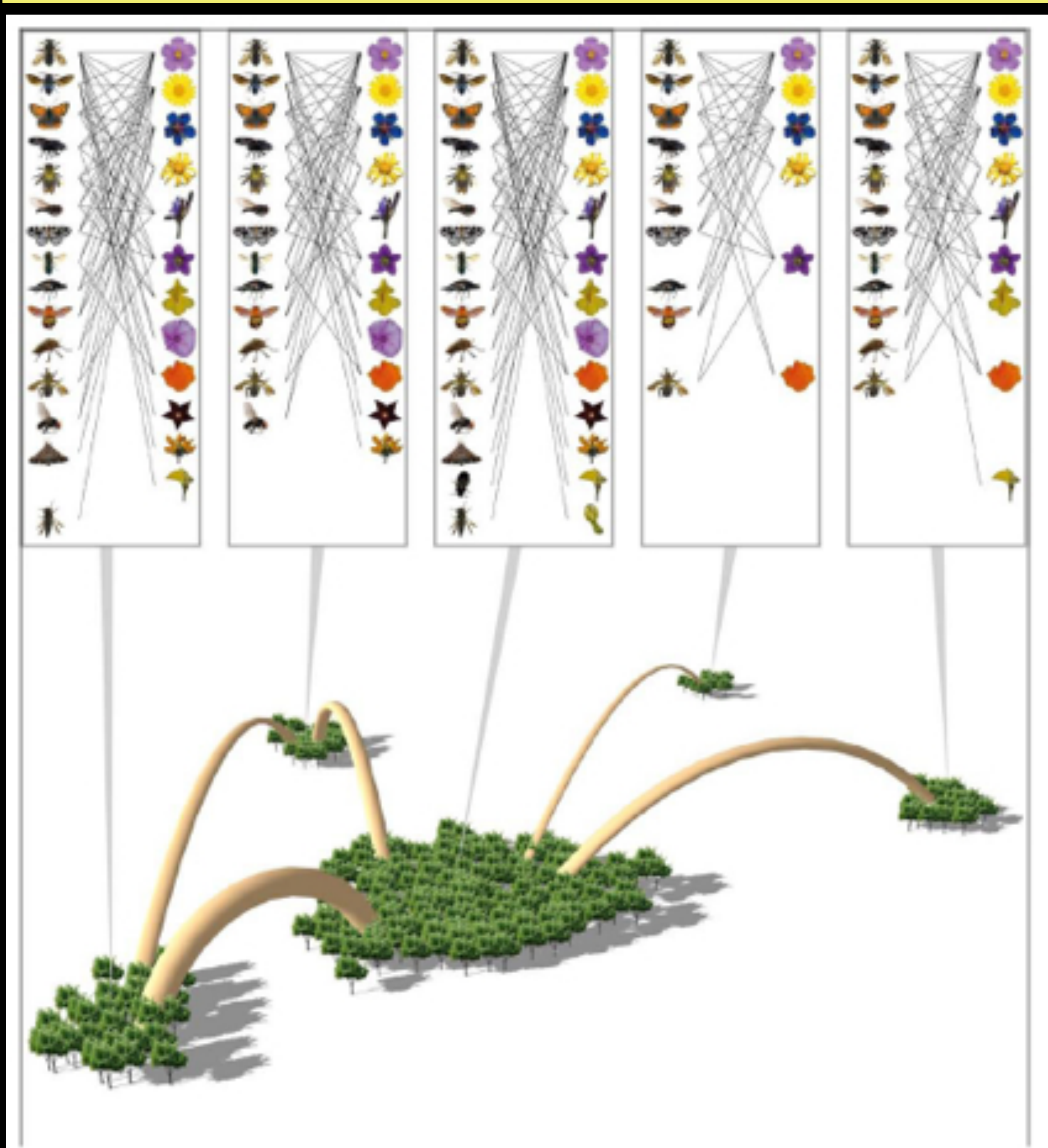


A key feature of habitat alteration and restoration is its fragmented nature....freshwaters are naturally fragmented but are we pushing them over the edge? (Hagen et al, Adv Ecol. Res. 2012)

Weirs and habitat fragmentation

(Hagen et al Adv. Ecol. Res. 2012)

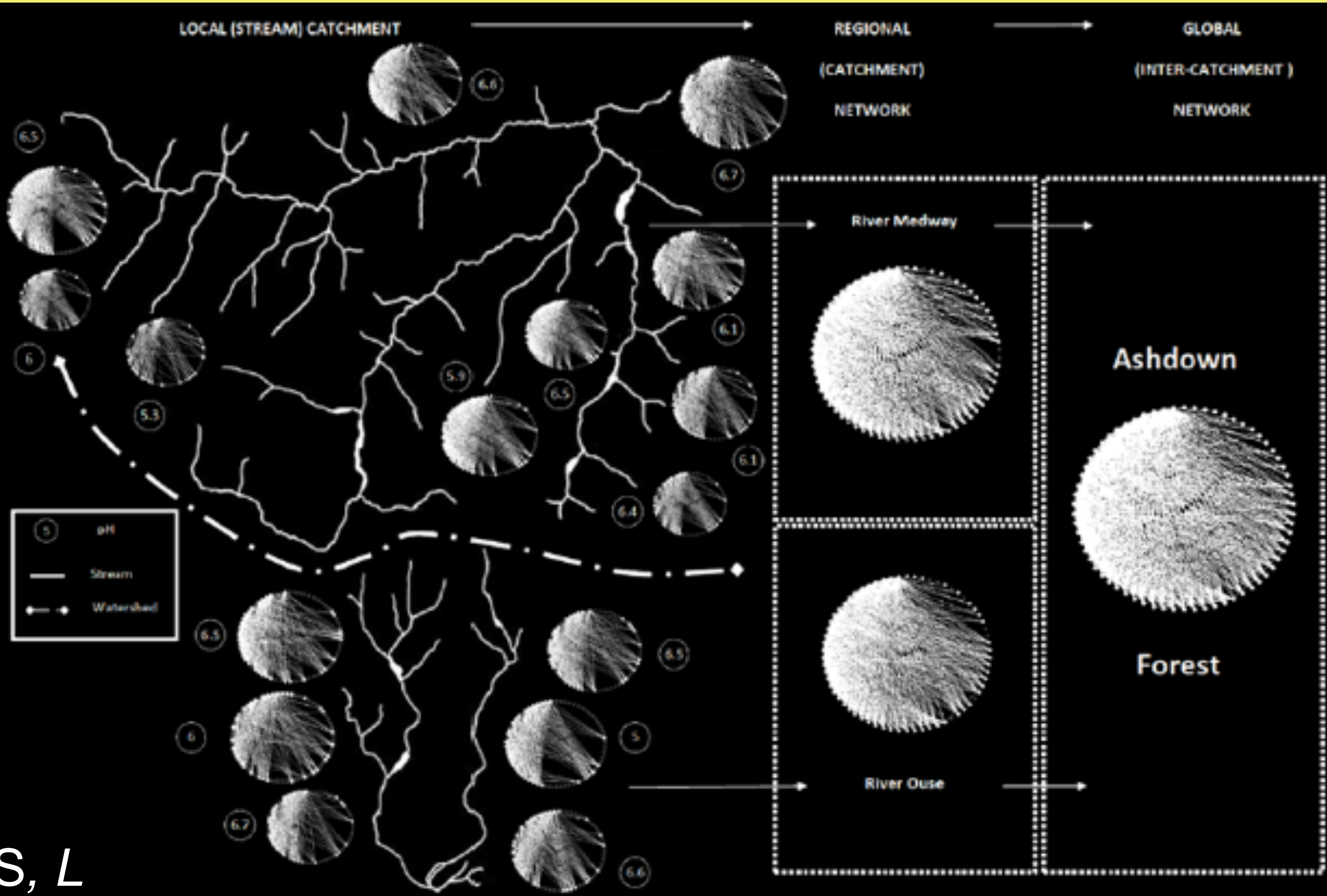
Lessons from terrestrial ecology?



Species forge and break interactions across time and space – a metacommunity or metanetwork approach could help understand how restoration works in a fragmented landscape

(Hagen et al Adv. Ecol. Res. 2012)

Food webs in a fragmented landscape...reconnecting the ecological network across hard and soft boundaries



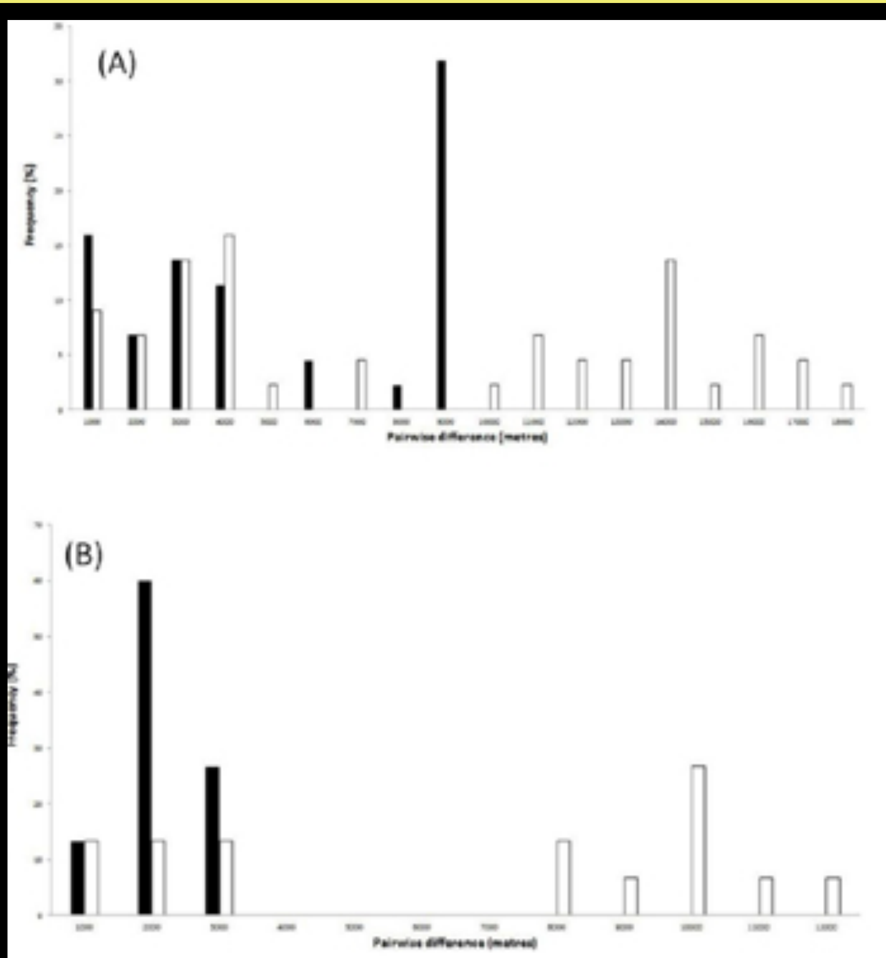
Data: S, *L*

(Hagen et al Adv. Ecol. Res. 2012)

Assessing the landscape and biotic context – weir removals could have dramatic impacts at the top of the web, but little effect on most insects

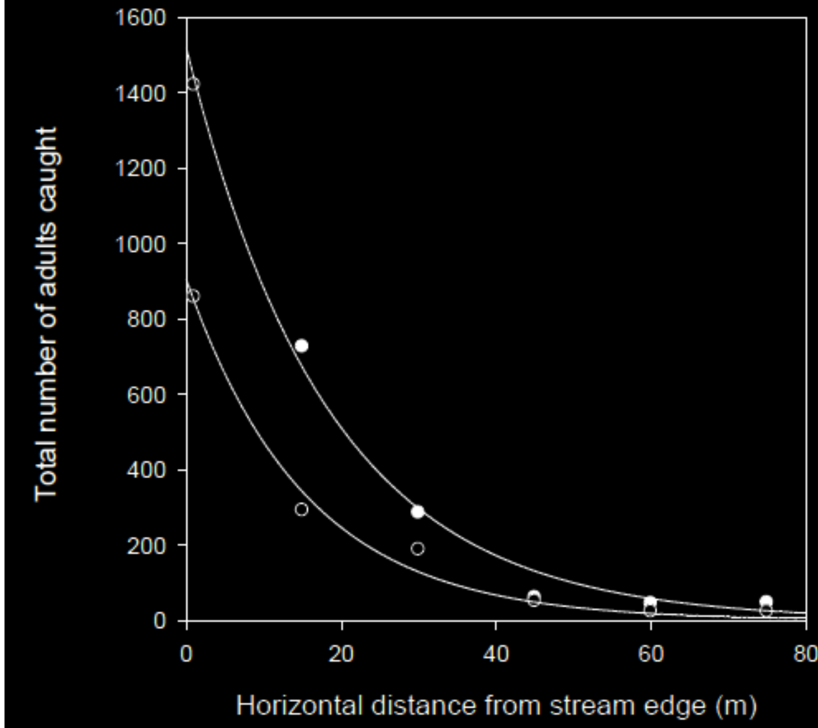
"as-the-fish-swims"

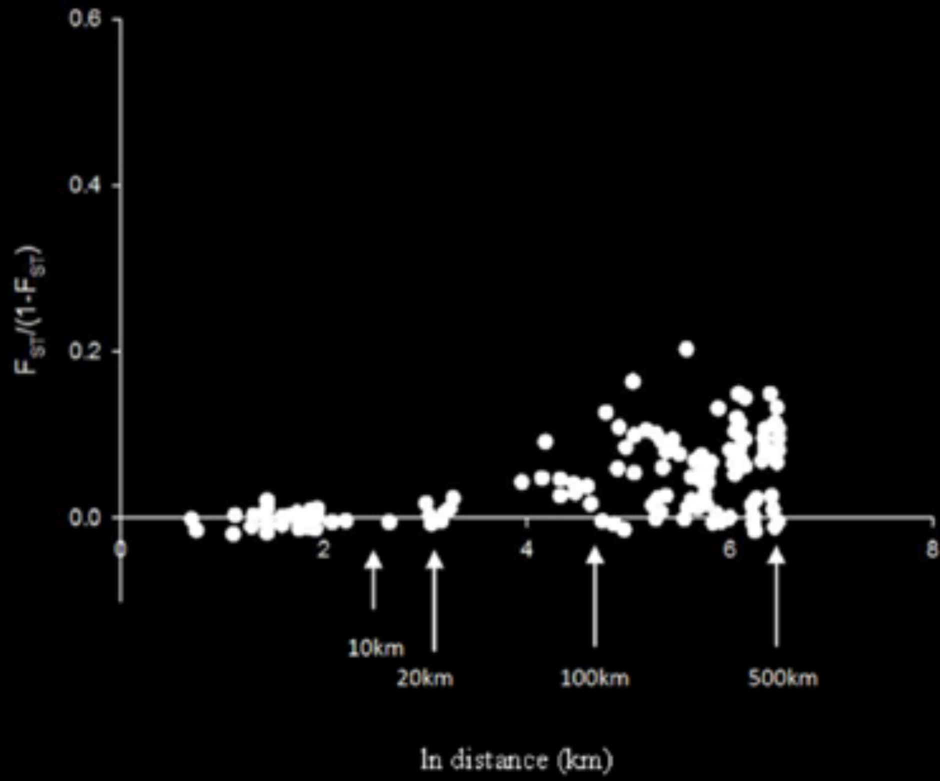
"as-the-insect-flies"



(Hagen et al Adv. Ecol. Res. 2012)

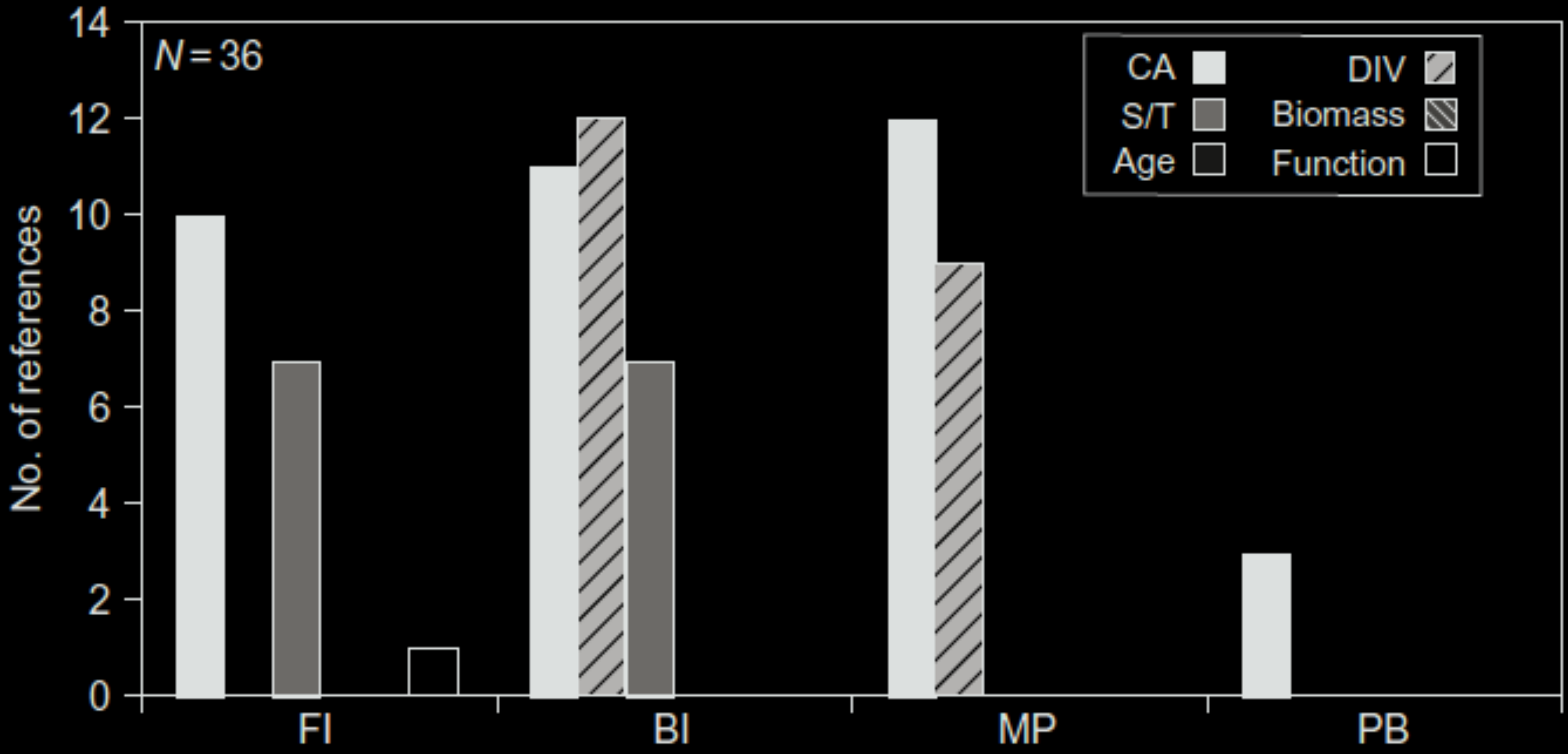
A few long-range dispersers may be enough to restore populations





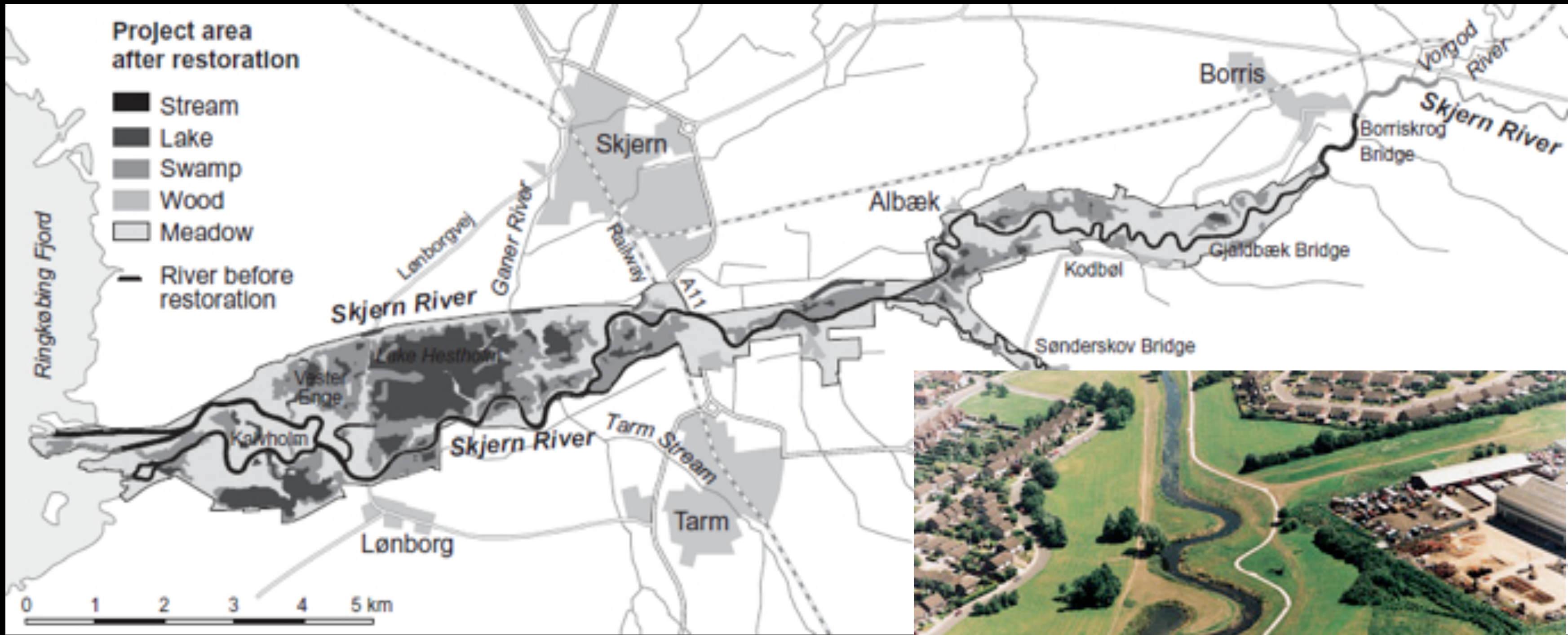
(Hagen et al Adv. Ecol. Res. 2012)

Weir removal....impacts on fishes, benthic inverts, macrophytes, phtyobenthos...functional effects ignored

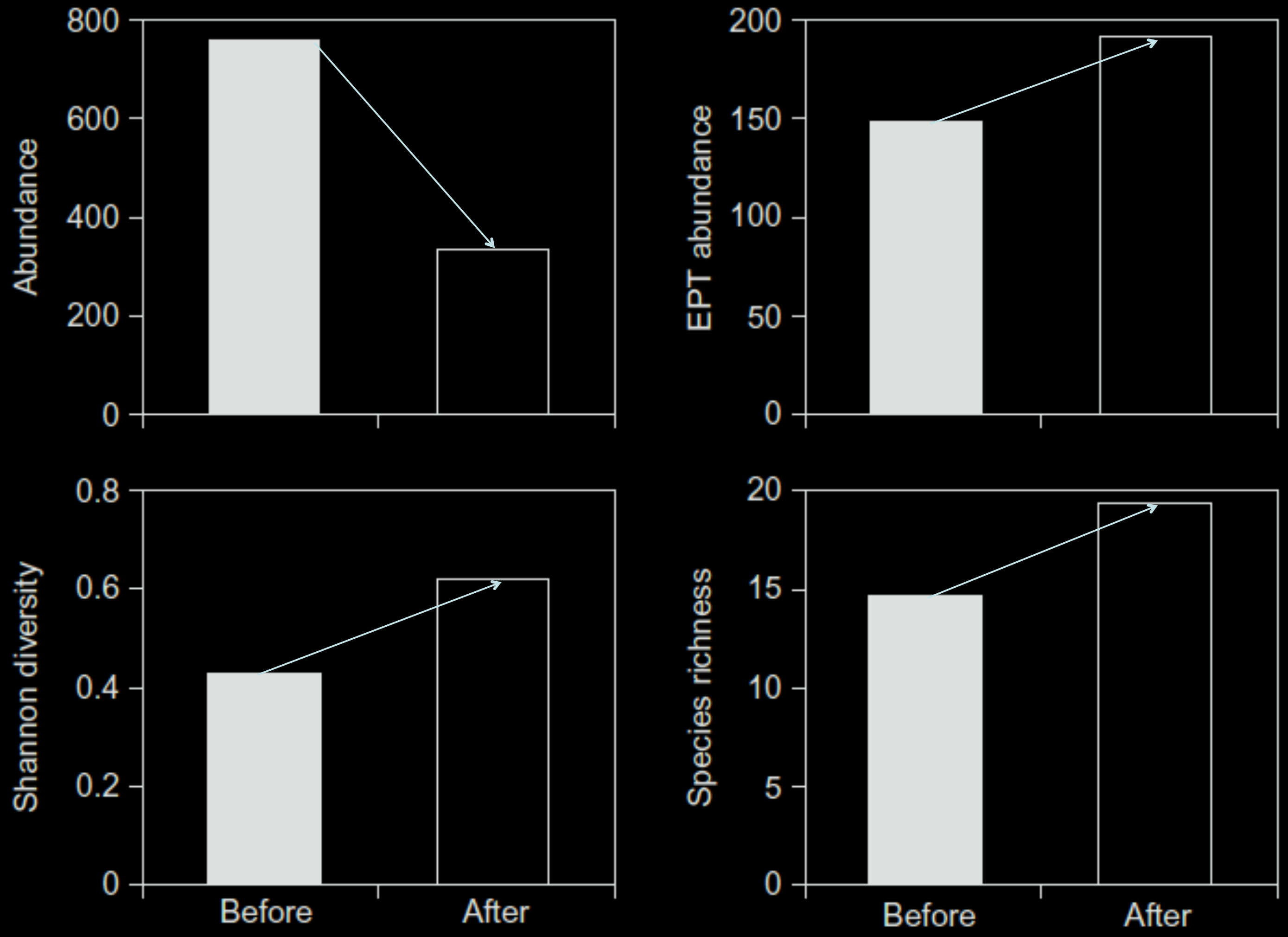


(Feld et al Adv. Ecol. Res. 2011)

The Skjern Project – a large-scale success story



Restoration of the Skjern (B-A design)



Data: *N*, S

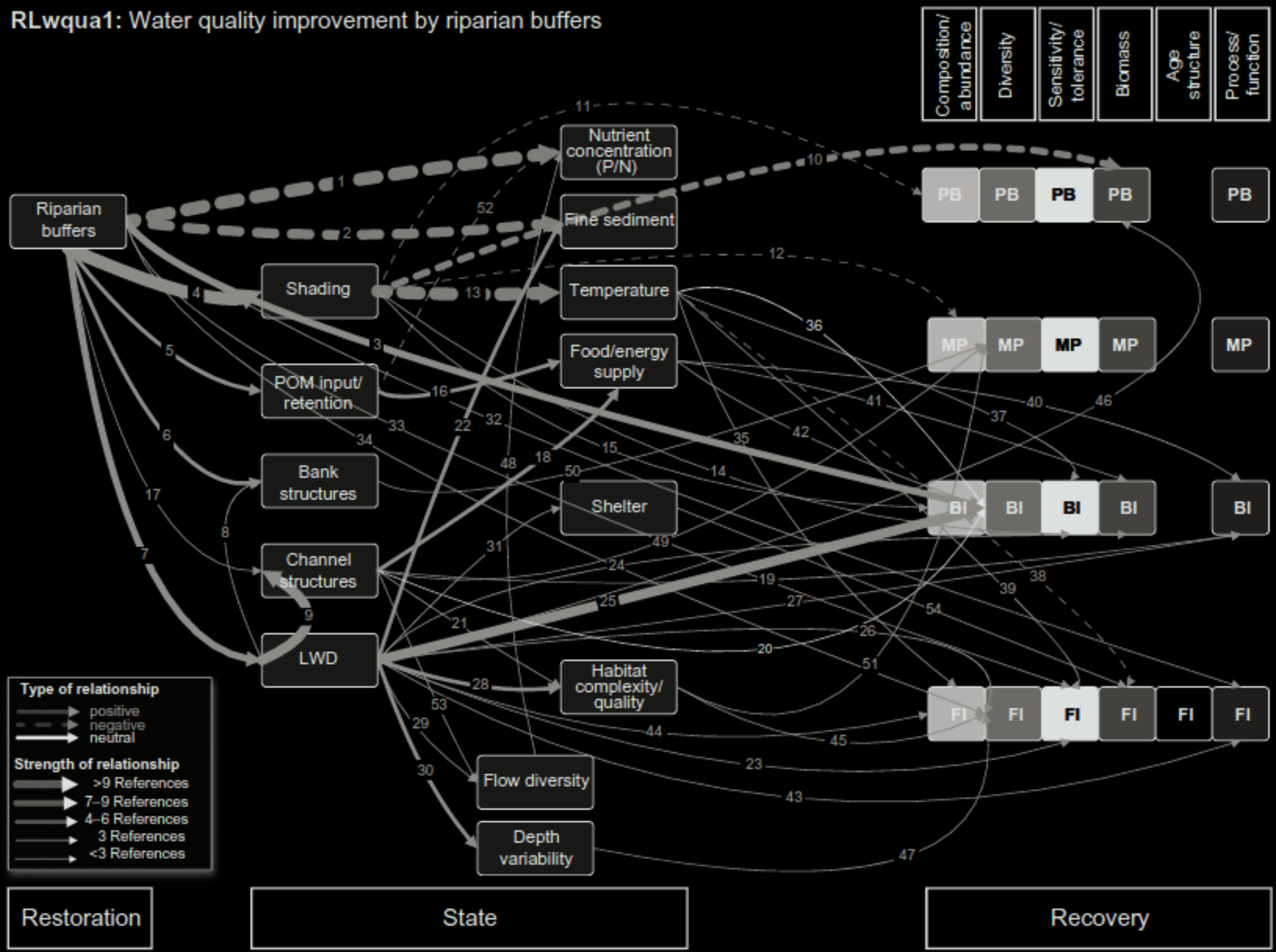
“Hard” v “soft” engineering – letting nature do the work?

Ecosystem engineers can shape the environment (e.g. beavers, macrophytes, riparian trees) – can alter food web functioning profoundly

Biota ⟷ Habitat

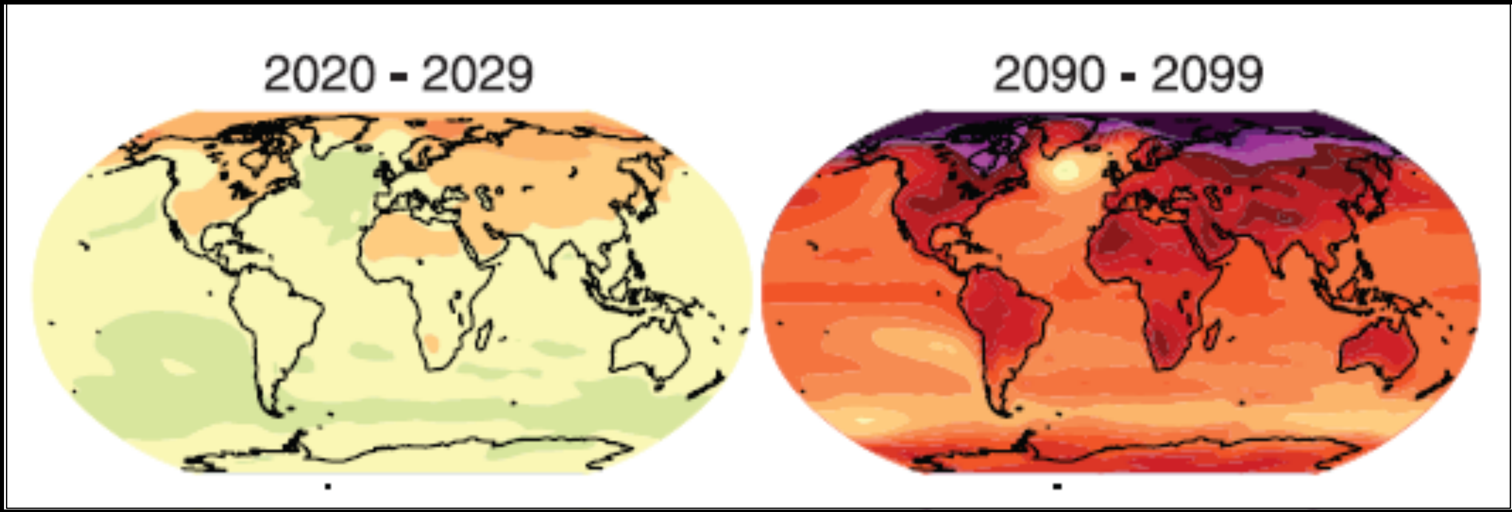
A cheaper solution -20 years of fencing in Alberta

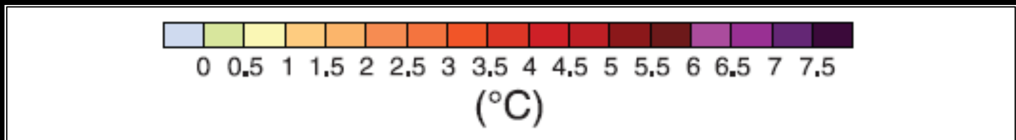
Developing a conceptual framework: riparian buffer model



(Feld et al Adv. Ecol. Res. 2011)

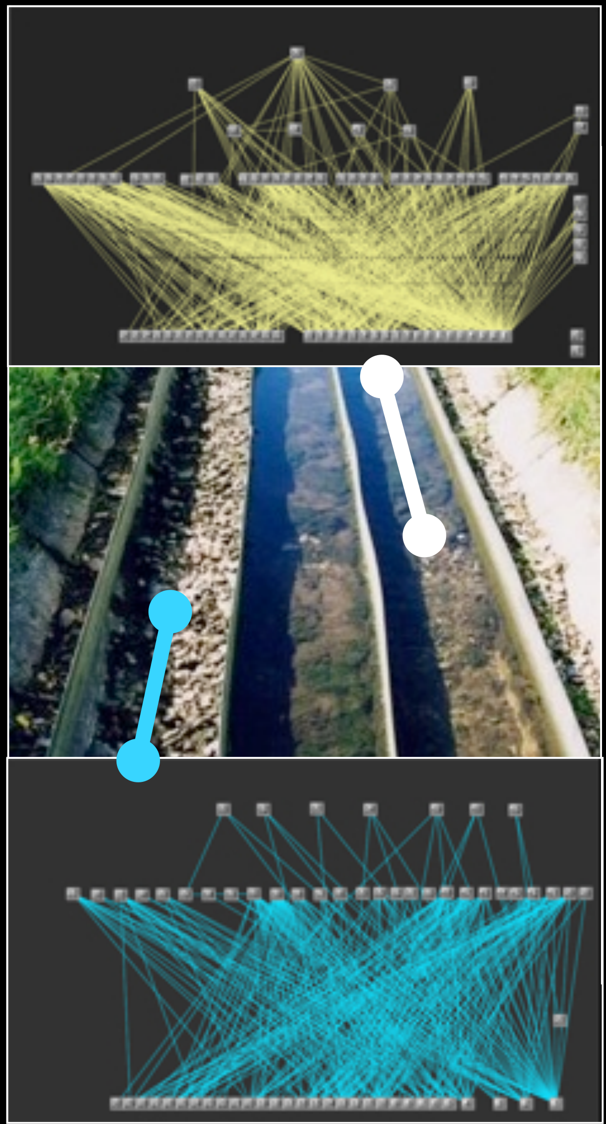
A new dimension – restoration in a changing climate?

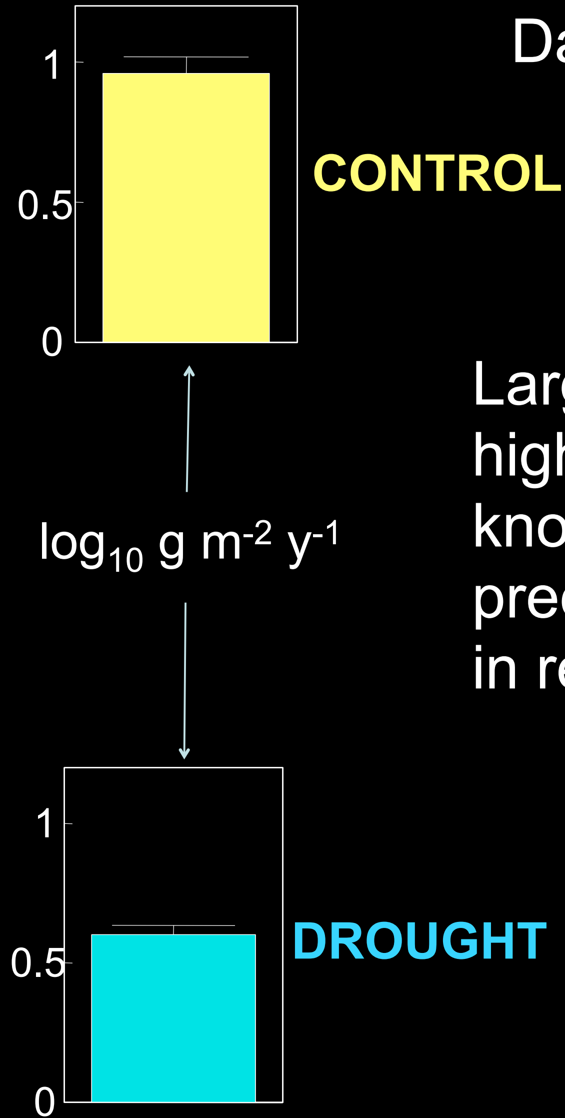




IPCC, 2007: Projected surface temperature changes for the 21st century relative to the period 1980-1999.

Habitat fragmentation affects both structure and functioning





Data: *N, M, S, L….F*

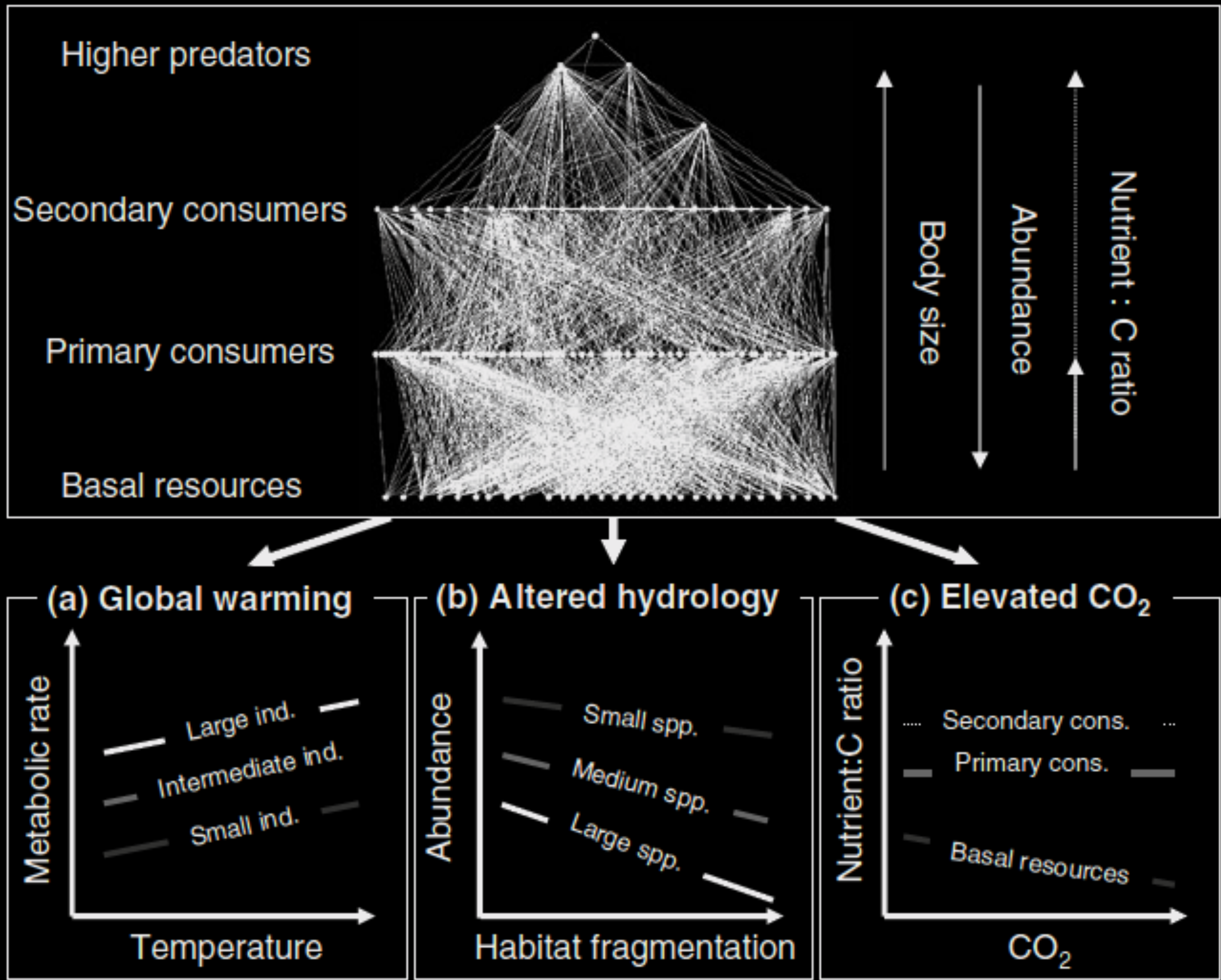
Larger & rarer taxa, higher in the web knocked out first…as predicted (Ledger et al, in review)

***Temperature* and *body mass* determine metabolic rates – which underpin ecosystem functioning**

$$\mathrm{MR} = a\boxed{M}^{3/4}e^{-E/(\boxed{kT})}$$

These key drivers operate at the individual level and scale up to the whole ecosystem...

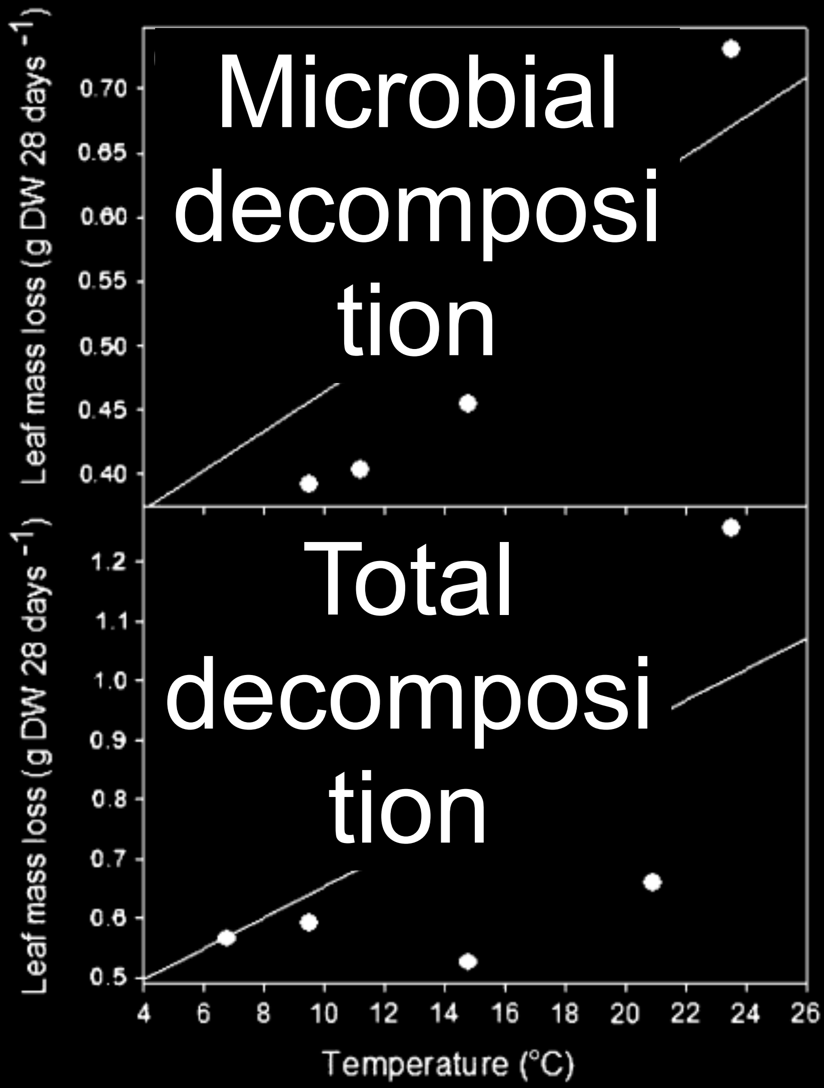
Body size and metabolism offer a means to predict climate change impacts across organisational levels

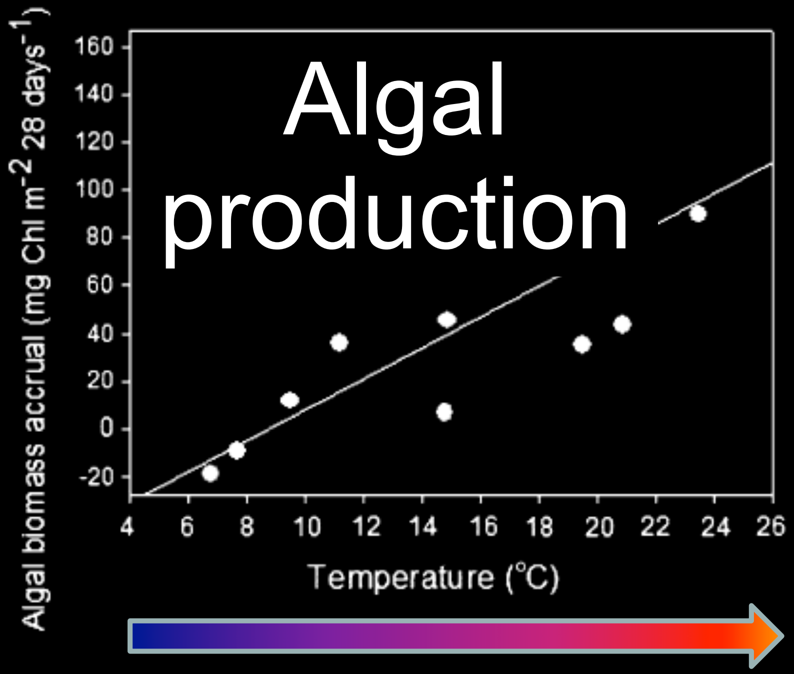


Perkins et al 2010 *Hydrobiologia*

Metabolism and whole-ecosystem functioning

Ecosystem process rates increase with temperature

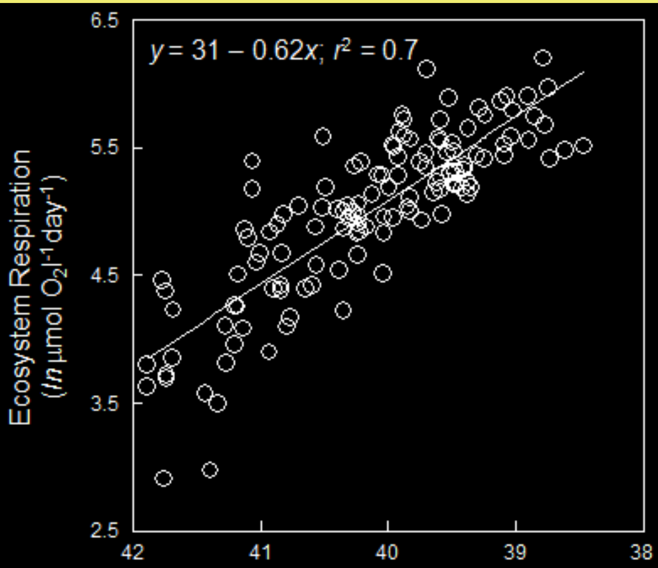


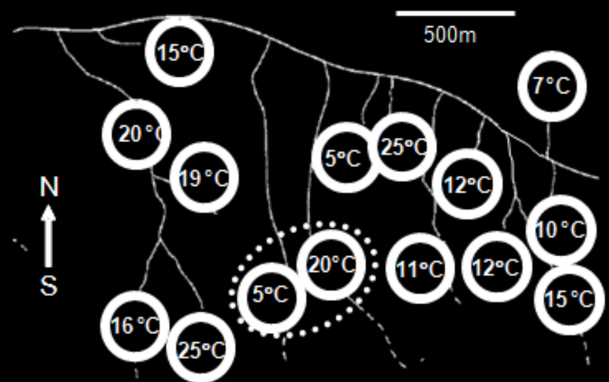


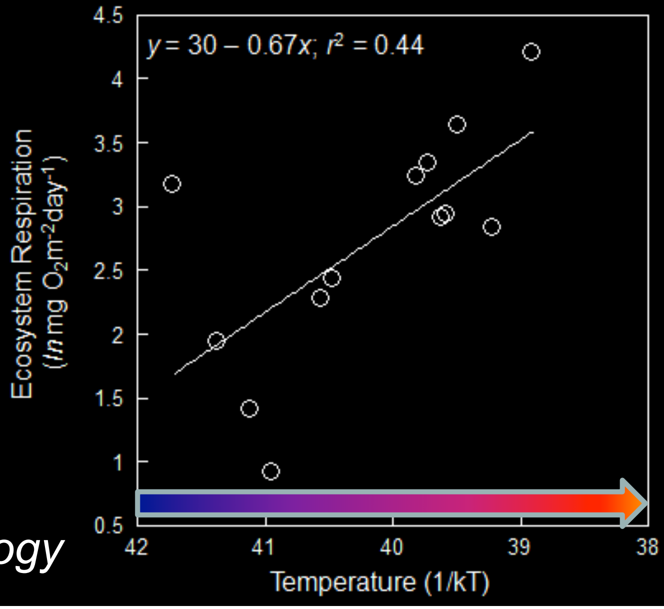
Data: *B, F*

Friberg et al 2009 *Freshwater Biology*

Universal patterns?
Congruence between Icelandic & U.K. results

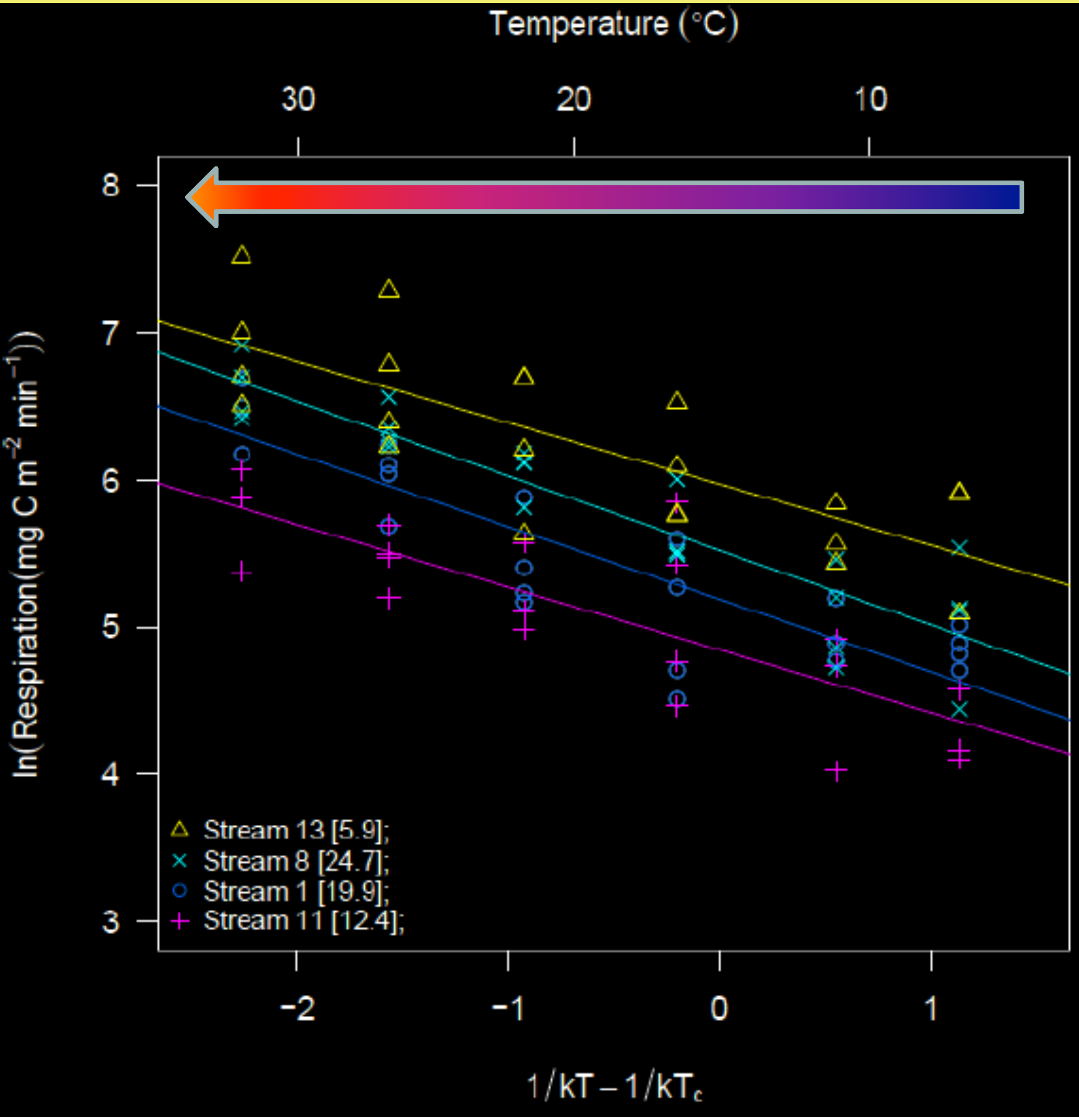






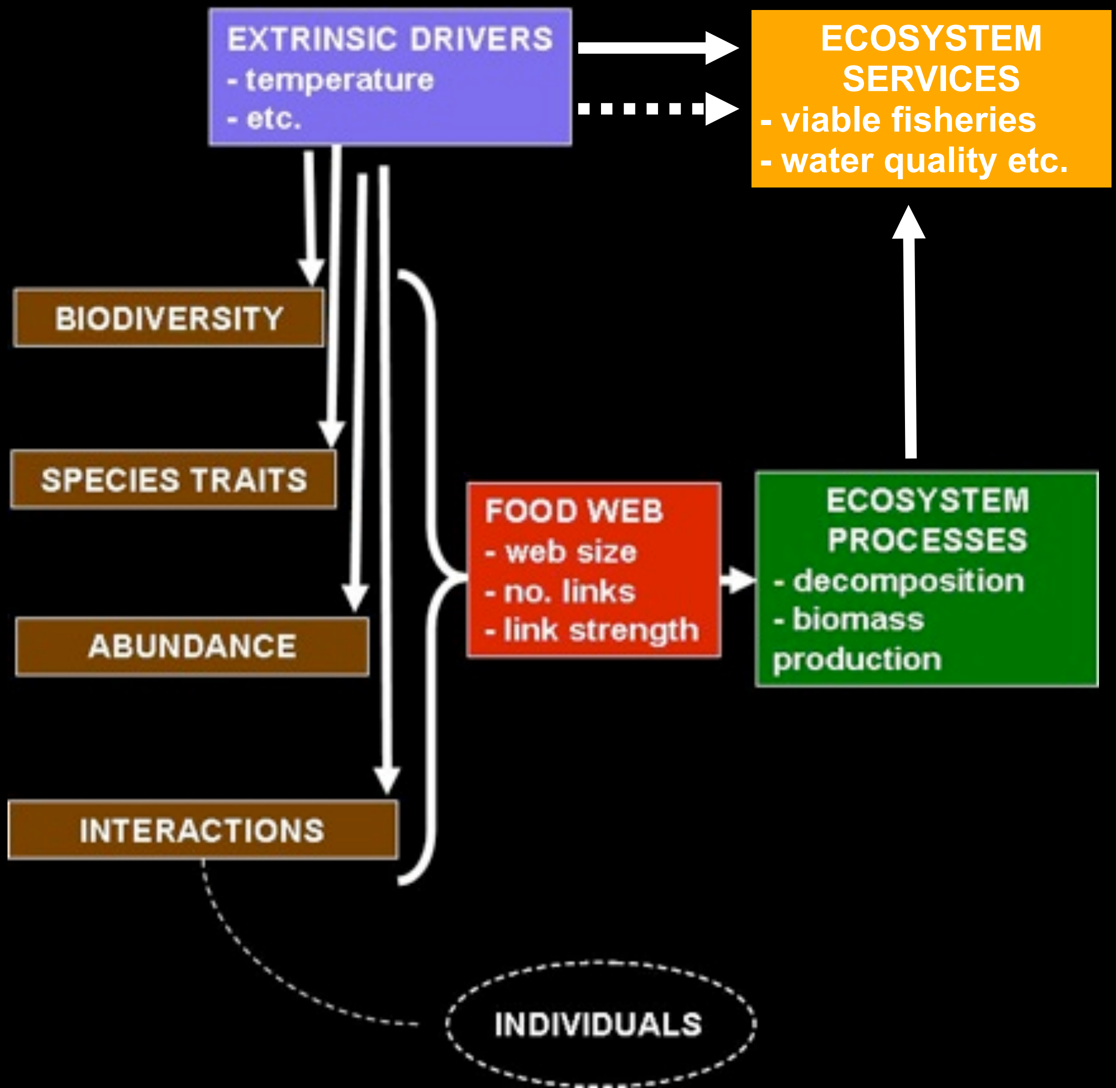
after Demars et al 2011 *Freshwater Biology*

Ecosystem respiration (after mass correction of biofilms) was independent of community composition



Perkins et al (2011) *Global Change Biology*

Dealing with multiple stressors and their interactions is the next big challenge of the 21st century



Thanks for listening

Pichler, D[1]., Friberg, N.[2,3], Thompson, M.[1], Christensen, J.B.[2], Perkins, D.M.[1], O'Gorman, E.[1] Reide, J.[8], Reiss, J.,[1] Trimmer, M[1]., Yvon-Durocher, G.[1], Demars, B.[3], Olafsson, J.S.[4], Gislason, G.M.[5], Ledger, M.E.[6], Brown, L[7]., Edwards, F. [9]

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