*A golden age of river restoration science?

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*Based on an editorial written for *Aquatic Conservation* December 2004

Aims and scope

1. Outline a theoretical context for river restoration;

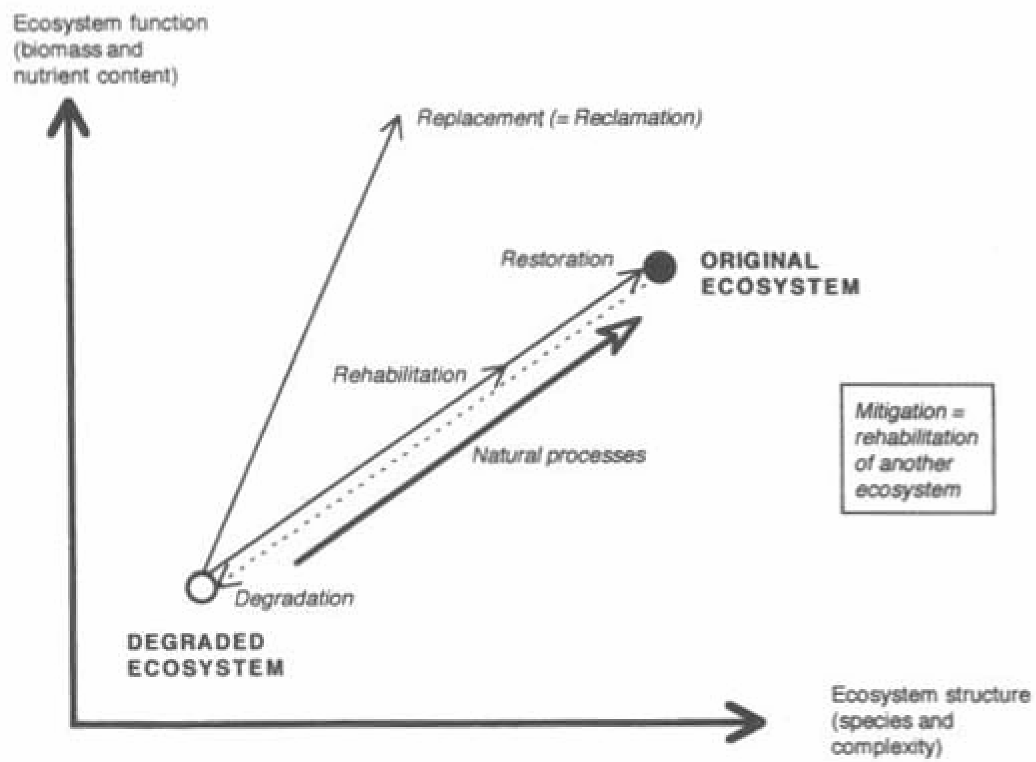
2. Outline some current trends and impetus for river restoration;

3. Reveal criticisms and design issues in some river restoration efforts;

4. Offer some experience from large-scale replicated experiments in restoration;

5. Suggest that we need more ecological input to the design and appraisal of river restoration.

Fig. 1. The several different options in remediation work.



A. D. Bradshaw (1996). Canadian Journal of Fisheries and Aquatic Sciences.

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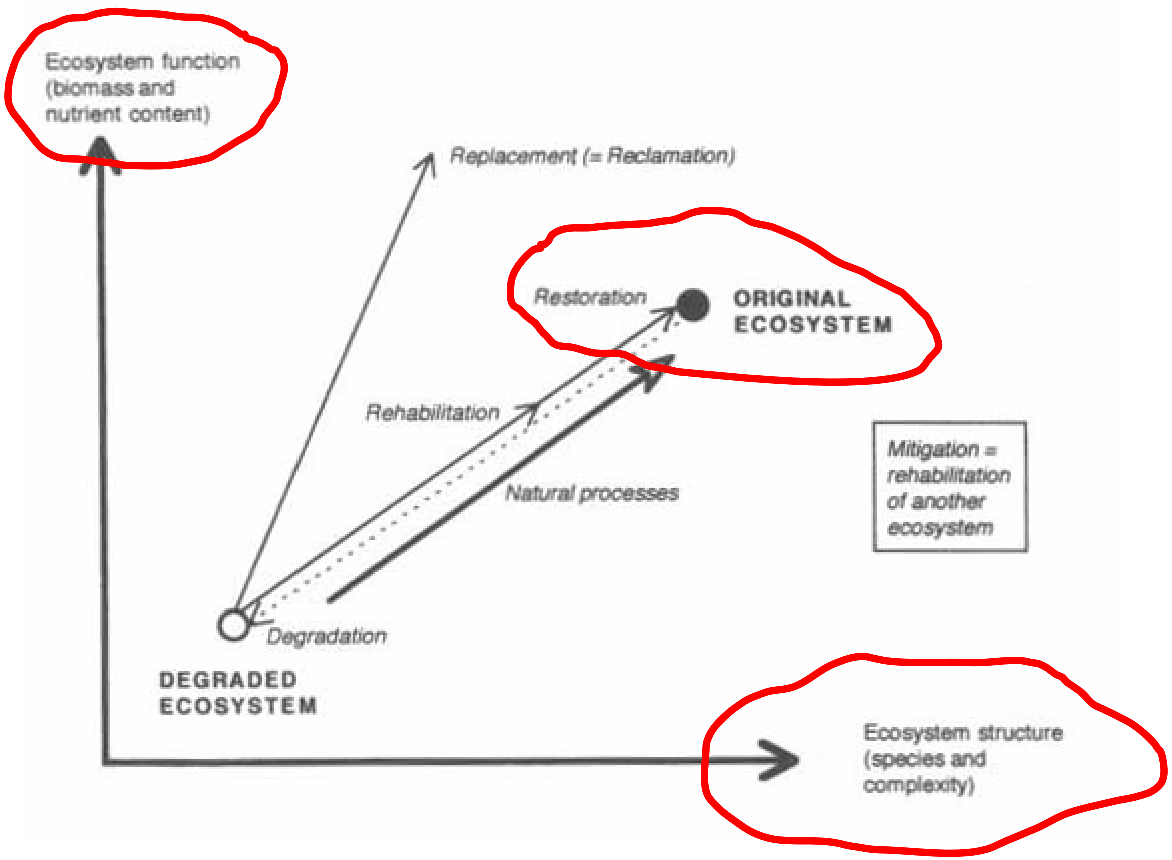

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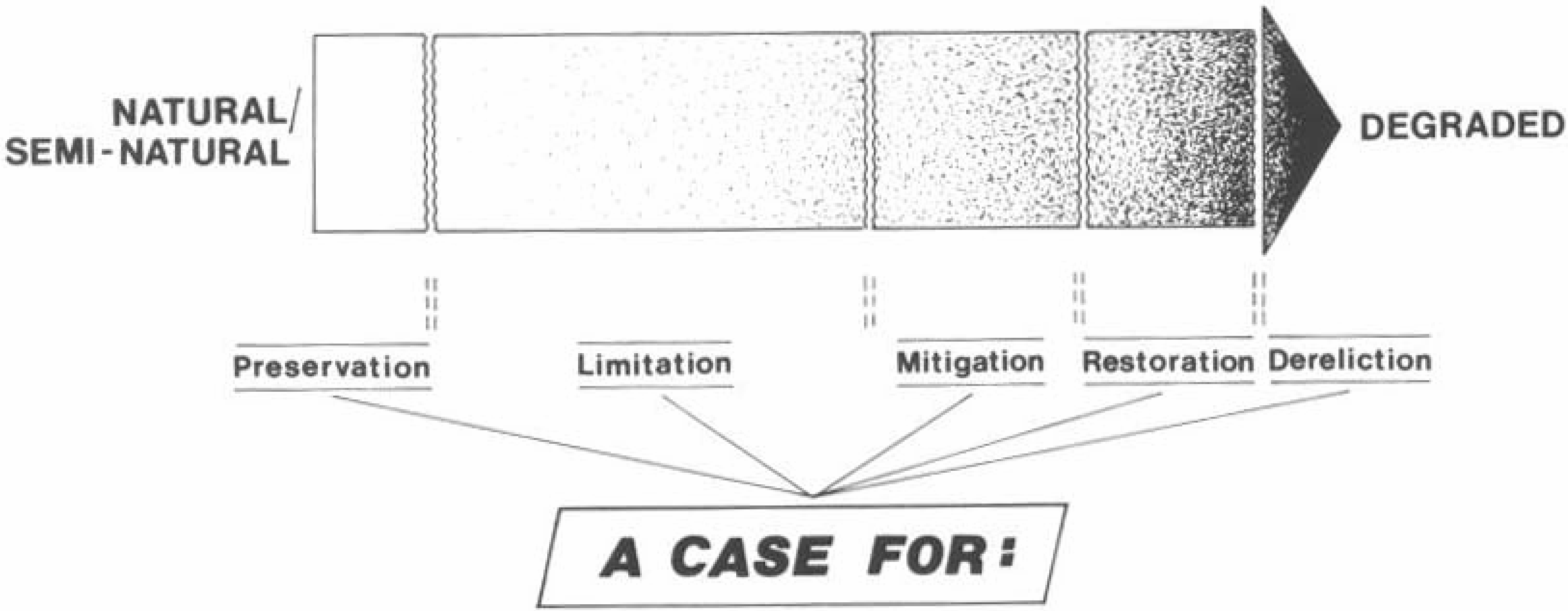

FIGURE 2.4 The case for conservation: a range of management options along a spectrum of decreasing conservation value

P. J. Boon *et al.* (1992): River conservation and management. Wiley.

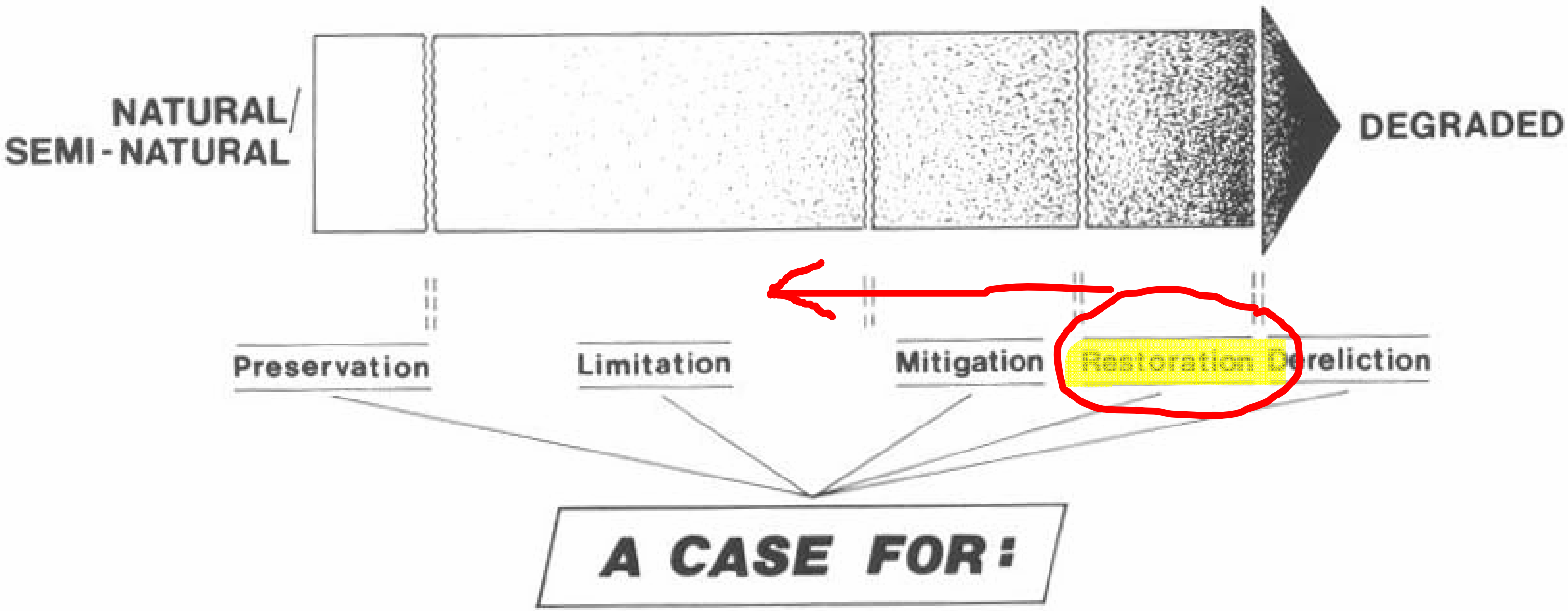

FIGURE 2.4 The case for conservation: a range of management options along a spectrum of decreasing conservation value

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Potentially, and if applied widely enough across landscapes, restoration might become as important to the conservation of biodiversity as are protected areas currently.

(Dobson, Bradshaw & Baker 1997; Science 277, 515-522)

On river and channel restoration:

"….abiotic endpoinds such as physical quality and water quality are appropriate targets for restoration rather than biological endpoints such as density, diversity or production of certain species."

"….. If natural hydrology and morphology are recreated, with careful consideration given to hydraulic aspects, then there is every possibility that natural ecological recovery will follow."

A. Brookes and F. D. Shields (1996) River channel restoration: guiding principles for sustainable projects. Wiley.

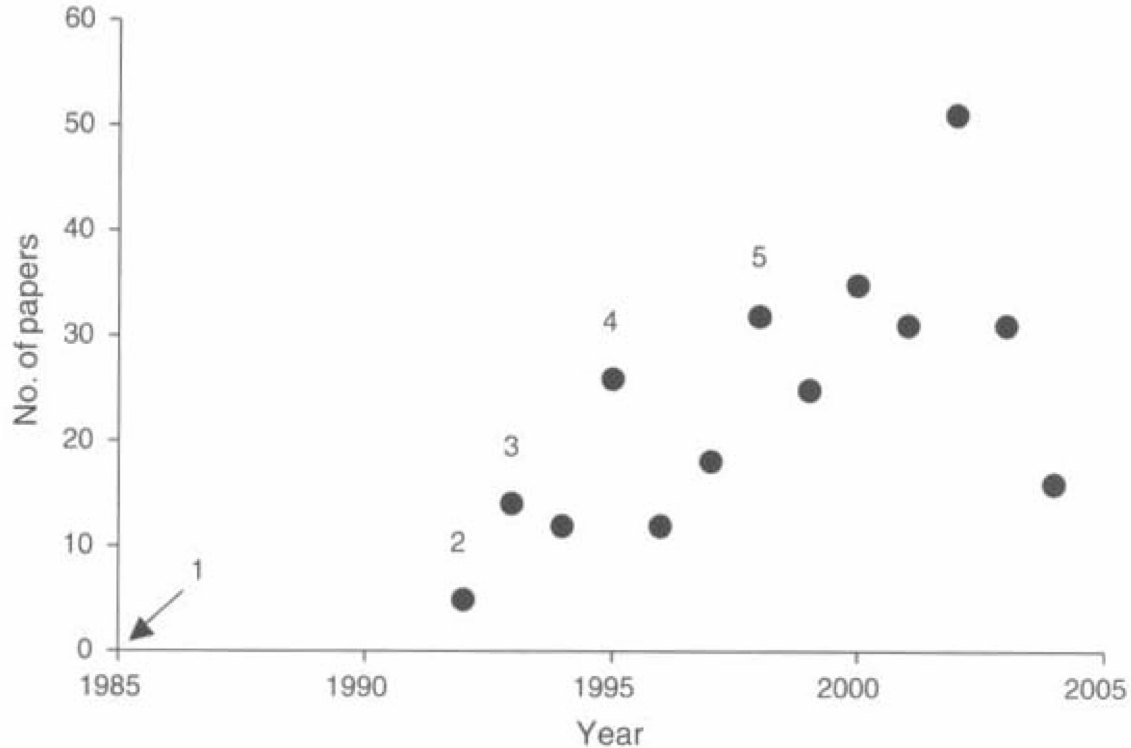
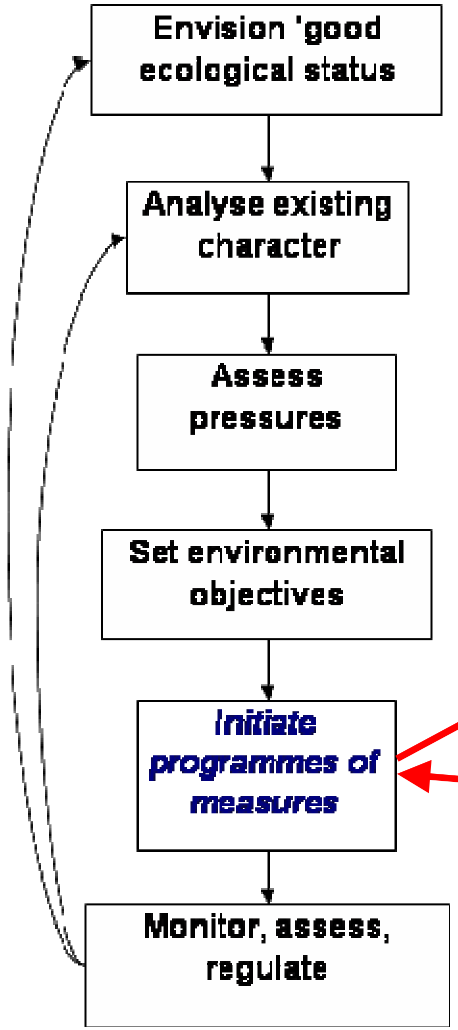


Figure 1. The numbers of papers published in mainstream journals (ISI® qualifying, 1981–2004) using the terms 'river restoration', 'river rehabilitation', 'stream restoration' or 'stream rehabilitation' in the title, key words or abstract. The events labelled are: (1) Jim Gore's (1985) seminal textbook on river and stream restoration; (2) The first use of the term 'stream restoration' in *Aquatic Conservation: Marine and Freshwater Ecosystems* (Charbonneau and Resh, 1992); in the same year, 'River Conservation and Management' (Boon *et al.*, 1992) carried a themed section on 'Recovery and Rehabilitation'; (3) *Freshwater Biology* **29**(2) published a special issue on 'Lowland Stream Restoration'; (4) *Restoration Ecology* **3**(3) published a special issue on 'Restoring the Kissimmee'; (5) *Aquatic Conservation: Marine and Freshwater Ecosystems* **8**(1) published a special issue on 'River Restoration: The Physical Dimension'.

And now, one of the largest catalysts for river restoration is upon us…..

The pursuit of good ecological status under the EU Water Framework Directive.



Organisms figure explicitly:

Diatoms
Macrophytes
Invertebrates
Fish…

Ecological processes?

Essentially, ecological restoration through management….

… at all scales from reach to whole basin.

But how prepared are we to meet this new challenge ?

Table 1. Papers on river or stream restoration and rehabilitation that used the subject terms listed below in the title, summary or key words. Note that the categories are not mutually exclusive. (Source: ISI® database, 1981–2004)

Subject	Rivers (%)	Streams (%)
Habitat	49.7	59.0
Bio- (e.g. biodiversity, biota)	35.5	33.1
Species	26.2	25.2
Fish	24.5	30.2
Hydrology	19.1	11.5
Geomorphology	15.3	12.2
Water quality	13.6	15.1
Macroinvertebrate	12.5	17.3
Macrophyte	4.9	2.2
Bird	3.2	0.0
Diatom	0.5	0.7
Bryophyte	0.0	1.4
Total papers	183	139

Table 2. Journals most frequently carrying papers on river or stream restoration and rehabilitation linked in some way to 'habitats' (Source: ISI® database, 1981–2004)

Journal	No. of papers
Aquatic Conservation: Marine and Freshwater Ecosystems	19
River Research and Applications (= Regulated Rivers)	17
Environmental Management	15
Hydrobiologia	11
Freshwater Biology	8
Restoration Ecology	7
Ecological Applications	6
Ecological Engineering	4
Fisheries	4
North American Journal of Fisheries Management	4
Water Resources Bulletin	4
Geomorphology	3
Journal of the American Water Resources Association	3
Journal of Applied Ecology	3
Archiv für Hydrobiologie	2
Applied Geography	2
Canadian Journal of Fisheries and Aquatic Sciences	2
Journal of Hydraulic Engineering	2
Physical Geography	2
Journal of the North American Benthological Society	2
Journal of Environmental Management	2
Thirty-two other journals	1

River restoration is potentially very multi-disciplinary but...

There are range of problems identified by commentators:

i) ***A small proportion of published studies evaluate restoration outcomes (c 30%)***
ii) ***A very small proportion of schemes are evaluated***
iii) ***A small proportion of evaluations are on ecological criteria (c 20% in published studies)***
iv) ***Few evaluations extend over time-scales long enough for outcomes to develop (i.e. > 3-5+ years)***
v) ***Few evaluations use robust experimental designs (replicated sites; before-after designs; independent treatments v references….)***
vi) ***Multi-disciplinary collaboration is still rare, with authors variously suggesting that restoration is too biological, not biological enough, too geomorphological or not geomorphological enough.***

Experience from the Llyn Brianne experiments….

…. established to assess the exacerbatory effects of land use and management on acidification and to seek methods of ***mitigation or restoration in <u>replicated</u> catchments.***

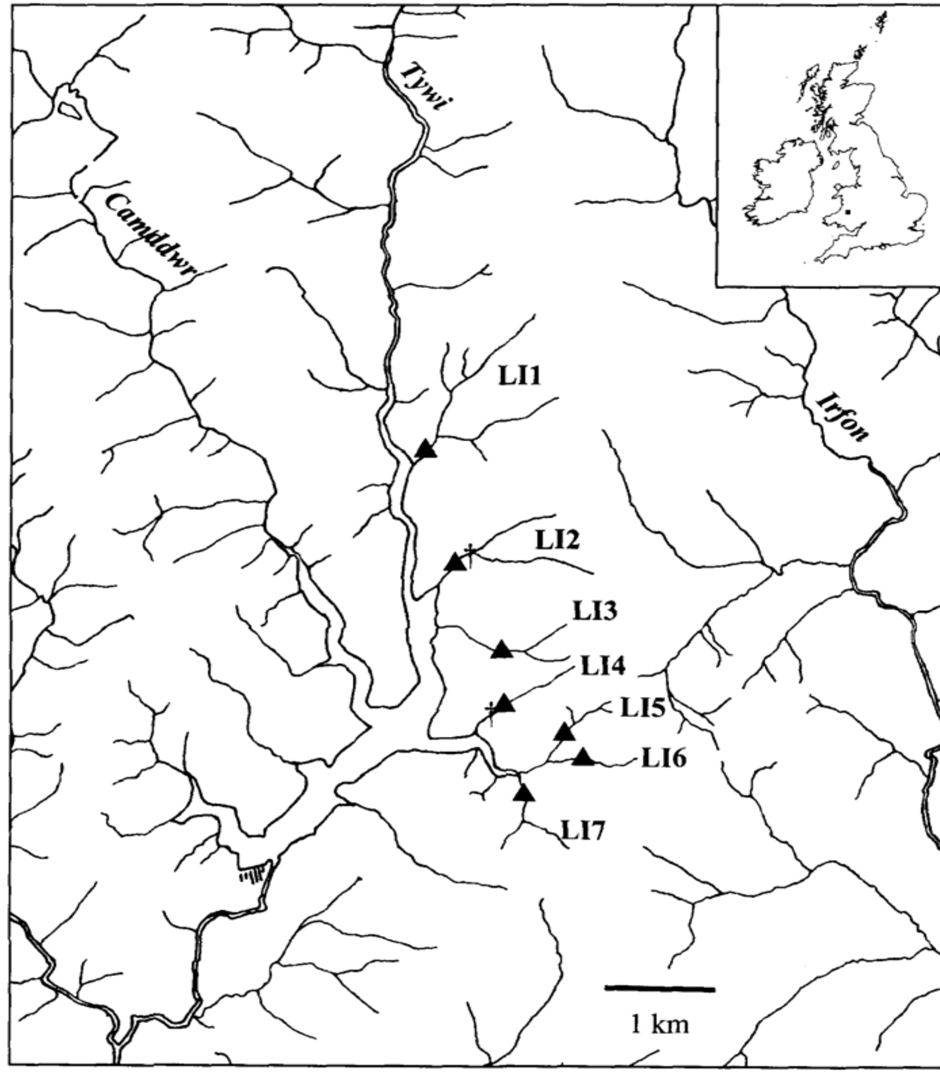
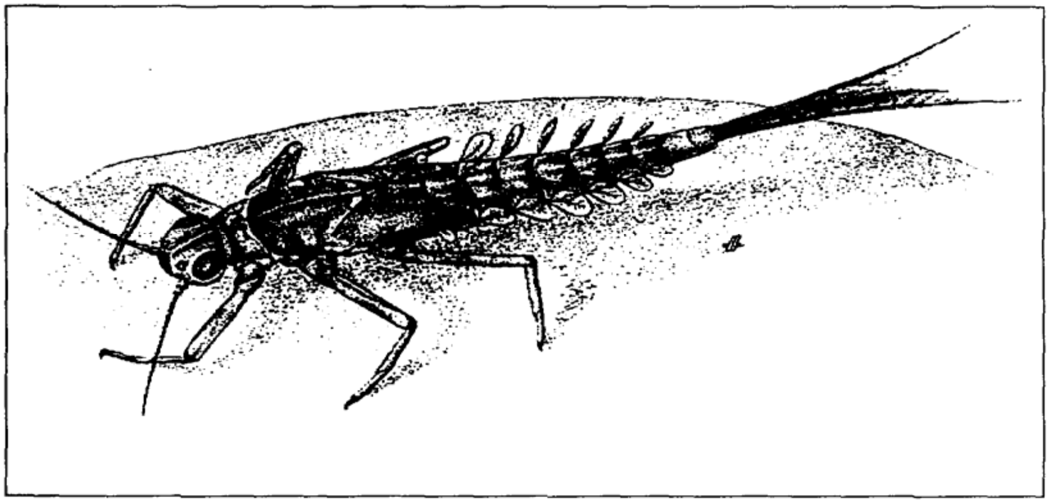


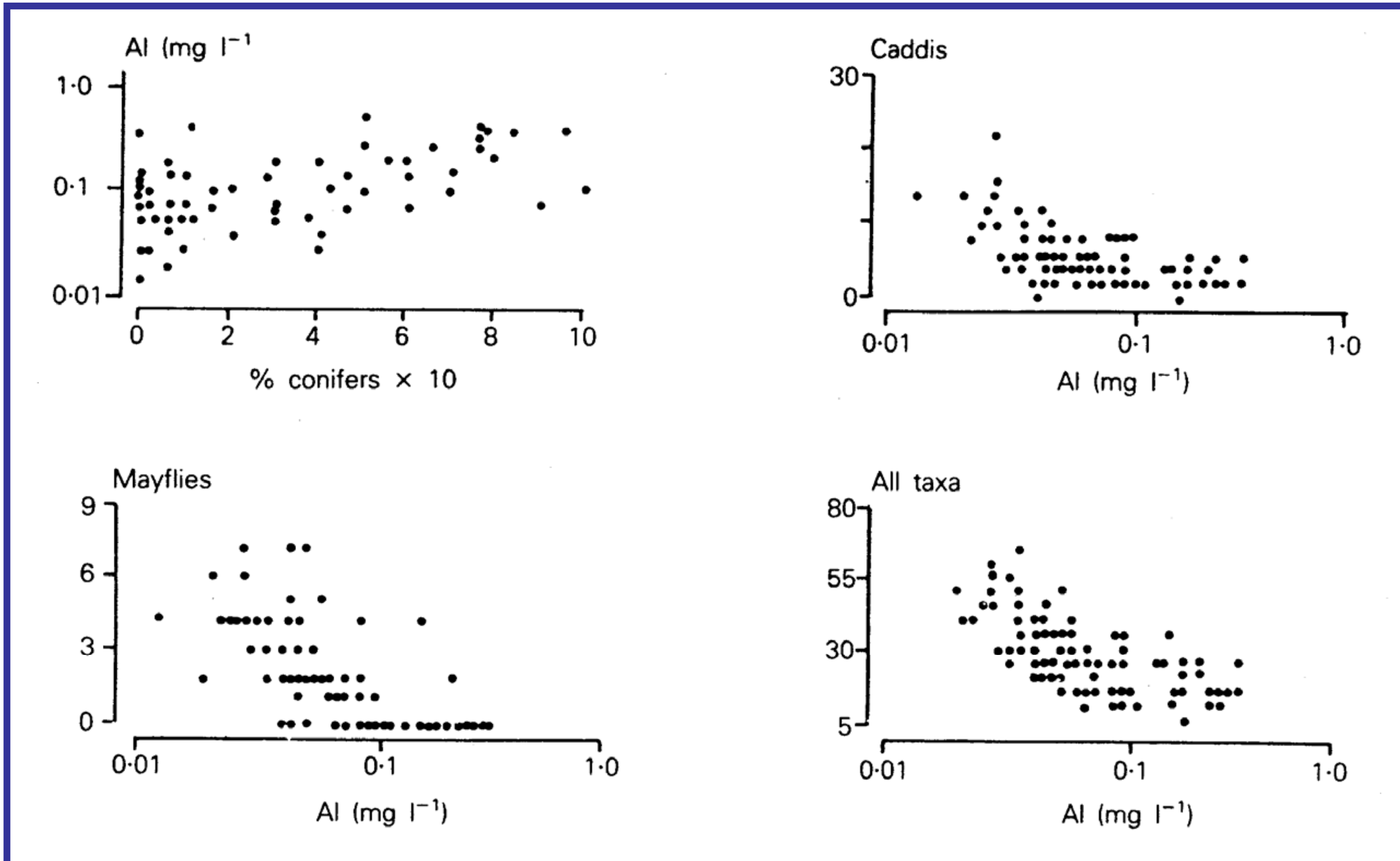
Figure 6.1: Location of study sites (▲) and weather stations (†) within the Llyn Brianne experimental area, mid-Wales. Grey shading indicates afforestation.

The model group:

Figure 1.1 *Baetis rhodani* larva (taken from Elliot *et al.*, 1988).



(Ormerod et al.)



Mean annual dissolved aluminium (<0.45 μm) in Welsh streams in relation to catchment afforestation, and invertebrate species richness

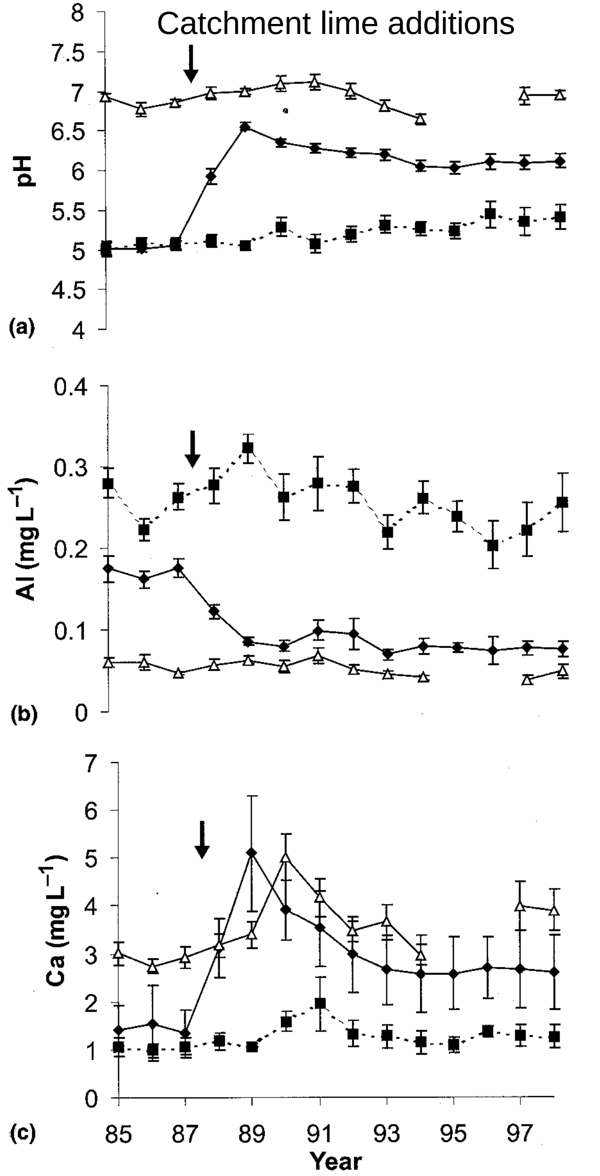


Fig. 1 Mean annual chemistry (± SE) between 1985 and 1998 for replicate groups of limed (◆), acid reference (■) and circum-neutral streams (△) at Llyn Brianne, mid Wales. (a) pH; (b) aluminium (mg L^{-1}); (c) calcium (mg L^{-1}). Arrows indicate lime additions.

Chemical data from circumneutral, acid and limed catchments at Llyn Brianne showed that liming had marked, durable effects….

Bradley & Ormerod 2002

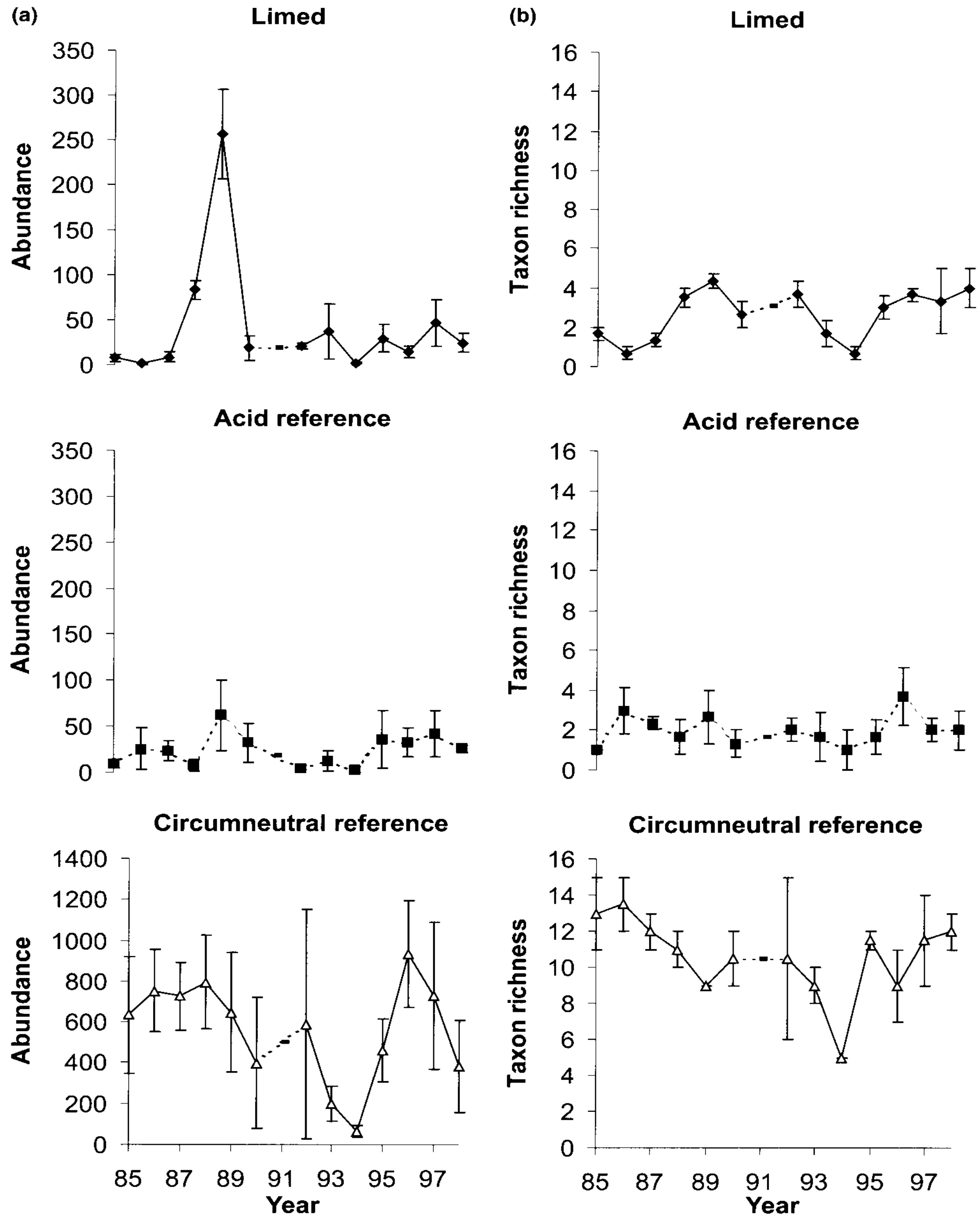
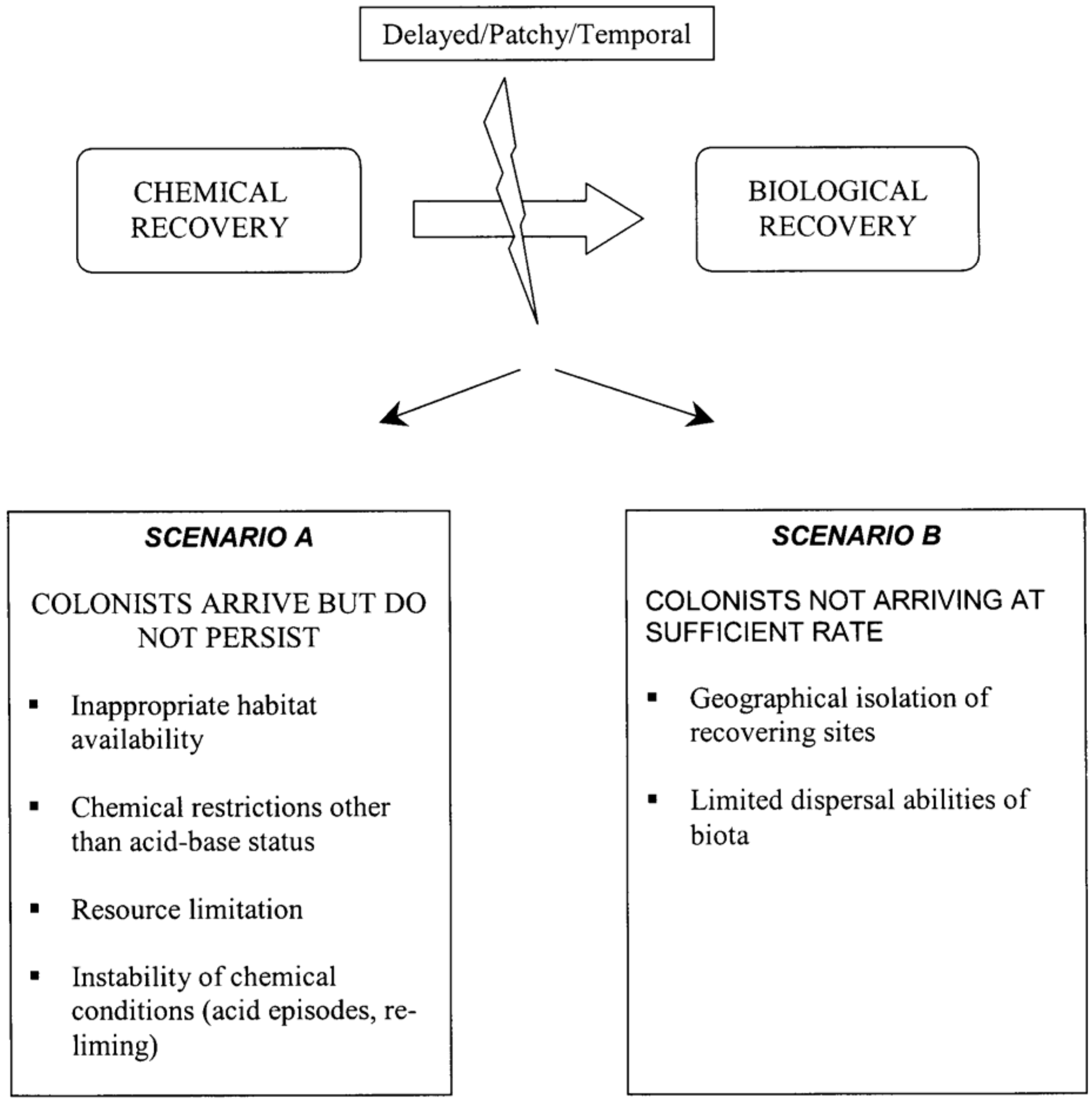


Fig. 2 (a) Mean abundance and (b) mean taxon richness ± SE of 18 acid-sensitive macroinvertebrate taxa between 1985 and 1998 in replicate groups of limed, acid reference and circumneutral streams at Llyn Brianne, mid Wales. Dashed line represents missing data for 1991. Arrows indicate lime additions.

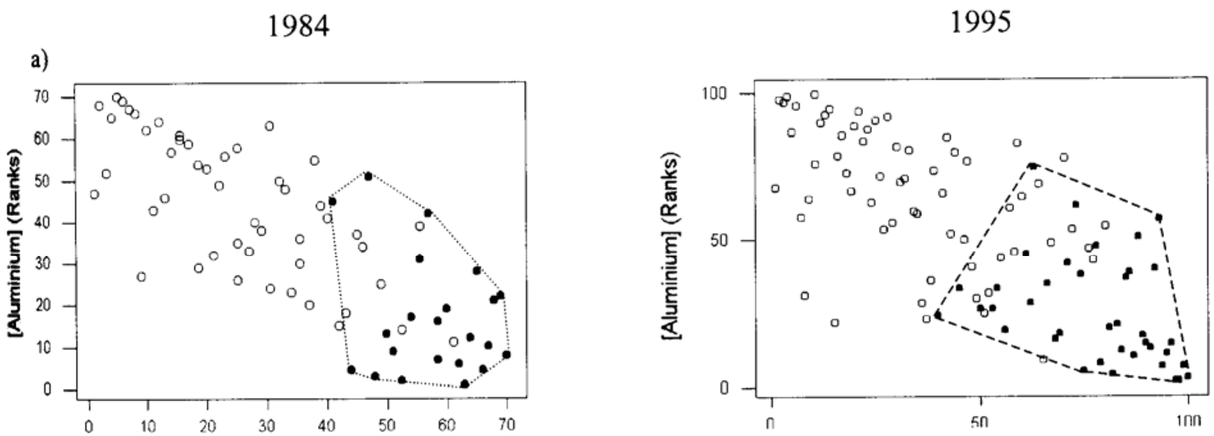
….but the effects on invertebrates were less marked.

Why might biological recovery have failed in these cases ?



(Masters & Ormerod unpubl.)

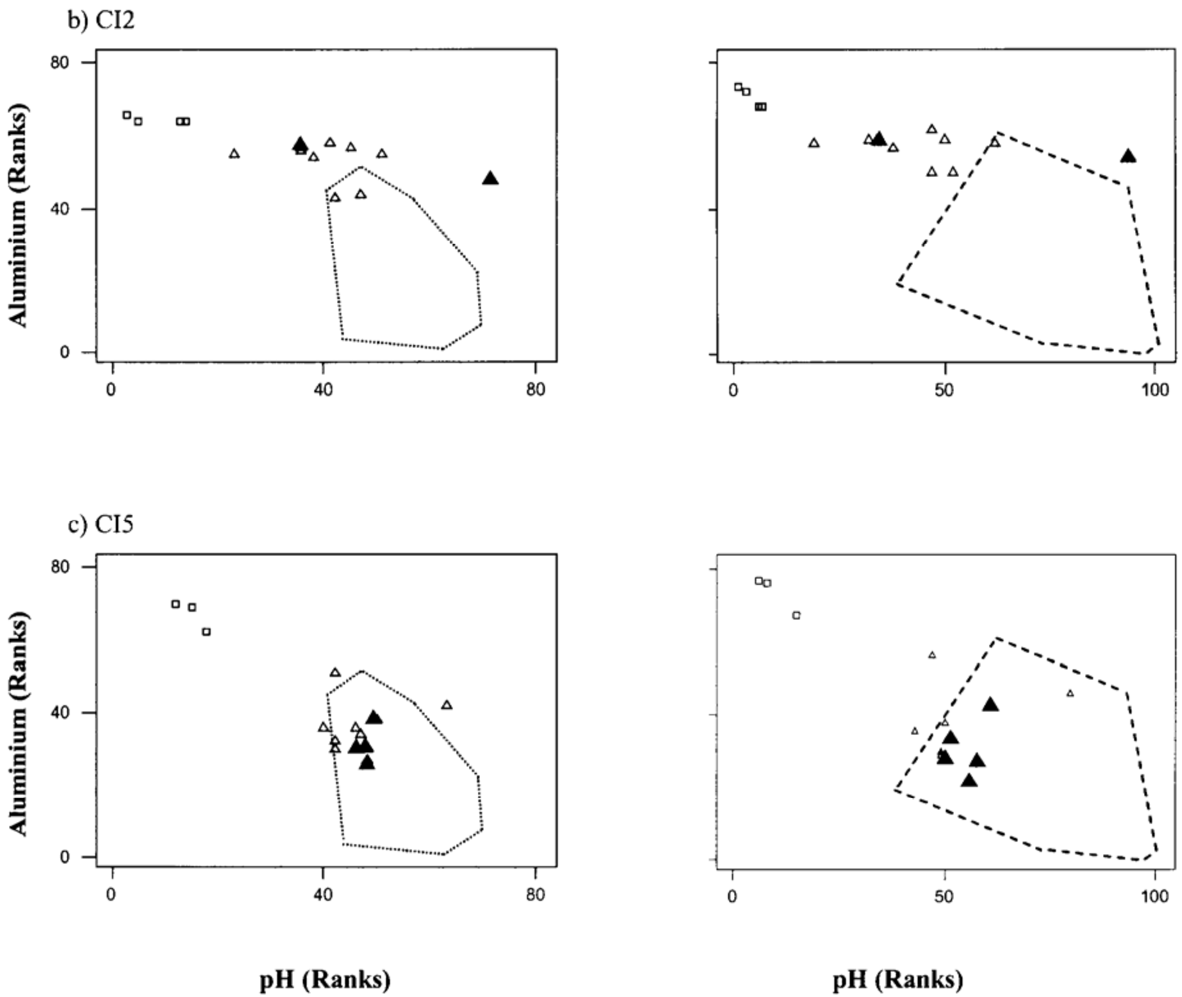
Regional surveys across Wales have revealed the water quality needs of invertebrates………



Baetis rhodani prefers high pH/low Al streams….

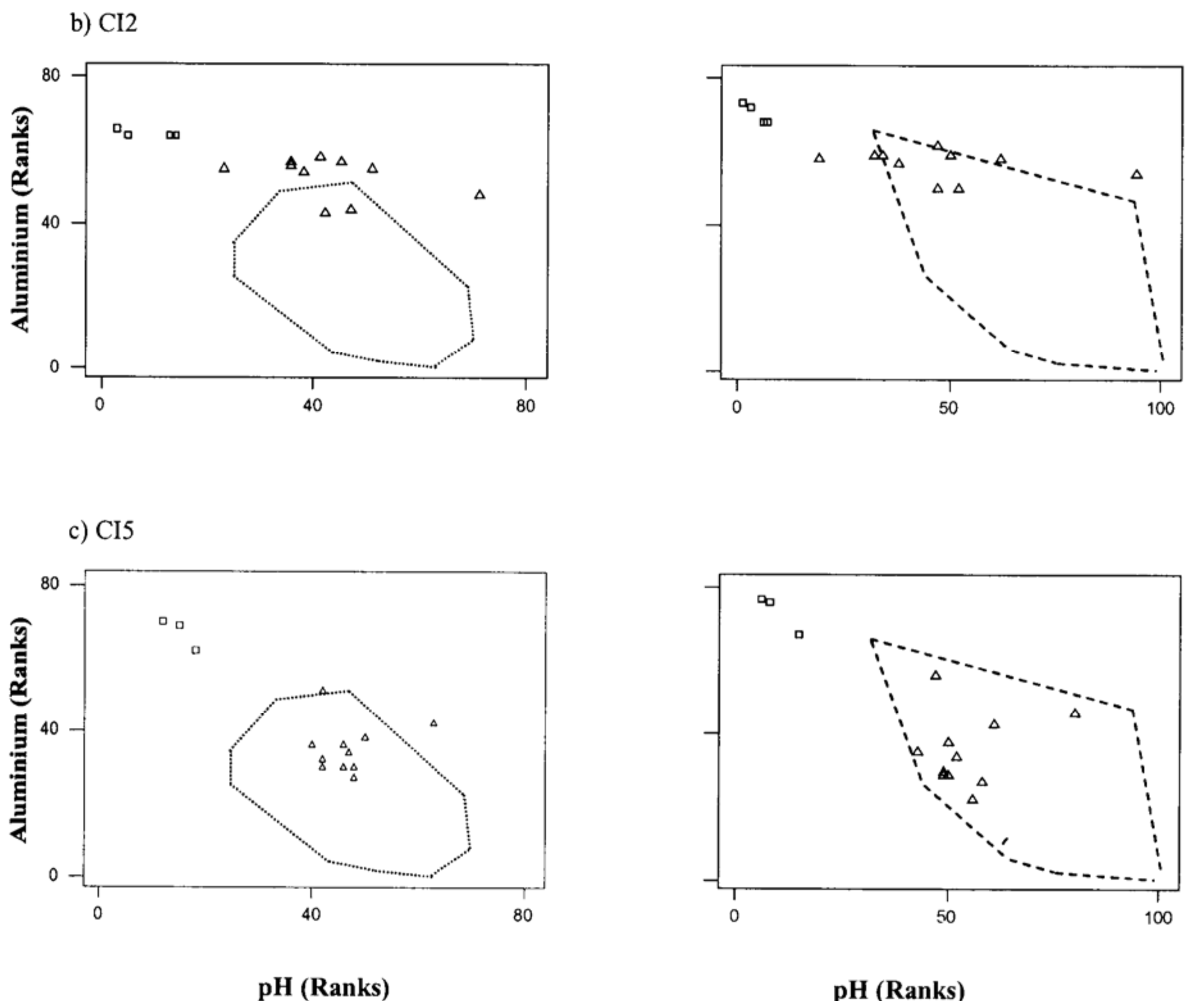
(Masters & Ormerod unpubl.)

Catchment liming at Llyn Brianne provided water quality suitable for *Baetis rhodani* which sometimes occurred thereafter…..



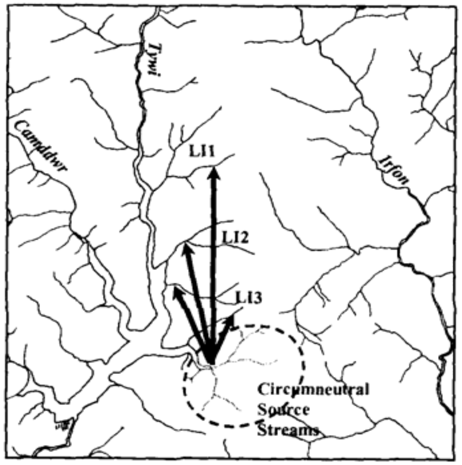
(Masters & Ormerod unpubl.)

Catchment liming at Llyn Brianne provided water quality suitable for *Rhithrogena semicolorata* which never occurred thereafter…..

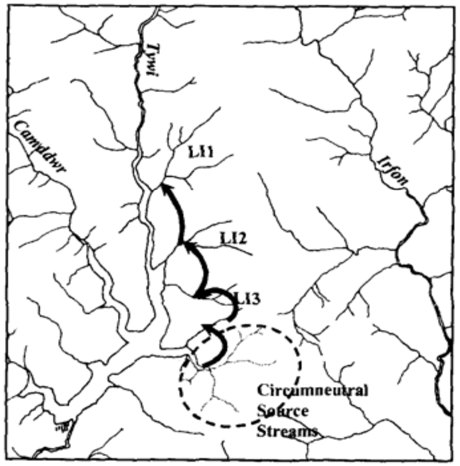


(Masters & Ormerod unpubl.)

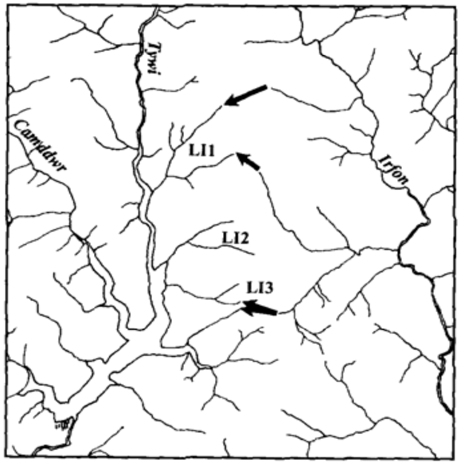
Might dispersal be a limiting factor ?



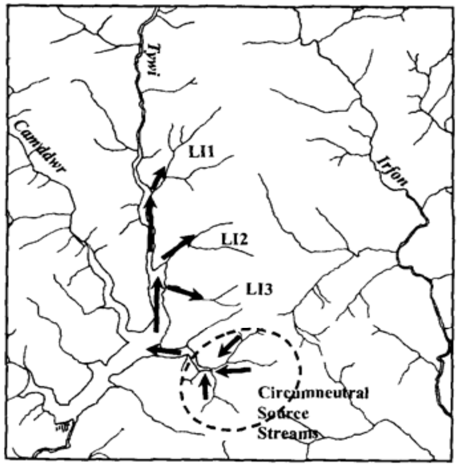
i) Overland flight (at height/with wind)



ii) "Stepping stone"(adjacent streams colonised)



iii) Flight between headwaters



iv) Flight over water

(Masters & Ormerod unpubl.)

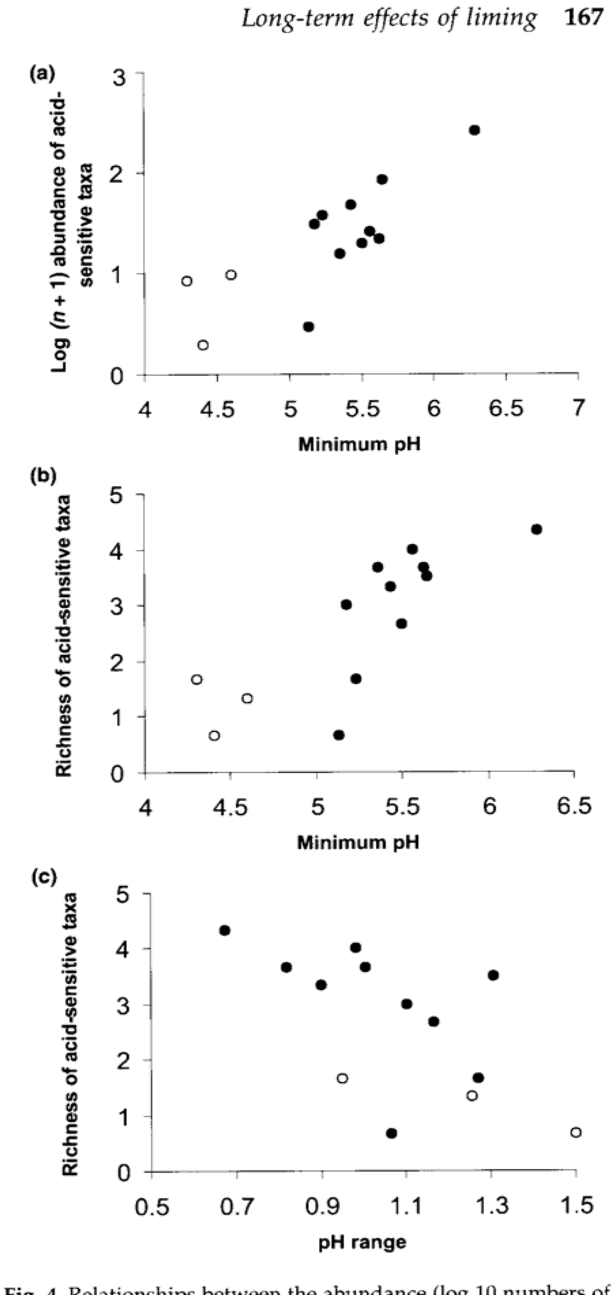
Adult invertebrates at Llyn Brianne occur often alongside streams where they are absent as larvae.

Table 6.1: The abundance of acid-sensitive insect species, in their larval and adult stages, across 7 adjacent catchments of varying acidity in mid-Wales. Black symbols = total abundance of adults (A) in malaise traps (within species-specific flight periods): · = <10, • = 10-100, ● = >100. Grey symbols = mean abundance of larvae (L) in annual kick samples: · = <10, • = 10-100, ● = >100. Data for LI4 are post-liming (i.e., post 1988).

Species	Site													
	LI1		**LI2**		**LI3**		**LI4**		**LI5**		**LI6**		**LI7**	
	A	L	A	L	A	L	A	L	A	L	A	L	A	L
Ephemeroptera														
Baetis spp.			·		·		•	·	●	·	●	•	●	●
Heptagenia lateralis						·		·		·	●	·	●	•
Paraleptophlebia submarginata													·	·
Rhithrogena semicolorata	·				·				·		•	•	•	●
Plecoptera														
Brachyptera risi	·	·	·	·	•	·	·	·	•	·	•	•	●	•
Chloroperla tripunctata						·		·	•	·	•	·	●	·
Isoperla grammatica	·		·		•		·	·	●	•	●	•	●	•
Leuctra inermis	·	·	•	·	●	·	·	•	●	●	●	●	●	●
Trichoptera														
Diplectrona felix			·				•	·	·	·	·	·	•	·
Drusus annulatus		·		·	·				•	●	•	·	●	•
Glossosoma sp.		·	·										•	·
Philopotamus montanus			·		·		·		·		●	·	●	·
Sericostoma personatum			·		·		·	·	·		·	·	·	·
Wormaldia sp.							•	·	·	·	•	·	•	·

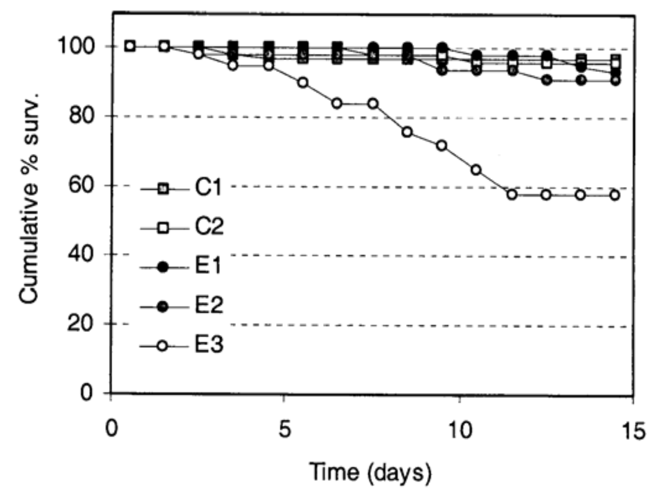
(Masters & Ormerod unpubl.; all data from Malaise trapping)

Acid episodes might be a continuing problem…..



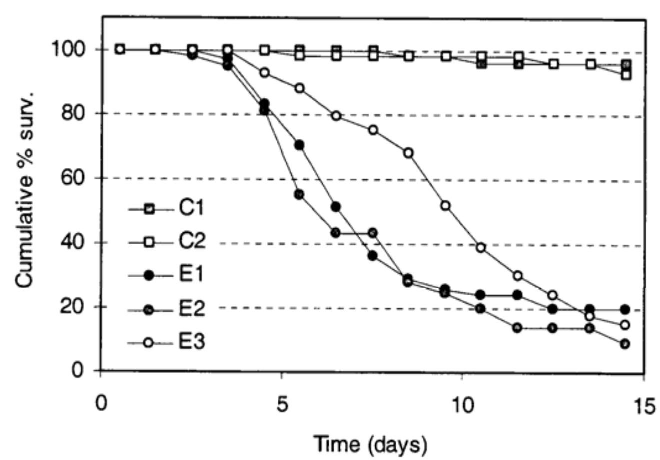
(Bradley & Ormerod 2001)

A) Series I (low flow)



Episodes bring conditions that are toxic for *Baetis* in streams where they survive at low flow.

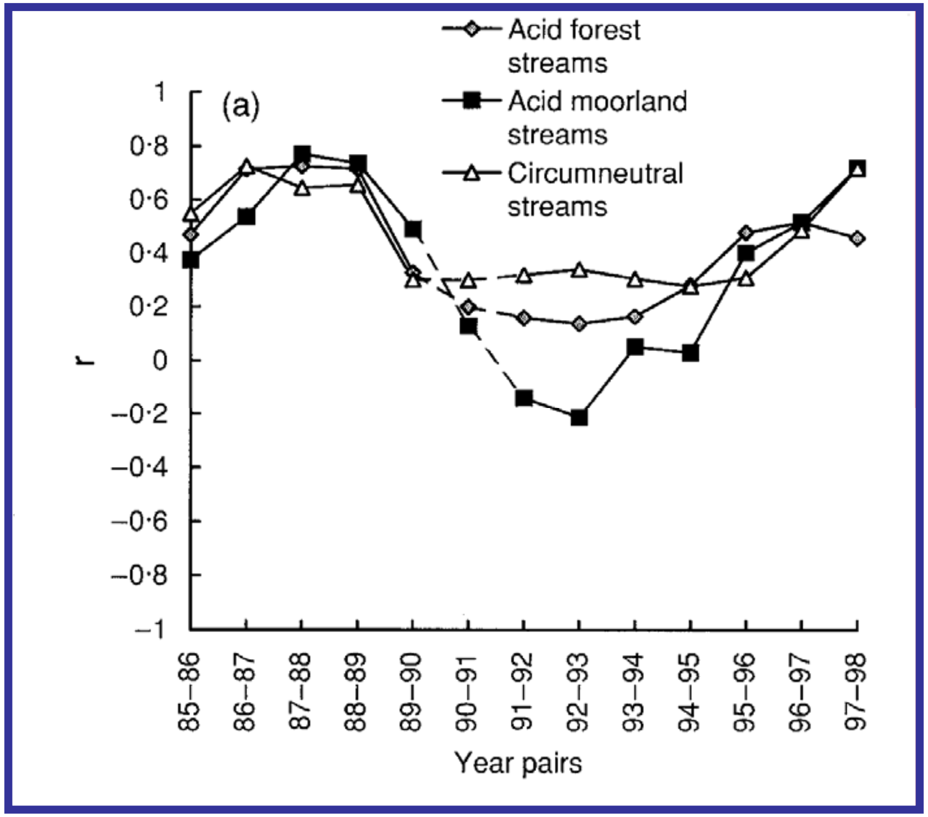
B) Series II (high flow)

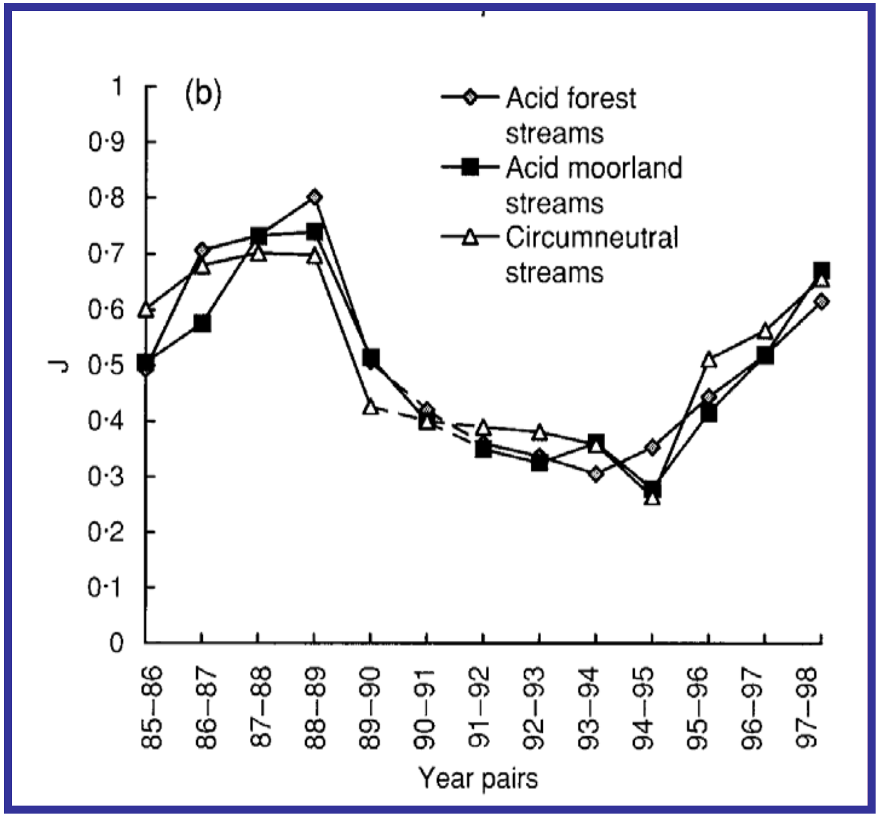


(Lepori & Ormerod unpubl.)

And what about changing climate ?

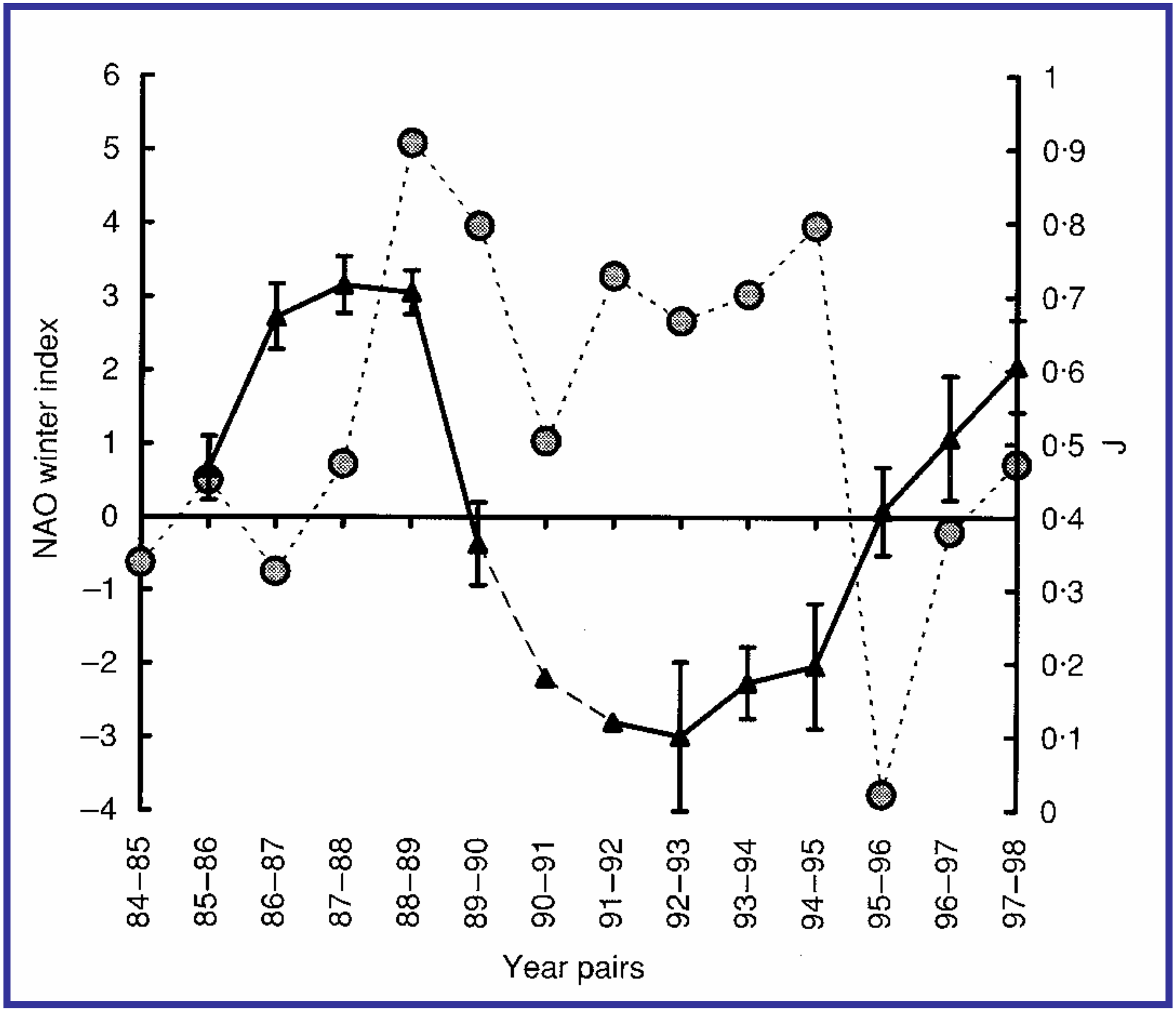
(Bradley & Ormerod 2001)





Year-to-year trends in community persistence in replicate groups of streams at the Llyn Brianne experimental catchments, 1985-1998

(Bradley & Ormerod 2001)



Year to year trends in community persistence and the NAO winter index

Imagine it had started here……

Llyn Brianne project starts

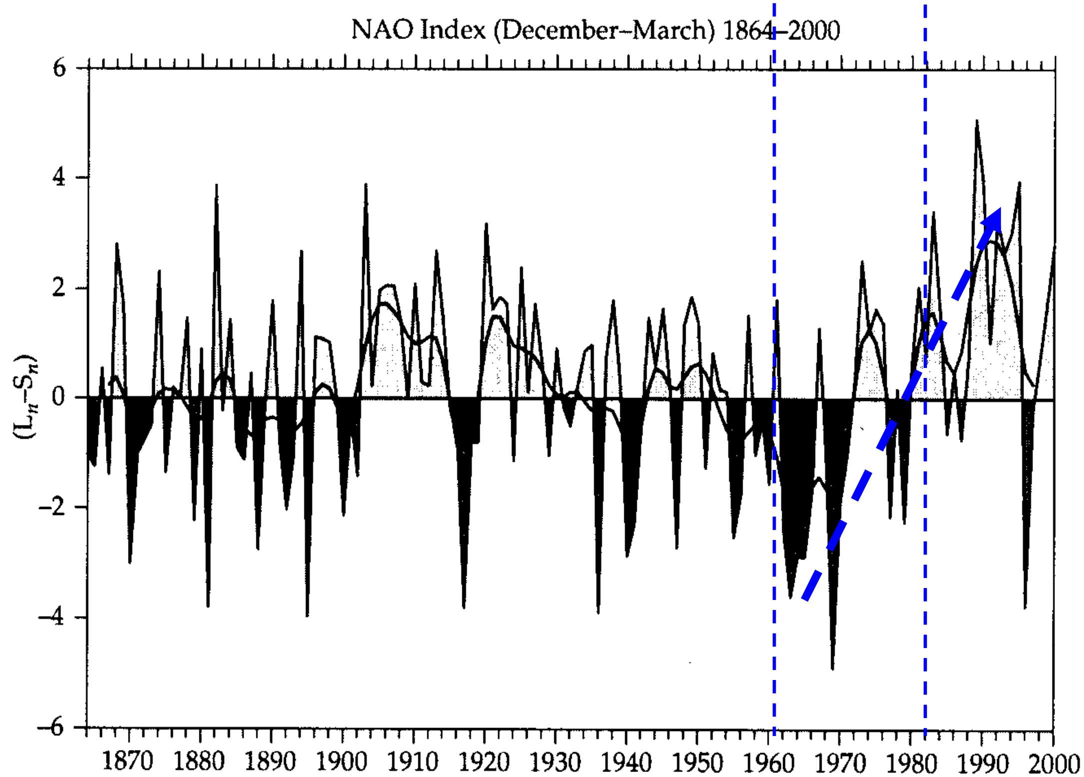


Figure 2.2 Winter (December–March) index of the NAO based on the difference of normalized SLP between Lisbon, Portugal, and Stykkisholmur/Reykjavik, Iceland from 1864 through 2000. The indicated year corresponds to January (e.g. 1950 is December 1949–March 1950). The average winter SLP data at each station were normalized by division of each seasonal pressure by the long-term mean (1864–1983) standard deviation. The heavy solid line represents the index smoothed to remove fluctuations with periods less than 4 years.

J. W. Hurrell et al. 2004

On river and channel restoration:

"….abiotic endpoinds such as physical quality and water quality are appropriate targets for restoration rather than biological endpoints such as density, diversity or production of certain species."

"….. If natural hydrology and morphology are recreated, with careful consideration given to hydraulic aspects, then there is every possibility that natural ecological recovery will follow."

A. Brookes and F. D. Shields (1996) River channel restoration: guiding principles for sustainable projects. Wiley.

Some conclusions:

1. The restoration of river ecosystems is not straightforward: habitat or water quality in isolation is insufficient to deliver success.
2. Shortfalls arise sometimes because restoration is insufficiently extensive in scale…
3. … or because abiotic limits over-ride restoration efforts (water quality including episodes, habitat quality, misdiagnosis of abiotic limits, disturbance caused by restoration, externalities – eg climate …);
4. …or because intrinsic biological limits offset recovery (dispersal, colonisation, competition, population recovery, food-web effects, rarity…).
5. The more we understand, the better is the chance of success, but our efforts must be truly inter-disciplinary.