Report on bioremediation of Hoveton Great Broad by exclusion of bream (*Abramis brama* L.)

Prepared by the Institute of Fisheries Management
for the Broads Angling Services Group (BASG)

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INTRODUCTION

Hoveton Great Broad, including the interconnecting Hudson's Bay compartment (HGB), became eutrophic in past decades due to inputs of phosphate nutrients from sewage works and diffuse sources via interconnections with the River Bure. This led to low water clarity due to high densities of phytoplankton and suspended sedimentary particles, which in turn caused a loss of characteristic macrophytes, as well as accumulation of silt and shallowing. The conservation status of both Hoveton Great Broad and Hudson's Bay has been in an 'Unfavourable No Change' condition under the Habitats Directive for at least 40 years.

The Hoveton Great Broad Restoration Project is part of the Bure LIFE project, managed by Natural England, and funded by over £4 million from LIFE and HLF. Its main aim is to restore the naturally eutrophic lake habitat to a species-rich, clear-water state through minimal carbon footprint project actions. The nutrient accumulation will be reduced by removal of sediment from Hoveton Great Broad and from Hudson's Bay. Biomanipulation will also be carried out, with the intention of removing 75% of target fish species (principally roach and bream). The aims are to bring HGB to an 'Unfavourable Recovering' conservation status under the Habitats Directive by 2020, a task informally described on the project's website as 'to transform 37 hectares of lifeless lake into an idyllic aquatic haven for wildlife.' Restoration of the ecological status of fish stocks is also a stated aim.

Nutrient loadings entering from the Bure have declined in recent years due to improvements in sewage treatment and agricultural practices. Large-scale removal of bottom sediments (begun in 2016 and due for completion in December 2019) is helping to deepen the broad to about 1.1m and to remove at least some of a potential reservoir of bound phosphate that otherwise could be released during summer. Sediment removal should also help expose any buried viable propagule bank and provide a favourable rooting medium for macrophytes. The sediment is being used to create new areas of habitat corresponding to former marginal habitats.

However, it is considered that to achieve sustainable increases in water clarity and macrophyte establishment, reductions are needed in fish populations, especially bream and roach (Kelly, 2008; Hoare *et al.*, 2008; Phillips *et al.*, 2015, 2016). It is proposed that six fish-proof barriers and a three-year fish removal programme will be used from 2020 to progressively exclude fish (especially spawners) by preventing them from entering the broad from the River Bure and Hoveton Marshes dyke network during immigration periods. It is considered that resulting reductions in densities of zooplanktivorous 0+ bream and roach will be beneficial in reducing predation of zooplankton (especially of large-bodied daphnid cladocera) that are important in grazing-down the excessive phytoplankton populations that cause high turbidity. Re-establishment of plants over a few years should help by providing refuges for zooplankton from fish predators. Reducing the density of benthivorous adult bream could also reduce bioturbation of sediments during feeding, which enhances nutrient release and turbidity and can disturb and uproot macrophytes. It is considered that recovery of water clarity and macrophyte colonisation will take 5 to 10 years, after which fish will be allowed back.

Concerns have been expressed by the Broads Angling Services Group (BASG) and other organisations and individuals about the potential impacts on local stocks if bream are prevented from using HGB for spawning. Bream angling is of economic importance to the local economy but they are also intrinsic components of the fish fauna and overall ecology of the broads and associated rivers. These concerns have led to assessments of seasonal fish populations and potential bream spawning habitat in HGB compared to other sites in nearby broads and rivers (Hindes, 2017, 2018). A tracking study is also underway to assess movements of bream and pike (Winter, 2019).

This report, prepared on behalf of the Institute of Fisheries Management, reviews available reports and data, both recent and historical, and questions both the philosophy behind the project and the criteria for assessment of success. In view of the potential effects on angling and compliance with Water Framework Directive ecological status of water bodies, the following questions are treated in more detail:

- How important to the restoration of HGB is the exclusion of bream?
- How important is HGB as a bream spawning and nursery habitat and hence to populations in the local catchment?

REVIEW OF REPORTS AND DATA

Reports have been provided by BASG, consisting of:

<u>Hoveton Great Broad Restoration Project: seasonal comparative fish surveys: summary report</u> (Hindes, 2017)
Fish population densities were relatively higher in the Hoveton Great Broad/Hudsons Bay (HGB/HB) complex than other adjacent broads in all four seasons, but especially in spring and summer, suggesting that the complex provides key spawning sites for the immediate area and is potentially important to the River Bure system. Most of these fish are roach and bream. Evidence was collected of bream spawning in HGB.

<u>Bream spawning habitat assessment, Hoveton Great Broad and environs</u> (Hindes, 2018)
This survey emphasised the high proportion of good quality spawning habitat that occurs in HB and HGB relative to other nearby broads.

<u>Investigating the fish stocks of Hoveton Great Broad: A multi-method approach to a complex system. Recap of baseline surveys for BASG ESG 17 Jan 2019</u> (Lane & Hindes 2019)
This presentation gives the background to the project and the need for biomanipulation, including both barriers and fish removals, and presents results of various fish surveys. It also emphasises the very large contribution to the local economy that comes from angling. A hydroacoustic survey of the River Bure showed very high population densities of fish around Hoveton. Hoveton Marsh Dykes represent a notable winter refuge for roach and there is much diurnal and seasonal movement between HGB and the River Bure. Adult bream move into the river at dusk to feed, while juvenile roach move into HGB from the river to feed. These movements are reversed at dawn. Bream moved into HGB to spawn.

<u>The behavioural ecology of lowland river bream and pike</u>. (Winter, 2019)

Tagging studies have revealed a peak in range of movement of bream during April and May, probably associated with spawning migration, several moved to HGB area.

Hoveton Great Broad – status of the fishery; Hoveton Project Update for Broads Angling Services Group (BASG) –January 2019 (Bielby, 2019)
This presentation gives further details about progress. Dredging should be completed October-December 2019 and biomanipulation scheduled from January 2020 onwards. Fish removals are included as well as fish barriers, subject to EA permission. The importance of HGB for fish is recognised, including its significance for spawning bream although fish are found in other areas and may adapt to lack of access for spawning. The impact of closure alone is uncertain but is suggested probably not significant given the adaptability of species and other spawning sites and suitable habitats available. Bielby suggests that the project will be of long-term benefit to the fishery by improving habitats, although barriers to entry to HGB could increase risks from *Prymnesium* and salinity to fish by displacing them to areas where they are vulnerable. EA and NE need to work together on a mitigation plan and conduct further surveys.

These were the only reports supplied by BASG. They leave significant gaps regarding some of the other data collected about fish sizes and ages and lack clarity about the methods of biomanipulation to be employed.

PROBLEM ANALYSIS

Removal of phosphate inputs and the reservoir in sediments are usually not enough to trigger a change from a metastable state of turbid water dominated by phytoplankton to clear water where macrophytes can flourish. This has been achieved most reliably (but not very!) in other lake restoration projects by removing, fish that feed on zooplankton that, in turn, were feeding on phytoplankton. Surveys and data have not been collected from HGB to show the diets and collective feeding effects of bream and roach to demonstrate this.

The benefits of restoration to local fish populations and angling have not been made clear. This could involve an abundance of new species that make for good angling experiences, such as rudd and tench, alongside continued access to bream and roach, once a new equilibrium is established. However, clear water and an abundance of macrophytes makes for more difficult angling. There also appear to be no benefits for the fishery in the River Bure, and there are risks to its ecological status because of the loss of lateral connectivity for fish during planned biomanipulations.

The methods to be used for fish removals, and the target species and sizes of fish, seem to vary among the reports supplied and web pages on the internet. Some sources indicate that complete barriers to fish movements will be installed, others that spawners will be selectively excluded from entering HGB from the river and dykes by barriers (as opposed to fishing them out). Some sources do not distinguish the species and spawning status of the fish to be excluded; while other sources do not distinguish the direction of fish movements and seasonality of the exclusion process by the barriers. The Hoveton Great Broad web page https://hovetongreatbroad.org.uk/the-project/biomanipulation-a-fishy-business/ states that, 'We have been using sonar cameras to monitor the natural movements of fish in and out of the broad. By carefully choosing the right season and the right time of day to close the broad off from the river, we will lock out a lot of the fish as they move into the river by themselves.' Past Environment Agency surveys and Lane &

Hindes (2019) have shown that many adult bream move out of HGB at dusk and return at dawn, while juvenile roach move into HGB at dusk and return to the river at dawn. Large individual bream immigrate from riverine habitats to spawn in HGB in spring. It is however unclear how effective these means of selective exclusion will be in achieving the aims of the project.

Objections to the restoration project should have been countered by time-bound scenarios based on how well the project has achieved its goals. At the moment, timescales for achievement of goals are vague (between 5 and 10 years) and the assessment of achievement of goals is not specified, nor if, why, how and when bream migration could be restored. Also, actions to restore a fishery in HGB according to the success or otherwise of the lake restoration project have not been agreed. The question of compensation for loss of amenity for BASG also does not appear to have been discussed.

The project outline states that "It is considered that recovery of water clarity and macrophyte colonisation will take 5 to 10 years, after which fish will be allowed back." Defining this endpoint and its stability is essential. If no recovery were to take place after 10 years, would bream still be allowed back? If the recovery was apparent before 5 years, could bream be allowed back earlier?

DISCUSSION

The stated aims of the project focus almost entirely on restoration of clear water and macrophyte communities in Hoveton Great Broad (and Hudson's Bay) as related to its Habitats Directive status. No information seems to have been provided about the current ecological statuses of HGB or the River Bure under the Water Framework Directive (WFD). Data Explorer provided by the Environment Agency indicates that the ecological status of HGB is assessed as Poor and that of the Bure for ecology, in 2014, as Good. Unfortunately, the fish element of ecological classification for lakes is still under development, so the effects of fish removal and exclusion from HGB cannot be assessed for the WFD. Although the ecological status of the River Bure is assessed as Good, it is not clear how the fish element has been assessed. The fish element used in England is based on a restricted method working with species presence and general abundance. The Water Framework Directive gives ecological status for fish as Good for both rivers and lakes, when: 'numbers and species of fish present show only slight changes due to human impacts on water and habitat quality or when age structures of fish communities show some disturbance due to human impacts and may even have age classes missing'. Without having data on age structures of fish communities, it is not possible to show the degree of compliance with Good ecological status for the fish element.

The fish surveys have emphasised the importance of the HB/HGB complex as part of a local ecosystem including the River Bure and that bream and roach move freely between these environments for feeding, spawning and refuge. Without complete barriers to fish movement, it is unknown whether their abundance in the HGB could be significantly reduced.

Although the Bure restoration project for Hoveton Great Broad and Hudson's Bay may bring about restoration of the lakes in terms of the Habitats Directive bringing them to a 'Unfavourable Recovering' conservation status by 2020, it would do this in the short term by reducing the ecological status of these lakes in terms of fish under the Water Framework Directive. It could also reduce the ecological status of the River Bure as the fish populations of these lakes and the River

Bure are intimately linked, with HGB probably providing essential spawning, nursery and refuge habitats. Since the objective of the biomanipulation element of the HGB project is to restrict recruitment of bream and roach, this could be construed as a human impact causing deterioration of the ecological status of the fish element in the lake, although possibly outweighed by improvement in other elements and regarded by the competent authority as having benefits to society. However, if the HGB biomanipulation caused a decrease in recruitment of bream and roach in the Bure, as shown by unfavourable changes in age structure or overall abundance, then this could result in deterioration in ecological status of the fish element in the Bure, contrary to the aims of the Water Framework Directive, but without improvements in other elements and significant benefits to society. This could invoke the possibility of infraction proceedings in Europe for producing such deterioration.

Although there are some historical Environment Agency data on ages, sizes and growth rates of HGB and Bure bream, no details are given in any of the studies cited above about the size and age composition of current fish stocks in the HB/HGB complex, nor how this relates to their diet, especially with regards to potential impacts of zooplankton predation versus benthivory. Details of these aspects would also be needed to follow effects of recruitment in HGB and the River Bure.

A proportion of adult bream move into HGB in spring to spawn and then leave again after spawning, while others remain local, moving into the river at night to feed and resting up during the day in HGB. The effectiveness of partial barriers to block spawning bream is unknown and some bream probably remain in HGB permanently or for long periods. Juvenile roach, however, move into HGB at night to feed. It is the feeding of these roach that is probably more important for biomanipulation in reducing consumption of zooplankton by fish. Although the fish reports indicate that sizes and ages of fish were recorded, there is no discussion of year classes that would indicate variability in recruitment, or links of sizes to diet to indicate grazing pressure on zooplankton. No data are provided on the relative role of young bream in predating zooplankton in HGB or the role of immigrant bream spawners in determining recruitment of young bream in HGB. The majority of zooplanktivorous fish in HGB are roach, and these probably are largely recruited from the breeding of the resident population, so restricting entry of spawners from the Bure is unlikely to affect predation levels by roach on zooplankton.

Reviews of biomanipulation indicate that mass removals of fish are needed to increase the likelihood of success. In HGB, the stated aim is to remove 75% of fish (principally bream and roach), but there is a lack of information on resident populations and targets have not been quantified in terms of species, numbers, sizes and biomass reductions. As discussed above, whether or not restricting the entry of spawning fish will produce significant benefits is unknown. The project outline states that recovery of water clarity and macrophytes will take 5 to 10 years, after which fish will be allowed back, but actual target measures of water clarity and macrophyte abundance have not been set.

If a large reduction in bream numbers could be achieved, problems could then arise from the pumping of interstitial P in the sediments into the water column as a result of increased bioturbation by chironomids following reductions in predation pressure from bream. Monitoring of the Hoveton Great Broad fish exclosure relative to the main lake basin provides some evidence of this mechanism (Phillips *et al*., 1994). Predation on cladocera by invertebrates, such as *Neomysis integer*, could also cause phytoplankton to increase (Meijer *et al*. 1994).

There is much evidence that biomanipulation of fish populations can be beneficial in reducing phytoplankton densities and producing clear water (Bernes *et al*., 2015). However, this appears to be sustainable only if excess nutrient inputs and sediment reserves are reduced first, such that water column total phosphorus is <0.05 mg/l and certainly <0.1 mg/l. The evidence is often less clear about relationships between reductions in nutrients and the subsequent recovery of plant communities.

Overall, evidence from lakes where most or all of the fish stock is removed suggest that a short-term reduction in P is unlikely, with in fact the opposite often being observed. In the medium term, binding of the P in the biomass of increasing fish and macrophyte populations might become low enough to guarantee stability of the desirable macrophyte-dominated state, but in the longer term, if the fish stock continues to recover, the conditions leading to high TP concentrations in the water column could well be re-activated, as has been found in other studies, e.g. in 27 Danish lakes subject to effective biomanipulation (removal of >200 kg ha-1) by Søndergaard *et al*. (2008).

Studies in Norfolk Broads generally show results similar to those in the literature for other still waters. For example, studies carried out in HGB in 1978-81 showed that zooplankton populations mainly comprised small Cladocera and rotifers in the broad, whilst larger-bodied Cladocera dominated in the inter-connected HB (Timms & Moss, 1984). Water lily beds in HB probably provided refuges for zooplankton from fish predation during daylight, similar patterns being observed in fish-free enclosures in the broad in 1981 and 1990-2003 (Phillips et al.¸1994, 2015, 2016). Enclosure studies in the broad have confirmed that in the absence of zooplanktivorous fish like young bream and roach, large Cladocera were able to survive and graze down phytoplankton to produce chlorophyll a concentrations of < 0.01 mg/l, compared to >0.1 mg/l in open water. Flushing by through-flow from the River Bure appears to favour small rapidly-growing phytoplankton, rather than inedible colonial cyanobacteria with slow growth. However, although these and studies in other broads have shown strong positive relationships between biomanipulation and *Daphnia* numbers and water clarity, conclusive evidence of long-term relationships with macrophyte density and diversity is often lacking (Moss et al., 1996; Hoare et al,, 2008; Phillips et al, 2016).

A review by Phillips *et al.* (2016) of the use of lake restoration techniques in Broadland demonstrated the complexity of understanding likely responses to phosphate reduction, sediment removal and biomanipulation. Unexpected outcomes have often occurred, including short-term reductions in water quality. This is also the case in many other studies elsewhere, e.g. Meijer *et al*. (1994). Probably the most certain result is an adverse effect on the existing fishery as it is perceived by anglers. Despite this, the project proposals give little attention to restoring the angling value of HGB and the timescales for this, whether or not the project is deemed successful in terms of water clarity and macrophyte re-establishment. BASG should have been persuaded of the potential benefits to angling of the restored lake and how they could be assisted in achieving satisfaction with these, e.g. by stocking with species that should thrive in the restored lake, yet not compromise continuing good water quality, and also provide good angling catches, albeit of a changed type, e.g. rudd and tench.

Recruitment of roach is likely to be a significant factor in the success or otherwise of biomanipulation. The majority of zooplanktivorous fish in the HGB complex are juvenile roach. Little is known about the factors influencing successful recruitment of roach. Spawning stock:recruitment relationships are largely unknown, but abiotic factors are often very important. For example, strong recruitment of riverine cyprinids may occur in warm summers (Nunn *et al*., 2003). However, studies by Cryer *et al.* (1986) in Alderfen Broad demonstrated links both ways between roach recruitment success and zooplankton abundance. When fry were abundant (in 1979 and 1981, but not in 1980 or 1982) the summer zooplankton became sparse and was dominated by copepods and rotifers. Reduced food availability for roach lowered fecundity, leading to two year cycles in cladoceran prey abundance and in roach recruitment.

Fish surveys show the HGB complex supports relatively large bream and roach populations and dominates the overall mean density and biomass estimates for bream in the local catchment during spring (Hindes, 2017, 2018; Bielby, 2019; Lane & Hindes, 2019). Past Environment Agency fish surveys have shown that bream sampled in the eutrophic HGB exhibited higher than national average growth rates in most years and that many individuals were >12+, some reaching >20+. The high mean weights of individual bream in spring-early summer indicate HGB is very important for mature spawners. This is supported by evidence from the more recent surveys cited above and initial results from on-going tracking studies of bream (Winter, 2019). These all show the HGB complex is a key spawning and nursery site for the immediate area and, probably, the whole River Bure system. Previous EA surveys show 0+ and 1+ bream were absent from the Bure, but that particular hotspots for adults occur in daytime near entrances to broads and in boatyards and dykes between Salthouse and Wroxham Broad. Large adult bream (35-55 cm) appear to migrate from riverine habitats to spawn in spring but at other times, many feed in the river but move into the broad at dawn and show strong fidelity to certain resting sites. The HGB complex is also very important as a roach spawning, nursery and wintering habitat, with many juveniles moving into HGB out of cover in the broad and river to feed on plankton in open waters at night.

The importance of off-stream habitats like HGB for bream spawning and early growth is illustrated by studies such as those of Molls (1999). This showed that during spring, adults migrated from the River Rhine into permanently connected oxbows and harbour backwaters to spawn and then migrated back again, although some ≥5+ adults remained to constitute a resident breeding stock. Newly-hatched bream tended to remain in oxbows for one to two years before migrating into the river. Such age-dependent habitat shifts are probably associated with the availability for 0+ and1+ bream of larger cladocera and benthic chydorids and plant cover in shallower marginal areas, whereas the riverine habitats provided a richer source of zoobenthos, such as chironomids, as food for adults.

All these findings emphasise the importance of the HGB complex to the sustainability of bream in the catchment. Furthermore, evidence from visual estimates of spawning habitat concluded that HGB and HB were of unique importance compared to five nearby broads (Hindes, 2018). Thus it appears that other quality spawning and nursery habitats are poorly available in the catchment.

CONCLUSIONS REGARDING BIOMANIPULATION OF BREAM STOCKS

1. **It appears unlikely that exclusion of spawning bream from entering HGB will be sufficient biomanipulation to reduce phytoplankton densities, increase water clarity and ensure macrophyte recovery.**

2. **Biomanipulation in HGB by excluding spawning bream could have severe impacts on local stocks in both HGB and the River Bure, affecting fish community structures, aquatic ecology and angling. It also produces a dilemma for the Environment Agency with its duties to 'maintain, improve and develop fisheries in a way that, amongst other things, enhances the socio-economic contribution of fisheries and puts people at the centre', and as a competent authority for the Water Framework Directive charged with maintaining or improving the ecological status of water bodies.**

RECOMMENDATIONS

1. Discussions should be held with Natural England to clarify the points raised in the Problem Analysis above.

2. The targets for fish exclusion by the fish barriers need to be quantified and overtly stated. Likely impacts of the biomanipulation of fish on the WFD ecological status of both HGB and the River Bure should be modelled.

3. The age and size structures and diets of relevant fish species in the communities of HGB and the River Bure should be monitored and related to the need, if any, to remove fish of particular species and sizes in order to achieve project objectives.

4. The roles of fish and other organisms in phosphate recycling and control of zooplankton that in turn control phytoplankton, water clarity and macrophyte recovery should be regularly monitored and modelled against project objectives.

5. End points for fish removal and fish exclusion operations should be pre-determined for various scenarios.

6. A preliminary study should be carried out (possibly in Hudson's Bay alone) to assess the efficacy of excluding bream spawners, effects on recruitment, potential impacts on catchment stocks and to inform future approaches.

7. Mitigation measures for effects on angling during the fish exclusions should be discussed, as well as establishment of a new fishery adapted to a restored environment.

REFERENCES

Bernes, C., Carpenter, S.R., Gårdmark, A., Larsson P., Persson, L. & Skov, C. (2015) What is the influence of a reduction of planktivorous and benthivorous fish on water quality in temperate eutrophic lakes? A systematic review. *Environmental Evidence* 4:7

Bielby, C. (2019) Hoveton Project Update for Broads Angling Services Group (BASG). Presentation to BASG ESG 17January 2019

Cryer, M., Peirson, G. & Townsend, C.R. (1986) Reciprocal interactions between roach, *Rutilus rutilus*, and zooplankton in a small lake: Prey dynamics and fish growth and recruitment. *Limnology and Oceanography* 31: 1022-1038.

Hoare, D., Phillips, G. & Perrow, M. (2008) *Review of Biomanipulation - Appendix 4 - Broads Lake Restoration Strategy*. Broads Authority.

Hindes, A. (2017) *Hoveton Great Broad Restoration Project: Seasonal comparative fish surveys Summary Report. V 2.1* April 2017 (unpublished).

Hindes, A. (2018) *Bream spawning habitat assessment: Hoveton Great Broad and environs. V 1.3* May 2018 (unpublished)

Kelly, A. (2008) *Lake Restoration Strategy for the Broads*. Broads Authority.

Lane, S. & Hindes, A. (2019) Investigating the fish stocks of Hoveton Great Broad: A multi-method approach to a complex system. Recap of baseline surveys. Presentation to BASG ESG 17 January 2019.

Meijer, M.L., Breukelaar, A.W. & Hosper, S.H. (1994) Mass removal of fish from Lake Wolderwijd, The Netherlands. Part III: Effects on water quality. In Cowx, I.G. (ed.) *Rehabilitation of Freshwater Fisheries*, Fishing News Books, Oxford, pp. 415-434. Molls, F. (1999) New insights into the migration and habitat use by bream and white bream in the floodplain of the River Rhine. *Journal of Fish Biology*, 55: 1187-1200.

Moss, B., Stansfield, J., Irvine K., Perrow, M. & Phillips G. (1996) Progressive restoration of a shallow lake: A 12-year experiment in isolation, sediment removal and biomanipulation. *Journal of Applied Ecology* 33, 71-86

Nunn, A.D., Cowx, I.G., Frear, P.A. & Harvey, J.P. (2003) Is water temperature an adequate predictor of recruitment success in cyprinid fish populations in lowland rivers? *Freshwater Biology*, 48: 579-588.

Phillips, G., Jackson, R., Bennett, C. & Chilvers, A. (1994) The importance of sediment phosphorus release in the restoration of very shallow lakes (The Norfolk Broads, England) and implications for biomanipulation. *Hydrobiologia* 275, 445–456

Phillips, G., Bennion, H., Perrow, M.R. , Sayer, C.D. , Spears, B.M. , Willby, N. (2015) *A review of lake restoration practices and their performance in the Broads National Park, 1980-2013.* Report for Broads Authority, Norwich and Natural England.

Phillips, G., Bennion, H., Perrow, M.R., Sayer, C.D., Spears, B.M., Willby, N. (2016) *Hoveton Great Broad Dossier. Part of the review of lake restoration practices and their performance in the Broads National Park, 1980-2013*. Report for Broads Authority, Norwich and Natural England.

Søndergaard, M., Liboriussen, L., Pedersem, A.R. & Jeppesen, E. (2008) Lake restoration by fish removal: short- and long-term effects in 36 Danish Lakes. *Ecosystems*, 11, 1291-1305.

Timms, R.M & Moss, B. (1984) Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland ecosystem. *Limnology and Oceanography*, 29, 472-486

Winter. E. (2019) Tracking Common Bream and Northern Pike in the Norfolk Broads. Focus on Science, Hoveton Great Broad Restoration Project website, 4 January 2019. https://hovetongreatbroad.org.uk/tracking-common-bream-and-northern-pike-in-the-norfolk-broads/