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Rehabilitation of urban lake fisheries for angling by managing habitat: general overview and case studies from England and Wales

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Abstract

In industrialised societies, angling provides a major recreational activity which creates high social and economic benefits. Urban fisheries in particular offer great potential for increasing angling opportunity. Many urban lakes and ponds, however, are situated in places such as city parks and industrial areas which has led to environmental problems of eutrophication, siltation, the absence of suitable fish habitat and poor angling quality. Not only has this resulted in low aesthetic value but the potential of these lakes as an angling resource was not being fully realised. A recent initiative promoted by the Environment Agency in England and Wales has identified lakes suitable for rehabilitation and an urban fishery development programme is now in place. This paper describes problems with urban stillwater fisheries and gives examples of the type of mitigation and enhancement measures that have been carried out. The primary techniques for physical habitat improvement in lakes include management of aquatic macrophytes, installation of artificial structures, desilting and adjusting the profile of the banks. Typical measures included floating reed rafts, restructured lake margins and fish refuges. Although such physical modifications were a key component of rehabilitation, it was also important to address the social context by raising awareness of issues amongst fishery owners and anglers in order to establish ongoing commitment to effective management. It is doubtful, however, that habitat rehabilitation alone can solve all the issues that impact on fishing quality in urban water bodies and a variety of management approaches might be needed to achieve desirable outcomes for all stakeholders.

Key words: habitat improvement, ecohydrology, recreational fisheries, socio-economic value.

1. Introduction

Many of the larger human settlements were built around a river system (Paul, Meyer 2001) and, in addition, canal networks have developed in association with industrial centres to aid human movements and the trade of goods (Wolter, Arlinghaus 2003). Consequently, every large city nowadays has within its jurisdiction aquatic ecosystems that are commonly described as "urban". Such water bodies are often characterised by multiple, long-lasting and often irreversible human impacts (Grosch *et al.* 2000; Wolter *et al.* 2003). Typically, they are situated in areas that have high population density and have been artificially created, e.g. in public parks. Therefore, shoreline development (being the alteration within ecotones of one essential habitat feature for successful fish recruitment, e.g. Winfield 2004) is often intense in urban aquatic ecosystems. Nonetheless, urban ecosystems generate important ecological services for society such as micro-climate regulation ("urban heat island effect"), noise reduction, rainwater drainage, indirect effluent "treatment" and homes for a diversity of aquatic organisms and birds (Bolund, Hunhammar 1999). In addition, recreational and cultural values are enhanced by urban aquatic ecosystems such as ponds and small still-water lakes. As well as providing opportunities for activities such as bird-watching, boating and swimming, they can form a valuable fishery resource of benefit to many people (Allen 1984; Pajak 1994; Schramm, Edwards 1994; Grosch *et al.* 2000; Wolter *et al.* 2000; Arlinghaus, Mehner 2003a, 2003b; Wolter *et al.* 2003; Arlinghaus, Mehner 2004a). Often angling is the single largest recreational activity in urban water bodies (Caffrey, Donnelly 1998). The play, rest and relaxation aspects of all urban ecosystems are perhaps the highest valued ecosystem services in cities (Bolund, Hunhammar 1999). Indeed, Ulrich *et al.* (1991) reported that stress levels decreased rapidly when people were exposed to more natural as compared with purely urban environments. Often found in public open spaces such as city parks, urban waters can have a wide range of possibly conflicting uses and an ownership regime not particularly suited to management for the benefit of fish stocks and angling (Allen 1984; Arlinghaus, Mehner 2003a, 2003b). For example, as urbanisation is increasing world-wide, city planners and political decision-makers often do not consider the demands of angling stakeholders when deciding on the management of urban ecosystems or the waterfronts of urban waters (Allen 1984; Arlinghaus, Mehner 2003b). Consequently, either the availability of angling sites is reduced or the quality of angling is poor (Allen 1984; Arlinghaus, Mehner 2004a). Urban ecosystems typically are under intense pressure from high nutrient loads and anthropogenic activities, including shipping, hydraulic engineering, pollution, as well as from many of the recreational uses. As a result of such intensive anthropogenic impacts, the diversity of fish species is often low (Boët *et al.* 1999; Wolter, Vilcinskas 2000; Wolter *et al.* 2003). Moreover, non-native fish can be present in high relative abundance (McKinney 2002; Vila-Gispert *et al.* 2002) and fish growth has been found to be inversely correlated with urban residential development (Schindler *et al.* 2000). The low availability of both highly valued fish species and large individual sizes was found to be a major reason for out of city angling activity by urban residents (Arlinghaus, Mehner 2004a). The importance of the contribution that recreational ecosystems make to urban life needs to be understood in order to be appreciated fully by politicians and city planners (Bolund, Hunhammar 1999).

Angling participation is usually less in urban areas than in more rural ones (Hendee 1969; Aas 1996a; Arlinghaus 2004a) and input to management of urban fisheries has been low (Minte-Vera, Petrere 2000). It is necessary, therefore, to understand the desires of anglers who do not use urban fisheries because of unsatisfactory conditions or the availability of more appealing substitutes elsewhere (Arlinghaus, Mehner 2004a). Paramount is the provision of access to quality fishing opportunities within urban areas to enable people to fish in close proximity to their residence. This is not only desirable for the social benefits of urban fishing (Peirson *et al.* 2001), particularly for children (Aas 1996b), but also to reduce environmental impacts. Arlinghaus, Mehner (2004a) have shown that by providing and enhancing urban angling opportunities, recreational fishing can benefit anglers, communities, public agencies, and fisheries resources by:

- increasing the equity goals of sustainable fisheries management;
- increasing the benefit/cost ratio of individual anglers;
- minimising environmental pollution by reduction of travel distances;
- minimising potential user conflicts and angling impacts on the less degraded rural water bodies outside cities;
- increasing revenues to urban economies and agencies.

Unfortunately, the nature of urban fisheries does not allow the straightforward application of efficient management systems designed for less disturbed areas (Arlinghaus, Mehner 2004a).

As cultural differences can be pronounced between countries, any meaningful treatment of urban fisheries potential needs to focus on a specific jurisdiction or regional area. The perspective

for rehabilitation of urban fisheries in England and Wales is based on the concept of intermediate restoration of physically degraded fish habitats (Zalewski, Welcomme 2001). At an intermediate stage, biodiversity is at its highest with the best balance between species additions and species replacements (Zalewski, Welcomme 2001). Furthermore, high productivity at intermediate stages means that the resilience of the system can be strong. Rehabilitating habitats in urban waters towards intermediate stages is pursued because, amongst the many human activities that cause habitat loss in aquatic ecosystems, urbanisation not only produces some of the greatest impacts but, also, is often more lasting than other types of habitat loss (McKinney, 2002). Thus, rehabilitating habitat structure and function can be considered a promising management strategy for urban waters; but rehabilitation into pristine (altered ecosystems) or quasi-pristine states (artificial water bodies) is unrealistic.

This paper describes habitat management as a general approach to enhancing wildlife, fish abundance and angling quality in urban waters. Although the potential for habitat management to benefit recreational fisheries management has been recognised (Arlinghaus *et al.* 2002), notwithstanding limitations (Cowx, van Zyll de Jong 2004), habitat rehabilitation as an option for reconciling resource use with resource conservation has only been examined once with respect to urban fisheries management (Buckley, 1982). This paper is, therefore, mostly conceptual but also provides some examples from England and Wales in which habitat rehabilitation was found to constitute a useful recreational fisheries management strategy. Firstly, however, the context of recreational fisheries management in urban waters is explained in terms of the management environment, benefit components and characteristics of urban water systems.

2. Management of urban fisheries

All inland fisheries in Central Europe in general and in England and Wales in particular are in private ownership (Arlinghaus *et al.* 2002). In England and Wales, the responsibility for implementation and enforcement of legislation rests with the Environment Agency (Lyons *et al.* 2002). The Agency has a statutory duty to "maintain, improve and develop" fisheries. It has adopted a corporate goal that "All waters in England and Wales will be capable of sustaining healthy and thriving fish populations and everyone will have an opportunity to experience a diverse range of good quality fishing." (Environment Agency 1999). In addition, the Agency has consulted on a vision for its contribution to sustainable development (Environment Agency 2000). Within this vision there are two important components which recognise the human and non-human dimensions of recreational fisheries systems, namely "improving the quality of life" and "enhancing wildlife". Thus the regulation and management of recreational fisheries must address overall fishery performance (Hickley, Aprahamian 2000), i.e. the total package of conservation or improvement of fish stocks and habitats, fishing satisfaction as measured by catches, and the anglers' environment such as scenic beauty, access to the water, congestion management, etc. (Arlinghaus *et al.* 2002; Arlinghaus 2004b). In this context a UK Government review of policy and legislation relating to inland fisheries (M.A.F.F. 2000) concluded that the management of fisheries should aim to:

- ensure the conservation and diversity of freshwater and migratory fish and conserve their aquatic environment;
- enhance the contribution freshwater fisheries make to the economy;
- enhance the social value of fishing as a widely available and healthy form of recreation.

Fisheries management is turning increasingly toward social science and economics because recreational fisheries management is as much about people as fish stocks and ecosystems (Arlinghaus *et al.* 2002; Arlinghaus 2004b). Against this background, and one of increasing urbanisation, urban fisheries management is receiving more attention. Rarely have urban ecosystems been the focus of ecological studies because it was more common to study "natural" systems (Wali *et al.* 2003). In contrast, these days ecologists increasingly advocate effective conservation and management of natural resources in areas where people "live and work" (Miller, Hobbs 2002; Palmer *et al.* 2004). Therefore, a research and management perspective that incorporates human activities as integral components of ecosystems is needed. Whilst patently non-natural systems, such as artificial urban waters, may be an anathema to many conservationists and ecologists, and certainly are not a substitute for natural systems, necessarily they will be part of a future sustainable world. A shift in focus from historical, undisturbed environments to one that acknowledges humans as components of ecosystems, together with new research on ecosystem services and ecological design, will lay the foundations for sustaining quality of life in general and in urban environments in particular (Palmer *et al.* 2004).

The Environment Agency has developed a programme of urban fishery restoration as part of its contribution to sustainable development which includes the statutory remit 'to enhance the social value of angling as a widely available and healthy

form of recreation'. Combining the expert knowledge of Agency fisheries staff in partnership with local councils and angling clubs, the programme is designed to increase the availability and quality of coarse fishing in urban areas. Desired outcomes are:
- new fisheries created;
- poor quality fisheries restored;
- more fishing places;
- better wheelchair access;
- improved urban environment;
- increased quality of life.

3. Benefits of urban stillwater fisheries

Recreational angling in industrialised societies constitutes an important and highly valued leisure activity (Arlinghaus *et al.* 2002). In England and Wales, about 3.5% of the population goes fishing, comprising 2.3 million coarse (non-salmonid) anglers and 0.8 million game (salmonid) anglers (National Rivers Authority 1995). Direct expenditure on fishing trips has been estimated at £2.4 billion (US $3.41 billion) for coarse angling and £0.92 billion (US $1.30 billion) for game angling. Always associated with direct expenditure are indirect and induced financial flows in local, regional and national economies, including effects on employment and transfer of expenditure out of the country via tourism (Arlinghaus 2004a). In addition to economic impacts created by angler expenditure, angling has high economic value for individual anglers. Such value accrues to each individual angler, whereas the economic impact accrues to the region or the society as a whole. This can be thought of as the economic value that goes beyond the money paid directly into angling, i.e. what the angler would be willing to invest before choosing to stop going fishing (Arlinghaus, Mehner 2004b). Overall, angling provides a myriad of economic, social and ecological benefits to society, albeit the exact dimensions are often poorly known or very difficult to quantify (Arlinghaus *et al.* 2002). It should not be forgotten, however, that angling can impact negatively on fish populations and ecosystems (Post *et al.* 2002; Cooke, Cowx 2004).

Often, urban populations are regarded not only as a major new source of recruits to recreational fishing, but also as a source of income from increased licence sales to support natural resource agency programmes (Allen 1984). Furthermore, as the avidity of these new recruits increases, many might move into more rural fisheries outside towns and cities (Ditton *et al.* 2002; Arlinghaus, Mehner 2004a). Therefore, increasing angling participation by urban populations may not only affect the metropolitan centres themselves but also benefit comparatively undeveloped, rural, surrounding areas. In this respect, out of city angling can be regarded as an "ecotourism" activity (Ditton *et al.* 2002). This consequential migration of urban residents to fish in rural waters may help to educate urban anglers, promote respect for less disturbed landscapes, provide funds for fisheries management, directly benefit rural economic development, and enhance respect for the divergent cultures of rural anglers. Urban fisheries are particularly important in terms of accessibility and their environmental and social benefits (Peirson *et al.* 2001). The most important reason for fishing in urban environments has been found to be close access (Manfredo *et al.* 1984), and improving physical access has been reported to be a preferred management option for many urban anglers (Arlinghaus, Mehner 2003a, 2004a). Urban fisheries provide a fishing opportunity for those unable to travel or with limited time availability, e.g. the young, the disabled and the elderly. It has been shown that significantly more young people, school age children, students and homemakers, single people, and less educated people fished in urban than in rural waters (Manfredo *et al.* 1984; Schramm, Dennis 1993; Arlinghaus, Mehner 2004a). The importance of accessibility is reflected in the sales of fishing licences per unit of population in the Manchester (UK) area increasing with greater availability of waters (Diamond *et al.* 2000).

Urban fisheries not only serve the constituencies of the less mobile groups but also highly committed anglers. Arlinghaus, Mehner (2004a) have recently shown that urban fisheries are especially important to people for whom angling is of great importance to their life-style (Bryan 1977; Hahn 1991; Ditton *et al.* 1992). These urban anglers were found to be more active than rural anglers (Arlinghaus, Mehner 2003a, 2004a). Also, limited time available for angling means that urban residents more dedicated to angling are likely to fish in urban waters rather than the outside rural venues favoured by those less involved in the sport. Highly committed anglers are particularly important angling stakeholders because they are typically more successful and engaged as compared with less committed anglers and tend to benefit more from their angling (Arlinghaus, Mehner 2004b).

Motivations of urban anglers are equally as diverse as the expected outcomes of angling experiences for other angler groups. Arlinghaus, Mehner (2004a) found the following motivation subdimensions to be of importance for urban anglers in Berlin (Germany), in priority order: nature/escape, social, challenge/thrill, catching fish, novelty and achievement. Manfredo *et al.* (1984) reported that motivations related to enjoying outdoors, escaping physical and social pres-

sures, family togetherness/being with people, and catching fish were the most highly regarded aspects for urban anglers in Colorado (U.S.A). The general outcomes desired from angling were similar for urban and non urban fishing (Manfredo *et al.* 1984; Arlinghaus, Mehner 2004a) although urban anglers were found to be more catch orientated (Manfredo *et al.* 1984; Arlinghaus, Mehner 2004a). In Berlin, they placed greater importance on the achievement and quantity aspects of the angling experience (Arlinghaus, Mehner 2004a). In North America (Manfredo *et al.* 1984), urban anglers had expectations of catching trophy fish and/or many fish with less emphasis on finding a challenging and unique fishery. Also, a sense of privacy was less important in urban fishing when compared with wilder type fishing experiences. Schramm, Dennis (1993) investigated anglers in Lubbock (Texas, U.S.A.) and found that urban anglers preferred better fish to catch over a better place to fish, while rural anglers' preference was the converse. Urban anglers in Texas rated their fishing trip success not to be high unless some fish were caught (Ditton, Fedler 1984). Although non-catch aspects of the fishing experience are certainly important for overall fishing satisfaction, it is important to note that certain non-catch motives are probably easier to satisfy than catch based motives (Ditton, Fedler 1984), hence unsatisfactory catches often being the limiting factor of angler satisfaction in general (Connelly, Brown 2000; Arlinghaus, Mehner in press).

As regards England and Wales, Peirson *et al.* (2001) described the social benefit of urban fisheries using a case study in Leeds, a large city (population c. 725 000) in the north of England. The authors found that, in line with the arguments described above, actually catching fish was regarded as the most important factor of angling, although being in a pollution free environment, peace and seeing wildlife were almost as important. Many of the angling clubs in England and Wales are based at social clubs and places of work which highlights how fishing plays an important social, communication and relaxation role in the lives of the participants. In the inner city, recreational fishing can be particularly important in raising social and environmental awareness amongst young people, who are increasingly disconnected from the natural world (Brämer 2004; Turner *et al.* 2004).

Urban fisheries are also an important educational tool for non-anglers, it being increasingly recognised that recreational fishing fulfils a valuable role in raising environmental awareness of wildlife and the environment. Angler presence can suggest good environmental quality. A recent telephone survey of London residents (Mac Alister, Elliott, Partners Ltd 1999) highlighted that the greatest benefit of having salmon in the River Thames would be derived from "Knowing it means that the river is clean".

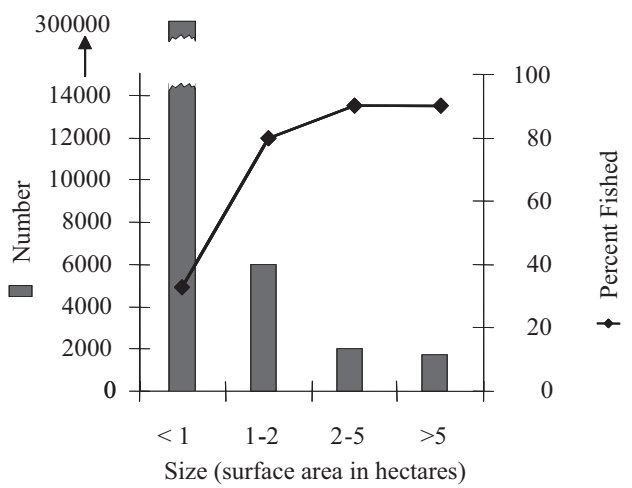

Fig. 1. Number and use of stillwaters in England & Wales.

4. Urban stillwaters in England and Wales

The fishery resource of England and Wales is rich and varied and ranges from highland streams to lowland rivers, natural lakes to water supply reservoirs and canals to old gravel pits. Stillwater fisheries are most popular with coarse anglers, 52% of whom fish stillwaters more often than rivers or canals (National Rivers Authority 1995). Also, the creation of stillwater trout fisheries, which principally stock rainbow trout (*Oncorhynchus mykiss*), has made game fishing much more accessible. Approximately 30 000 ponds and lakes are fished, their size and exploitation being shown in Fig. 1.

In the context of the following, urban fisheries are those in relatively small stillwaters, differing remarkably from the conditions found, for example, in the metropolis of Berlin, where large regulated rivers characterise the majority of the fishable water bodies (Arlinghaus, Mehner 2003a, 2003b, 2004a). Located in such places as public parks, housing estates and industrial sites, small urban stillwaters can be prone to noticeable lack of care and maintenance. Indeed, notwithstanding those that have retained their natural features (Schoen 1999), many urban waters are in such a poor state that access has been prohibited on grounds of safety and the consumption of any fish caught banned (Pflugh *et al.* 1999; Grosch *et al.* 2000).

Anecdotal and survey evidence gathered during advisory site visits by Environment Agency fisheries staff suggests that many small, mostly neglected, urban stillwaters within England and Wales possess certain characteristics not conducive to performance as a good fisheries. Relative to the known desirable environmental qualities of stillwater fisheries (Templeton 1995; Moss *et al.* 1996; Birch, McCaskie 1999), said adverse characteristics include:

- Physical - artificial construction, shallow depth (<1.5m), hard margins, silted bed, lack of habitat and a surface water supply.
- Biological - relatively high biomasses of phytoplankton, benthivorous fish, waterfowl, chironomid larvae and, occasionally, alien fish species; relatively low biomasses of submerged macrophytes, zooplankton, benthic invertebrates and piscivorous fish.
- Chemical characteristics - linked to the above factors and include nutrient enrichment from both surface run-off and resident fauna, serious dissolved oxygen fluctuations sometimes inducing fish mortalities, high biological oxygen demand and contaminated sediments.

In addition to this unfortunate abiotic and biotic scenario, a further cause of urban fishery dilapidation is the loss of the sense of ownership; for example, the local authority not being able to maintain the site and protect it thereby allowing vandalism and degradation to take place. Inappropriate activities can induce the demise of an urban fishery. Interference with water levels, general lack of maintenance and lack of control on the users can all bring about the damage and destruction of what can be considered a sensitive environment. For example, children and dogs do break down embankments during play, and waterfowl, when they are being fed, erode and damage embankments. Location can play a part in poor quality habitat. Often the fishery was created at a time when the surrounding environment was different; for example, in a wooded urban valley surrounded by housing developments, as the trees mature so the fishery becomes too shaded, habitat is compromised and fish stocks reduce. Similarly, inappropriate planning of a fishery when it was first constructed can result in a lack of surrounding habitat features and direct encroachment of the margins, which in turn reduces the ability for marginal vegetation to sustain itself. Most situations are, however, recoverable and there are now many examples of well managed, well structured, rehabilitated urban fisheries. Managing fish habitat constitutes one means to rehabilitate and increase the quality of urban fisheries. Some of the techniques are outlined below.

5. Options for fish habitat improvement

The primary techniques for physical habitat improvement in lakes include management of aquatic macrophytes, installation of artificial structures, desilting and adjusting the profile of the banks. In many cases this work has to be associated with prevention of damaging practices in the catchment such as surface run-off and nutrient input so as to counter poor water quality and algal blooms. Similarly, some manipulation of fish populations might be necessary (Moss *et al.* 1996).

Macrophytes

The importance of emergent and submerged macrophytes to fishes as spawning sites, refuges and substrates for invertebrate prey is well known (Jeppesen *et al.* 1997) with even small isolated patches of aquatic plants proving vital particularly for phytophilic species such as tench (*Tinca tinca*), rudd (*Scardinius erypthrophthalmus*), carp (*Cyprinus carpio*) or pike (*Esox lucius*). Also, the balance between phytoplankton and macrophytes can be extremely important in small, shallow still waters.

Locations for the establishment of macrophytes include:

- lake margins of suitable depth and slope;
- embayments excavated to provide suitable depth and slope;
- artificial islands from rubble or dredgings;
- floating islands;
- gabion baskets or artificial secured raised platforms.

Sources of plant material can be silt dredgings from areas where aquatic plants are known to flourish, whole plants (either obtained from the wild, with the necessary consents, or from an approved nursery), cuttings or seed. Macrophytes can be planted mechanically, en masse by machine, although hand planting is more precise. Shallow water marginal plants can be pushed into soft substrates or anchored with stones whereas fibrous rhizomes can be planted between stones and held in place with wooden stakes. Obviously, an understanding of the conditions required for the chosen plant species is necessary if successful establishment of macrophytes is to be achieved. Depth, light penetration, bed profile and wave action all need to be taken into account.

Although macrophytes are a desirable feature in any stillwater fishery, they can become too prolific and then some form of intervention becomes necessary. The more common of the available techniques for macrophyte control are manual or mechanical cutting of unwanted growth, shading of selected areas of substratum by black polythene sheet and killing with contact

or translocated herbicides. Biological control methods include the use waterfowl and grass carp (*Ctenopharyngodon idella*) but, especially in the case of the latter, specific conditions are required for control to be effective (Anon 1992).

Artificial habitat

The ability of artificial reef structures to attract and concentrate fish in a specific area with a concomitant increase in angler's catches has long been recognised (Wilbur 1978). Proposed advantages of installing artificial structure include providing spawning habitat to increase natural production. This is an option when, for whatever reason, plants are not able to grow in particular stillwaters. Moreover, artificial habitat provides cover to increase survival of fish (Bolding *et al.* 2004), for example against predation by fish-eating birds.

Much work has been undertaken in North America on the use of artificial reef structures for freshwater fish and the primary techniques of artificial habitat creation were recently reviewed by Bolding *et al.* (2004). Habitat, food, refuge from predators and shade have all been cited as benefits (Johnson *et al.* 1988). Many types of structure are in common usage: brush shelters, evergreen trees, hay bales, woody debris, plastic trees, manufactured plastic forms, log constructions and tyre reefs (Moring, Nicholson 1994; Bolding *et al.* 2004). The most effective types of artificial structure resemble natural structure with varied complexity and interstitial spaces (Bolding *et al.* 2004). For spawning habitat, such materials as frayed polypropylene rope and hessian sacking attached to house bricks can be used (Hendry *et al.* 1994). Dredged material can be used to create shallow water areas where desired. More recently, floating reedbeds have become popular to both improve water quality in situ and to create a wetland habitat suitable for wildlife and fish. Drawbacks of artificial structure include aggregated fish being more susceptible to overfishing, slowed fish growth in overpopulated communities, decreases in aesthetic enjoyment, increases in fishing gear snags, hazards to boating, and potential leachate from structures (Bolding *et al.* 2004).

De-siltation

Siltation is one of the primary causative factors of urban water degradation and prevention of siltation should be used alongside removal (Winfield 2004). In addition to managing external sources of sediment and vegetation, provision of silt traps upstream of a stillwater to intercept waterborne silts is an effective management practice in many instances where the lake or pond is fed by running water. A silt trap can be created quite simply, by widening and deepening part of the feeder stream (Barrington 1983) to reduce stream velocity, allowing fine particulates to drop out of suspension before entering the lake.

Nonetheless, despite attempts to reduce silt inputs to still waters, dredging is often the only effective way of arresting or reversing the natural successional process. Dredging, however, is a very disruptive process and can often lead to a short term deterioration in both the fishery itself and the conservation value of the water body. In addition, the high costs involved indicate that it should not be undertaken lightly. As an alternative to the physical methods hydrated lime can be added to sediments to reduce both its volume and oxygen demand, in the process liberating nutrients to encourage plant growth and ultimately fish biomass, but is only effective where the organic content of the silt is high (Hendry *et al.* 2001).

Bed profile

Bank shape and profile should be adjusted to facilitate and enhance the above mentioned habitat improvements, particular attention being paid to bed slope and water depths. Such work will necessarily be linked to the need for non-habitat related angler facilities such as paths and fishing platforms. Generally, shallow areas characterised by smooth natural-like shorelines are desirable to create shallow banks allowing juvenile fish to find refugia. Shallow water areas are of paramount importance for the recruitment of many freshwater fish species. It might be very effective to ban access to parts of the shorelines to protect areas from human disturbance and bank erosion.

Practical considerations

Wherever possible the principles of re-use and re-cycling should be adopted. For example, coppiced timber such as alder and willow make good bank protection and the thinned trees themselves aid in giving more light to dark over-shaded areas. It also helps the trees to regenerate for future use. Fishing platforms and path edgings can be made from the trimmed, straighter sections of timber. Once a light space has been created or a bank strengthened and opened up, it is then possible to plant the area with a variety of native and locally sourced aquatic vegetation and marginal plants. Once planted, it is important to protect the area both in the water and on the bank to avoid grazing, trampling and erosion. In addition, the creation of set-aside areas within fisheries aids their sustainability of the fishery. Wildlife breeding areas need to be sanctuaries

away from the main fishing effort. The combination of bankside and aquatic vegetation adds to the biodiversity of a fishery and complements the improved habitat structure within the renovated fishery.

6. Angler facility improvement

Clearly, a key task within urban fishery development and rehabilitation is enabling good and environmentally sympathetic access to the fisheries. Accordingly, alongside the physical habitat improvement for fish, plans should include the creation of angling places and platforms, access paths, connection to public transportation and specialist facilities for the disabled. Well defined access and pathways to fishing places helps to avoid encroachment onto those areas that need to be protected, and allows the other site users to pass by without needing to come into contact with the anglers. Promoting night-fishing might be a good alternative to allow for time and space zoning by avoiding user conflicts (Arlinghaus, Mehner 2004a). In large urban areas, however, safety problems may preclude this. Where appropriate, the provision of toilet facilities and car parking should be incorporated into the overall scheme.

Irrespective of the above, some parts of the angling experience (e.g., solitude) may be disrupted by the provision of too many angling stations. Urban anglers, however, are less likely to be dissatisfied with overcrowded fishing sites suggesting that anglers may adjust their expectations depending on the frequency of contacts with others (Berrens *et al.* 1993). Nonetheless, certain angler types may never be able to find quality fishing in high contact angling experiences (Arlinghaus, Mehner 2004a). Therefore, social analysis of local angler preferences should be part of every properly planned rehabilitation project so as to assess existing constraints to angling participation and the likely responses to the rehabilitated fishery in terms of increased or continued participation.

7. Addressing potential disbenefits

Every enhancement of fisheries opportunities carries a degree of risk. In particular, rehabilitation tools and techniques are often technically challenging and may require the application of poorly understood ecological and social principles (Lackey 2004). Altering ecosystems to create some desired past or new state can result in unexpected, sometimes undesirable results (Cowx, van Zyll de Jong 2004; Lackey 2004). Potential negative outcomes are real and need to be taken into consideration by learning from experience (Walters 1986; Arlinghaus 2004b).

Although relative participation in angling is low in urban areas, absolute participation can be high. Therefore, enhancement of urban angling opportunities may lead to paradox of enhancement phenomena (Johnson, Staggs 1992). This means, that angling effort may quickly increase if fishing quality increases and the news is transmitted through the angler network. If fish mortality from harvest or catch and release is high (Munoeke, Childress 1994; Cooke *et al.* 2002), increased fish abundance may quickly be fished down (Cox, Walters 2002; Post *et al.* 2002). If such potential occurs, traditional recreational fishery practice should complement habitat rehabilitation practice. This includes stock enhancement by stocking or implementation of various regulations e.g. size-limits, closed seasons and access restrictions (Hickley *et al.* 1995). Applied with caution, stocking can be a useful and sustainable rehabilitation strategy (Arlinghaus *et al.* 2002) often supported by urban anglers (Arlinghaus, Mehner 2003b, 2004a) particularly in artificial water bodies where certain recruitment bottlenecks are very difficult to circumvent. Management of fisheries entirely by maintenance stocking can lead people to believe that good fishing simply results from putting fish in the water (Schramm, Edwards 1994) and reduces the effectiveness of aquatic education programmes and the efforts to make anglers part of the management process. Therefore, anglers need to be educated as to the risks associated with such "artificial fisheries" (Hickley, Chare 2004) and that abnormally high fish densities and opulent catch opportunities cannot be expected in every fishery. This education will help to overcome shifting baseline syndromes (Arlinghaus, Mehner 2003b) or environmental generational amnesia (Turner *et al.* 2004): it has been proposed that with an increasing degree of industrialisation and urbanisation of societies and associated anthropogenic impacts, anglers may lose the ability to link aquatic ecosystem status to fish stock health and angling quality; healthy or rehabilitated ecosystems being no longer considered a prerequisite for healthy fish stocks and the references against which to judge appropriate management measures changing towards lower optima (Arlinghaus, Mehner 2003b, 2004a). To increase angler satisfaction and educate for realistic expectations that match biological reality, providing information about likely catch opportunities is especially recommended for urban water bodies (Schramm *et al.* 1998).

Enhancing urban angling opportunities may lead later to an increase in out of city angling. High rural angling participation by urban residents may be the result of the desire of city residents to escape from social contact and pressures

of modern living and simply "get away from it all" (Hendee 1969). Certain angling experience components such as less congested and more remote fishing waters are only offered outside the urban setting, which may be an incentive for many urban residents to travel longer distances to the non-urban angling sites (Manfredo *et al.* 1984; Arlinghaus, Mehner 2004a). Angling activity by urban residents may cause serious conflicts between non resident and resident anglers in rural areas, especially if rural fishing opportunities are evaluated as inadequate by resident anglers (Ditton *et al.* 2002). Furthermore, any substantial use of rural aquatic ecosystems by urban residents fishing in both urban and rural waters may have substantial negative impacts on these systems, thus challenging the implementation of ecosystem-based sustainable recreational fisheries management (Arlinghaus, Mehner 2004a). This calls for a holistic, regional perspective of urban fisheries management and collaborations between rural and urban fisheries managers (Arlinghaus, Mehner 2003a, 2004a).

8. The management process

From the viewpoint of fishery stakeholders, the four components contributing to good fishery performance are fish stocks, fish habitat, angler catches and the non-catch related anglers' environment (Hickley, Aprahamian 2000). For urban fisheries creation, rehabilitation or development it is important to account for these four components in an integrated way without leading to long-term or irreversible change in the ecosystem and without comprising the interests of non-angler stakeholders. The most critical and costly activity is likely to be the physical habitat improvement aspect. In this context, the interested parties need to be thoroughly informed about the negative effects of habitat degradation and the positive effects of habitat rehabilitation (Arlinghaus, Mehner 2003b). Providing a well-informed public could be the most important application of urban ecology, as a means of promoting effective management and conservation of fish species (McKinney 2002). Therefore, to be successful, it is essential to:

- understand the lake ecology;
- understand social and economic issues;
- articulate broad management goals;
- identify clearly stated and measurable objectives;
- select appropriate habitat enhancement or alternative measures;
- holistically manage fish populations and anglers;
- evaluate actions and outcomes and re-evaluate the management cycle.

Ideally, private fishery owners should take the lead in planning and executing habitat rehabilitation projects. Otherwise, it is essential to meet and influence the owners and angling clubs, agree a partnership approach and form an active and committed local working group. This partnership working group should then:

- identify issues and opportunities;
- conduct site inspection and fisheries survey;
- incorporate scientific and management advice into a strategy;
- develop and agree a plan of action;
- manage the project.

Responsibility for managing the project itself, and the approach to management (Walters 1986), depends upon the way in which partnerships and funding sources have been set up. Within England and Wales, for work part-sponsored by the Environment Agency, it is the principal partner who does this.

9. Case studies

Throughout England and Wales, local knowledge was used to create a database of urban stillwaters and riparian ownership. This led to identifying potential angling opportunities and liaison with stakeholders and other interested parties in order to promote the concept of urban fisheries development; all culminating in the establishment of management partnerships. The examples described briefly below give an indication of what can be readily achieved.

London

In Greater London there are 33 Boroughs which together host 198 existing fisheries. There is a huge demand for urban fisheries because 21% of anglers in England & Wales live in the River Thames catchment. There is, however, a history of neglect, poor management and user conflicts. In order to make progress, partnerships needed to be established with the city corporation, local councils, royal parks, angling clubs and conservation action groups. A typical project is the installation of fish refuges in the otherwise featureless Enfield Lock, a wide and deep section of a navigation canal. The pre enhancement results revealed extremely low densities of fish of all species in this section. Cormorant predation, lack of recruitment and poor survival were all identified as contributory factors. Partnership was with British Waterways and the Lee Anglers Consortium.

The aim was to improve the long term biomass and density of the fish population, especially roach (*Rutilus rutilus*), bream (*Abramis brama*) and perch (*Perca fluviatilis*), together with

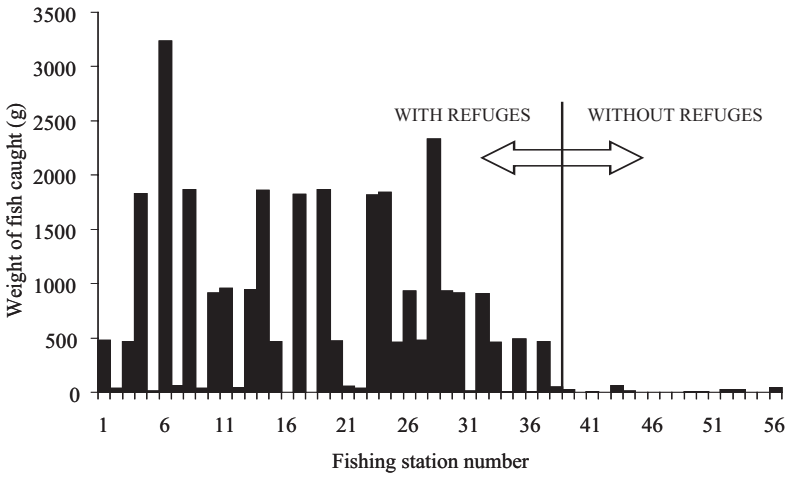

Fig. 2. Results of a fishing competition held on 3/10/2004 at Enfield Lock. Fifty six anglers took part, 37 fishing opposite the floating reed island refuges and 19 fishing in the unimproved section.

improving the amenity value by creating an enhanced environment for anglers, other water users and wildlife. This was to be achieved by better recruitment and survival of the target species. The need, therefore, was provision of extensive spawning areas (plant root structure) and juvenile 'nursery' habitat (wet margin). Also required was provision of extensive fish refuge areas to mitigate against predation from cormorants, predatory fish species and theft.

The approach taken was to install 70 reed rafts over a distance of 1 km. Rafts comprised 2 m x 3 m coir pallets with pre-planted and established reeds. General illustrations of the type of rafts used can be found on the www.mmgces.co.uk or www.aquascience.co.uk /reed.html web sites. The rafts were installed against sheet steel piling and fixed with a submerged wire mesh frontage to provide artificial structure habitat, particularly for fish in the 50-200 mm length class. A monitoring programme, including angler catch census, has been put in place to evaluate the long term effectiveness of the refuges.

Preliminary findings indicate a noticeable improvement in fishery performance. For example, when (as part of a more extensive questionnaire) a sub-set of 42 (out of 407) anglers were asked specific questions about the habitat improvement structures, the responses were positive:

- Have the reed rafts improved your fishing experience around Enfield lock?

No - 10%; Yes, slightly - 38%; Yes, a lot - 33%; Not sure - 19%.

- Would you like to see reed rafts extended to other parts of the Lee?

No - 5%; Yes - 78%; Don't mind - 17%.

- Do you think the overall fishing experience at Enfield Lock has improved since this time last year?

No - 19%; Yes - 48%; Not sure - 33%.

Also, when an angling competion was held, during which the participants were split between those allowed to fish near the fish refuge structures and the remainder which had to fish an unimproved area, the success rate of the former group was much higher ($p<0.001$). Catch distribution is shown in Fig. 2. Finally, repeat electric fishing population estimates within a 1500 m^2 section of the improved area in 2002 (before installation of rafts), 2003 and 2004 (both after installation) showed the biomass of roach, the most abundant species, to be 0.9, 1.5 and 2.7 g m^2 in the three years respectively.

North West England

From the database of urban stillwaters, those with potential for rehabilitation were selected for further investigation. To be selected a fishery had to meet certain basic conditions: open to the public, angling opportunity in actual or putative demand and likely to be suitable for a partnership scheme. Also, any final scheme would have to address the Environment Agency's key issues of sustainability, angling participation and disabled access (section 2 above). Detailed further investigation then included assessment of the candidate water's proximity to other fisheries in the vicinity, its accessibility, the predicted value for money of any rehabilitation and what assurances could be given regarding appropriate management of the fishery in the future. The result was that nineteen projects were identified in the north-west of England and partnerships were established with 8 Local Councils and 7 Angling Clubs. A summary of actions for four of the selected projects is given Table I. A generalised schematic drawing of a restored, small urban pond destined for use as a fishery is shown in Fig. 3. Although every rehabilitation scheme targets the same generic outcome, specific details vary. For example, for Rowley Lake (No. 1 in Table I) the aim of Burnley Borough Council in working with the

Table I. Four examples of urban fishery improvement in North West England. Bullet points are the rehabilitation actions that were considered necessary for the benefit of the fish populations and the anglers.

FISHERY	HABITAT IMPROVEMENT	
	FISH	ANGLERS
1) Rowley Lake, Burnley	• Install silt trap • Create spawning areas for fish • Isolate a bird sanctuary • Create a flood relief channel and desilted area	• Improve existing paths • Install platforms for able and disabled anglers
2) Shruggs Wood, Leyland	• Create spawning and conservation area for fish	• Improve paths for anglers and public • Create access and fishing places for disabled anglers • Provide management advice to angling club
3) Ducky Pond, Halewood	• Enlarge and deepen the water area • Create areas of aquatic vegetation	• Create paths • Install fishing platforms
4) Haslem Park, Preston	• Remove silt • Create areas of aquatic vegetation	• Reform banks for disabled anglers

Environment Agency was to "improve the fishing and wildlife value of the lake". The lake was very silted up, fish were being lost over the outflow weir, bank erosion was serious and suitable habitat for birds was lacking. First, the immediate problem of ongoing siltation was tackled by installation of a silt trap. Then followed the additional measures to reduce loss of fish, reduce bank erosion, create a bird reserve and enhance access and facilities for the anglers (Table I). Ongoing stakeholder involvement has been assured by assigning the fishing rights to the local angling club.

10. Concluding remarks

Although small urban water bodies are artificial lakes for which Arlinghaus, Mehner (2004a) and Hickley, Chare (2004) advocate a less rigid approach towards sustainable management as compared to more natural waters, an intermediate ecohydrology approach to physical habitat improvement can enable derelict and neglected fisheries to be restored. An appropriate target to satisfy angling objectives is an intermediate level whereby the capacity for the ecosystem to cope with the demands upon it remains high (Zalewski,

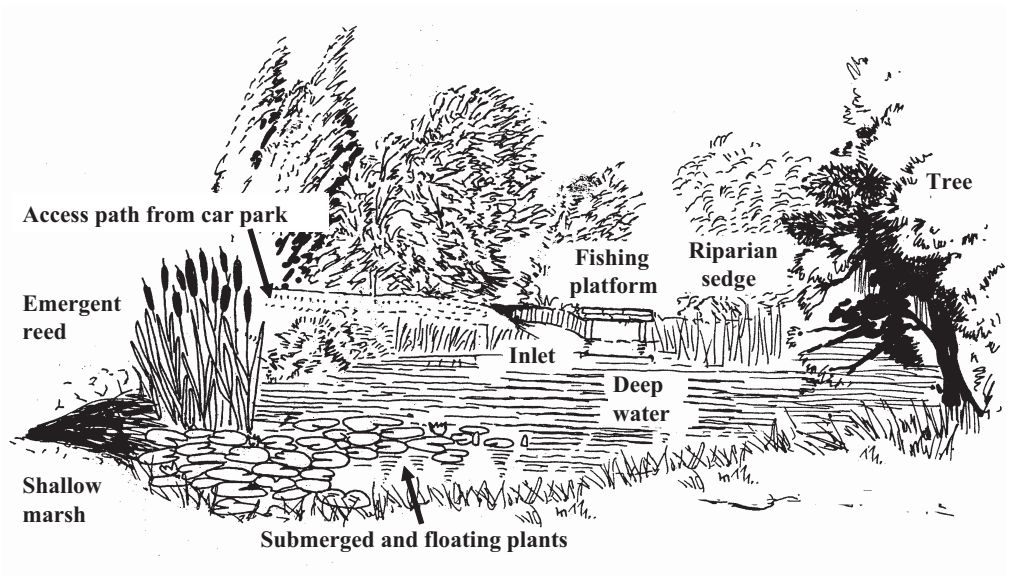

Fig. 3. Generalised schematic drawing of a small urban pond after restoration.

Welcomme 2001). Urban fisheries of all sizes are a valuable asset to any community and give pleasure to a wide range of the general public as well as anglers. It is in everyone's interest to preserve and, where possible, enhance these valuable resources for future generations to come. Although physical habitat improvement is a key component of the rehabilitation of urban fisheries, experience has shown that projects cannot be successful without full stakeholder consultation and support (Zalewski *et al.* 1997; Arlinghaus *et al.* 2002). Future urban fisheries programmes should not only be directed at the poor, the elderly, the disabled and minorities but also, in particular, towards young anglers (Aas 1996b), individuals less able to travel and the more committed anglers. In the urban environment there is less conflict potential between the degraded status of a water body and angling activity than is the case for other fishery types (Arlinghaus, Mehner 2004a). So, although reduction of anthropogenic impacts on aquatic ecosystems should always be a management goal, urban fisheries management should be directed especially at offering ease of access to shorelines, parking places, connections to public transportation, moderate prices, and diverse fish stocks depending on angler desires and considerations of biodiversity. Nonetheless, habitat rehabilitation can greatly improve urban fisheries performance for the benefits of anglers and the environment.

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