From darkness to light

the restoration of Barton Broad

Broads Authority
The Broads - a member of the National Park family

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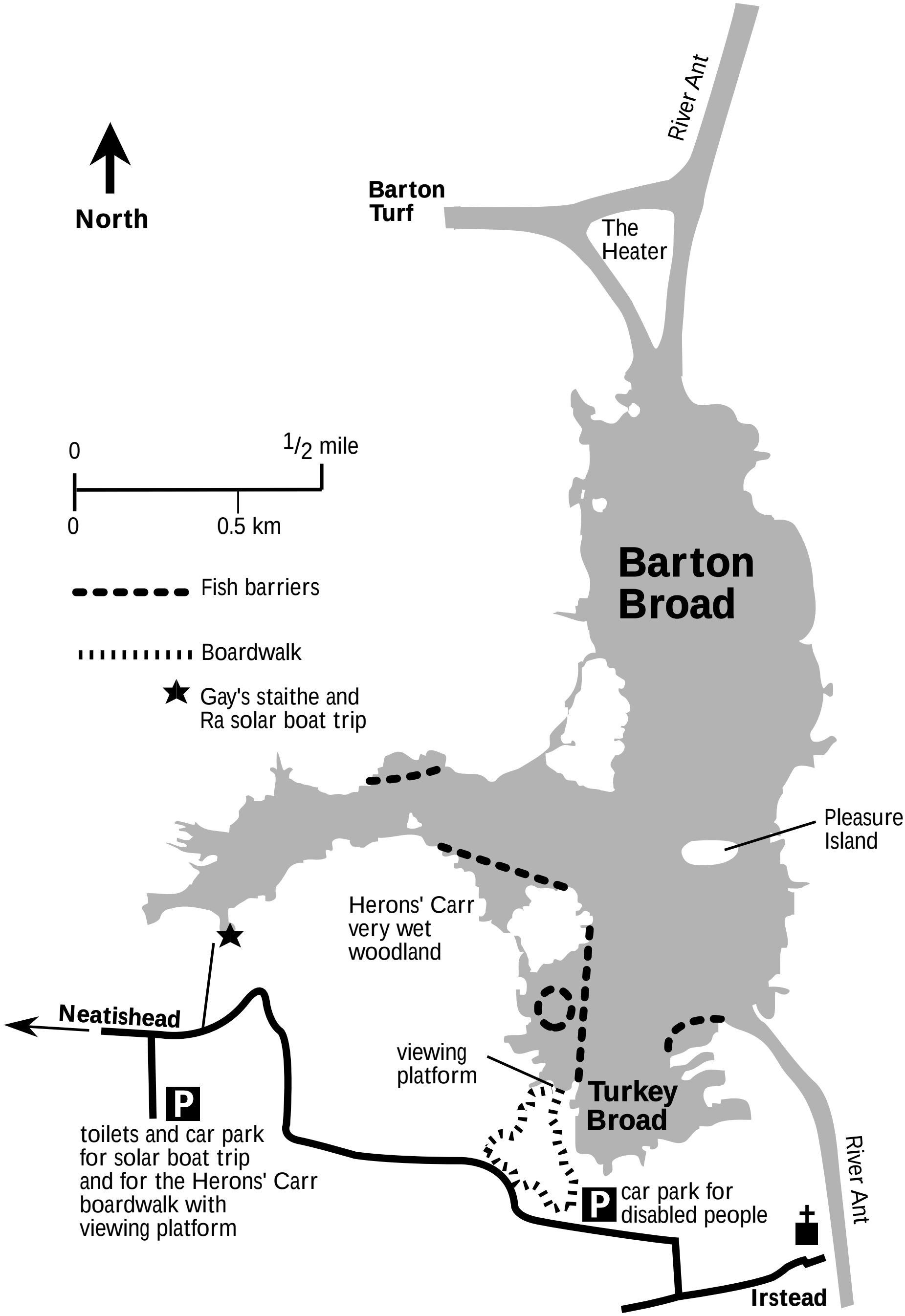

North
Barton Turf
River Ant
The Heater
0
1/2 mile
0
0.5 km
Fish barriers
Boardwalk
Gay's staithe and Ra solar boat trip
Barton Broad
Pleasure Island
Herons' Carr very wet woodland
Neatishead
viewing platform
Turkey Broad
toilets and car park for solar boat trip and for the Herons' Carr boardwalk with viewing platform
car park for disabled people
River Ant
Irstead

Introduction

Clear Water 2000 was the Broads Authority's millennium project to restore the clear water and landscape of Barton Broad, encourage back the wildlife, and improve and expand access to this beautiful broad. Barton Broad is owned by the Norfolk Wildlife Trust and is the second largest of the broads. It is a national treasure, as a National Nature Reserve and international site for wildlife conservation, and as an important site for boating and sailing for many local people and visitors.

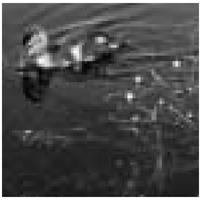
Research and monitoring has formed an essential part of the Barton Broad restoration project, and this document sets out its results. Investigation of nutrient budgets, sediment nutrient release and creation of clear water areas were part of the research programme, which informed the project's inception, development and success.

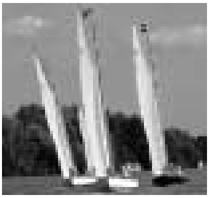
The restoration of Barton Broad

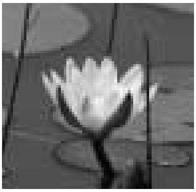
Since the 1950s the underwater ecosystem in the broads and rivers has changed from one characterised by abundant and diverse aquatic life to one dominated by algae, as a result of nutrient enrichment from sewage treatment works and agriculture. The algal growth blocked out sunlight, with the result that underwater plants and the habitats they provide were lost. Barton Broad was an example of these degraded ecosystems. By the 1970s its turbid waters had no aquatic plants, a poor fish community and summer blue-green algal blooms.

Lake restoration began on Barton Broad in the late 1970s when improvements to sewage treatment works meant less phosphorus was discharged into the River Ant, upstream of Barton Broad. This resulted in considerable water quality improvements, however vast quantities of nutrient remained locked in the sediment at the bottom of the broad, which had also become too shallow for boats. The £3 million Clear Water 2000 project set about restoring the silted up Barton Broad to ecological health, with sufficient water space and water depth to make it navigable for all Broads craft.

Project objectives were to:







1 Improve water quality;

2 Increase water depth and area of water open for navigation;

3 Create clear water areas to facilitate re-growth of water plants;

4 Create a better habitat for wildlife in and around the margin of the broad;

5 Improve accessibility and facilities for visitors by land and on water; and

6 Interpret the science for the benefit of visitors.

Top to bottom: stonewort, sailing on Barton, water lily, reed warbler, Herons' Carr Boardwalk, interpretation board for Barton Broad.

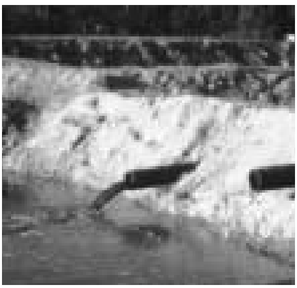
Two techniques were principally employed at Barton: suction dredging to remove phosphorus and biomanipulation to encourage the return of clear water and wildlife.

Suction dredging

Dredging was vital to achieving the first three objectives. It had two purposes - to reduce nutrient leaking from the sediment into the water, which fuels algal growth, and to increase water depth to safeguard navigation for all Broads craft.

Dredging took six years (1996-2001), removing over 305,000 m^3 of sediment, equivalent to 160 Olympic size swimming pools. This sediment was pumped into specially constructed settlement lagoons on adjacent agricultural land, with topsoil forming bunds to contain the liquid sediment as it dried out. After drying the lagoons had approximately 1m depth of sediment. The restoration of the sediment disposal site back to agricultural land involved mixing dredgings with subsoil, re-covering with topsoil and planting with a conditioning crop of oil seed rape or wheat, before returning to commercial agricultural use.

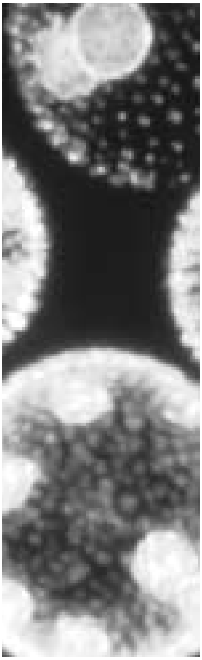
Left to right:
suction dredging,
mud pumped into
sediment lagoon,
sediment lagoons


After incorporation of the dredged silt the soil had a higher organic matter and nutrient content compared to the original soil. This resulted in improved moisture retentive capacity of the soil and a lower requirement for additional artificial fertiliser.

The location of the fields was adjacent to the broad. This meant that any water that ran off the agricultural fields carried nutrients directly back into the broad. Therefore it would have been desirable (but proved impossible here) to site the sediment lagoons and their outflow downstream from the broad.

Aerial view of Barton Broad in relation to the sediment lagoons (bottom right)



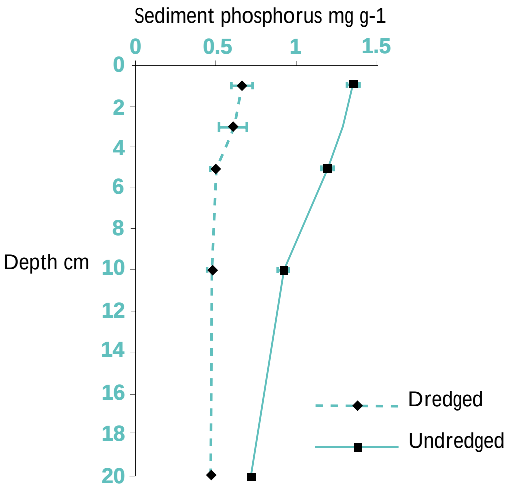
Algae

Lower phosphorus levels in the sediment

Phosphorus is a key aquatic nutrient that can either limit algal growth or allow algae to bloom. Suction dredging removed 50 tonnes of phosphorus from the sediment in Barton Broad. The nutrient reduction is equal to approximately 20 years of phosphorus inputs from the River Ant catchment.

Immediately after dredging the sediment phosphorus concentration was lowered to 50% of its original level (Figure 1). Phosphorus concentration at 3 to 20 cm depth in the sediment remained significantly lower (approximately 50%) in the dredged areas for a period of five years after dredging. However, phosphorus levels of the surface sediment, at 1 cm depth, rapidly increased after dredging, to reach a similar concentration to that of the undredged surface sediment. This increase is probably a result of phosphorus rich algal material settling and reaching a state of re-equilibrium with the water.

Figure 1
Graph to compare phosphorous concentration in dredged and undredged sediment



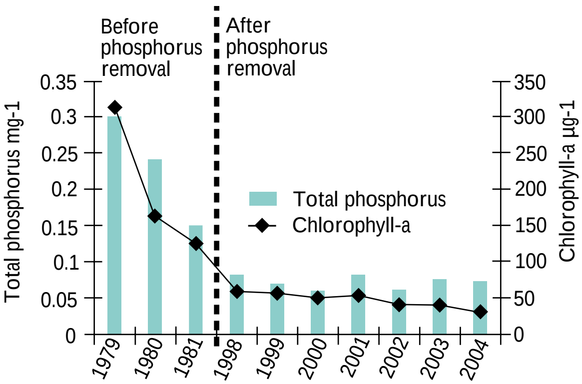
Diatoms and algae

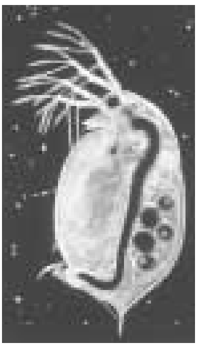
Lower phosphorus levels in the water

During the six-year dredging operation the average annual phosphorus concentration decreased each year. This encouraging trend is supported by longer clear water periods in the spring, with lower algal populations. Experiments showed 50% decrease in phosphorus release from the sediment after dredging. Therefore dredging has contributed towards lower phosphorus levels and fewer algae in the water (Figure 2).

Figure 2
Annual average total phosphorus and algal (Chlorophyll-a) concentration in Barton Broad before and after phosphorus removal from sewage treatment works.

(Data source: Environment Agency)





Daphnia

Change in the algae

Since the late 1970s the algal population has shifted from domination by diatoms and potentially toxic blue-green algae, to small green algae and fewer blue-green algae. This change in the algal community is thought to be a response to the lower phosphorus concentration in the water, rather than being influenced by *Daphnia* (zooplankton) grazing. The *Daphnia* population has decreased each year from 1996 to 2000, probably resulting from the clearer water allowing fish to prey on them more effectively (see table below). However in 2005 large blue-green algae were obvious in the relatively clear water, indicating that grazing *Daphnia* were removing small algal cells and leaving the large cells as they are unable to cope with them.

These improvements in water quality may not be totally related to the sediment removal for two main reasons. Firstly, the improvement is part of a general trend in water quality improvements in the Broads, such as those seen in Wroxham Broad on the River Bure. Secondly, improved phosphorus stripping at sewage treatment works upstream of Barton Broad coincided with the start of the dredging programme. However the 50% decrease in nutrient release certainly has improved water quality.

Conditions before and after dredging in Barton Broad (mean ± standard errors).

	1995 pre-dredging	2000 post-dredging Main Broad	2000 post-dredging Exclosures
Water depth	1.2m	1.7m	1.5m
Total Phosphorus mg $/1^{-1}$(a)	0.121±0.015	0.06±0.005	0.06±0.005
Chlorophyll-a µg/l^{-1}(*a)	70±14	50±8.9	16.4±4.8
Daphnia individuals/l^{-1}(a)	45±16	7±4	91±16

* Chlorophyll-a is a measure of the amount of algal pigments in the water and is used to indicate the total algal population.

a Source: Environment Agency

Securing water space for recreation

Dredging has increased the water depth by an average of 0.43 m, resulting in a sailing depth of around 2 m in the winter and over 1.5 m in the summer. In addition to the depth increase, the navigable area has increased as a result of dredging the shallow margins, which were previously inaccessible to many craft. Over one third of the broad (or 28 ha) has been reopened as good navigable water space as a result of the Clear Water 2000 project, benefiting racing sailors and novices alike. Since dredging the annual sailing regatta has celebrated the increased water space by extension of racing courses to include an area of Turkey Broad at the southern end of Barton Broad.

Sailing regatta on Barton Broad

Biomanipulation is a technique often used to manage degraded shallow lakes. It involves the temporary removal of selected fish species to increase the number of grazer zooplankton, particularly *Daphnia* species. This in turn effects a change in the ecosystem, in this case gaining clear water and plant re-growth.

In shallow lakes without aquatic plants, fish that eat zooplankton (zooplanktivores) often predominate, reducing the number of zooplankton that might otherwise suppress algal growth. Reducing the numbers of these fish by removal or by adding piscivores (fish that eat other fish) is an established technique to create clear conditions. Clear water gives aquatic plants a chance to re-grow; these act as refuges for zooplankton which in turn sustain clear water without the need to continually remove the fish.

In Barton Broad it was difficult to remove fish because a wide channel has to remain open to enable free navigation. Thus fish were removed from isolated bays or 'exclosures', which were separated from the main lake by 'fish curtains' (Figure 3).

Using a technique called 'electrofishing', fish were captured in nets, whilst they were temporarily stunned. They were then gently transferred into



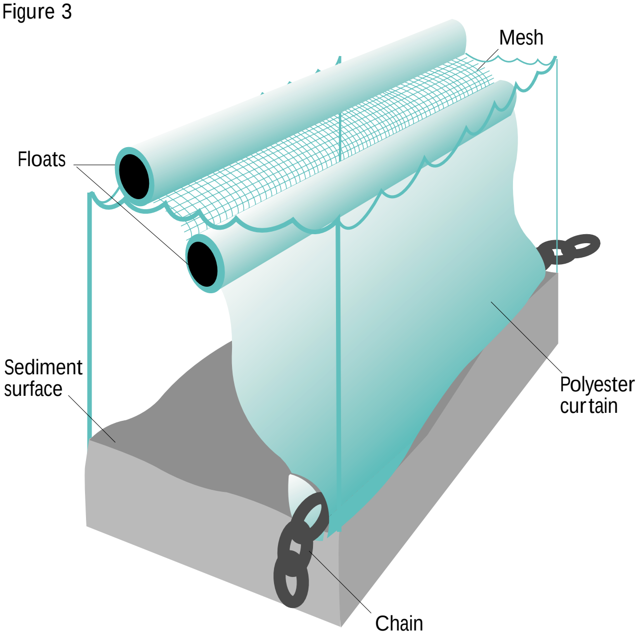
Left to right:
installing a fish curtain,
electro fishing,
pike (a piscivore)

the main broad where they soon recovered.

Many previous rigid barrier constructions have failed as a result of being under-cut due to unequal tidal fluctuations in water levels inside and outside the barrier. The barriers installed in Barton Broad were designed to overcome this problem by being flexible, consisting of a heavy polyester curtain coated in PVC. The bottom edge was weighted into the soft sediment with a heavy chain. The top consisted of two rows of polyethylene floats, with a section of mesh running between them. Water was able to transfer over the top of the barrier.

View along a fish barrier. You can see the calmer water inside the barrier

Figure 3



Creating clear water

Biomanipulation resulted in lower fish numbers; zooplankton began to thrive and significantly reduced the algae population inside the exclosures, creating clear water. However, when fish got into the exclosures clear water was lost rapidly, often for the whole summer season. Where the water remained clear submerged plants grew in the exclosures, while there was almost total absence of submerged plants throughout the other areas of the broad. Plant species that have grown within three years since biomanipulation include:

Pondweeds (*Potomogeton crispus, P. pectinatus, P. pusillus*)
Stoneworts (*Chara vulgaris, C. virgata, C. hispida*)
Water-crowfoot (*Ranunculus circinatus*)
Canadian pondweed (*Elodea candensis*)
Holly leaved naiad (*Najas marina*)
Hornwort (*Ceratophyllum demersum*)

It is possible that ancient seeds, exposed after dredging, germinated. This is the first biomanipulation project in the Broads that has resulted in such a rapid re-establishment of a diverse range of aquatic plants.

Pond-weed
(Potomogeton)

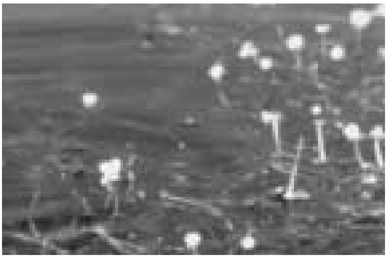
Reducing wave energy

The barriers significantly lowered the amount of suspended sediment in the water column. Suspended material in shallow waters, such as Barton Broad, is highly influenced by wind and boats. The fetch distance, or distance waves travel, was reduced from 1000 m to 50 m on Barton by installation of the barriers perpendicular to the predominant wind direction. This fetch reduction creates calmer water where plants are protected from burial and uprooting.

Re-growth of aquatic plants

Yellow lilies (*Nupha lutea*) appeared in a non-biomanipulated exclosure, suggesting that installing barriers, which reduce wave energy, may aid the re-growth of submerged plants. However exclosures also reduce the circulation of water and this can lead to the build up of high algal populations, therefore effective fish removal is essential for gaining clear water. This is proved by the fact that exclosures that have had the fish successfully removed have excellent re-growth of plants, with over 11 plant species recorded during 2000 and 2004. In 2005, for the first time in over 30 years aquatic plants grew outside the clear water areas, without the help of biomanipulation, we hope this natural recovery will continue.

Left to right: stonewort *(Chara)*, water-crowfoot *(Ranunculus circinatus)*, yellow water lily *(Nupha lutea)*



Reed margin restoration

Around Barton Broad scrub encroachment accounted for the loss of the reed swamp (reed that grows in permanent standing water) that occurred in the 1800s. However, since the1950s remanant reed swamp has also been lost by bank erosion. Reed swamp was therefore lost from both sides and was limited to a narrow margin around the broad or had completely disappeared.

To combat continuing scrub encroachment and resultant shading effect, the Norfolk Wildlife Trust removed a 20 m strip of scrub from the broad edge. An actively growing reed swamp margin provides valuable habitat for invertebrates such as dragonfly larvae and snails, refuges for *Daphnia*, and spawning sites for fish, as well as helping to resist erosion. It is important that reed swamp growth is encouraged, however it is also important to consider the role of marginal scrub and trees in providing summer shade for fish.

A healthy reed fringe

Additional restoration work

The Clear Water 2000 project has been built on by an English Nature Lake Restoration Project (2002/04). This work has extended the fish exclusion areas and created two further areas of clear water and aquatic plant growth. In addition a novel floating reed swamp island has been installed. The island provides refuges for fish in the open water in addition to restoring some of the hover reed swamp that has been lost over recent years. Water quality in the clear water areas and the rest of the broad will continue to evolve and improve over time. Monitoring will continue so that we continue to learn from this project and develop plans for future projects.

Visiting Barton Broad

Improving access for victors was an integral part of Clear Water 2000 - to enable people to see, enjoy and learn about Barton Broad. An innovative public boat trip is available on board Ra - Britain's first solar-powered passenger boat, which is wheelchair accessible. A boarded walkway also takes visitors through ancient, wet 'carr' woodland to a viewing platform on the edge of the broad. The boardwalk is accessible to wheelchair users and an access pack is available for loan to make it more user-friendly for visitors with sensory impairment. At the Norfolk Broads Study Centre at How Hill, just downstream from Barton Broad, a new, 'green' building was provided to improve facilities for educational visits. The new building won an Environment Award from North Norfolk District Council in 1999, and the whole Clear Water 2000 project received an award from the Campaign to Protect Rural England (The Norfolk Society) in 2004.

Left to right
Ra (solar boat),
boardwalk at Herons' Carr,
the boardwalk platform on
Barton Regatta day

What happens next?

The Broads Authority is working closely with local interested parties and organisations to develop a Waterspace Management Plan. This plan, due for completion in 2006, records and values existing uses and landscape, prioritises future restoration works, and provides a framework for continued dialogue with interested parties who have supported the restoration works for over 10 years.

Glossary

Algae - A general term for photosynthetic aquatic organisms, which range from microscopic floating forms to large, rooted seaweeds. Hundreds of species occur in the rivers and broads.

Biomanipulation - A technique often used to restore shallow lakes, which involves the temporary removal of selected fish species to increase the number of grazer zooplankton, particularly *Daphnia* species. This in turn effects a change in the ecosystem, in this case gaining clear water and plant re-growth.

Daphnia - These belong to a larger group of microscopic crustaceans called zooplankton, and they graze on algae. *Daphnia* are some of the most effective grazers due to their large body size.

Diatoms - These are a type of algae. They can turn the water a brown colour in the early spring when they tend to reach a peak in numbers.

Phosphorus - This is a plant nutrient found in fertilisers, detergents and sewage effluent. Phosphorus stripping at sewage treatment works is an effective way of reducing the addition of phosphorus into the Broads, although a significant proportion comes from agriculture.

Sediment - A layer of mud, silt and dead organic matter, which collects at the bottom of rivers and broads..

More reading

Moss B, Madgwick J, Phillips G (1996) *A guide to the restoration of nutrient-enriched shallow lakes*. Environment Agency, Broads Authority, LIFE. (Available from the Broads Authority, price £5 plus postage. Free to students.)

Phillips G *[1], Kelly A [2], Pitt J-P [1], Sanderson R [1] and Taylor E [2] (2005) The recovery of a very shallow eutrophic lake, 20 years after the control of effluent derived phosphorus *Freshwater Biology*

For more information:

about the project and visiting Barton Broad, please contact:

Broads Authority
tel 01603 610734
www.broads-authority.gov.uk

Norfolk Wildlife Trust
tel 01603 625540
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about the Norfolk Broads Study Centre, please contact:

How Hill Trust
tel 01692 678555
www.how-hill.org.uk

The Countryside Agency
DETR
EEDA
Anglian Water
Environment Agency
ukcpi
English Nature
NEWS Norfolk Environmental Waste Services
Anglian Water Environmental Partnership
a non-profit distributing company
Norfolk Wildlife Trust
A Millennium Commission Lottery Project