River Restoration Monitoring, Linking Theory with Results – Initial lessons from the Eddleston Project

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Global and local interest in *River Restoration* part of a wider catchment approach to sustainable management

In Scotland *'restoring'* rivers and catchments is being driven by four main factors:

- **High profile flooding - NFM**
- **Poor Ecological status of rivers**
- **Loss of Biodiversity**
- **Climate Change**

Other drivers include:

Woodland expansion
Social deprivation
Land Use Planning
Ecosystem services

Globally and locally ££ millions is being spent on 'river restoration'

Netherlands – '*Room for the River*' programme €2.2 billion

Scotland – *Water Environment Fund*

£4.6 million in 2017/18.

But do interventions actually increase habitat diversity?
…and does increased habitat diversity lead to increased biodiversity?

The Theory - and very much the Accepted wisdom…….

If there is an increase in habitat heterogeneity (the number and connectedness of habitats) there should be a subsequent increase in biological diversity (Ricklefs & Schluter, 1993).

Empirical evidence for this relationship is very poorly represented in freshwater systems.

Recent review of published scientific studies investigating the link between river restoration and macroinvertebrate diversity, (Palmer *et al*., 2010) found that surprisingly few (two studies of 78) successfully demonstrated a positive relationship.

The authors ascribed this lack of a measurable relationship, not to the failure of the theory, but to the difficulty of measuring the response in the macroinvertebrate community.

But do interventions actually increase habitat diversity?
…and does increased habitat diversity lead to increased biodiversity?

More recent studies have similarly questioned the linkages, or to be more precise the evidence for the linkages….

EU REFORM database (Angelopoulos, Cowx and Buijise 2017)

671 Restoration projects:

- 10% reported ecological success (9%) or failure (1%)
- 5% unclear in their findings
- 9% the restoration works were not monitored
- 77% no information on the outcome

This interrogation of the EU meta-database supports the conclusions expressed elsewhere (Downs and Kondolf, 2002; Bernhardt et al., 2005; Roni et al., 2008; Cowx et al., 2013; Roni and Beechie, 2013) that success or failure of habitat restoration projects is often not evaluated and therefore little is known about their effectiveness

Whilst there is less concern that many river restoration projects per se are failing, there is increasing anxiety from many quarters about the lack of evidence of success

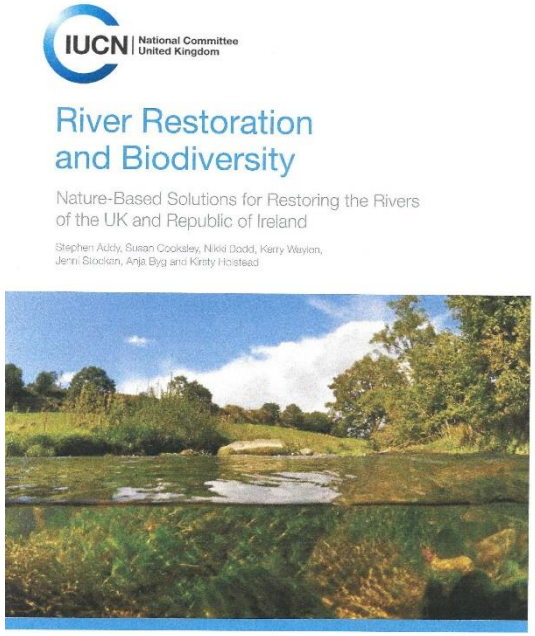
IUCN River Restoration and Biodiversity report (2016)

Need for better information embodied in *Recommendations for restoring rivers*
Section 6:

- **Improve the evidence for the effectiveness of river restoration by investing in long-term monitoring (i.e. >5 years) at selected sites.**

- **These should encompass a large geographical range and use robust scientific approaches to evaluate projects that focus on process-based approaches**

- **Monitoring should be undertaken before restoration and afterwards for a sufficient timescale to detect both rapid and longer term changes.**



Bangor
October
2017

Eddleston Water – sub-catchment of Tweed UNESCO HELP basin - part of EU North Sea Region *Building with Nature* programme

PROJECT AIMS

a) assess ***impact of specific types of NFM measures*** to reduce flood risk and improve ecological status – using detailed experimental studies of individual NFM interventions

b) assess **impact of restoration** on flood risk and habitats at ***a catchment scale*** - by assessment of flood risk using flood hydrographs, groundwater monitoring, river flow and rainfall; and by measurements of biology and 'ecological status' (WFD).

c) Whilst maintaining ***sustainable farming*** and land management

- Long-term study
- Empirical base
- Scottish Government funded
- 69 sq km

answer key national policy questions concerning the costs and benefits of 'restoring' our rivers and their catchments for people and for wildlife

The Eddleston Water Project

Partnership Approach – in phases

Phase I: Scoping study - 2009/10

Phase II: Base line monitoring & planning 2010 - 2012

Phase III: Implementation & Monitoring 2013 – 2016

Phase IV: EU INTERREG – 2020.

Long-term partnership

University of Dundee

Scottish Natural Heritage

Tweed Foundation / Forth Fisheries Trust

Forest Research

Environment Agency

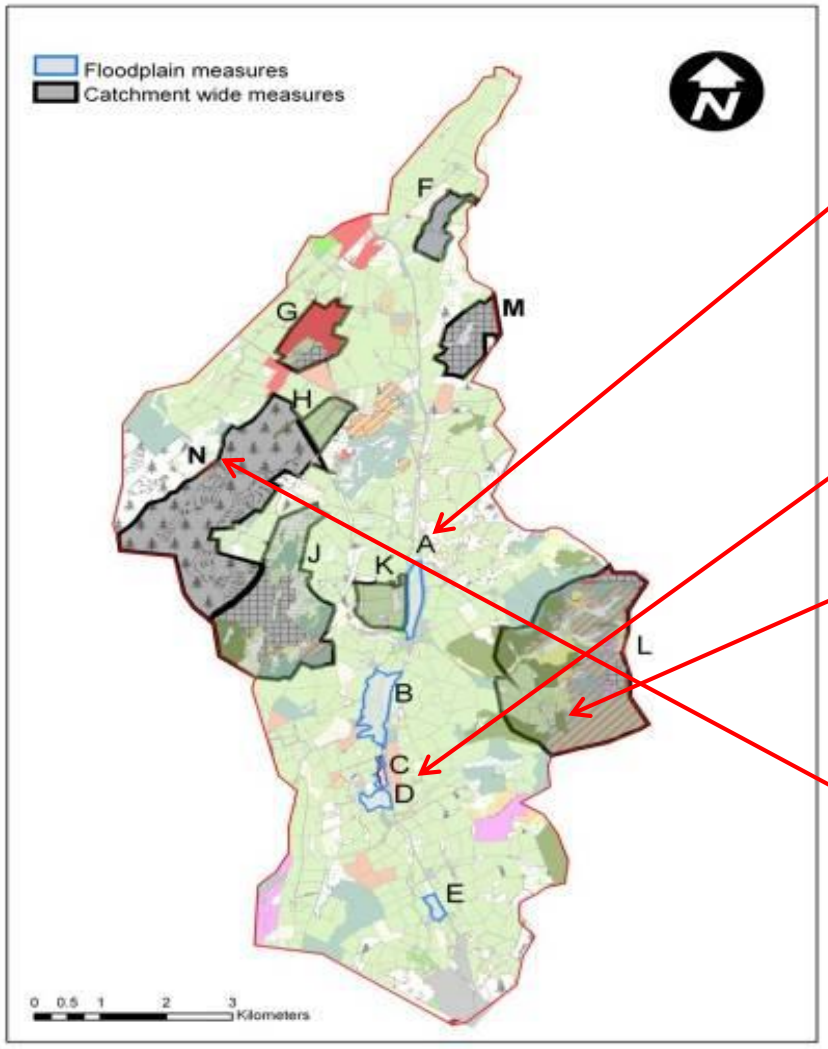
Cbec Ltd

APEM

The Land owners and Community

Scoping Study

- Identified different options to reduce flood risk and improve habitats
- Set up Monitoring strategy and network at outset



Potential options/measures:

A: breach/set back embankments, new fence margins, riparian woodland, wet woodland,

C: **re-meander channel** - **Cringeltie**

L: Reduced stocking density, **tributary woodland, floodplain forest – Longcote burn**

N: create ponds, wetlands, riparian woodland block ditches, **engineered log jams – Middle burn**

Design, install and run detailed monitoring network and survey programme

University of Dundee

TWEED FORUM

The Scottish Government
Riaghaltas na h-Alba

SEPA
Scottish Environment Protection Agency

Interreg
North Sea Region
Building with Natur

Measurements include:

River flow and flood gauges

Ground water surveys and boreholes

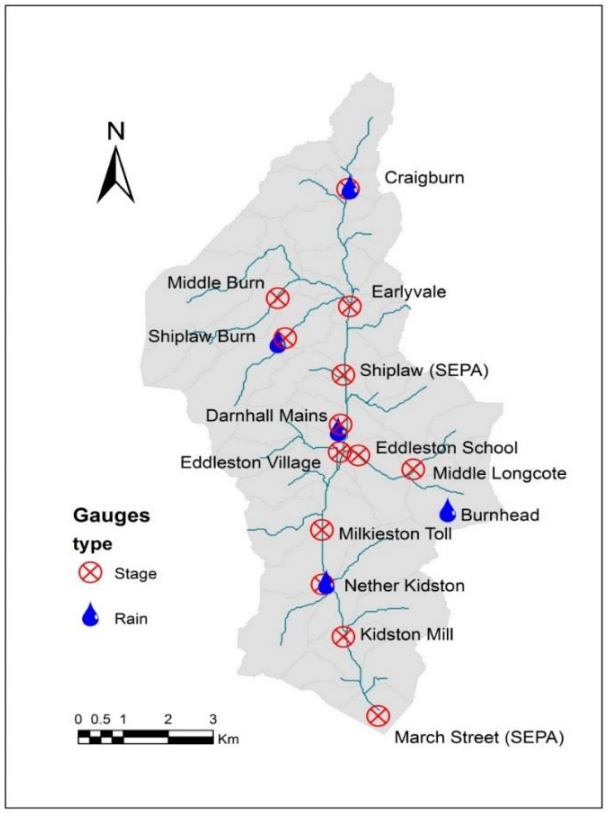
Rainfall and weather stations

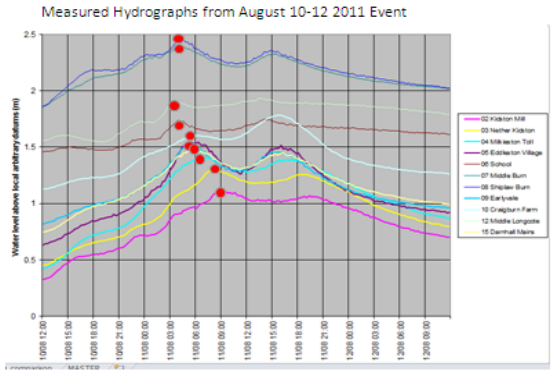
River habitats and hydro-morphology

River biology* – fish, plants, *invertebrates

Land-owner & community engagement

Ecosystem services initiative





Restoration (NFM) measures introduced so far

To date, Tweed Forum and partners have worked with 20 farmers, to:

Upland (Source) areas:

- ***Constructed 116 high-flow log structures*** to restrict flow and recreate a basin mire
- ***Planted 207 hectares*** with >312,000 native trees
- ***Created 27 upstream off-line ponds***

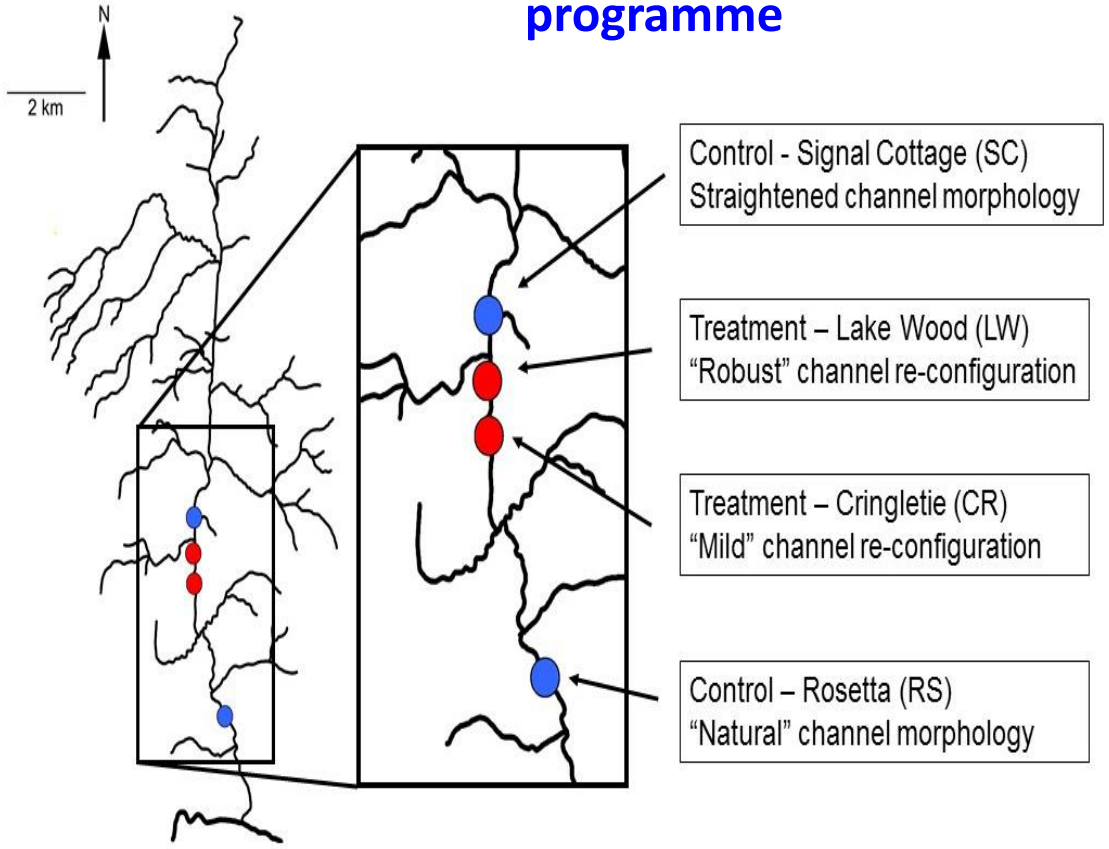
Valley/Floodplain (Pathway) areas:

- ***1 km contour planting*** of hedges
- ***Created one floodplain pond***
- ***Re-meander 2.2 km of river***, and reconnect with the floodplain

Have improved the river from '***Bad to 'Moderate' Ecological Status***, and on target for 'Good' (WFD)

How have the hydro-morphological interventions for NFM (meanders) impacted on river ecology?

Hydro-morphology / Ecology sampling programme



BACI (Before-After-Control-Impact) design

Sediment sampling and **Ecological** sampling undertaken at the same locations

2012 - pre works
2013 - pre works
meanders
2014 - analysed
2015 - analysed (part)
2017 - being analysed
2019 - planned

- Channel re-configuration was completed on 25th July 2013 at Cringletie and on 11th September 2013 at Lake Wood.


Cringletie
Treatment Reach
(Re-configured)
Control Reach
Field Set up
Re-meandering on the Eddleston Water
(dotted line denotes the old course)
Lake Wood
Control Reach
Treatment Reach
(Re-configured)

Physical work – meander excavation Autumn 2013

‘Official Opening’ of Cringletie meander by Environment Minister - Autumn 2013

Year +1 - September 2014

Building with Nature

Year +3 - May 2016

Rapid changes to channel even in a ‘low energy’ river - May 2016

Year +4 - September 2017

(EU Interreg funding for monitoring to year + 6 in 2019)

Habitat monitoring and channel sediment sampling

100m within each Reach is surveyed for Habitat Information and Macroinvertebrates

Pre- and post-restoration sampling undertaken at experiment and control sites for each geomorphic unit type.

- **Habitat measures**
- **Channel sediment sampling**

Measure grain-size distribution, ranging from fine gravel to coarse cobble, as classified using the Wentworth Scale.

Ecological monitoring - aquatic macro-invertebrates

- **modified kick sampling method**
  - 20 kicks assigned in proportion to the 5 habitat types (riffle, run, glide, pool, slack). Same sampler throughout.
- **3 replicates in each of 4 reaches** (2 restored reaches & 2 controls)
- **identification to mixed taxon level** (SEPA standard)
  - majority of individuals to species level = approx. 45,000 individuals of 90 species each year.

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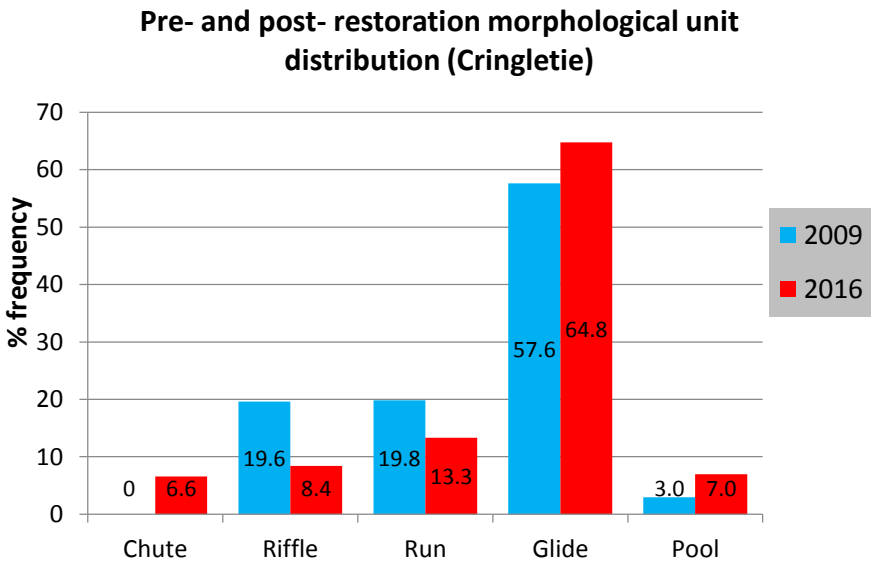
University of Dundee

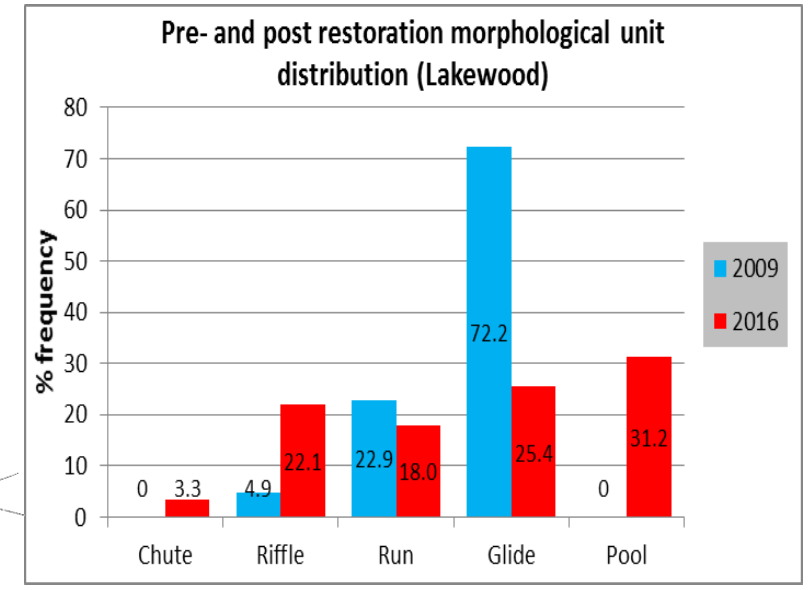
Veritas Ecology

Distribution and extent of habitat (hydro-morphological unit/flow category) types in response to re-meandering

2009 *vs* 2016 (+ 2 years)

- **Greater variety of habitat types** recorded following works at both experimental sites
- The amount of **run habitat type was reduced** at both sites
- **Channel length increased** at both sites: - Lake Wood 37% (266 - 362m); Cringletie 3% (474 - 489m).
- However, a reduction of run habitat and an increase in glide habitat was also recorded from the control sites, so unclear





Has the physical habitat changed in the restored channels?

- 10 transects per 100m section (in each reach; 2 x restored & 2 x control)
- Multiple physical habitat variables measured (see table)
- Data analysed using Principal Components Analysis (PCA)
- Available physical habitat measured as the size of ellipse enclosing data from each reach

Table 2.2: Details of the physical habitat information recorded as 10 metre transects within each 100 metre survey section

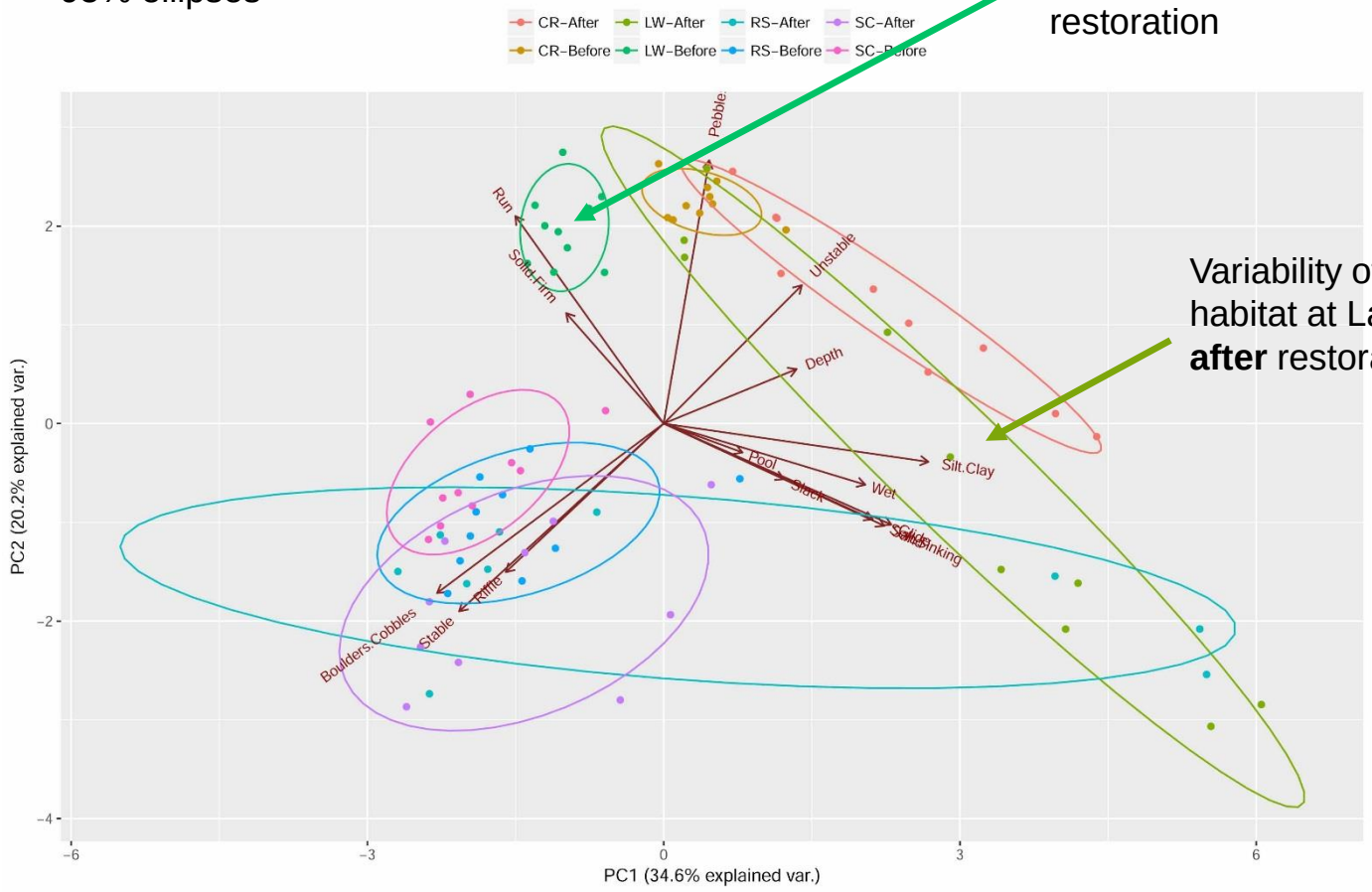
Variable	Details
Wet width	Width of channel that is wetted
Depth	Measured at the channel mid-point
Substrate	Measured as proportion coverage of: Boulder/Cobble Pebble/Gravel Sand Silt/Clay
Hydromorphological unit	Measures as proportional coverage of: Riffle Run Glide Pool Slack
Bed stability	Measured as proportional coverage of: Solid/Firm Stable Unstable Soft/Sinking

Has the habitat changed significantly?

Variability of the physical habitat before and after restoration

95% ellipses

Variability of available habitat at Lake Wood **before** restoration



Variability of available habitat at Lake Wood **after** restoration

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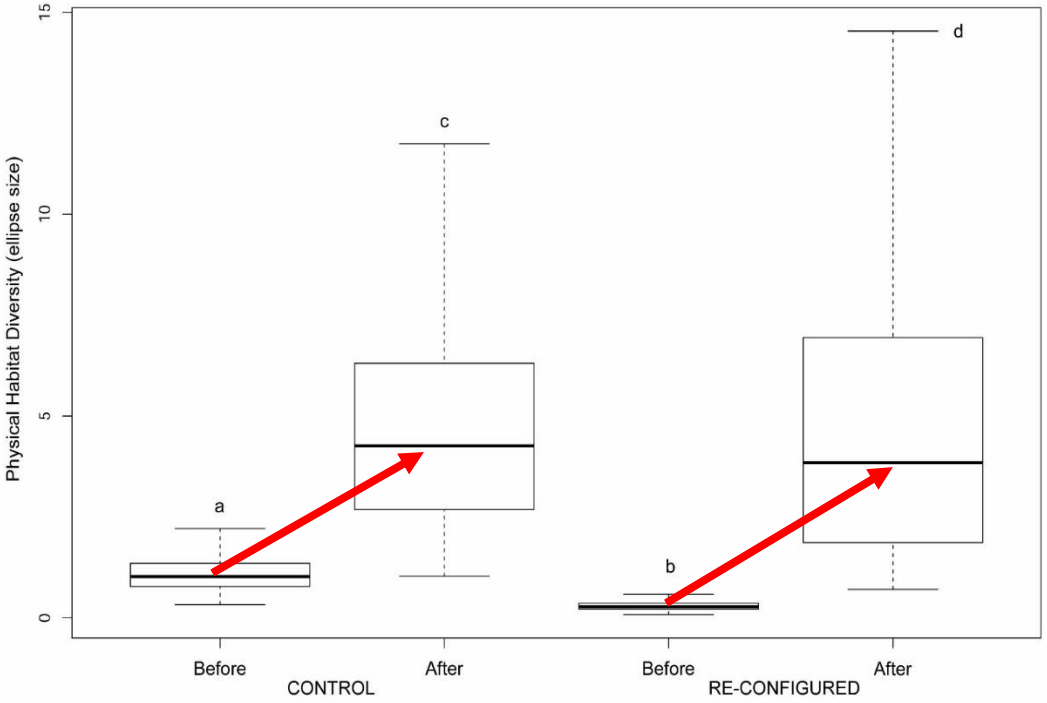
What about 'natural' variation in physical habitat over time though?

Comparing 'elipse' size in control and restored reaches - BACI

Ellipse data was bootstrapped to generate multiple estimates of ellipse size



Take home message:

Habitat variability increased at both restored and control sites, but increased by a significantly greater amount in the restored river sections

(i.e. no over lap in the 95% CI).

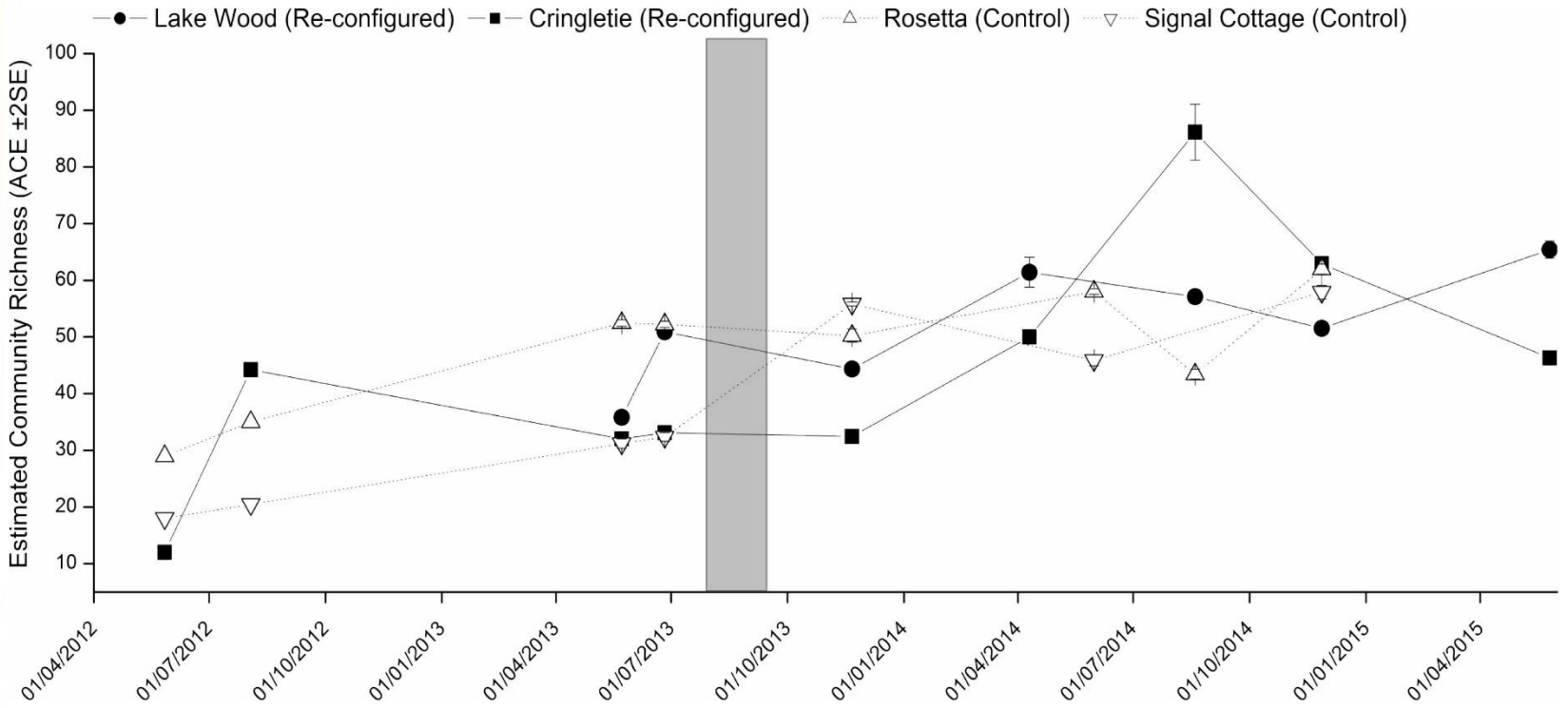
What is the impact of re-meandering on the macroinvertebrate community?

Simple Measures of Community Structure

1. **Richness**
2. **Abundance**
3. **Diversity**
4. **Ephemeroptera, Plecoptera, Trichoptera**
   - How are elements of the community responding?
   - How could we improve efficiency of monitoring

Ecological Response to hydro-morphological change from re-meandering – Community Richness

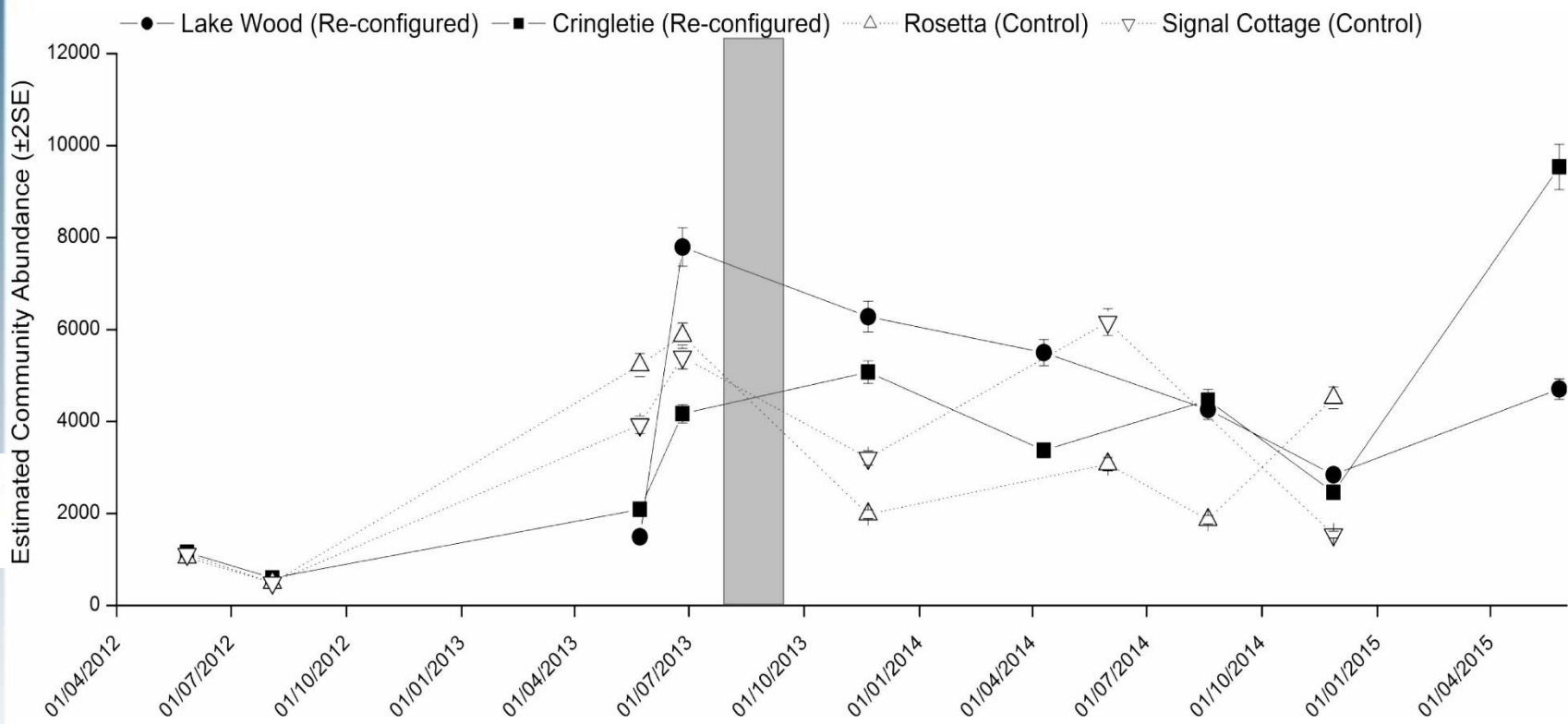
Long-term change in macroinvertebrate community richness.



18 months after restoration (grey bar)

Ecological Response to hydro-morphological change from re-meandering – Community Abundance

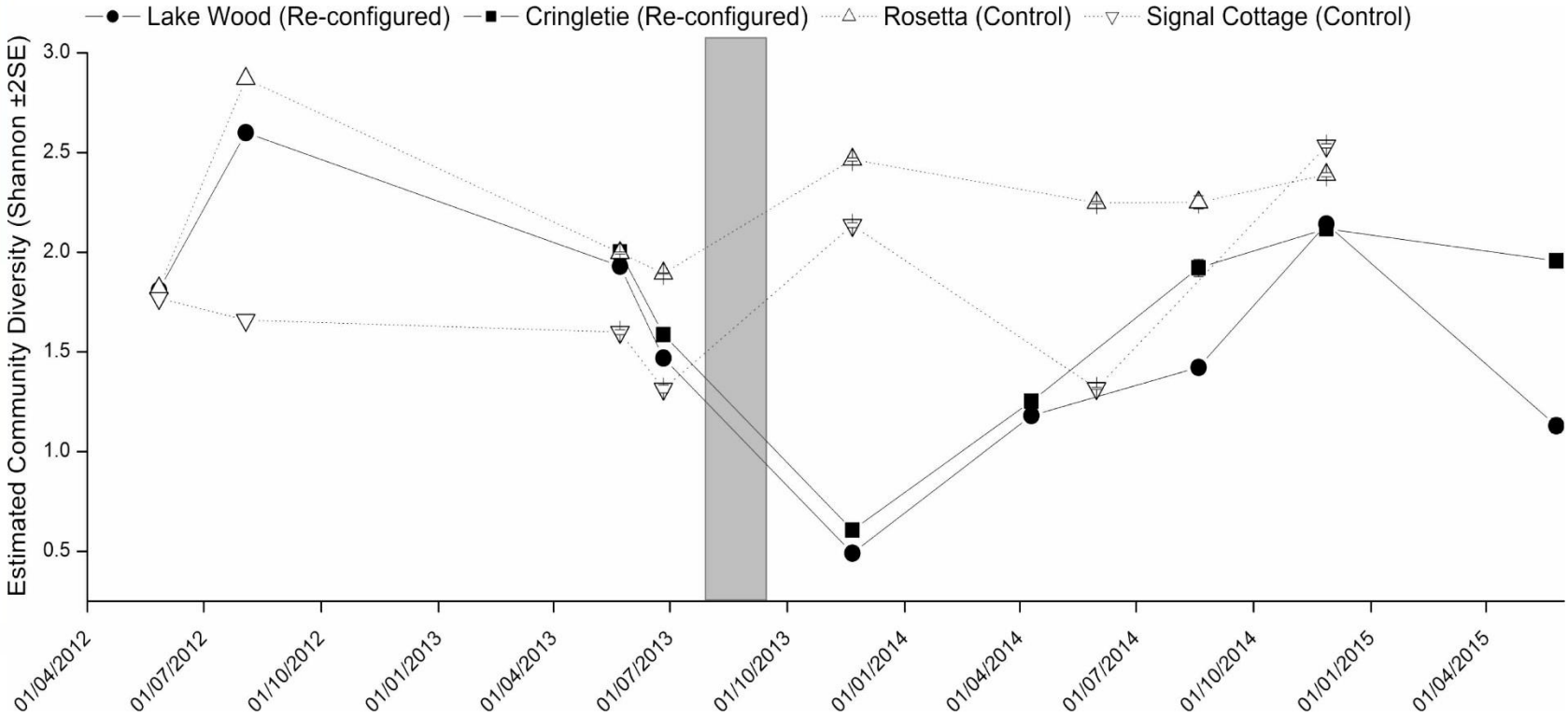
Long-term change in macroinvertebrate community abundance



18 months after restoration (grey bar)

Ecological Response to hydro-morphological change from re-meandering – Community Diversity

Long-term change in macroinvertebrate community diversity

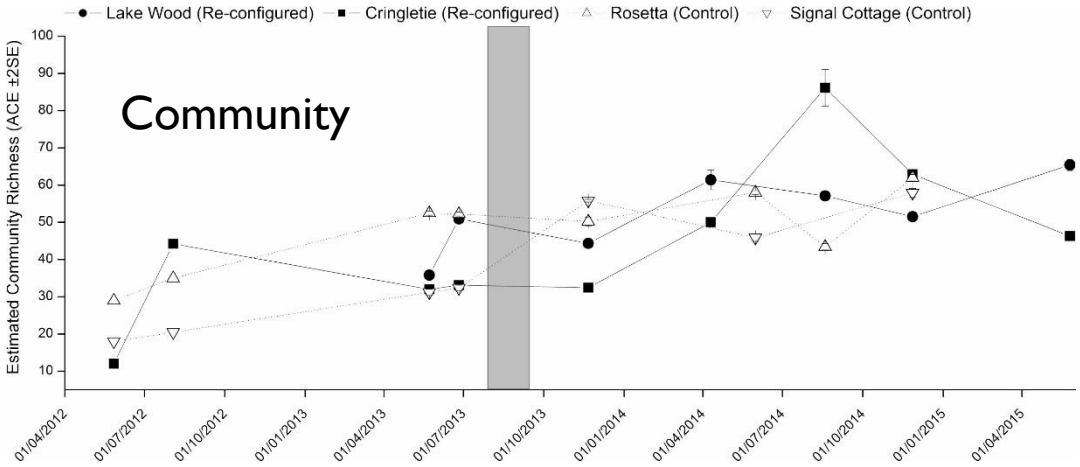


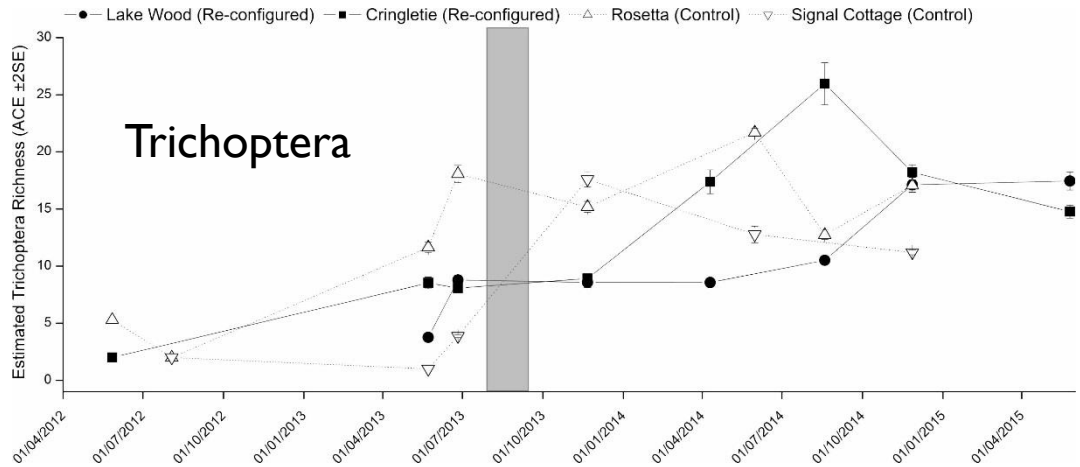
18 months after restoration (grey bar)

Comparative EPT Response: Richness of the Community : Trichoptera richness

Compared with Ephemeroptera & Plecoptera the Trichoptera appear to follow whole community change.

As a group, Trichoptera show a broader range of FFG, flow preferences, general tolerance to environmental stress.



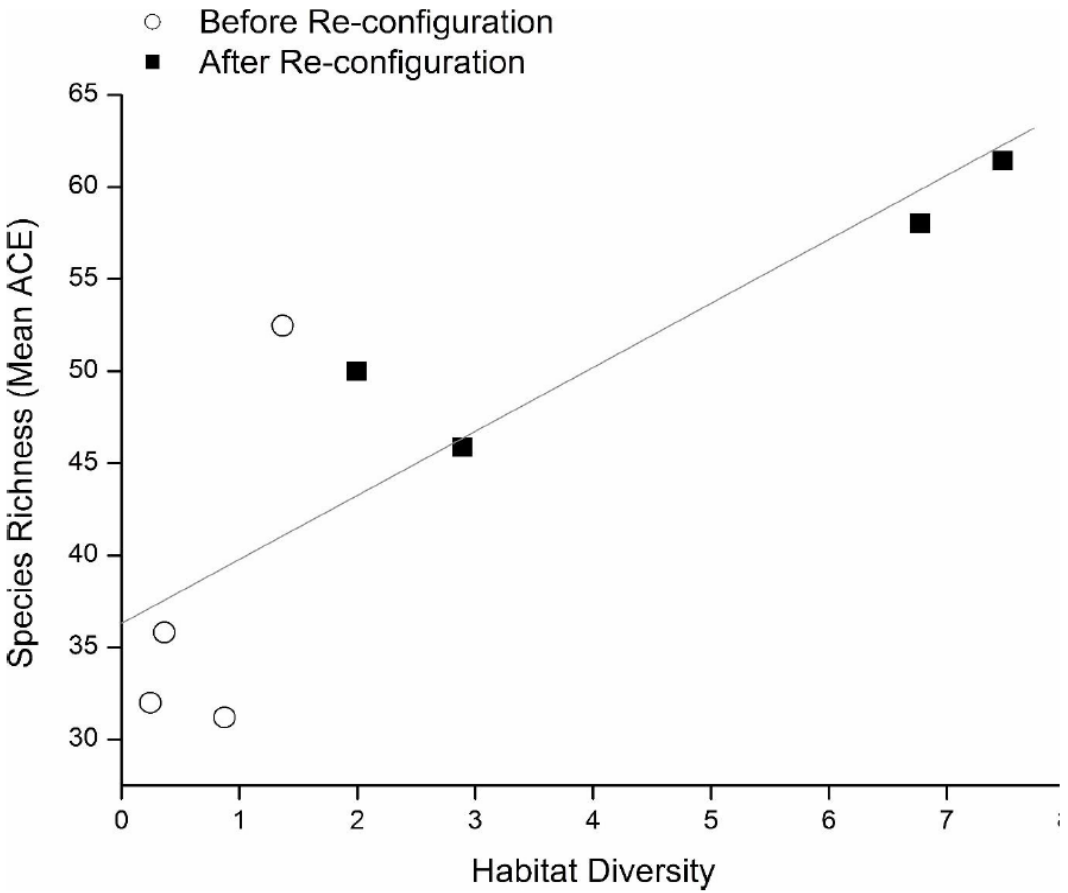


18 months after restoration (grey bar)

How does Species richness respond to Habitat variability?

Links to the THEORY - Habitat heterogeneity and Biodiversity

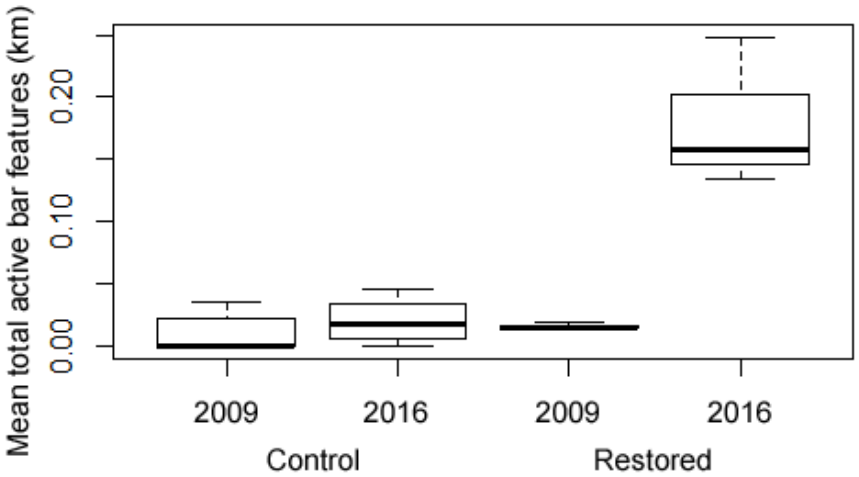
- **Significant linear relationship found between species richness and habitat variability** (ellipse size)
- Due to measured increase in habitat diversity at controls, difficult to attribute this change solely to channel re-configuration
- However, we have increased habitat diversity at re-configured sites and this is significantly linked with community richness.



Based on samples collected in spring 2013 (before) and spring 2014 (after) channel restoration
Richness estimated using Abundance-based Coverage Estimator

Key habitat: active bar features - response to re-meandering for Natural Flood Management

Mean total length of active bar features pre- (2009) and post-restoration (2016) for Control sites and Restored sites



Boxplot details 5, 25, 50, 75 & 95 percentiles of the data

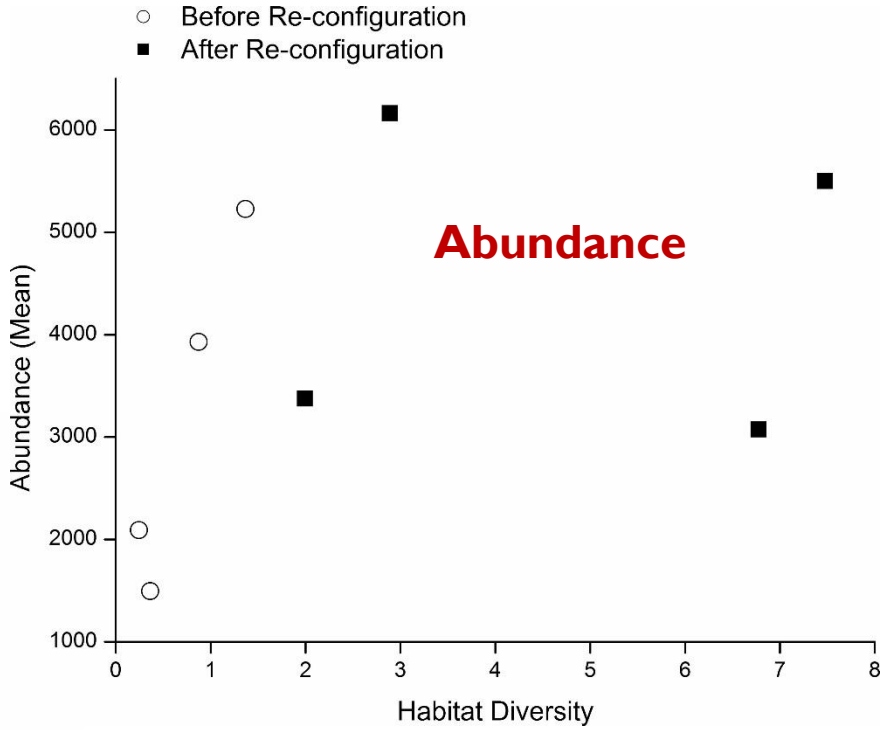
Significant increase in the total amount in restored sections compared with control sections.

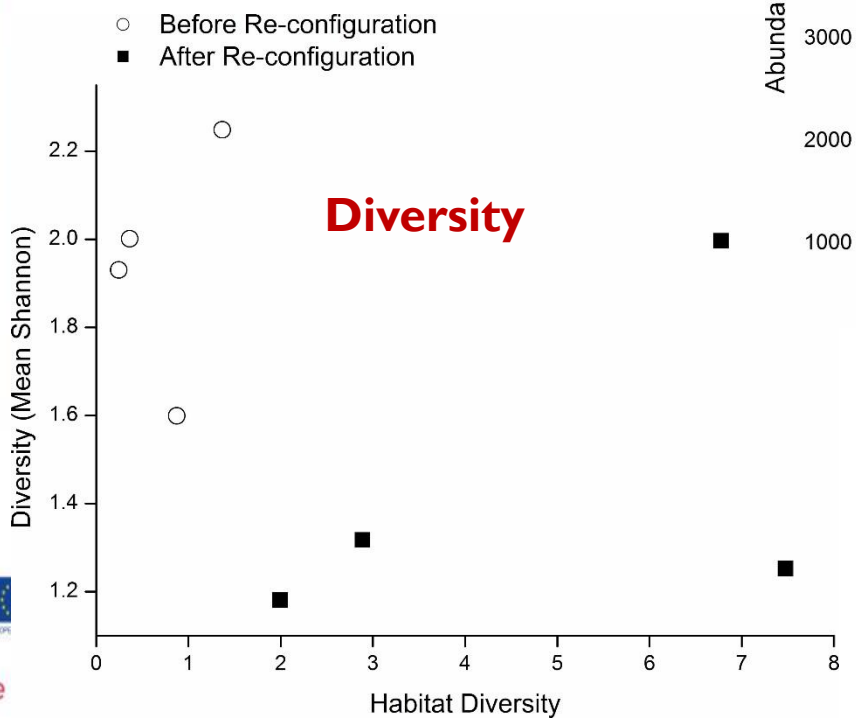
Such changes are important as it is the spatial distribution of alluvial bar features that drives patterns/ extents/ variability in morphological unit types.

How does Species diversity and Species abundance respond?

Links to the THEORY - Habitat heterogeneity and Biodiversity

No simple relationship to Species Abundance or Species Diversity eight months after in-stream physical work





Lessons from the Eddleston Project so far……..

- Importance of BACI design
- Alignment of ecological and hydro-morphological sampling key
- Variation in control sites can be large
- Need a wide range of values for environmental parameters in pre- and post-intervention periods
- Importance of difficulties in comparison of before/after at hydro-morphological unit level
- Need to have long-term study
- *Within* season variation in macroinvertebrate community can be large – Autumn sampling best
- Time/costs of detailed macroinvertebrate sampling and analyses is prohibitive
- Trichoptera may be a suitable measure

Thanks to:

- **Co- workers (past and present):**

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- **Local landowners, land managers and communities of Eddleston**
- **Project Partners and Steering Group**
- **Project Funders**

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http://www.tweedforum.org/projects/current-projects/eddleston