Hoveton Project: creating a sustainable future for the Bure system

Purpose of document

This document has been developed to provide background information, including the justification for, and risks relating to, the Hoveton Great Broad Restoration project.

The document has been commissioned to aid EA and NE senior managers' understanding of the wider benefits and risk associated with this project, prior to coming to an agreed, justified and reasonable decision on the future of the project. The document will be supported by a collection of other documents referenced throughout the text.

The current design and rationale for the project has been challenged by EA fisheries and external angling bodies as a result of concerns over the impact of the project on the fish community in Hoveton Great Broad (HGB) & Hudsons Bay (HB), and also the wider broadland system which consists of a series of interconnected wetland habitats, shallow lakes and rivers. The project aims to restore the ecology of HGB & HB, partly through the use of biomanipulation, a technique that modifies the food chain to allow ecosystem recovery. This essentially involves the temporary removal of a large proportion of the current fish community whilst the lake ecology recovers. Water permeable barriers will keep the fish out of the broad for up to 10 years, during which time it is expected that the broad will improve its failing WFD elements and also achieve Favourable - recovering status under the Habitats Regulations. The broad is currently in WFD Poor status and Unfavourable - no change status.

The EA is an associate beneficiary of the project, which is being led by NE. The other project partner is the Hoveton Estate, which owns the broads and the surrounding land. The project has over £4m funding following successful grants from LIFE and HLF. The project is in year five of six. Most of the work to date has involved sediment removal and physical habitat removal, but there is also an active communication programme running throughout the duration of the project. It will deliver better community engagement, public access, scientific understanding and ecological integrity.

The EA have been collecting fish data and information for the last four years as part of their contribution to the project. This has provided evidence that HGB & HB are well used by both bream and roach. There is evidence that the broad may be preferentially used by some fish given the densities found during the four years of study compared to other closely located broads. This has caused serious concerns to be expressed by the EA fisheries function and the local angling community, especially regarding the isolation of the broad of what they considered as a favoured spawning habitat. A number of challenges have been raised and this document aims to provide the evidence for and against these challenges to aid effective decision making. It is hoped that the document can be used as a wider communications tool to explain the scientific basis for the project and the benefits that it aims to provide to the broad and also wider broadland.

Some of the key challenges relate to why Hoveton was chosen, and why now. There is also some concern that biomanipulation is not the relevant tool to achieve the statutory improvements sought. There has also been a question raised over whether a project that is designed to create WFD and HD improvements should continue if there is a chance of causing deterioration in the fish element of the broad and the wider connected water bodies. The rationale and arguments for these issues are presented in the following text.

The document has been circulated for comment to those officers within NE and the EA with an interest, relevant specialism or historic involvement in the project. The comments are appended to the document to aid transparency.

The key question to be answered is whether the installation of the fish barriers as proposed by the project can go ahead.

Sections 1 to 6 was prepared by the project with input from NE and EA staff and provides evidence for the importance of the project’s continuation and the legal drivers for biomanipulation. Section 7 onwards provides evidence from EA fisheries team on the potential impact of biomanipulation on bream and the fishery, and the legal and socio-economic challenges to allowing the project to continue with biomanipulation in its current form.

Summary of the Issues:

- Hoveton Great Broad and Hudson’s Bay are part of are part of the Bure Marshes National Nature Reserve, the Bure Broads and Marshes SSSI, the Broads Special Area of Conservation (SAC) and Broadland Special Protection Area (SPA) and the Broadland Ramsar site. They are a single WFD lake water body and a Protected Area under the WFD. These sites are in Unfavourable Condition – no change for the Habitats Directive, and Poor ecological status under the WFD. The current HLF & EU LIFE funded project is applying well-established lake restoration techniques to these broads, including sediment dredging and biomanipulation of the fish population.

- The issues to be resolved regarding the continuation of the restoration project arise from a perceived conflict between the achievement of the Conservation and WFD Objectives and the interests of the wider Broadland fishery for angling purposes:

    - Both NE and EA have a statutory duty to restore the sites to Favourable Condition, but the EA also have a duty to maintain, improve and develop fisheries

    - Isolation of the broads for biomanipulation would remove a significant spawning site for bream from the wider broads system, the impact of this on the bream population for the duration of the project is not known, although compensatory habitat mitigation measures have been proposed

    - Bream are currently an important component for the wider Broads fishery, and there is concern about potential economic impact locally if angling interests were adversely affected. However the dominance of bream (and roach) in the fish population is indicative of a disturbed ecosystem and is in conflict with the WFD definition of good status and the conservation objectives.

- Exclusion of the fish from these broads is intended as a temporary measure to kick-start an improvement in other biological elements such as macrophytes and phytoplankton. While this could have a short-medium term (c. 10 years) impact on the fish population, the scale and extent of the impact cannot be predicted – it is possible the fish may fail to spawn, or they may move elsewhere in the system with unknown impact on spawning success.
- It is expected that a restored Broads ecosystem would support a different, more diverse fish population in future, leading to a different angling experience.

Abbreviations

GES – Good Ecological Status

HRA – Habitat Regulations Assessment

STW – Sewage Treatment Work

DWPP – Diffuse Water Pollution Plan

RBMP – River Basin Management Plan

HGB – Hoveton Great Broad

HB – Hudsons Bay

Contents

1. Legal drivers for the project

1.1 SAC & SSSI drivers for restoring Hoveton Great Broad and Hudson's Bay.

Hoveton Great Broad and Hudson's Bay are part of the Bure Marshes National Nature Reserve they are leased to and managed by Natural England. They are part of the Bure Broads and Marshes Site of Special Scientific Interest (SSSI) as notified under Section 28 of the Wildlife and Countryside Act 1981. They are also notified as part of The Broads Special Area of Conservation (SAC) and Broadland Special Protection Area (SPA) under the EU Habitats Directive (Council Directive 92/43/EEC) and EU Birds Directive (Council Directive 79/409/EEC) respectively, transposed into UK legislation under The Conservation of Habitats and Species Regulations 2017. Hoveton Great Broad and Hudson's Bay are further designated as part of the Broadland Ramsar under Ramsar Convention on Wetlands.

Natural England have a statutory duty under the Wildlife and Countryside Act 1981 & The Conservation of Habitats and Species Regulations 2017 to ensure management schemes are in place and delivered for these protected sites to:

a) conserve the flora, fauna, or geological or physiographical features by reason of which the land (or the part of it to which the scheme relates) is of special interest; or

b) restore them; or

c) both.

In order to achieve favourable condition for the notified features of the site.

Biodiversity 2020: A strategy for England's wildlife and ecosystem services has an outcome to achieve "… at least 50% of SSSIs in favourable condition, while maintaining at least 95% in favourable or recovering condition. Currently across England 38.9% of SSSIs are in favourable condition, with 93.6% in favourable or recovering condition. The Government's 25 year environment plan aims to deliver 75% of protected sites at favourable condition by 2044.

In addition, all public bodies have a duty to consider conserving biodiversity when exercising its functions. Under Natural Environment and Rural Communities Act 2006 Section 40:

Duty to conserve biodiversity

(1) Every public authority must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity.

Under The Conservation of Habitats and Species Regulations 2017 competent authorities i.e. any Minister, government department, public body, or person holding public office, '*have a general duty, in the exercise of any of their functions, to have regard to the EC Habitats Directive and Wild Birds Directive*'.

As land managers for Hoveton Great Broad and Hudson's Bay, Natural England have a duty under the Wildlife and Countryside Act 1981 & The Conservation of

Habitats and Species Regulations 2017 to deliver the management scheme for the site with the aim of achieving favourable condition of the notified features.

The duty to achieve favourable condition under the Habitats and Birds Directives Council Directive 92/43/EEC & 79/409/EEC) is written in to the EU Water Framework Directive (council directive 2000/60/EC) under article 4.1c. The directive is transposed in to UK legislation by the statutory instrument The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017, which states:

13. 6) For each protected area, other than a shellfish water protected area, the objective is to achieve compliance with any standards and objectives required by or under any EU instrument under which the area or body is protected—

- by 22nd December 2021, if not already achieved, or

- if different, by any date for compliance set in that EU instrument.

(7) Where two or more objectives set under this regulation apply to the same body of water, or the same part of a body of water, the most stringent objective applies.

As such, achieving favourable condition for The Broads SAC and Broadland SPA is an objective of the River Basement Management Plan, and therefore the EA has a statutory duty to deliver the objectives as the competent authority for WFD.

1.2 Water Framework Directive

The **Government's 25 year environment plan** aims to achieve clean and plentiful water by improving at least three quarters of our waters to be close to their natural state as soon as is practicable. In reality this means reaching or exceeding WFD objectives for rivers, lakes, coastal and ground waters that are specially protected, whether for biodiversity or drinking water as per our River Basin Management Plans. (RBMP) Only 16% or lakes met this target (good ecological status / potential) in 2016 and less than 5% of Norfolk's designated lakes are currently at this target, and unlikely to recover without intervention. EA also have statutory drivers for this project.

On 23 October 2000 Directive 2000/60/EC (known as the Water Framework Directive ("WFD")) was passed by the European Parliament. The Directive's aims were to establish a framework for community action in the field of water policy. It is the most substantial piece of water legislation ever produced by the European Community.

The purpose of the Directive is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater which prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems.

The main aim of the Directive is to improve the ecological and chemical condition of all surface waters and groundwaters. Member States are required to achieve specific environmental objectives in all waters within specified timescales, the default target being 2015. The environmental objectives of WFD are defined by a set of biological, hydromorphological, chemical and physico-chemical quality elements, which are listed in Annex V to the Directive. Member States must take steps to achieve the default objective of **Good Ecological Status or Good Ecological Potential** (see figure 3 below) within all waters. The Agency is the Competent Authority for the WFD in England and Wales.

The key elements of the WFD for the purpose of this decision are Article 4. Article 4 lists the environmental objectives of the WFD in relation to surface waters. It requires member states to:

- Take steps to prevent deterioration of the status of all bodies of surface water.
- Protect, enhance and restore all bodies of surface water with the aim of achieving Good Ecological Status or Good Ecological Potential.

The directive is transposed in to UK legislation by statutory instrument - The Water Environment (Water Framework Directive) (WFD) (England and Wales) Regulations 2017. These regulations require the EA to exercise its relevant functions, including the determination of permits, to prevent deterioration of the status of a water body and otherwise support the achievement of the environmental objectives set for the water body. In this case the authorisations are those covered in the EPR (2016) and abstraction and impoundment permits under WRA (1991). *There is no mention of fish transfer permits under SAFFA and Keeping and Introduction of Fish Regs (2015) in the WFD regs, although our legal advice states that we must exercise all our powers and duties including those under SAFFA and KIF Regs to secure compliance with requirements of the WFD.*

EA therefore have two WFD requirements to consider in relation to this project

1. To achieve the environmental objectives set for the water body (phytoplankton, macrophytes, invertebrates, phosphorus and fish)
2. To Prevent deterioration in status of any element

1.3 SSSI & SAC status/condition

Notified features and condition of Hoveton Great Broad and Hudson's Bay

The Broads are designated for their lake habitat. Although the type of habitat they are designated for is described by the vegetation it supports, the habitat and all the biota that supports including plants, invertebrates and fish are the feature of interest. The Broads, although of artificial origin having been created by peat digging in medieval times, have historically supported a diverse range of aquatic assemblages. Due to the current impacted state of the Broads much of this interest has been restricted to the ditches and a few Broads that have escaped the worst effects of eutrophication. Stonewort – pondweed – water-milfoil – water-lily (*Characeae – Potamogeton – Myriophyllum – Nuphar*) associations would be expected in the Broads, as would club-rush – common reed (*Scirpo – Phragmitetum*) associations (Natural England 2019, European Site Conservation Objectives: Supplementary advice on conserving and restoring site features - The Broads Special Area of Conservation (SAC) Site Code: UK0013577). The Broads is the richest area for stoneworts (charophytes) in Britain (Stewart, 2004).

The notified features for Hoveton Great Broad and Hudson's Bay (unit 10 & 11 of SSSI respectively) are:

- H3140 Hard oligo-mesotrophic waters with benthic veg of *Chara* spp
- H3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*
- S1355 Otter, *Lutra lutra*

The water bodies in the Broads have been identified as an intermediate type between H3140 and H3150. As nutrient enrichment has occurred many of the Broads including Hoveton and Hudson's Bay have lost the characteristic species associated with H3140. However, the palaeolimnological evidence is clear that prior to nutrient enrichment Hoveton would have supported charophyte species, and in cores from this pre-enrichment period charophyte spores are numerically the dominant plant remains in the sediment at 40-50 cm and 50-60 cm (pre-sediment removal) probably equating to 50-100 years ago (Goldsmith *et al.* 2014). **Targets for this site are to restore these natural pre-enrichment conditions and the biota (including macrophytes, invertebrates and fish) they support.**

The current condition of both Hoveton Great Broad and Hudson's Bay are unfavourable – no change. Both sites lack the macrophyte community composition and structure expected under natural conditions and the water quality targets are not met, with siltation and water pollution cited as reasons for the sites adverse condition.

The European Site Conservation Objectives: Supplementary advice on conserving and restoring site features - The Broads Special Area of Conservation (SAC) Site Code: UK0013577 provides targets for favourable condition of Hoveton Great Broad and Hudson's Bay. The following are a selection of targets relevant to the restoration work and highlight the outstanding issues that need to be addressed for Hoveton Great Broad and Hudson's Bay to reach favourable condition.

- Restore a characteristic zonation of macrophyte vegetation; *Chara* beds should normally cover a minimum of 50% of the photic zone, although extent will be variable according to site and seasonal changes.
- Maintain and where necessary restore the abundance of the typical species listed below to enable each of them to be a viable component of the Annex 1 habitat;
  Key Magnopotamion species: *Potamogeton alpinus*; *P. coloratus*, *P. gramineus*, *P. lucens*, *P. perfoliatus*, *P. praelongus*, *P. x angustifolius* (or any other hybrid with one of the above species as a parent).
  Key Hydrocharition species: *Spirodela*; *Hydrocharis morus –ranae*; *Riccia fluitans polyrhiza*; *Stratiotes aloidies*; *Utricularia australis/ vulgaris* agg; *Wolffia arrhiza*

Other characteristic species: *Callitriche* spp.; *Chara* spp.; *Littorella uniflora*; *Potamogeton crispus*; *Potamogeton filiformis*; *Potamogeton friesii*; *Potamogeton obtusifolius*; *Ranunculus circinatus*

- **Maintain or where necessary restore a total projected estimate for biomass of total fish production at less than 200kg/ha (this should take into account the growth potential of the resident and stocked fish). This should be a balanced, mixed, native fish assemblage characteristic of the lake under natural conditions. The total fish biomass should also reflect that expected under natural conditions.**
- Maintain and where necessary restore stable nutrient levels appropriate for lake type. The maximum annual mean concentration of TP is 30 µg P l^{-1}
- Maintain and Restore a stable nitrogen concentration, which will be Total Nitrogen TN <1.5 mg L^{-1} and no deterioration from baseline.
- **Maintain and restore the clarity of water at or to at least a depth of 3.5 metres. For shallow lakes, where depth is less than 3.5m, water should be clear enough to allow macrophyte cover to be present throughout the submerged habitat**
- Maintain and where necessary restore the natural sediment load
- Maintain the natural connectivity of the water body to other water bodies.
- Maintain and where necessary restore a characteristic zonation of vegetation. Extensive beds of submerged macrophytes should be present, with emergent vegetation which may include beds of common reed *Phragmites australis*, bulrushes *Schoenoplectus lacustris* and *S. tabernaemontani* or reedmace *Typha latifolia* and *T. angustifolia*.

There is no indication that the ecological condition of Hoveton Great Broad and Hudson's Bay is improving with recent data confirming they persist in an algal dominated low macrophyte state. In order for macrophytes to re-establish, clear water chlorophyll concentrations of <30 µgL^{-1} that will typically allow light penetration to depths of about 1.5m are required to ensure that macrophytes are not light limited over the majority of the area of a lake (Phillips et al. 2015). Figure 1a & b shows that with Hoveton Great Broad and Hudson's bay these chlorophyll concentrations and light penetration depths are not being met during the growing season (spring/summer).

Hoveton Great Broad and Hudson's Bay are failing to meet their objectives for macrophyte diversity and coverage. The impact of the high turbidity can be clearly seen from the Broads Authority macrophyte monitoring data shown in figure 2, which shows that Hoveton Great Broad has among the lowest macrophyte diversity and abundance within The Broads. A 2014 invertebrate survey of Hoveton Great Broad and Hudson's Bay highlighted the low abundance and diversity of the open water macro-invertebrates linking this to the lack of macrophytes (Abrehart Ecology 2014).

As discussed throughout this document, natural recovery without intervention is unlikely in the short or medium term, therefore biomanipulation is required to restore this habitat towards favourable condition.

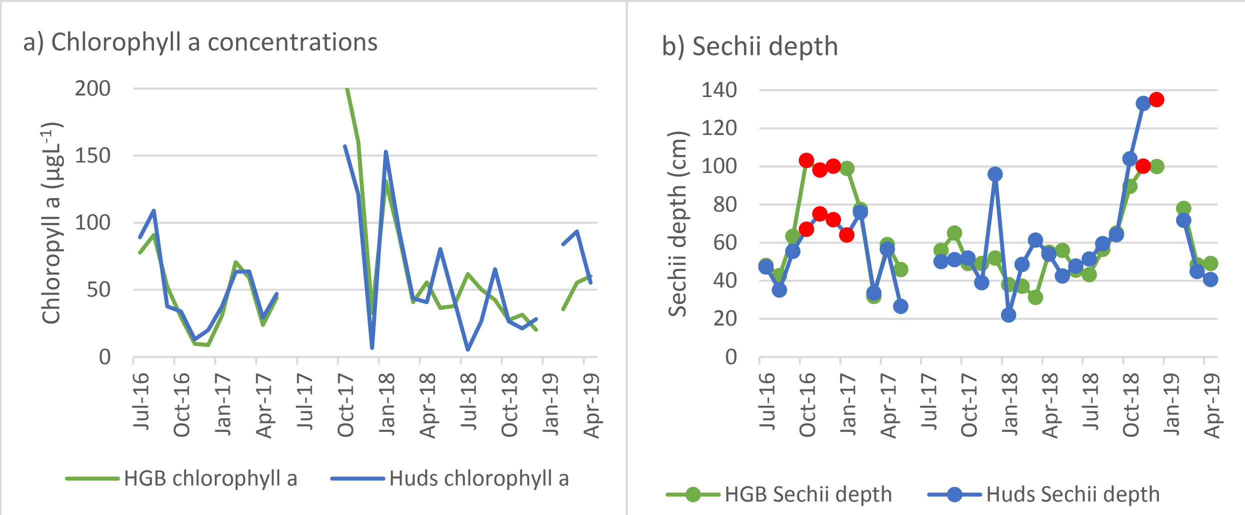
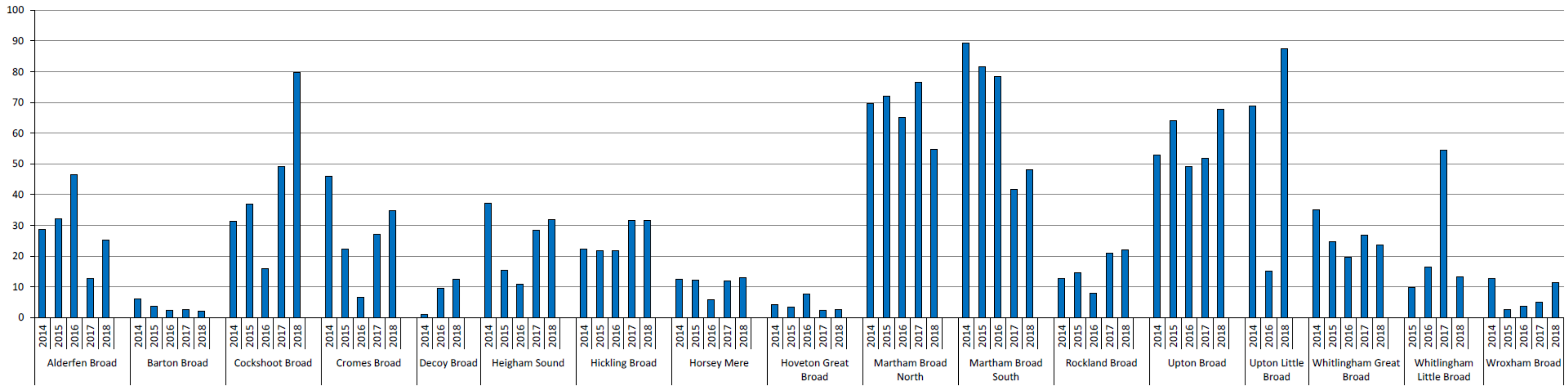


Figure 1. Turbidity monitoring in Hoveton Great Broad & Hudson's Bay as shown by: a) chlorophyll a concentrations, b) Sechii depth (red points represent disk visible on lake bed)

Mean overall abundance per point sampled in the key broads between 2014 and 2018.



Mean species richness per point sampled in the key broads between 2014 and 2018.

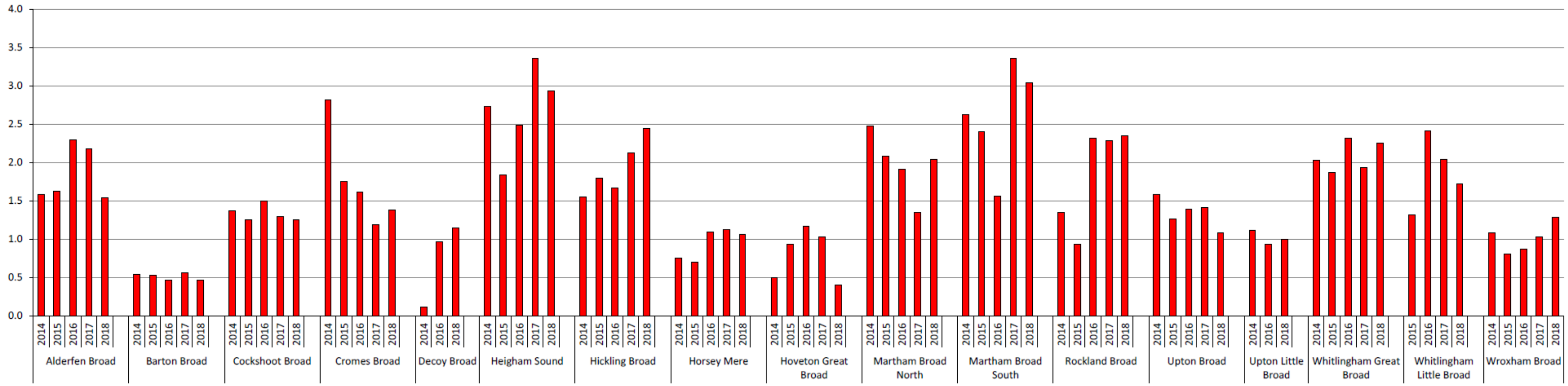


Figure 2: Macrophyte species richness and abundance in the Broads, The Broads Annual Water Plant Monitoring report 2018 (Tomlinson et al. 2019).

1.4 WFD status/condition

Hoveton Great Broad (including Hudson's Bay for the purposes of SSSI and WFD designation) is in **poor ecological status.** The reasons for this classification are shown below but in essence, there is too much algal growth (phytoplankton) and too few water plants (macrophytes). This is a typical response to eutrophication (the nutrient enrichment of freshwater habitats that has been occurring in the Norfolk Broads for decades). This leads to impacts on the wider ecology often leading to an ecology that is dominated by fewer species that are better adapted to such degraded conditions at the expense of other less tolerant species. The Broads have generally been in this state for decades, and will unlikely return to good clear water status without intervention.

Extended Waterbody Summary Report

15 October 2019
12:36:20

Environment Agency

Hoveton Great Broad

Please be aware that data is based on the best available information as of the date shown above, and may be subject to change

WATERBODY ID	GB30535977	CYCLE / LATEST VERSION	Cycle 2 / 2
TYPE	Lake	DESIGNATION	Not Designated A/HMWB
LENGTH (km)		EASTING	631752
AREA (km2)		NORTHING	316368
Alkalinity		CATCHMENT AREA (Ha)	

Geographical Boundaries	
EA AREA	Essex Norfolk and Suffolk
RBD	Anglian
MAN CATCHMENT	Broadland Rivers
OP CATCHMENT	Bure

Bathing Water Directive	Nitrates Directive	Safeguard Zone	Shellfish Water Directive	Freshwater Fish Directive	Habitats and Species Directive	Drinking Water Protected Area	Conservation of Wild Birds Directive
NO	NO	NO	NO	NO	YES	NO	YES

Classifications

Year	Overall	Ecological	Chemical	MMA	Chironomids (CPET)	Fish	Phytoplankton	Phytobenthos (Sub-Element)	Macrophytes (Sub-Element)	Total P	Ammonia	Dissolved Oxygen	pH
2013	Moderate	Moderate	Good						Moderate				
2014	Moderate	Moderate	Good				Moderate		Moderate	Moderate			
2015	Poor	Poor	Good				Poor		Poor	Moderate			
2016	Poor	Poor	Good				Poor		Poor	Moderate	High		
2019	o Be Assesse	o Be Assesse					Poor		Poor	Moderate	High		

Note: DNSG = 'Does Not Support Good', DNRA = 'Does Not Require Assessment'

The following Classification Year(s) are set to Draft: 2019. This document should therefore be for internal use only.

Figure 3. Extract from Catchment Planning System (CPS) showing the current WFD ecological status for Hoveton Great Broad (including Hudsons Bay).

The map below shows the status of other designated Broads in the Norfolk and Suffolk Broads. Yellow lakes are at moderate ecological status and orange lakes are poor. Most lakes are failing because of high levels of phytoplankton and limited macrophyte growth (as is the case for Hoveton Great Broad). These are typical indicators of lakes suffering from eutrophication. It has been evident for many years that the situation is widespread and therefore action is required to move towards our statutory environmental targets.

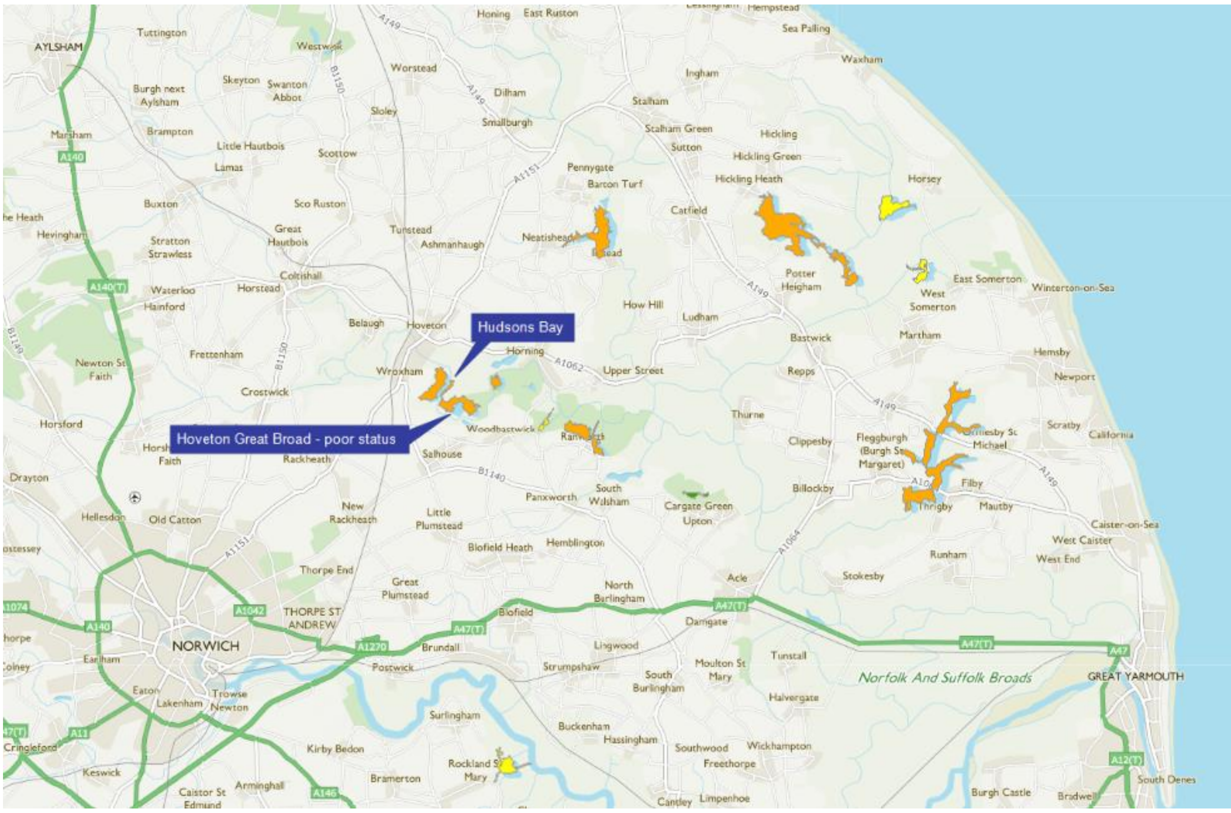


Figure 4. Map of the current ecological status of Norfolk Broads. Yellow lakes are moderate, orange are poor status.

Ecological status classification consists of:

- the condition of biological elements such as macrophytes, fish and invertebrates
- concentrations of supporting physico-chemical elements, for example, phosphorus and ammonia levels
- concentrations of specific pollutants, for example, copper
- and for high status, largely undisturbed hydromorphology and absence of invasive species

Ecological status is reported on the scale of high, good, moderate, poor or bad. High denotes largely undisturbed conditions and the other classes represent increasing deviation from this reference condition. The classification of ecological status for the water body and the confidence in this assessment is determined by the worst scoring quality element (the one out, all out rule). The status objective for Hoveton Great Broad is to achieve good ecological status by 2027, it is currently failing for phytoplankton, macrophytes and phosphorus – refer to figure 3).

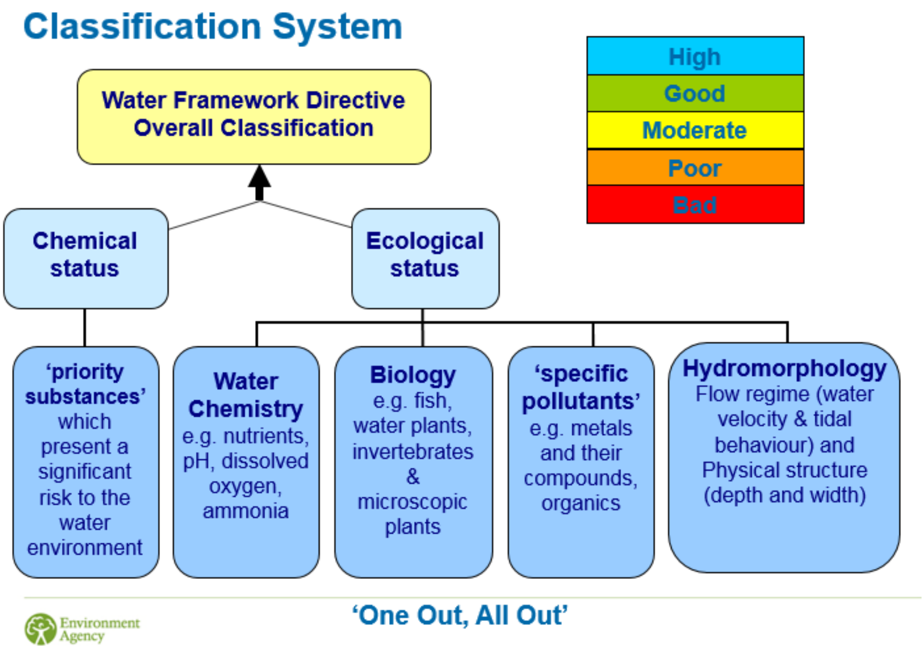


Figure 5. WFD classification

2. Why choose Hoveton Great Broad?

From a strategic viewpoint, The Broads Lake Restoration Strategy (Kelly, 2008) prioritises lakes in terms of likely restoration success as a result of direct investment and low risk of increasing saline incursion with climate change (figure 6). All of the sites with a high probability of success have already had restoration management and indeed some recovery. Hoveton Great Broad and Hudson's Bay, as medium priority sites that have a low risk of saline incursion, have become the top priority for restoration in the Broads. All other lakes in this category already have active or planned lake restoration measures (e.g. Trinity Broads), apart from Decoy Broad. Hoveton Great Broad therefore provides the best remaining opportunity to deliver a sustainable restoration project in Broadland.

Figure 6: Matrix identifying broads suitable for lake restoration investment.

The risk of increasing saline incursion poses a major threat to the restoration success of broadland lakes. Large grazing zooplankton (such as water fleas) which are critical for controlling algal populations and providing clear water, cannot live in saline environments. Biomanipulation therefore only exists as a potential reverse switch where fresh water conditions exist.

It is also important to note that Hoveton Great Broad and Hudsons Bay are owned by a project partner. This has given the project every chance of success as landowner permission and direct involvement is provided through the project steering group. This also means that the riparian owner is fully committed to the project and therefore immediate catchment management activities are unlikely to risk the objectives of the project.

The project would not have been possible without the joint grants of LIFE and HLF. NE are the project lead and both EA and the landowners are associate beneficiaries of the project. The ecological restoration of clear water in line with WFD and SAC requirements is only one of the beneficial outcomes sought by the project. It will also achieve better use and understanding of the broads by school children and the wider community. The project has a communications officer to facilitate this aspect of the project. The project will also increase public access to this private broad through improved land and boat access. A new electric boat facility is being delivered by the project. This broad currently has limited public access from a boardwalk. There is no open access to navigation or anglers who can only fish the broad with landowner permission.

3. Restoration of Hoveton Great Broad and Hudson's Bay

3.1 Restoring ecological integrity of shallow lakes

It is well known that shallow lakes can exist in two states, both of which are considered stable states (Sheffer et al, 1993). The idea was first proposed in the 1960's (Lewontin, 1969) and described mathematically within ecological communities in the 1970's (May 1977). This means that it is difficult to move from one state to another without certain switching mechanisms being applied. The two states of shallow lakes are

1. clear-water macrophyte dominated state
2. algal dominated turbid state

The WFD and SSSI drivers require us to obtain the clear-water macrophyte dominated state. Unfortunately most of the broads are currently in the second state (refer to figure 7) as a result of nutrient enrichment (eutrophication) over recent decades from sewage treatment, agricultural, and other diffuse sources.

Figure 7 below shows that the two states can exist over a wide range of overlapping nutrient concentrations. They are essentially stable owing to ecological feedback mechanisms (food chain relationships such as top down predation that aid grazing on plankton and bottom up relationships such as algae shading light and thus stopping plant growth). These controlling relationships both maintain the current state and prevent it switching to the other state. The effort required to switch between states is dependent on the nutrient status of the lake.

Figure 7 also indicates some of the forward switches that acted in combination with increased nutrient concentrations to move most broads to the turbid state (these included boat damage, anti-fouling chemicals, pesticides, coypu grazing and loss of piscivorous fish. The reverse switch required to restore these shallow lakes is biomanipulation or very low nutrient concentrations.

It is important to realise that the clear water plant dominated state is not devoid of fish. A more diverse fish assemblage is associated with lakes in the plant dominated state than the algal dominated state. In the plant dominated state picivores such as pike and perch dominate the fish assemblage which also contains species such as tench eels and rudd (see figure 14, section 3.5 below).

If a P concentrations of <0.03mg/l required to promote natural recovery of the ecosystem cannot be achieved, then **biomanipulation of the fish community is the only option to restore these broads to favourable condition and good ecological status** as per the statutory duties of Natural England and the Environment Agency under The Conservation of Habitats and Species Regulations 2017 and The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 respectively.

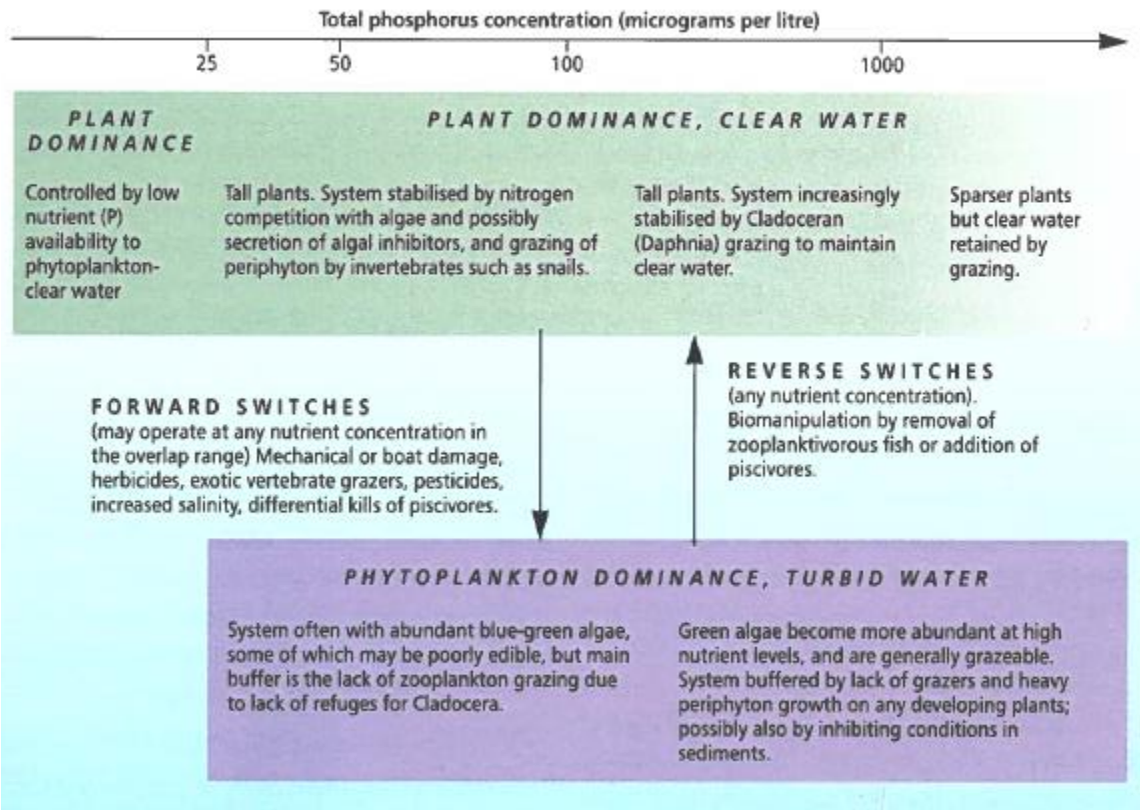


Figure 7. The alternative stable states model for dominance by aquatic plants or phytoplankton in shallow lakes, over the gradient of total phosphorus concentrations that includes both pristine values and those encountered in polluted conditions (Moss et al. 1996)

3.2 Can restoration of Hoveton Great Broad and Hudson's Bay be achieved without biomanipulation?

Phophorus concentrations of <0.03mg/l required for Hoveton Great Broad and Hudson's Bay to recover naturally are not achievable without significant and widespread land use change within the Bure catchment. The Broads catchment has had a long history of nutrient stripping from the larger STWs since the 1980s which has significantly reduced the phosphorus concentrations in the River Bure which runs through Hoveton Great Broad. Figure 8 is from a presentation and shows the reduction in riverine phosphorus over the years. The rivers Bure, Ant and Thurne (but not the broads attached to them) are now generally at high WFD status for phosphorus, reflecting the historic and ongoing efforts to minimise point and diffuse sources of pollution.

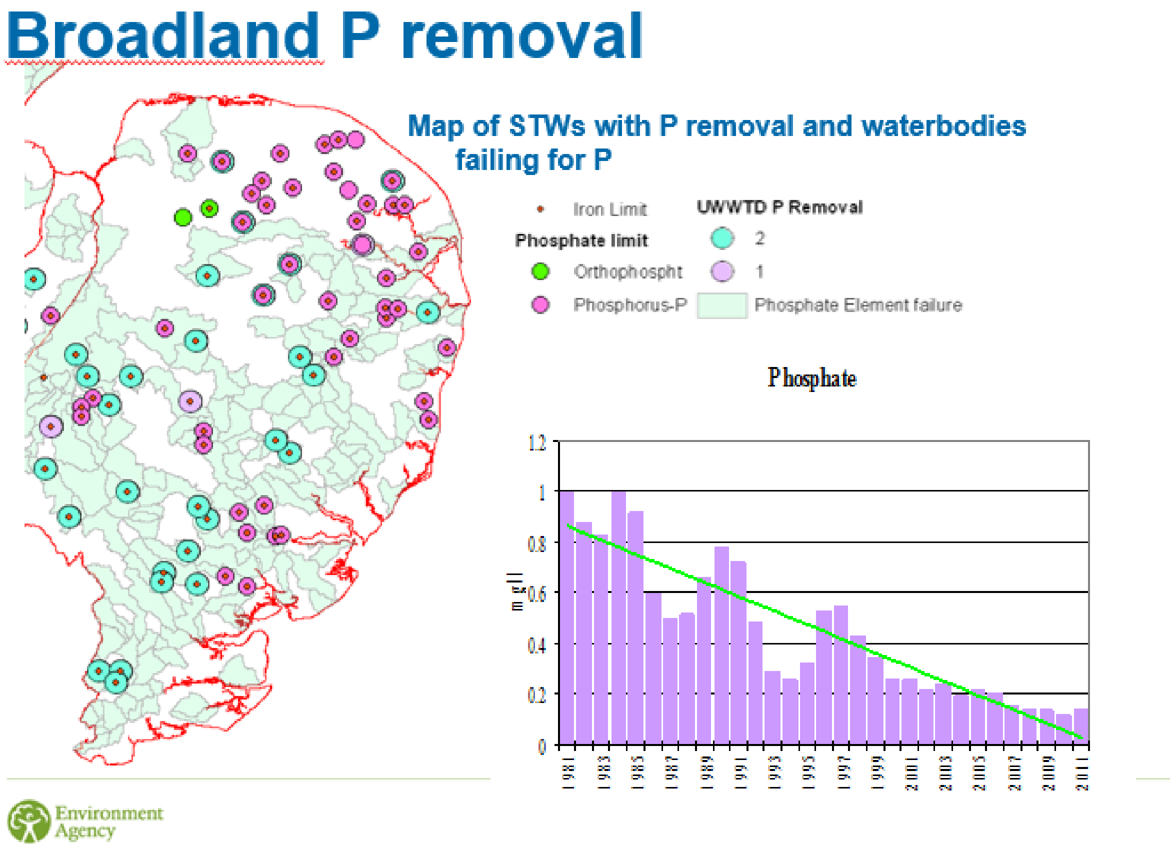


Figure 8. Reduction on phosphorus loading from STWs 1981 to 2011.

Over recent years the improvements in water quality have levelled off (see figure 9) and improvements have slowed.

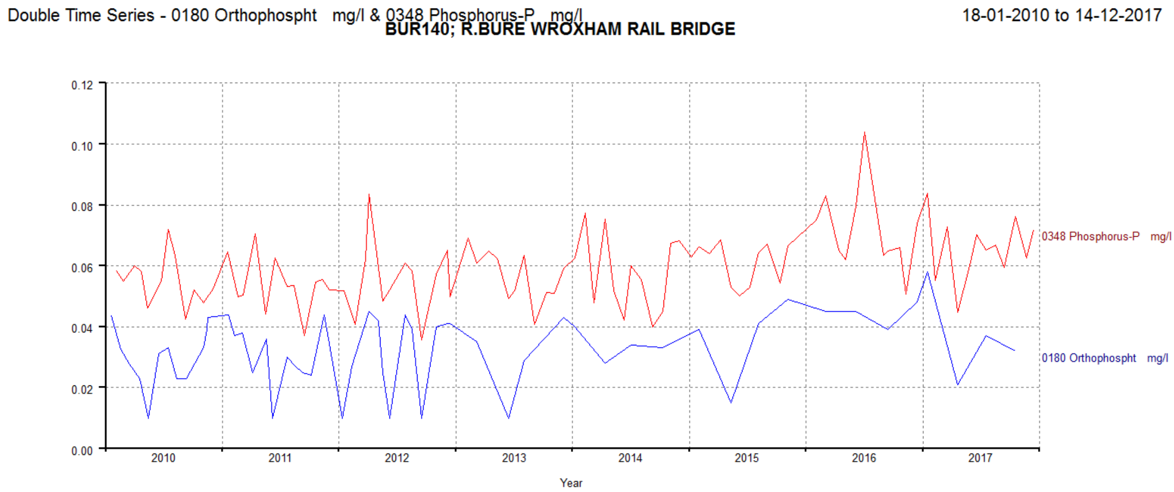


Figure 9. Total and dissolved phosphorus (2010-17) at BUR140 sample point

The Diffuse Water Pollution Plan (DWPP – still in draft and unpublished) has modelled the current sources of P in the river Bure as shown in figure 10. This shows that the major contributors are Sewage Treatment Works (STWs), livestock, and urban run-off. In order to achieve the target of 0.03mg/l in the Bure the DWPP has modelled that 12 STWs will need further P stripping up to the technical achievable limit, and 100% uptake of P reduction methods across agriculture.

Whilst Anglian Water have committed to delivering their fair share reduction in P by 2030 this would only deliver a P concentration within the River Bure of 0.052mg/l. The Catchment Sensitive Farming review 2006 -2018 shows that since 2006 34% of the farmed area in England is managed by CSF engaged farmers with an uptake of 59.6% uptake of advised measures. This has seen a modelled decrease of 2.4% for total P in rivers from farm sources within target areas up to January 2018 (EA 2019). It is evident from this data that a 100% of uptake for all agriculture methods on all agricultural land within the Bure catchment is not going to be achieved within the short to medium term. **Therefore, to meet the statutory timeframes for achieving GES and favourable condition biomanipulation is required.**

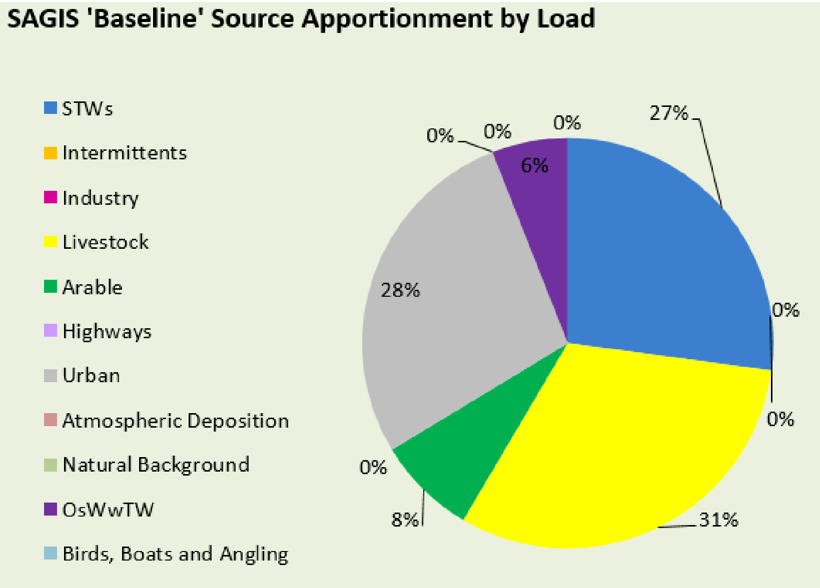


Figure 10. Source appointment of phosphorus within the river Bure catchment.

3.3 Principles of biomanipulation

Biomanipulation involves making a change to the food web interactions in shallow lakes. In essence, you remove the fish that eat the zooplankton which would otherwise eat the algae, which cause turbid water and shade out plant growth (see figure 11 below). This reduces the algal crop through increased grazing by zooplankton. Removing fish that eat by rummaging in the sediment (benthivores) is also important. This is because the feeding activity re-suspends sediment in the water column reducing light penetration and increases nutrient release from the sediment that fuels algal growth. This resulting lack of light inhibits the growth of macrophytes, which can also be uprooted by the rummaging behaviour (Phillips *et al.* 2015). The manipulation of the food chain for ecological benefit is termed biomanipulation and is a well-established restoration technique with much of its early research roots in Broadland.

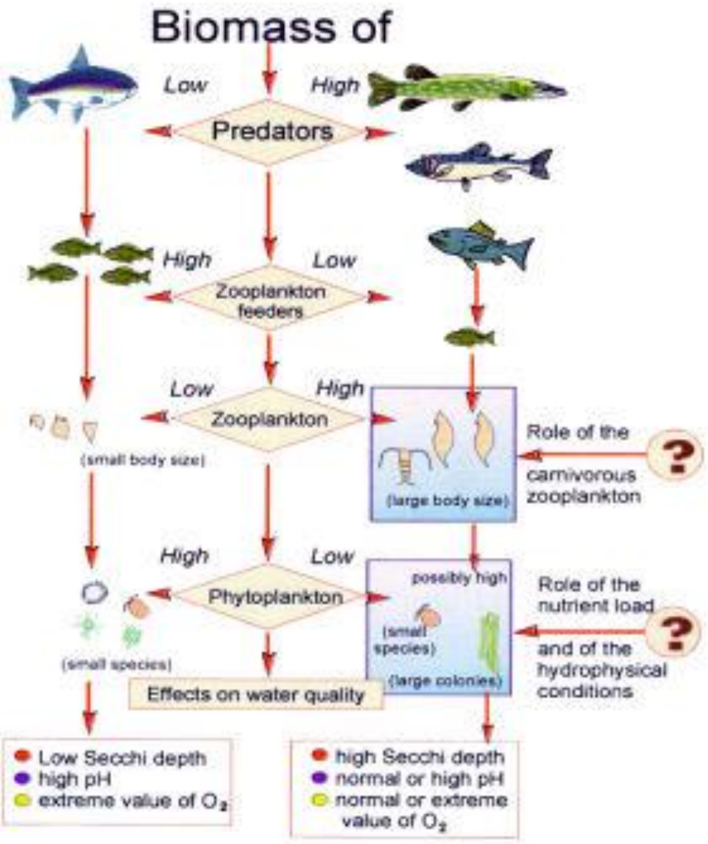


Figure 11. Biomanipulation involves moving the ecosystem balance to the right by removing planktivorous fish (like small roach) and encouraging piscivorous fish (like pike and perch) to thrive.

In the case of Hoveton Great Broad fish proof barriers are proposed to be placed on the openings to Hoveton Great Broad at the locations shown in figure 12. They will allow water to circulate normally but most fish (excluding pike, tench and perch) will be excluded for up to 10 years after which the barriers will be removed. Natural England are hopeful this should provide sufficient time for the clear-water state to be recreated which should then be stable once again owing to the presence of sufficient water plants. However, macrophyte re-establishment rates can vary based on a number of variables including propagule availability (Phillips *et al.* 2015), and has taken up to 15-20 years in the successfully biomanipulated Cockshoot and Ormesby Broads. If an extensive, diverse, and stable macrophyte community has not established within 10 years in HGB and HB then NE will apply for an extension in the lifespan in the barriers for an additional 10 years if required. Under the planning permission this would go to full consultation. This and the legal implications are discussed later in section 6.

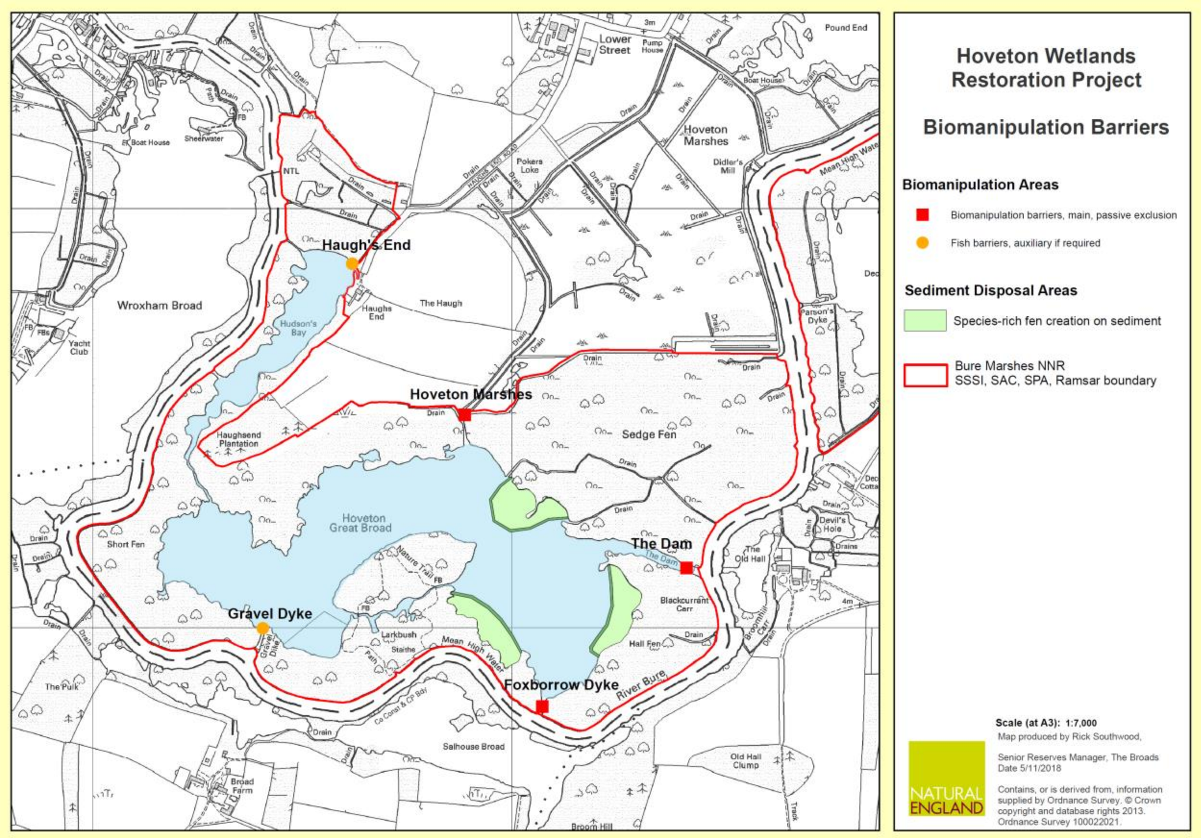


Figure 12. Location of fish barriers on Hoveton Great Broad and Hudson's Bay.

3.4 Precedent for biomanipulation in the Broads

The Broads have been at the forefront of the science behind biomanipulation for decades, work the EA has always been involved in. A number of Broads have been biomanipulated and this has involved isolating both water bodies (such as Cockshoot and Ormesby) and part of water bodies (such as at Hoveton and Barton broad). The results of this have been an improvement in plant abundance and diversity increased water clarity and a more diverse fish assemblage. This project would continue this tradition of improving the condition of these water bodies for the benefit of a full range of users.

3.5 Which fish need to be removed and why?

The response of fish communities to eutrophication is well documented with roach, bream and carp eventually dominating the fish community (e.g. Jeppessen *et al.,* 2000; Moss, 2010), see figure 13. Surveys in the Broads have led to the same conclusions. Where habitat complexity provided by macrophytes remains, the piscivores (pike and perch) dominate by biomass. Tench, eels and rudd are also found in greater abundance in these habitats. Conversely, under turbid, algal dominated conditions roach and bream are more abundant and there are fewer pike, perch, tench, rudd and eel (refer to figure 14 Kelly, 2008). Perrow and Jowitt (1993) also found that as macrophyte cover increases, communities dominated by roach (*Rutilus rutilus*) and bream (*Abramis brama*) are likely to become more diverse with representation of a greater range of species including perch and rudd.

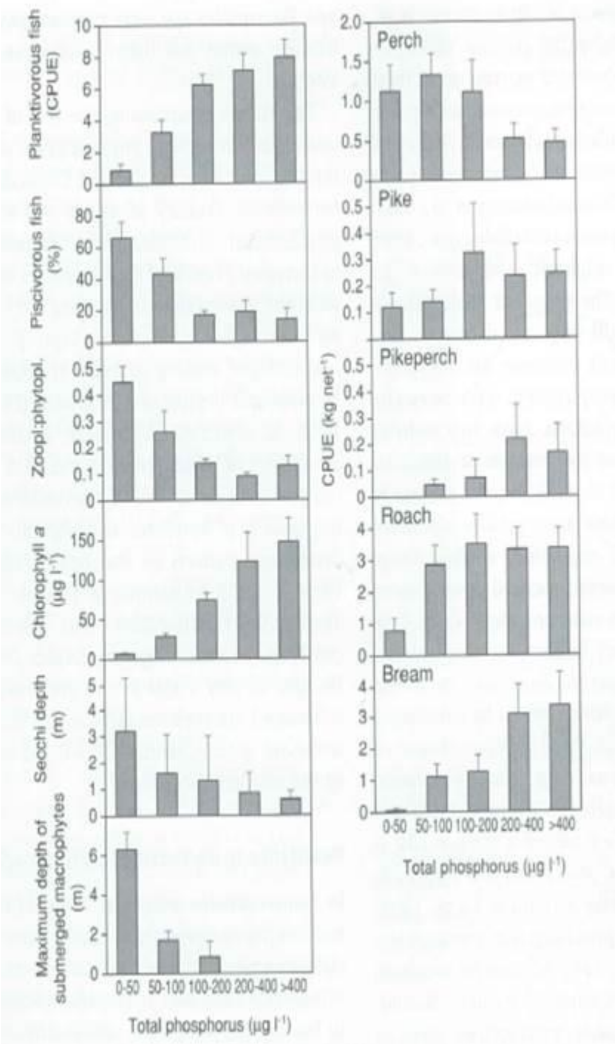


Figure 13: Response of fish communities to increase phosphorus (Jeppesen & Sammalkorpi 2002)

The dominance of roach and bream under eutrophic conditions is not just a symptom of eutrophication, these species play a critical role in the food web, which reinforces the turbid, algal dominated state. In effect, they act as a forward switch, maintain the stability of the algal dominated turbid state and make it harder to switch the lake back to a macrophyte dominated state, even if nutrient concentrations reduce (Bernes *et al*., 2015, Phillips *et al*., 2015). Large numbers of small roach significantly alter the zooplankton community in lakes, which reduces their ability to control the phytoplankton through grazing, allowing algal dominated water to persist. Bream also play an important role as benthic feeders re-suspending the sediment, increasing turbidity and uprooting macrophytes. They also promote nutrient release and cycling from the sediment (see figure 15). This also reinforces the algal dominated state (Breukelaar *et a*l., 1994).

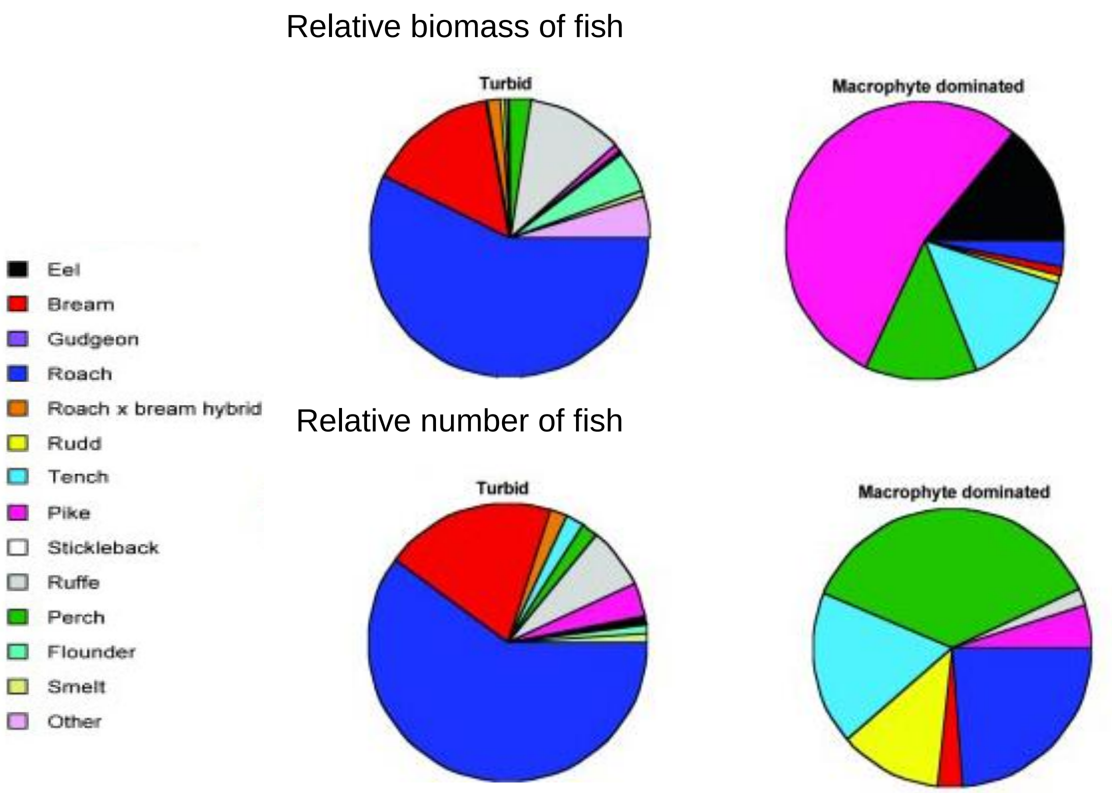


Figure 14. Relative biomass and number of fish in the Broads in macrophyte dominated and turbid conditions. Presented in Kelly (2008). Data from selected Environment Agency (National Rivers Authority) fisheries surveys and surveys conducted for the Broads Authority.

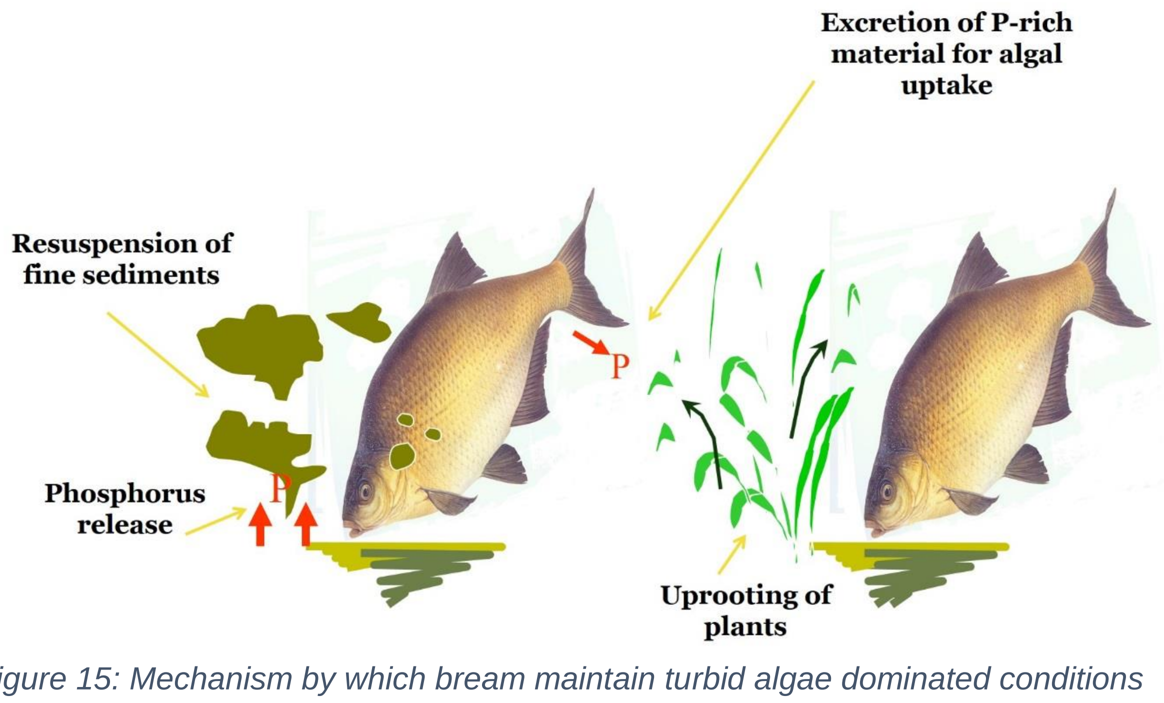


Figure 15: Mechanism by which bream maintain turbid algae dominated conditions (Presentation by Perrow 2018)

Moss et al (1996) in their Guide to the restoration of nutrient-enriched shallow lakes provides a summary of the characteristics of the most common fish species in lowland Britain in respect to their compatibility with shallow lakes restored to diverse plant communities. The more negative the score the more incompatible they are with lake restoration. It clearly shows that a fish community so heavily dominated by bream and roach in Hoveton Great Broad and Hudson’s Bay is not compatible with restoring shallow lakes, i.e. to WFD good status and SSSI favourable status targets. It is of note that bream can coexist with a vegetated state as part of a diverse fish community, but in eutrophic conditions they dominate the fish community, and help reinforce the algal dominated state (Moss *et al*, 1996). **Biomanipulation aims to restore both the plant dominated state and the natural fish assemblage this would support.**

	Bream	Common carp	Crucian carp	Dace	Eel	Roach	Rudd	Perch	Pike	Tench	Brown trout
Native/Introduced	N	I	(N)[1]	(N)[1]	N	N	N	N	N	N	N
Breeds prolifically	+	-	±	+	++	++	++	++	++	+	+
Disturbs bottom	++	++	+	-	-	-	-	-	-	++	-
Pelagial zooplantivore[3]	++	+	±	-	-	++	+	++	-	-	-
Weed-bed zooplanktivore[3]	-	-	+	-	-	-	+	+	-	-	-
Piscivorous[3]	-	-	-	-	+	-	-	+	++	-	+
Intrusive angling	++	++	-	-	-	-	-	-	-	-	-
Usually abundant	+	++	±	±	++	++	+	++	++	+	±
Destroys plants	-	++	±	-	-	?+	-	-	-	?+[2]	-
*Total score**	-7	-23	-2	+20	+28	-3	+1	+5	25	-4	+33

Scoring system
Origin N=5, (N) =0, I=-5; for breeding, -=5, ±=3, +=0,++=-5; for bottom disturbance, ++=-5, +=0, -=5; for zooplanktivory, -=5, ±=-1, +=-3, ++=-5: for piscivory, ++=5, +=3, -=-5; for angling intrusion, -=5, +=-3, ++=-5; for abundance, ±=0, +=-3, ++=-5; for plant destruction, -=5, ±=-1, +=-3, ++=-5.

[1] Introduced from Southern England. [2] Because of predation on epiphyte eating snails. [3] Post-larval.
Pelagial means open water, middle of the lake.

Figure 16. Summary of the characteristics of the most common fish species in lowland Britain in respect of their compatibility with shallow lakes restored to diverse plant communities (from Moss et al 1996).

Fish surveys of HGB & HB (2013-2015) reveal roach and bream populations which are likely to be having an impact on the condition of these broads.

Perrow *et al.* (1999) reported that in open water with no refuges, >0.2 ind. m^{-2} of zooplanktivorous fish, such as roach, may exert a negative effect on zooplankton, although where there were submerged plants, the density may have to be much higher (> 1 ind.m^{-2}) to exert the same effect. Hindes (2017) reported finding more than 5 roach individuals per m^{-2} in Hoveton Broad in spring, although this later decreased it remained above 0.2 m^{-2} throughout the rest of the year. As Hoveton has extremely sparse macrophytes this level of roach abundance has the capacity to detrimentally affect the lake.

Although the exact boundaries of any relationship between fish biomass and macrophyte cover remain difficult to define, a general rule of thumb appears to be that a broad is unlikely to support good populations of plants with more than around 100 kg ha^{-1} of benthivorous fish (Kelly, 2008). At Hoveton in spring, a mean bream biomass of over 250 kg ha^{-1} was recorded, this declined to nearer 150 kg ha^{-1} in summer and declined further in autumn, but it rose to over 100 kg ha^{-1} again in winter (Hindes, 2017). The presence of such a high biomass of bream, particularly at the start of the growing season, has the capacity to detrimentally affect Hoveton Broad. For more information see Annex 1.

P concentrations will remain above 0.03mg/l for in excess of 10years (see section 3.2), so whilst roach and bream dominate the fish community in Hoveton Great Broad and Hudson's Bay these broads will remain in this turbid algal dominated low macrophyte state, and therefore unfavourable no change condition. **Therefore biomanipulation of the fish community is the only option to restore these broads to favourable condition and good ecological status**.

3.6 Nutrient levels for successful biomanipulation

In simple terms, the lower the nutrient concentration, the greater the chances of ensuring stable state lake recovery following biomanipulation. Phillips et al 2015 concluded that a '*Significant reduction of external nutrient loading to eutrophic shallow lakes is essential to create a light climate in which dominance and long term stability of macrophyte cover is possible and buffering mechanisms to retain plant dominance are re-instated. Annual mean total Phosphorus concentrations of <55µgl-1 are likely to be required. Phillips et al 2015. A review of lake restoration practices and their performance in the Broads National Park, 1980-2013. This research looked at all the evidence amassed from lake restoration projects in broadland over the years.'*

The annual average total phosphorus in the River Bure at Wroxham is 0.60 ug/l (last 10 years) which is very close to the level quoted in the lake review work above and indicates that the nutrient conditions are favourable for a sustained improvement in water clarity, chemistry and ecology following lake biomanipulation. Anglian Water have committed to delivering further P stripping at STW by 2030 under their AMP programmes. The Diffuse Water Pollution Plan (DWPP) (2018 in draft- unpublished) has modelled that this will reduce P within the River Bure to 0.052mg/l. There are also ongoing and significant actions being undertaken to reduce diffuse catchment sources of nutrients in the Bure catchment. Catchment Sensitive Farming (CSF) officers are active, Broadland Catchment Partnership and Norfolk Rivers Trust are providing Water Sensitive Farming advice and installing sediment traps on farms, natural flood management projects (which are designed to slow the flow and reduce sediment loads) have been undertaken, and a major national collaboration with the National Trust Riverlands project in the Bure catchment is providing further improvements.

The annual average TP in Hoveton Great Broad is higher than the river (84 ug/l over the last 7 years) which is likely the result of internal loading from P within the sediment which accumulated during periods of high nutrient loads. This will also be influenced by the longer residence time of water within Hoveton Broad and Hudson's Bay compared to the river. Activities that re-suspend the sediment such as wind creating waves disturbing the sediment, and the rummaging activities of bream will also affect total phosphorus concentration in these lakes (Breukelaar *et al.* 1994).

The sediment removal in Hoveton Great Broad and Hudson's bay due for completion January 2020 will remove some of the P rich sediment. This has generally been seen to reduce nutrient concentrations in the sediment in the short- term, often for around 1 year (Phillips *et al.* 2015). Increased water depth created by dredging could also reduce sediment P release by stabilising and reducing water temperature in summer. Increasing water depth will also reduce wind induced sediment disturbance and reduce bird grazing on new macrophyte growth. Reducing the number of benthivorous fish will reduce this further. Increased depth will also reduce bird grazing on new macrophyte growth.

Dredging has the additional benefit of potentially exposing the propagule bank and providing a more stable substrate for plants to anchor into. Disturbance to the sediment will be greatly reduced within these broads as macrophytes establish and their roots stabilise the sediment, therefore reducing the phosphorus load from disturbed sediment. Further to this the macrophytes will absorb P from the sediment and water to support their own growth further reducing the P concentrations in the water (Phillips *et al.* 2015).

In summary, sediment removal undertaken as part of this project will further improve the chances of successful lake restoration through biomanipulation.

The project is therefore confident that levels of P required for a stable macrophyte community ($<55 \mu g l^{-1}$) will be achieved within 10 years and prior to reconnected HGB and HB to the River Bure. It is also worth noting that other broads (i.e. Cockshoot) have maintained stable macrophyte communities at P concentrations slightly higher than 0.05mg/l after biomanipulation.

3.7 Have the other forward switches been removed?

WFD chemical status is good throughout the system (Catchment Planning System). The use of antifouling chemicals on the hull of broadland boats is now strictly controlled. Coypu have been absent for decades following a successful eradication programme and mechanical damage from boats is strictly controlled by the Broads Authority via speed controls to reduce boat wash. There are few forward switches left, and with nutrient levels being generally at good status in the rivers around the project it is likely that biomanipulation will provide the necessary reverse switch to regain a stable clear water state.

3.8 Does biomanipulation work?

Biomanipulation of the fish community (reducing roach and bream) has been shown to be successful in delivering lake restoration at P concentrations of less than 100 $\mu g L^{-1}$ (e.g. Hupfer & Hilt, 2008). Hoveton is well within this recommended limit at 79 $\mu g L^{-1}$ and Hudson's Bay is only 3 $\mu g L^{-1}$ above this. In addition a recent systematic review of biomanipulation has overturned this previous advice instead finding that lakes with higher pre-manipulation P concentrations responded more strongly to biomanipulation (Bernes et al., 2015). **This fits with the findings of the Broads**

Review that biomanipulation always produced clear water in the Broads (Phillips *et al.* 2015). Combined with the additional P concentration reductions the project expects to achieve through the sediment removal, biomanipulation, and macrophyte recovery, there is every reason to expect biomanipulation to be successful in Hoveton Great Broad and Hudson's Bay.

Indeed, Stansfield, Caswell, Perrow (1993) in their Restoration of the Norfolk Broads – Biomanipulation as a restoration tool (LIFE 92-93/UK/031) stated that *maintenance of a low fish stock was seen to be the single most important factor in producing clear water.*

Within the Broads biomanipulation has proved successful on Ormesby and Cockshoot Broads. Indeed a trail biomanipulation enclosure in Hoveton has previously delivered clear water conditions (see figure 17) albeit at an insufficient scale to remain stable after reconnection to the rest of the broad and the influx of algal dominated water.

Figure 17: Previous biomanipulation enclosure on Hoveton Great Broad. Copyright Mike Page (www.mike-page.co.uk)

4. Impacts on fish

4.1 The approach taken by the project to consider potential impacts on the fishery

Concerns were raised about the biomanipulation of such a large broad at the onset of project planning. Anglers were consulted on the project and voiced concerns, as did EA local fisheries officers. There was very little data or evidence on the fish populations of HGB and HB at the time. The project therefore developed a programme of innovative sampling to provide this baseline data over the next four years. This involved a year of collecting SONAR surveys on HGB and HB. This was followed by similar surveys involving other middle Bure Broads. Both of these surveys indicated that HGB and HB were used extensively by large bream and roach in apparently greater densities than the other broads.

This conclusion was supported by point abundance sampling (PASE) around the edge of the broads and also when looking at the quality of edge habitat in HGB and HB compared to the other broads (figure 18).

This led to a further year of spring spawning surveys, where EA looked extensively for signs of spawning behaviour in the northern broads. This survey indicated that Hudsons Bay appeared to be used more than any other surveyed area in the broads system for spawning bream. The survey was not meant to be conclusive (as there were limited resources available for a massive area of potential connected broadland spawning habitat), but it did strongly indicate that Hudsons Bay in particular was important for bream spawning.

The project is also funding a PhD study which is working jointly with EA fisheries to better understand the degree of movement and behaviour of adult pike and bream around broadland. This research has highlighted the migration of bream from the Rivers Ant and Thurne to HGB and HB during the spawning season. It will also provide much needed information to help the ongoing management of the wider broadland fishery as well as help to understand any impact of the project on the fishery.

The angling community (Broads Angling Services Group, Angling Trust, Fish Legal) and the EA fisheries experts (local and national) have expressed serious concerns that the project places an unacceptable risk on the economically and recreationally important broadland fish community, and therefore that the biomanipulation should not go ahead in its proposed state.

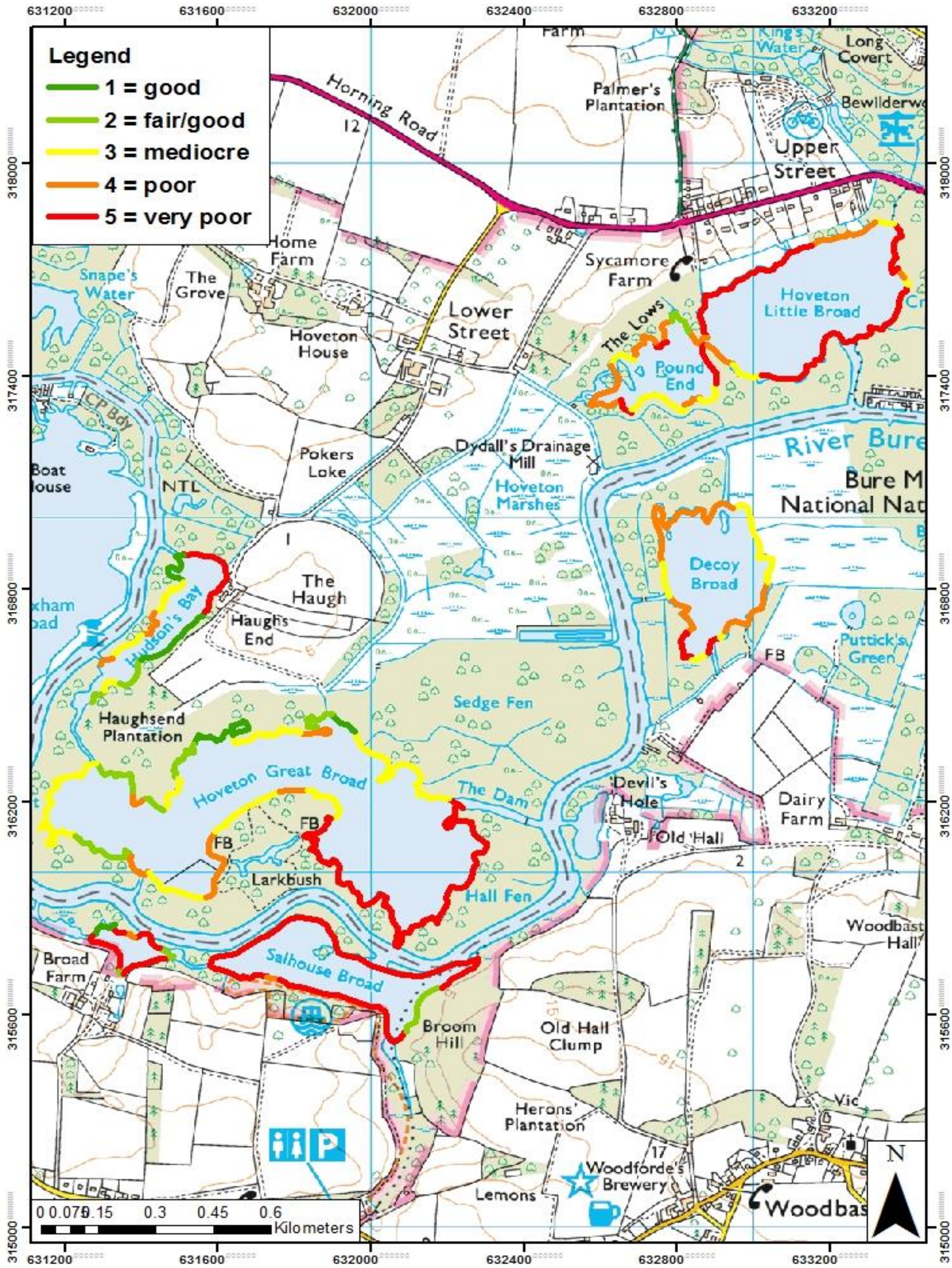


Figure 18. Map of Bream spawning habitat quality assessment and distribution, 2018. Fishtrack ltd.

4.2 Project impact on the fish community of the Broads

There is a difference of opinion as to the likely impact of the isolation of Hoveton Great Broad and Hudson’s bay on the wider fishery. The PhD fish tracking study has shown bream travel within and between the various broads and it appears that Hoveton Great Broad is a favoured habitat especially around spawning time.

Figure 19 shows the number of tagged bream that visit just Hoveton Great Broad or travel between more broads between 15 April and 31 May (covering likely spawning window). The data indicates that although a number of fish only visited HGB, many fish also visited two or more broads. This does not tell us exactly where they spawned, but it does indicate that many fish travel to other broads during the spawning season. Figure 20 shows the other broads that were visited by these fish.

The large number of Bream and roach found to visit HGB and HB illustrates the magnitude of the problem and why the broad will not recover on its own without measures to reduce the abundance of these fish species in the broads.

It is too early to draw specific inference from these data with respect to spawning site fidelity as they are yet to be analysed by the PhD student, in particular no analysis of residency time at each of these broads has been conducted. However, one interpretation is that at least a proportion of the adult broadland bream may not rely solely on HGB / HB for spawning areas.

The tracking project has indicated that bream and pike make significant migrations throughout broadland. This poses a concern that preventing fish access to HGB/HB will reduce the number of bream throughout the wider broads system. This concern can be viewed in two ways. It is possible that any reduction in recruitment and survival of fish as a result of HGB/HB habitat not being available could be felt around the whole of the broads. It is also possible that the large area of interconnected broads and rivers will provide suitable habitat to maintain the broadland fishery during the period that HGB/HB may be unavailable to fish.

Closing off HGB and HB may only have an impact on broadland fisheries if those bream which would normally spawn, feed, rest on HGB and HB fail to find alternative sites during the period the barriers are in situ. Bream are a very common species across England (and indeed northern Europe), found in a wide variety of waters from ponds and canals to large lakes and slow-to-moderate flowing rivers (Maitland, 1972). This suggests they are able to spawn successfully in a broad range of environments. Indeed, locally bream will attempt to spawn on a wide variety of substrates including lilies, sedge roots and tree roots. Bream numbers have been successfully managed in the Ormesby Broad by allowing them to spawn on fishing nets which are then removed before hatching. It is therefore highly unlikely that within the wider broadland catchment that HGB offers the only suitable spawning habitat for bream. It is also very unlikely – given that bream have already been recorded covering large distances and wide areas - that bream would not be able to access such suitable spawning / feeding / loafing habitat elsewhere, even if it does not occur local to HGB.

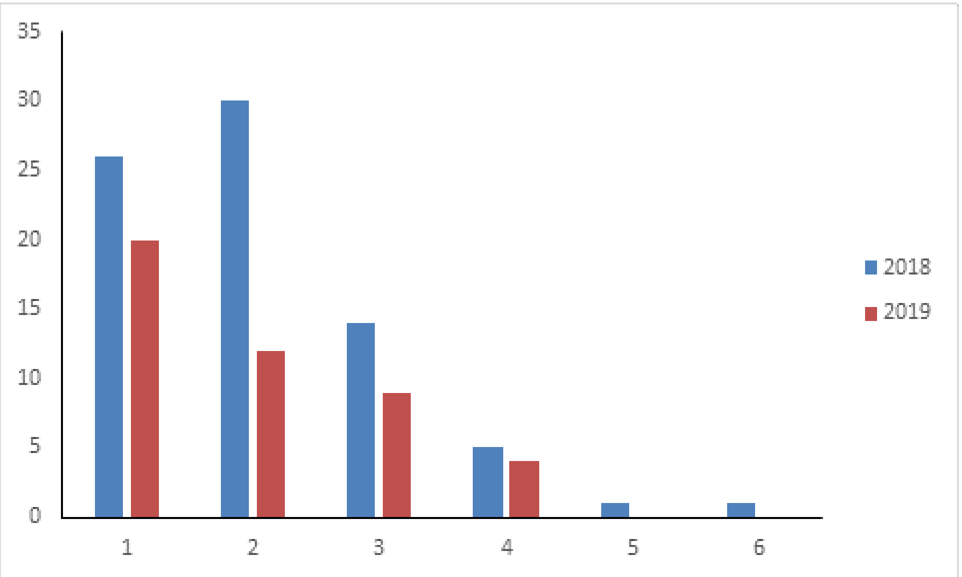


Figure 19. Data from northern broads PhD project showing the number of broads visited during the spawning season by tagged adult bream.

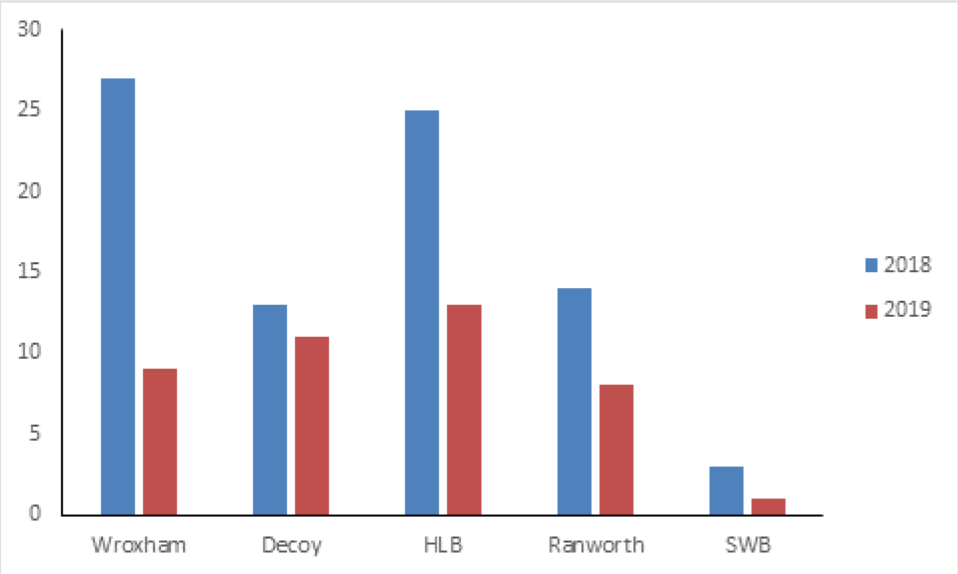


Figure 20. Data from northern broads PhD project showing where adult bream visited other than Hoveton Great Broad during the spawning season.

It is the very adaptability of bream and their ability to successfully colonise (either naturally or via artificial stocking) and maintain strong populations in a range of different habitats across the UK which has been the key to their success. In the literature bream are described as favouring rich, muddy and weedy lakes where their sticky eggs are deposited onto submerged macrophytes. However, many fully enclosed lake sites maintain strong populations of bream with a macrophyte assemblage which is largely limited to an emergent fringe and effectively devoid of submerged forms – like many of the broads including Hoveton. The highly fecund nature of bream and their ability to adapt to environments in which their favoured spawning habitat is absent indicates a strong competitive advantage over other species with more restricted spawning habitat requirements.

Each female may spawn several times over a week or so until all eggs are laid. The number of eggs laid depends on the size of the female but can range from 90,000 – 340,000 (Maitland & Campbell 1992). Adámek *et al.* (2002) recorded the average number of eggs obtained by stripping 1 kg of female bream biomass from the river Sow and Trent to be in the range of 93,642 ± 20,896 and 151,179 ± 25,123, respectively. Given the fecundity of this species, it is unlikely that the overall success of bream recruitment will be related to the brood stock size and number of eggs laid, as only relatively few females have to spawn successfully to provide large numbers of fry. Conversely, it is recognised that excessive recruitment may affect the survival and growth of young fish. For example, Grenouillet *et al*. (2001) found that survival of roach in the first year was density-dependent and Cryer, Peirson & Townsend (1986) and Perrow & Irvine (1992), studying lacustrine populations of roach, demonstrated that abundant 0-group roach can sometimes show poor growth as a result of depression of their prey populations (i.e. they are so numerous that the ecosystem cannot sustain them).

One thing that is certain is that ecological systems, especially those so well connected as broadland lakes, are subject to many and varied influences which will impact the fishery. The reasons for relatively low levels of bream recruitment in broadland apparent from the late 1970's until early 2000's are not fully understood. However, the habitats provided by the middle tidal Bure were available to the bream as they are now and the quantity and quality of the spawning and fry nursery habitat were not thought to be the reason for poor recruitment.

So in summary, whilst a number of bream might preferentially choose HGB and HB due to habitat quality and the low disturbance levels, it is likely they will use lower quality habitats if HGB and HB were unavailable.

4.3 Will the project cause a deterioration in the fish element of the Water Framework Directive?

The project has been challenged by the Broads Angling Services Group stating that the isolation of HGB/HB will cause a deterioration in the fish element of the lake and connected waters which could be in contravention of the WFD. The ECJ ruled in the Weser case that the deterioration in any single element from one class to another (not within class deterioration) represents a deterioration in terms of the WFD. This means that any class deterioration (i.e. from moderate to poor) in the fish element associated with this project would constitute deterioration. Any within class deterioration would not. According to the court, Member States must refuse authorisation for an individual project where it might cause a deterioration in the status of a body of surface water or where it jeopardises the attainment of good surface water status or of good ecological potential and good surface water chemical status.

Currently no fish classification tool is used for shallow lakes in the UK. EA also have very little historic WFD fish data from the Broads and as such, EA have no fish class status information. EA also have no fish classification for the River Bure directly outside Hoveton Great Broad. This paucity of fisheries data is problematic but it does not detract from the fact that EA have to consider the likely impact of the project on the fish element status in WFD terms. EA do not have monitoring data for all water bodies but this does not mean that we negate our statutory duties when considering the impact of a project on the water environment.

EA therefore still have an obligation to avoid deterioration in the fish element, unless a derogation is granted. As there is currently no operational WFD lake fish tool in the UK judgement, prospective tolls and WFD tools from other countries have been used to inform whether a drop in class ,rather than a within class deterioration may occur.

4.3.1 What does Good Status look like in Broadland lakes for the fish community?

Would a near natural fish community have a dominance of small roach and bream? The scientific literature is clear that these species increase in response to eutrophication and when present at such abundance a macrophyte dominated system will not prevail (see annex 1 & section 3.5), and therefore the current fish assemblage inhibits WFD GES (Good Ecological Status) being achieved. Given the aim of WFD is to achieve GES in open waters and rivers a fish population which prevents overall GES being achieved cannot be considered to be in 'Good Status'. The Broads were dominated by macrophytes pre-eutrophication and are therefore unlikely to have always been dominated by bream and roach. This is highlighted by the more diverse balanced fish communities observed in broads with clear water macrophyte dominated conditions (refer to figure 14, section 3.5) This shows that **the project is not just about reducing bream and roach but restoring this more diverse fish assemblage. There is no doubt that bream and roach will form part of a more undisturbed broadland community, but not to the numeric extent currently observed.**

There is no evidence to suggest that any reduction in the dominance of bream would be considered as a deterioration in status on the contrary it would be considered an improvement. To test this assumption EA have trialled the use of the nearest thing EA have to a broadland shallow lake fish classification tool from Holland. Graeme Pierson undertook this rudimentary analysis on behalf of the project to try to understand what may happen to the status if there was a reduction in the number of bream as a result of the project. This model comes with very many caveats as it is not Broadland specific, but it does consider high bream biomass as a percentage of community biomass as an indication of eutrophication and is detrimental to the status of a lake (figure 21). **Therefore reducing bream number would generally result in an improvement in WFD fish status.**

There is also a proposed new standard approved for consultation by UK admins based on an e dna fish tool for use in the UK. This supports the findings from the Dutch classification as this sees the presence of bream and roach as negative indicators in eutrophic lakes so that any decrease in number would improve the lake classification. **Together these two tools support the view that the current fish assemblage would not be considered to be at GES and reducing bream and roach would move it in the right direction.**

M 14, M 27 - Type-specific class boundaries for shallow lakes

Indicator	Weight	Bad	Poor	Moderate	GES	HES (max)
% W *Abramis brama*	0.25	50-100	25-50	8-25	2-8	0,5-2 (0)
% W (roach+perch)/euryt.	0.25	0-10	10-20	20-30	30-35	35-40 (100)
% W phytophilic	0.25	0-8	8-20	20-40	40-65	65-80 (100)
% W low oxygen tolerant	0.25	0-1	1-3	3-10	10-20	20-30 (100)
EQR		0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0

Figure 21. Class boundary information for fish from Dutch fish classification tool.

The project has also come under criticism that the deterioration would relate to the connected rivers and lake in close proximity as a result of the known migration of adult bream. The above information would indicate that any reduction in the dominance of bream would be likely be beneficial to the WFD fish element and would therefore constitute an improvement not a deterioration. Instead it is likely that if bream and roach numbers were to reduce more widely as a result of this project it would be beneficial in terms of the environment of the broads including WFD status and SAC and SSSI condition. Professor Geoff Phillips (pers. comms.) has suggested that a reduction in bream numbers in wider system could see improvements in water quality within the entire upper bure system. Within the Trinity Broads, restoration through biomanipulation of Ormesby Broad was seen to improve the water quality within Rollesby and Filby Broad despite no restoration management on these broads (pers comms, Eilish Rothney, NWT)

4.4 Risk to the fishery

The apparent lack of risk of WFD deterioration does not equate to a lack of risk to the broadland fishery. Anglers' annual expenditure on fishing inland waters in the East of England, of which the broads are a significant attraction, totalled almost £110 million, supporting approximately 2,100 jobs and £52 million of household income (Mawle & Peirson 2009). A figure of £100m/year (Lane 2015) is widely cited as the economic value of angling to The Broads local economy; however this figure has not used robust economic modelling, attributing an individual's entire visitor spend to angling if they undertook any fishing whilst visiting The Broads (18% of direct visitor spend, £569m/year), and therefore is considerably less certain.

The potential risk to the fishery comes from a risk of reduced spawning and feeding grounds, specifically in relation to bream and roach There is insufficient data to currently describe the level of risk posed to the wider community although with both bream and roach being rather well adapted to thrive in lowland nutrient rich environments, there is an argument that with the multitude of connected waters available, that any decline is unlikely to be significant, and could also be effected by any number of climatic factors. For example, markedly differing spawning success have been observed in recent years with little understanding of the cause.

There is also an argument that HGB & HB are in a location that is relatively unsusceptible to saline incursion. This is true, and it is one of the reasons why this broad was chosen to be the subject of a multi-million pound investment in ecological restoration. Assuming that there is little spawning success in other broadland habitats, then this could be a risk but, as discussed in section 4.2, NE do not believe this to be a significant risk given the multitude of connected waters where fish could spawn. The connectivity of the broads is also key, providing the ability for fish to migrate away from saline threat. Fish will be free to move upstream of HGB up to the tidal limit extent which is approximately 5 km upstream.

Hoveton Great Broad has a surface area of 37 hectares whilst the broads in connection total approximately 370 hectares. The broad is also connected to over 100km of river, excluding the TRAC water body. There is therefore significant lake and river habitat available to any fish that are temporarily displaced from HGB & HB. This not only provides a large selection of alternative habitats to support a thriving fishery, but also provides large areas within which fishes can escape the infrequent threats of prymnesium algae and saline incursion.

4.5 Impact of current condition on fishery

In considering the risk to the current fishery from biomanipulation of HGB and HB, little has been made of how the degraded condition of The Broads is impacting the quality of this fishery. Bream and roach form and important part of the course fishery on the broads, but they currently dominate in the algal dominated water at the expense of other course species such as rudd, tench, roach, pike, eel, and perch which form a part of a more balance fish community under clear water macrophyte dominated waters; see figure 14, section 3.5. The Broads were once synonymous with large specimen pike, a species which thrived in the clear macrophyte dominated broads, but recent times have seen significant declines in large pike. This decline has been identified as being of particular concern in the Broads Angling Strategy. However, the literature is clear (see figure 13, section 3.5) that pike will decline in eutrophic conditions.

In addition, the stunting of fish in eutrophic still waters due to density dependent resource limitation is well documented with Burrough and Kennedy (1979) documenting it at Slapton Ley. Wright (1990) demonstrated additional growth of an ageing stunted bream population when bream biomass was artificially reduced within a Buckinghamshire gravel pit. The study also demonstrated that the reduction in bream standing crop brought about other changes in the lake. Prior to the fish removal, the invertebrate fauna was extremely limited within the lake and there was very little aquatic vegetation. After the removal of 158 kg ha-' of bream in 1987, (48% of total fish biomass removed) stands of *Potamogeton pectinatus* L. and *Elodea canadensis* dramatically increased and there was a subsequent increase in the abundance and diversity of the invertebrate fauna.

Lammens (1982) in a review of the literature relating growth to food supply concluded that if the standing crop of chironomids exceeds 20 g freshweight m^2, the growth of bream is very good. Poor growth is associated with standing crops of chironomids of less than 5 g fresh weight m^2. In 1988, following the reduction in the population density of bream in the Main Lake, the standing crop of chironomids increased to 21 g fresh weight m^2 and there was a marked increase in growth (0.5 kg in one season) in the remaining bream population. Inveterate surveys have shown very low abundance and diversity of chironomids within of HGB & HB. The average number of individual chironomids recorded was 37 measured across a total of 36 visits and 12 sample sites; representing a chrominid density likely to be <1 g fresh weight m^2

In addition, inter- and intra-cohort and inter-specific competition may also influence year class strength. Grenouillet et al. (2001) found that survival of roach in the first year was density-dependent, and stated that intraspecific competition within the 0-group cohort could influence recruitment to older age classes. This may be of particular importance in years of good recruitment. Cryer, Peirson & Townsend (1986) and Perrow & Irvine (1992), studying lacustrine populations of roach, demonstrated that abundant 0-group roach can sometimes show poor growth as a result of depression of their prey populations. Therefore in communities with a high biomass of roach, such as those observed in the algal dominated waters of The Broads, competition is likely to inhibit growth.

Healthy, macrophyte dominated habitats support a more diverse community of zooplankton and macroinvertebrates providing more feeding opportunities and reducing competition for the current limited resources. Therefore, restoring the broads to GES, which requires biomanipulation (as evidenced above), will deliver overall benefits to the fishery in terms of providing a more diverse fish community for general course angling. Improvements in the size of roach and bream for specialist anglers of these species, and improvements to the pike fishery in line with the Broads Angling Strategy.

4.6 Agreed fishery improvements programme

The EA has a duty to maintain, improve and develop fisheries and as a project partner there is an obvious tension caused by the unquantified risk posed by biomanipulation. This duty has to be reconciled with our duty to achieve Good Ecological Status. NE believe the data presented above indicates a long-term improvement to the fishery with biomanipulation HGB and HB and achieving GES delivering a more sustainable, diverse and resilient fish population. However, NE acknowledge the short term unquantified risk to bream, and the potential changes to the fish community which could affect some of the angling community; / so NE & EA have agreed a fishery improvement programme with the project to reduce the potential impact by restoring the elements of natural ecological function which sustain thriving fish populations as a natural part of the overall.. The project is also undertaking extensive monitoring and research that will help with the longer term management of the entire system. Leaving aside the fact that a better habitat for fish will be provided in HGB & HB once restoration has been achieved, the project will deliver many benefits for broadland fish management, thereby helping the EA to achieve its duties to fishery improvement.

The current fishery improvement programme is attached (see annex 2) although it is recognised that this is not the final version and this will be a live working document as new monitoring results become available. For example, the project is looking in to how the fish tracking project could be carried forward with another PhD study. They have also started discussions with the Broads Authority, NE's NNR function and Norfolk Wildlife Trust regarding opportunities to enhance fish habitats as part of their role. The project is therefore taking a proactive approach to providing fishery benefits even though this is not a core part of its remit to ensure that the project delivers multiple benefits through its actions

5. Legal consequences of preventing the biomanipulation of Hoveton Great Broad & Hudson's Bay

Under the Water Framework Directive most of the Broads are recorded as having 'poor ecological status' due to poor water quality (high turbidity) and low macrophyte coverage and diversity. The Environment Agency have a statutory duty to restore these water bodies to 'good ecological status'. Delivery of the Water Framework Directives has been widely supported by the Angling Trust, indeed they have legally challenged when they have perceived a failure by statutory bodies to deliver its objectives. Following a judicial review by WWF-UK, Angling Trust and Fish legal, the Environment Agency, working with NE, are required to evaluate and identify the measures necessary to achieve protected area objectives in each N2K site that is unfavourable due to diffuse pollution, as soon as practically possible.

The objectives for Hoveton Great Broad set out in the RBMP are to achieve Good Ecological Status by 2027 in the measured elements of phytoplankton (good status) and Total P (high status) and good chemical status (already achieved). Within the RBMP there is also the objective to achieve favourable condition to the SAC. There are no objectives set for the other elements including fish. The default, however, is that good status will be achieve in all elements by 2027, and to do this would require lake restoration.

Clear water (chl a concentrations <~30µgl^{-1}) is essential for aquatic plant establishment but, equally, is not a guarantee that this will occur (Bakker et al., 2013). **Effective biomanipulation will virtually assure clear water conditions due to a reduction in zooplanktivory and reduction in sediment resuspension.**

A huge amount of resources have been put into the Broads over the years to improve water quality both from the water companies and public money via agri-environment schemes and CSF. If despite these investments NE & EA are unable to deliver their statutory duties of restoring lake habitat in good condition this represents a significant reputational risk and could present difficulties, both in Broadland and elsewhere, where NE & EA continue to ask water companies and landowners to make significant investments to improve freshwater habitats. Water companies and landowners could quite rightly ask why they should continue to invest if f NE & EA do not deliver our duties and responsibilities.

This is a decision between maintaining the fish assemblage associated with polluted conditions or restoring the natural environment and the fish assemblage this would support.

If the Environment Agency decided not to permit the biomanipulation of Hoveton Great Broad and Hudson's Bay, this would prevent these sites from achieving favourable condition and good ecological status. This would prevent Natural England delivering their statutory duty under The Conservation of Habitats and Species Regulations 2017, it would be a failure of statutory duty for the Environment Agency to deliver good ecological status under The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 and favourable condition under regulation 13.6 the same legislation. It could also be considered a failure of the Environment Agency under the NERC Act (2000) to '*in exercising its functions, have regard…..to the purpose of conserving biodiversity'* and under The Conservation of Habitats and Species Regulations 2017 to '*have a general duty, in the exercise of any of their functions, to have regard to the EC Habitats Directive and Wild Birds Directive'.* Putting economic benefits of recreational angling before environmental improvement to achieve statutory objectives is likely to be an infraction risk. **It is therefore likely that such a decision would come under considerable scrutiny from the public, conservation NGO's, and other interest groups. If a legal challenge was launched by these groups such a decision could be hard defend, and needs exploring with our legal teams.**

These risks also apply if the Environment Agency were to request early removal of the fish barriers before a stable macrophyte community (as defines by SSSI and SAC targets) has been established. However, this has further legal implications as discussed in section 6.

6. Removal of fish barriers

6.1 Current lifespan of the barriers

It should be noted that the fish barriers being installed at Hoveton Great Broad are temporary structures designed to temporarily exclude target fish to achieve clear water and allow macrophyte recovery within Hoveton Great Broad and Hudson's Bay. Once the macrophyte coverage and diversity meets the targets as set out in the SSSI favourable condition tables and SAC supplementary information, as assessed by common standards monitoring, it is believed the habitat will be stable enough to buffer the inputs from the wider Broad's system. As such condition 18 of the planning permission (Planning ref: BA/2016/0228/COND) for the fish barriers states '*the fish barriers shall be removed as soon as is reasonably practicable in accordance with the monitoring plan… [i.e. when stable macrophyte community established]…or after a period of ten years from the date of installation, whichever is earlier*'. Therefore at present the maximum timescale for the barriers is 10 years.

Whilst the project is hopeful restoration of the macrophyte community within 10 years could be achieved, evidence from other sites in the broadland suggest it could take longer. The composition and diversity of the plant assemblage has also been reported as key to the success and stability of lake restoration. More than 10 macrophyte species has been reported as being key to lake stability in the Broads and the presence of submerged macrophytes and charophytes are particularly important (Phillips *et al*., 2015). This has taken 15-20 years in the Broads that have been biomanipulated successfully (Cockshoot and Ormesby Broad). (see annex 3 for further information)

Every effort will be made to achieve restoration with 10 years. However if monitoring indicates sufficient recovery of the macrophyte community will not be achieved within 10 years, NE will apply to extend the biomanipulation period until a diverse and stable macrophyte community has established, which could take up to 20 years. It should be noted that this application would need to be made to the Broads Authority as a variation of condition and therefore would go to full consultation.

6.2 Legal implications of early barrier removal

The planning permission states that the barriers will be removed after 10 years. This is the timeframe that has been agreed during the development of the project and has been repeatedly discussed with anglers and fisheries officers. There is now a question over whether the barriers could be removed before this time if there was a catastrophic decline in the fishery or if after 10 years the project has not achieved a stable clear-water state with associated diverse and stable macrophyte community.

Under the Conservation of Habitats and Species Regulations 2017 (as amended) a Habitat Regulations Assessment (HRA) is required for all plans and projects (including planning applications) which are not directly connected with, or necessary for, the conservation management of a habitat site, require consideration of whether the plan or project is likely to have significant effects on that site.

The installation of fish barriers and biomanipulation of Hoveton Great Broad and Hudson’s Bay have undergone a HRA (Habitat Regulatory Assessment) as part of the Bure Marshes NNR (National Nature Reserve) management plan. This concluded that the biomanipulation was necessary for the conservation management of a habitat site and no appropriate assessment was required.

Once Hoveton Great Broad and Hudson’s Bay are biomanipulated it is expected that clear water will be achieved within the first year, and it is anticipated that a diverse macrophyte community will establish over time (15-20 years, Phillips *et al.* 2015). These improvements in water clarity and macrophyte cover represent improvements in the SAC condition and would move Hoveton Great Broad and Hudson’s Bay into unfavourable- recovering condition.

It had been proposed that as a condition of permitting the fish removal licences that Hoveton Great Broad and Hudson’s Bay should be reopened to the river if a ‘significant’ decline in the bream population is recorded during the biomanipulation period. Leaving aside what ‘significant’ means with reference to a healthy diverse fish community in the broads, likely changes in fish distribution as a result of the works, and where the burden of evidence should lie for demonstrating a decline, opening the broads before a stable macrophyte community has established is highly likely to result in a return of an algal dominated, low macrophyte state.

If fish populations are allowed to return to their pre-biomanipulation community and numbers before a stable macrophyte community capable of buffering these impacts has established biomanipulation is likely to fail (Phillips *et al.* 2015). In Denmark biomanipulation has repeatedly been attempted as a one off measure (fish being removed from a lake and then no further action being implemented) and as a result in nearly all these attempts the lake has returned to its original condition within 10 years (Søndergaard, 2008). On this basis, any plan to open up Hoveton Great Broad and Hudson’s Bay to the river before a stable macrophyte community has established would reverse improvements to the SAC habitat, and move these habitats in to unfavourable declining condition.

A plan to open up the barriers would be a significant change to the plans considered under the original HRA, and would require a revision of the original HRA or a new

HRA to be undertaken. Opening the barriers would not be '*directly connected with, or necessary for, the conservation management of a habitat site'*, and therefore an appropriate assessment would be required. Using the precautionary approach and the evidence available opening the barriers before restoration is complete '*is likely to have an adverse effect on the site*' and given that opening the gates would not meet the conditions to be consider as '*required for imperative reasons of over-riding public interest*', the plan to open the gate could not proceed as it would be in violation of the Conservation of Habitats and Species Regulations 2017.

In addition, under the Wildlife and Countryside Act 1981 opening the barriers would represent '*the release into the site of any wild, feral or domestic animal, plant or seed*' which is an Operation Requiring Natural England Consent. Consent could only be granted under our statutory duty if the operation would not impact on the SSSI condition.

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7. EA fisheries response

The following text represents the conclusion of six years of research into the potential effects of the Hoveton Great Broad Restoration upon fisheries within the area. It is drawn together from peer reviewed literature, novel investigation, cutting-edge research and the work and expert opinion of the following individuals : Steve Lane (EA – East Anglia, Fisheries), Kevin Grout (EA – East Anglia Fisheries) Jeff Compton (EA – East Anglia, Fisheries) , Jim Lyons (EA- National Fisheries), Graeme Peirson (EA – National Fisheries), Alan Henshaw (EA – National Fisheries), Jake Reeds (EA – Lincs & Northants, Fisheries), Adrian Wood (EA – East Anglia), Andy Hindes (Fishtrack Ltd), Emily Winter (Bournemouth University).

These comments represent a review of the available data following the most recent work undertaken into bream spawning within the Northern Broads between April and May 2019. This review includes, but is not limited to, evidence from the following sources:

- baseline multi-method fish monitoring on HGB/HB[1 2 3 4 5 6 7 8 9]
- comparative fish surveys of the Bure Broads[10]
- Bure Broads comparative spawning habitat assessment[11]
- Northern Broads/PhD fish tracking data[12 13 14 15]
- supporting contemporary evidence from assessments of bream population distribution, spawning behaviour, migration & habitat change in other UK lowland systems (Jake Reeds)[16] and factors influencing bream spawning, egg development, feeding and recruitment (Alan Henshaw) [17]
- accepted international catchment management practice for the removal of barriers and obstructions to fish migration
- the Agency's statutory fisheries duties, statutory guidance from Government, WFD fish classification[18 19 20 21]and the socio-economic importance of the Broads fishery[22]

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[1] Hoveton Great Broad Fisheries Assessment NeedsSept2013 V2
[2] HGBRP BASG ESG meeting outcomes
[3] Pike Spawning Assessment
[4] Investigating the fish stocks of Hoveton Great Broad A multimethod approach to a complex system, Presentation to IFM Conference, Lane and Hindes, 2016
[5] HGB BASG Env Group 17JAN19
[6] Observations & multibeam (ARIS) sonar point sampling of bream spawning event May 2015 e.g. Spawning bream in HGB
[7] HGB BASG ESG 19April2016
[8] Hoveton Marginal Fry Densities no vids April 2019
[9] Fisheries family ask 16-17
[10] HGBRP – Seasonal Comparative Fish Surveys Summary Report V2
[11] Bream Spawning Habitat Assessment v1.3
[12] FIP 2017_18 Broads Fish Migration V5 Project description FINAL AREA SUBMISSION
[13] Year 1 Annual Report for PhD Steering Group Nov 2018
[14] Ant bream Jan-July 2018
[15] Thurne bream Tracking Jan-July 2018
[16] Lincolnshire bream study, Reeds, J. Environment Agency
[17] Coarse fishing close season on English Rivers, outcome briefing, Environment Agency, August 2019
[18] Protecting and Improving Water Environment WFD_488_10
[19] Hoveton Great Broad Legal Questions
[20] Supporting implementation of river basin management plans position 1340_16, Environment Agency
[21] ECJ ruling clarifies "deterioration" under Water Framework Directive, CMS Law Now 23.07.2015
[22] The Socio Economic Importance of ENS inland Fisheries V5.1, Environment Agency 2015

Based on this evidence and given the proposed fisheries mitigation with respect to the Hoveton Great Broad Restoration project, it can be concluded that:

- the evidence clearly indicates the unique importance of HGB & HB to the fishery at both a local and catchment scale
- there is a high risk that the isolation of HGB and HB will have a significant detrimental impact on the Broads fishery at both a local and catchment scale
- there are likely to be significant additional risks that are not yet fully understood e.g. disruption of fish migration and social structure of fish populations
- the impacts of isolating HGB and HB on the wider system could not be mitigated[23] [24]

Given the aforementioned evidence and conclusions, and assuming no significant changes to the Hoveton Great Broad Restoration project, the proposals currently present a substantial risk to the viability of the Broads fishery. Moreover, there remain significant areas of uncertainty that bring with them a risk of the unknown. We are only now beginning to understand the complex and extensive relationship that coarse fish within the Broads system have with this unique lowland environment. As such and given the evidence currently available, we could not consent and authorise permits related to this proposal without substantial new information.

[1] Hoveton Great Broad Fisheries Assessment NeedsSept2013 V2
[2] HGBRP BASG ESG meeting outcomes
[3] Pike Spawning Assessment
[4] Investigating the fish stocks of Hoveton Great Broad A multimethod approach to a complex system, Presentation to IFM Conference, Lane and Hindes, 2016
[5] HGB BASG Env Group 17JAN19
[6] Observations & multibeam (ARIS) sonar point sampling of bream spawning event May 2015 e.g. Spawning bream in HGB
[7] HGB BASG ESG 19April2016
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[22] The Socio Economic Importance of ENS inland Fisheries V5.1, Environment Agency 2015
[23] Notes on viability of HGB mitigation from Jake Reeds EA Aug 2019
[24] HGB Fish barriers permitting meeting notes Nov 2018 – SL Objections Dec 2018 to AW

[23] Notes on viability of HGB mitigation from Jake Reeds EA Aug 2019
[24] HGB Fish barriers permitting meeting notes Nov 2018 – SL Objections Dec 2018 to AW