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Impact of the introduction of the red-eared slider (*Trachemys scripta elegans*) on survival rates of the European pond turtle (*Emys orbicularis*)

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Abstract. Recent massive imports of slider turtles (*Trachemys scripta elegans*) into Europe as pets have induced frequent release of these exotic turtles in natural habitats. As a consequence, *T. s. elegans* is now widely distributed in most wetlands. Moreover, reproduction of this species has been repeatedly observed in Europe under Mediterranean climatic conditions. In this context, we studied competition between this introduced species and the European pond turtle (*Emys orbicularis*) under experimental conditions. We compared weight variation and survival between control groups and mixed groups during three years of monitoring. We found both weight loss and high mortality in *E. orbicularis* of the mixed groups. This study argues for applying a precaution principle and stopping slider turtle introductions in all wetlands in Europe.

Introduction

Introduction of alien species can alter the organisation and the functioning of resident communities through various processes such as predation, parasite transfer, or competitive exclusion. Within a given guild, an introduction brings together species that have not shared a common coevolutionary pathway. As a consequence, new selective pressures arise, affecting the demographic characteristics of both introduced and native species, and influencing the way by which they use habitat resources (Herbold and Moyle 1986; Williamson 1996). Within a guild, differences in life histories and habitat use between introduced and native species lead to asymmetries in their competitive abilities. However, the outcome of an introduction is usually unpredictable unless demography, resource utilisation and biotic relationships have been carefully investigated (Lodge 1993; Kareiva 1996; Shigesada and Kawasaki 1997). Competition with closely related species is one of the more predictable consequences of the introduction of an alien species.

After turtle trade was banned in the USA in 1975, some turtle farms turned their production of slider turtles (*Trachemys*) toward exportation, mainly to Europe and Asia where the market for baby turtles has grown in the past 15 years. The most commonly exported species is *Trachemys scripta elegans* (the red-eared slider), with 52,122,389 individuals exported between 1989 and 1997

(Telecky 2001). France imported 4,238,809 young turtles between 1985 and 1994, with a maximum of 1,878,809 in 1989/1990 (Warwick 1991). At present slider turtles are commonly observed in the field as a result of the frequent release of animals by owners unable to house them when they reach large sizes. This phenomenon also occurs in other European countries (Warwick 1991), in South Africa (Newberry 1984) and in Asian countries (Warwick 1991; Moll 1995).

Chelonian assemblages in North-American freshwaters differ from European assemblages in their species richness. Whereas most European freshwaters are commonly occupied by only one species (*Emys orbicularis*), some North-American freshwaters support up to six species (*T. scripta elegans, Pseudemys floridana, Deirochelys reticularia*, *Sternotherus odoratus, Kinosternon subrubrum* and *Chelydra serpentina*) (Gibbons 1990). In such assemblages, species are expected to exhibit high competitive abilities (niche partitioning, adapted life history traits) that ought to favour their establishment in European waters, at the expense of the niche breadth of the European pond turtle.

The expected advantage of the slider turtle on the native European pond turtle relies on lower age at maturity, higher fecundity and larger adult body size (Arvy and Servan 1998). Competitive interactions between these species are important, as the European pond turtle is registered as an endangered species (Appendix II of the Bern Convention, Corbett 1989; Luiselli et al. 1997; Martinez-Silvestre et al. 1997). Turtles may compete for food, nesting sites and basking places, and they can be involved in interference competition. Because their metabolism is governed by body temperature, basking is a vital activity in regions where mean temperatures fall below minimum requirements (Rollinat 1934; Cagle 1946; Lebboroni and Chelazzi 1991). In a previous study, *Emys* were shown to shift their basking activity toward places considered to be of lower quality, while *Trachemys* occupied the better basking site, thus suggesting a dominance of the latter in the use of basking sites (Cadi and Joly 2003).

The aim of the present study was to investigate the impact of the introduction of *Trachemys* in large experimental *Emys* ponds. Our experimental design investigated the long-term effect of dominance on body condition and survivorship.

Material and methods

Study site

The experiments were performed in four 30 m × 8 m ponds built on the bank of a large fishpond in the estate of the Pierre Vérots Foundation (Saint-Jean-de-Thurigneux, Ain, France) (Figure 1). Maximum depth reached 1 m at the foot of the embankment that separates the experimental ponds from the main pond. Each pond was connected to the main pond by a ditch closed by a 1 cm mesh grating that allowed small organisms (crustaceans, molluscs, fish) to cross it,

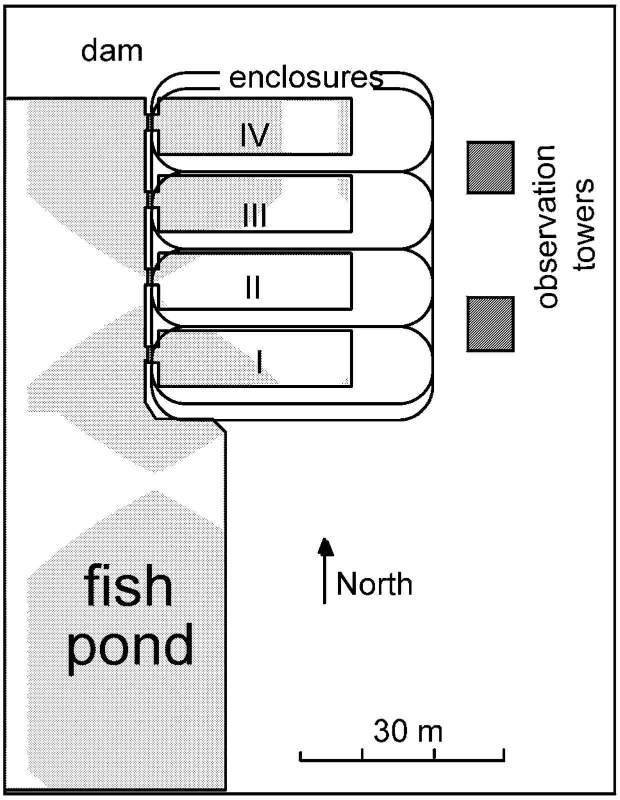

Figure 1. Map of ponds (I–IV) and observation towers used in the present study.

but prevented turtles from escaping towards the fishpond. The ponds were surrounded by herbaceous banks delimited by 50-cm high T-shaped fences. Natural vegetation grew similarly in all ponds, as well as abundant communities of insects, molluscs, fish and amphibians. No additional food was provided.

Animals studied

Both species lived in natural enclosures. Thirty-two European pond turtles were lent by the SOPTOM (Turtle Village, Gonfaron, France). All originated from southern France (*E. o. galloitalica*). Slider turtles were obtained from several zoological gardens. They were selected for body size similar to that of the pond turtles used in these experiments (*Trachemys* usually reach greater body size than *Emys*). The turtles were introduced into the experimental ponds in September 1997. They hibernated in the study ponds prior to the first observations.

Table 1. Weight variation values in g (mean ± standard variation).

	Control ponds		Experimental ponds	
	Pond I	Pond III	Pond II	Pond IV
Emys				
Females	−2.4 ± 5.7	−9.9 ± 4.6	−8.6 ± 6.8	−9.3 ± 6.6
Males	−1.3 ± 17.9	−9.0 ± 7.9	−2.8 ± 11.8	−5.6 ± 8.5
Trachemys				
Females	–	–	18.5 ± 14	10.3 ± 5.5
Males	–	–	5.2 ± 11.4	31.0 ± 38.4

In two ponds, experimental treatment involved eight individuals of each species. In two other ponds, control treatments were conducted using eight individuals of the European pond turtle. The sex ratios were balanced in both experimental and control groups (four males and four females of each species in experimental ponds; four males and four females of European pond turtle in the control ponds). Each turtle was marked by shell-notching (Cagle 1950). Coloured marks were also painted on the shell to allow remote identification of individuals from the observation towers.

Experimental plan

The turtles were sampled by emptying each pond once a year (1998, 1999, 2000 and 2001 in April). Sampling effort was similar at each date. Each sampled individual was weighed to the nearest 0.1 g.

Results

Weight variation

Descriptive statistics regarding weight variation are summarised in Table 1. To measure the impact of competition, we pooled the individuals from each sex for each situation (control: ponds I and II, experimental: ponds I and IV, Figure 2).

The impact of competition on body weight was asymmetrical, as only *Emys* turtles lost weight in the mixed treatment (Wilcoxon test for weight variation in *Trachemys*: $z = -1.332$, $P > 0.1$ for females and $z = -0.632$, $P > 0.1$ for males; Wilcoxon test for weight variation in *Emys*: $z = -1.992$, $P < 0.05$ for females and $z = -2.117$, $P < 0.05$ for males). In the control groups, *Emys* body weight remained stable (Wilcoxon test, $z = -1.826$, $P > 0.05$ in females and $z = -1.342$, $P > 0.1$ in males).

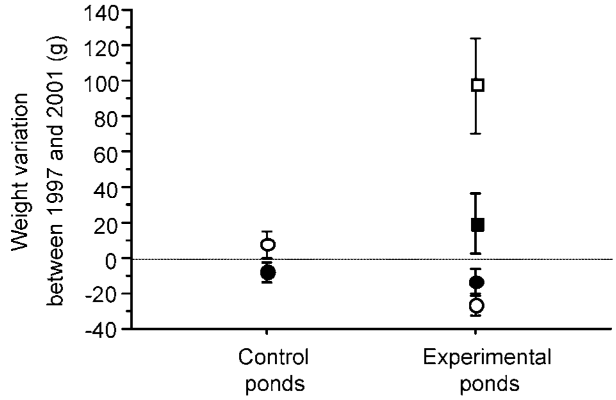

Figure 2. Weight variation for both species in control and experimental ponds for the whole period 1997–2001. Depicted intervals around the median indicate standard error. Squares: *Trachemys*; circles: *Emys*; open symbols: females; filled symbols: males.

Table 2. Number (and percentage) of turtle death in each group.

	Control ponds		Experimental ponds	
	Pond I	Pond III	Pond II	Pond IV
Emys	1 (12.5%)	0	4 (50%)	5 (62.5%)
Trachemys	–	–	1 (12.5%)	1 (12.5%)

Mortality

Mortality of *Emys* turtles was higher in treatment groups than in control ponds (Table 2; $\chi^2 = 7.127$, $P < 0.001$). Each sex was similarly affected by competition ($\chi^2 = 1.309$, $P > 0.1$). In the treatment groups, mortality was higher in *Emys* than in *Trachemys* ($\chi^2 = 4.987$, $P < 0.05$). Such mortality was not predictable (Mann–Whitney test, $u = 69$, $P > 0.05$).

Discussion

By applying a competition treatment for several years, the present study demonstrates asymmetrical responses to competition. Both high survival and stable body condition in control groups show that available resources were sufficient for the maintenance of a group of eight European turtles. Several reproductive attempts occurred each year in the control groups and some of them led to the emergence of young turtles. The loss of mass and the high mortality that was observed in the European turtles of the experimental groups, together with high survival and growth of the added slider turtles, demonstrate the competitive dominance of this last species.

The high density of animals in the experimental enclosures led to higher levels of competition than those experienced by turtles in the wild, where densities are not so high. Consequently, we have to take care in extrapolating our findings to natural populations. However, our purpose was not to estimate the strength of competition in the wild (this question is a very difficult task), but to test the asymmetry of such competition. These results make it possible to predict the outcome of the introduction of slider turtles in habitats where local density leads to strong competition.

We are unable to identify the proximate causes of competitive asymmetry. Food exploitation is not the only cause of competition, as the diets of the two species probably differ. Preliminary observations performed on some individuals using stomach flushing showed that *Trachemys* foraged mainly on plants (*Juncus* and other non-identified plant species) while *Emys* foraged on animal prey (dragonfly larvae, fish, newts) (Vauboin, Cadi and Joly, unpublished data). Competition for basking places may occur and can have a strong impact just after wintering when water temperature is low and the need for heat high. However, safe alternative basking places were available in the experimental enclosures and this cause alone cannot explain the results. During the mating period, we regularly observed underwater pursuits in the experimental ponds between *Trachemys* males and *Emys* females that were naturally never observed in the control ponds. This behaviour suggests a kind of interference competition, but our data are too scarce to confirm its role and its impact.

Whereas *Trachemys* showed evidence of competitive dominance in the experimental ponds, the poor fitness of *Emys* could be also due to susceptibility of this species to high density. Because of additive protocol, our experiment indeed did not allow us to discriminate between competition and density. Another explanation could be high sensitivity of *Emys* to pathogens that belong to the usual parasite assemblage of *Trachemys*. Whatever these different possible causes, our results remain conservative in demonstrating the deleterious impact of *Trachemys* on *Emys* viability.

Our results confirm the validity of the measures taken by several European countries to stop the importation of the red-eared slider from North America. This species survives most winters in western Europe, even extreme winters in some regions (extended periods where temperature fell to $-10\,^{\circ}\mathrm{C}$ in our experimental site). Successful breeding of *Trachemys* has been proven in Italy (Luiselli et al. 1997), Spain (Martinez-Silvestre 1997; Capalleras and Carretero 2000), and in the south of France (Cadi et al., submitted for publication), which leads to permanent establishment of this species in regions with a Mediterranean climate. In other countries, regular introductions of turtles can maintain high densities because of high longevity of most individuals, even when reproduction does not occur (Luiselli et al. 1997; Martinez-Silvestre et al. 1997; Bringsøe 2001). The presence of *Trachemys* potentially threatens natural populations of *E. orbicularis* and *Mauremys caspica*. As a consequence, we propose to forbid importation and sale of all freshwater exotic species of turtles potentially adaptable to European climates. At the same time, we argue for removing the exotic turtles from European wetlands while giving them convenient rearing conditions. Such actions are urgent and remain a challenge for the managers of natural environments.

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