

Successful reproduction of Trachemys scripta in the Altrhein of Kehl (Germany) and simultaneous increase in population estimate

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14	ABSTRACT - The European Union categorises pond sliders (Trachemys scripta) as invasive
15	species for which all member countries have to develop an action plan. To date it has been assumed
16	that the climate in Germany is too cold for T. scripta to survive for long or to reproduce. Data
17	collected annually from 2016 to 2020 showed that the population of exotic pond turtles in an oxbow
18	lake (Althrein of Kehl, Germany) did not decrease but increased. In addition, the diversity of
19	species released was found to be high, five other exotic species in addition to T. scripta were
20	observed. The population of <i>T. scripta</i> in particular appeared to be increasing, with no indication
21	of high mortality due to cold winters and apparently regular successful reproduction (hatchlings
22	observed in four out of five study years and caught in two years). The current action plan in
23	Germany for T. scripta will have to change if potential negative impacts are to be avoided. Other
24	west and central European countries might also have to modify their action plans accordingly.
25	INTRODUCTION
• •	

26 Invasive species are threatening native biodiversity worldwide. Neobiota are alien species that

establish themselves outside their natural distribution range due to human action, i.e. they
reproduce successfully in the areas in which they have been released and they maintain their
population (Geiger & Waitzmann 1996; Wilson *et al.* 2009). They are regarded as being invasive
if they have the capacity to spread into new areas and at the same time cause harm to the native
fauna and / or flora by predation and/or competition (Lowe *et al.* 2000; Wilson *et al.* 2009).

32 Of the world's 100 worst invasive alien species, only two species are reptiles, the brown 33 tree snake (Boiga irregularis) from Australia and the red-eared slider (Trachemys scripta) from 34 North America (Lowe et al. 2000). Compared to invertebrates (26 of the 100 worst invasive 35 species) and small mammals (10 of the 100 the worst invasive species), reptiles grow, mature, and 36 reproduce slowly, which can be one reason why so few reptiles are invasive. However, a slow life history also makes it more difficult to monitor and predict the long-term consequences of an 37 38 introduced alien species, i.e. whether it will establish itself and become invasive or not. From an ecological point of view it is not important whether an invasion takes a few years or 100 years, as 39 40 the long-term consequences on the native flora and fauna would still be deleterious. The potentially invasive T. scripta has been released worldwide, including central and south America (Böhm 41 42 2013), Asia (Mo 2019), and Europe (Standfuss et al. 2016). While the slow life history of the species should theoretically allow a timely reaction by authorities, unfortunately the opposite has 43 44 occurred. Small neobiota populations are often ignored and long-term monitoring programmes are 45 only established many years after the population has grown to a size that makes population control difficult (Sancho & Lacomba 2016). While T. scripta has become invasive in areas with tropical, 46 47 sub-tropical, and Mediterranean climates (Lowe et al. 2000; Foglini & Salvi 2017), the consequences in areas with temperate climates are unclear (Cadi et al. 2004; Prevot et al. 2007; 48 49 Kopecký, Kalous & Patoka 2013; Standfuss et al. 2016).

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In 2014, the European Union published Regulation (EU) No 1143/2014, declaring an action

plan to prohibit the import, breeding and release of invasive species (European Parliament 2014), 51 52 including T. scripta (European Commission 2016). A regulation is a legal act of the European Union that becomes immediately enforceable as law in all member states. Thus, this regulation 53 54 forces all member states to take actions to avoid the spread of the declared invasive species. As 55 environmental conditions differ between members states, the individual states are allowed to respond differently. In Germany, the proposed actions against T. scripta are to increase public 56 57 awareness, allowing non-commercial transfer of individuals that are already kept in captivity (to avoid these individuals being released into the wild), while the removal of individuals from wild 58 59 habitats is not considered to be feasible as it is thought to be both ineffective and very costly (StA "Arten- und Biotopschutz" 2018a). Instead, the approach taken in Germany has been to assume 60 that populations of this species are not stable (StA "Arten- und Biotopschutz" 2018a) since cold 61 62 winter weather would result in high mortality of any released T. scripta (Geiger & Waitzmann 1996) and that successful reproduction would only be sporadic (Pieh & Laufer 2006) 63

The overall aim was to establish one of the first long-term monitoring programmes in Germany to investigate the population dynamics of *T. scripta* in an oxbow lake, the Altrhein of Kehl (Pieh & Laufer 2006; Laufer 2007). This was undertaken to determine 1) If there is evidence of population decrease or increase, 2) Whether there is evidence of successful reproduction of this population, and 3) Whether there is evidence that additional individuals are released into the wild.

69

MATERIALS AND METHODS

70 Study area and study period

The study was conducted in the city of Kehl in Baden-Württemberg, Germany. Kehl is in the Upper Rhine Valley close to the French city of Strasbourg. Data were collected from the Altrhein of Kehl (48° 34'1.95"N, 7° 48'35.41"E), which is an oxbow lake formed over 100 years ago from the River Rhine. It is 690m long and between 25 and 80m wide. The climate in Kehl is temperate, but the Upper Rhine Valley is one of the warmest areas of Germany. During the study period, the minimum temperature in winter was around -12°C (2016), and daily maximum temperatures in summer reached 40°C in 2019. Periods of permanent frost in winter were relatively short with 1 -2 weeks in the years 2016 - 2019, and no such period in 2020.

79 The study was implemented from May to July in the years 2016 to 2019 as part of a course that I gave at the Hector Kinderakademie Kehl, which provides additional education to highly 80 81 gifted school children. In this course, I taught school children 8 - 9 years old about ecology and nature conservation. Due to the COVID-19 crisis, this course was cancelled in 2020. In this year, I 82 83 used the opportunity to collect data on two sunny days in March (at this stage it was unsure whether 84 later data collection would be possible) as well as during six afternoons in May and June. There was no indication that the March data differed from the later data (peak counts of individuals and 85 species were recorded in May and June, the normal period of monitoring), and excluding these data 86 would not have changed the results. 87

88 Monitoring

In the years 2016-2018, the population of exotic pond turtles was monitored on six afternoons, but on seven in 2019, and eight in 2020. At five locations along the eastern shore of the lake, that were previously determined to have a high abundance of pond turtles, observations were made using binoculars. In addition, any pond turtle observed between these locations was recorded. For every individual, the carapace length was estimated to be in one of the following categories: 5cm, 10cm, 20cm or 30cm.

In 2016, only the number and size of observed pond turtles was noted. In this year it became
evident that besides *T. scripta* several other species were present. In the following years, I took
photographs of each of the individuals I observed from distances up to 30 m. From 2017 to 2019,

98 photographs were taken with a Panasonic HC-V380EG-K camcorder with 50x optical zoom, and 99 in 2020 with a Nikon Coolpix P1000 Digital camera with 125x optical zoom. Using characteristics 100 of the carapace and especially the head, the genus, species and if possible sub-species of the 101 photographed individuals was determined using a guide to the introduced turtles of Alsace (Pellerin 102 2014). If the individual was in a position where it could not be identified it was scored as 'unknown 103 genus'.

104 Measurement of hatchlings

I was contacted by kindergarten teachers near the lake when they found hatchlings of *T. scripta*.
These were measured and then sent to an animal shelter in Munich (Germany) that specialises in
reptiles (<u>https://www.reptilienauffangstation.de/</u>). I was also informed about sightings of large
females that were believed to have left the lake to lay eggs.

109 Data analysis

Data have been expressed as peak counts, the maximum number of live individuals observed in one survey afternoon of a particular year. Where the peak count of all turtle species is given then this is the sum of peak counts of several species but potentially from observations made on different afternoons; similarly for the peak counts of individuals in different carapace size categories. Data were analysed using Spearman's rank correlation and Fisher's exact test in GraphPad Instat 3.05.

115

RESULTS

116 Turtle numbers

The annual total peak counts for all species increased continuously from 33 individuals in 2016 to 166 individuals in 2020 (Fig. 1), which resulted in a statistically significant correlation between year and peak count (Spearman rank correlation, $r_s=1.00$, df=3, p=0.02). These findings were contrary to the expectation that the population should decline each year due to cold weather

121	mortality. The expected ratio for a decline each year would be 4:0, when this is compared with the
122	observed ratio of 0:4 the difference is statistically significantly (Fisher's exact test, p=0.03)

123	Over the years, increasing numbers of very small pond turtles with a carapace of not more
124	than 5cm were observed which was close to statistical significance (Spearman rank correlation,
125	r _s =0.90, df=3, p=0.08, Fig. 2). All photographed pond turtles in this category were <i>T. scripta</i> .
126	Additionally, the number of large pond turtles with a carapace of more than 20cm increased over
127	the years (Spearman rank correlation, r_s =0.90, df=3, p=0.08, Fig. 2). All pond turtles with a
128	carapace of 30cm belonged to one of the three following species: T.scripta, Pseudemys concinna,
129	or Pseudemys nelsoni.
130	Altogether six different species were observed, with three subspecies of T. scripta (Table
131	1). Over the years the number of observed individuals of <i>T. scripta</i> seemed to increase (Fig. 3).
132	The two species of Pseudemys and Graptemys pseudogeographica occurred in all years. A few
133	individuals of Chrysemys picta and Mauremys sinensis were observed in all years except 2018
134	(Fig. 3).

135	Table 1. Annual peak counts for the turtle species observed in the Althrein of Kehl. Cloudy weather
136	in 2018 made it difficult to determine the subspecies / species of both Trachemys and Pseudemys.
137	Individuals for which the taxon could not be determined have been excluded.

Genus, species, or	Peak counts				
sub-species	2017	2018	2019	2020	
Trachemys scripta					
undetermined sub-	1	7	5	14	
species					
Trachemys s. elegans	8	5	11	24	
Trachemys s. scripta	4	1	6	4	
Trachemys s. troosti	1	0	5	1	
Pseudemys sp	3	12	2	1	
Pseudemys nelsoni	3	1	1	7	
Pseudemys concinna	10	3	7	26	
Graptemys	6	2	1	7	
pseudepgeographica	0	5	4	/	
Mauremys sinensis	1	0	1	2	
Chrysemys picta	1	0	1	1	







Estimated carapace diameter (cm)

Figure 2. Annual peak counts for all turtle species observed in the Althrein of Kehl by carapace
size category from 2016 to 2020

146



Figure 3. Annual peak counts of turtle species observed in the Althrein of Kehl from 2017 to 2020

150 Breeding of Trachemys scripta

Altogether, 12 *T. scripta* hatchlings were found on land walking from a park towards the lake, more than 100 m away from the water. Eight were found in the period 12th to 22nd May 2019, one the 153 15th of July 2019, one the 19th of May 2020, one the 17th of June 2020 and one the 30th June 2020. Two of these were found dead on a bicycle path between the kindergarten and the lake, one died in the aqua-terrarium of the kindergarten. These dead individuals were disposed of by the kindergarten and not measured. The remaining nine individuals were kept and I was able to measure them, confirming that these were all hatchlings of *T. scripta* (Fig. 4, Table 2).

158	Table 2. Measurements of nine hatchling T. scripta found at the Altrhein of Kehl (six from 2019
159	and three from in 2020) and of hatchlings from the USA* for comparison

Trait (mm or g)	Mean	Standard deviation	Maximum	Minimum	Data from the USA (mean ± SD)*
Carapace length	30.6	1.3	32.0	28.0	31.2 <u>+</u> 1.4
Carapace width	30.4	1.3	32.0	29.0	-
Carapace height	15.8	1.5	19.0	13.5	-
Plastron length	28.7	2.0	31.0	26.0	-
Plastron width	22.3	2.1	27.0	19.5	-
Body mass (g)	6.5	0.7	7.8	5.3	6.9 ± 0.8

160 *Data from Illinois, USA (Tucker 2000)

161 On 6th June 2019 a female *T. scripta* was caught at the kindergarten, with a body mass of 162 3064g and a carapace length of 29cm. A female *T. scripta elegans* was seen laying eggs in the park 163 behind the kindergarten on 15th June 2020. The clutch was excavated on 16th of June, the top of 164 which was 15cm below ground. There were a total of 24 eggs with a length of 32.8 ± 1.2 mm and 165 a width of 23.9 ± 0.7 mm. The total clutch weighed 218g which represented 9.1g per egg. 166



Figure 4. Three different *T. scripta elegans* hatchlings found at the Altrhein of Kehl in May 2019.
The scale on the left photo is in cm.

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DISCUSSION

171 In the current study I have shown that the population of exotic pond turtles in an oxbow lake, the 172 Altrhein of Kehl, comprises six exotic species with the invasive T. scripta being the most 173 abundant. Contrary to predictions that in the cold climate of Germany populations would decline 174 (Nehring, 2016; StA, "Arten- und Biotopschutz" 2018a; Geiger & Waitzmann 1996), population 175 size seemed to have increased steadily over the five study years. This could be partly due to the 176 release of more individuals into the wild as evidenced by 1) A high proportion of the observed 177 individuals being from genera other than *Trachemys*, indicating that species that are still available 178 in pet shops are regularly released into the wild, and/or 2) The constant increase of the size 179 category of carapace diameter 20cm and 30cm (Fig. 2), indicating that old individuals have been 180 released, that might have been bought a long time ago and have become too big and as a 181 consequence released by pet owners. Furthermore, the regular observation of hatchlings indicates 182 that it cannot be assumed that the cold climate of Germany will prevent exotic pond turtles from breeding. 183

I had expected to observe mainly individuals from the three different subspecies of *T*. *scripta* in the lake and, based on previous reports, maybe some individuals of *Graptemys pseudogeographica* (Pieh & Laufer 2006; Laufer 2007). Instead it was a surprise to find a high exotic biodiversity with four commonly observed species (*T. scripta*, *P nelsoni*, *P. concinna*, and *G. pseudogeographica*) and few individuals of the two species *Mauremys sinensis* and *Chrysemys* *picta* (Table 1). This high diversity is most likely a consequence of the trade ban on *T. scripta*,
leading to a trade in other species (Maceda-Veiga *et al.* 2019), which in turn have been released
into the wild. Overall, the combined peak counts of all pond turtles increased consistently over the
years (Fig. 1) which was due to an increased number of both small and large individuals (Fig. 2),
especially of *T. scripta* (Fig. 3).

In southern France, clutch size of T. scripta varied between four and 11 eggs (Cadi et al. 194 195 2004), while here I found one clutch consisting of 24 eggs. I also observed one very large female 196 of 3 kg that probably laid a clutch. Egg laying by itself is not evidence of successful reproduction 197 since females will lay eggs whether or not they are fertilised and it is unknown whether fertilised 198 eggs would develop successfully under the prevailing climatic conditions. In the current study, 199 very small T. scripta were observed in four out of five years, making it likely that reproduction 200 occurred repeatedly. The capture of hatchlings in both 2019 and 2020 showed that successful 201 reproduction had occurred, especially as they were found in a park hundreds of meters away from the lake (any releases would have been into the lake). This is the second case of proven 202 203 reproduction in Kehl with the first case having been in 2004 (Pieh & Laufer 2006). The absence of 204 a report of reproduction in Kehl for the years 2005 to 2016 can be explained by a lack of monitoring 205 during these years. In 2019, the seven hatchlings found in Kehl within 10 days in May plus the 206 single hatchling found in July indicates that these might be from two or three different clutches. 207 The hatchlings must likely originate from clutches laid in summer 2018, and probably overwintered 208 in a nest burrow as suggested by Pieh & Laufer (2006). Reproduction might have been possible 209 due to the recently mild winters, as it is known that eggs easily survive temperatures as low as -210 4°C in the soil (Tucker & Packard 1998), which would represent much colder air temperatures. For 211 example, in the winter 2019 / 2020, frost was uncommon in Kehl. In its northern range, mean summer temperatures are around 23°C (June to August, embryonic period) and winter temperatures 212

6-8°C (September to April, posthatching dormancy) (Willette, Tucker & Janzen 2005). While mean
summer temperatures in Kehl are clearly colder (18.7°C), winters are within the reported range
(7.9°C) (data from the closest weather station at Entzheim, France). As such, the climate in Kehl
does not preclude successful reproduction.

217 The size and mass of both hatchlings and eggs was similar to those reported from their 218 natural habitat (Tucker 2000) as well as other populations in Europe (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008). The mean egg mass reported here was 9.1 g compared to 10.5 g 219 in Illinois and 9.4 g in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008), while 220 hatchling mass in the current study was 6.5 ± 0.7 g compared to 6.8 ± 0.8 g in Illinois (Tucker 221 222 2000) and 6.7 + 1.0 g in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008). As such, data from both eggs and hatchlings do not indicate constraints on reproduction of T. scripta in 223 224 Kehl, Germany.

Reproduction of released *T. scripta* has been reported in southern Europe (Cadi *et al.* 2004;
Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008; Sperone *et al.* 2010; Sancho & Lacomba
2016; Foglini & Salvi 2017), but also in a part of Croatia with a continental climate (Koren *et al.*2018), as well as in central Europe in Slovenia (Standfuss *et al.* 2016). The regular reproduction of *T. scripta* reported here for Germany adds to previous records of successful reproduction in other
temperate climates.

Even though successful reproduction of *T. scripta* in Europe has been observed, it has been argued that this will not make the species invasive, as sex determination in this species is temperature dependent (Geiger & Waitzmann 1996). The sex ratio of clutches is influenced by soil temperature, and at low temperatures all hatchlings are male while both sexes can be produced from incubation temperatures between 28.3 and 30.6°C (Cadi *et al.* 2004). Female hatchlings have been observed both in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008) and in

237 southern France (Cadi et al. 2004). So far, no soil temperature data are available for Kehl, but air 238 temperatures above 33°C during the day and above 20°C at night are common in summer and often occur for periods of two weeks or more. The hatchlings captured in the current study were too 239 small to be sexed. Climate warming will make it more likely that females will hatch in the future. 240 241 To make management decisions for the long-lived, slow reproducing T. scripta, it is 242 essential to estimate how their populations will develop for several decades. Most T. scripta sold 243 in pet shops are female, as breeders in the USA used high temperatures for faster hatching, and higher temperatures induce a female biased sex-ratio (Prevot et al. 2007). The combination of a 244 245 potential female biased sex ratio of released sliders (Prevot et al. 2007) and a male biased sex ratio 246 of hatchlings could cause an increased population growth in the medium-term (5-20 years), as more females will lay fertilized eggs. An overall increase in the number of hatchlings together with rising 247 248 temperatures due to global warming makes it more likely that female hatchlings will occur in the 249 coming decades. Heat waves, such as the one experienced in Kehl in 2019 when temperatures reached 40°C, will increase the number of female hatchlings (Breitenbach et al. 2020). This 250 251 scenario makes it likely that the *T. scripta* population in Kehl is now fully entrenched and that other 252 populations will become established in other areas of the Upper Rhine Valley.

253 Pseudemys nelsoni, P. concinna, G. pseudogeographica and M. sinensis have a low risk of 254 becoming invasive in Europe (Kopecký, Kalous & Patoka 2013; Masin 2014). In contrast, T. 255 scripta is generally regarded as being invasive, as in many countries it can survive, breed, and colonise additional habitats with negative impact on the native biodiversity (Lowe et al. 2000). 256 However, detailed studies on its effect on the native fauna and flora are rare. In France, young T. 257 scripta are omnivores, eating invertebrates, amphibians and fish, while older individuals have a 258 259 more herbivorous diet (Prevot et al. 2007). They have been observed to disturb the nests of water birds when searching for basking spots (Laufer 2007). They might have a negative impact on the 260

endangered native European pond turtles (*Emys orbicularis*) by trying to mate with them (Jablonski
et al. 2017) and by competing for basking spots (Cadi & Joly 2003). In Kehl, the oxbow lake is not
known as an important site for native biodiversity, but there are ecologically important areas close
by (less than 1km), especially the Rhine floodplains. Increasing population size in the lake
increases the risk that these habitats would be colonized. Further, *T. scripta* have also been
observed next to the Kehler nature reserve Sundheimer Grund (less than 3kms from the Altrhein),
an ecologically important and vulnerable habitat (Schradin, personal observation).

268 Implications for German and European legislation

269 The regulation (EU) No 1143/2014 demands that all member states should take action against 270 invasive species (European Parliament 2014) including T. scripta (European Commission 2016). 271 After the trading ban in 2006 it was expected that the release of T. scripta into the wild would 272 decline in Germany. But the current study, undertaken 14 years later, does not support this 273 assumption. In Germany, it has been believed that the only action needed was to advise the public not to release exotic pond turtles into the wild since it was too cold for the released individuals to 274 275 survive for long periods or to reproduce (Geiger & Waitzmann 1996; Pieh & Laufer 2006; Laufer 276 2007; Nehring 2016). Thus, populations in Germany are officially believed to be unstable (Nehring 277 2016; StA "Arten- und Biotopschutz" 2018b), which has influenced the national action plan (StA "Arten- und Biotopschutz" 2018a). In light of the facts uncovered by the current study that 278 279 population size is not decreasing, there is no indication of high mortality and successful 280 reproduction occurs more regularly than previously believed, the management plan in Germany 281 should be reconsidered.

The results presented here add to several other studies indicating that *T. scripta* has the potential to become invasive in western, middle and central Europe (Mačát & Jablonski 2016;

284 Standfuss et al. 2016; Koren et al. 2018). Thus, action plans to avoid an invasion might not only 285 have to be changed for Germany, but for many other European countries. For France, removal of sliders from wetlands has been suggested (Cadi et al. 2004), and this has been done in Spain 286 (Sancho & Lacomba 2016). While the invasion is slower in colder regions, the fact that the exotic 287 288 populations there do not decline but reproduce and increase should be of concern. Additional 289 actions are required; good examples have been suggested by (Teillac-Deschamps et al. 2009). An 290 obvious need is public education with a focus on pet owners such as a social media campaign 291 targeting Facebook groups of owners of exotic pond turtles. Education is also needed for law 292 enforcement (police, order enforcement offices, wardens), whose focus is often the poor pet owner 293 who has 'lost' a pond turtle instead of the criminal that released it. Police statements to the local news outlets could then emphasize the unlawfulness of the release of exotic animals. Local order 294 295 enforcement officers could check owners of exotic pond turtles to ensure no breeding takes place 296 and animals kept in the garden cannot escape. An active search for advertisements posted by people selling hatchlings of exotic pond turtles followed by legal action would be useful. Alternatives to 297 298 release should be made available which means that more financial state support is needed for 299 animal shelters to create more space for unwanted pond turtles.

300 Other important actions would be 1) Destruction of clutches; 2) Removal of large females 301 from the population when they are found on land before / after laying clutches, and 3) Active 302 removal of released exotic pond turtles, especially from ecologically valuable waters. For this, local resources would be needed, especially staff being able to perform and coordinate these actions. 303 304 Collaboration between nature conservation officers of the local communities with nature 305 conservation groups, hunters, and local fishery association are needed for this. Last but not least, 306 the increased release of other exotic pond turtle species leads to the question which of these species should also be banned from trade, and how the trade is regulated to ensure that individuals will not 307

be released. Individual marking (transponders) and registration of exotic pond turtles to allowprevious owner to be identified may be an effective option.

310 Going forward

The population of exotic pond turtles at the Althrein of Kehl has not decreased since the ban of the 311 312 trade of T. scripta in the European Union. On the contrary, the diversity of species being released has increased. In addition, the population size of T. scripta is increasing, and there is no indication 313 314 of high mortality due to cold winters. In contrast, there seems to be regular successful reproduction 315 in summer. This might lead to a more balanced sex ratio in the future and as such a further increase 316 in reproduction and population size. It is now important to measure soil temperatures, to determine 317 the sex ratio of hatchlings, and to combine this with climate predictions for the next 30 years. 318 Furthermore, ecologically important wetlands close to waters into which pond sliders have been 319 released must be monitored and actions must be taken to remove pond sliders from these areas 320 before they can establish themselves there. The further growth of existing neobiotic pond slider 321 populations must be stopped. The current action plan in Germany for T. scripta will have to change 322 if an invasion is to be avoided. Other west and central European countries might have to apply 323 similar action plans.

324

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334	REFERENCES
335 336	Böhm, S. (2013). Records of invasive <i>Trachemys scripta elegans</i> (WiEd-NEuWiEd, 1839), in cenotes of the Yucatán Peninsula, Mexico. <i>Herpetozoa</i> 26: 98-100.
337 338 339 340	Breitenbach, A.T., Carter, A.W., Paitz, R.T. & Bowden, R.M. (2020). Using naturalistic incubation temperatures to demonstrate how variation in the timing and continuity of heat wave exposure influences phenotype. <i>Proceedings of the Royal Society B: Biological Sciences</i> 287: 20200992.
341 342 343	Cadi, A., Delmas, V., Prevot-Julliard, A.C., Joly, P., Pieau, C. & Girondot, M. (2004). Successful reproduction of the introduced slider turtle (<i>Trachemys scripta elegans</i>) in the South of France. <i>Aquatic Conservation-Marine and Freshwater Ecosystems</i> 14: 237-246.
344 345 346 347	 Cadi, A. & Joly, P. (2003). Competition for basking places between the endangered European pond turtle (<i>Emys orbicularis galloitalica</i>) and the introduced red-eared slider (<i>Trachemys scripta elegans</i>). <i>Canadian Journal of Zoology-Revue Canadienne de Zoologie</i> 81: 1392-1398.
348 349 350 351	 European Commission (2016). Implementing Regulation (EU) 2016/1141 of 13 July 2016 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. Official Journal of the European Union L 189/4.
352 353 354	European Parliament (2014). Regulation (EU) No 1143/2014 On the prevention and management of the introduction and spread of invasive alien species. European Parliament, Council of the European Union. <i>Official Journal of the European Union</i> L 317/35.
355 356 357	Foglini, C. & Salvi, R. (2017). Non-native turtles in a peri-urban park in northern Milan (Lombardy, Italy): species diversity and population structure. <i>Acta Herpetologica</i> 12: 151- 156
358 359	Geiger, A. & Waitzmann, M. (1996). Überlebensfähigkeit allochthoner Amphibien und Reptilien in Deutschland – Konsequenzen für den Artenschutz. In <i>Gebietsfremde Tierarten</i> .

- 360 Auswirkungen auf einheimische Arten, Lebensgemeinschaften und Biotope. Situationsanalyse,
 361 Gebhardt, H., Kinzelbach, R. & Schmidt-Fischer S. (Eds). ECO Med Verlag.
- Jablonski, D., Mrocek, J., Grula, D. & Christophoryová, J. (2017). Attempting courtship between
 Emys orbicularis and *Trachemys scripta* (Testudines: Emydidae). *Herpetology Notes:* 10:
 123-126.
- Kopecký, O., Kalous, L. & Patoka, J. (2013). Establishment risk from pet-trade freshwater turtles
 in the European Union. *Knowledge and Management of Aquatic Ecosystems* 410: 02p0102p11.
- Koren, T., Stih, A., Buric, I., Koller, K., Laus, B. & Zadravec, M. (2018). The current distribution
 of pond slider *Trachemys scripta* (Reptilia: Emydidae) in Croatia. *Natura Slovenia* 20: 33-34.
- 370 Laufer, H. (2007). Buchstaben-Schmuckschildkröte Trachemys scripta (Schoepff). Die
- *Amphibien und Reptilien Baden-Württembergs*, Laufer, H., Fritz, K. & Sowig, P. (Eds), pp.
 525-536. Ulmer-Verlag, Stuttgart.
- Lowe, S., Browne, M., Boudjelas, S. & De Poorter, M. (2000). 100 of the World's Worst Invasive
 Alien Species. A selection from the Global Invasive Species Database. pp 12.
- http://www.issg.org/pdf/publications/worst 100/english 100 worst.pdf (accessed Oct 2020)
- 376 Mačát, Z. & Jablonski, D. (2016). Good invasion ability is not enough: Predation on the pond
- 377 slider (*Trachemys scripta*) by the wels catfish (*Silurus glanis*) in the Czech Republic.
- 378 *Herpetological Bulletin* 135: 38-39.
- 379 Maceda-Veiga, A., Escribano-Alacid, J., Martínez-Silvestre, A., Verdaguer, I. & Mac Nally, R.
- 380 (2019). What's next? The release of exotic pets continues virtually unabated 7 years after
- enforcement of new legislation for managing invasive species. *Biological Invasions* 21: 29332947.
- Masin, S. (2014). Risk of invasion by frequently traded freshwater turtles. *Biological Invasions*16: 217-231.
- Mo, M. (2019). Possible Records of Yellow-bellied Sliders (*Trachemys scripta scripta*) or River
 Cooters (*Pseudemys concinna*) in Hong Kong. *IRCF Reptiles and Amphibians* 26: 51-53.

- 387 Nehring, S. (2016). Die invasiven gebietsfremden Arten der ersten Unionsliste der EU-
- 388 *Verordnung Nr. 1143/2014.* Bundesamt für Naturschutz, Bonn.
- 389 Pellerin, E. (2014). Les tortues introduites. *Bufo contacts* 15.
- 390 Perez-Santigosa, N., Díaz-Paniagua, C. & Hidalgo-Vila, J. (2008). The reproductive ecology of
- 391 exotic *Trachemys scripta elegans* in an invaded area of southern Europe. *Aquatic*
- 392 *Conservation: Marine and Freshwater Ecosystems* 18: 1302-1310.
- 393 Pieh & Laufer (2006). Die Rotwangen-Schmuckschildkröte (*Trachemys scripta elegans*) in
 394 Baden-Württemberg mit Hinweis auf eine Reproduktion im Freiland. Zeitschrift für
 395 *Feldherpetologie* 13: 225-234.
- 396 Prevot, A.-C., Gousset, E., Archinard, C., Cadi, A. & Girondot, M. (2007). Pets and invasion
- risks: Is the slider turtle strictly carnivorous? *Amphibia-Reptilia* 28: 139-143.
- Sancho, V. & Lacomba, I. (2016). Expansion of *Trachemys scripta* in the Valencian Community
 (Eastern Spain). *International Symposium on Freshwater Turtle Conservation*, 41-49.
- 400 Schradin, C. & Hayes, L.D. (2017). A synopsis of long-term field studies of mammals:
- 401 achievements, future directions, and some advice. *Journal of Mammalogy* 98: 670-677.
- 402 Sperone, E., Crescente, A., Brunelli, E., Paolillo, G. & Tripepi, S. (2010). Sightings and
- 403 successful reproduction of allochthonous reptiles in Calabria. *Acta Herpetologica* 5: 265-273.
- 404 StA "Arten- und Biotopschutz" (2018a). Buchstaben-Schmuckschildkröte Management- und
 405 Maßnahmenblatt zu VO (EU) Nr. 1143/2014. *LANa*.
- 406 StA "Arten- und Biotopschutz" (2018b). Länderspezifische Anlage zur Verbreitung–
- 407 Management- und Maßnahmenblatt zu VO (EU) Nr. 1143/2014. *LANa*.
- 408 Standfuss, B., Lipovšek, G., Fritz, U. & Vamberger, M. (2016). Threat or fiction: is the pond
- slider (*Trachemys scripta*) really invasive in Central Europe? A case study from Slovenia. *Conservation Genetics* 17: 557-563.
- 411 Teillac-Deschamps, P., Lorrilliere, R., Servais, V., Delmas, V., Cadi, A. & Prevot, A.-C. (2009).
- 412 Management strategies in urban green spaces: Models based on an introduced exotic pet
- 413 turtle. *Biological Conservation* 142: 2258-2269.

- 414 Tucker, J.K. (2000). Annual variation in hatchling size in the red-eared slider turtle (*Trachemys*415 *scripta elegans*). *Herpetologica* 56: 8-13.
- 416 Tucker, J.K. & Packard, G.C. (1998). Overwinter survival by hatchling sliders (*Trachemys*417 *scripta*) in West-Central Illinois. *Journal of Herpetology* 32: 431-434.
- 418 Willette, D.A.S., Tucker, J.K. & Janzen, F.J. (2005. Linking climate and physiology at the
- 419 population level for a key life-history stage of turtles. *Canadian Journal of Zoology* 83: 845420 850.
- Wilson, J., Dormontt, E., Prentis, P., Lowe, A. & Richardson, D. (2009). Something in the way
 you move: dispersal pathways affect invasion success. *Trends in Ecology & Evolution* 24:
 136-144.
- 424