

The incidence of non-native fishes in water courses: example of the United Kingdom

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Abstract

In recognition of the potential threat posed by introduced species to ecosystem function, the incidence of non-native fishes in rivers and streams of the UK was examined for the years 1961 to 2000 inclusive using data from the *Database and Atlas of Freshwater Fishes*. The proportion of records pertaining to non-native fishes has remained more or less constant, but the mean number of non-native species was found to be significantly higher in 1991-2000 than in earlier decades, and the proportion of records pertaining to certain species have increased whilst others have decreased.

Key words: introductions, alien species, ornamental fishes, goldfish, ide, common carp, bitterling, rainbow trout, pikeperch

Introduction

The introduction of non-native species is of increasing concern in both aquatic and terrestrial environments (Manchester and Bullock 2000), but there are relatively few long-term datasets available in which aquatic species such as fish are recorded. Of particular concern are the releases of ornamental aquarium and garden fishes (e.g. Copp et al. 2005, Rixon et al. 2005, Weigle et al. 2005), which have been found to be associated with modern socio-demographic features such as fair grounds (Wheeler 1998, Copp et al. 2005). Indeed, the number of varieties of ornamental fish found in ponds accessible to the public increased as pond distance from the nearest road, footpath or inhabitation decreased (Copp et al. 2005). The abandonment of pet fish appears to be driven by the diversity of fish species (and their varieties) available in pet shops (Duggan et al. 2006). Rivers and streams are common features in cities and towns of the UK, often acting as the central attribute of public parklands. As such, rivers and

streams are likely locations for the release of unwanted pet fish (Arthington et al. 1983). Additionally, non-native fish species stocked into, or present in, still waters connected to water courses are likely to find their way into the adjacent streams (Copp et al. 1993; S. Stakėnas and G.H. Copp, unpublished data). Therefore, the aim of the present study was to assess the incidence of non-native fish species in UK water courses using a published database (DAFF 2002) on the occurrence of native and non-native fishes in the UK.

Methods

Original records in DAFF (2002) were extracted for the period 1961 to 2000 inclusive for non-native fish occurrences in surveys at: 1) sites categorised in the database as river, channelised river, stream or brook; and 2) locations for which no habitat categorisation was allocated but the habitat type could be deduced from the site's name (including the equivalent words for river, stream or brook in Welsh or Gaelic) or by

checking the location against Ordnance Survey maps). Records excluded from the analysis were those relating to canals, ponds, lakes and reservoirs, as well as those from secondary sources (e.g. books) for which a precise location (national grid reference) was not given.

Our analyses were based on absence/presence data because DAFF (2002) does not consistently report on species abundance, and because records over the four decades did not necessarily derive from the same type of sampling source (Annex 1). For example, the majority of records in the 1960s derive from those compiled by Peter Maitland and published as map distributions in Maitland (1972). Maitland's database includes records of fish captured by various means, but the authenticity of the species identifications was verified (Maitland 1972). In subsequent decades, the majority of records derive from government agencies, which carried out fisheries surveys, presumably of increasing accuracy and precision over time. However, routine survey methods applied in past decades in the UK have generally concentrated on fish > 10 cm fork length, which suggests a potential bias against small-bodied fish species. This may explain in part why some novel non-native species, such as topmouth gudgeon *Pseudorasbora parva* (Gozlan et al. 2002) were not included in DAFF until after 2000. Indeed, the DAFF (2002) is not necessarily comprehensive, as it does not include record of new species to the UK, e.g. white sucker *Catostomus commersoni* (Copp et al. 1993). Identification errors are of concern, in particular for native crucian carp *Carassius carassius* L. and the brown variety of the introduced congener goldfish *C. auratus* L. The physical similarity between these two species (Figure 1) has led to the mis-identification of brown goldfish as native crucian carp by fisheries survey staff (Wheeler, 2000).

Despite these short-comings, which include the presence of some among-source variability in the numbers of species per 100 records in the database for rivers (Annex 1), the total number of species recorded per decade increases only slightly; this reflects the arrival of novel non-native species (Annex 2), as the number of native species remained relatively constant, being 31, 34, 35, 34 species in the four respective decades. This suggests that for our purposes of absence/presence analysis, the DAFF (2002) records can provide a reasonably reliable picture of changes in fish species in the UK over the last four decades. As regards species

changes, all species of fish with a native range that historically does not encompass the UK (see Manchester and Bullock 2000) were included in the analysis, including those permitted under UK legislation to be released into still waters but not river systems, i.e. all varieties of goldfish, common carp *Cyprinus carpio* L., and ide (including golden orfe) *Leuciscus idus* (L.). The mean numbers of non-native species per year were compared between decades using a non-parametric test (Kruskal-Wallis) due to the non-normal distribution of the data.



Figure 1. Native crucian carp *Carassius carassius* (lower) and brown variety of introduced goldfish *C. auratus* (upper) in England (photo: G.H. Copp)

Results and Discussion

The numbers of records of both native and non-native fishes have increased over the last four decades, but the proportion of records pertaining to non-native fishes has remained more or less constant (Annex 2). In terms of species richness, the proportion of non-native species has, however, increased during the period 1991-2000; this reflects a significantly higher (Kruskal-Wallis H corrected for ties = 20.084, $P = 0.0002$) mean number of non-native species recorded in 1991-2000 relative to earlier decades. The proportion of total and of non-native records that refer to common carp, correspondingly, remained relatively constant. Similarly, the records of goldfish have not followed a perceivable pattern, but data for this species is subject to doubt due to mis-identification problems, as mentioned above (Wheeler 2000). The proportion of records of bitterling *Rhodeus amarus* (Bloch) and of pikeperch (zander) *Sander lucioperca* increased, and the trend for ide and rainbow trout *Oncorhynchus mykiss* has been a gradual decrease following the peak proportions reported for the period 1961-1970 (Annex 2).

Although the proportion of records pertaining to non-native species in rivers has remained relatively constant over the last 40 years, the number of non-native species has increased (Annex 2). This may reflect an increase in the density of non-native fish species in UK water courses, as species richness is known to increase with increasing fish density, both in native (Černý et al. 2003) and non-native freshwater fish species (e.g. Arthington et al. 1983). Non-native species richness in rivers was highest in the 1990s (Annex 2), coinciding with a similar peak in non-native variety richness (especially goldfish varieties) observed during the 1990s in ponds of Epping Forest (Copp et al. 2005). Indeed, species of fish sold in the ornamental trade (e.g. sterlet *Acipenser ruthenus*) are starting to appear in village ponds (G.H. Copp, personal observation) and rivers (R.E. Gozlan, personal communication).

The increased incidence of non-native fishes in the wild is perhaps not surprising, given that fish are the third most popular pets in the UK after cats and dogs (Elvira 2001). Greater controls on the range of species imported to the UK for the aquarium trade (see above), public education and initiatives to avoid the abandonment of unwanted fish pets (e.g. guidance given to members of the Ornamental Aquatic Trade Association, point-of-sale advice to discourage the release of pet fish to open waters), should have resulted in a reduction in the incidence of non-native fishes in UK inland waters. However, the available evidence suggests otherwise (Annex 2; Copp et al. 2005). This represents a pathway for the introduction of non-native species that continues to put native aquatic species and ecosystems at risk. A similar concern surrounds the escape or release into rivers of fish species, e.g. goldfish, orfe and common carp, which are intended for still-water angling amenity (Wheeler et al. 2004, Whitehead 2004).

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Annex 1

Proportion (%) of total DAFF (2002) records (see Annex 2) and the number of species recorded per 100 records for each decade from various sources: Agencies = UK Environment Agency and its predecessors (i.e. the National Rivers Authority and prior to that the various Water Authorities), Centre for Ecology & Hydrology and its predecessors, the Institute of Freshwater Ecology, the Natural History Museum, Freshwater Research Services (Scotland), Scottish Natural Heritage, and Maitland (i.e. records from P.S. Maitland that included national grid references)

Source	1960s	1970s	1980s	1990s
<i>% of records</i>				
Agencies	10.4	51.0	91.3	99.6
Maitland	89.6	47.2	7.2	0.1
Other	0.0	1.8	1.5	0.3
<i>No. species per 100 records</i>				
Agencies	3.4	2.1	0.1	<0.1
Maitland	1.0	2.7	0.6	0.9
Other	—	40.7	3.4	5.6

Annex 2

Total numbers of species (S) per decade in DAFF (2002), the proportion of species that are non-native ($S_{\%N}$), Total numbers of records (n_T) per decade, the proportion (%) of that represented by all non-native fish species (n_N) and by the principal species of non-native fish reported in riverine sites (canals excluded) in the UK (given in %): goldfish *Carassius auratus* (Ca), common carp *Cyprinus carpio* (Cc), pumpkinseed *Lepomis gibbosus* (Lg), ide *Leuciscus idus* (Li), sunbleak *L. delineatus* (Ld), rainbow trout *Oncorhynchus mykiss* (Om), bitterling *Rhodeus amarus* (Ra), and pikeperch *Sander lucioperca* (Sl). Also given are values based only on records of non-native species, with $S_{\%N}$ replaced by the mean number of non-native species (S_{Mean}) per year, which was significantly higher in the period 1991-2000 (see Results section)

Decade	S	$S_{\%N}$	n_T	n_N	Ca	Cc	Lg	Li	Ld	Om	Ra ^a	Sl
<i>All records</i>												
1961-1970	37	16.22	4555	2.20	0.02	0.50	0	0.20	0	1.36	0.02	0.09
1971-1980	39	12.82	3229	1.15	0	0.37	0	0.09	0	0.56	0.03	0.09
1981-1990	42	16.67	57020	1.41	0.08	0.50	0	0.02	0.02	0.15	0.08	0.57
1991-2000	43	20.93	166667	1.52	0.03	0.43	0.005	0.01	0.01	0.43	0.08	0.51
<i>Non-natives only</i>												
		S_{Mean}										
1961-1970	6	2.0	100	—	1.00	23.00	0	9.00	0	62.00	1.00	4.00
1971-1980	5	0.8	37	—	0	32.43	0	8.11	0	48.65	2.70	8.11
1981-1990	7	3.5	806	—	5.71	35.24	0	1.12	1.24	10.55	5.71	40.45
1991-2000	9	5.7	2538	—	2.13	28.41	0.315	0.55	0.79	28.53	5.52	33.69

^aThis species was listed in the database under *R. sericeus* (see Wheeler et al. (2004) for nomenclature)