Collaboration for Environmental Evidence

Systematic Review No. 76

WORKING TITLE: Is 'liming' of streams and rivers an effective intervention for managing water quality to support fish and invertebrate populations?

Review Protocol

Lead Reviewer: **Rebecca Mant**

Postal Address:
Centre for Evidence-Based Conservation
School of the Environment and Natural Resources
Bangor University
Bangor
LL57 2BU

E-mail Address: **r.mant@bangor.ac.uk**
Telephone: +44 (0) 1248 382953
Fax: +44 (0) 1248 354997

Cover Sheet

Title	*Working title: Is 'liming' of streams and rivers an effective intervention for restoring water quality to support fish and invertebrate populations?*
Systematic review	*Number 76*
Reviewer(s)	*Rebecca Mant, Diane Jones, James Bussell, Davey Jones, Doug Godbold, Brian Reynolds, Steve Ormerod and Andrew Pullin*
Date draft protocol published on website	*10th July 2009*
Date final protocol published on website	*21st July 2010*
Date of most recent amendment	*21th July 2010*
Date of most recent SUBSTANTIVE amendment	
Details of most recent changes	*Update to search criteria*
Contact address	Centre for Evidence-Based Conservation School of the Environment and Natural Resources Bangor University Bangor LL57 2UW
Sources of support	This review is funded by the UK Natural Environment Research Council.
Conflicts of interest	None declared

1. Background

Acidification of streams and rivers has long been of concern to environmental managers. Significant changes in the pH of water bodies are primarily caused by increased acid deposition since the industrial revolution. This phenomenon has been popularly termed 'Acid Rain'. Considerable efforts to manage industrial emissions that were contributing to acid rain have been made since the 1980's. Subsequently, some streams and rivers have recovered naturally, at least in terms of their chemical characteristics (Davies et al. 2005; Reynolds et al. 2004). Biological recovery, in terms of fish and invertebrates, has often been slow to follow on (Ormerod & Durance 2009).

Acidified waters frequently undergo changes in stocks of fish and invertebrates (Herrmann et al. 1993). Land and river managers have developed tools to mitigate the effects of acidification and maintain biologically healthy water courses (e.g. Ormerod et al. 1990). One typical intervention is to add calcium carbonate (lime) to the system in order to raise the pH. Several methods of 'liming' have been used; from stream source (Miller et al. 1995) and point source dosing using lime dosers (Fjellheim & Raddum 2001), to catchment scale applications (Dalziel et al. 1994).

One of the best ways to monitor the effectiveness of these liming interventions uses multiple long-term case studies (Ormerod & Durance 2009). However, funding of such long-term studies is often unavailable and only a few are successfully established (Fjellheim & Raddum 2001). More often, monitoring of the effects is over shorter time scales (Simmons & Doyle 1996; Weatherley & Ormerod 1992).

This systematic review aims to find the best available evidence on the effectiveness of liming in restoring suitable habitat in streams and rivers for invertebrates and fish.

2. Objective of the Review

2.1 Primary question

Is liming of streams and rivers an effective intervention for restoring water quality to support fish and invertebrate populations?

The question contains the following components:

Subject: Streams and Rivers

Intervention: Liming of streams and rivers

Outcome: Change in abundance of fish species, diversity/richness of invertebrates, species composition.

Comparator: No intervention or before after studies or both (Before after control impact studies - BACI)

3. Methods

This review is part of a collaboration between Environment Agency Wales (EAW) and the Centre for Evidence Based Conservation (CEBC). The review question has been formulated following consultation with the EAW's policy group and staff at Cardiff and Swansea who form the stakeholder group for the review.

3.1 Search strategy

The search aims to capture an unbiased and comprehensive sample of the literature relevant to the question, whether published or unpublished. Different sources of information will be searched in order to maximise the coverage of the search.

3.1.1 Search terms

Search terms are separated into those relevant to the subject, those relevant to the intervention and those relevant to the outcome of the question. These will be combined in the most efficient way possible depending upon which database is being searched. For example, Web of Science would typically allow combinations of all terms in one search. * denotes wildcard.

Subject: Stream, River, Catchment, brook, creek, burn, fluvial, source area, gravel.

Intervention: Liming, lime*, chalk*, calcium carbonate, dolomite.

Outcome: Fish* (includes fishes, fishery etc.), Salmo*, Trout, Marcroinvertebrate*, Invert*, macrofauna, meiofauna, insect*, Ephemeroptera, Plecoptera, Trichoptera, Mollus*, crustacea*, microcrustacea*, bivalve*, gastropod, zooplankton, coleopteran, chironomid.

Outcome measure: Abundance, diversity, richness.

Scandanavian search terms:
Stream = vandløb, bekk
River = flod, elv
Lake = sø, sjö, innsjø/vann
Catchment = (no direct translation seems possible - often rewriten to make use of the term groundwater ("grundvand") instead)
e.g.catchment area = "grundvandsdannende område" (also "opland" is seen used for "catchment"), Avrinngsområde, Nedbørsfelt
Liming = kalkning
lime = kalk
Fish = fish

Salmon = laks, lax, laks
Trout = ørred, öring, ørret
Marcroinvertebrate = makroinvertebrater
macrofauna = makrofauna
meiofauna = meiofauna
insect = insekt
abundance = rigelig, overflod
(depends on context)
antal = number,
mangd = amount or large number, overflod, riklig

diversity = diversitet, mangfold
richness [depends on context] = mangfoldighed;
frugtbarhed, mångfald or biologiskamångfald, rikdom, mangfold

Where possible a search will contain at least one term from each category. Terms within categories will be linked with the Boolean operator 'OR'. Terms between categories will be linked with the Boolean operator 'AND'. The outcome measure terms will not be included within the searches as scoping indicated they exclude several relevant articles.

3.1.2 Databases

The search aims to include the following online databases which cover the breadth and depth of available literature on the topic:

1) ISI Web of Knowledge
2) Science Direct
3) Directory of Open Access Journals
4) Copac
5) Index to Theses Online
6) CAB Abstracts
7) ConservationEvidence.com
8) CSA Illumina (Aqualine, ASFA1, ASFA3, Biology Digest, BioOne, Conference papers Abstracts, Ecology Abstracts, Pollution Abstracts)
9) Agricola

No time, language or document type restrictions will be applied. Where possible references retrieved from the computerised databases will be exported into a bibliographic software package (Endnote 9) and duplicates removed prior to assessment of relevance using inclusion criteria (Section 3.2).

3.1.3 Websites

An Internet search will also be performed using meta-search engines and recommended sites:

http://www.alltheweb.com
http://www.dogpile.com
http://www.google.com
http://scholar.google.com
http://www.Scirus (All journal and web sources)
http://data.esa.org/

The search will be limited to Word and/or PDF documents where this can be separated and the first 50 hits will be examined for appropriate data which will be retrieved (Section 3.2.).

3.1.4 Specialist sources

Websites of relevant specialist organisations, listed below, will also be searched. Bibliographies of included material will be searched for relevant references. Authors of relevant articles will also be contacted for further recommendations, and for provision of any unpublished material or missing data. Links pages of websites will be followed to look for relevant organisations that may have been missed by these searches.

Fisheries research service (SERAD) – Lock Dee study
Salmon and trout association
Anglers trust
Scandinavian organisations – to be finalised

Alterra
British Ecological Society
Centre for Ecology and Hydrology
Countryside Council for Wales
Department for the Environment, Food and Rural Affairs
Dŵr Cymru / Welsh Water
Environment Agency
Environment Canada
Environmental Protection Agency
Environment Protection Agency Ireland
EHS –Northern Ireland Environment Agency
European Commission Joint Research Centre
European Environment Agency
International Union for Conservation of Nature
Joint Nature Conservation Committee
Macaulay Land Use Research Institute
National Parks
Natural England
Natural Resources Canada
Research Councils UK
Severn Trent Water
Scandinavian Environment Agencies
Scottish Agricultural College
Scottish Executive

Scottish Environment Protection Agency
Scottish Natural Heritage
Society for Ecological Restoration
United States Environment Protection Agency
United Utilities
Welsh Assembly Government
Yorkshire Water

3.2 Study collection

Articles retained in the Endnote database by the above search strategy will be subject to a three stage process to identify the most relevant articles for the review question. The aim of this process is to systematically remove studies that are not relevant or do not contain relevant information or data. At each stage, if there is insufficient information to exclude a study it will be retained until the next stage.

In the first instance, the inclusion criteria, which are identified below, will be applied to the title of the article only in order to remove spurious citations. Articles remaining after this filter will be filtered on viewing the abstract and then the full text.

To assess and limit the effects of between-reviewer differences in determining relevance, two reviewers will apply the inclusion criteria to 20% of articles at the start of the abstract filtering stage. The kappa statistic (Edwards et al. 1985) will be calculated, which measures the level of agreement between reviewers. If kappa is less than 0.6, the reviewers will discuss the discrepancies and clarify the interpretation of the inclusion criteria. This may entail a modification in the criteria specification. After this discussion, one reviewer will apply the inclusion criteria to the rest of the citations.

To reduce duplication of effort web searches will be performed after the articles found in the database searches have been sorted to inclusion at full text level. Only the first 50 hits from web searches will be included. URLs for hits deemed relevant at the title and abstract level (or introduction section if an abstract is not available) will be maintained within an Excel spreadsheet, and subsequently viewed at full text.

3.2.1 Study inclusion criteria

Each article must pass each of the following criteria in order to be included after each filter. However, on cases of uncertainty, the reviewer will tend towards inclusion.

- **Relevant subject(s):** Any stream, river, or catchment that is suffering, or has suffered, from the effects of anthropogenic acidification.

- **Types of intervention:** Addition of lime to ameliorate the effects of acidification in streams, rivers, and catchments. Methodologies include hydrological source liming, point source liming, doser liming, stream liming,

river liming, and catchment liming. No particular method of liming will be excluded.

• **Types of comparator:** No intervention or before after comparisons or both (Before after control impact studies – BACI).

• **Types of outcome:** Change in abundance or density of fish species. Diversity or richness of invertebrates or invertebrate groups.

• **Types of study:** Any primary study comparing limed and un-limed subjects whose outcomes fit the above. Review articles will not normally contain primary data but will be searched for the primary studies they include. No geographic restriction will be applied to this review.

3.3 Study quality assessment

Before data extraction (section 3.4) study quality assessment is required to add quality covariates to the analyses. Well-conducted studies of high quality have less potential for bias than their poorer counterparts. Reviewers will assess the methodologies used in all articles accepted at full text.

Study quality will be scored according to a hierarchy of evidence adapted from systematic review guidelines used in medicine and public health (Stevens & Milne 1997) and conservation (Pullin & Knight 2001); e.g. a randomised control trial would be weighed higher than a site comparison study. A second reviewer will examine a random subset of at least 25% of the selected studies to assess repeatability of study quality. Disagreement regarding study quality will be resolved by consensus, or following assessment by a third reviewer.

Experimental design in these studies is likely to include:

- Multiple before and after measures on the same river.
- Single before and after measures on the some river.
- Upstream control on the same river.
- Paired rivers or catchments, one with no intervention.
- Multiple rivers or catchments, some with either no intervention or gradients of intervention intensity.
- Combinations of these designs leading to BACI type studies.

The study quality assessment methodology will be further developed once the articles included in the review have been identified.

3.4 Data extraction strategy

The availability of data will not be known until after applying the inclusion criteria. Where possible, data will be extracted from each article and recorded in a spreadsheet. Data to be extracted will include the data on the outcomes, methodology and other factors that have been identified as reasons for

heterogeneity in outcome (effect modifiers). **Potential reasons for heterogeneity are:**

Characteristics of the subject e.g. flow rate, water temperature, river width, catchment size, Strahler stream order, riparian zone width, level of afforestation in catchment. drainage pattern, conservation status of catchment or river, soil type, geology, age of forest, age of catchment, fish condition, age structure of fish, soil type base flow, residence time, barriers.

Chemical characteristics e.g. Calcium, Aluminium, Sulphur (SO_4, SO_2), Nitrogen (NO_X), dissolved organic carbon, Iron, pH, hardness, alkalinity. Phosphorus (SRP and TP).

Methodological variables e.g. liming method, type of lime, time since intervention, longevity of intervention, outcome measure used (Shannon, Margalef, richness etc.), invertebrate sample method, fish sample method, method of analysis.

General study variables e.g. latitude and longitude of study site, altitude, mean annual temperature, mean annual precipitation, timing of snow melt, presence or absence of acid sensitive taxa, additional interventions such as fish stocking, North Atlantic Oscillation Index, presence of sea salt episodes (periods of increased salinity).

Data extraction forms will be piloted on a purposive sample of the articles, to represent the range of articles available, and amended if necessary to improve repeatability and efficiency. Missing data (e.g. sample size or variance) will be calculated or inferred where possible from the summary statistics presented, or the authors contacted.

3.5 Data synthesis

If extracted data are suitable for quantitative synthesis, we will aim to calculate effect sizes and carry out a meta-analysis. Sensitivity analysis will be run to explore the effects of including studies with different designs and methodological quality. Variation in effect sizes between studies will be explored using *a priori* reasons for heterogeneity.

If insufficient data are extracted or data are mainly of low methodological quality, we will summarise the outcomes of studies in tables or by using harvest plots.

4. Potential Conflicts of Interest and Sources of Support

None identified. The project is funded by the Natural Environment Research Committee UK (NERC).

5. References

Dalziel, T. R. K., E. J. Wilson, and M. V. Proctor. 1994. The Effectiveness of Catchment Liming in Restoring Acid Waters at Loch-Fleet, Galloway, Scotland. Forest Ecology and Management **68**:107-117.

Davies, J. J. L., A. Jenkins, D. T. Monteith, C. D. Evans, and D. M. Cooper. 2005. Trends in surface water chemistry of acidified UK Freshwaters, 1988-2002. Environmental Pollution **137**:27-39.

Fjellheim, A., and G. G. Raddum. 2001. Acidification and liming of River Vikedal, western Norway. A 20 year study of responses in the benthic invertebrate fauna. Water Air and Soil Pollution **130**:1379-1384.

Herrmann, J., E. Degerman, A. Gerhardt, C. Johansson, P. E. Lingdell, and I. P. Muniz. 1993. Acid-Stress Effects on Stream Biology. Ambio **22**:298-307.

Miller, J. D., H. A. Anderson, R. Harriman, and P. Collen. 1995. The consequences of liming a highly acidified catchment in central Scotland. Water Air and Soil Pollution **85**:1015-1020.

Ormerod, S. J., and I. Durance. 2009. Restoration and recovery from acidification in upland Welsh streams over 25 years. Journal of Applied Ecology **46**:164-174.

Ormerod, S. J., N. S. Weatherley, W. J. Merrett, A. S. Gee, and P. G. Whitehead. 1990. Restoring Acidified Streams in Upland Wales - a Modeling Comparison of the Chemical and Biological Effects of Liming and Reduced Sulfate Deposition. Environmental Pollution **64**:67-85.

Reynolds, B., P. A. Stevens, S. A. Brittain, D. A. Norris, S. Hughes, and C. Woods. 2004. Long-term changes in precipitation and stream water chemistry in small forest and moorland catchments at Beddgelert Forest, north Wales. Hydrology and Earth System Sciences **8**:436-448.

Simmons, K. R., and K. Doyle. 1996. Limestone treatment of Whetstone Brook, Massachusetts .3. Changes in the invertebrate fauna. Restoration Ecology **4**:284-292.

Weatherley, N. S., and S. J. Ormerod. 1992. The Biological Response of Acidic Streams to Catchment Liming Compared to the Changes Predicted from Stream Chemistry. Journal of Environmental Management **34**:105-115.