Summary Report

A review of lake restoration practices and their performance in the Broads National Park 1980-2013

Produced by the Broads Authority

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Environment Agency
Essex & Suffolk Water
Norfolk Wildlife Trust
Natural England
Broads Authority

This is a summary document of the main report written by Andrea Kelly, Broads Authority. The main study is a Broads Authority and Natural England initiative, undertaken by Geoff Phillips, Helen Bennion, Martin Perrow, Carl Sayer, Bryan Spears and Nigel Willby, funded by a Broads Authority and Natural England with additional contributions from Environment Agency, Essex & Suffolk Water and Norfolk Wildlife Trust.

Project manager
Andrea Kelly, Senior Ecologist (Broads Authority)

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[1] Honorary - Biological and Environmental Sciences University of Stirling, Stirling FK9 4LA
[2] University College London - Department of Geography, Gower Street London WC1E 6BT
[3] ECON Ecological Consultancy Ltd, Unit 7, Octagon Business Park, Hospital Road, Little Plumstead, Norwich NR13 5FH
[4] University College London - Department of Geography, Gower Street London WC1E 6BT
[5] Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian, UK EH26 0QB
[6] University of Stirling - Biological and Environmental Sciences, Stirling FK9 4LA

Context

1. The Broads Biodiversity and Water Strategy aims to use scientific data 'to improve our knowledge to enable a stronger evidence-based approach to habitats and species management'[1]
2. 'The review of lake restoration practices and their performance in the Broads National Park, 1980-2013' provides an assessment of much of the monitoring data and scientific evidence of lake ecology in the Broads to date.
3. The last time the full range of lake management and restoration measures in the Broads was evaluated was in the mid-1990s[2]. This review evaluates the research, monitoring and management which has been ongoing since then, to understand success of management over a longer time scale, to take account of more recent management measures, and for the first time, to consider the impact of climate change.
4. The review builds on interim results published from the Broads in the 1990s, and recent reviews on the effectiveness of restoration approaches applied to shallow lakes in the Netherlands[3] and Denmark[4,5], to offer new insights into shallow lake restoration.
5. The review has been undertaken by some of the UK's leading freshwater scientists from Centre of Hydrology and Ecology, ECON Ecological Consultancy, Stirling University and University College London.

Purpose

The purpose of this summary is to provide a non-technical short report for stakeholders involved in the Broads. Those who wish to read the full review will find further technical detail on overall ecological trends and responses to management in the Broads in the main report. Within the Annex they will find individual lake dossiers which provide further site specific analysis and discussion.

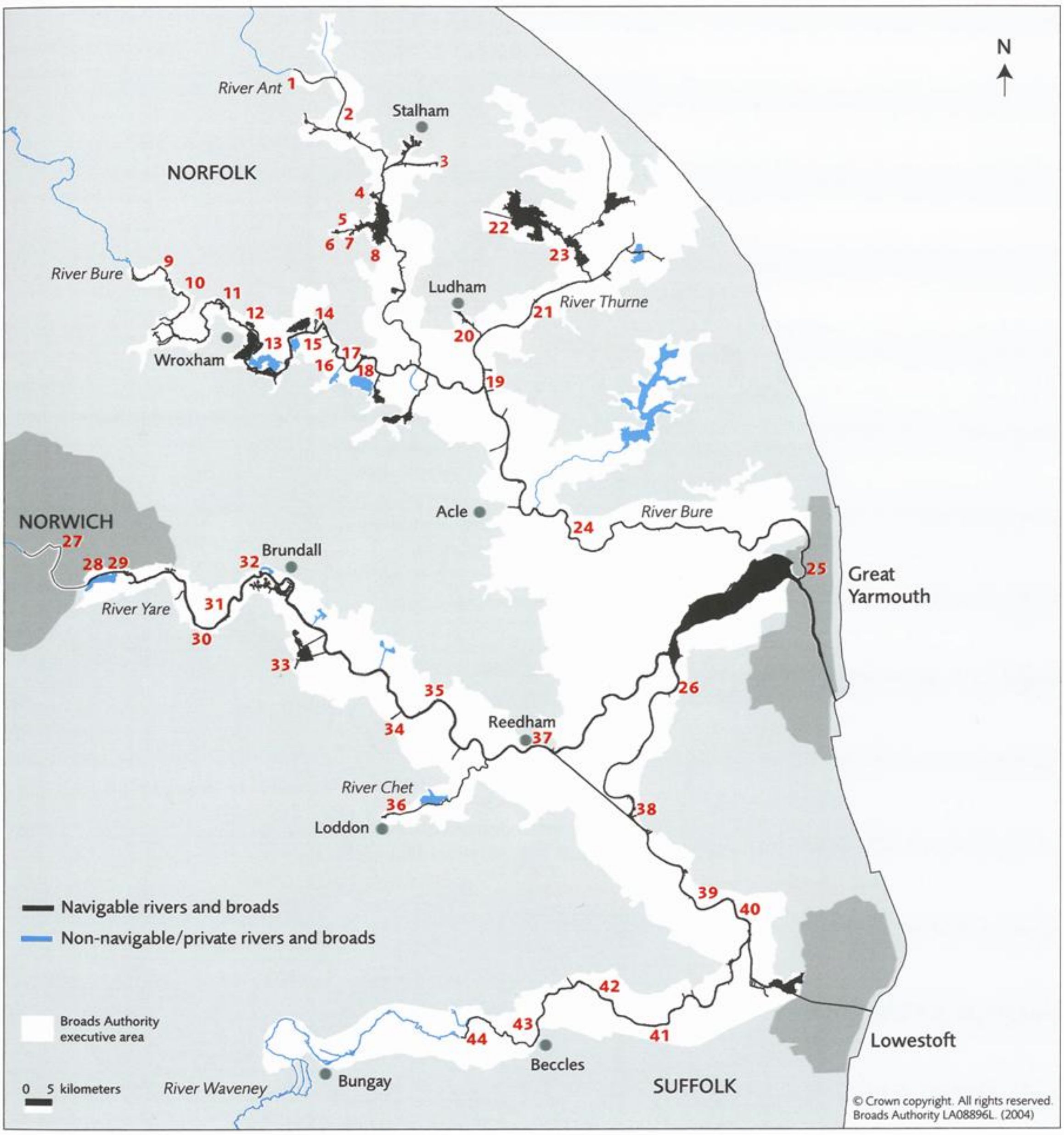
Introduction

The Broads encompasses a large freshwater system of rivers and lakes. There are many stresses on freshwater ecosystems in the Broads and enrichment with nutrients (eutrophication) still represents the single biggest threat. Since the early 1980s, it has been a priority for partner organisations to restore and manage broads which have suffered from eutrophication to create wildlife rich lakes for people to enjoy.

The Broads has immense national significance, both as a resource for tourism, recreational boating and other water-based pursuits, and as a hotspot of aquatic and wetland biodiversity. The 60 or so shallow lakes (Figure 1), formed by the flooding of mediaeval peat diggings, were once clear water, where rich water plant beds supported vast numbers of water birds and excellent fish populations. However, intensification of agriculture and increases in human population density over the last 150 years has put pressures on the

[1] Broads Biodiversity and Water Strategy (2013). Broads Authority Report. The Broads, UK
[2] Madgwick & Phillips, 1996
[3] Gulati et al., 2008
[4] Jeppesen et al., 2012
[5] Sondergaard et al., 2007
See main report for full references

aquatic environment. These pressures include increased nutrients leading to: algal blooms, shadowing out light; almost complete loss of water plants and associated invertebrates; shallowing broads; simplification of the fish community with more small fish that eat *daphnia*, resulting in lower natural water filtration from *daphnia* ('so called water fleas'), and more algal blooms.



1 Dilham Staithe
2 Wayford Bridge
3 Sutton Staithe
4 Paddy's Lane
5 Barton Turf
6 Neatishead
7 Gay's Staithe
8 Irstead Staithe
9 Coltishall Common
10 Belaugh Staithe
11 Hoveton Viaduct
12 Hoveton Horseshoes
13 Wroxham Broad Spit
14 Horning Staithe
15 Horning Island
16 Woodbastwick
17 Cockshoot Dyke
18 Ranworth Staithe
19 Thurne Mouth
20 Womack Island
21 Potter Heigham
22 Catfield
23 Deep and Deep Go Dykes
24 Stokesby
25 Great Yarmouth Yacht Station
26 Burgh Castle
27 Norwich Yacht Station
28 Thorpe Green
29 Whitlingham Cut
30 Bramerton Common
31 Postwick Wharf
32 Brundall Church Marsh
33 Rockland Staithe
34 Langley Dyke
35 Cantley
36 Chedgrave Common
37 Reedham Quay
38 St Olaves
39 Herringfleet
40 Somerleyton
41 Worlingham Staithe
42 Aldeby Hall Staithe
43 Beccles Bypass Bridge
44 Geldeston Lock

Figure 1: Map of locations of the broads

Over the past 45 years, much research into lake ecology and lake restoration has been undertaken in the Broads. In the first instance various measures have been undertaken to reduce external nutrient load working with water companies. Further measures have included working on individual lakes to remove sediment and in some cases attempts to create clear water through selective removal of fish to promote more grazing of algae by *daphnia* (biomanipulation). There have also been several attempts to overcome factors constraining the recovery of water plants such as limiting grazing by feral geese and scrub removal to allow more light into the water bodies.

The aim of the main report, and separate dossiers for each broad, was to provide a comprehensive review of monitoring data collected over a period of intense restoration of the broads since the late 1970s. In addition, the aim was to use this data to assess the impact of restoration efforts and inform future strategic investment in rivers and broads.

It was beyond the scope of the work to compile and analyse all data available for every broad, particularly where common data was not available for each broad. For example there was not accurate data on depth, water volume and flow for each site, or data on heavy metal in the sediment. These data would need to be considered at the site specific level when considering any detailed restoration scheme.

The main report firstly considers the management actions targeted at lake restoration, supported by an analysis of climatic changes, as these potentially have a significant bearing on the interpretation of results, including perceived responses of water chemistry or water plants to management.

It then analyses water chemistry and plant data across the broads network before grouping the broads into isolated, riverine, and near brackish and identifying key thresholds, such as phosphorus, that restoration actions should aim to achieve in order to promote recovery.

The report then explores the effects of the three major restoration methods - external load reduction, sediment removal and biomanipulation.

The final section of the report provides current achievements and challenges and details some remaining questions for future research and monitoring.

In addition, dossiers on individual broads[6] covering the larger or more significant water bodies are annexed.

Significant achievements over the past 30 years as a result of management include:

- Decline in total phosphorus concentrations due to mainly 1. external load reduction and 2. internal load reduction through sediment removal in isolated water bodies
- Increase in water clarity due to the decline in total phosphorus concentrations and, in biomanipulated broads, by increased grazing of phytoplankton by zooplankton.
- Increase in number of water plant species and their abundance in response to increased water clarity
- Increase in rare plants[7] in response to lower nutrient concentrations
- Increase in abundance and occupancy of plant-associated fish species such as rudd and tench.

[6] The broads covered in these dossiers include Alderfen, Barton, Cockshoot, Cromes, Hoveton Great, Hoveton Little and Pound End, Heigham Sound, Hickling, Horsey, Martham North and South, Ranworth, South Walsham, Trinity Broads, Upton and Wroxham.

[7] *Chara spp* and *Najas marina*

Key rules to consider in lake restoration:

- Reduction of external nutrient loading is essential, so that annual mean total phosphorus concentrations are less than 55 μgl^{-1}.
- Consideration of sediment removal or chemical isolation may be required if total phosphorus concentrations cannot be reduced by external load reduction (e.g. in isolated lakes). Success will be variable based on factors such as substrate, water depth and access to plant seeds.
- Clear water (chlorophyll a concentrations less than ~30 μgl^{-1}) is essential (but not a guarantee) for water plant establishment
- Biomanipulation of the fish community will only be sustainable over the long term where water column total phosphorus is about 40 $\mu gl^{-1}$and certainly less than 100 μgl^{-1}. The ultimate target of biomanipulation is a low biomass mixed fish community.
- Plants are essential to structure the aquatic ecosystem, compete with algae and promote stability and reliance. A realistic target in the broads to ensure ecosystem stability is a diverse (more than 10 species) and high cover (more than 50%) of aquatic plants.
- The effects of climate and climate change need to be understood as these are significant
- Expect that lake restoration will take time (5-10 years or more). There are no quick wins.
- All lakes are different so need to be considered individually.
- Monitoring is essential to judge effectiveness of restoration measures and to learn from the results (ideally 3 years pre- and 5 years post-monitoring of key parameters).

Future Aspiration and Actions

The aspirations for lakes in the Broads National Park and possible actions are set out in Table 1 below. This table has been developed by the Broads Authority officers to describe how they will use this information to shape management. As the conclusions of the lake review become more widely shared these aspirations and actions are likely to evolve to be translated into various partner initiatives.

Aspiration	**Action**
Decrease total phosphorus concentrations to below 55μgl^{-1}, which is the threshold for success	Broadland Catchment Partnership to continue to reduce phosphorus input to support further recovery of rivers and lakes
To co-evolve aims for water quality across the catchment with reference to evidence from the lake review	Broadland Catchment Partnership to use the review to help inspire action and connect the beneficiaries of better water quality to upstream providers
To integrate the aspirations for both people and wildlife over the long term for the 'big challenge lakes'[8]	Use the guidelines set out in the lake review to input into future plans for managing the 'big challenge lakes'
Create conditions for water plants to return and	Broads Authority and partners continue

[8] These are the lake that remain turbid, without plants and connected to often large river catchments (e.g. Ranworth, Hoveton and Barton Broads).

form diverse (greater than 10 species) and stable high cover (over 50%) which promotes sustainable stability	to manage lakes, with a continued focus on isolated lakes, and support research on connectivity and environmental degradation in influencing species distributions and potential for species recovery as water quality improves in main connected system
Rebuild reedswamp margins in areas of decline, such as Hickling Broad, and help provide sheltered areas for aquatic life	Broads Authority and partners to find funding for edge and island management and restoration in Hickling
Greater awareness of impact of invasive species on aquatic food webs and reducing the spread of these species	Broads Authority and partners continue to support research and monitoring and promote 'Check Clean Dry' to all water users

Table 1. Aspirations for lakes in the Broads National Park and possible actions

Figure 2 is taken from the Lake Review report and provides some diagrammatic guidance on thresholds and major restoration options that could be and have been undertaken on the Broads.

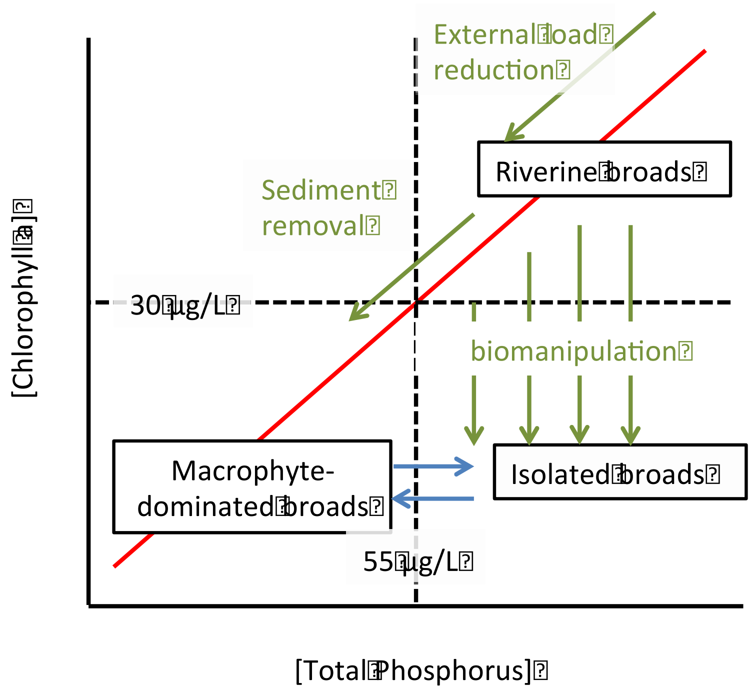


Figure 2. Shows the relationship (in red) between annual mean algae (chlorophyll) and total phosphorus concentrations in the Broads and the role of the major restoration options in creating water plants (green). Blue arrows represent feedback mechanisms that may affect plants (e.g. bird grazing, germination of plant seeds).

Conclusions

The conclusions presented here are the Broads Authority officer's perspective and response to the conclusions in the lake review report itself.

The River Bure, Ant and Yare connected broads show impressive improvements in water quality over the past 45 years, with lower phosphorus levels and improvements in water plant populations in the main rivers, indicative of direction of change.

Many of the broads that are not connected to main rivers have clear water and healthy ecology in most years. This is a direct result of successful restoration projects, many lead by the Broads Authority and partners such as Essex & Suffolk Water, the Environment Agency and Natural England. The Trinity Broads restoration demonstrates that clear water, water plants and a vast increase in water birds can be achieved and recovery sustained by partnerships.

The findings also encourage new thinking about the whole wetland and an assessment of the ecosystem value of connected floodplain areas.

In addition, the findings demonstrate that climate change, both warming and increase in sunshine, appear to be influencing the ecology of the broads. Within the restoration process the success in restoring a system to plant dominance will be influenced by climatic conditions, with sunshine and water temperature during the spring perhaps being most critical. It is likely that the observed climate changes further support water plants, at least in the isolated lakes, and rising temperatures may enhance *daphnia* grazing, thus favouring control of algae by grazing. However, warmer water, perhaps coupled with salinity episodes, might yet trigger a shift to algal dominance, even after several decades of effective reduction in availability of phosphorus.

The report reminds us that that lake restoration takes time. For example, although the Trinity Broads have clear water and good water plants, the high phosphorus concentration brings a risk to sustaining this recovery, so the job cannot be considered as done and further nutrient reduction is required with consideration of where the main sources of the nutrient are. Despite the general shallow lake ecological principles discussed in the main report, each lake is will respond differently to management according to its shape, water movement and source and history. Monitoring is essential to fully understand the ecology of each lake and judge the effectiveness of restoration measures.

Despite the overall picture of water quality recovery, most of the larger broads have green water every summer. These are the 'big challenge lakes'[9] where less phosphorus in the rivers is essential for continued recovery, to achieve government commitments for water and biodiversity.

In addition to government targets the boating and visitor economy depends on high quality rivers and broads with clear water, free from blue green algae and shallowing muds and silts. The Broads Plan provides a holistic approach, covering the common interests of ecology and boating.

The evidence presented in this report calls for further action in decreasing phosphate levels by long-term investment strategies for the Broads that will sustain recovery. This will, involve

[9] These are the lake that remain turbid, without plants and connected to often large river catchments (e.g. Ranworth, Hoveton and Barton Broads).

action to drive down phosphate levels from waste water and work with abstractors to maintain river flows by stepping up water efficiency projects targeted towards the national park. Action from land managers in the water catchment will prevent minor soil and fertiliser loss from the 80% arable land which can make a real difference to water quality. In addition, action to capture rainfall in the ground to help top up water in the underground stores and slow river flows at times of flood will be needed. Finally, yet not exclusively, local actions by many people, such as property owners with non-mains sewerage considering options for reducing nutrient input or using products that do not contain microbeads[10], or not feeding water birds bread[11] can help protect the Broads.

This report highlights what works for lake restoration in the Broads and provides good evidence for us to continue the good practice we have developed, in addition to highlighting areas to focus on for the future. The Broadland Catchment Partnership is supported by both water companies and farmers and aim to put in place projects to complete the restoration of the broads. The benefit of moving towards clear water makes economic sense for business and visitors' enjoyment of the national park.

Author: Andrea Kelly, Senior Ecologist, Broads Authority

The main report and the site dossiers are on the Broads Authority website

[10] Microbeads or minuscule balls of plastic are found in many personal care products such as toothpaste and facial scrubs. They are too small to be removed at sewage treatment works and flow into rivers. The beads absorb organic pollutants and can result in bioaccumulation in aquatic wildlife.
[11] Attracting large numbers of water birds by feeding, introduces nutrient to broads which fuels the growth of algae.