

## When an ‘invasive’ fish species fails to invade! Example of the topmouth gudgeon *Pseudorasbora parva*

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Received 13 February 2007; accepted in revised form 20 April 2007

### Abstract

A major problem in evaluating biological invasions is the lack of information on failed non-native species introductions, with invasiveness determined purely on establishment successes. This is the case of topmouth gudgeon *Pseudorasbora parva*, an Asiatic cyprinid fish that now occurs throughout most of Europe and is said to be highly invasive. Although the species has established itself in many locations, and often in high densities, not all topmouth gudgeon invasions are successful. In this brief communication, the appearance and disappearance (following pond drain down and repeated electrofishing depletion) of topmouth gudgeon *Pseudorasbora parva* from a small pond in northeast London (England) is described, along with two other cases elsewhere in Europe.

*Key words:* failed introductions, alien species, eradication, ornamental pet fishes, establishment success, depletion removal

### Introduction

The rates of establishment success for deliberately-introduced commercial fishes, such as salmonid species, are relatively well known (e.g. Miller and Alcorn 1945, Peterson and Fausch 2003, Colautti 2005, Stohlgren et al. 2006). There is limited information on some non-commercial species, such as the North American centrarchid pumpkinseed *Lepomis gibbosus* (Linnaeus), which underwent repeated, failed introductions in France before becoming established and subsequently a pest (Roule 1931). However, in general there is a lack of detailed information on un-authorized (both accidental and deliberate) introductions that subsequently fail to result in established populations (e.g. Lodge 1993, Marchetti et al. 2004). Fish species that do establish populations following accidental introductions to a number of water bodies

(i.e. stage IVb, as per Colautti and MacIsaac 2004) are often labelled as ‘invasive’ or ‘successful invaders’. In the context of this paper, ‘invasive’ organisms are “native or alien species that spread, with or without the aid of humans, in natural or semi-natural habitats, producing a significant change in composition, structure, or ecosystem processes, or cause severe economic losses to human activities”, as per Copp et al. (2005a). Based purely on successful introductions, these species are sometimes perceived as able to invade virtually all similar water bodies. A good example of this phenomenon is topmouth gudgeon *Pseudorasbora parva* (Temminck & Schlegel), a freshwater cyprinid native to Asia. Following its accidental introduction to Europe in the 1960s (Bănărescu 1964), the species spread rapidly throughout Europe, mainly as a contaminant of commercial fish consignments (Domaniewski and Wheeler

1996, Pinder et al. 2005, Gaviloaie and Falka 2006).

The introduction of topmouth gudgeon to the UK in the mid-1980s (Gozlan et al. 2002) was probably as a contaminant of a golden orfe *Leuciscus idus* (Linnaeus) consignment imported from Germany (see Pinder et al. 2005). For a short period thereafter, topmouth gudgeon were sold in the UK as an aquarium fish under the name 'clicker barb' (Wheeler 1998), and because the abandonment of pet fish is a known introduction vector (Arthington et al. 1983, Wheeler 1998, Copp et al. 2005b, Duggan et al. 2006), this is the likely origin of topmouth gudgeon in Goldings Pond. Following the establishment of a number of populations around the UK (Pinder et al. 2005) and a risk assessment of the species (Copp et al. 2005c), topmouth gudgeon is considered to be an 'invasive' species in the UK (e.g. Gozlan et al. 2005, Hill et al. 2005) as it is elsewhere in Europe (e.g. Rosecchi et al. 2001, Gaethofs et al. 2002, Gaviloaie and Falka 2006). To our knowledge there are no detailed reports of failed establishment by topmouth gudgeon in its introduced European range. The aim of the present brief communication is to report on the only known failures by topmouth gudgeon to establish a population following their unauthorised introduction, and in so doing to emphasize the need to consider 'failed' as well as 'successful' introductions when evaluating the 'invasiveness' of introduced non-native species.

### Study site, Material and Methods

Data on topmouth gudgeon occurrence in, and subsequent disappearance from, Goldings Hill Pond (Latitude 51°39'49"N, Longitude 0°03'53"E) were obtained from published (Wheeler 1998, Copp et al. 2005b) and subsequent field surveys associated with the management of this pond as an amphibian habitat (Conservators of Epping Forest 2002). Details on the history of this pond, which was originally excavated as a 'horse pond' and now of approximately 0.38 ha area (maximum depth  $\approx$  1.5 m), can be found in Wheeler (1998). Fish were sampled by electrofishing, using a consistent effort ( $\approx$  2 minutes per 100 m<sup>2</sup>) in August 1995 and October 1997 (Wheeler 1998). In the summer of 2001, the pond was drained down, with concurrent fish removal, and then de-silted (Conservators of Epping Forest 2002). In November 2001, the pond was refilled with

water but not restocked with any fish in order to maintain it as a 'fish-free' amphibian habitat. Using the same electrofishing technique as in 1995 and 1997, the pond was sampled again in March 2003 (Copp et al. 2005b) and June 2005, when all captured fishes were removed. In February 2006, electrofishing of the pond was undertaken specifically to capture and remove some moderate-to-large specimens of koi carp *Cyprinus carpio* Linnaeus that had been observed; therefore, the removal of smaller specimens may have been less efficient than on previous dates. On each occasion, all captured fish were counted and identified to species and variety (see Copp et al. 2005b), and no fish were ever returned to the pond. In March 2003 and June 2005, all fish were measured and scales taken for age determination.

### Results and Discussion

During the electrofishing survey of Goldings Hill Pond in October 1997, eight native and three non-native species of fish were captured and removed (Annex); one specimen was a topmouth gudgeon (sex unknown) of 4 cm total length (Wheeler 1998). When the pond was drained in November 2001, three native and three non-native species (5 varieties in total) of fish were captured and removed, including another single specimen of topmouth gudgeon (sex unknown, size not recorded). In March 2003 ( $\approx$  14 months later), one native and three non-native species (4 varieties in total) of fish were captured and removed, with five specimens being topmouth gudgeon (four females and one individual, the smallest, of unknown sex: 59 mm - 72 mm TL). The scales were mostly unreadable, but some scales suggested an age of 1 year. The sampling in March 2003 was part of a wider study of clandestine fish introductions to the ponds of Epping Forest, including Goldings Hill Pond (Copp et al. 2005b). In subsequent electrofishing surveys, no topmouth gudgeon were captured (Annex). In June 2006, two native species and three non-native species (7 varieties in total) were captured and removed, and in February 2006 two species of non-native (3 varieties in total) were captured and removed.

Despite the success of topmouth gudgeon in establishing populations in a variety of inland waters throughout Europe (e.g. Pinder et al. 2005, Gaviloaie and Falka 2006), some introductions of the species clearly do not succeed. In

the case of Goldings Hill Pond, there are at least two possible explanations for this failure and for the lack of subsequent appearances by the species in this pond (Annex). Firstly, it is not clear whether the species actually succeeded in reproducing in the pond, nor is it known exactly when the fish were introduced (i.e. only just prior to their capture, and therefore not permitted the opportunity to breed). Although the size of fish captured in March 2003 suggest they could be progeny of topmouth gudgeon in the pond at the time of it was drained and de-silted, only single specimens of the species were found previously and these five specimens could have been abandoned pet fish (Wheeler 1998, Copp et al. 2005b). Indeed, it is possible that all of the topmouth gudgeon captured in the pond were simply abandoned pet fish, perhaps all from the same pet owner (this phenomenon of habitual pet abandonment has been reported for other, nearby, ponds of Epping Forest; P. Murfin, personal communication). Under this scenario, the absence of topmouth gudgeon in the pond after March 2003 could suggest that recent legislative controls on the keeping and release of non-native species (through 'The Prohibition of Keeping or Release of Live Fish (Specified Species) Order' 1998, under the Import of Live Fish Act 1980 (ILFA)) have begun to reduce the likelihood of clandestine introductions of some species, such as topmouth gudgeon, but is unlikely to affect the spread of such species as contaminants of fish consignments.

Whereas, if the fish captured in March 2003 are assumed to be the progeny of topmouth gudgeon present prior to pond rehabilitation, then the failure to populate the pond in moderate-to-high densities could be attributed in part to the successive removal of the species from the pond and in part to the small size of the 'founder' population. This suggests that the use of a piscicide, e.g. rotenone (Allen et al. 2006), to eradicate a relatively low number of topmouth gudgeon may not be required in some water bodies, such as Goldings Hill Pond, where the founder population is very small and/or local factors such as poor habitat suitability (spawning substratum, food resources) and elevated avian predation (Copp et al. 2005b) may combine to limit recruitment success. In these circumstances, repeated removal of specimens during intensive electrofishing and netting could be sufficient, but where reproduction has led to large numbers of fish, then use of a piscicide is

likely to be required (e.g. Britton and Brazier 2006).

There exist other examples of failure by topmouth gudgeon to establish self-sustaining populations, though in these cases the species demonstrated explosive reproduction followed by disappearance. For example, topmouth gudgeon were reported by S. Stakėnas (in Copp et al. 2005a) to have appeared (along with electrois *Micropercops cinctus* Darby de Thiersant) in a small, isolated Lithuanian lake after an introduction of grass carp *Ctenopharyngodon idella* Valenciennes. Topmouth gudgeon became very abundant in the lake but subsequently disappeared without apparent cause. A similar phenomenon has been reported for Webbekomsbroek Pond, near Diest, Belgium (Latitude 50°58'33"N, Longitude 5°04'34"E), where topmouth gudgeon was one of the most abundant species during a fish survey in 1997, but the species was not found in 2004 (Van Thuyne and Breine 2005) nor during a subsequent survey in June 2006 (personal observations).

Webbekomsbroek pond was created as an artificial flood-relief pond in the early 1990s and legal stocking of it with native fishes for angling began in 1993 (rudd *Scardinius erthroptthalmus* L., tench *Tinca tinca* (L.), glass eel *Anguilla anguilla* L., pike *Esox lucius* L., gudgeon *Gobio gobio* (L.), bitterling *Rhodeus amarus* (Bloch), roach *Rutilus rutilus* L.), with on average 100 kg of fish stocked per annum in 1993-1995 and 1997-2002. The stocked fish were from the aquaculture facilities of the Belgium Research Institute for Nature & Forest and guaranteed not to contain topmouth gudgeon. Angling was permitted only after the first three years of stocking, and in the late 1990s poaching activity was reported (removal of large pike) and illegal stocking may have taken place. The pond is subject to very occasional inundation by the River Demer, which already contained topmouth gudgeon, and this is a likely source of introduction.

As with Goldings Hill Pond, Webbekomsbroek Pond seemed to possess all the characteristics of a good habitat for topmouth gudgeon but despite a period of population explosion, the species nonetheless disappeared. The reasons for the failure of these 'boom and bust' introductions of topmouth gudgeon such as these remain unknown, however the common factors cited for such failures are genetic bottlenecks

(Allendorf and Lundquist 2003), biological resistance (e.g. predation, native diseases; Arpent 2006) or simply to some form of biological incompatibility (insufficient habitat and/or dietary resources for persistent completion of the life cycle).

In conclusion, despite the success of topmouth gudgeon in establishing one or more (even numerous) populations in virtually every European country, it should not be assumed that all accidental introductions of the species have been or will be successful. This exemplifies that invasiveness potential will vary between ecoregions and among sites within ecoregions, depending on local conditions. Good examples of this in Europe are goldfish *Carassius auratus* (Linnaeus), pumpkinseed, and largemouth bass *Micropterus salmoides* Lacépède. In Belgium, goldfish have been observed to reproduce in private garden ponds but not in open public waters, whereas in England the species rapidly populates open still water (Copp et al. 2005b) where it is known to undermine the genetic integrity of native crucian carp *Carassius carassius* (Hänfling et al. 2005, Smartt 2007). Similarly, pumpkinseed and largemouth bass are considered to be invasive in some parts of Europe (south and central) but not in England, where pumpkinseed dispersal has been very slow (Copp and Fox 2007) and largemouth introductions were generally unsuccessful and the species is now considered extinct (database associated with Hill et al. 2005). Local conditions can facilitate or impede an introduced species in establishing a self-sustaining population, and this provides encouragement for the control and management of introduced species. This variability in establishment success, however, does not diminish the potential risks of non-native species introductions, specifically those of topmouth gudgeon, and it emphasizes the need to consider both 'failures' and 'successes' when assessing whether or not a species is 'invasive'.

### Acknowledgements

We thank P. Broxup, D. Huckfield, and P. Murfin for assistance in the field. This research was funded by the UK Department for Environment, Food and Rural Affairs. We thank the Conservators of Epping Forest (Corporation of London) for providing unpublished information on Goldings Hill Pond.

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**Annex**

Numbers of fish captured in Goldings Hill Pond (Epping Forest, London, England) on dates before (95/97 = August 1995 + October 1997) and after de-silting (March 2003, data from Copp et al. 2005b) of the pond (drain down) in November 2001, as well as from subsequent depletions (June 2005, February 2006). Mean electro-fishing effort in all years was: 2 minutes per 100 m<sup>2</sup>)

Species/variety	Before		After de-silting		
	95/97*	Nov01	Mar03	Jun05	Feb06
NON-NATIVE					
common carp ( <i>Cyprinus carpio</i> )	1	≥1 <sup>¥</sup>		10	
mirror				1	
ghost				4	2
koi			1		
goldfish† ( <i>Carassius auratus</i> )	11	≥1 <sup>¥</sup>	4	35	15
red		≥1 <sup>¥</sup>	10	18	
Shubunkin (London)				1	
hybrid (goldfish × common carp)					1
ide or orfe ( <i>Leuciscus idus</i> )		≥1 <sup>¥</sup>			
golden orfe				1	
topmouth gudgeon ( <i>Pseudorasbora parva</i> )	1	1	5		
NATIVE					
common bream ( <i>Abramis brama</i> )	4				
crucian carp ( <i>Carassius carassius</i> )	8				
Eurasian perch ( <i>Perca fluviatilis</i> )	1				
northern pike ( <i>Esox lucius</i> )	1				
roach ( <i>Rutilus rutilus</i> )	10+	≥1 <sup>¥</sup>	1		
rudd ( <i>Scardinius erythrophthalmus</i> )	9			2	
golden rudd				1	
tench ( <i>Tinca tinca</i> )	4	≥1 <sup>¥</sup>			
threespine stickleback ( <i>Gasterosteus aculeatus</i> )	>100‡	≥1 <sup>¥</sup>			

\* Data from Wheeler (1998), but note that topmouth gudgeon was first observed in 1997 (K.J. Wesley, personal observation); † natural brown variety; ¥ exact numbers not available due to theft of original records, so species composition derived from an absence/presence data table; ‡ exact number not given, reported as 'numerous', which we interpret to mean > 100