FISHERIES MANAGEMENT OF THE UPPER LAKE AT WIMPOLE

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Introduction

Originally designed by famous landscape gardener, Capability Brown, the Upper or carp lake is the second of a sequence of three interconnected lakes (the upstream lake is no longer part of the Estate). The lakes are linked by a spring-fed stream, which eventually flows into the River Rhee. Associated with the carp lake is a large reed (*Phragmites australis*) bed, thought to be the largest in Cambridgeshire. However, the reed bed has been reduced somewhat in size over the years, as a result of the accumulation of fine sediments, transported by the stream and management work in 1996. During the latter, the lake was dredged, returning most of it to approximately four metres in depth. Around the same time c. 5 000 small carp (*Cyprinus carpio* L.) were introduced into the lake, followed by larger specimens (up to 10 lbs) rescued from various water bodies throughout the Estate. Rudd (*Scardinius erythropthalmus* (L.)) are also known to be present in the lake.

Dr Martin Perrow (ECON) drafted a preliminary management plan for the Estate's numerous and diverse aquatic resources in 1999. The upper lake was noted as turbid and combined with a poor littoral margin was short of its conservation and landscape potential. With regard to the upper lake, the management plan stated that the fish community would probably require manipulation, predominantly in the form of removal of undesirable elements, in order to transform the turbid lake into the desired conservation asset, whilst also providing the opportunity for recreational angling and a further income for the estate. Biomanipulation is a "tried and trusted" and relatively inexpensive tool for lake restoration (Perrow & Tomlinson, in press). Removal of an unknown number of carp was subsequently undertaken by Framlingham Fisheries.

A fisheries survey was required to reveal the exact nature of the fish community including species composition, overall density and biomass. This was to also help elucidate the likely interactions within the lake and, ultimately, the cause of the turbidity in the lake. The survey was thus to form the basis of a management plan for the lake.

The purpose of this report is to reveal the results of the fisheries survey of the carp lake, and to set out the options available to the future management of the lake, with particular regard to the fish community.

Methods

Seine nets were used as the primary method for the fisheries survey, as the depth of the lake (> 2 m) precluded point abundance sampling by electrofishing (PASE). Seines were also favoured as a result of the need to sample a large area of water to increase the chances of capture of a potentially small number of large fish. As seine netting fails to sample the littoral margin (edge) as effectively as the limnetic zone (open water), an additional survey using free (i.e. without stop-nets) electrofishing of the littoral margin was undertaken to sample species and age groups associated with the littoral margin (e.g. pike, *Exos lucius* and tench, *Tinca tinca*).

Seine netting

The survey using seine nets was undertaken on 22nd October 2001 when the lake was turbid after heavy rain. Four hauls were conducted around the lake, using a 60 m long, 5 m deep seine net with a 6.5 mm mesh size cod end, in conjunction with a additional 25 m length of 2.5 m deep net of the same mesh. With retention of some net on the bank the resulting net was 80 m long. On each occasion, the net was set from a 3 m dinghy, and the size and shape of the enclosed area was noted, allowing an area for each haul to be calculated. Hauling was conducted by three personnel: Martin Perrow and Mark Tomlinson of ECON and Simon Damant of the National Trust.

At the bank, fish were removed using long handled nets and transferred to large, aerated tubs. All fish were identified and measured to the nearest mm fork length, apart from with abundant distinct size classes of some species, which were counted after approximately 100 – 200 individuals (ind.) had been measured. Larger fish were weighed to the nearest 25 g, but otherwise biomass was calculated using length-weight regressions held by ECON. Scales were removed from the shoulder region of a representative sample of fish for ageing purposes (see below).

The abundance (ind. ha^{-1}) and biomass (kg ha^{-1}) of each species at each haul was calculated by dividing the total number of individuals or weight by the area of the haul. Overall densities were than expressed as a mean with standard error (±1SE) of all hauls.

Electrofishing

The electrofishing of the littoral margin was undertaken on 17th December 2001 after the lake had cleared and visibility was suitable. The survey was conducted from a 3 m dinghy, using high frequency pulsed DC electrofishing equipment, with two personnel, one operator and oarsman manoeuvring the dinghy by push rowing. The operator explored the littoral margin, capturing all stunned fish with a long handled net. Fish were held in two large water-filled containers within the boat until being processed (see above).

A minimum abundance and biomass measure was calculated by dividing the total number/biomass of each species by the area of the lake. Length frequency data gathered during perimeter electrofishing was added to that gathered during seine netting.

Fish ageing

Scales were taken from carp, rudd and tench. The scales were then aged using a Projectina, a specially designed piece of equipment similar to a microscope. The scales were magnified to a suitable magnification (x10 – x30) and the number of annuli (densely packed circuli which represent winter months) on each scale determined. As the fish were sampled during the winter, the edge of the fish scale was classed as a year.

Results

Seine netting

A total of six species were captured in the four hauls sampled in the lake. In order of abundance these were: three-spined stickleback *Gasterosteus aculeatus* (1332 ind.); rudd (399 ind.); carp (12); tench, rainbow trout *Oncorhynchus mykiss* and; brown trout *Salmo trutta* (all 1 ind.). Three-spined sticklebacks dominated the lake numerically, but, as expected, carp dominated the biomass; at 122 kg ha^{-1}, more than double the biomass of the next species, rudd at 56 kg ha^{-1} (Table 1; Fig. 1). For rudd, the reasonable biomass figure was achieved despite the mean biomass of the numerically dominant young-of-the-year (YOY) being only 0.85 g (a value less than the mean biomass of the dominant fish, three-spined stickleback at 1.18 g) (Fig. 2). The reasonable biomass is thus testament to the contribution of larger fish.

Electrofishing

A total of four species were captured in the survey of the littoral margin: rudd (778), three-spined stickleback (115), tench (5) and carp (4). This reinforced the result from seine netting that rudd and three-spined sticklebacks are the numerically dominant fish in the lake (Table 1; Fig. 1). Also worthy of note was the capture of only three small (< 150 mm) carp, indicating that although recruitment has occurred, it has been sporadic and the population is dominated by introduced large individuals.

Fish ageing

Of the small carp captured and aged, the 45 mm fish was aged at 1 year old, two fish at 84 and 130 mm were aged as 2 years old. Of the larger individuals, 300 to 400 mm fish were aged as 5 and the largest individuals >500 mm appeared to be either 7 or 8 years old. Fish thus displayed a typical pattern of small size at the end of the first year on account of late spawning (carp require at least 18°C to spawn successfully) and then grow increasingly quickly. Overall, growth was good.

Table 1
Mean abundance (ind. ha) and biomass (kg ha) of all fish species captured by the two survey techiniques, seine netting and electrofishing the littoral margin, during the fisheries survey of the carp lake, Wimpole Hall, Winter 2001.

		Carp		Rudd		Tench		Rainbow Trout	
		$Ind.ha^{-1}$	$Ind.kg^{-1}$	$Ind.ha^{-1}$	$Ind.kg^{-1}$	$Ind.ha^{-1}$	$Ind.kg^{-1}$	$Ind.ha^{-1}$	$Ind.kg^{-1}$
Seine Netting	Mean	56.075	121.831	1864.486	56.446	4.673	0.161	4.673	5.607
	SE	15.530	31.995	362.336	6.393	3.595	0.124	3.595	4.313
Electrofishing	Mean	1.905	0.699	375.238	2.348	2.381	0.140	0.000	0.000

		Brown Trout		Three-spined Stickleback		Total	
		$Ind.ha^{-1}$	$Ind.kg^{-1}$	$Ind.ha^{-1}$	$Ind.kg^{-1}$	$Ind.ha^{-1}$	$Ind.kg^{-1}$
Seine Netting	Mean	4.673	8.178	6224.299	7.339	8158.879	199.562
	SE	3.595	6.290	1872.594	2.211	1850.266	30.687
Electrofishing	Mean	0.000	0.000	54.762	0.065	434.286	3.252

Fig. 1
Relative abundance and biomass of all fish species captured as revealed by seine netting and electrofishing the littoral margin, during the fisheries survey of the carp lake, Wimpole Hall, winter 2001.

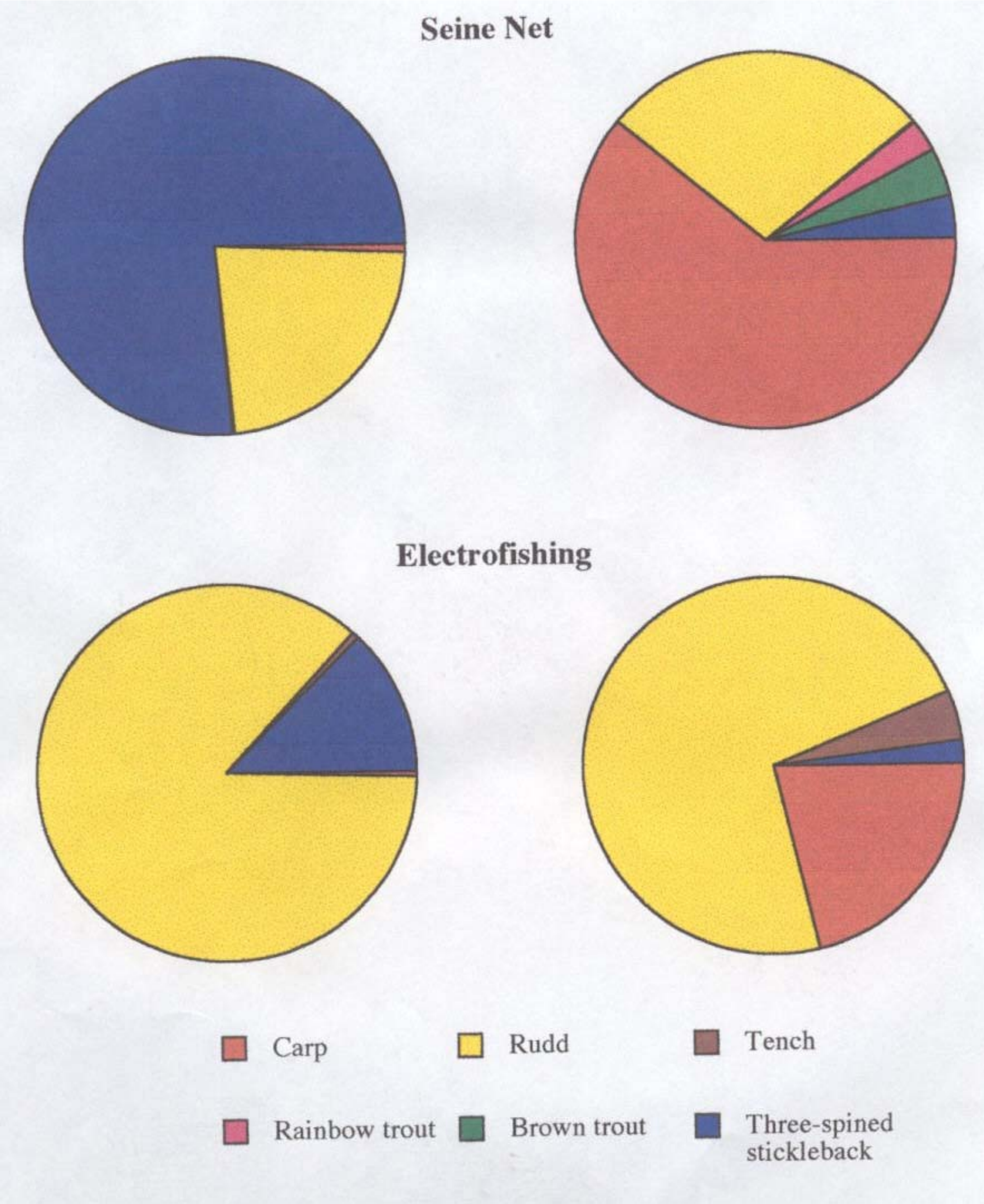
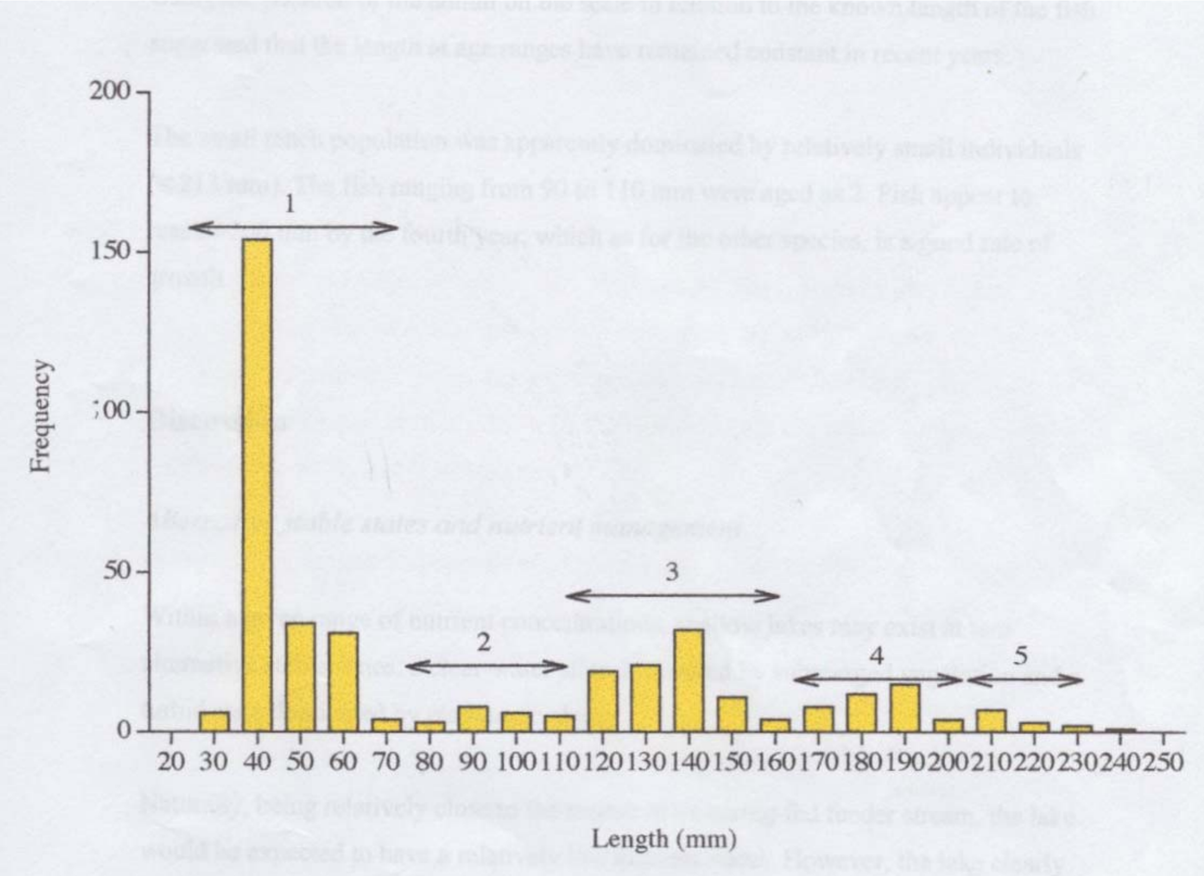


Fig. 2

Length frequency and age of Rudd (n=390) captured by both techniques of the fisheries survey of the carp lake, Wimpole Hall, Winter 2001.



Five different age classes, 1 to 5 years old, were recorded from the rudd population ranging from 40 to 225 mm in size (Fig. 2). Despite some overlap between the age classes, growth was generally good and above the national average for the species. Using the position of the annuli on the scale in relation to the known length of the fish suggested that the length at age ranges have remained constant in recent years.

The small tench population was apparently dominated by relatively small individuals (< 213 mm). The fish ranging from 90 to 110 mm were aged as 2. Fish appear to reach >200 mm by the fourth year, which as for the other species, is a good rate of growth.

Discussion

Alternative stable states and nutrient management

Within a given range of nutrient concentrations, shallow lakes may exist at two alternative stable states: a clear-water state dominated by submerged vegetation and a turbid state dominated by planktonic algae.

Naturally, being relatively close to the source of its spring-fed feeder stream, the lake would be expected to have a relatively low nutrient status. However, the lake clearly receives a high loading of fine sediments and almost certainly nutrients from its arable catchment and the lake (managed as a trout fishery) immediately upstream. Excessive loading of fine sediments obviously necessitated the dredging of the lake in the past and although some nutrients will be flushed through the system, much is likely to be retained in the lake. Whilst some of the legacy of previous enrichment will have been removed by dredging, the lake is still likely to receive a considerable nutrient loading. Thus, although the exact nutrient status of the upper lake is not known, it is likely to be eutrophic, but as indicated by the presence of at least some vegetation (*Myriophyllum* spp., was present on the site visit in 1999) should still retain the ability to become clear. Whether or not a clear water state may be self-sustaining without measures to control nutrient (and silt) loading is unclear. Such measures could be:

- Buffer strips alongside arable fields.
- Regularly managed silt traps on the feeder stream.
- Control of the Canada goose (*Branta canadensis*) population.

However, the greatest threat may prove to come from the trout fishery and its current management.

Ideally, a nutrient budget would be compiled and the major sources of nutrients identified and a plan of action put forward for these to be tackled. However, this would not be without considerable expense and would almost certainly require negotiation with third parties outside of the jurisdiction of the estate. Consequently, it is debateable if this is plausible or not.

Consequently, for the purposes of this report it is assumed that the biotic interactions within the lake have a great impact upon the status of the lake and the clear-water state may become self-sustaining without further control of nutrients in the short-term. However, the estate should look toward the long-term management of nutrient (and silt) input into the upper and lower lakes and stream, which constitute a significant part of the aquatic resource of the estate.

The impact of fish

Turbidity in shallow lakes may be caused by i) input of fine sediment ii) resuspension of fine sediment or iii) algal growth. The first two are expressed as brown water and the latter as green water. The two major fish related processes that can result in turbidity in ii) and iii) above, are benthivory and zooplanktivory respectively. In the former, the bottom feeding habits of typically large species causes the re-suspension of the bottom sediments. Nutrient release and the excretion of nutrients from the fish themselves can also result in algal growth. Zooplanktivory involves selective predation of large bodied cladoceran zooplankton, e.g. *Daphnia* spp. often by small species and individuals, thereby reducing the grazing potential of zooplankton upon algae, whose populations increase as a result.

It is often possible to judge which process may be occurring, depending on the nature of the fish community and the density and biomass of particular species and age groups. The results of the survey suggest that both benthivory and zooplanktivory may be occurring in the Upper lake. The abundance of both rudd and particularly three-spined sticklebacks, 1864 (0.19 m^{-2}) and 6224 ind. ha^{-1} (0.62 ind. m^{-2}) is far above the threshold of 0.2.m^{-2} at which zooplanktivorous fish are predicted to have an impact (Perrow *et al*. 1999*a*).

Indeed, the very presence of a high density of sticklebacks suggests the fish community is yet to mature and may reach even higher density. Sticklebacks are generally an earlycolonising species that are gradually out-competed by cyprinid (carps and their allies) fishes over time.

Even if sticklebacks are gradually replaced by rudd and perhaps small carp, densities will remain high as a result of the absence of predatory fish in the lake. Not a single pike or perch were captured, despite anecdotal reports of at least the former species being present. Although a single rainbow and brown trout were captured by seine net, the odd escapee from the stream will have very little effect in controlling zooplanktivorous fish.

In addition, the biomass of benthivorous carp present in the lake is also well above the value thought likely to cause significant sediment resuspension and nutrient release (50 kg ha^{-1}- de la Haye & Meijer 1991, Breukelaar *et al.* 1994). The vast bulk of the carp biomass is made up of large fish (>500 mm), which in turn, are likely to generate the bulk of fish resuspended material. These large fish appear to be the fingerlings introduced in 1996. Without further introduction it is assumed that all younger fish are the progeny of these and the older fish introduced in 1996 (see Introduction) – none of which were captured and it is unclear if some of these have been removed. Recruitment of young fish has thus been poor, which is typical of carp populations, reliant on high water temperatures for spawning and larval survival. Small carp thus present no obvious threat in their own right.

The available options

The manipulation of the fish community appears essential if clear water and submerged macrophytes are to be promoted in the upper lake. In essence, there are two available options for manipulation which differ in severity and therefore cost.

The first is the wholesale removal of all elements of the fish community likely to have an impact upon water clarity (i.e. carp, small rudd and three-spined sticklebacks). This option would certainly attain clear water within a short time scale. In terms of conservation, this would possibly prove to be the best option. With the establishment of macrophytes, shifts in the fish community would be expected, with tench, especially, increasing. The presence of macrophytes would also provide refuges for zooplankton and reduce the impact of predation by small rudd. Large individuals, which also consume some macrophytes and the invertebrates associated them, would also benefit from macrophyte-dominated conditions. In fact, rudd would be a key component of the fish community of a macrophyte-dominated lake. The removal of rudd thus centres on the short-term manipulation of small fish.

Unfortunately, the removal of small rudd and sticklebacks is likely to be time-consuming and therefore costly. There is no chance of this being undertaken by a fish dealer, as payment / part payment for the work, as neither have any real financial value. A dealer may remove the carp in such a deal however, although the efforts by Framlingham Fisheries show this is not easy and it may not be worthwhile for any dealer to make a second attempt.

Moreover, the removal of all carp would detract from the commercial interest of the lake. Consequently, it is suggested that 75% of the current biomass be removed to reduce the biomass to around 25 kg ha^{-1}, in order to provide angling interest but at a biomass where any detrimental impact is unlikely. However, it should be noted that if mortality does not keep pace with growth, the biomass of carp will increase over time.

Unfortunately, the size of the carp in the lake at present, precludes the establishment of a syndicate of carp anglers. To attract specialist carp anglers, fish between 10 –15 kg (c. 20 and 30 lb) would be necessary, far larger than the fish between 1.6 and 4.6 kg (c.4 to 10 lb) captured in the survey. Larger fish (the large fish introduced in 1996) may still be present, although it is unclear if at least some of these were removed in the removal exercise undertaken. The fish present could however form part of a diverse fish community attractive to “pleasure” anglers, in this case perhaps families purchasing day permits as part of their visit to the estate.

The second biomanipulation technique is simply to introduce predators to the lake in order to control the numbers of three-spined sticklebacks and small rudd, which currently enjoy little or no predation pressure (apart from birds). With predation pressure zooplankton populations could be maintained throughout spring / summer providing clear-water conditions.

Pike and perch are the two major predators naturally present in the UK and both would need to be introduced. This is because current thinking on piscivory, suggests that a suite of predators with contrasting feeding techniques – pike hunt alone ambushing their prey, and perch are an open water, chasing, group-living predator – are required in order to control populations of small fish. Greater emphasis may indeed be placed on perch, which are suggested to be more efficient predators of small cyprinid fish (Perrow *et al.* 1999*b*) although the presence of large pike in a lake would also be of benefit in attracting anglers.

Both pike and perch have been successfully stocked in lakes in Denmark (C. Skov, Danish Fisheries Institute *pers comm.*), although perch can be difficult fish to transfer between lakes. In order to control zooplanktivorous fish, approximately 50 kg ha^{-1} of perch and 25 kg ha^{-1} pike (i.e. 75 kg ha^{-1} total) would be required. Perch over 15 cm and pike of a range of sizes, with the bulk of fish between 20-35 cm, are recommended. This equates to approximately 1 300 perch and 150 pike. Unfortunately, the availability of both perch and pike is generally poor and a dealer and / or source of fish may be difficult to find. Ideally, the source lake would be local and have similar conditions to the upper lake. Lakes on other National Trust estates may be a good option.

Even if fish are available, the cost – in the region of £1000-£1500 – may be prohibitive. In this case, a lesser number of fish may be introduced with the aim of establishing breeding populations that develop a suitable biomass over the medium term to effect control upon small fish. However, in order to achieve the latter, an increase in amount of suitable habitat may be required: in particular, the extent of littoral margin occupied by emergent vegetation. Currently, emergent vegetation is more or less absent from two sides of the lake. Establishing this will not only increase the habitat for fish but also increase visual amenity. Planting of both *Phragmites* (reed) and *Typha* spp. (Reedmace) obtained from elsewhere on the estate is recommended. This may need to be protected from grazing livestock – readily achieved by an electric fence limiting access to the margin – and grazing birds – usually requiring a chicken-wire fence preventing access from both the land and water.

With the purchase of any fish the Environment Agency information booklet on purchasing fish “Buyer beware” should be consulted. In basic terms, the dealers should provide copies of both Section 28 (to remove fish) and Section 30 (to introduce fish) consents from the Environment Agency. Health certification from the Agency or an approved agent should also be supplied.

Conclusions & recommendations

- The Upper lake is in a turbid state. Although loading of nutrients (and fine sediments) is the primary cause, zooplanktivory by sticklebacks and rudd, and the benthivorous effects of carp are more than capable of ensuring the lake remains in a turbid state. Although reduction of nutrient loading is desirable, this requires the source of the nutrients to be identified and management measures suggested. The latter are likely to prove difficult to put into practice and in the short term at least, the manipulation of the fish stock offers the best chance of promoting a clear-water state and increased conservation and amenity value.

- It is also assumed that recreational angling use of the lake is required to generate additional revenue for the Estate to at least fund lake management work. To provide benefit for both conservation and recreation it is recommended that pike and perch are stocked, with the aim of controlling small rudd and three-spined sticklebacks and providing additional angling interest. Removal of half the current biomass of carp would also limit their impact upon the lake whilst retaining a source of angling interest. Predation by the introduced pike and perch should ensure carp do not recruit strongly even with suitable climatic conditions.

- Should the cost of introducing a stock of pike and perch capable of controlling zooplanktivorous fish (~ 75 kg ha^{-1}), a smaller biomass may be introduced as a brood stock. The development of a larger stock through recruitment may hinge on an increase in suitable habitat.

- To enhance the natural recruitment of the introduced perch and particularly pike stock, the area of emergent vegetation needs to be increased through planting of locally grown material. This will require protection from both grazing animals and birds.

- The target fish community is thus a maximum of 50 kg ha^{-1} each of perch and rudd, with 25 kg ha^{-1} each of pike, carp and tench (i.e. 175 kg ha^{-1}) accompanied by small numbers of other species (e.g.escaped trout and perhaps eels, *Anguilla anguilla*). The balance within the population may shift depending on the biomass and cover of submerged vegetation supported. At high values, tench are likely to be favoured over rudd and carp. However, if submerged vegetation is slow to develop, recruitment from the current small tench population is likely to be limited. Thus, in the longer term, further introduction of tench may be considered (as may introducing eels and Crucian carp *Carassius carassius*).

- Such a biomass of fish should provide sufficient angling interest for pleasure anglers, most notably perhaps families purchasing day permits as part of their visit to the estate. Provided the use remains at a low level, little or no bailiff presence will be required. Should use increase, regular patrols will be required.

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