Aquatic Invasions (2007) Volume 2, Issue 3: 190-196
doi: http://dx.doi.org/10.3391/ai.2007.2.3.6

Open Access

Research Article

Establishment of self-sustaining populations of non-native fish species in the River Trent and Warwickshire Avon, UK, indicated by the presence of 0+ fish

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Received: 4 July 2007: Accepted: 2 August 2007

Abstract

This study investigated the reproduction of non-native fish species, inferred from the presence of 0+ fish, in three English lowland rivers over an 8 year period. Evidence of self-sustaining populations was found for three non-native fish species, namely zander *Sander lucioperca* (in the River Trent and Warwickshire Avon), bitterling *Rhodeus amarus* (in the Trent) and carp *Cyprinus carpio* (in the Trent and Avon). Notwithstanding, such fishes are currently rare, accounting for <1% of the 0+ fish communities of these two rivers, and no non-native species were recorded from the Yorkshire Ouse. It is possible, however, that improvements in water quality and habitat, together with the potential effects of climate change, may facilitate consolidation and expansion of their populations, as well as those of other non-native fish species already present or introduced in the future. This could have repercussions for the ecology and management of non-native fishes in the UK.

Key words: alien species, bioinvasion, biological pollution, exotic species, invasive species, pest species

Introduction

Non-native fish species are being reported from an increasing number of waterbodies across the UK (Copp et al. 2006). A number of such species have established self-sustaining populations, including zander *Sander lucioperca* (L.), pumpkinseed *Lepomis gibbosus* (L.), topmouth gudgeon *Pseudorasbora parva* (Temminck & Schlegel) and sunbleak *Leucaspius delineatus* (Heckel) (Smith et al. 1998, Copp et al. 2002, Gozlan et al. 2002, 2003). However, not all introductions culminate in self-sustaining populations, with a number of the records of non-native fish species representing captures of either escapees from the ornamental trade or individuals released for angling (e.g. Copp et al. 1993, 2007, Britton and Davies 2006a, b, 2007).

This study analyses 0+ fish data collected fortnightly/monthly over an 8 year period on the River Trent, Warwickshire Avon and Yorkshire Ouse (Figure 1), representing probably the most comprehensive dataset on larval and 0+ juvenile non-salmonid fishes in the UK. The Trent is the third longest river in the UK (274 km), and has a catchment area (10 500 km^2) that is similar in size to those of the rivers Severn and Thames, while the Ouse is 200 km long (catchment 10 000 km^2) and the Avon 180 km long (catchment 3000 km^2). The Trent and Ouse both flow to the Humber Estuary, and between them drain approximately one fifth of the area of England. In common with the majority of rivers discharging into either the English Channel or the southern North Sea, the Trent and Ouse have a high natural diversity of fish species compared with elsewhere in the UK, attributable to the process of colonisation by fishes following the last Ice Age (Wheeler 1977). By contrast, the Avon is a major tributary of the River Severn, which discharges into the Bristol Channel, and has a less diverse natural fish fauna. All three catchments are known to contain several non-native fishes, such as carp *Cyprinus carpio* L.,

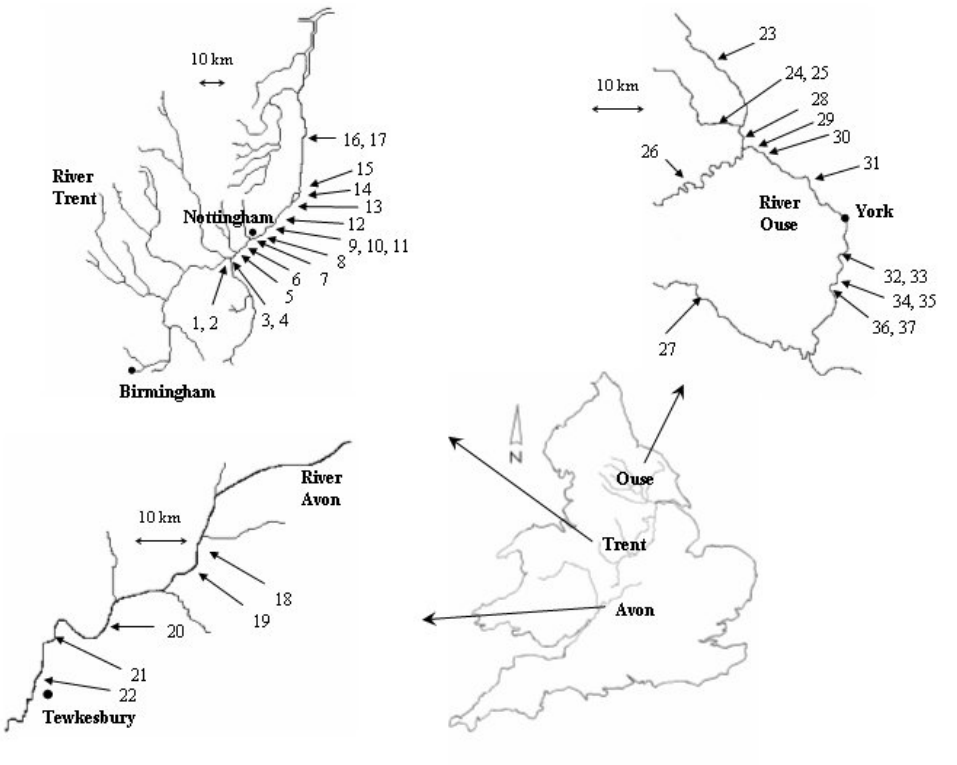

Figure 1. Sampling site locations in the River Trent, Warwickshire Avon and Yorkshire Ouse catchments, UK. Site numbers are the same as in Annex 1.

rainbow trout *Oncorhynchus mykiss* (Walbaum) and European catfish *Silurus glanis* L., and it is likely that there are others that, as yet, have been undetected. The aim of the study was to provide evidence of self-sustaining populations of non-native fish species in three of the UK's largest river systems, indicated by the presence of 0+ fish. The possible implications of establishment of self-sustaining populations of non-native fish species are discussed.

Materials and Methods

The 0+ fish populations of the lower River Trent, Warwickshire Avon and Yorkshire Ouse were surveyed at 37 sites (Figure 1, Annex 1) approximately fortnightly/monthly from May 1999 to March 2007 inclusive in daylight hours, using a micromesh seine net (25 m long by 3 m deep, 3 mm hexagonal mesh). The seine net captured larvae as small as 5 mm, although its efficiency is reduced for fish shorter than ~15 mm (Cowx et al. 2001). In all cases, sampling was restricted to areas devoid of large woody debris, in the margins in water ≤1.5 m deep. All fish were, where possible, identified to species (Pinder 2001) and measured for standard length (SL, nearest mm) in the field. When identification was not immediately possible, fish were preserved in 4% formalin and returned to the laboratory. When excessively large numbers of fish were caught, a random sub-sample of a known percentage of the total catch was processed.

Seine net catches were used to calculate the frequency of occurrence and relative abundance of non-native fish species at each site. The frequency of occurrence of a given species is defined as the number of surveys in which the species occurred, expressed as a frequency of the total number of surveys in which fish were

captured, while the relative abundance of a species is defined as the percentage of total catches (numbers) in all surveys comprised by the given species (Hynes 1950).

Results

Over 2 million specimens of 28 fish species were captured during the study period. Roach *Rutilus rutilus* (L.), bream *Abramis brama* (L.), chub *Leuciscus cephalus* (L.), dace *Leuciscus leuciscus* (L.), bleak *Alburnus alburnus* (L.), gudgeon *Gobio gobio* (L.) and perch *Perca fluviatilis* L. were the most abundant species. Evidence of self-sustaining populations was found for three non-native fish species, namely zander (in the River Trent and Warwickshire Avon), bitterling *Rhodeus amarus* (Bloch) (in the Trent) and carp (in the Trent and Avon) (Annex 2). No 0+ non-native fish species were captured from the Yorkshire Ouse.

For the Trent, total catches of 0+ zander, bitterling and carp were 313, 383 and 4151, respectively (Annex 2). Note, bitterling numbers were enhanced by a catch of 243 individuals in a single net (3 m^{-2}), while carp numbers were boosted by catches of 102 (3 m^{-2}), 140 (4 m^{-2}), 150 (4 m^{-2}) and 3504 (70 m^{-2}) individuals in a single net. Length ranges were 14-121 mm for zander, 10-48 mm for bitterling and 7-106 mm for carp. Zander were recorded from ten of the 17 sites on the Trent, while bitterling were recorded from six sites and carp from seven sites (Annex 2). For the Avon, total catches of 0+ zander and carp were 23 and ten, respectively (Annex 2), with length ranges of 19-139 mm and 6-32 mm. Zander were recorded from four of the five sites on the Avon, while carp were recorded from one site (Annex 2). Overall, non-native fish species are currently rare in the lower River Trent and Warwickshire Avon, accounting for <1% of their 0+ fish communities.

Discussion

The establishment of self-sustaining populations of non-native organisms has received considerable attention in recent years. Reports of the damage caused by such organisms to native flora and fauna, and the integrity of entire ecosystems, are numerous. There is evidence to suggest that zander can have significant impacts upon fish populations (Linfield and Rickards 1976, Fickling and Lee 1983, Smith et al. 1998). Indeed, as zander consume relatively small fishes throughout their life, the species can decimate the juvenile component of prey populations in some situations (Hickley 1986). However, the species has been present in the River Trent and Warwickshire Avon since at least the 1980s but, as yet, does not appear to have had any noticeable impacts upon the fish communities. A total of 313 zander was recorded from the Trent and 23 from the Avon, out of more than 2 million 0+ fishes captured during the study period. Fickling and Lee (1983) noted that zander populations in diverse fish communities generally stabilise at low levels. Thus, it could be that the zander populations of the Trent and Avon have stabilised or, alternatively, that they are restricted by low spawning stock. Whatever the explanation, the species has, thus far, remained a relatively minor component of the fish communities and its presence should not necessarily be a cause for concern. However, should zander increase in abundance in the future, inherent implications include elevated predation on prey fish species and the possibility of competition with native piscivores.

The exact date and source of the introduction of bitterling into the UK is uncertain, but the species probably arrived in the first half of the 20th century in association with the ornamental fish trade (van Damme et al. 2007). It is also unknown when bitterling were introduced into the River Trent, although small numbers were present by at least 1993/94 (T. Jacklin pers. comm.). However, the species is thought to have become established in the River Cam, a tributary of the Great Ouse, in the 1970s, and it is possible that it was introduced into the Trent at around the same time. Bitterling have an unusual spawning relationship with freshwater bivalves (see Smith et al. 2004), and it has been hypothesised that the species could pose a threat to bivalve populations in regions where they are already threatened (van Damme et al. 2007). As with zander, bitterling are currently rare in the lower Trent and should not be a cause for concern. However, small numbers were captured on a regular basis from one of the floodplain waterbodies (site 2), and it is possible that continued improvements in the water quality of the Trent (Jacklin 1996) and connection of floodplain waterbodies to the lower river (Nunn et al. 2007) may facilitate an increase in bivalve and, thence, bitterling populations.

The carp was introduced into the UK in the mid-14th century (Currie 1991, Balon 2004) and, for the past 40 years, has been extensively stocked for angling. Until recently, self-sustaining populations of carp, especially in rivers, were uncommon in the UK, due partly to the cool summer water temperatures compared with their native range. Carp are known to damage aquatic macrophytes due to the direct (e.g. physical damage, herbivory) and indirect (e.g. increased turbidity, mobilisation of nutrients) effects of bioturbation (Crivelli 1983). This is of significance as aquatic macrophytes are integral to ecosystem functioning, for example, through their provision of habitat for phytophilic zooplankton (Garner et al. 1996) and refuge for planktonic species from fish predation (Stansfield et al. 1997). Carp are currently rare in the lower Trent and Avon, with the majority captured from or near to connected floodplain waterbodies. However, the continued stocking of carp into stillwaters and rehabilitation of floodplains, and the potential effects of climate change, could serve to increase the carp populations of lowland rivers. Notwithstanding the negative impacts, some benefits may occur as the species is popular with specialist anglers.

The lower River Trent currently has more species and records of 0+ non-native fish than the Warwickshire Avon and Yorkshire Ouse. The potential reasons for this are manifold, and probably different for each species. One possibility may be a greater incidence of releases of non-native fish species compared with the Avon and Ouse; the Trent drains numerous large conurbations, with increased possibilities of non-native fishes being released (e.g. discarded pets), whereas the Avon drains smaller urban areas and the catchment of the Ouse is predominantly rural. The Trent is also the closest of the three rivers to the lower reaches of the Great Ouse, which support substantial populations of zander and bitterling, and it is possible that these species originated from there. Another potential factor may be the larger number of floodplain waterbodies, which are frequently key spawning areas for bitterling and carp in lowland rivers, connected to the lower Trent than the Avon and Ouse.

This study has demonstrated that micromesh seine netting can be used to detect the establishment of self-sustaining populations of non-native fish species, indicated by the presence of 0+ fish. However, given that the original purpose of the sampling was not specifically to detect non-native fishes, it is possible that the site selection and experimental design under-estimated the abundance of such species. For example, areas of dense vegetation, favoured by 0+ bitterling and carp, cannot be sampled efficiently using micromesh seine nets, and larger (e.g. >80 mm) 0+ zander are unlikely to inhabit marginal areas during daylight hours, except for brief foraging periods. As such, a more specific sampling strategy should be devised, perhaps employing point abundance electric fishing (Persat and Copp 1990), if non-native fish species are to be targeted deliberately. This would allow efforts to be concentrated on areas most likely to support non-native fish species, thereby reducing the amount of sampling effort required.

The current study has provided evidence of self-sustaining populations of three non-native fish species. Notwithstanding, such species are currently rare in the lower Trent and Avon, with no obvious impacts upon the fish communities or ecosystem functioning as a whole, and none were recorded from the Ouse. It is possible, however, that improvements in water quality and habitat, together with the potential effects of climate change, may facilitate consolidation and expansion of their populations, as well as those of other non-native fish species already present or introduced in the future. This could have repercussions for the ecology and management of non-native fishes in the UK. As such, efforts should continue to focus on reducing the possibility of species introductions, and mitigating any negative impacts when invasions occur (Andersen et al. 2004, Kolar 2004, Copp et al. 2005).

Acknowledgements

The authors wish to thank Richard Noble, Darren Rollins and Ryan Taylor for their assistance in the collection of field data. Thanks are also due to the Environment Agency and numerous angling clubs for granting permission to undertake the surveys. The manuscript benefited greatly from the constructive criticism of an anonymous referee. The work was funded by the Fisheries Society of the British Isles (A.D.N.) and the Environment Agency (J.D.B.).

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Supplementary material

The following supplementary material is available for this article:

Annex 1. Sites sampled for 0+ fishes in the River Trent, Warwickshire Avon and Yorkshire Ouse catchments, UK.

Annex 2. Frequency of occurrence (%Fi), relative abundance (%Ai) and numbers (n) of 0+ non-native fish species captured from the River Trent and Warwickshire Avon, UK.

Annex 1. Sites sampled for 0+ fishes in the River Trent, Warwickshire Avon and Yorkshire Ouse catchments, UK.

Site no.	Site name	Habitat	Site coordinates		Catchment
			Latitude, ºN	Longitude, ºW	
1	Glazebrook	Floodplain	52.8647	1.32558	Trent
2	Ully Gully	Floodplain	52.8727	1.31357	Trent
3	Thrumpton	Floodplain	52.8724	1.26752	Trent
4	Thrumpton	River	52.8724	1.26603	Trent
5	Attenborough	River	52.8964	1.22846	Trent
6	Clifton	River	52.9239	1.16698	Trent
7	Trent Bridge	River	52.9389	1.13545	Trent
8	Colwick	Floodplain	52.9476	1.09361	Trent
9	Holme Pierrepont	Floodplain	52.9501	1.06081	Trent
10	Holme Pierrepont	Floodplain	52.9501	1.06825	Trent
11	Holme Pierrepont	River	52.9501	1.06526	Trent
12	Polser	River	52.9508	1.04590	Trent
13	Farndon	Floodplain	53.0499	0.86469	Trent
14	Bingham	Floodplain	53.0970	0.80521	Trent
15	Winthorpe	Floodplain	53.1123	0.80329	Trent
16	Dunham	Floodplain	53.2549	0.77383	Trent
17	Dunham	River	53.2612	0.77215	Trent
18	Warwick	River	52.2653	1.59114	Avon
19	Old Pasture	River	52.2053	1.64291	Avon
20	Twyford	Floodplain	52.1123	1.93133	Avon
21	Birlingham	River	52.0754	2.08751	Avon
22	Tewkesbury	River	51.9917	2.15871	Avon
23	Maunby Demesne	River	54.2829	1.48387	Ouse
24	Boroughbridge	River	54.0983	1.39748	Ouse
25	Boroughbridge	Floodplain	54.0974	1.39596	Ouse
26	Kirk Hammerton	River	53.9853	1.28625	Ouse
27	Boston Spa	River	53.9066	1.34391	Ouse
28	Linton	River	54.0354	1.24723	Ouse
29	Newton	River	54.0272	1.22142	Ouse
30	Beningbrough	River	54.0126	1.19575	Ouse
31	Clifton	River	53.9780	1.12170	Ouse
32	Fulford	River	53.9408	1.08440	Ouse
33	Fulford	River	53.9318	1.07546	Ouse
34	Naburn	Floodplain	53.9076	1.09122	Ouse
35	Naburn	River	53.9022	1.09285	Ouse
36	Acaster Malbis	River	53.8960	1.10212	Ouse
37	Naburn	River	53.8924	1.09915	Ouse

Annex 2. Frequency of occurrence (%Fi), relative abundance (%Ai) and numbers (n) of 0+ non-native fish species captured from the River Trent and Warwickshire Avon, UK.

Site no.	Site name	Catchment	Zander			Bitterling			Carp		
			%Fi	%Ai	n	%Fi	%Ai	n	%Fi	%Ai	n
1	Glazebrook	Trent	–	–	–	–	–	–	–	–	–
2	Ully Gully	Trent	9.1	<0.1	2	36.4	1.4	256	–	–	–
3	Thrumpton	Trent	–	–	–	–	–	–	–	–	–
4	Thrumpton	Trent	–	–	–	10.0	0.3	21	–	–	–
5	Attenborough	Trent	6.8	<0.1	12	9.5	<0.1	69	2.7	<0.1	2
6	Clifton	Trent	–	–	–	9.1	<0.1	5	–	–	–
7	Trent Bridge	Trent	2.7	<0.1	4	2.7	<0.1	25	–	–	–
8	Colwick	Trent	3.5	<0.1	57	5.2	<0.1	7	1.7	<0.1	6
9	Holme Pierrepont	Trent	6.7	0.2	46	–	–	–	–	–	–
10	Holme Pierrepont	Trent	17.1	0.6	82	–	–	–	12.2	1.2	177
11	Holme Pierrepont	Trent	9.7	0.2	99	–	–	–	3.2	<0.1	20
12	Polser	Trent	–	–	–	–	–	–	–	–	–
13	Farndon	Trent	8.3	<0.1	1	–	–	–	–	–	–
14	Bingham	Trent	–	–	–	–	–	–	8.3	<0.1	1
15	Winthorpe	Trent	3.2	<0.1	9	–	–	–	12.7	<0.1	60
16	Dunham	Trent	–	–	–	–	–	–	71.4	45.9	3885
17	Dunham	Trent	1.4	<0.1	1	–	–	–	–	–	–
18	Warwick	Avon	7.7	<0.1	5	–	–	–	–	–	–
19	Old Pasture	Avon	2.8	<0.1	7	–	–	–	–	–	–
20	Twyford	Avon	4.7	<0.1	8	–	–	–	2.3	<0.1	10
21	Birlingham	Avon	–	–	–	–	–	–	–	–	–
22	Tewkesbury	Avon	9.1	<0.1	3	–	–	–	–	–	–

–, species not captured