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Interference competition between native Iberian turtles and the exotic *Trachemys scripta*

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The red-eared slider, *Trachemys scripta elegans*, is a worldwide invasive species, currently introduced in most freshwater habitats as a consequence of the exotic pet trade. In the Iberian Peninsula, this American turtle is competing and displacing the Iberian turtles, *Emys orbicularis* and *Mauremys leprosa*. Recent studies have pointed out to diverse competitive advantages of sliders over Iberian terrapins. For instance, native turtles avoid chemical cues from *T. scripta*, which is more aggressive and dominant in direct competition for food and basking places. This avoidance behaviour displayed by Iberian terrapins might serve as a spacing mechanism to avoid unfavourable competitive interactions with the introduced species. Sliders also benefit from morphological and thermoregulatory advantages: they are more spherical, thus presenting a less surface to volume ratio and a greater thermal inertia that facilitates heat retention. On the other hand, introduced turtles show a more accurate assessment of predatory risk in altered habitats, and are more efficient predators of local prey than native species. These inter-specific asymmetries could contribute jointly to the greater competitive ability of introduced *T. scripta*, thus facilitating the expansion of this alien species in detriment of native populations of Iberian terrapins.

Key words: biological invasions; chemical communication; competition; Iberian turtles; morphology; thermal biology.

Interferencias competitivas entre los galápagos nativos ibéricos y el galápago exótico *Trachemys scripta*. El galápago de Florida, *Trachemys scripta elegans*, es una especie invasora a nivel mundial, introducida en la mayor parte de los ecosistemas acuáticos como consecuencia del comercio masivo de mascotas. En la Península Ibérica, este galápago americano compite y desplaza a los galápagos ibéricos, *Emys orbicularis* y *Mauremys leprosa*. Estudios recientes han puesto de manifiesto la existencia de diversas ventajas competitivas del galápago de Florida sobre los galápagos nativos ibéricos. Por ejemplo, los galápagos nativos evitan ocupar espacios donde detectan secreciones químicas de los galápagos exóticos, quienes se muestran más agresivos y dominantes en la competencia directa por la comida y los recursos de asoleamiento. Este comportamiento aversivo podría ser utilizado por las especies nativas para evitar las interacciones competitivas desfavorables con la especie invasora. Los galápagos de Florida se benefician también de ventajas morfológicas y termorreguladoras: presentan una forma más esférica y por tanto una menor relación superficie-volumen y una mayor inercia térmica que facilita la retención de calor. Por otra parte, los galápagos exóticos muestran un mejor ajuste del riesgo de depredación en hábitats alterados y poseen ventajas en la captura de presas nativas. Estas asimetrías inter-específicas podrían contribuir conjuntamente a una mayor habilidad competitiva del galápago de Florida, facilitando la expansión de esta especie invasora en detrimento de las poblaciones nativas de galápagos ibéricos.

Key words: biología térmica; competencia; comunicación química; galápagos ibéricos; invasiones biológicas; morfología.

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The introduction of alien species outside their natural distribution ranges represents, after habitat destruction, the second greatest threat to biodiversity (WILCOVE *et al.*, 1998; GUREVITCH & PADILLA, 2004). Introduced species have caused severe alterations in terrestrial and aquatic ecosystems, altering energy flows and displacing native organisms from their ecological niches (HERBOLD & MOYLE, 1986; WILLIAMSON, 1996; MOONEY & HOBBS, 2000; LOCKWOOD *et al.*, 2007). Competition for resources is one of the most habitual ways alien species may impact native populations (SHIGESADA & KAWASAKI, 1997; LOCKWOOD *et al.*, 2007).

The red-eared slider (*Trachemys scripta elegans* Wied, 1839) is a chelonian belonging to the family Emydidae. Native from Southeast USA and Northeast Mexico, the species has become introduced worldwide, especially in Mediterranean countries, as a result of the massive exotic pet trade occurred during the last decades (LUISELLI *et al.*, 1997; CHEN & LUE, 1998; PLEGUEZUELOS, 2002). *Trachemys scripta* is a semiaquatic turtle, generalist and ubiquitous, with a great adaptive capacity (GIBBONS, 1990). In the Iberian Peninsula, a large number of young red-eared sliders have been imported from the USA and released in the natural environment, causing a great expansion of the species. Many populations have become naturalized in marshes and wetlands of the littoral, as well as in dispersed points inland (PLEGUEZUELOS, 2002). These populations may cause important impacts on the ecosystems and eventually the displacement of native fauna (DA SILVA & BLASCO, 1995; PLEGUEZUELOS, 2002; VILÀ *et al.*, 2008; LINDSAY *et al.*, 2013).

Field observations have pointed out the existence of competitive interactions between *T. scripta* and the two species of Iberian turtles, the European pond turtle, *Emys orbicularis*, and the Spanish terrapin, *Mauremys leprosa.* These two native species have suffered a considerable recession of their populations and a reduction of their distribution ranges (Figs. 1a,b) during the last decades, both being currently considered as endangered (TORTOISE & FRESHWATER TURTLE SPECIALIST GROUP, 1996; VAN DIJK *et al.*, 2004). Habitat destruction and human pressure are major factors responsible for this decline, but competition with exotic introduced turtles might be worsening the state of the remaining populations (Fig. 1c).

Competition for food, basking places or nesting sites is likely to occur (CRUCITTI *et al.*, 1990; CADI & JOLY, 2003, 2004), since both introduced sliders and native terrapins overlap in diet and feeding areas, devote a high percentage of their time budget to bask and coincide in the timing of reproductive seasons (GIBBONS, 1990; ANDREU & LÓPEZ-JURADO, 1998; KELLER & BUSACK, 2001; PLEGUEZUELOS, 2002). Transmission of pathogens between introduced turtles and native ones is another interaction likely occurring in syntopic populations (HIDALGO-VILA *et al.*, 2009; VERNEAU *et al.*, 2011). Potential advantages of *T. scripta* over native Iberian turtles might be a larger adult body size, a more diverse diet, a higher fecundity and a greater tolerance to pollution and human presence (PLEGUEZUELOS, 2002). Also, the origin of *T. scripta* in environments with saturated fauna where a great number of competitive turtle species coexist, compared to the few competitors of Iberian turtles, might endow the introduced species with competitive advantages in Mediterranean habitats.

Here we review some biological, ecological and behavioural aspects of introduced sliders and Iberian turtles, especially focu-

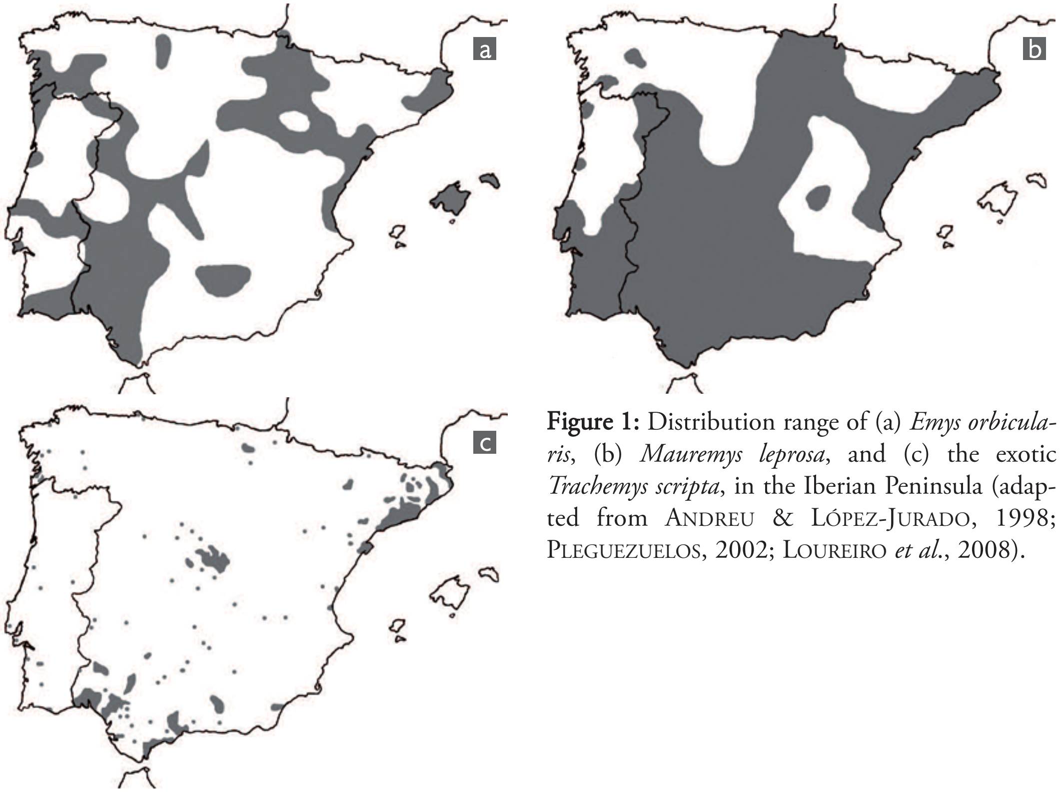

Figure 1: Distribution range of (a) *Emys orbicularis*, (b) *Mauremys leprosa*, and (c) the exotic *Trachemys scripta*, in the Iberian Peninsula (adapted from ANDREU & LÓPEZ-JURADO, 1998; PLEGUEZUELOS, 2002; LOUREIRO *et al*., 2008).

sing on *T. scripta* and *M. leprosa*, which may contribute to explain competitive interactions between freshwater turtle species. We firstly examine the effect of direct competition with *T. scripta* on three key factors affecting the ecology and behaviour of *M. leprosa*: use of space, feeding efficiency and basking efficiency. Subsequently, we compare the specific morphology and thermal biology of the native and invasive species, which might have consequences for the outcome of competition. Finally, we examine other potential advantages that antipredatory behaviour (i.e. inter-specific differences in risk assessment) and predator efficiency (i.e. the inability of prey to recognise introduced predators) might confer to invasive turtle species.

DIRECT COMPETITION

Chemical Avoidance

Experiments studying direct competition between native and introduced turtles have demonstrated that different functions and activities of native terrapins are limited in presence of red-eared sliders. Moreover, semiochemicals (chemical substances conveying a signal for communication between organisms) seem to play an important role in inter-specific competition between native and exotic turtles. In an experiment comparing the use by *M. leprosa* and *T. scripta* of pools with clean water and pools with water containing chemical cues from conspecific or heterospecific turtles, *M. leprosa* preferred water with chemical stimuli from conspecifics and avoided water with chemical cues from *T. scripta*, whereas *T. scripta* neither avoided nor preferred water pools with chemical cues from native *M. leprosa* (POLO-CAVIA *et al.*, 2009a; Fig. 2). This suggests that *M. leprosa* is able to discriminate water-borne cues from introduced *T. scripta* and modify their use of space to avoid the costs of potential encounters with *T. scripta*. If scents of *T. scripta* result aversive for native turtles, dispersal would be a logical consequence in natural environments. On the other hand, the lack of chemosensory responses by *T. scripta* towards chemical cues of native terrapins –due to its inability to detect heterospecific cues, or simply to that, although detected, these cues do not represent a threat for them–, might further favour the expansion of the invasive species.

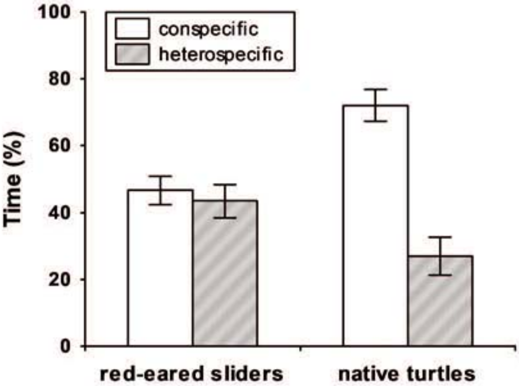

Figure 2: Percent time (mean ± SE) that exotic red-eared sliders and native turtles spent in experimental ponds with water-borne chemical cues from conspecifics (open rectangles) and heterospecifics (barred rectangles). Native turtles prefer water with cues from conspecifics and avoid water with cues from introduced turtles (adapted from POLO-CAVIA *et al.*, 2009a).

Feeding Competition

Alteration in space use by *M. leprosa* in presence of *T. scripta* seems to respond to the negative effects of direct competition with the invasive species for limited resources. The two species are likely to compete for feeding areas in nature, given that both native and introduced turtles mainly consume animal matter, though they also feed on plants (KELLER & BUSACK, 2001; PLEGUEZUELOS, 2002). *Trachemys scripta* individuals are aggressive omnivores with high preferences for a carnivorous diet (PARMENTER, 1980; GIBBONS, 1990), capable of threatening or biting other individuals during competitive activities such as feeding (ARVY & SERVAN, 1998; LINDEMAN, 1999). Given that the access to resources is constrained by dominant individuals when competition between foragers is asymmetrical (HOLMGREN, 1995; MOODY & HOUSTON, 1995; SPENCER *et al.*, 1995), a higher level of aggressiveness displayed by introduced sliders during feeding might lead *M. leprosa* to the displacement from areas with more profitable feeding resources.

Recent findings indicate that feeding competition between native *M. leprosa* and introduced *T. scripta* follows an asymmetrical pattern (POLO-CAVIA *et al.*, 2011). Food ingestion of *M. leprosa* and *T. scripta* were compared in the laboratory under situations of intra- and inter-specific competition, analysing the frequency of aggressive interactions between individual turtles of similar size, and observing that, when the two turtle species were forced to forage together, the access of *M. leprosa* to feeding resources was severely restricted by *T. scripta*, which ingested a greater percentage of the

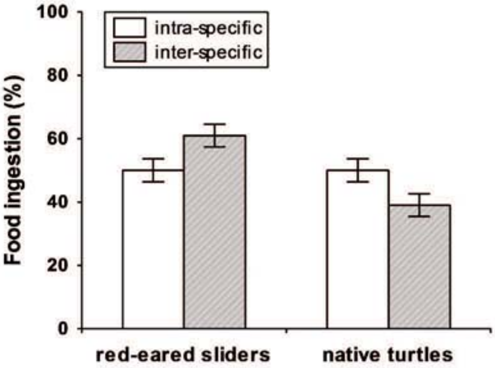

Figure 3: Percentage of food (mean ± SE) ingested by exotic red-eared sliders and native turtles under situations of intra- (open rectangles) and inter-specific (barred rectangles) feeding competition. When native and introduced turtles are forced to forage together the exotic species restrict the access of native turtles to food resources (adapted from Polo-Cavia *et al.*, 2011).

supplied food (Polo-Cavia *et al.*, 2011; Fig. 3). As expected, aggressions occurred more frequently between heterospecific individuals and were more frequently inflicted by introduced *T. scripta* than by native *M. leprosa*. This high percentage of aggressions directed from *T. scripta* to *M. leprosa* suggests that the former is a more aggressive species and dominant over the latter. Furthermore, the percentage of food ingested by *M. leprosa* under inter-specific competition correlated positively with the level of suffered aggressiveness, thus indicating that daring *M. leprosa* which incurred in active competition for food were harshly punished by aggressive sliders, whereas shier individuals that displayed a subordinate role were less attacked (Polo-Cavia *et al.*, 2011). These findings suggest the existence for *M. leprosa* of a trade-off between feeding efficiency and costs of aggressive competition with *T. scripta*.

Basking Competition

Competition for basking sites is another important matter concerning direct competition between freshwater turtle species. Aerial basking serves to activate metabolism by attaining optimal body temperatures that maximize the efficiency of physiological processes (Jackson, 1971; Kepenis & McManus, 1974; Crawford *et al.*, 1983; Hammond *et al.*, 1988; Ben-Ezra *et al.*, 2008; Dubois *et al.*, 2008), favours dermal synthesis of vitamin D (Pritchard & Greenhood, 1968; Avery, 1982), and allows conditioning of the skin and the shell (Cagle, 1950; Neill & Allen, 1954; Boyer, 1965). Thus, both native terrapins and *T. scripta* spend a large amount of their diel activity basking (Meek, 1983; Gibbons, 1990; Andreu & López-Jurado, 1998). However, appropriate basking sites such as logs and stones emerging in deep water are limited, and therefore, *T. scripta* may monopolize optimal basking resources, displacing native terrapins to less preferred sites, and ultimately causing deficiencies in their basking behaviour and thermoregulation (Díaz-Paniagua *et al.*, 2002; Cadi & Joly, 2003; Polo-Cavia *et al.*, 2010a). In a long-term competition experiment, native *M. leprosa* subjected to inter-specific competition with *T. scripta* reduced basking activity, basked for shorter periods than sliders, and avoided sharing platforms with exotic turtles (Polo-Cavia *et al.*, 2010a; Fig. 4). Likewise, Cadi & Joly (2003) reported that native *E. orbicularis* sharing experimental ponds with *T. scripta* were reluctant to climb onto solaria that were already occupied by *T. scripta*, shifting instead to basking places of lower quality. Also, field observations of the western pond turtle, *Emys*

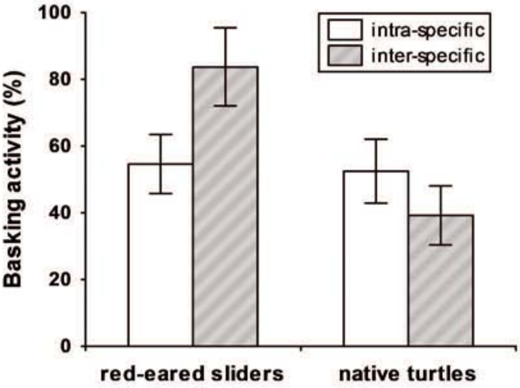

Figure 4: Percent time (mean ± SE) that exotic red-eared sliders and native turtles spent basking under intra-specific (open rectangles) and inter-specific competition (barred rectangles). When native and introduced turtles compete for basking sites native turtles significantly reduce the time devoted to bask (adapted from POLO-CAVIA *et al.*, 2010a).

marmorata, sharing basking sites with *T. scripta* indicate that introduced sliders are much more selective in habitat use than native terrapins (LAMBERT *et al.*, 2013). This avoidance and subordinate behaviour and the consequent detriment in basking activity might lead native turtles to a loss in the efficiency of their physiological functions associated with ineffective thermoregulation, thus favouring the expansion of the invasive species.

MORPHOLOGICAL AND THERMAL ADVANTAGES OF EXOTIC SLIDERS

Body shape has been established as a critical factor in the ability of organisms to thermoregulate (BOGERT, 1949; GOULD, 1966). Hence, morphological differences between native and exotic turtles, resulting from adaptation to different original habitats, might also confer thermoregulatory advantages to introduced sliders in the new environments in which they are introduced, in detriment of native terrapins. Compared to *M. leprosa*, *T. scripta* turtles present a more rounded shell shape that confers them a low surface-to-volume ratio and a greater thermal inertia (POLO-CAVIA *et al.*, 2009b; Fig. 5), thus facilitating heat retention and favouring the efficiency of physiological functions such as aquatic foraging or digestion (HUEY & SLATKIN, 1976; DUNHAM *et al.*, 1989). In temperate zones, mechanisms for conserving body heat could have selective advantages in aquatic turtles, since individuals that have achieved high body temperatures through aerial basking may suddenly be exposed to very cool conditions when entering the water (BARTHOLOMEW, 1982). Consequently, slight differences in thermal inertia between species might favour introduced *T. scripta* in Mediterranean habitats. For instance, in the Iberian Peninsula, *T. scripta* specimens have been observed to be active at lower water temperatures than native terrapins, and therefore, they can start earlier their annual cycle (ACEITUNO, 2001). Such adaptation is consistent with the higher thermal inertia of *T. scripta* observed in the laboratory. In contrast, the more flattened shell shape and lower thermal buffering of *M. leprosa* compared to *T. scripta* may entail a difficulty for retention of body heat that, with the presence of a new competitor species interfering in their basking activity, might result in the achievement of suboptimal body temperatures, subsequently causing reduced locomotor activity and food intake, or altered digestive function (POLO-CAVIA *et al.*, 2009b).

In particular, a reduced body temperature negatively influences righting performance of turtles. Turtles may result overturned acci-

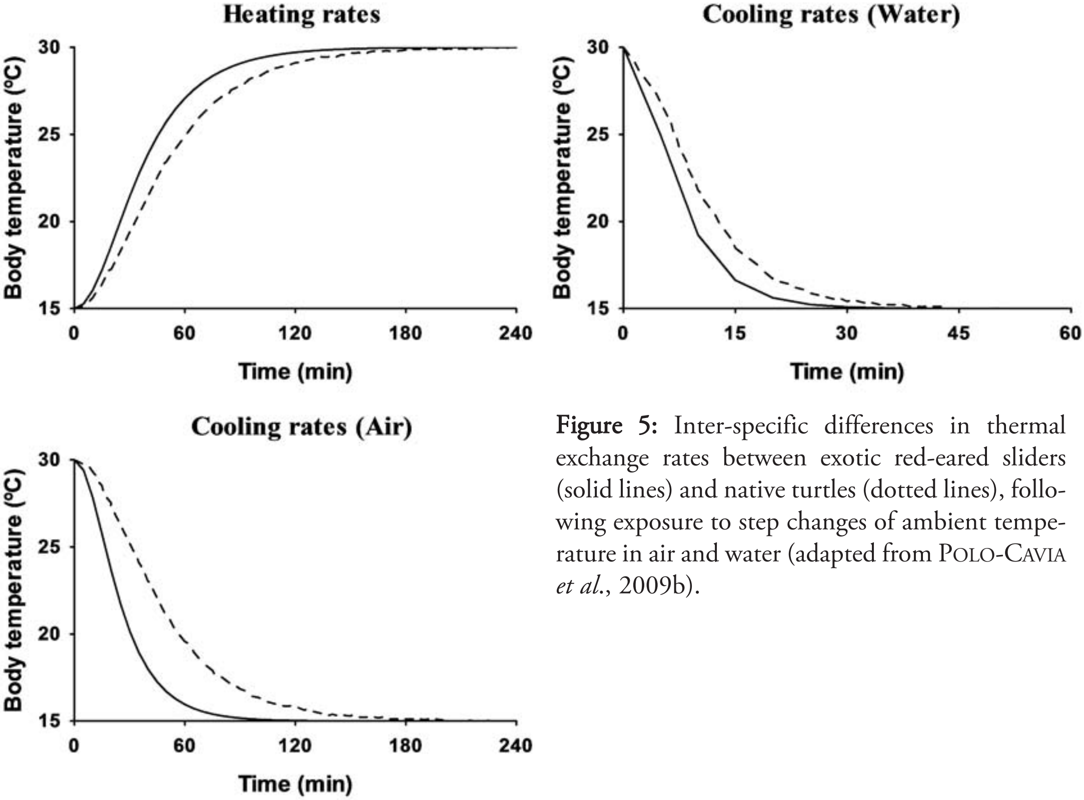

Figure 5: Inter-specific differences in thermal exchange rates between exotic red-eared sliders (solid lines) and native turtles (dotted lines), following exposure to step changes of ambient temperature in air and water (adapted from POLO-CAVIA *et al.*, 2009b).

dentally while climbing to basking sites, during male fights, or as consequence of predatory attacks (CORTI & ZUFFI, 2003; STANCHER *et al.*, 2006). In these cases, righting behaviour is critical to survival, since turtles in an upside-down position may suffer increased predation exposure, changes in body temperature and dehydration, as well as experience difficulties to breathe (FINKLER, 1999; STEYERMARK & SPOTILA, 2001; MARTÍN *et al.*, 2005). At suboptimal temperatures, both native and exotic terrapins were found to increase the time needed to turn themselves over (POLO-CAVIA *et al.*, 2012a). Consequently, turtles that attain and maintain optimal body temperatures will increase their survival possibilities. Thus, the high thermal inertia of *T. scripta* is also advantageous insofar as it favours the performance and reduces the risks of exposure to potential predators and overheating while overturning (CARR 1952; WYNEKEN *et al.*, 2008; POLO-CAVIA *et al.*, 2009b). Also, the domed shape of the shell facilitates mechanical righting in *T. scripta*, which needs shorter times on average to turn right-side up than *M. leprosa* (DOMOKOS & VÁRKONYI, 2008; POLO-CAVIA *et al.*, 2012a).

Experiments comparing bioenergetics of *M. leprosa* and *T. scripta* also revealed that the two turtle species differ in thermal requirements (POLO-CAVIA *et al.*, 2012b). Thus, the upper set point body temperature (i.e. the body temperature at which turtles cease basking and dip into the water; KINGSBURY, 1993, 1999; TOSINI & AVERY, 1994; BEN-EZRA *et al.*, 2008; DUBOIS *et al.*, 2008; POLO-CAVIA *et al.*, 2012b) is 5ºC higher on average in *M. leprosa* compared to *T. scripta*. This suggests that native *M. leprosa*, more flattened and with higher surface-to-volume ratio than *T. scripta*, might compensate their greater tendency to loss body heat by attaining higher optimal temperatures during basking. Also, individuals with higher surface-to-volume ratios have been observed to bask until attaining higher set point body temperatures, suggesting a close relation between specific thermal requirements and carapace morphology of each species. On the other hand, in response to starvation, the two turtle species similarly reduce their set point temperatures, which points out to the existence of an adaptive energy saving mechanism during periods of low food availability (POLO-CAVIA *et al.*, 2012b). As a result, interferences of *T. scripta* on feeding and basking behaviour of native terrapins might ultimately cause a reduction in their metabolic rates and a general depression of their physiological functions (PARMENTER, 1981; SIEVERT *et al.*, 1988; GIANOPULOS & ROWE, 1999). Such negative effects may explain the loss of weight and decreased survival rates found in *E. orbicularis* after long term competition with *T. scripta* (CADI & JOLY, 2004).

PREDATORY RISK IN ALTERED HABITATS

When a predator approaches, turtles typically flee to safe refuges such as deep water or dense vegetation (LÓPEZ *et al.*, 2005). However, if the predator gets close enough, turtles tend to withdraw inside the shell with the legs, tail and head hidden (GREENE, 1988; HUGIE, 2003). Then, the decision of when to emerge is accurately adjusted basing on risk factors such as the perceived predation threat, the persistence of the predator or the probability of reaching a safer refuge, *vs.* the costs of remaining within the shell (i.e. overheating risk, interruption of basking, loss of foraging or mating opportunities, etc.) (SIH *et al.*, 1998; MARTÍN *et al.*, 2005; POLO-CAVIA *et al.*, 2008). In these cases, the high thermal inertia of *T. scripta* protects turtles from desiccation (CARR, 1952; WYNEKEN *et al.*, 2008; POLO-CAVIA *et al.*, 2009b) and its spherical shell shape reduces the risk of successful predatory attacks, as it hampers the capture by snapping jaws or avian predators (PRITCHARD, 1979; JANZEN *et al.*, 2000). In contrast, *M. leprosa* hidden within the shell are more prone than *T. scripta* to overheating or predation due to their more flattened shape. Thus, as expected, *M. leprosa* escapes quickly to the water when facing a terrestrial threat while *T. scripta* tends to remain for longer in land, hidden inside the shell (POLO-CAVIA *et al.*, 2008). These inter-specific differences in response to predation risk between native and introduced turtles may result advantageous for the introduced species in altered habitats where human pressure has considerably reduced the risk of predation by natural predator species. In such environments, where *T. scripta* is mainly introduced, the costs derived from interruption of basking and repeated unnecessary flees to water due to human disturbance (DILL & FRASER, 1997; SIH, 1997; MARTÍN & LÓPEZ, 1999) might suppose a disadvantage for native turtles when competing with introduced sliders.

INTERACTIONS WITH TADPOLE PREY

Human alteration of ecosystems may cause disruption of the antipredatory behaviour of native turtles, but may also affect their predatory efficiency by means of introducing a competitor species that fed on the same prey and benefit from an evolutionary release. Antipredatory responses of prey are expected to be adaptive in the specific habitats in which they evolved, but however, prey may not be innately equipped to cope with suddenly introduced predators with which they have not shared a long evolutionary past (SCHLAEPFER *et al.*, 2002, 2005). For this reason, native prey are generally unable to detect or adequately respond to the hunting tactics of novel predators, which do not experience some of the difficulties of finding prey that keep working for native predators (LAWLER *et al.*, 1999; KIESECKER *et al.*, 2001; BABER & BABBITT, 2003). This is the case of tadpoles of several Iberian anuran species, which are common prey of both native and introduced turtles. These tadpoles have been observed to innately respond to predator chemical cues from the two Iberian turtles, *E. orbicularis* and *M. leprosa*, but contrarily, tadpoles are not able to recognise exotic predatory turtles of the genera *Trachemys* or *Graptemys* (POLO-CAVIA *et al.*, 2010b). Consequently, exotic turtles may easily capture larval amphibian prey outcompeting native Iberian turtles. The advantage of an evolutionary release may explain the paradox of why invasive species sometimes prosper better in their new habitats than native adapted species (BLOSSEY & NÖTZOLD, 1995; SHEA & CHESSON, 2002; ALLENDORF & LUNDQUIST, 2003).

SYNTHESIS AND FUTURE RESEARCH

The studies to date analysing interference competition between native Iberian turtles and *T. scripta* suggest a greater competitive ability of the exotic *T. scripta* in vying for resources. In direct competition, native turtles seem to rely on water-borne chemical cues to discriminate between conspecifics and heterospecifics, thus avoiding potential costly interactions with exotic turtles, deserting resources or displacing to less preferred areas (POLO-CAVIA *et al.*, 2009a). Thus, the higher aggressiveness and dominance of sliders in competition for food or basking sites may lead native terrapins to a detriment in their nutritional state and thermoregulatory behaviour (POLO-CAVIA *et al.*, 2010a, 2011). On the other hand, species-specific traits such as a more spherical shell shape and a greater thermal buffering may confer additional competitive advantages to exotic *T. scripta* in comparison to turtles native to the new habitats where they are introduced. Hence, the high thermal inertia of *T. scripta* facilitates heat retention and favours physical and physiological performances (POLO-CAVIA *et al.*, 2009b, 2012a). Also, a greater thermal buffering reduces overheating and dehydration risks in situations in which turtles have lost the behavioural control of their body temperature (e.g. if they result overturned or suffer a predatory attack) (CARR, 1952; WYNEKEN *et al.*, 2008).

Inter-specific differences in risk perception between introduced *T. scripta* and native Iberian turtles may also benefit the former in anthropogenically disturbed environments in which they are mainly introduced. In these habitats, where terrestrial predators are reduced and human presence carries little risk of actual predation, *T. scripta* could avoid unnecessary flees to water and subsequently basking interruptions by remaining hidden in the shell (POLO-CAVIA *et al.*, 2008). These findings emphasise the importance of further studies linking habitat conservation with invasion success. Likewise, comprehension of adaptive evolutionary responses of native and introduced species is essential in understanding competition processes, given that alien introduced species create new ecological contexts in which adaptive responses of native organisms may loss functionality (CALLAWAY & ASCHEHOUG, 2000; SHEA & CHESSON, 2002). Hence, the inability of amphibian tadpoles to innately recognise chemical cues from exotic predatory turtles may represent a further competitive advantage for introduced turtles over native ones in the Iberian Peninsula (POLO-CAVIA *et al.*, 2010b). However, the magnitude and impact of this evolutionary release on native populations of Iberian turtles remains uncertain, as amphibian prey might acquire learned recognition of novel competitive predators and enhance survival (MIRZA & CHIVERS, 2000; GAZDEWICH & CHIVERS, 2002; POLO-CAVIA & GOMEZ-MESTRE, 2014).

Native organisms have been observed to alter morphology and/or behaviour as a result of their interactions with exotic species (REZNICK & ENDLER 1982; MAGURRAN, 1989; SINGER *et al.*, 1993; CARROLL *et al.*, 1997, 1998). Thus, under favourable circumstances, native species may induce or evolve mechanisms to cope with invasions and maintain their populations (MEYERS & BULL, 2002). However, despite the existing cases of induced plasticity and rapid evolution in response to sudden environmental changes (ASHLEY *et al.*, 2003; RICE & EMERY, 2003; STOCKWELL *et al.*, 2003; SHINE, 2012), the evolutionary processes are hardly ever incorporated into conservation plans (SCHLAEPFER *et al.*, 2005). The studies reviewed here evidence the necessity of managing biological invasions basing on evolutionary dynamics, behaviour and plasticity of native species, with the purpose of guaranteeing the conservation goal of long-term persistence (ASHLEY *et al.*, 2003; STOCKWELL *et al.*, 2003; SHINE, 2012).

In conclusion, the existing asymmetries in morphology, ecology and behavioural responses of native Iberian turtles and introduced red-eared sliders, resulting from adaptation to their respective natural habitats, seem to be jointly responsible for the greater competitive ability of exotic *T. scripta*. These inter-specific differences might favour the displacement of native turtles to suboptimal resources and facilitate the expansion of introduced sliders in their new habitats. Future investigations comparing native populations of Iberian turtles in coexistence and free from introduced turtle competitors will help to evaluate the ability of native terrapins to resist the invasion in a long-term scenario (WILLIAMSON, 1996; JOLY, 2000), enabling the design of management strategies that support native populations long enough to allow them to adapt to the new challenges posed by invasive turtle species (ASHLEY *et al.*, 2003; SCHLAEPFER *et al.*, 2005; SHINE, 2012).

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