Extreme climatic events in freshwater ecosystems: recent advances and future directions

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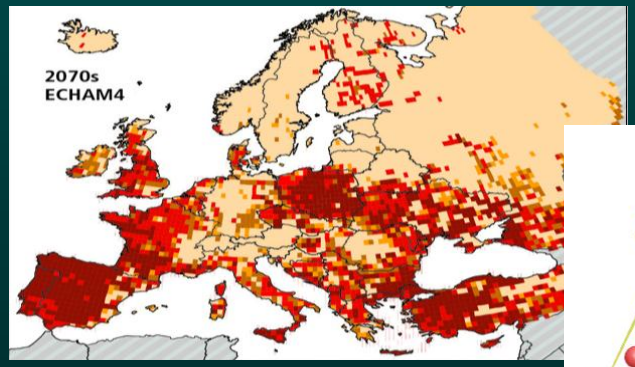
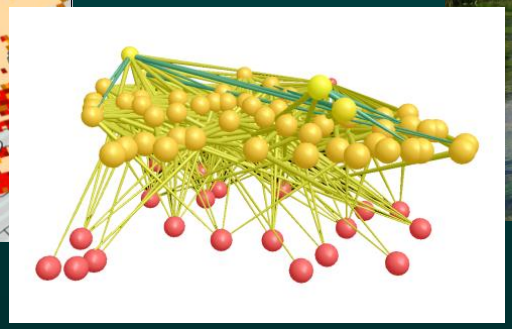
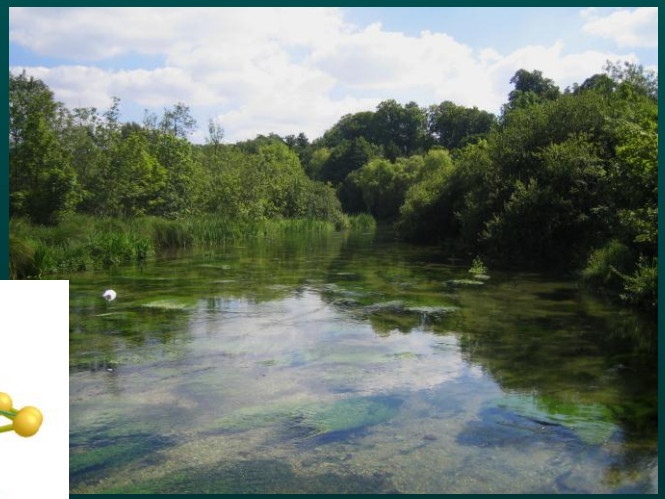
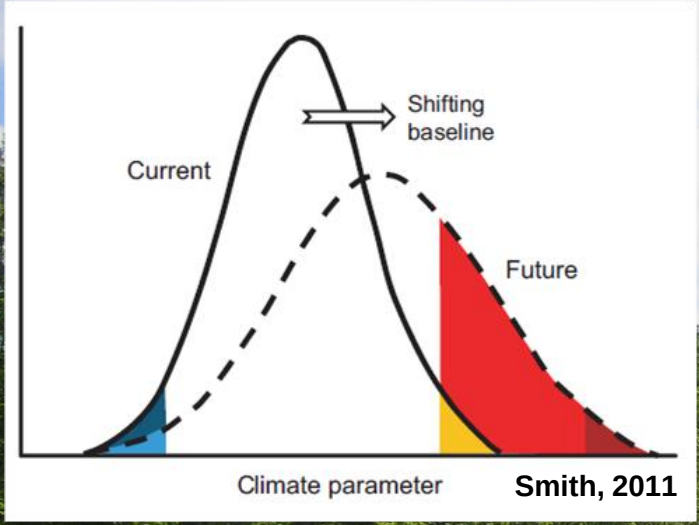








Smith, 2011

Climate change and river systems

Extreme events (e.g. floods, drought, heat waves) are key elements of natural variability in freshwaters

Rare but can have impacts that are disproportionate to their short duration

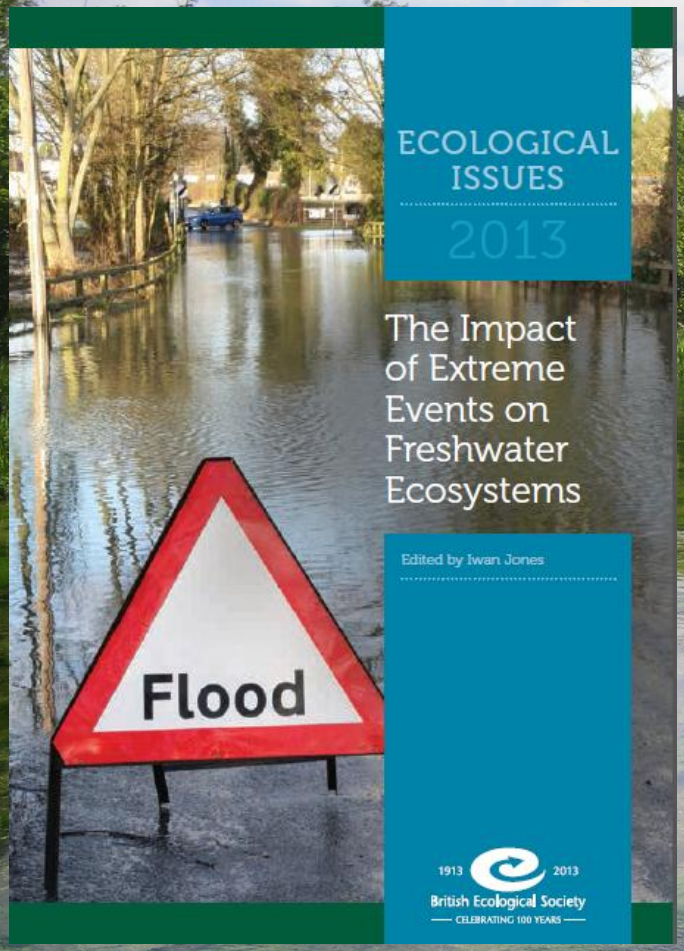
IPCC (2014): Climate change is increasing the occurrence of extreme events, and may result in unprecedented events

Ecosystem consequences?

Extreme event?

Occurrence of a variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values (IPCC, 2014)

Stranger than fiction?



Ecological Issues
"The impact of extreme events on freshwater ecosystems"

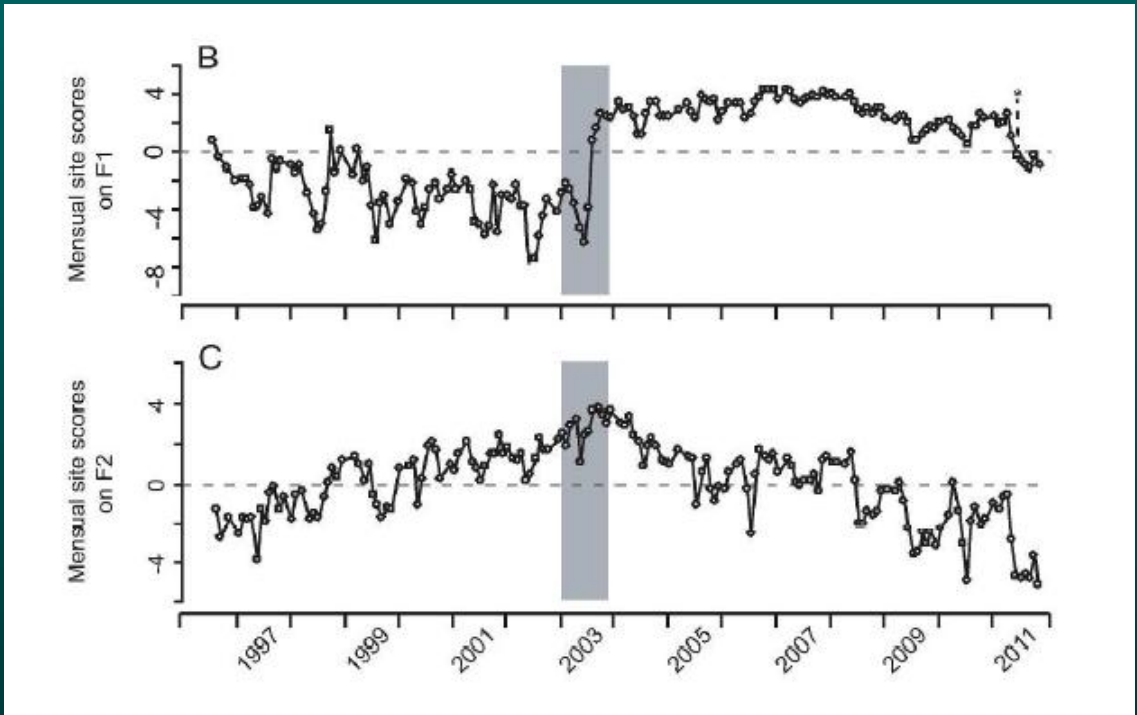
Policy-focused (PR) special publication of the British Ecological Society

Freshwater Biology

Freshwater Biology Special Issue
Extreme Climatic Events in Riverine Ecosystems
Guest Editors: ME Ledger, AM Milner

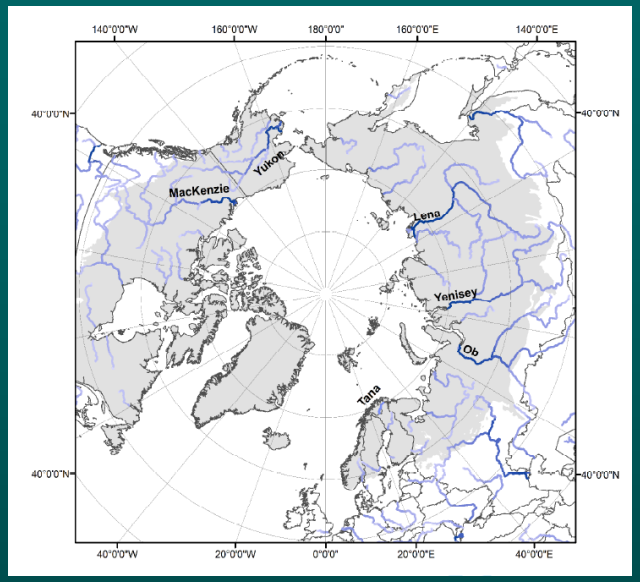
- **Extreme rainfall and floods**
- **Hydrologic drought**
- **Wildfire**
- **Cryosphere**
- **Heatwaves**

Impacts can be long lasting: e.g. 15-yr time series shows molluscs in the Saone river have not recovered following the 2003 heatwave in Europe



Mouthon J & Daufresne M. (forthcoming) Resilience of communities to extreme climatic events: mollusc communities of the Saone river and its two main tributaries (eastern France). *Freshwater Biology*.

IPCC: impacts on cryosphere expected in northern latitudes where warming crosses physical thresholds



Climate change in (sub)arctic regions
- Higher overall and summer temperatures
- More instances of winter temperature > 0° C
- Increased precipitation
- Later winters, earlier thaw

Change in abiotic base conditions
- Permafrost thaw
- Increased ice dynamics
- Glacial melt
- Increased precipitation (snow or winter rain)
- Increased saturated ground with increased frequency of rain events
- Decreased snowmelt magnitude

Extreme events

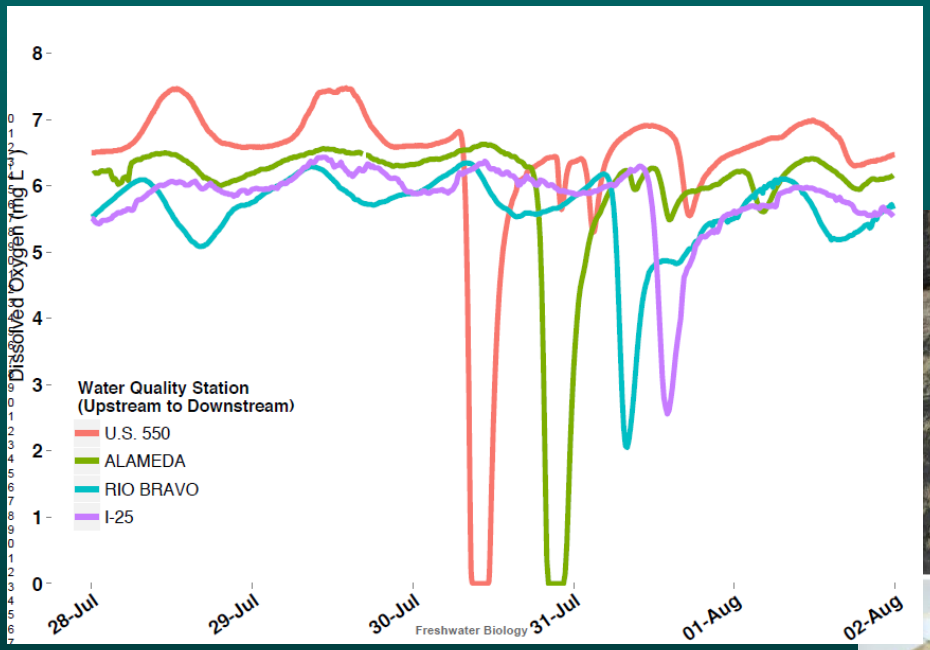
Outside of norm in terms of **magnitude, duration, frequency, intensity, or seasonality** of rare **meteorological, hydrological, or geomorphic events, e.g.,**
- Flooding
- Ice dynamics
- Permafrost thaw slumps

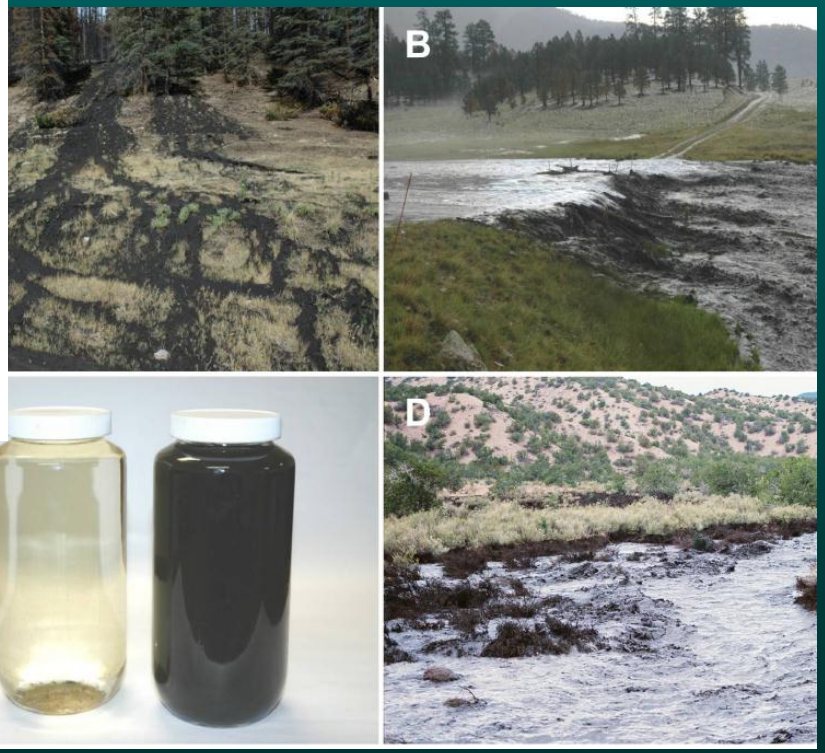
Cumulative and threshold effects:
- Cumulative effects of changes in base conditions can cause extreme event
- Change in base conditions can cause internal thresholds crossings leading to extreme event

Riparian and aquatic biotic effects
- **Direct effects**
- **Cumulative biotic effects:**
  - **Baseline changes in addition to extreme events**
  - **Changes in competition**
  - **Changes in resilience**
  - **Changes in migration**

Nilsson C, Polvi L, Lind L. (forthcoming) Extreme events in streams and rivers in northern cold regions in an uncertain future. Freshwater Biology.

IPCC: “frequent events will interact, producing compound events”. Evidence from freshwaters suggests impacts severe and/or unexpected... monitoring is key





DO crashes when floods follow fire

Dahm et al. (forthcoming) Extreme water quality degradation following a catastrophic forest fire. Freshwater Biology.

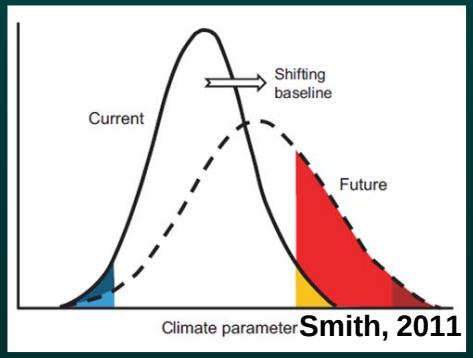
Extreme events: methods and approaches

Variety of approaches required to understand current and future extremes (IPCC 2014):

1. **Inference from analogous situations in the past/present, assuming similar scales of variability**

2. **Statistical or mechanistic models**

3. **Experiments e.g. to understand changes in disturbance regimes *beyond the range of natural variability***



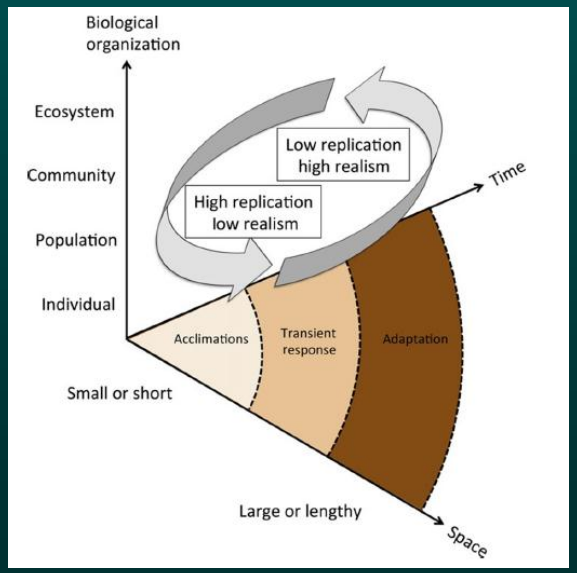
Smith, 2011

Mesocosm experiments to inform climate change research

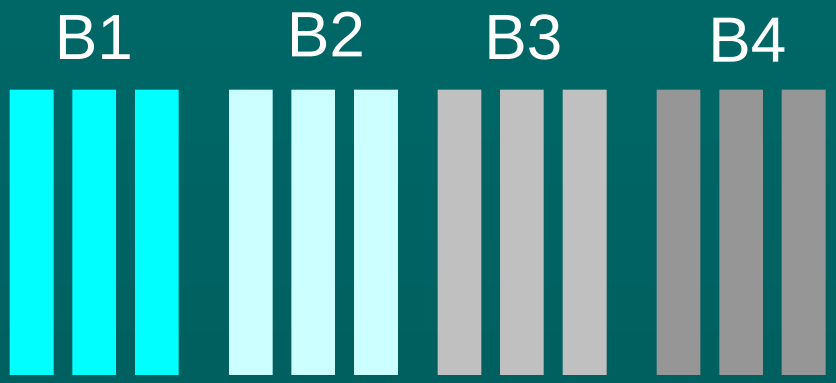
Impact of recurrent low flow disturbances, stream drying?

Greater realism than microcosms?

Greater control, mechanistic understanding than natural systems?



Stream mesocosms



Drought disturbance experiment

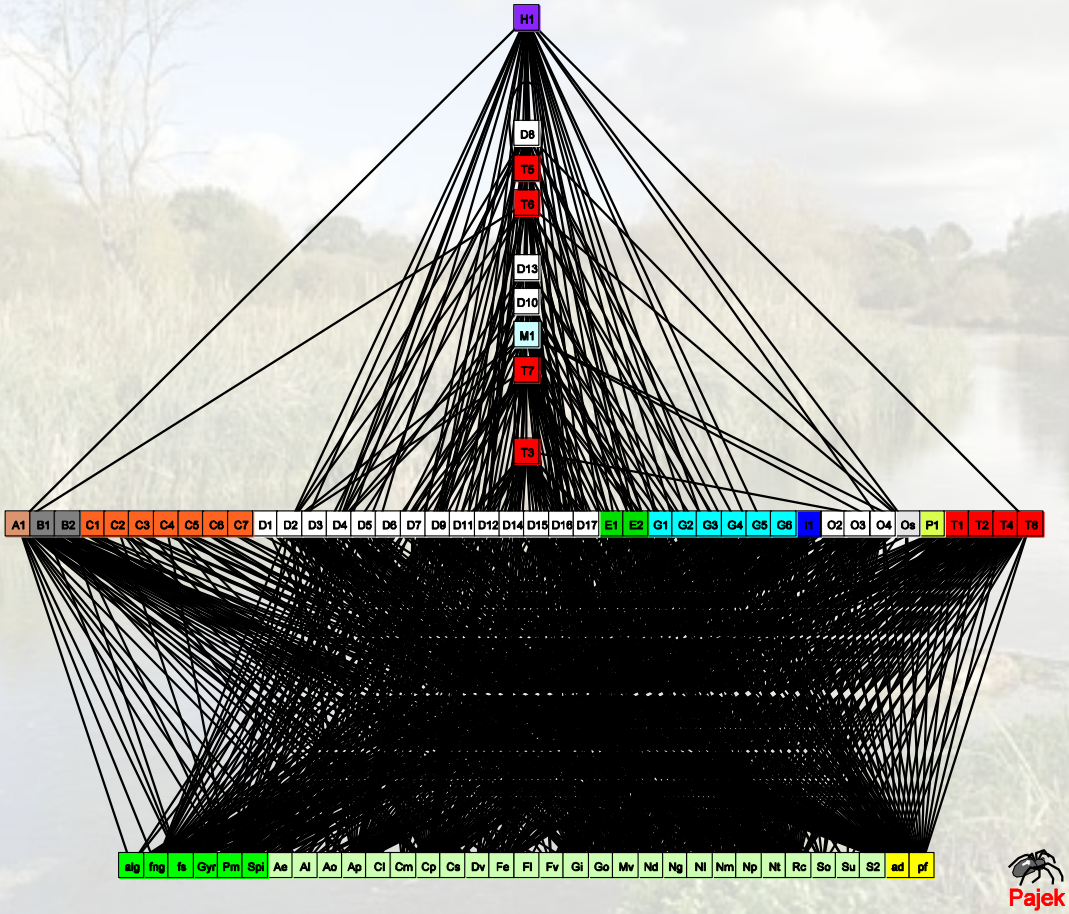
2 years

Intermittent flow:
Patchy drying (n=4)

Perennial flow:
Control (n=4)

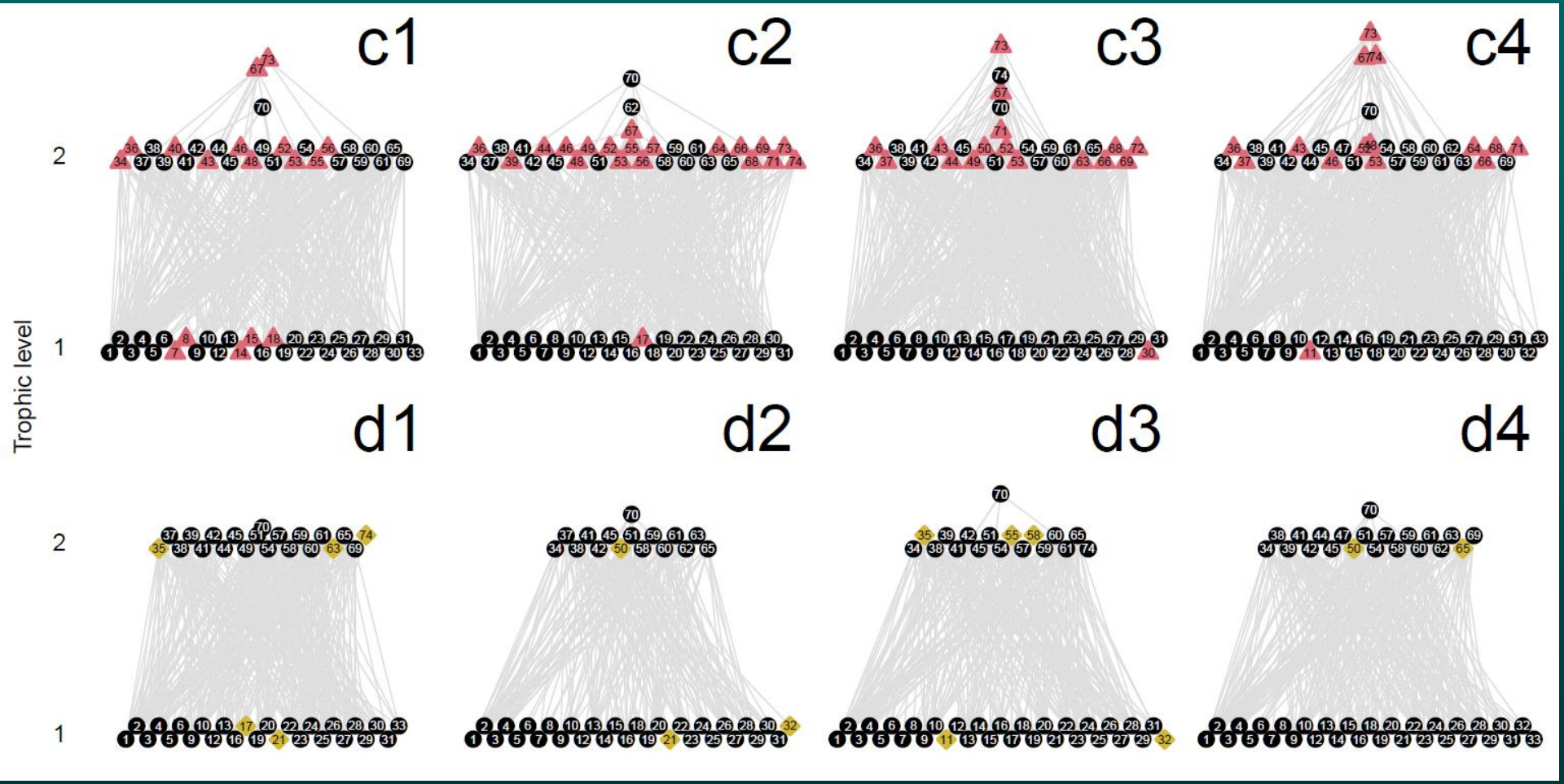
Paired design

Mesocosm Food Webs

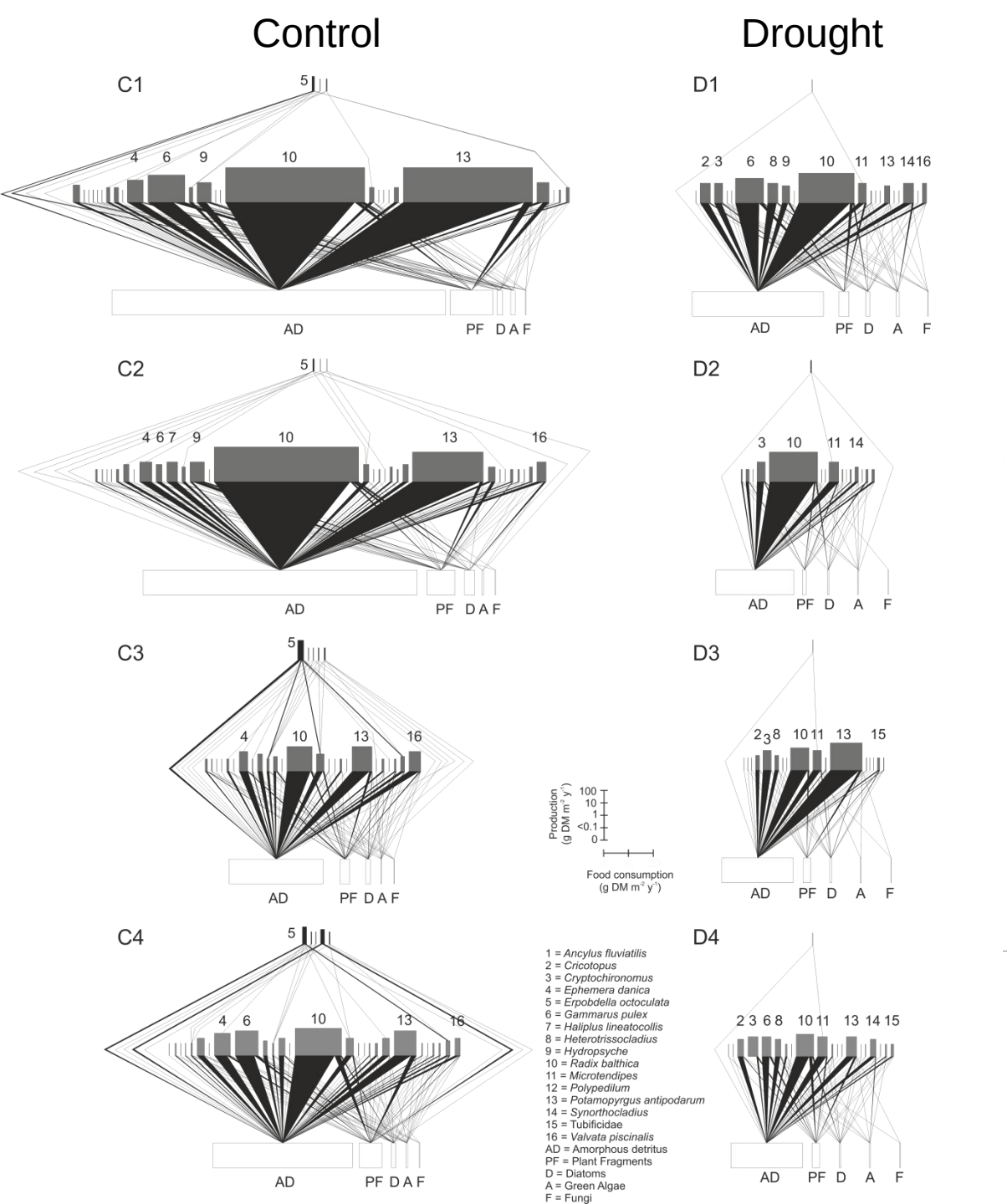


Brown, L.E., Edwards, F., Milner, A.M., Woodward, G & Ledger, M.E. (2011) Food web complexity and allometric scaling relationships in stream mesocosms: implications for experimentation. *Journal of Animal Ecology*, 80, 884-895.

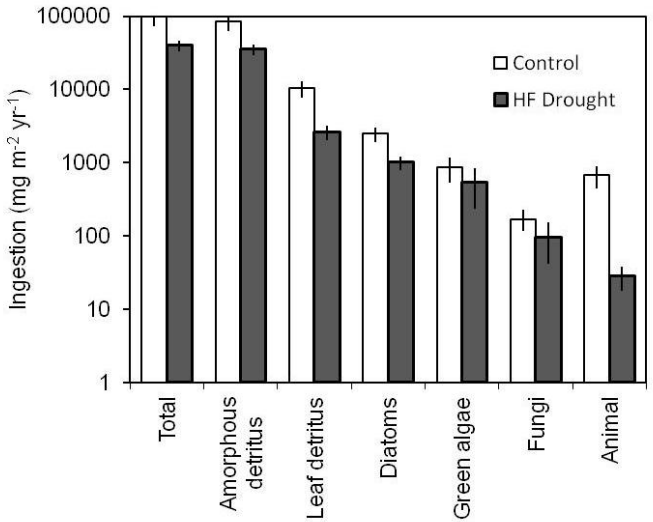
Drought impacts on food web structure: c=control, d=drying treatment



Drought reduced height and size (by 21%) of webs. Extinction (red) risk greatest for predators and rare species.



Responses of food webs to stream drying: stocks, production, fluxes



Ledger et al. (2013) *Nature Climate Change*, 3, 223-227

Exposure in IPCC AR5

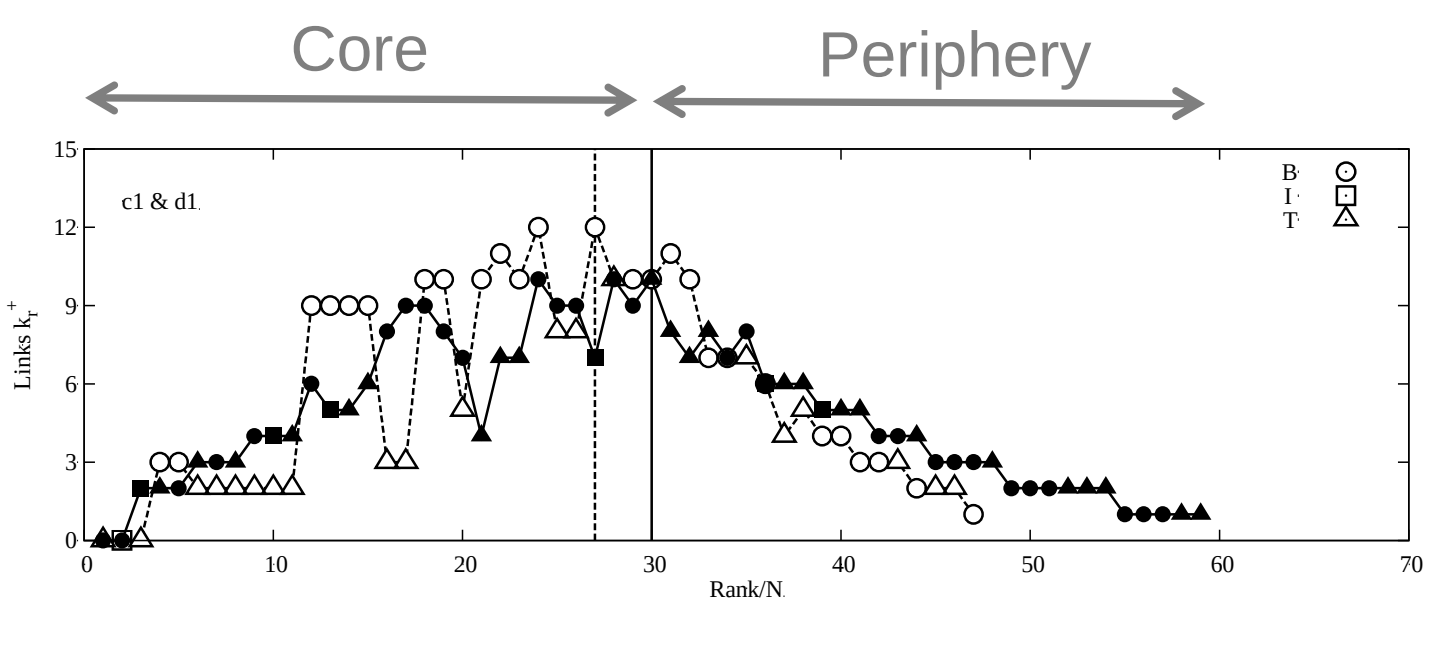
Implications of responses for binary food web topology and stability?

Structure:

Food webs have a "rich-core" of highly connected species surrounded by a loosely connected "periphery"

A reduction in core size makes webs less robust to biodiversity loss

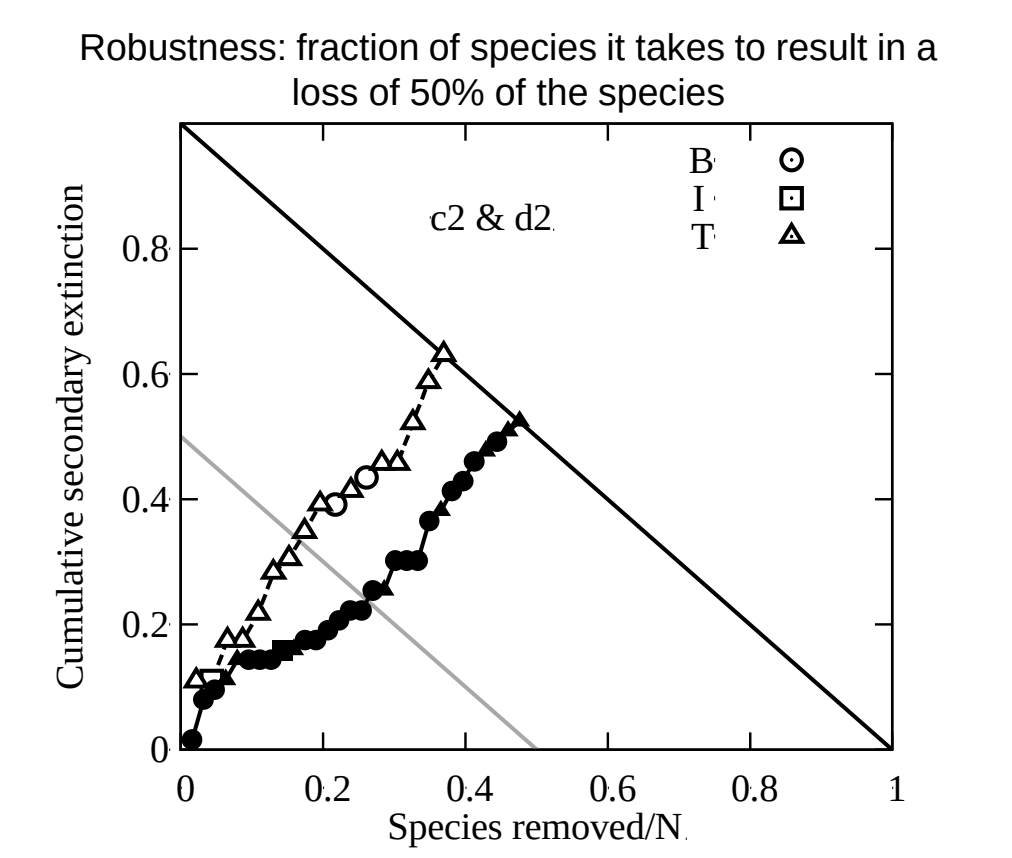
No. links each node shares with nodes of a higher rank



Lu, Ma et al. (in prep)

Food web robustness:

Simulated sequential species removals show that drought does not significantly reduce robustness to secondary extinctions



Why?

Species loss but reshuffling of links between core and periphery

Conserved connectance preserves robustness

Impoverished but stable

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Summary and conclusions

1. Experiments incorporating extremes and variability may improve understanding of future impacts of climate change (Thompson et al. 2014; Kreyling et al. 2014)

2. Recurrent disturbance altered food webs: losses of predators and rare species, biomass, secondary production and OM processing

3. Shifts in community composition led to rewiring of web links, maintaining web topology and stability.

Summary and conclusions

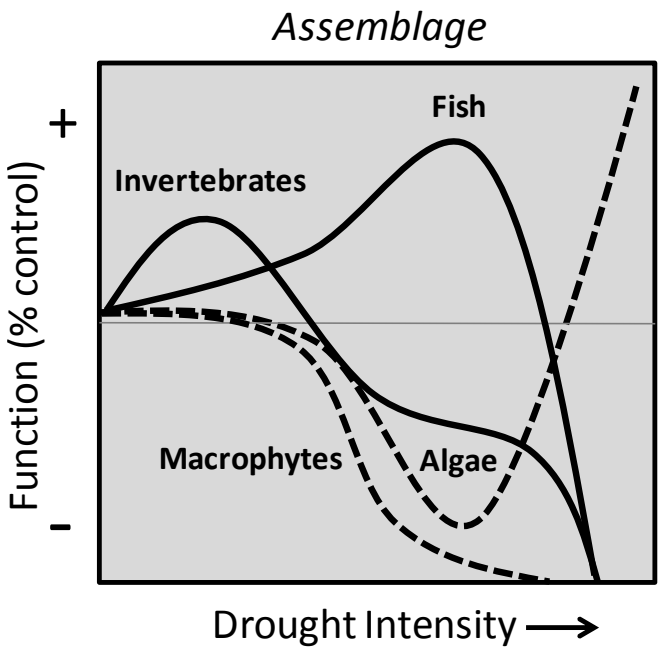
Next steps:

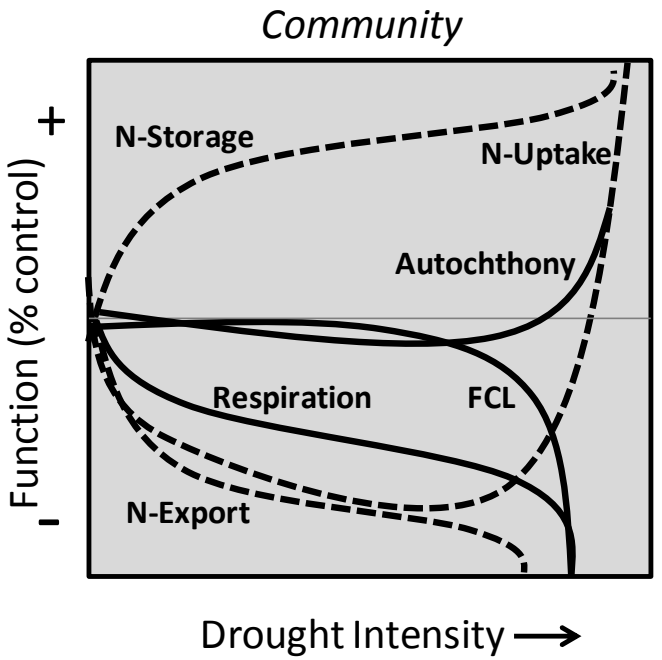
4. Explore non-linear responses and trigger points – experiments with regression/gradient designs to determine response thresholds to stressors

Drought impacts on stream ecosystem functioning (DRI-STREAM)

Ledger (PI), Trimmer (QMUL) and Woodward (ICL)

To quantify the effects of habitat loss on structural-functional attributes of stream ecosystems





NERC DRI-STREAM PROJECT