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# *WHAT ARE THE EFFECTS OF SALMONID STOCKING IN LAKES ON NATIVE FISH POPULATIONS AND OTHER FAUNA AND FLORA?*

## *Systematic Review Protocol*

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# CENTRE FOR EVIDENCE-BASED CONSERVATION

## SYSTEMATIC REVIEW NO. 13

# WORKING TITLE: WHAT ARE THE ECOSYSTEM EFFECTS OF SALMONID STOCKING IN LAKES ON NATIVE FISH POPULATIONS AND OTHER FAUNA AND FLORA?


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## REVIEW PROTOCOL

### 1. BACKGROUND

Lake systems are often stocked with salmonid species to provide game fisheries. These fisheries have socio-economic value but concerns have been raised about the potential ecological impact of salmonid stocking (Aprahamian *et al.* 2003). The addition of a species high in the food chain can impact on other organisms, which may have conservation value (Saura *et al.* 1990). Salmonids are usually considered a 'low risk' species in this context, but further investigation is warranted, especially for 'put-and-take' fisheries (i.e. stocking with catchable-size individuals) where fish density is often not closely connected to ecological carrying capacity.

The impact of stocking on the abundance and species richness of non-stocked native fish species is the primary focus of the review. As wild fish populations continue to decline, fisheries managers are increasingly concerned about how hatchery and stocking operations might be contributing to declines of highly valued wild populations (Pearsons and Hopley 1999). Interbreeding between stocked and native fish populations is of interest as population viability may be affected (Youngson *et al.* 2003) and native species lost through hybridisation or being out-competed.

Secondary concerns include changes in the abundance or species richness of other fauna and flora including invertebrates, aquatic plants and plankton.

The species used for stocking of relevance to the review are:
Brown trout *Salmo trutta*
Rainbow trout *Oncorhynchus mykiss* (there are many other *Oncorhynchus* species but they are not usually stocked in the UK)
Atlantic salmon *Salmo salar* (landlocked forms)
Arctic charr *Salvelinus alpinus*
Brook charr *Salvelinus fontinalis*
*Salvelinus* X *Salmo* hybrids

The impact of salmonid stocking may be modified by variation in the number of fish stocked and the time of year when stocking occurs (impacts carrying capacity Milner *et al.* 2003). Other variables identified by Countryside Council for Wales (CCW) in order of importance are: lake type (mean depth and area determine habitat availability and limit carrying capacity Milner *et al.* 2003), sampling method used to assess fish abundance (e.g. rod survey, netting, electro-fishing), presence/absence of sensitive features, initial stocking density (salmonids are density dependent Gibson 1993, Elliott 1994), species stocked (impacts carrying capacity Milner *et al.* 2003), size/age class when stocked (impacts carrying capacity Milner *et al.* 2003), follow-up period (duration of monitoring) and the occurrence of any acid episodes (salmonids do not respond well to variation in pH, Hendry *et al.* 2003). The impact of these potential effect modifiers also requires investigation.

A systematic review methodology will be used to retrieve data pertaining to the impact of salmonid stocking on lake systems. The review will limit bias through the use of a comprehensive literature search with specific inclusion criteria and formal assessment of the quality and reliability of the studies retrieved. Subsequent data synthesis will summarise empirical evidence assisting in the formulation of appropriate evidence-based management guidelines and highlight gaps in research. The review should be of use to policy makers and site managers in the conservation and environment field, such as the Environment Agency (EA), Rivers Trusts and fisheries managers. The scale is primarily of local to national interest but may be of international relevance assuming that any fundamental differences in ecological response in lakes from different geographic areas are identified.

## 2. OBJECTIVE OF THE REVIEW

### 2.1 Primary question

What are the potential ecosystem effects of salmonid stocking in lakes on native fish populations and other fauna and flora?

**Table 1:** Definition of components of the primary systematic review question.

| Subject (Population) | Intervention | Outcome | | |
|---|---|---|---|---|
| | | Primary | Secondary | Tertiary |
| Lake systems | Stocking with Brown trout, Rainbow trout, Atlantic salmon (landlocked forms), Arctic charr, Brook charr, charr X salmon hybrids<br><br>Vs<br><br>No stocking | Change in abundance or species richness of non-stocked fish species | Changes in the abundance or species richness of other species including invertebrates, aquatic plants and plankton. Change in the genetic structure of fish populations. Change in size of individual fish. | Any other outcomes |

### 2.2 Secondary question

What influence does the number of fish stocked, time of year when stocking occurs, lake type (mean depth and area), sampling method used to assess fish abundance (e.g. rod survey, netting, electro-fishing), presence/absence of sensitive features, initial stocking density, species stocked, size/age class when stocked, follow-up period and the occurrence of any acid episodes have on the impact of salmonid stocking in lakes?

## 3. METHODS

### 3.1 Search strategy

The following electronic databases will be searched:

1. ISI Web of Knowledge
2. Science Direct
3. Directory of Open Access Journals (DOAJ)
4. Copac
5. Scirus
6. Scopus
7. Index to Theses Online (1970-present)
8. Digital Dissertations Online
9. Agricola
10. Europa
11. English Nature's "Wildlink"
12. JSTOR
13. BIOSIS via EDINA
14. SIGLE via ARC2WebSPIRS

The following English language and latin search terms will be used:

1. Trout*
2. *Salmo**
3. *Oncorhynchus* and *mykiss*
4. Charr*
5. *Salvelinus**

Further terms may be added as the search progresses involving combination of the existing terms and the use of further taxa-specific terms if necessary. Publication searches will be undertaken on conservation and statutory organisation websites (CCW, Department of Agriculture and Rural Development, Department of Environment, Food and Rural Affairs, English Nature, EA, Freshwater Fisheries Lab, Joint Nature Conservancy Council, National Parks and Wildlife Service, Scottish Natural Heritage) and using the meta-search engines Dogpile, Alltheweb and Google Scholar. Fishbase.org. will also be searched. The first 100 word document or PDF hits from each data source will be examined for appropriate data. Additional foreign language searches will be undertaken on Google to capture information from the following non-English speaking countries with significant salmonid lake fisheries: Denmark, Finland, France, Norway, Spain and Sweden. In addition bibliographies of articles viewed at full text will be searched. Authors, recognised experts and practioners will also be contacted for further recommendations and for provision of any unpublished material or missing data that may be relevant. Participants in the pan-European FAME project (Development, Evaluation and Implementation of a Standardised Fish-based Assessment Method for the Ecological Status of European Rivers) will be asked to provide access to data. Questionnaires will be circulated to practioners in order to collate experience.

### 3.2 Study inclusion criteria

- **Relevant subjects:** Lakes
- **Type of Intervention:** Salmonid stocking vs no stocking.
- **Types of Outcome:** The primary outcome is change in abundance or species richness of native non-stocked fish species. Secondary outcomes are change in the abundance or species richness of other biota including invertebrates, aquatic plants and plankton; changes in the genetic structure of fish populations are also of interest. However studies will not be rejected on the basis of outcome and other outcomes will be catalogued. Adverse outcomes have been defined by CCW as deviation from the Water Frameworks Directive reference condition.
- **Types of Study:** Type of study will not be used to define inclusion or exclusion criteria. It is envisaged that all information regarding the primary outcome will be collated within a Bayesian framework. Appropriate spatial or temporal controls are a prerequisite for studies to be included in inferential meta-analysis.

Where there is insufficient information to make a decision regarding study inclusion when viewing titles and abstracts, then relevance to the next stage of the review process will be assumed. Reviewers will consider articles viewed at full text for relevance excluding or admitting them to different categories of relevance and quality.

At least two reviewers will independently assess a random subset of 25% of articles viewed at full text. Disagreement will be resolved by consensus, or following assessment by a third reviewer.

### 3.3 Study quality assessment

Reviewers will consider articles viewed at full text excluding or admitting them to different categories of information quality. At least two reviewers will independently assess a random subset of 25% of articles viewed at full text. Disagreement will be resolved by consensus, or following assessment by a third reviewer.

### 3.4 Data extraction strategy

Data regarding study characteristics, quality and results will be recorded on a specially designed data extraction form. These forms may be amended after consultation with statisticians and piloting of the data extraction process.

### 3.5 Data synthesis

It is envisaged that all information will be collated either qualitatively or within a Bayesian framework. This will incorporate meta-analysis where appropriate data exists. Reasons for heterogeneity in results including number of fish stocked, time of year when stocking occurs, lake type (mean depth and area), sampling method used to assess fish abundance (e.g. rod survey, netting, electro-fishing), presence/absence of sensitive features, initial stocking density, species stocked, size/age class when stocked, period of follow-up and the occurrence of any acid episodes will be investigated by meta-regression where appropriate data exists.

### 3.6 Reasons for heterogeneity

The following potential reasons for heterogeneity have been formally identified *a priori* in order of importance by CCW.

1. Lake type (especially mean depth)
2. Sampling method (e.g. rod survey, netting, electro-fishing)
3. Presence/absence of sensitive features.
4. Initial stocking density
5. Species stocked
6. Size/age class when stocked
7. Follow-up period
8. Acid episodes

## 4. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

No conflicts of interest to be declared. This systematic review is funded by NERC.

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## 6. APPENDIX

Contacts: Tristan Hatton-Ellis (CCW) and Terry Rowell (CCW).

Stakeholders: Environment Agency fisheries staff, Fisheries staff in other public bodies in Scotland and Ireland, Fisheries Trusts, The Association of Fisheries Trusts and other angling organisations.

Experts (researchers): Ian Cowx (University of Hull), Brian Moss (Liverpool University).