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

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1           **Successful reproduction of *Trachemys scripta* in the Altrhein of Kehl**  
2           **(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 *T. scripta* 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

27 establish themselves outside their natural distribution range due to human action, i.e. they  
28 reproduce successfully in the areas in which they have been released and they maintain their  
29 population (Geiger & Waitzmann 1996; Wilson *et al.* 2009). They are regarded as being invasive  
30 if they have the capacity to spread into new areas and at the same time cause harm to the native  
31 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  
37 history also makes it more difficult to monitor and predict the long-term consequences of an  
38 introduced alien species, i.e. whether it will establish itself and become invasive or not. From an  
39 ecological point of view it is not important whether an invasion takes a few years or 100 years, as  
40 the long-term consequences on the native flora and fauna would still be deleterious. The potentially  
41 invasive *T. scripta* has been released worldwide, including central and south America (Böhm  
42 2013), Asia (Mo 2019), and Europe (Standfuss *et al.* 2016). While the slow life history of the  
43 species should theoretically allow a timely reaction by authorities, unfortunately the opposite has  
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  
46 difficult (Sancho & Lacomba 2016). While *T. scripta* has become invasive in areas with tropical,  
47 sub-tropical, and Mediterranean climates (Lowe *et al.* 2000; Foglini & Salvi 2017), the  
48 consequences in areas with temperate climates are unclear (Cadi *et al.* 2004; Prevot *et al.* 2007;  
49 Kopecký, Kalous & Patoka 2013; Standfuss *et al.* 2016).

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

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

64 The overall aim was to establish one of the first long-term monitoring programmes in  
65 Germany to investigate the population dynamics of *T. scripta* in an oxbow lake, the Altrhein of  
66 Kehl (Pieh & Laufer 2006; Laufer 2007). This was undertaken to determine 1) If there is evidence  
67 of population decrease or increase, 2) Whether there is evidence of successful reproduction of this  
68 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

71 The study was conducted in the city of Kehl in Baden-Württemberg, Germany. Kehl is in the Upper  
72 Rhine Valley close to the French city of Strasbourg. Data were collected from the Altrhein of Kehl  
73 (48° 34'1.95"N, 7° 48'35.41"E), which is an oxbow lake formed over 100 years ago from the River  
74 Rhine. It is 690m long and between 25 and 80m wide. The climate in Kehl is temperate, but the

75 Upper Rhine Valley is one of the warmest areas of Germany. During the study period, the minimum  
76 temperature in winter was around -12°C (2016), and daily maximum temperatures in summer  
77 reached 40°C in 2019. Periods of permanent frost in winter were relatively short with 1 -2 weeks  
78 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  
80 that I gave at the Hector Kinderakademie Kehl, which provides additional education to highly  
81 gifted school children. In this course, I taught school children 8 - 9 years old about ecology and  
82 nature conservation. Due to the COVID-19 crisis, this course was cancelled in 2020. In this year, I  
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  
85 was no indication that the March data differed from the later data (peak counts of individuals and  
86 species were recorded in May and June, the normal period of monitoring), and excluding these data  
87 would not have changed the results.

## 88 **Monitoring**

89 In the years 2016-2018, the population of exotic pond turtles was monitored on six afternoons, but  
90 on seven in 2019, and eight in 2020. At five locations along the eastern shore of the lake, that were  
91 previously determined to have a high abundance of pond turtles, observations were made using  
92 binoculars. In addition, any pond turtle observed between these locations was recorded. For every  
93 individual, the carapace length was estimated to be in one of the following categories: 5cm, 10cm,  
94 20cm or 30cm.

95 In 2016, only the number and size of observed pond turtles was noted. In this year it became  
96 evident that besides *T. scripta* several other species were present. In the following years, I took  
97 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**

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

#### 109 **Data analysis**

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

## 115 **RESULTS**

### 116 **Turtle numbers**

117 The annual total peak counts for all species increased continuously from 33 individuals in 2016 to  
118 166 individuals in 2020 (Fig. 1), which resulted in a statistically significant correlation between  
119 year and peak count (Spearman rank correlation,  $r_s=1.00$ ,  $df=3$ ,  $p=0.02$ ). These findings were  
120 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 *T. scripta*.  
 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 *T. scripta* 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).

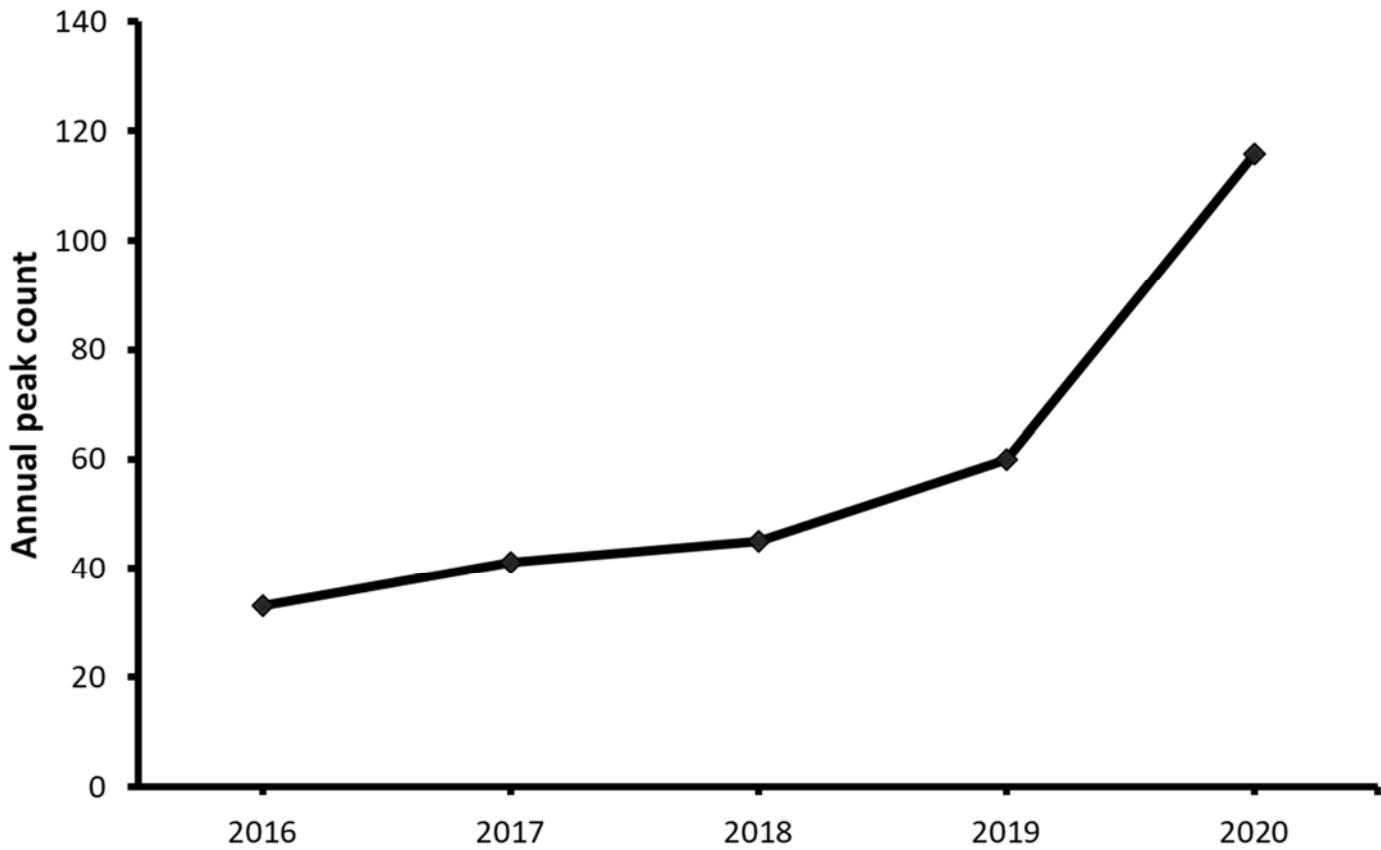
135 **Table 1.** Annual peak counts for the turtle species observed in the Althrein of Kehl. Cloudy weather  
 136 in 2018 made it difficult to determine the subspecies / species of both *Trachemys* and *Pseudemys*.  
 137 Individuals for which the taxon could not be determined have been excluded.

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

<b>TOTAL</b>	<b>38</b>	<b>32</b>	<b>43</b>	<b>87</b>
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138

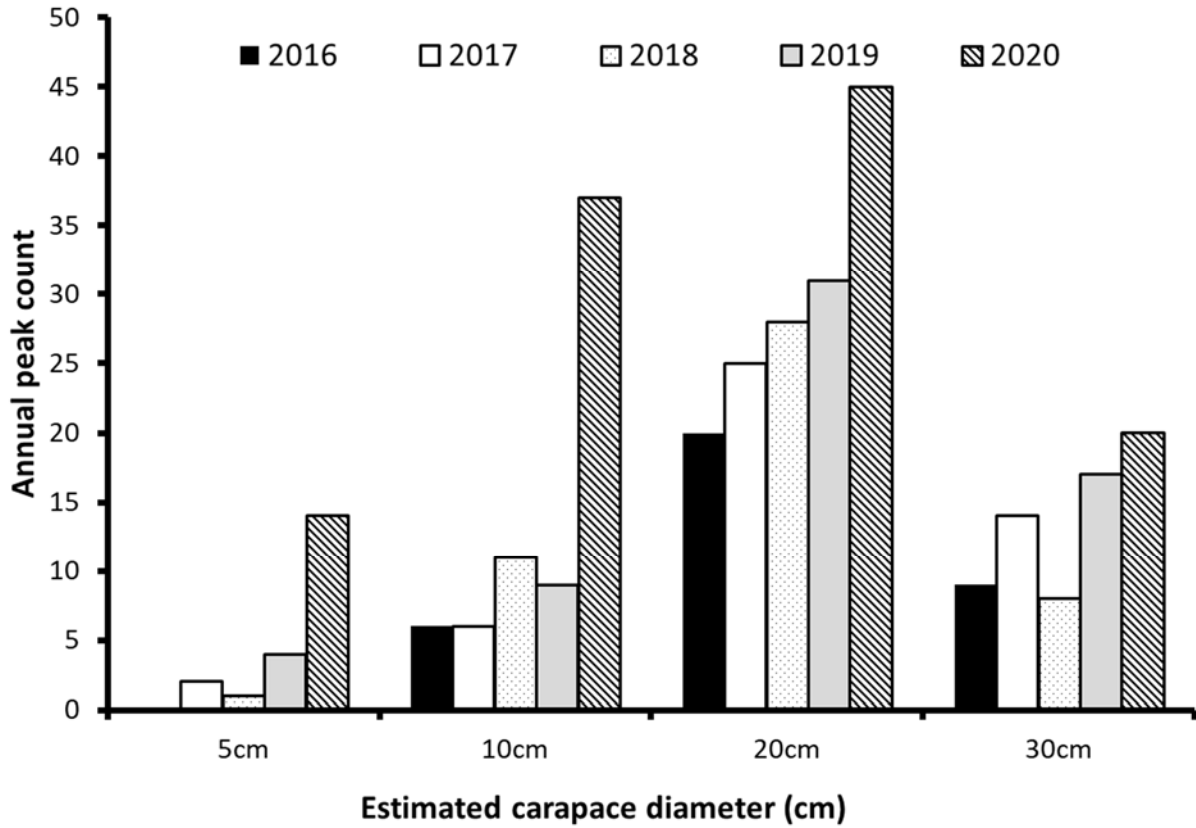
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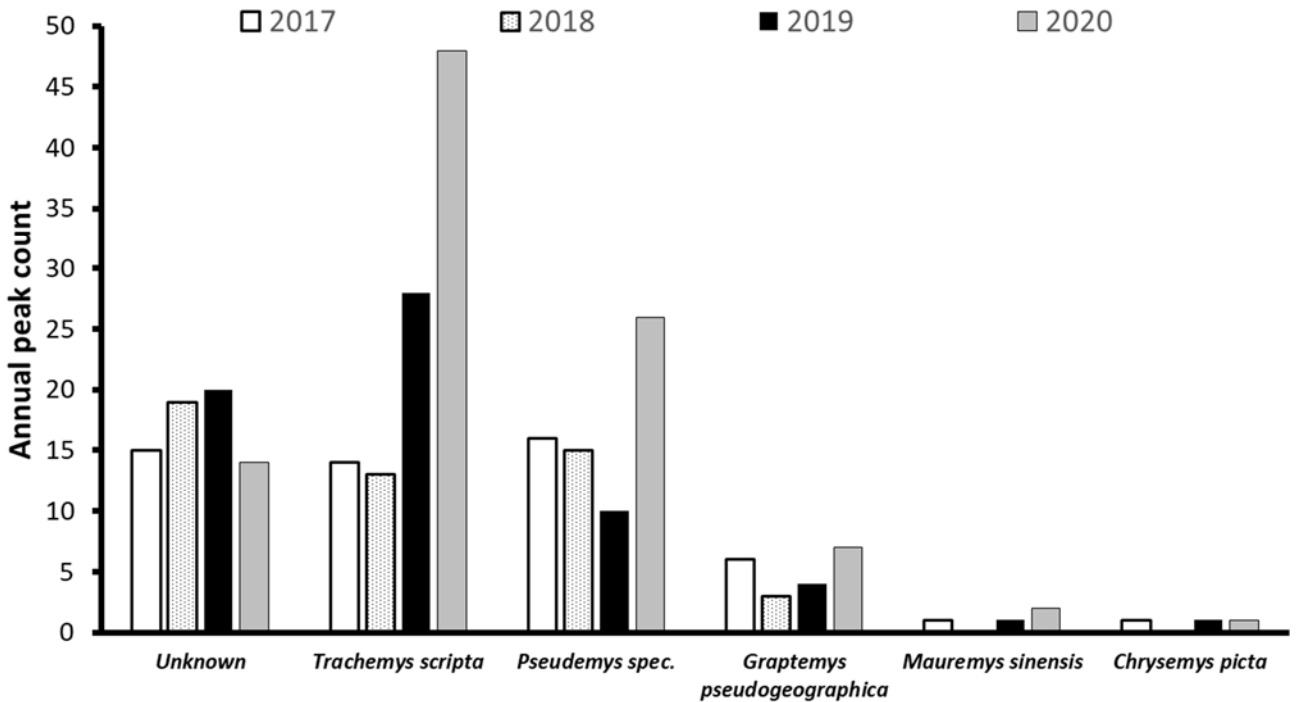
140

141 **Figure 1.** Annual peak count for all turtle species in the Althrein of Kehl combined (including  
 142 individuals for which the taxon could not be identified and which are not shown in Table 1)





143  
 144 **Figure 2.** Annual peak counts for all turtle species observed in the Althrein of Kehl by carapace  
 145 size category from 2016 to 2020  
 146



148 **Figure 3.** Annual peak counts of turtle species observed in the Altrhein of Kehl from 2017 to 2020  
149

### 150 **Breeding of *Trachemys scripta***

151 Altogether, 12 *T. scripta* hatchlings were found on land walking from a park towards the lake, more  
152 than 100 m away from the water. Eight were found in the period 12<sup>th</sup> to 22<sup>nd</sup> May 2019, one the  
153 15<sup>th</sup> of July 2019, one the 19<sup>th</sup> of May 2020, one the 17<sup>th</sup> of June 2020 and one the 30<sup>th</sup> June 2020.  
154 Two of these were found dead on a bicycle path between the kindergarten and the lake, one died  
155 in the aqua-terrarium of the kindergarten. These dead individuals were disposed of by the  
156 kindergarten and not measured. The remaining nine individuals were kept and I was able to  
157 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

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

160 \*Data from Illinois, USA (Tucker 2000)

161 On 6<sup>th</sup> 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 15<sup>th</sup> June 2020. The clutch was excavated on 16<sup>th</sup> of June, the top of  
164 which was 15cm below ground. There were a total of 24 eggs with a length of 32.8  $\pm$  1.2mm and  
165 a width of 23.9  $\pm$  0.7mm. The total clutch weighed 218g which represented 9.1g per egg.

166



167  
168 **Figure 4.** Three different *T. scripta elegans* hatchlings found at the Altrhein of Kehl in May 2019.  
169 The scale on the left photo is in cm.

## 170 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  
183 breeding.

184 I had expected to observe mainly individuals from the three different subspecies of *T.*  
185 *scripta* in the lake and, based on previous reports, maybe some individuals of *Graptemys*  
186 *pseudogeographica* (Pieh & Laufer 2006; Laufer 2007). Instead it was a surprise to find a high  
187 exotic biodiversity with four commonly observed species (*T. scripta*, *P. nelsoni*, *P. concinna*, and  
188 *G. pseudogeographica*) and few individuals of the two species *Mauremys sinensis* and *Chrysemys*

189 *picta* (Table 1). This high diversity is most likely a consequence of the trade ban on *T. scripta*,  
190 leading to a trade in other species (Maceda-Veiga *et al.* 2019), which in turn have been released  
191 into the wild. Overall, the combined peak counts of all pond turtles increased consistently over the  
192 years (Fig. 1) which was due to an increased number of both small and large individuals (Fig. 2),  
193 especially of *T. scripta* (Fig. 3).

194 In southern France, clutch size of *T. scripta* varied between four and 11 eggs (Cadi *et al.*  
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  
202 the lake (any releases would have been into the lake). This is the second case of proven  
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  
212 summer temperatures are around 23°C (June to August, embryonic period) and winter temperatures

213 6-8°C (September to April, posthatching dormancy) (Willette, Tucker & Janzen 2005). While mean  
214 summer temperatures in Kehl are clearly colder (18.7°C), winters are within the reported range  
215 (7.9°C) (data from the closest weather station at Entzheim, France). As such, the climate in Kehl  
216 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-  
219 Paniagua & Hidalgo-Vila 2008). The mean egg mass reported here was 9.1 g compared to 10.5 g  
220 in Illinois and 9.4 g in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008), while  
221 hatchling mass in the current study was  $6.5 \pm 0.7$  g compared to  $6.8 \pm 0.8$  g in Illinois (Tucker  
222 2000) and  $6.7 \pm 1.0$  g in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008). As such,  
223 data from both eggs and hatchlings do not indicate constraints on reproduction of *T. scripta* in  
224 Kehl, Germany.

225         Reproduction of released *T. scripta* has been reported in southern Europe (Cadi *et al.* 2004;  
226 Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila 2008; Sperone *et al.* 2010; Sancho & Lacomba  
227 2016; Foglini & Salvi 2017), but also in a part of Croatia with a continental climate (Koren *et al.*  
228 2018), as well as in central Europe in Slovenia (Standfuss *et al.* 2016). The regular reproduction of  
229 *T. scripta* reported here for Germany adds to previous records of successful reproduction in other  
230 temperate climates.

231         Even though successful reproduction of *T. scripta* in Europe has been observed, it has been  
232 argued that this will not make the species invasive, as sex determination in this species is  
233 temperature dependent (Geiger & Waitzmann 1996). The sex ratio of clutches is influenced by soil  
234 temperature, and at low temperatures all hatchlings are male while both sexes can be produced  
235 from incubation temperatures between 28.3 and 30.6°C (Cadi *et al.* 2004). Female hatchlings have  
236 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  
239 occur for periods of two weeks or more. The hatchlings captured in the current study were too  
240 small to be sexed. Climate warming will make it more likely that females will hatch in the future.

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  
244 higher temperatures induce a female biased sex-ratio (Prevot *et al.* 2007). The combination of a  
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  
247 females will lay fertilized eggs. An overall increase in the number of hatchlings together with rising  
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  
250 reached 40°C, will increase the number of female hatchlings (Breitenbach *et al.* 2020). This  
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  
256 colonise additional habitats with negative impact on the native biodiversity (Lowe *et al.* 2000).  
257 However, detailed studies on its effect on the native fauna and flora are rare. In France, young *T.*  
258 *scripta* are omnivores, eating invertebrates, amphibians and fish, while older individuals have a  
259 more herbivorous diet (Prevot *et al.* 2007). They have been observed to disturb the nests of water  
260 birds when searching for basking spots (Laufer 2007). They might have a negative impact on the

261 endangered native European pond turtles (*Emys orbicularis*) by trying to mate with them (Jablonski  
262 et al. 2017) and by competing for basking spots (Cadi & Joly 2003). In Kehl, the oxbow lake is not  
263 known as an important site for native biodiversity, but there are ecologically important areas close  
264 by (less than 1km), especially the Rhine floodplains. Increasing population size in the lake  
265 increases the risk that these habitats would be colonized. Further, *T. scripta* have also been  
266 observed next to the Kehler nature reserve Sundheimer Grund (less than 3kms from the Altrhein),  
267 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  
274 not to release exotic pond turtles into the wild since it was too cold for the released individuals to  
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  
278 „Arten- und Biotopschutz“ 2018a). In light of the facts uncovered by the current study that  
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.

282         The results presented here add to several other studies indicating that *T. scripta* has the  
283 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  
286 sliders from wetlands has been suggested (Cadi *et al.* 2004), and this has been done in Spain  
287 (Sancho & Lacomba 2016). While the invasion is slower in colder regions, the fact that the exotic  
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  
294 news outlets could then emphasize the unlawfulness of the release of exotic animals. Local order  
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  
297 selling hatchlings of exotic pond turtles followed by legal action would be useful. Alternatives to  
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  
303 resources would be needed, especially staff being able to perform and coordinate these actions.  
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  
307 should also be banned from trade, and how the trade is regulated to ensure that individuals will not



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

### 310 **Going forward**

311 The population of exotic pond turtles at the Althrein of Kehl has not decreased since the ban of the  
312 trade of *T. scripta* in the European Union. On the contrary, the diversity of species being released  
313 has increased. In addition, the population size of *T. scripta* is increasing, and there is no indication  
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.

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334

## REFERENCES

335 Böhm, S. (2013). Records of invasive *Trachemys scripta elegans* (WiEd-NEuWiEd, 1839), in  
336 cenotes of the Yucatán Peninsula, Mexico. *Herpetozoa* 26: 98-100.

337 Breitenbach, A.T., Carter, A.W., Paitz, R.T. & Bowden, R.M. (2020). Using naturalistic  
338 incubation temperatures to demonstrate how variation in the timing and continuity of heat  
339 wave exposure influences phenotype. *Proceedings of the Royal Society B: Biological*  
340 *Sciences* 287: 20200992.

341 Cadi, A., Delmas, V., Prevot-Julliard, A.C., Joly, P., Pieau, C. & Girondot, M. (2004). Successful  
342 reproduction of the introduced slider turtle (*Trachemys scripta elegans*) in the South of  
343 France. *Aquatic Conservation-Marine and Freshwater Ecosystems* 14: 237-246.

344 Cadi, A. & Joly, P. (2003). Competition for basking places between the endangered European  
345 pond turtle (*Emys orbicularis galloitalica*) and the introduced red-eared slider (*Trachemys*  
346 *scripta elegans*). *Canadian Journal of Zoology-Revue Canadienne de Zoologie* 81: 1392-  
347 1398.

348 European Commission (2016). Implementing Regulation (EU) 2016/1141 of 13 July 2016  
349 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No  
350 1143/2014 of the European Parliament and of the Council. *Official Journal of the European*  
351 *Union* L 189/4.

352 European Parliament (2014). Regulation (EU) No 1143/2014 On the prevention and management  
353 of the introduction and spread of invasive alien species. European Parliament, Council of the  
354 European Union. *Official Journal of the European Union* L 317/35.

355 Foglini, C. & Salvi, R. (2017). Non-native turtles in a peri-urban park in northern Milan  
356 (Lombardy, Italy): species diversity and population structure. *Acta Herpetologica* 12: 151-  
357 156

358 Geiger, A. & Waitzmann, M. (1996). Überlebensfähigkeit allochthoner Amphibien und Reptilien  
359 in Deutschland – Konsequenzen für den Artenschutz. In *Gebietsfremde Tierarten*.

- 360 *Auswirkungen auf einheimische Arten, Lebensgemeinschaften und Biotope. Situationsanalyse,*  
361 Gebhardt, H., Kinzelbach, R. & Schmidt-Fischer S. (Eds). ECO Med Verlag.
- 362 Jablonski, D., Mrocek, J., Grula, D. & Christophoryová, J. (2017). Attempting courtship between  
363 *Emys orbicularis* and *Trachemys scripta* (Testudines: Emydidae). *Herpetology Notes*: 10:  
364 123-126.
- 365 Kopecký, O., Kalous, L. & Patoka, J. (2013). Establishment risk from pet-trade freshwater turtles  
366 in the European Union. *Knowledge and Management of Aquatic Ecosystems* 410: 02p01-  
367 02p11.
- 368 Koren, T., Stih, A., Buric, I., Koller, K., Laus, B. & Zadavec, M. (2018). The current distribution  
369 of pond slider *Trachemys scripta* (Reptilia: Emydidae) in Croatia. *Natura Slovenia* 20: 33-34.
- 370 Laufer, H. (2007). Buchstaben-Schmuckschildkröte *Trachemys scripta* (Schoepff). *Die*  
371 *Amphibien und Reptilien Baden-Württembergs*, Laufer, H., Fritz, K. & Sowig, P. (Eds) , pp.  
372 525-536. Ulmer-Verlag, Stuttgart.
- 373 Lowe, S., Browne, M., Boudjelas, S. & De Poorter, M. (2000). *100 of the World's Worst Invasive*  
374 *Alien Species. A selection from the Global Invasive Species Database.* pp 12.  
375 [http://www.issg.org/pdf/publications/worst\\_100/english\\_100\\_worst.pdf](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  
381 enforcement of new legislation for managing invasive species. *Biological Invasions* 21: 2933-  
382 2947.
- 383 Masin, S. (2014). Risk of invasion by frequently traded freshwater turtles. *Biological Invasions*  
384 16: 217-231.
- 385 Mo, M. (2019). Possible Records of Yellow-bellied Sliders (*Trachemys scripta scripta*) or River  
386 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  
397 risks: Is the slider turtle strictly carnivorous? *Amphibia-Reptilia* 28: 139-143.
- 398 Sancho, V. & Lacomba, I. (2016). Expansion of *Trachemys scripta* in the Valencian Community  
399 (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  
409 slider (*Trachemys scripta*) really invasive in Central Europe? A case study from Slovenia.  
410 *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: 845-  
420 850.
- 421 Wilson, J., Dormontt, E., Prentis, P., Lowe, A. & Richardson, D. (2009). Something in the way  
422 you move: dispersal pathways affect invasion success. *Trends in Ecology & Evolution* 24:  
423 136-144.
- 424