Comparing Activity Patterns and Aquatic Home Range Areas Among Exotic and Native Turtles in Southern Spain

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ABSTRACT. – We radiotracked individuals of the exotic aquatic turtle *Trachemys scripta elegans* and 2 coexisting species of native turtles (*Mauremys leprosa* and *Emys orbicularis*) in southern Spain. Aquatic home range areas differed among species only in winter, when *T.s. elegans* moved in larger areas and showed shorter inactivity periods than the native turtles. Differences in these activity patterns may provide an advantage for individuals of the exotic species, which were already moving widely when native turtles started their posthibernation activity and would have been expected to be recolonizing their home ranges in depleted physical condition.

The introduction of invasive species and their impact on co-occurring native species is one of the most important causes of biodiversity loss in natural ecosystems (Walker and Steffen 1997; Simberloff 2001; Strayer et al. 2006; Strayer 2010). Among reptiles, *Trachemys scripta elegans* is the most widespread aquatic invader globally (Lowe et al. 2004; Kraus 2009). These turtles have been introduced from their native range in the southeastern United States to numerous countries through the pet trade (e.g., Ramsay et al. 2007), although the confirmation of establishment of reproducing populations has not been so widely reported (Chen and Lue 1998;

Pérez-Santigosa et al. 2006; Perry et al. 2007; Ficetola et al. 2009; Kikillus et al. 2010).

Control of *T. scripta* requires efficient methods for population removal as well as knowledge of the factors influencing their successful establishment in nonnative areas. It is also important to detect the effect of these exotic turtles on the native community, especially on closely related species with which they may compete for resources. In Spain, exotic turtles may coexist in aquatic habitats and potentially compete with 2 native species, *Emys orbicularis* and *Mauremys leprosa*, both presently considered to be vulnerable species in Spain, with competition with exotic turtles being included among their main threats (Pleguezuelos 2002).

The ecology of *T. scripta* has been studied intensively in their native range (e.g., Gibbons et al. 1990). These turtles are diurnal and may remain in aquatic habitats in all seasons, even for hibernation (Gibbons et al. 1990). They are active mainly from early spring to late autumn, reducing their movements during the colder winter months (Spotila et al. 1990). Their home range areas have been considered among the largest reported for freshwater turtles and are larger for males than for females (Schubauer et al. 1990). However, there is little information regarding their populations established in invaded areas, although competition with native species has received special attention. From experimental studies, it was concluded that exotic *T.s. elegans* compete with *E. orbicularis* for basking sites, forcing native turtles to use suboptimal basking resources and causing an increase in their mortality rate (Cadi and Joly 2003, 2004). Their presence also affects basking behavior in *M. leprosa*, which reduced their basking activity when they were in coexistence with exotic turtles under experimental conditions (Polo-Cavia et al. 2010). None of these effects have been confirmed in wild populations.

Trachemys scripta elegans is widely distributed in Spain, where reproducing populations have been reported for different localities, especially in eastern and southern areas (Martínez-Silvestre et al. 2011). The characteristics of established populations, reproductive ecology, and diet in southern Spain have been described in detail (Pérez-Santigosa et al. 2006, 2008, 2011).

In order to contribute to the knowledge of the ecology and behavior of *T.s. elegans* in their introduced habitats and their interactions with native aquatic turtles, we aimed to describe its aquatic home range areas and activity periods. This information was compared with similar data obtained for the 2 co-occurring native turtle species, *M. leprosa* and *E. orbicularis*.

Methods

We monitored exotic and native turtles using radio-transmitters in El Portil Pond (lat 37°14'N, long 7°2'W) from May 2003 to June 2004. This is a freshwater pond close to the Atlantic coast in which a reproducing population of *T.s. elegans* was established before 1996. This pond has an area of 18 ha and a maximum depth of

Figure 1. Schematic description of El Portil Pond.

approximately 200 cm and experiences wide fluctuations in depth seasonally (Fig. 1). A detailed description of the study area and composition of established populations of exotic turtles in this pond was given in Pérez-Santigosa et al. (2006).

We radiotracked 5 *T.s.elegans*, 6 *M.leprosa*, and 3 *E.orbicularis*, all of which were captured in the same pond (details on biometry and sex of radiotracked individuals are given in Table 1). We used baited fyke nets for trapping native turtles, but this method was not efficient for *T.scripta*. Thus, for this species we could monitor only females, 2 of which were captured on land returning to the pond after nesting and 3 that were captured by diving in the pond. The uniform growth of shell plates and large size of the monitored individuals of *T.s.elegans* indicated that these turtles had been born in the wild and were not released pets.

We attached Biotrack 10 TW-3 single-celled tag radiotransmitters on carapaces of *M.leprosa* and *E.orbicularis* and Biotrack 5 TW-3 twin celled tag on carapaces of *T.s.elegans*. Signal reception was recorded through a Yaesu FT-290R II handheld receiver and a Lintec flexible 3-element Yagi antenna. Transmitters were glued with epoxy on the costal scutes of the posterior carapace. The sites of capture and release of each monitored turtle are indicated in Figs. 2–4.

From May to October 2003 we located turtles monthly over a 3-d period. We received the radio signal 1–6 times/day, although we finally considered only 1

Table 1. Body mass, straight-line carapace length (SCL), and sex of monitored individuals of *Trachemys scripta elegans*, *Mauremys leprosa*, and *Emys orbicularis* in El Portil Pond. The aquatic home range and hibernation areas, the length of the hibernation period, dates of the start and end of monitoring periods, and the number of locations used for these estimates are also shown for each individual.

Species	No.	Sex	Mass (g)	SCL (mm)	Monitoring period	Locations (n)	Hibernation period	Home range (ha)	Hibernation area (ha)
<i>T. s. elegans</i>	210 ^a	Female	1974.0	233.7	22 May 2003/18 May 2004	13	—	7.56	—
<i>T. s. elegans</i>	211	Female	1187.0	184.5	16 May 2003/28 Apr 2004	62	29 Dec 2003/22 Mar 2004	2.84	0.15
<i>T. s. elegans</i>	214	Female	801.0	171.0	1 Jul 2003/22 May 2004	77	23 Jan 2004/11 Mar 2004	3.90	0.10
<i>T. s. elegans</i>	216	Female	1512.0	219.0	11 Aug 2003/18 May 2004	32	29 Dec 2003/31 Jan 2004	7.23	0.10
<i>T. s. elegans</i>	223	Female	1075.0	194.4	16 Sep 2003/9 Jun 2004	36	Active in winter	5.78	1.07
<i>E. orbicularis</i>	2003	Male	502.0	146.8	22 May 2003/18 May 2004	85	17 Dec 2003/2 Mar 2004	3.24	0.08
<i>E. orbicularis</i>	2012	Male	451.0	142.3	16 May 2003/13 Apr 2004	82	14 Nov 2003/9 Apr 2004	3.24	0.26
<i>E. orbicularis</i>	2013	Female	433.0	129.7	1 Jul 2003/9 Jun 2004	68	14 Nov 2003/9 Apr 2004	4.07	0.08
<i>M. leprosa</i>	5511	Male	533.0	168.6	30 Jun 2003/22 May 2004	37	7 Jan 2004/11 Mar 2004	2.21	0.03
<i>M. leprosa</i>	5517	Male	470.0	151.3	14 Oct 2003/22 May 2004	26	17 Dec 2003/22 Mar 2004	4.15	0.32
<i>M. leprosa</i>	5521	Male	778.0	178.5	14 Oct 2003/22 May 2004	28	28 Nov 2003/2 Mar 2004	3.51	0.02
<i>M. leprosa</i>	5563	Female	1048.0	191.3	16 May 2003/30 Jun 2004	94	17 Dec 2003/23 Jan 2004	3.32	0.21
<i>M. leprosa</i>	5591	Female	774.0	179.3	16 May 2003/28 Apr 2004	83	17 Dec 2003/9 Apr 2004	3.90	0.26
<i>M. leprosa</i>	5602	Male	528.0	163.0	24 May 2003/22 May 2004	55	17 Dec 2003/11 Mar 2004	2.54	0.26

^a This individual was not found from 2 Jul 2003 to 15 Oct 2003 and from 14 Nov 2003 to 9 Apr 2004.

Figure 2. Minimum convex polygons estimates of home ranges of monitored *Trachemys scripta elegans* for the winter, hibernation (inactivity period in winter), and reproductive and postreproductive periods. Capture sites are indicated with circles, release sites with triangles.

Figure 3. Minimum convex polygons estimates of home ranges areas of monitored *Mauremys leprosa* for the winter, hibernation, and reproductive and postreproductive periods. Capture sites are indicated with circles, release sites with triangles.

Figure 4. Minimum convex polygons estimates of home range areas of monitored *Emysorbicularis* for the winter, hibernation, and reproductive and postreproductive periods. Capture sites are indicated with circles, release sites with triangles.

location/day (recorded about midday). From November 2003 to February 2004, we located turtles in a 1-d period, recording 1–3 locations/month. We lost the signal of some transmitters in March and April 2004; the remaining active transmitters were then recorded within 3–10-d intervals until June (Table 1).

Turtle locations were obtained by triangulation from 3 different reference sites at the shores of the pond. The resulting turtle positions were uploaded into Arc View 3.2 (Environmental Systems Research Institute, Inc., Redlands, CA, USA) and projected onto a digital orthophoto of the area (Junta de Andalucía 2003).

To estimate home range areas, we calculated minimum convex polygons (MCP; White and Garrot 1990) using the Home Range extension of ArcView 3.2 (Rodgers and Carr 1998). These estimated areas were then corrected by subtracting the terrestrial portions of the area to calculate the aquatic home range areas. We estimated lineal distances between locations in consecutive months. Hibernation period was considered as the period when turtles considerably reduced their movements in winter, which we designated as the time when intramonth locations were within 50 m of one another. The MCP estimated in this period was then termed the hibernation area. We also calculated the aquatic home range areas for each turtle in 3 different periods: winter (November–February) and reproductive (March–June) and postreproductive (July–October) periods.

We used Pearson correlation to assess the relationships between carapace length of the turtles and their total aquatic home range. We compared aquatic home range and hibernation areas among species and periods as well as the length of hibernation periods using analysis of variance. We transformed (logarithmic or square-root transformation) the variables when it was necessary to fit normality and heteroscedasticity assumptions of residuals.

Results

Home Range. — The periods during which each turtle was monitored and their individual aquatic home

range areas are shown in Table 1. In general, considering individuals of the 3 species together, aquatic home range areas were significantly correlated with the carapace length of the individuals ($r = 0.787$; $p = 0.001$; $n = 14$). The largest home ranges detected (> 7 ha) were for 2 individuals of *T. s. elegans*, although there was much variation within and among species.

All turtles moved in areas around their sites of capture, even those that had been released on the side of the pond opposite their capture sites. Except for 3 *T. s. elegans* individuals that moved mainly among palustrine vegetation of the shorelines, all other turtles moved both in deep and shallow areas (over the entire depth range) of the pond (Figs. 2–4).

We did not find significant differences in aquatic home range areas among turtle species ($F_{2,34} = 0.82$; $p = 0.449$). However, home range areas differed among periods ($F_{2,34} = 6.09$; $p = 0.0007$), and post hoc comparisons revealed that they were significantly lower during the winter period (winter vs. reproductive, $p = 0.004$; winter vs. postreproductive, $p = 0.0002$), but there was no difference between the reproductive and postreproductive periods ($p = 0.198$). In winter, the aquatic home range areas were marginally different among species ($F_{2,9} = 3.21$; $p = 0.089$), with those of *T. s. elegans* being larger than those of the other species (post hoc Tukey HSD comparisons: *T. s. elegans* vs. *M. leprosa*, $p = 0.835$; *T. s. elegans* vs. *E. orbicularis*, $p = 0.010$; *M. leprosa* vs. *E. orbicularis*, $p = 0.138$). However, hibernation areas did not differ among species ($F_{2,10} = 1.50$; $p = 0.27$).

The aquatic home range area of *M. leprosa* did not differ among activity periods ($F_{2,15} = 2.36$; $p = 0.13$). However, for *T. s. elegans* the aquatic home range areas were significantly different among periods ($F_{2,9} = 4.36$; $p = 0.048$), with larger areas during the postreproductive period than in the other periods (postreproductive vs. reproductive, $p = 0.041$; postreproductive vs. winter, $p = 0.023$) and the smallest areas during winter (reproductive vs. winter, $p = 0.041$). For *E. orbicularis*, we detected a notable reduction of the aquatic home range

Figure 5. Mean ($\pm$ SE) home range sizes of monitored individuals of the 3 species of aquatic turtles (*Trachemys scripta elegans*, *Mauremys leprosa*, and *Emys orbicularis*) in winter and reproductive and postreproductive periods.

area in winter, significantly smaller than their range areas in the other 2 periods ($F_{2,6} = 35.36$; $p = 0.0004$; winter vs. other periods, $p < 0.005$; Fig. 5).

Hibernation Period. — Length of the hibernation period differed significantly among species ($F_{2,10} = 5.42$; $p = 0.025$). Individuals of *T. s. elegans* had shorter hibernation periods than the other species. The first turtles that reduced their activity were 2 individuals of *E. orbicularis*, about mid-November, whereas the third turtle that we monitored of this species became inactive by mid-December. Individuals of *M. leprosa* were inactive from late November to early January. For *T. s. elegans*, 1 turtle was active during the whole winter period, whereas the remaining 3 turtles reduced their activity by late December. All monitored *T. s. elegans* turtles were active by March. Two *E. orbicularis* and 1 *M. leprosa* delayed the start of activity until April (Table 1).

Discussion

In general, large-bodied species move longer distances than smaller species (Morreale et al. 1983; Gibbons et al. 1990). Among our 3 studied species, *T. s. elegans* reaches the largest body size, as described in detail by Pérez-Santigosa et al. (2006), and probably uses wider areas than native species. In this study, the largest individuals of *T. s. elegans* had the largest aquatic home range areas, although we found no differences in home range size among species. The lack of significance among species is probably due to the wide variation in size among the individuals monitored as well as their low number that included only females in the case of *T. s. elegans*.

The largest home range detected in this study was 7.6 ha, notably smaller than the home ranges reported for *T. s. elegans* in localities in its native range (39.8 ± 6.1 ha for males and 15.0 ± 3.5 ha for females; Schubauer et al. 1990). No turtle ranged through the entire pond, but they moved across half or two-thirds of its total area, indicating that pond size in this locality did not constrain turtle movements.

The 2 native turtle species showed similar aquatic home range areas. Home ranges reported for different turtles of Testudinoidea from North and Central America show wide variation, ranging between 0.076 ha for *Glyptemys muhlenbergii* (Pittman and Dorcas 2009) and 103.5 ha for *T. scripta* in South Carolina (Schubauer et al. 1990). Compared with these reported home ranges, our native species (*M. leprosa* and *E. orbicularis*) showed a large home range area (approximately 2–3 ha).

Turtle movements differed seasonally in the 3 studied species. *Trachemys scripta elegans* experienced a gradual increase in their movements, showing the largest home range in summer, during the postreproductive period. This differed from the movement pattern described in their native range in the United States, where they moved within larger home range areas in spring compared with summer (Gibbons et al. 1990). The increase in their movements in the invaded area of southern Spain may be due to the availability of spatial resources they have found in the large and permanent waters of El Portil Pond.

In contrast, the 2 native turtle species moved in similarly wide areas in both the reproductive and postreproductive periods. Home ranges have been reported for *E. orbicularis* in France (Cadi and Joly 2004), Italy (Lebboroni and Chelazzi 2000), and Lithuania (Meeske and Mühlenberg 2004), where they gradually increased the home ranges during their activity period; home ranges became wider in June, July, and August in France and Lithuania, whereas they decreased their movements in spring. In our study area, the lack of seasonal differences could not be related to spatial constraints but may be influenced by co-occurrence with *T. s. elegans*. Because exotic turtles start their annual activity period earlier than native turtles, they also have earlier access to the available feeding or basking areas, which are colonized when native turtles are still inactive or just starting their activity period.

In this study, one of the main differences among exotic and native turtles was the length of the hibernation period and the extent of their wintering areas. Native turtles had long hibernation periods, as reported for *E. orbicularis* in other localities in Europe (Dall'Antonia et al. 2001; Cadi and Joly 2004). In contrast, the individuals of *T. s. elegans* monitored in winter did not experience a true inactivity period. Similar patterns have been described for *T. scripta* in the United States, where turtles remain active during rainy winters (Gibbons et al. 1990).

Although it is not known whether maintenance of winter activity causes energetic costs detrimental to *T. s. elegans*, a consequence is that they increase their postwinter activity earlier than native turtles. Therefore, most of them were already moving widely when native turtles were starting their posthibernation activity. During hibernation, turtle physical condition is depleted and must be restored at the beginning of the activity period (Lawrence 1987). Thus, during the first days after hibernation, turtles are still weak and are probably not able to perform normal movements. At this time, they

also have to recolonize their foraging and basking areas that are already occupied by the exotic species. Thus, alien turtles have distinct advantages over the native turtles in establishing feeding and basking areas because of their shorter winter inactivity period and their larger body size.

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ABSTRACT.— We report on a Euphrates softshell turtle (*Rafetuseuphraticus*) nest and hatchling that emerged from the nest that was constructed in a sand patch of the Dez River in southwestern Iran and discovered on 8 July 2012. Information on nest location and structure and hatchling morphology is presented.

Freshwater turtles are long-lived animals characterized by low mortality in adults but often high mortality in

as 34

°C in June and

36°C in July (Anonymous 2012).

Methods. — During the *R. euphraticus* breeding season in June and July, we conducted field surveys for possible nests on sandbars in the counties of Dezful and Andimeshk, Khuzestan Province. After the single nest described in this article was found, we centered a 4-m² plot on the nesting site. Within this area, we counted and measured the number of tree stems per square meter, the number of tree species, the number of shrub species, tree height, and distance to nearest tree within the plot. Tree and shrub height were ranked into 4 categories (< 0.5 m, 0.5–2 m, 2–5 m, and > 5 m). The distance between the river and the nest and nest dimensions were measured