



CEE review 11-003

WHAT IS THE IMPACT OF 'LIMING' LAKES ON THE ABUNDANCE AND DIVERSITY OF LAKE BIOTA?

Systematic Review Protocol

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1. Background

“Acid rain” and the associated acidification of waterways first became a widespread environmental concern in the 1970’s (Menz and Seip 2004). Since the industrial revolution humans have been releasing sulphur and nitrogen oxides into the atmosphere from industrial emissions, causing a decrease in the pH of rainfall in many areas, and hence of associated water bodies.

Acidification frequently causes changes in freshwater ecosystems including in the fish and invertebrates (Schindler et al 1985, Moiseenko 2005). In order to mitigate the problems of ‘acid rain’, including acidification of water bodies, considerable efforts have been made to reduce industrial emissions since the 1980’s. The emissions of sulphur have been successfully reduced through various legislations, both in Europe and North America, reducing the acidity of rainfall (Evans et al 2001). However, recovery is not uniform, there are still areas where the acid load outstrips the soils neutralizing capacity, nitrate emissions have not decreased to the same extent as sulphate emissions and the recovery of areas with decreased deposition is not uniform. Thus, there are still many areas that suffer from acidic surface waters and it may be many years before all surface waters recover, if ever (Evans et al 2001).

In order to protect lakes and fish stocks until the emissions can be reduced other methods have had to be implemented. One of the most widespread mitigation techniques is adding of calcium carbonate (lime) in order to raise the pH (Henrikson and Brodin 1995, Clair and Hindar 2005). Liming has been implemented in North America and many European countries but the largest liming programs are in Norway and Sweden. Sweden has invested 3.8 billion SEK (approximately €0.4 billion) on liming between 1983 and 2006 (Bostedt et al 2010).

Several studies have shown liming to increase salmon and trout stocks (ref), however there has previously been no systematic review of the impact and the impact of liming on other biota is more uncertain. Therefore this systematic review aims to find and summarise the best available evidence on the impact of liming on invertebrates, fish, diatoms and macrophytes (a sister review, CEE-09-015, is being conducted on river and streams; the reviews were divided as different parts of an ecosystem may react differently to liming). In conducting this review the impact of different liming techniques will also be investigated.

2. Objective of the Review

2.1 Primary question

Is liming of lakes an effective intervention for restoring water quality to support lake biota?

The question contains the following components:

Subject: Biota in freshwater lakes (of all sizes, although size will be included in later analysis)

Intervention: Liming of lakes (including the indirect liming of lakes by liming of catchment areas and tributaries).

Outcome: Change in abundance and diversity of lake biota; fish, invertebrates, zooplankton, phytoplankton and macrophytes.

Comparator: No intervention or before the intervention or both

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.

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: Lake, Catchment, watershed, loch, pond, llyn, mere, tarn

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

Outcome:

Fish* (includes fishes, fishery etc.), Salmo*, Trout, Roach, rutilus, charr, salvelinus, Perch, Pike,

Invert*, Macroinvertebrate*, macrofauna, meiofauna, zooplankton, crustacea*, microcrustacea*, daphnia, insect*, Ephemeroptera, Plecoptera, Trichoptera, coleopteran, chironomid, Mollus*, bivalve*, gastropod,

phytoplankton, diatom*, cyanobacteria, Macrophyte*

Terms within categories will be linked with the Boolean operator 'OR'. Terms between categories will be linked with the Boolean operator 'AND'. All combinations of terms will be covered by the search. The final search string will be made available (in text or as an appendix) in the final review.

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. However, only English language terms will be searched as most databases convert titles into English (in order to reduce the chances of missing non-English studies, specific websites and organisational databases will be searched, see section 3.1.4). 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

The Swedish, Norwegian and Finnish environment agencies will be contacted in order to increase the likelihood of Scandinavian language reports being found. Through the national environment agencies we hope to access general Scandinavian language reports, specific national

environment agency reports and local/regional environment agency reports.

Websites of relevant specialist organisations, listed below, will also be searched (including using the term 'liming' in the native language of the organisation). Bibliographies of included material will be searched for relevant references. Links pages of websites will be followed to look for relevant organisations that may have been missed by these searches.

Alterra
Anglers trust
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
Norwegian Institute of Water Research (NIVA)
Norwegian Institute of Air Research (NILU)
Norwegian Institute of Natur Research (NINA)
Ontario Ministry of Environment (Dorset Research Centre).
Research Councils UK
Salmon and trout association
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

All articles retrieved will be entered into an Endnote database and duplicates removed. The articles which are relevant to the specific question being asked will be identified in three stages using specific inclusion criteria. In order to systematically remove articles which do not contain relevant data. At each stage, if there is insufficient information to exclude a study it will be retained.

At the first stage only the titles of the articles will be assessed and irrelevant articles removed (according to the inclusion criteria listed below). Articles remaining after this first stage 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. 2002) 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.

3.2.1 Study inclusion criteria

Each article must pass all of the following criteria in order to be included at each stage. If there is uncertainty the reviewer will tend towards inclusion.

- **Relevant subject(s):** Biota in freshwater lakes (of any size – the effect of size will be investigated in the review).
- **Types of intervention:** Direct or indirect addition of lime to ameliorate the effects of acidification; including directly adding lime to lakes as well as, indirectly adding lime by liming tributaries or catchments of lakes. All methods of liming will be included.
- **Types of comparator:** No intervention or before after comparisons or both (Before after control impact studies – BACI).
- **Types of outcome:** Change in abundance/density or richness/diversity of fish, invertebrate, zooplankton, phytoplankton or macrophyte 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

Study quality will be assessed along with data extraction (section 3.4) in order to assess the reliability of and potential bias in the effects reported. 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 categorised 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). The types of study design that may be encountered include:

- BA (Before, After) - Before and after measures of the same lake
- CI (Control, Impact) - Paired lakes, one with treatment, one without
- BACI (Before, After, Control, Impact) – Lakes both with and without treatment, both before and after measurements taken for both.

BACI studies are generally more reliable than BA or CI studies. No studies will be excluded from the review due to study design but their design will be assessed. The number of replicate samples within a lake and the number of lakes included within the study will also be recorded. Studies with more replicates will provide a more reliable estimate of the mean.

Additionally, other potential sources for bias will be assessed. This includes differences in the measurement of the before/after or control/impact data, changes in the lake other than liming over the period of the study ie the presence of stocking of fish and differences between control and treatment lakes other than the treatment (ie where they selected randomly).

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.

3.4 Data extraction strategy

Where possible, data will be extracted from each article and recorded in a spreadsheet. Data on the outcomes, methodology and other factors that have been identified as reasons for heterogeneity in outcome (effect modifiers) will be extracted. Potential reasons for heterogeneity are:

Characteristics of the subject e.g. lake depth, lake volume, **water retention time**¹, level of management of lake, water temperature, level of afforestation in catchment, drainage pattern, soil type, geology, age of forest, age of catchment, fish condition, age structure of fish, barriers.

¹ The time it takes for a changeover (inflow/ outflow) of water equivalent to the volume of the lake.

Chemical characteristics e.g. Calcium, Aluminium, Sulphur (SO₄, SO₂), Nitrogen (NO_x), **dissolved organic carbon**, Iron, pH, hardness, alkalinity. Phosphorus (SRP and TP).

Methodological variables e.g. **liming method**, type of lime, **dose of lime applied**, **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).

If there is limited data available, allowing limited subgroup analysis, the impact of factors in bold will be investigated. These factors were chosen due to being of interest to the stakeholders, suggested by peer-reviewers or having been cited as important factors in the literature (Clair and Hindar 2005) or a combination of these reasons.

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

A narrative synthesis table will be constructed giving information on the methods, outcome and potential bias of each paper. Additionally, wherever possible, an effect size will be calculated for each outcome measure for each study found. If sufficient, suitable data are found we will then carry out a meta-analysis of the data. 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.

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

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