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BRIEF COMMUNICATION

Is topmouth gudgeon *Pseudorasbora parva* responsible for the decline in sunbleak *Leucaspius delineatus* populations?

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In England, a severe decline of introduced sunbleak *Leucaspius delineatus* populations has been attributed to the introduction of the invasive topmouth gudgeon *Pseudorasbora parva*. In France, however, after 4 years of *P. parva* colonization in a large natural lake, no demonstrated impacts on the native *L. delineatus* populations have been observed. This suggests that the original impacts observed in England, such as spawning inhibition and high mortality, were the result of an emerging pathogen, the rosette-like agent, hosted by *L. delineatus* rather than *P. parva*.

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Linked to international trade, the rate of species introduction is continuously increasing (Levine & D'Antonio, 2003), notably in freshwater ecosystems (Copp *et al.*, 2005). Introduced fish species are often suspected of impacting ecosystems and inhabiting native communities in different ways: direct or indirect effects on food chain equilibrium, habitat modification, interspecific competition, predation, parasite or disease transmission (Adams, 1991; Fernando, 1991; Bain, 1993; Declerck *et al.*, 2002), causing potentially high ecological and economic damage (Pimentel *et al.*, 2000; Casal, 2006).

The Asiatic cyprinid, topmouth gudgeon *Pseudorasbora parva* (Temminck & Schlegel), is one of the most successful invasive fish species in Europe (Gozlan *et al.*, 2005; Pinder *et al.*, 2005), having colonized Europe in <40 years (Gozlan *et al.*, 2002). *Pseudorasbora parva* was accidentally introduced to England in the

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mid 1980s (Domaniewski & Wheeler, 1996) and has since established numerous populations across the country (Gozlan *et al.*, 2002; Pinder *et al.*, 2005). A recent study (Gozlan *et al.*, 2005) has demonstrated that *P. parva* could severely impact populations of another cyprinid introduced in the 1980s (Farr-Cox *et al.*, 1996), sunbleak *Leucaspius delineatus* (Heckel), by transmitting an infectious pathogen [a rosette-like intracellular eukaryotic parasite (RLA) similar to *Spharethecum destruens*]. Experimental studies of cohabitation of these two species (Gozlan *et al.*, 2005) revealed that *L. delineatus* reared in aquaria using water shared by *P. parva* (water exchange) suffered complete spawning inhibition and high mortality rates and that a population of *L. delineatus* reared together with *P. parva* in a small, semi-natural pond experienced a decline in abundance of >50% during the first year, followed by extinction within 4 years. Two years after this initial discovery, however, it is still unclear whether the observed inhibition of *L. delineatus* reproduction was the direct result of the pathogen or of pheromonal interference from *P. parva*. Despite observations of coincidental *L. delineatus* declines in central Europe following *P. parva* introductions (Giurcă & Angelescu, 1971; Mikschi *et al.*, 1996), until now no attempt has been made to examine this potential interaction elsewhere in Europe within the context of the Gozlan *et al.* (2005) results.

Comparisons of *P. parva* introductions in other European waters will help to discriminate between the roles played by the host (*P. parva*) and the pathogen in the decline of *L. delineatus* populations. It could also provide a better understanding of disease prevalence amongst *P. parva* populations, as the presence of RLA is difficult to detect in a healthy carrier using conventional molecular tools (St-Hilaire *et al.*, 2001; Gozlan *et al.*, 2005, 2006). The aim of the present study was to assess the abundance and reproductive success of *L. delineatus* following the introduction of *P. parva* to a French hydrosystem (Lake Grand-Lieu; 47°05′ N; 1°39′ W) where native populations of *L. delineatus* are present and compare these with the observations in England (Gozlan *et al.*, 2005).

Lake Grand-Lieu is a very large, shallow, natural lake of variable surface area (40–63 km^2), depending on the annual water regime. Paillisson & Marion (2006) provide a detailed description of the study site. In summer, the lake's permanently flooded area is restricted to extensive beds of floating-leaved plants (*c.* 10 km^2), consisting mainly of nymphaeid beds, and a central area of open-water (10 km^2). Fish surveys were conducted in the vegetated area during summer (1–10 days; 5 to 31 July depending on the year) from 1999 to 2006 (except 2004) using point abundance sampling by electrofishing (PASE; n = 36–367, depending on the year; EFKO F.E.G 8000, 30 cm anode diameter, 400–600 V and 6–10 A; Cucherousset *et al.*, 2006). Fish species occurrence and co-occurrence were expressed as a proportion (%) of point samples (relative to the total) in which *L. delineatus* or *P. parva* or both (co-occurrence) were present. Fish relative densities were estimated as catch per unit effort (CPUE; means ± S.E.), which was the number of fish per point sample, and then $\log_{10}(x + 1)$ transformed due to the skewed frequency distribution.

High densities of *L. delineatus* were observed in Lake Grand-Lieu [Fig. 1(a); mean ± S.E. occurrence = 61·63 ± 5·45%], representing the dominant component of the fish assemblage [Fig. 1(b); mean ± S.E. = 60·24 ± 6·51% of the total CPUE). *Pseudorasbora parva* were first recorded in Lake Grand-Lieu in

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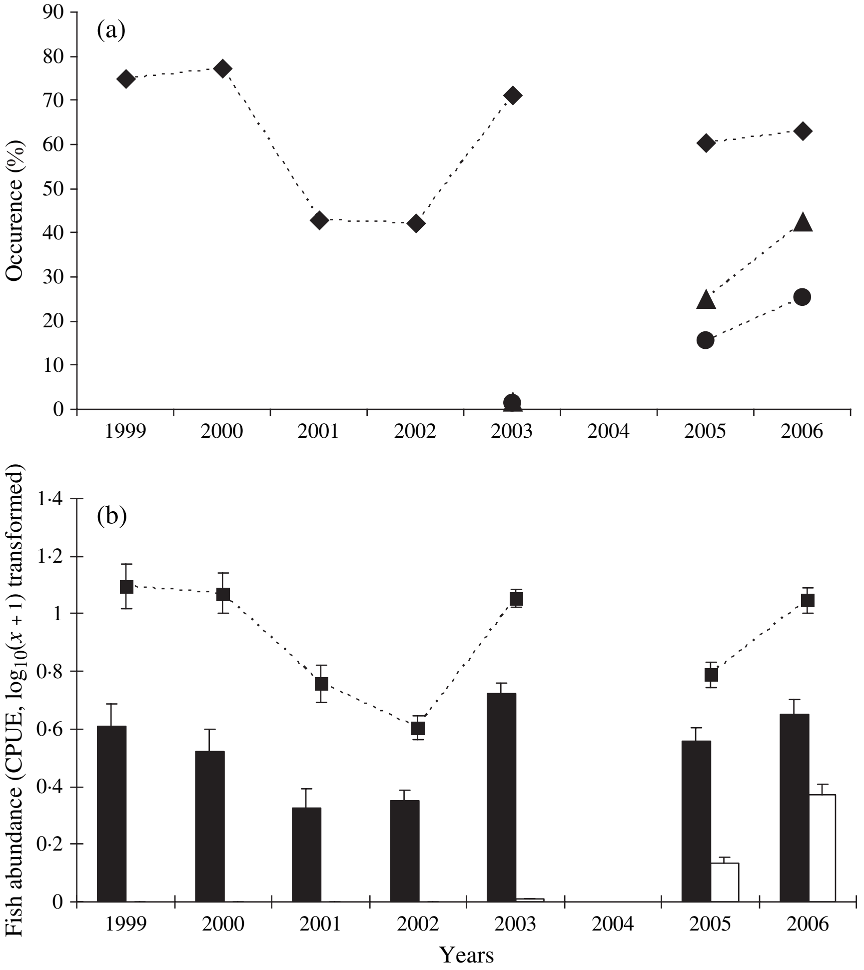

FIG. 1. (a) Occurrence of *Pseudorasbora parva* (--▲--) and *Leucaspius delineatus* (--◆--) and co-occurrence (--●--) expressed as the relative number of point abundance sampling (PAS) species caught per total number of point samplings performed. (b) Change of CPUE [mean ± S.E. calculated from $\log_{10}(x + 1)$ transformed data] for *L. delineatus* (■), *P. parva* (□) and all fish species (--■--) in Lake Grand-Lieu from 1999 to 2006 (no sampling in 2004).

summer 2003, probably after natural invasion from the River Loire. Its occurrence rapidly increased annually from 1·64% in 2003 to 42·55% in 2006 (χ^2, d.f. = 2, $P < 0·001$). Mean CPUE significantly increased over the same period [Fig. 1(b); Kruskall–Wallis non-parametric one-way test, d.f. = 2, 740, $P <$ 0·001]. Pair-wise comparisons (Tukey HSD *post hoc* test) revealed a continuous increase over the 2003–2006 period in CPUE of *P. parva* [Fig. 1(b); $P < 0·05$ for each combination], which accounted for 16·79% of total fish abundance in 2006. Surprisingly, and contrary to observations in England, the occurrence of *L. delineatus* did not vary significantly (Fisher's exact test, d.f. = 1, $P > 0·05$) between periods pre- and post-introduction: 59·25 ± 9·70% over the 1999–2002

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period (before the first record of *P. parva*) and 64·81 ± 3·26% over the 2003–2006 period. Despite fluctuations, *L. delineatus* CPUE also remained high and even increased slightly after 2003 [Fig. 1(b); Kruskall–Wallis, d.f. = 1, 1057, $P < 0{\cdot}001$]. At the same time, the co-occurrence of the two fish species increased significantly (χ^2, d.f. = 2, $P < 0{\cdot}001$) from 1·36% in 2003 to 25·13% in 2006. Association analyses between species were not significant (χ^2, d.f. = 1, $P > 0{\cdot}05$) in 2005 and 2006 (Legendre & Legendre, 1998). Observations and capture of young-of-the-year *L. delineatus* in 50% of sampling points where the two species co-occurred highlighted divergence with the English situation (Gozlan *et al.*, 2005).

Although, *P. parva* and *L. delineatus* densities were lower in Lake Grand-Lieu, when compared to the experimental set up in England, *P. parva* reached 56·87% of *L. delineatus* abundance in 2006. The important conclusion that can be drawn from the Gozlan *et al.* (2005) experimental study is that when contact between the two species was through water exchanges alone (*i.e.* no direct effect of density), complete spawning inhibition of *L. delineatus* and high mortalities were recorded. These results highlighted the presence of an agent in the water that was responsible for the spawning inhibition and was attributed to an intracellular parasite (rosette-like agent). Until now, a doubt exists in the role of *P. parva* as a carrier of this pathogen as analytical limitations make its detection difficult in a healthy carrier (St-Hilaire *et al.*, 2001; Gozlan *et al.*, 2005, 2006). In Lake Grand-Lieu, the two species are cohabiting in the same water (though in less close proximity than under experimental conditions) with no suppression of *L. delineatus* spawning and with no observed increase in mortality. These results suggest that spawning suppression in *L. delineatus* may not be the result of the presence of *P. parva* (*e.g.* facultative parasitism) but rather of an external agent such as the one identified by Gozlan *et al.* (2005). This is not to say that all declines in *L. delineatus* populations in Europe are linked to this pathogen or to the presence of *P. parva*. Habitat degradation, pollution and other environmental stressor may have played a role locally.

It is clear that field surveys need to be maintained in Lake Grand-Lieu to document population dynamics of the two species as well as investigations on the potential presence of RLA. Although *L. delineatus* is listed in the Bern Convention (Appendix III) and several European Red lists (Lelek, 1987; Fiers *et al.*, 1997; Keith & Allardi, 2001), the threat posed by the non-host-specific pathogen goes beyond the decline in *L. delineatus* (Gozlan *et al.*, 2005, 2006) and is of concern to fish biodiversity in general.

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