

# Competition for basking places between the endangered European pond turtle (*Emys orbicularis galloitalica*) and the introduced red-eared slider (*Trachemys scripta elegans*)

A. Cadi and P. Joly

**Abstract:** Large numbers of red-eared sliders (*Trachemys scripta elegans*) have been imported into Europe for several years as part of the pet trade. These alien turtles have entered habitats where they interact with native pond turtles (*Emys orbicularis*). We investigated competition for basking sites, because optimal basking sites may be a restricted resource in the wild. We used experimental ponds to compare basking-place selection between single-species groups and mixed-species groups. Both species preferred basking places in open deep water. In mixed groups the sliders outcompeted the European turtles for preferred basking places. Although competition for basking places is only one component of resource partitioning between these two species, it provided an insight into the relationships between an introduced and a native species. Behavioural asymmetries like those detected in our experiments argue for the caution principle in the animal trade.

**Résumé :** La tortue à tempes rouges (*Trachemys scripta elegans*) a été importée en Europe en grands nombres pendant plusieurs années. Vendue comme animal de compagnie, elle a été relâchée massivement dans la nature, en particulier dans des habitats occupés par la cistude d'Europe (*Emys orbicularis*), espèce en danger d'extinction. Dans ce contexte, nous nous intéressons à l'éventuelle compétition entre les deux espèces au moment du bain de soleil, considérant que la disponibilité de cette ressource peut être limitée en conditions naturelles et que ce comportement revêt une importance particulière pour la thermorégulation de ces ectothermes. Notre étude s'est déroulée en conditions expérimentales afin de comparer simultanément les comportements de groupes monospécifiques et de groupes mixtes. Lorsqu'elles sont élevées séparément, les deux espèces sélectionnent le même type de site de bain de soleil, en eau profonde et à découvert. Lorsqu'elles sont élevées ensemble, la tortue à tempes rouges domine nettement la cistude d'Europe pour l'utilisation de ces sites préférés de bain de soleil, cette dernière occupant alors des sites moins bien exposés. Même si les sites de bain de soleil ne sont qu'une composante des niches des deux espèces, notre étude illustre les relations de compétition que l'on peut craindre entre une espèce introduite et une espèce indigène. Dans le contexte de la conservation de la biodiversité, les résultats de notre travail plaident pour l'application du principe de précaution et de l'arrêt des importations de tortues vers l'Europe et d'autres pays.

## Introduction

The introduction of alien species affects both the structure and the functioning of ecosystems by altering processes such as deviation of energy flows or displacement of native species from their ecological niches (Herbold and Moyle 1986; Williamson 1996). Variation in life histories and competitive abilities among species of the same guild causes differences in their abilities to invade extraneous guilds or resist competition from an invader. However, the outcome of an introduc-

tion is usually unpredictable unless demography, resource utilization, and biotic relationships have been carefully investigated (Joly 2000). Within-guild competition is a predictable consequence of the introduction of alien species. The outcome of competition depends on differences in the respective abilities of native and alien species to use habitat resources. In Great Britain, the replacement of the native red squirrel (*Sciurus vulgaris*) by the alien grey squirrel (*Sciurus carolinensis*) in oak forests is related to the higher foraging efficiency of the latter species in such forests (Kenward and Holm 1993). In the same way, the replacement of native geckos (*Lepidodactylus lugubris*) by an alien gecko (*Hemidactylus frenatus*) in Hawai'i occurred because the latter species was better able to exploit short periods of prey abundance (Petren and Case 1996).

Turtles have become invasive because they are traded as pet animals. During recent decades, large numbers of juvenile red-eared sliders (*Trachemys scripta elegans*) have been imported into Europe and this has led to frequent introductions into many freshwater ecosystems. Natural reproduction

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of the red-eared slider in Europe under Mediterranean-climate conditions was reported (Luiselli et al. 1997; Martinez-Silvestre et al. 1997; Cadi et al. 2003). Competitive interactions between this species and the European pond turtle (*Emys orbicularis*) are of particular interest, as the latter is registered as an endangered species (Appendix II of the Bern Convention; Corbett 1989; Luiselli et al. 1997; Martinez-Silvestre et al. 1997). The advantages of the slider may be lower age at maturity, higher fecundity, and larger adult body size (Arvy and Servan 1998). Turtles may compete for food, egg-laying sites, or basking places (Bury and Wolfheim 1973; Bury et al. 1979; Rovero et al. 1999; Lindeman 1999). Moreover, the species richness of most freshwater chelonian assemblages in North America is dramatically higher than that of European assemblages. For example, whereas most European wetlands are occupied by only one turtle species (*E. orbicularis*), in south Alabama and Mississippi wetlands, at least six species can often be counted (*T. s. elegans*, *Pseudemys floridana*, *Deirochelys reticularia*, *Sternotherus odoratus*, *Kinosternon subrubrum*, and *Chelydra serpentina*) (Gibbons 1990). As a consequence, a species from North American assemblages entering European waters could have a competitive advantage over the European pond turtle.

Our aim was to investigate competition for basking places between turtles of the genera *Emys* and *Trachemys*. Basking is a vital activity in regions where mean temperatures fall below minimum thermal requirements (Hutchinson 1979; Crawford et al. 1983). Basking increases body temperature and thus activates metabolism (Jackson 1971; Kепенis and McManus 1974) and increases the ingestion rate (Parmenter 1980). Because increased metabolic rates and activity levels result in greater energy requirements (Gatten 1974; Parmenter 1981), there are costs associated with basking. Basking timing and basking-place selection are thus expected to obey optimality rules (Lefevre and Brooks 1995; Krawchuk and Brooks 1998). As basking behaviour probably exposes turtles to predation risk, vigilance remains high during basking bouts. Therefore, we expect that selection of a basking place results from a trade-off between heat gain and risk avoidance. The purpose of our experimental design was to investigate selection of a basking place by both species, and the alteration of this selection under competition. Basking-place selection was also monitored when the availability of the resource was reduced. The hypothesis of interference competition was also investigated by monitoring interactions among individuals.

## Material and methods

### Study site

We used four 30 × 8 m experimental ponds built in the bank of a large fish pond on the estate of the Pierre Vérot's Foundation (Fig. 1). The bottom slopes gently from dry ground to an embankment that separates the experimental ponds from the main pond. The depth reaches 1 m at the foot of the embankment. Each pond is connected to the main pond by a ditch through the embankment. This ditch is equipped with a grating that allows small organisms to cross it, while preventing escape of the turtles. Natural vegetation developed similarly in all ponds. Each pond is enclosed

within a T-shaped fence (50 cm high) that prevents turtle escape. The enclosure area is large enough to allow turtle nesting.

Turtle behaviour was monitored from two 5 m high observation towers built on the eastern banks of the ponds. Basking sites (solaria) were provided in the form of 40 cm × 30 cm wooden platforms fixed on two floats. A board with a 45° slope allowed the turtles to climb onto each solarium. As the mean dimensions of the studied turtles were 15 cm × 13.3 cm, each solarium provided enough space for 6 turtles basking simultaneously without lying over one another.

### Animals studied

We obtained 48 turtles from zoological gardens, where they were reared under seminatural conditions. The Station de Protection et d'Observation des Tortues dans le Monde (SOPTOM) (Turtle Village, Gonfaron, France) lent 24 European pond turtles (*Emys orbicularis galloitalica*), which originated from southern France. Several zoological gardens provided 24 red-eared sliders. These sliders were selected because they were similar in body size to the pond turtles used in these experiments (*Trachemys* spp. usually reach a greater body size than *Emys* spp.). Despite their similar size, *Trachemys* spp. were heavier than *Emys* spp., on average (Table 1). The individuals were simultaneously introduced into the experimental ponds in September 1997, and hibernated for 7 months prior to observation.

Twelve individuals were introduced into each enclosure. In two enclosures, experimental groups were made up of 6 individuals of each species, whereas in the other two enclosures control groups were made up of 12 individuals of the same species. Then sex ratio was equal in both experimental and control groups (3 males and 3 females of each species in the experimental groups; 6 males and 6 females of each species in the control groups). It was assumed that the turtles ate natural food. Each turtle was marked by shell-notching (Cagle 1950). Coloured marks were also painted on the shells to allow remote identification of individuals from the observation towers.

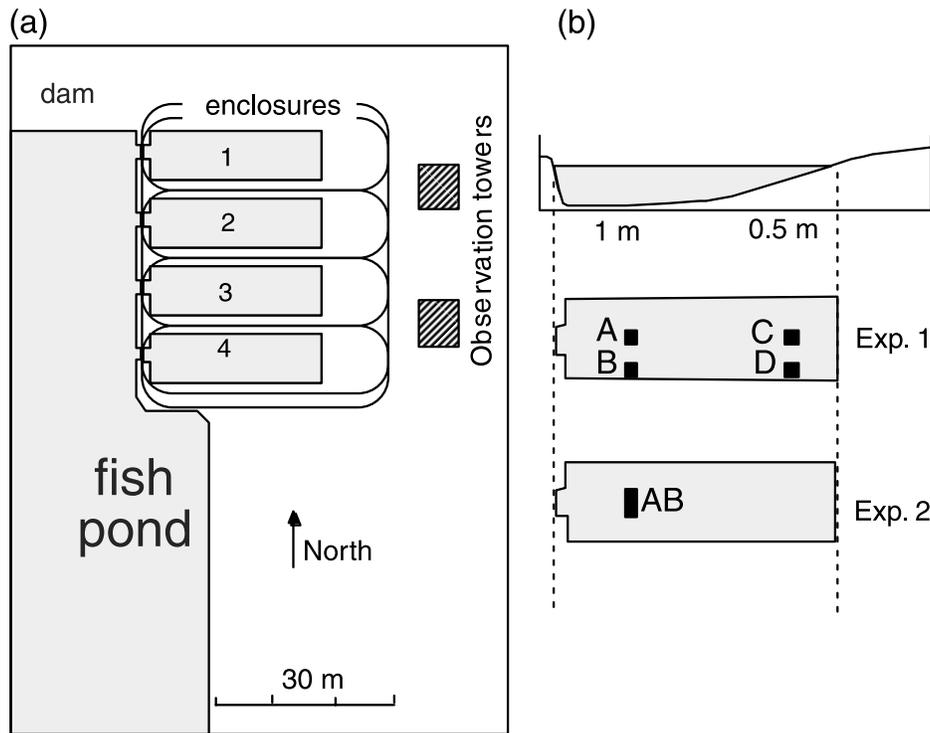
### Experimental plan

In the first experiment we installed four solaria in each pond, providing more space than needed for the 12 individuals. Two solaria (A and B) were placed in 1 m deep water and two others (C and D) in 50 cm deep water. For each of these pairs, one solarium was installed in the middle of the pond, while the other was installed close to the northern bank (Fig. 1). The solaria differed in neither timing nor quality of sunshine. In the second experiment the number of solaria was reduced. Only two solaria were assembled, thus providing the exact space required for all the turtles in a pond. They were placed at the location that was preferred during the first experiment (the middle of the pond at 1 m depth) (Fig. 1).

### Monitoring

For each experiment we monitored turtle behaviour for 7 days. The dates were selected to allow observations to be made in sunny weather, based on meteorological forecasting (these dates were distributed from 19 May to 4 June 1998 for the first experiment and from 23 June to 4 July 1998 for

**Fig. 1.** The experimental station. (a) The experimental site with enclosure ponds (1–4) and observation towers used in the study. (b) Lateral section of an enclosure showing the locations of the basking places (A–D) used by the turtles during the two experiments.



**Table 1.** Body mass (g) (mean and standard deviation) for each turtle group at the beginning and the end of the experiment.

	Control		Experiment 1		Experiment 2	
	<i>Emys orbicularis galloitalica</i>	<i>Trachemys scripta elegans</i>	<i>Emys orbicularis galloitalica</i>	<i>Trachemys scripta elegans</i>	<i>Emys orbicularis galloitalica</i>	<i>Trachemys scripta elegans</i>
Beginning						
Mean	457.59	500.00	378.67	634.25	395.17	539.33
SD	102.55	226.05	78.00	341.94	77.28	235.47
End						
Mean	485.81	690.33	360.00	800.50	388.67	567.20
SD	84.15	208.81	87.41	272.46	54.39	256.71

the second experiment). Two observers, each occupying an observatory, recorded the duration of basking behaviour for each turtle. Individual interactions on the solarium were also recorded (biting, scrambling, pushing another turtle down from a solarium, or climbing upon another turtle).

The turtles were sampled by emptying each pond at the end of hibernation (23 April) and at the end of the experiments (24 July). Each individual was weighed to the nearest 0.1 g. Ventral shell area was estimated from length and width measurements. Individual condition was calculated as the ratio of body mass to shell area. Individual condition was compared between successive capture sessions (end of hibernation, end of experiments, and 1 year after installation). The patterns of daily solar energy received on the pond bank and at an experimental basking site were established using a solar cell (Pulsonic, PLS RG1, sensitivity  $0.29 \text{ mV} \cdot \text{W}^{-1} \cdot \text{m}^{-2}$ ). Because of small numbers of individuals,

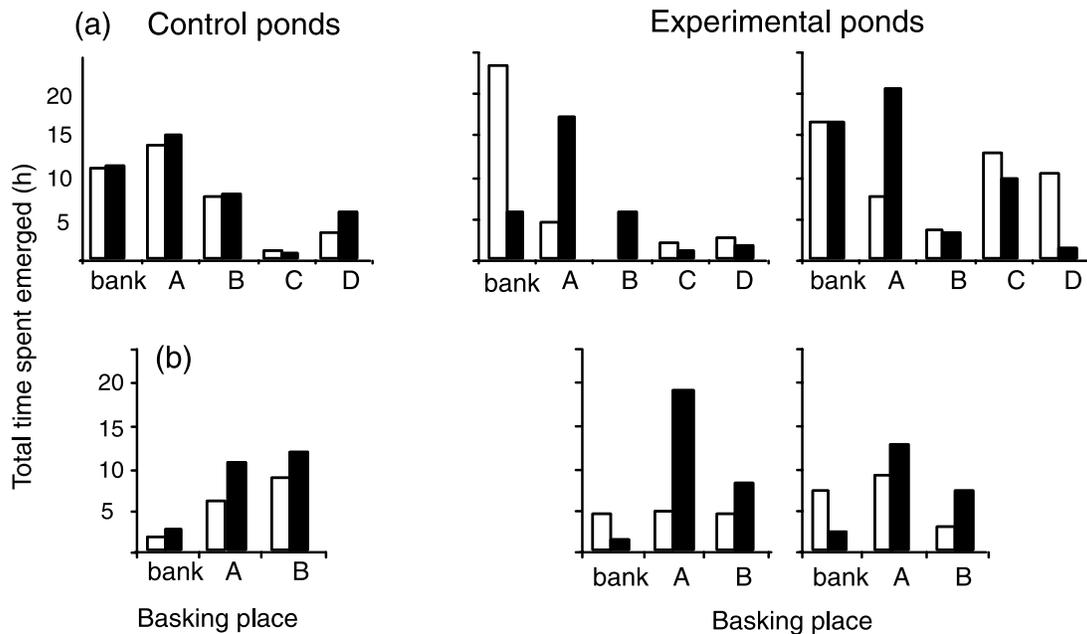
we pooled the data by group (total time spent on each solarium). Comparisons were then made using nonparametric tests.

## Results

### Body condition

For each species and each sampling date, condition coefficients did not vary significantly between control and experimental groups (Kruskal–Wallis test,  $p > 0.05$  for each test). At the end of hibernation, mass loss was only significant in the control *E. o. galloitalica* group (Wilcoxon's signed-rank test,  $p < 0.01$ ) and in one of the experimental *E. o. galloitalica* groups (pond 3,  $p < 0.05$ ). In the *T. s. elegans* groups, differences in body condition among individuals were more pronounced than in the *E. o. galloitalica* groups, with some

**Fig. 2.** Variation in the use of available basking places by the different turtle groups, in the first experiment (a) and second experiment (b). Open bars represent *Emys orbicularis galloitalica* and solid bars represent *Trachemys scripta elegans*.



individuals gaining mass during winter, whilst others lost mass.

During the experimental period, the body condition of most individuals increased, but gains were only significant in the *T. s. elegans* control group (Wilcoxon's signed-rank test,  $p < 0.05$ ). During the whole period from introduction into the ponds to the end of the experiments, the *E. o. galloitalica* control group lost body condition ( $p < 0.05$ ; maximum loss 13.1%), while the *T. s. elegans* control group gained body condition ( $p < 0.05$ ; maximum gain 11.5%). Variation in condition was not significant in the experimental groups. Overall, variation in condition was higher in *T. s. elegans* than in *E. o. galloitalica*.

### Basking-site selection

During the first experiment, use of the solarium by the control groups of each species differed from random ( $\chi^2$ ,  $p < 0.001$ , 3 df). Solarium A (deep water, middle position) was selected most often, followed by pond banks and solarium B. Solaria C and D (shallow water) were less used. No difference in basking-site selection was detected between the two species ( $\chi^2$ ,  $p > 0.05$ , 3 df) (Fig. 2).

During the second experiment, most individuals in the control groups used the remaining solarium almost exclusively. The pond banks were no longer used for basking. No difference in basking-site selection was detected between the two species ( $\chi^2$ ,  $p > 0.05$ , 3 df) (Fig. 2). In contrast, the distribution of use among the solarium in the experimental ponds always differed from that in the control ponds (Wilcoxon's signed-rank tests,  $p < 0.05$ ). In the first experiment, solarium A and B (mostly used by the two control groups) were mostly used by *T. s. elegans*, while *E. o. galloitalica* mainly used the banks of the pond and, to a lesser extent, solarium C and D (Friedman's test,  $p < 0.05$ ). Likewise, in the second experiment, *T. s. elegans* again preferentially used the re-

maining solarium, A and B (Friedman's test,  $p < 0.05$ ; Wilcoxon's signed-rank test,  $p < 0.05$  for pond 4; nonsignificant trend for pond 3), while *E. o. galloitalica* were distributed randomly over basking places, including pond banks (Friedman's test,  $p > 0.05$ ).

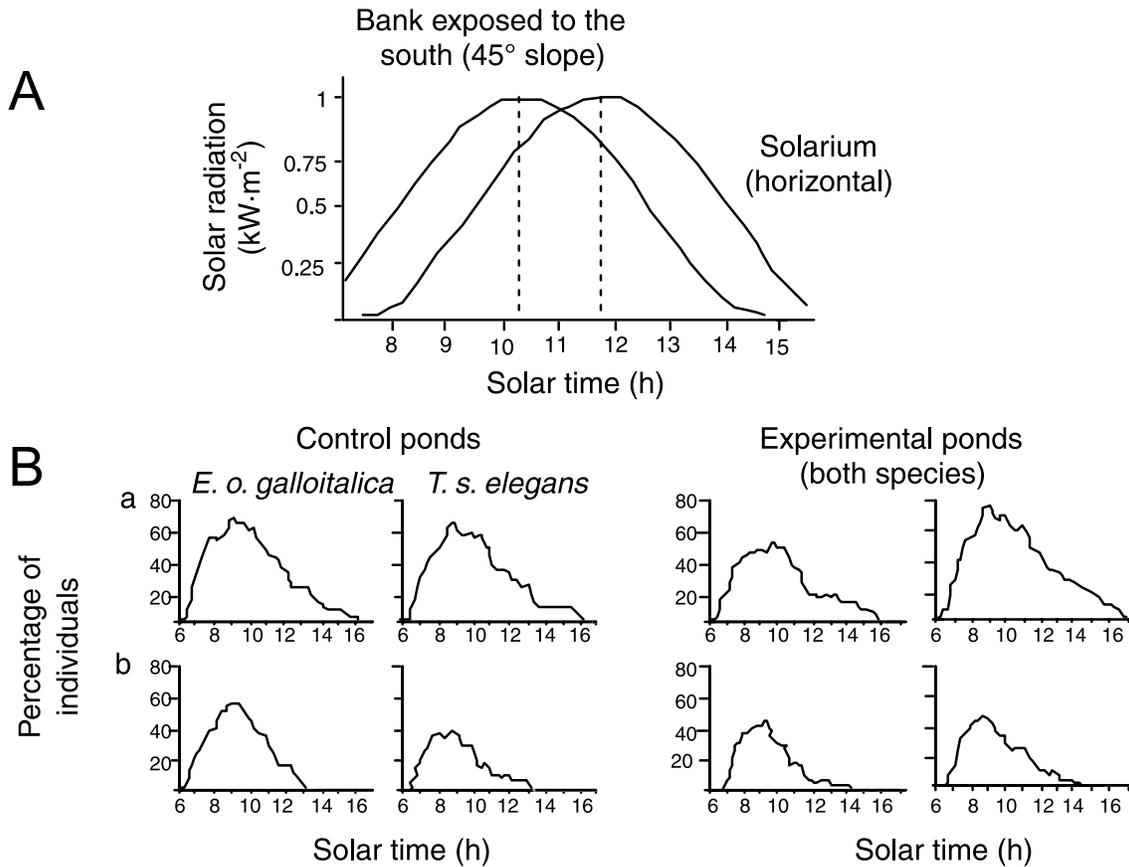
### Daily patterns of basking behaviour

At sunrise, the amount of energy available was greater on sunny pond banks because of their 45° slope that allowed turtles to bask perpendicularly to solar radiation (Fig. 3A). Because of their horizontal surface, the solarium received a similar amount of energy only 1.5 h later. This difference in energy availability between banks and solarium reversed as the angle of incidence of the sun increased. In all experiments, basking behaviour was related to the pattern of available solar heat (Fig. 3B).

In the control groups, basking patterns were similar in the two species. Turtles basked approximately from 7:00 to 11:00 (solar time). Most individuals climbed onto the basking places nearly synchronously (Wilcoxon's signed-rank test,  $p > 0.05$ ). Emergence from the water to climb onto a basking place preceded the peak of energy availability. No significant difference was detected between control and experimental groups. Moreover, no significant differences in times of emergence and departure from the solarium were detected between control and experimental groups (Mann-Whitney tests,  $p > 0.05$ ).

In the second experiment, the reduction in basking sites did not alter temporal basking patterns. Emergence times (the median of individual values during each experiment) varied neither among groups nor among conditions (Friedman's test,  $p > 0.05$  in all tests). The first species to climb onto solarium A was often the one that basked longer (Table 2). Thus, in the first experiment, 86% of first occupancy in the two experimental ponds was by *T. s. elegans*.

**Fig. 3.** Patterns of daily solar energy received on the bank exposed to the south and on an experimental basking place (A) and mean daily patterns of basking behaviour for the different turtle groups (B) in each of the four enclosures versus solar time in the first experiment (a) and second experiment (b).



**Table 2.** Numbers of first climbs onto solarium A by each species and numbers of interactions in the experimental groups for the two experiments.

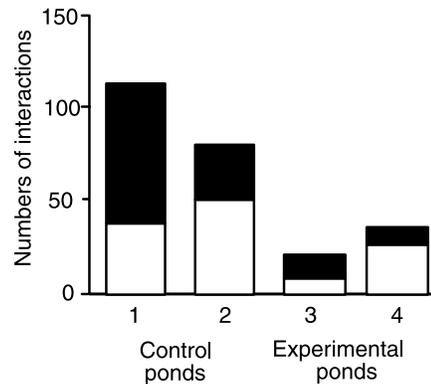
	Pond 3	Pond 4
<b>Number of first climbs</b>		
Exp. 1		
<i>Trachemys scripta elegans</i>	6	6
<i>Emys orbicularis galloitalica</i>	1	1
Exp. 2		
<i>Trachemys scripta elegans</i>	7	3
<i>Emys orbicularis galloitalica</i>	0	4
<b>Intraspecific interactions</b>		
Exp. 1	3	11
Exp. 2	5	16

**Behavioural interactions between species**

The frequency of behavioural interactions (such as scrambling, pushing another turtle down from a solarium, or resting over another turtle on the solarium) varied from 0.6 to 5.3/h. No aggressive behaviour (such as biting) was observed. There were so few interactions that a dominance hierarchy within the different groups cannot be established.

Interaction frequency varied significantly among ponds and basking locations (Fig. 4), with fewer interactions in the experimental groups than in the control groups ( $\chi^2$ ,  $p < 0.01$ , 4 df). But no significant difference was detected between ex-

**Fig. 4.** Numbers of behavioural interactions in control and experimental groups. Open bars represent the first experiment and solid bars the second experiment.



perimental groups or between control groups ( $\chi^2$ ,  $p > 0.05$ , 2 df). In the experimental groups, the frequencies of interspecific and intraspecific behavioural interactions did not differ ( $\chi^2$ ,  $p > 0.05$ , 1 df; Table 2).

**Discussion**

Competition for basking sites is only one of the potential interactions between *T. s. elegans* and *E. orbicularis*. It may be considered an important estimate of competition because

of the crucial need for heating by these ectotherms. With respect to the experimental design, *T. s. elegans* appeared more competitive than *E. o. galloitalica* in occupying preferred basking sites. Overall, *E. o. galloitalica* lost more mass than *T. s. elegans* whatever the experimental conditions. But after only one season of activity, this mass loss was not significant. Many factors can explain such differences in basking behaviour between *E. o. galloitalica* and *T. s. elegans*. The results of our experiments suggest that the exotic turtle outcompeted the native one for preferred basking places. An experimental constraint imposed a priori caused *E. o. galloitalica* to be near maximum adult size, whereas most *T. s. elegans*, particularly females, still had considerable growth potential. Therefore, the use of body-condition index and mass loss was confounded, and little inference about fitness effects due to competition can be made.

When reared separately, both species showed similar basking patterns. They also used the same solarium sites, preferring the deep-water sites at a distance from the banks. The banks were only used for basking immediately after sunrise, as the slope compensated for the low incidence of solar radiation, thus allowing the same energy gain as on a horizontal surface 1.5 h later. As the angle of incidence increased, the turtles left the banks and moved to the floating solarium. As a consequence, gaining heat appeared to be a crucial activity that outweighed the need to avoid disturbance on the banks of the pond. These observed patterns differ from those recorded in *Trachemys scripta* by Crawford et al. (1983), who found that basking mostly occurs during the hottest hours of the day. The probable reason is that they studied basking behaviour during summer, when the need for heat is probably less intense than during spring. For the same reason these authors did not observe any behaviour that optimized the angle of incidence of the animal with solar radiation, such as changes of basking places.

In most two-species treatments, *Emys* spp. shifted their basking activity to places considered to be of lower quality, based upon patterns observed in the control ponds (banks), while *Trachemys* spp. occupied the preferred basking sites. If dominance resulted in more efficient occupation of basking sites, these results suggest the dominance of *Trachemys* spp. over *Emys* spp. Agonistic behaviour between the two species was never observed, yet *Trachemys* spp. consistently occupied the preferred basking sites. This appropriation of better sites was probably due to earlier occupation of the solarium in the competition treatments rather than to interference behaviour, such as superimposition or displacement of other individuals. If superimposition and displacement are not considered properly aggressive behaviour, competition for basking sites results only from exploitation. *Trachemys* spp. have occasionally been considered aggressive and capable of threatening or biting other individuals (Arvy and Servan 1998). Such aggressive behaviour was never observed here, either at basking sites or in other parts of the ponds. The availability of basking sites for *Emys* spp. was reduced because this species seemed reluctant to climb onto a solarium that was already occupied by a *Trachemys* spp., which suggests remote identification of the individual on the solarium and active avoidance of any contact with it.

Our results demonstrate a need for estimating the availability of favourable basking sites in natural ponds. Intensive

cleaning of pond banks (e.g., removal of logs) decreases the availability of favourable basking places. Thus, artificial solarium may present a good opportunity for monitoring the presence of pond turtles and their interspecific relationships. Wild populations of *E. orbicularis* usually show low densities from 2 to 30/ha (Mazzotti 1995; Duguay and Baron 1998), whereas *T. s. elegans* may reach higher densities in its native habitats (up to 100/ha; Cagle 1950). With respect to these densities, the introduction of *Trachemys* spp. may quickly increase turtle densities and considerably modify habitat utilization, and especially with regard to basking sites.

For *E. orbicularis*, the usual response to disturbance is dispersal (Naulleau 1991). If the introduction of *Trachemys* spp. acts as a disturbance, *E. orbicularis* are expected to emigrate. However, habitat patches for *E. orbicularis* are now so restricted and isolated that any disturbance which would cause dispersal should be avoided. It is suspected that 90% of the animals that are sold as house pets die within the first 12 months (Warwick 1985). If this estimation is applied to French importations of *T. s. elegans* (100 000 are imported annually), more than 10 000 have theoretically survived each year since 1985 (Arvy and Servan 1996). We have no precise data on the proportions of these turtles that have been released into native habitats, but we can expect that most fresh waters (large ponds, lakes, rivers) are now inhabited by this species. Because of the decline of *E. orbicularis* populations, much attention is directed to the conservation of this threatened species. In this context, we consider that the introduction of alien turtle species should always be strongly discouraged. Each government should adopt the principle of caution and prevent any importation of freshwater turtles.

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