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Front Cover: Medo's pit viper (*Trimeresurus medoensis*) that appears to have died as a result of a self-inflicted bite. See article on page 43. Photographed by Jayaditya Purkayastha.

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RESEARCH ARTICLE

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

INTRODUCTION

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).

Of the world`s 100 worst invasive alien species, only two species are reptiles, the brown tree snake (*Boiga irregularis*) from Australia and the red-eared slider (*Trachemys scripta*) from North America (Lowe et al., 2000). Compared to invertebrates (26 of the 100 worst invasive species) and small mammals (10 of the 100 the worst invasive species), reptiles grow, mature, and 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 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 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, 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 occurred. Small neobiota populations are often ignored and long-term monitoring programmes are 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, 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; Kopecký, Kalous & Patoka, 2013; Standfuss et al., 2016).

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), 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 forces all member states to take actions to avoid the spread of the declared invasive species. As 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 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 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 that populations of this species are not stable (StA “Arten- und Biotopschutz”, 2018a) since cold 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)

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.

METHODS

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 690 m long and between 25 and 80 m 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.

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 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 used the opportunity to collect data on two sunny days in March (at this stage it was unsure whether 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 species were recorded in May and June, the normal period of monitoring), and excluding these data would not have changed the results.

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: 5 cm, 10 cm, 20 cm or 30 cm.

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

Measurement of hatchlings

I was contacted by teachers of a kindergarten 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 (https://www.reptilienauffangstation.de/). I was also informed about sightings of large females that were believed to have left the lake to lay eggs.

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.

RESULTS

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, N=5, p=0.02). These findings were contrary to the expectation that the population should decline each year due to cold weather mortality. The expected ratio for a decline each year would be 4:0, when this is compared with the observed ratio of 0:4 the difference is statistically significantly (Fisher's exact test, p=0.03)

Over the years, increasing numbers of very small pond turtles with a carapace of not more than 5 cm were observed which was close to statistical significance (Spearman rank correlation, r_s=0.90, N=5, p=0.08, Fig. 2). All photographed pond turtles in this category were *T. scripta*. Additionally, the number of large pond turtles with a carapace of more than 20 cm increased over the years (Spearman rank correlation, r_s=0.90, N=5, p=0.08, Fig. 2). All pond turtles with a carapace of 30 cm belonged to one of the three following species: *T. scripta*, *Pseudemys concinna*, or *Pseudemys nelsoni*.

Altogether six different species were observed, with three subspecies of *T. scripta* (Table 1). Over the years the number of observed individuals of *T. scripta* seemed to increase (Fig. 3). The two species of *Pseudemys* and *Graptemys pseudogeographica* occurred in all years. A few individuals of *Chrysemys picta* and *Mauremys sinensis* were observed in all years except 2018 (Fig. 3).

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 on 15th July 2019, one 19th May 2020, one on 17th June 2020 and one on 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

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

Genus, species, or sub-species	Peak counts			
	2017	2018	2019	2020
Trachemys scripta undetermined sub-species	1	7	5	14
T. s. elegans	8	5	11	24
T. s. scripta	4	1	6	4
T. s. troosti	1	0	5	1
Pseudemys sp	3	12	2	1
P. nelsoni	3	1	1	7
P. concinna	10	3	7	26
Graptemys pseudepgeographica	6	3	4	7
Mauremys sinensis	1	0	1	2
Chrysemys picta	1	0	1	1
TOTAL	**38**	**32**	**43**	**87**

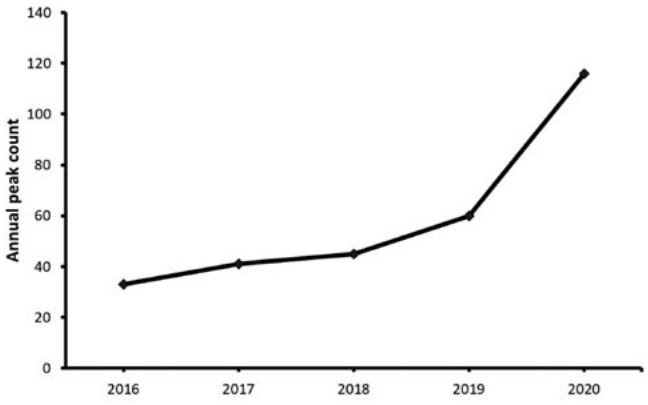

Figure 1. Annual peak count for all turtle species in the Althrein of Kehl combined (including individuals for which the taxon could not be identified and which are not shown in Table 1)

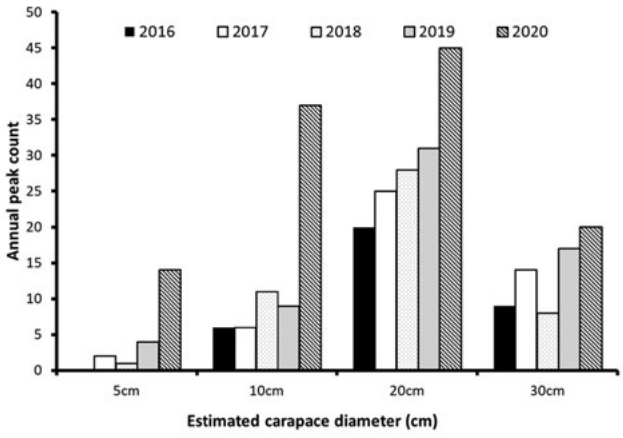

Figure 2. Annual peak counts for all turtle species observed in the Althrein of Kehl by carapace size category from 2016 to 2020

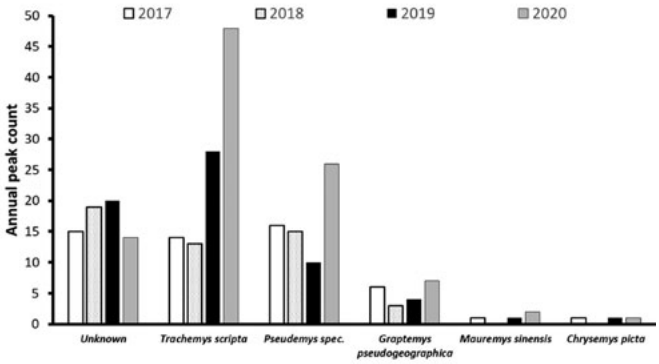

Figure 3. Annual peak counts of turtle species observed in the Althrein of Kehl from 2017 to 2020

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

Trait (mm or g)	Mean	Standard deviation	Max.	Min.	Data from USA (mean ± SD)*
Carapace length	30.6	1.3	32.0	28.0	31.2 + 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

*Data from Illinois, USA (Tucker, 2000)

nine individuals were kept and I was able to measure them, confirming that these were all hatchlings of *T. scripta* (Fig. 4, Table 2).

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

DISCUSSION

In the current study I have shown that the population of pond turtles in an oxbow lake, the Altrhein of Kehl, comprises six exotic species with the invasive *T. scripta* being the most abundant. Contrary to predictions that in the cold climate of Germany populations would decline (Nehring, 2016; StA Arten-und Biotopschutz, 2018a; Geiger & Waitzmann, 1996), population size seemed to have increased steadily over the five study years. This could be partly due to the release of more individuals into the wild as evidenced by 1) A high proportion of individuals being from genera other than *Trachemys*, indicating that species that are still available in pet shops are regularly released into the wild, and/or 2) The constant increase of the size category of carapace diameter 20 cm and 30 cm (Fig. 2), indicating that old individuals have been released, that might have been bought a long time ago

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

and have become too big and as a consequence released by pet owners. Furthermore, the regular observation of hatchlings indicates that it cannot be assumed that the cold climate of Germany will prevent exotic pond turtles from breeding.

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). 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., 2004), while here I found one clutch consisting of 24 eggs. I also observed one very large female of 3 kg that probably laid a clutch. Egg laying by itself is not evidence of successful reproduction since females will lay eggs whether or not they are fertilised and it is unknown whether fertilised eggs would develop successfully under the prevailing climatic conditions. In the current study, very small *T. scripta* were observed in four out of five years, making it likely that reproduction occurred repeatedly. The capture of hatchlings in both 2019 and 2020 showed that successful 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 reproduction in Kehl with the first case having been in 2004 (Pieh & Laufer, 2006). The absence of a report of reproduction in Kehl for the years 2005 to 2016 can be explained by a lack of monitoring during these years. In 2019, the seven hatchlings found in Kehl within 10 days in May plus the single hatchling found in July indicates that these might be from two or three different clutches. The hatchlings must likely originate from clutches laid in summer 2018, and probably overwintered in a nest burrow as suggested by Pieh & Laufer (2006). Reproduction might have been possible due to the recently mild winters, as it is known that eggs easily survive temperatures as low as -4 °C in the soil (Tucker & Packard, 1998), which would represent much colder air temperatures. For 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 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.

The size and mass of both hatchlings and eggs was similar to those reported from their 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 in Illinois and 9.4 g in Spain (Perez-Santigosa, Díaz-Paniagua & Hidalgo-Vila, 2008), while hatchling mass in the current study was 6.5 + 0.7 g compared to 6.8 + 0.8 g in Illinois (Tucker, 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 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 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 southern France (Cadi et al., 2004). So far, no soil temperature data are available for Kehl, but air 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 small to be sexed. Climate warming will make it more likely that females will hatch in the future.

To make management decisions for the long-lived, slow

reproducing *T. scripta*, it is essential to estimate how their populations will develop for several decades. Most *T. scripta* sold 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 potential female biased sex ratio of released sliders (Prevot et al., 2007) and a male biased sex ratio of hatchlings could cause an increased population growth in the medium-term (5-20 years), as more females will lay fertilised eggs. An overall increase in the number of hatchlings together with rising temperatures due to global warming makes it more likely that female hatchlings will occur in the 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 scenario makes it likely that the *T. scripta* populations in Kehl are now fully entrenched and that other populations will become established in other areas of the Upper Rhine Valley. *Pseudemys nelsoni*, *P. concinna*, *G. pseudogeographica* and *M. sinensis* have a low risk of becoming invasive in Europe (Kopecký, Kalous & Patoka, 2013; Masin, 2014). In contrast, *T. 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). However, detailed studies on its effect on the native fauna and flora are rare. In France, young *T. scripta* are omnivores, eating invertebrates, amphibians and fish, while older individuals have a 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 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 1 km), especially the Rhine floodplains. Increasing population size in the lake increases the risk that these habitats would be colonised. Further, *T. scripta* have also been observed next to the Kehler nature reserve Sundheimer Grund (less than 3 km from the Altrhein), an ecologically important and vulnerable habitat (Schradin, personal observation).

Implications for German and European legislation

The regulation (EU) No 1143/2014 demands that all member states should take action against invasive species (European Parliament, 2014) including *T. scripta* (European Commission, 2016). After the trading ban in 2006 it was expected that the release of *T. scripta* into the wild would decline in Germany. But the current study, undertaken 14 years later, does not support this 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 survive for long periods or to reproduce (Geiger & Waitzmann, 1996; Pieh & Laufer, 2006; Laufer, 2007; Nehring, 2016). Thus, populations in Germany are officially believed to be unstable (Nehring, 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 population size is not decreasing, there is no indication of high mortality and successful reproduction occurs more regularly than previously believed, the management plan in Germany 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; Standfuss et al., 2016; Koren et al., 2018). Thus, action plans to avoid an invasion might not only 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 (Sancho & Lacomba, 2016). While the invasion is slower in colder regions, the fact that the exotic populations there do not decline but reproduce and increase should be of concern. Additional actions are required; good examples have been suggested by (Teillac-Deschamps et al., 2009). An obvious need is public education with a focus on pet owners such as a social media campaign targeting Facebook groups of owners of exotic pond turtles. Education is also needed for law enforcement (police, order enforcement offices, wardens), whose focus is often the poor pet owner who has 'lost' a pond turtle instead of the criminal that released it. Police statements to the local news outlets could then emphasise the unlawfulness of the release of exotic animals. Local order enforcement officers could check owners of exotic pond turtles to ensure no breeding takes place 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 release should be made available which means that more financial state support is needed for animal shelters to create more space for unwanted pond turtles.

Other important actions would be 1) Destruction of clutches; 2) Removal of large females from the population when they are found on land before / after laying clutches, and 3) Active 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. Collaboration between nature conservation officers of the local communities with nature conservation groups, hunters, and local fishery association are needed for this. Last but not least, 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 be released. Individual marking (transponders) and registration of exotic pond turtles to allow previous owner to be identified may be an effective option.

Going forward

The population of exotic pond turtles at the Althrein of Kehl has not decreased since the ban of the 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 of high mortality due to cold winters. In contrast, there seems to be regular successful reproduction in summer. This might

lead to a more balanced sex ratio in the future and as such a further increase in reproduction and population size. It is now important to measure soil temperatures, to determine the sex ratio of hatchlings, and to combine this with climate predictions for the next 30 years. Furthermore, ecologically important wetlands close to waters into which pond sliders have been released must be monitored and actions must be taken to remove pond sliders from these areas before they can establish themselves there. The further growth of existing neobiotic pond slider populations must be stopped. The current action plan in Germany for *T. scripta* will have to change if an invasion is to be avoided. Other west and central European countries might have to apply similar action plans.

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RESEARCH ARTICLE

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Online news reports as a source of data on the occurrence and frequency of stowaway reptiles and amphibians entering Great Britain

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INTRODUCTION

Introduced species threaten biodiversity globally by acting as vectors of disease, sources of competition, and as predators of native species (Manchester & Bullock, 2000; Young et al., 2017). One way in which species may be introduced to a new area outside of their natural range (particularly in the case of islands) is as stowaways with goods in trade or with people (Chapple et al., 2013). This is most commonly thought to occur in animals (particularly vertebrates) but plants may also be dispersed in this way (Pyšek et al., 2011; Tomes et al., 2020). If the stowaways find themselves in a suitable climate then they may become established and subsequently threaten native species (Chapple et al., 2013). This is not always the case as some stowaways enter hostile environments or the number of individuals needed to found a viable population never arrives; this number depends on the species (Traill et al., 2007).

There is a history of stowaway animals becoming established in Great Britain. It is believed that midwife toads (*Alytes obstetricans*) were first introduced to a garden nursery in Bedford in packing cases of ferns and other plants from southern France (Smith, 1949). Sites of cargo importation such as ports are often colonised by shipping stowaways, as is the case with the European yellow-tailed scorpion (*Euscorpius flavicaudis*) in England (Kent) (Wanless, 1977). Some stowaway species such as the zebra mussel (*Dreissena polymorpha*) have both ecological and financial impacts, with costs incurred for their removal from water pipes and treatment works (Oreska & Aldridge, 2011). Whilst it is unlikely that stowaway reptiles and amphibians from the tropics will become established in Britain, those from temperate regions may have a greater chance of success. There is evidence to suggest that wall lizards (*Podarcis muralis*) can quickly adapt when introduced into cooler areas outside their natural range, such as southern England (While et al., 2015).

Currently, in the primary literature there is very little information on stowaway amphibians and reptiles attempting to enter Britain, although there are occasional reports or summaries (Allain et al., 2017; Clemens & Allain, 2020). Some historic records do exist (Banks, 1985; Mattison, 1986) but they are too few to enable adequate analysis. An obvious source of such information would be the RSPCA (Royal Society for the Prevention of Cruelty to Animals) but despite our best efforts, they were unwilling to supply the data we need. Consequently, as an alternative we investigated online news for reports of stowaways entering Britain and their countries of origin. With this data we compared the frequency of both different entry pathways and of different countries. It was expected that more reptiles than amphibians would be stowaways due to their greater vagility and robustness to environmental stressors.

METHODS

Suitable local and national online news reports were identified to establish when stowaways entered Britain and their countries of origin. For a sampling period of a little over 20 years (January 2000 to April 2020) searches were made using three search engines, Google, Bing and Yahoo to remove results bias. A number of keywords were used in combination such as 'stowaway' or 'hitchhiker' with suitable taxa names and the appropriate geographical location (to narrow the search down). An example of a suitable search term would be 'stowaway frog Britain'. To increase the supply of data, a search was also made of the British Newspaper Archive (www.britishnewspaperarchive.co.uk) using the same methods.

When a relevant story was located the following information was noted: the date or year of the report, the species of stowaway and the country of origin. In some instances, the stowaway wasn't identified in the article and so the accompanying photos were used to help determine species (or genus). The same stowaways were sometimes reported by different online news outlets and so care was taken to screen out these duplicates. The entry pathway of stowaways was also recorded as one of three categories: wholesale, retail or holidaymaker. We defined wholesale stowaways as those found in shipping containers or with industrial machinery, retail stowaways as those found in groceries or other goods, and holidaymaker stowaways as those accidentally brought back from holiday in a bag or suitcase.

RESULTS

Our exhaustive search produced 85 records of 50 different species of stowaway amphibians and reptiles entering Britain

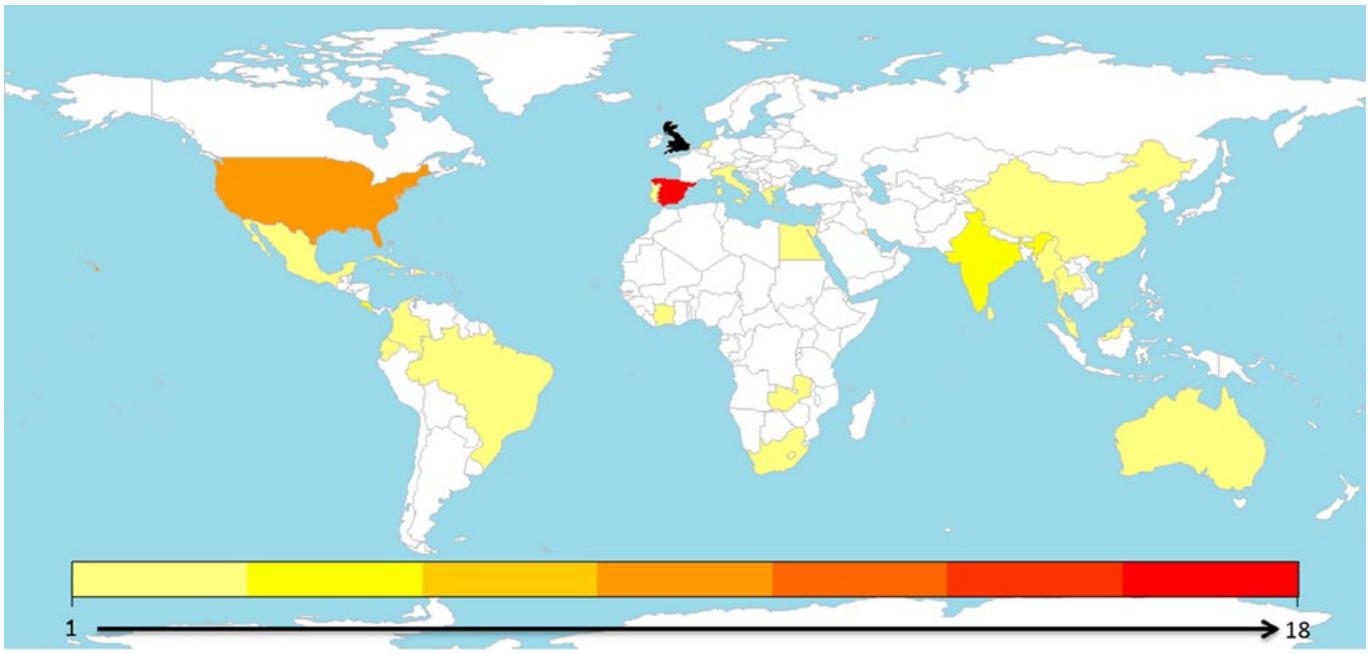

Figure 1. Numbers of online news reports of amphibian and reptile stowaways, by country of origin, entering Britain (black) between 2002 and 2020. The warmer the colour, the higher the number of stowaways.

from 32 countries between 2000 and 2020 (Fig. 1). The number of stowaways reported in the media each year varied widely (Fig. 2) with 73 % (n=62) of cases we recorded being reptiles. The mean number of cases for the period between 2002 and 2016 was three records, significantly lower than that for the three most recent full years (Fig. 2) with 39 out of the 85 reports (46 %) dating from between 2017 and 2019. All records together with links to the online reports are listed in Supplementary Material. There were two cases where the stowaways transported by holidaymakers were exotic aliens. Both species are endemic to the USA - a hognose snake (*Heterodon nasicus*) that arrived from Kuwait and a Californian kingsnake (*Lampropeltis getula californiae*) from Spain. These may be escaped pets although the Californian kingsnake is known as an invasive species in the Spanish Island of Gran Canaria (CABI, 2019).

Despite attempts to find records throughout the entire search period, none were found before 2002. All reptiles found during our searches were squamates (lizards and snakes) whereas the majority of amphibian stowaways were anurans (frogs and toads). An additional four records were found using the British Newspaper Archive that were missed when using the search engines, due to the fact that these news reports were no longer hosted by their parent organisation. Ten stowaways could not be identified any further than genus level and three could not be identified any further than family level. Older reports lacked photos of the individual animals or the detail of more recent reports which made identification harder. Over half of the stowaways we identified came from just five genera: four lizards *Hemidactylus* (n=15), *Tarentola* (n=11), *Anolis* (n=6), and *Podarcis* (n=5) and one tree frog *Osteopilus* (n=6).

The numbers of reports for each of the three potential stowaway entry pathways were statistically significant different (Chi-square goodness of fit, χ^2 = 14.971, df = 2, p = 0.00056) with holidaymakers being the most numerous (Fig. 3).

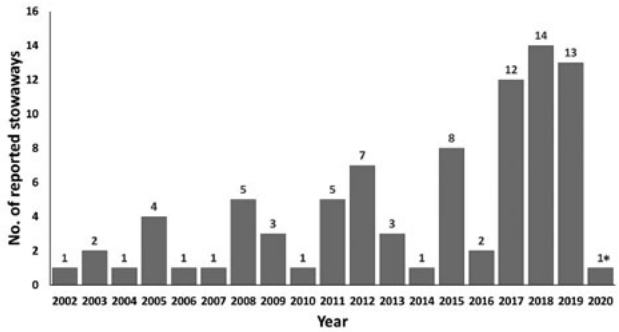

Figure 2. Annual number of online news reports of amphibian and reptile stowaways entering Britain. The years 2000 and 2001 have been omitted since no reports were found for these years. *Not a full calendar year

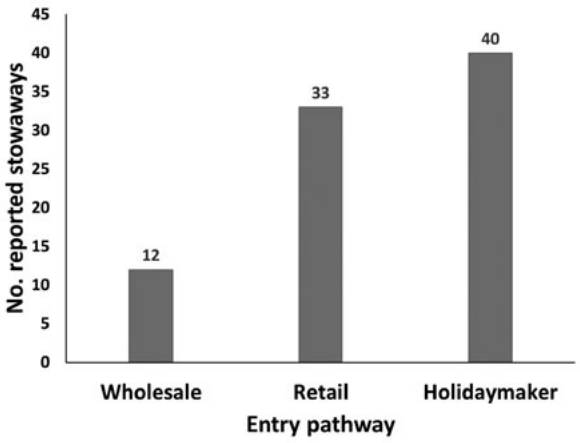

Figure 3. Number of online news reports of amphibian and reptile stowaways by entry pathway into Britain for the years 2002 to 2020

DISCUSSION

Our method of investigating the occurrence of stowaway amphibians and reptiles was relatively successful, although the number of reports was lower than expected, especially for the years earlier than 2017. This may be for a number of reasons including the legacy effect of websites, with older pages being deleted or removed from public servers. This indicates that searching for reports of stowaway amphibians and reptiles up to three years after their initial report may continue to yield useful numbers of results.

Despite the reduced number of reports prior to 2017, there were enough cases from which to draw some rudimentary conclusions given that results only provide an estimate and not the true number of stowaways. Our results show that most stowaway amphibians and reptiles came from the USA and Spain (Fig. 1). This is partly due to the fact that both countries are popular holiday destinations with British tourists. Spain also exports a large quantity of fruits and vegetables to Britain, particularly during the winter months which may increase the likelihood of animals becoming stowaways.

The apparent scarcity of reports may be due to the fact that only live animals are reported and that these may be biased by country of origin, the size of the stowaway, and its colour (which will influence detection). Additionally, there is presumably a high rate of mortality associated with stowaways due to the unfavourable conditions in which they find themselves. This may help to explain why more reptiles were recorded than amphibians, as amphibians are generally not as robust as reptiles to factors such as temperature related stress that can lead to an increase in disease susceptibility (Kiesecker, 2011). Not every case will be seen as newsworthy which will also bias the number of reports. Despite this, our results show that between 2002 and 2020, 85 individuals from across the world, representing 18 families of both reptiles and amphibians, entered Britain as stowaways.

Although the evidence suggests that there has been an increase in cases over the past three years, this may be due to reporting bias. For example in 2016 there appeared to be a drop in the number of stowaways (Fig. 2). At this time, other news such as the upcoming EU referendum would have taken precedence over the occurrence of a stowaway reptile being found in a holidaymaker's bag. The scarcity of reports from before this time may be linked to news articles being archived, as they are no longer seen as relevant.

There was no mention in any of the news articles as to whether rehomed stowaways had either been tested for parasites or diseases or were subject to quarantine procedures. None of the stowaways were identified as being likely to establish themselves in Great Britain. Nevertheless, spillover into native populations could have disastrous consequences, furthermore stowaways potentially harbour parasites that are new to science and so have as yet unknown consequences (Smales et al., 2020).

Holidaymakers were apparently the largest contributor to stowaways (Fig. 3). However, wholesale and retail stowaways may be under reported because businesses want to avoid news stories that could be sensationalist (Bombieri et al., 2008), associated with negative perceptions (Knight, 2018), or that could play on people's fear of amphibians and reptiles (Ceríaco, 2012). Certainly, wholesale movements of goods have for a long time been known as a source of stowaway amphibians and reptiles (Conant, 1945).

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SHORT NOTE
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Diversity and conservation potential of captive chelonian colonies at temple ponds in north-east India

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INTRODUCTION

Temples play an important role in socio-religious activities in north-east India. The rulers of ancient Assam (Kamarupa kingdom), mainly Ahoms (the ethnic group of Assam state), built many temples dedicated to various Gods and their incarnations, including Siva, Sakti, Vishnu, and Surya (Choudhury, 1985). Rivers and water bodies were considered sacred and the digging of ponds and building of reservoirs and dams within the kingdom was regarded by the Ahom monarchs as a sacred duty (Saikia, 1997). Thus, most of the temples built centuries ago in Assam have ponds on their premises (Fig. 1A).

The temple ponds are mainly used by priests for performing rituals, but also act as a means of flood control and groundwater recharge. Furthermore, these temple ponds are focal points for many cultural and religious activities (Agarwal & Narain, 1997). One of the significant religious rituals associated with temple ponds is 'merit release' or 'prayer release'. This ritual, originally an Indo-Buddhist practice, involves releasing wild animals such as birds, turtles, fishes, crabs or even ants for religious and spiritual purposes. This historical practice is also carried out on a large scale in other parts of India and throughout east and south-east Asia (Ahmed, 1997, Liu et al., 2012). In modern practice, it is usually birds and turtles that are released (Shiu & Stokes, 2008). In Indian mythology, turtles are revered as kurma, the incarnation of Lord Vishnu (Shiu & Stokes, 2008; Panigrahy et al., 2002), and are a symbol of stability (Miller, 1974). A traditional belief held by many people is that releasing animals such as turtles in a temple pond and feeding them (mostly with biscuits, and bread crumbs) (Fig. 1B & C), will benefit the creature, and ultimately improve the karma of the releaser and their loved ones and remove potential obstacles from their lives. The release of turtles is also thought to result in the individual and their family living a long life (Shiu & Stokes, 2008; Liu et al., 2012). The tradition of releasing wild-caught turtles into temple ponds has resulted in the ponds acting as a refuge for many turtle species (Purkayastha et al., 2013). A total of 29 chelonian species have been recorded in India, of these 21 species (3 tortoises and 19 freshwater turtles) have been reported from north-east India and are listed in the Supplementary Material.

Figure 1. Temple ponds in north-east India - **A.** Pond of Nagshankar temple, **B.** Devotees feeding biscuits to turtles, **C.** Black softshell turtle *Nilssonia nigricans* with biscuits offerings

In this study, we have updated the inventory of temples housing chelonians and present data on the diversity of chelonians at different temples across north-east India. Moreover, we discuss the role of temple ponds as an important resource for recovering wild populations of endangered species.

METHODS

Temples in the states of Assam, Tripura and West Bengal (India) were surveyed from 1 June 2018 to 30 July 2019, under PCCF (Wildlife) Assam Research Permit vide No: WL/FG.31/Pt/Technical committee 2018 dated 19 May 2018 and Office Order No: 97 dated 16 July 2018. A total of 29 temple ponds (Fig. 2; Table 1) were surveyed extensively. An average of six surveys were conducted in each temple pond during

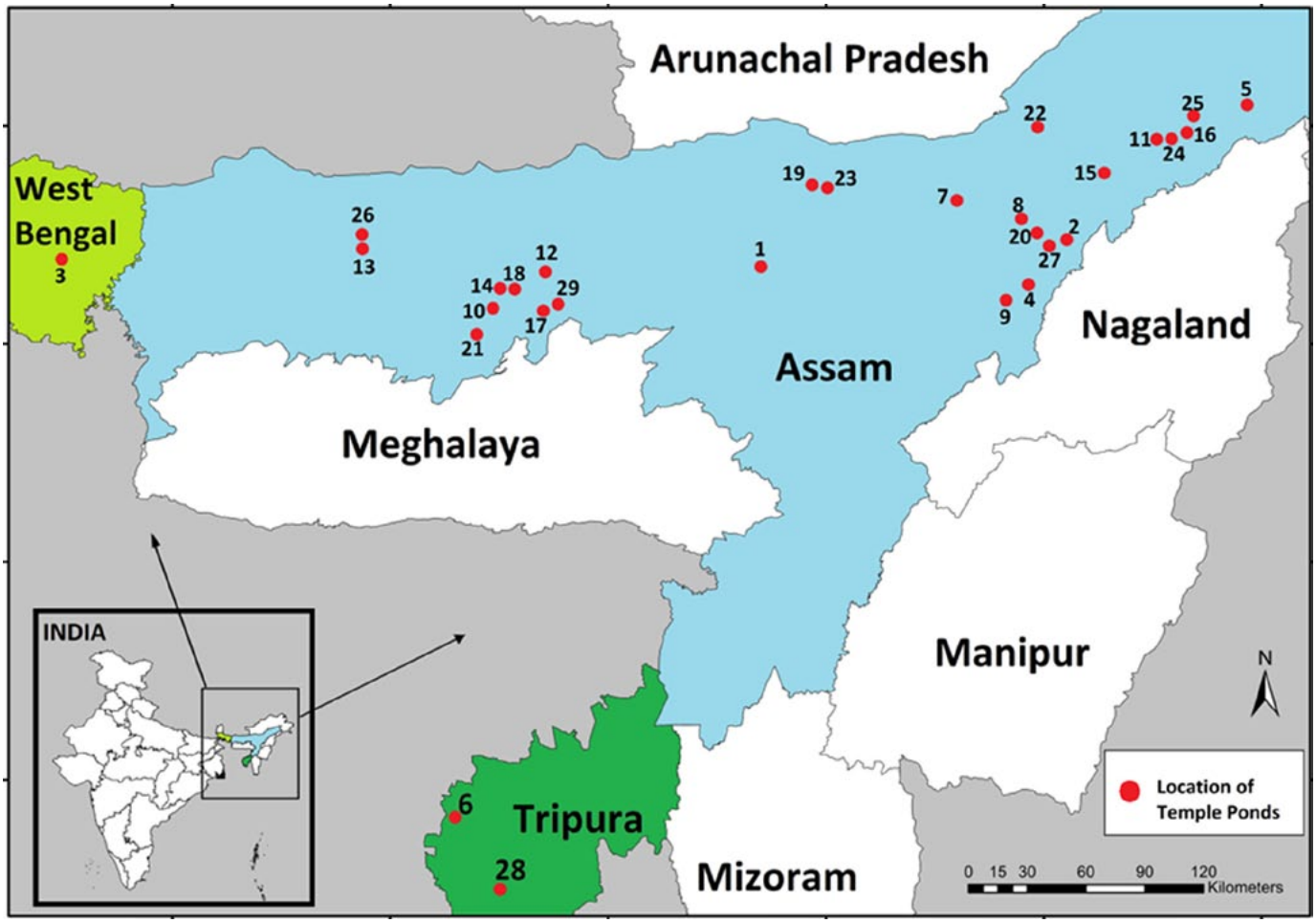

Figure 2. Locations of temple ponds in north-east India surveyed for chelonians, further details of each location are presented in Table 1

the study period. Visual encounter surveys using binoculars (Crump & Scott, 1994) were used to record the turtles present in the mornings (09:00 h to 11:00 h) and in the evenings (17:00 h to 19:00 h). In the case of ponds with extremely large areas, the species of turtle present was determined by showing turtle photos to the local people; the relevant ponds are marked with an asterisk in Table 1. Turtle species were identified following Smith (1931), Ahmed et al. (2009), and Purkayastya (2013). Unstructured interviews were held with 30 male temple committee members in relation to 16 temple ponds and, when available, records of the turtle donations were noted. Devotees offering turtles to the temple ponds were asked about the source of their turtles.

RESULTS

A total of fifteen species of freshwater turtles and one species of tortoise were recorded from the 29 temple ponds (Table 1). Particularly large numbers of different turtle species (9 to 13) were observed in the Haigrib Madhab, Nagshankar, Gorokhiya Gohain Than, and Ugrotara temples. Trionychidae was the most abundant turtle family (52.5 % of species) followed by Geoemydidae (46.8 %). There were wide differences between species in the frequency with which they occurred in temples (Fig. 3). Nineteen of the temples (65.5 %) had *Nilssonia hurum* (Fig. 4B), nineteen (65.5 %) had

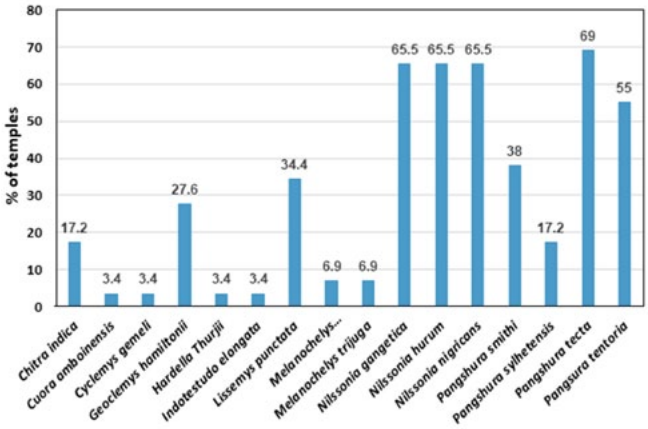

Figure 3. Percentage frequency of various turtle species in temple ponds of north-east India (same species abbreviations as Table 1)

Nilssonia gangetica (Fig. 4C) and *Nilssonia nigricans* (Fig. 4A) and twenty (69 %) had *Pangshura tecta* (Fig. 4F); in contrast the following species *Cuora amboinensis* (Fig. 4O), *Cyclemys gemeli* (Fig. 4N), *Hardella thurjii* (Fig. 4 K) and *Indotestudo elongata* (Fig. 4L) where found in only in 3.4 % of temples.

At the temple ponds, the turtles and tortoises do not receive their natural diet instead consuming food such as biscuits, bread crumbs, wheat balls, puffed rice etc. (Fig. 1A & B). It is likely that this has negative consequences for

Table 1. Temple ponds in north-east India and the chelonian diversity observed in them

	Temple	District/locality	Area m²	Location	Turtle species observed
1	Amlapatty Shiva	Nagaon, Assam	18	26° 21'37.1"N, 92° 42'00.5"E	Lp, Ng, Nh, Ps, Pt
2	Athkheliya Namgarh	Golaghat, Assam	763	26° 28'22.7"N, 94° 05'54.7"E	Nn, Pt, Ptn
3	Baneshwar Shiva	Cooch Behar, West Bengal	5,766	26° 23'53.7"N, 89° 29'53.4"E	Nh, Nn
4	Barokheliya Namghar	Golaghat, Assam	1,680	**26° 15'48.4"N, 93° 55'26.0"E**	**Nn, Pt, Ptn**
5	Bor Pukhri	Siva sagar, Assam	1,121	27° 04'51.9"N, 94° 55'49.7"E	Nh, Ptn
6	Chandan Pukur mandir	Agartala, Tripura	1,275	23° 50'10.4"N, 91° 16'48.0"E	Gh, Lp, Ng Nh
7	Chikan ata Than	Bokaghat, Assam	3,541	26° 39'59.0"N, 93° 36'47.9"E	Ci, Gh, Ng, Nh, Ptn
8	Chinatoli bor Namghar	Golaghat, Assam	56	26° 34'14.6"N, 93° 55'05.0"E	Ci, Ng, Nh, Nn
9	Deopani	Karbi Anglong, Assam	1,920	26° 13'09.3"N, 93° 49'40.8"E	Nn, Pt, Ptn
10	Dhareshwari devalaya	Siliguri , Assam	2,244	26° 10'35.8"N, 91° 28'36.5"E	Ng, Nn, Psy, Pt, Ptn
11	Gauri Sagar*	Siba Sagar, Assam	482,865	26° 56'39.5"N, 94° 32'13.9"E	Lp, Ng, Nh, Ptn
12	Gopeshwar	Guwahati, Assam	3471	26° 19'05.8"N, 91° 42'57.4"E	Ng, Nh, Pt, Ptn
13	Gorokhiya Gohain Than	Sarbog, Assam	3174	26° 29'16.0"N, 90° 52'52.0"E	Ci, Gh, Ie, Mtr, Ng, Nn, Psy, Pt, Ptn
14	Haigrib Madhab	Hajo, Assam	14,693	26° 14'39.9"N, 91° 31'35.2"E	Ca, Ci, Cg, Gh, Ht, Lp, Mtj, Ng, Nh, Nn, Ps, Psy, Pt, Ptn
15	Hatigarh Dewalay	Jorhat , Assam	6,823	26° 46'39.0"N, 94° 15'56.2"E	Nn, Ptn
16	Joy Sagar*	Siba Sagar, Assam	418,404	26° 57'09.7"N, 94° 37'22.7"E	Lp, Ng, Nh, Ps, Pt
17	Kamakhya	Guwahati , Assam	1,102	26° 09'56.2"N, 91° 42'17.8"E	Ng, Nh, Nn, Ps, Pt, Ptn
18	Kedar	Hajo, Assam	792	26° 14'30.6"N, 91° 32'38.5"E	Nn, Ps, Pt, Ptn
19	Madhab	Jamuguri ,Assam	3,026	26° 44'11.2"N, 92° 56'05.1"E	Lp, Nh, Nn, Pt
20	Mandir Devalaya	Golaghat, Assam	1720	26° 30'7.81"N, 93° 58'45.93"E	Nn
21	Mata Chandika Devi Mandir	Guwahati, Assam	62	26° 03'39.6"N, 91° 24'08.8"E	Gh, Lp, Ng, Nh, Ps
22	Monkey	Lakhimpur, Assam	1,252	27° 00'07.2"N, 93° 59'03.2"E	Nh, Nn, Ps, Psy, Pt
23	Nagshankar Mandir	Biswanath, Assam	9,350	26° 43'30.4"N, 92° 59'40.9"E	Ci, Gh, Lp, Mtj, Mtr, Ng, Nh, Nn, Ps, Psy, Pt
24	Rudra Sagar*	Siba Sagar, Assam	326,252	26° 56'59.9"N, 94° 35'01.9"E	Ng, Nh, Nn, Ps
25	Siva Sagar*	Siba Sagar, Assam	448,079	26° 59'30.1"N, 94° 38'00.8"E	Gh, Lp, Ng, Nh, Nn, Pt
26	Sorbhog Station Shiv Mandir	Sarbog, Assam	2,323	26° 29'41.6"N, 90° 53'02.3"E	Lp, Ng, Nh, Pt
27	Srimanta Shankardev Namghar	Golaghat, Assam	1,088	26° 28'0.91"N, 93° 59'59.22"E	Ng, Pt, Ptn
28	Tripureshwari	Udaipur, Tripura	28,748	23° 30'34.2"N, 91° 29'58.9"E	Ng, Nh, Nn, Pt, Ptn
29	Ugrotara	Guwahati, Assam	10,880	26° 11'21.9"N, 91° 45'11.8"E	Cg, Gh, Lp, Ng, Nh, Nn, Ps, Pt, Ptn

Abbreviations used; Ci- *Chitra indica*, Ca- *Cuora amboinensis*, Cg- *Cyclemys gemeli*, Gh- *Geoclemys hamiltonii*, Ht- *Hardella thurjii*, Ie- *Indotestudo elongate*, Lp- *Lissemys punctate*, Mtj- *Melanochelys trijuga*, Mtr- *Melanochelys tricarinata*, Ng- *Nilssonia gangetica*, Nh- *Nilssonia hurum*, Nn- *Nilssonia nigricans*, Ps - *Pangshura smithi*, Psy- *Pangshura sylhetensis*, Pt- *Pangshura tecta*, Ptn- *Pangshura tentoria*. *Ponds with extremely large area, where turtle diversity was recorded by showing photos to the locals.

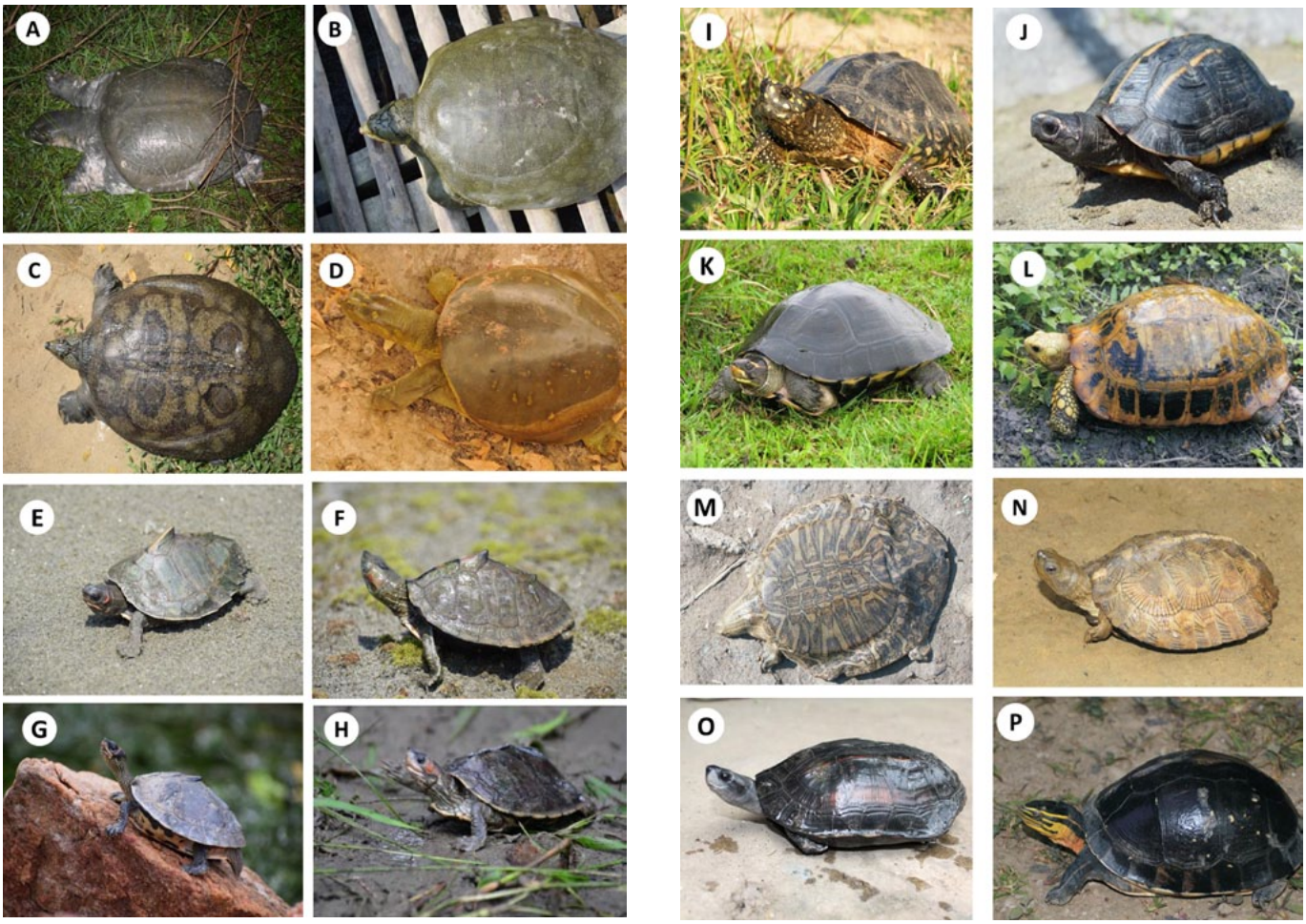

Figure 4. The 16 chelonian species observed during the temple pond survey- **A.** *Nilssonia nigricans*, **B.** *Nilssonia hurum*, **C.** *Nilssonia gangetica*, **D.** *Lissemys punctate*, **E.** *Pangshura sylhetensis*, **F.** *Pangshura tentoria*, **G.** *Pangshura tecta*, **H.** *Pangshura smithi*, **I**. *Melanochelys tricarinata*, **J.** *Geoclemys hamiltonii*, **K.** *Hardella thurjii*, **L.** *Indotestudo elongata*, M. *Chitra indica*, **N.** *Cyclemys gemeli*, **O.** *Cuora amboinensis*, **P.** *Melanochelys trijuga*

their health. Furthermore, this food contaminates these rain-fed ponds which were generally not cleaned regularly, have limited opportunity for oxygenation, and many ponds were found to be littered with large amounts of discarded polythene. In over 70 % of temples, the management committees had made masonry embankments and steps for beautification, to control erosion, and to provide easy access for rituals. Often such concrete embankments had resulted in injuries to the chelonians as they crawled on the cemented substrate or jumped from a steep gradient. Furthermore, in over 50 % of temple ponds there were insufficient basking areas. This is believed to have has an effect on chelonian health, with many suffering from discoloration of the carapace and severe skin infection (Fig. 5A). Most of the surrounding soil of temple ponds is hard clay so that the chelonians find it difficult to dig and lay eggs at a suitable depth. During the survey, some turtle eggs were found to be either laid on inappropriate substrate such as gravel due to lack of sand/nesting areas or depredated by stray dogs and monitor lizards (*Varanus bengalensis*). A few colonies were recorded with unintended hybridization between closely related species of Nilssonia. In spite of sustained efforts by certain environment organisations and individuals, temple committee members appeared to be over-possessive about their turtles and were often reluctant to participate in sustained husbandry, welfare, and conservation recovery programmes.

Informal questions about turtles put to the community members at temple ponds yielded little information about the turtles or their origins. The community only differentiated turtles as either large or small. Half the respondents were aware of turtle attempts to nest near the edges of the ponds. More positively, in the case of two temples (Haigrib Madhab and Ugrotara) there were dedicated caretakers employed to assist with nest translocation and the care of sick turtles. Using knowledge of the status of various temple ponds and their potential for turtle conservation, modest improvements have been made by various non-profit organisations. These have included the construction of basking substrates and sandy nesting banks. Make-shift hatcheries have been developed at Haigrib Madhab, Ugrotara and Nagshankar temples and selected clutches have been translocated to Assam State Zoo/Botanic Garden to increase the survival of neonates. In 2018 and 2019, a total of 12 turtle nests and 252 eggs were protected, and artificially incubated. Consequently, 197 hatchlings (Fig. 5B & C) were released in a protected area of Pobitora wildlife sanctuary (Assam) to supplement the wild populations.

Taken together, the 29 temple ponds surveyed were found to contain 16 of the 21 species of chelonians known from north-east India. These ponds are considered as a repository for some resilient threatened turtles such as *N. nigricans* (Fig. 4A), *Pangshura sylhetensis* (Fig. 4E), *Chitra indica* (Fig. 4M), *Lissemys punctata* (Fig. 4D) whose natural habitats are being destroyed. The five species not found in the ponds were *Cuora mouhoutii*, *Morenia petersii*, *Manouria impressa*, *Manouria emys* and *Amyda cartilaginea*. *Amyda cartilaginea* and both species of *Manouria* are comparatively rare in the area of study and elsewhere, furthermore *C. mahouti* and *M. petersii* are habitat specialists and they may not survive in the captive condition presented by the temple ponds.

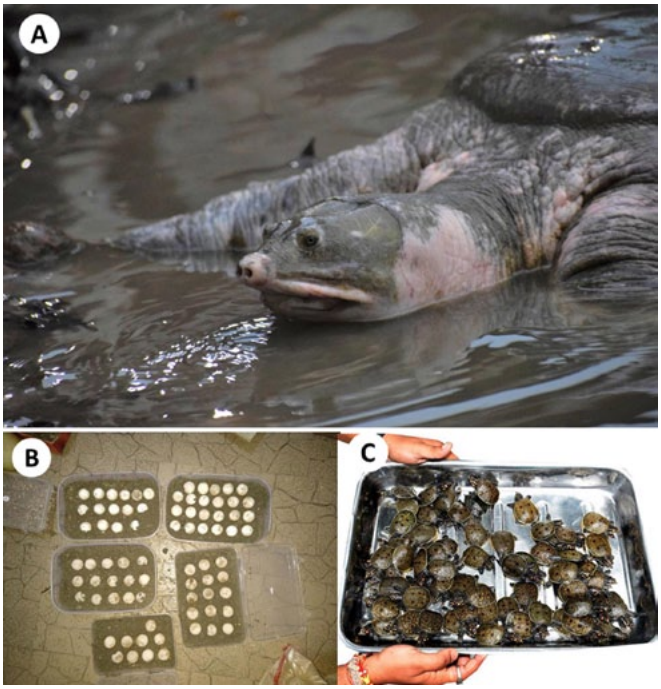

Figure 5. Turtles in temples - **A.** Skin discoloration in black softshell turtle *Nilssonia nigricans*, **B.** Turtle eggs being incubated in plastic boxes; **C.** Softshell turtles hatched in the care of temple authorities prior to release into the wild

DISCUSSION

From this study we have found that ponds in temples located close to urban settings, such as Haigrib Madhab temple, Nagshankar temple, Gorokhiya Gohain Than temple, and Ugrotara temple, have greater turtle diversity than those in remote areas such as Mandir Devalaya and Hatigarh Devalaya. The reason for this would appear to be that temples in urban areas are visited by larger numbers of people at times of festivals when a wide range of turtle species are donated to the temples.

We found that local people have a positive religious association with turtles as the incarnation of Gods, these sentiments can be used to the benefit of conservation. While the population of certain species such as *N. nigricans* (Fig. 1C; Fig. 4A) has already been decimated in its natural range, temple ponds actually provide important resources for research on their recovery and conservation in the wild. Furthermore, temple ponds with turtles also provide aesthetic pleasure for the local people, who often feed and watch the turtles (Fig. 1B). This may generate awareness of the need for turtle conservation among the youth and other stakeholders.

The way forward

To enhance the conservation potential of temple ponds in the region requires an inclusive network of all those temples with ponds. This should be established so that temple authorities can learn from, and support, each other in conservation practices. Simple guidelines for monitoring nesting activities and translocating eggs are warranted to ensure maximum survival and recruitment of hatchlings. Hatchlings should be raised to a certain minimum size in enclosures where they are separated from the adults. Larger size of hatchlings on release will ensure better survival rates and also facilitate the attachment of tracking devices that can be used to map dispersal and record survival in natural habitats. Disease monitoring in ponds is urgently required to safeguard turtle populations.

Temple ponds themselves are in need of improvement and to achieve this requires support to temple committees and local communities so that they can play a significant role in strengthening and cleaning temple ponds in association with conservation organizations. Finally, to reduce the capture and illegal trade of turtles, temples should be discouraged from accepting future donation of wild turtles.

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SHORT COMMUNICATION
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The unnatural history of cave olms *Proteus anguinus* in England

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INTRODUCTION

The olm or human fish, *Proteus anguinus* (Fig. 1), is a neotenous species of blind cave salamander, retaining its gills even in adulthood, found in Eastern Europe and usually growing to around 25 cm in length (Arnold & Ovenden, 2002). The species has a number of adaptations that allow it to survive in such a challenging environment such as the ability to undergo long periods of starvation (Hervant et al., 2001) and tolerance of anoxia (Issartel et al., 2009). Olms have a long life history and under ideal conditions may be very long-lived; the maximum recorded age has been 100 years or more (Voituron et al., 2011). *Proteus anguinus* is particularly vulnerable to both physical and chemical changes to the karst ecosystems they inhabit, including contamination from anthropogenic sources (Prelovšek, 2016; Kolar, 2019).

Figure 1. A male olm (*Proteus anguinus*) in pre-mating condition from a cave in Herzegovina

There have been rumours that wild olms are present in England. The origins of these would appear to stem from the 1930s and the illegal removal of some individuals from Slovenia (then part of the former Yugoslavia). These were of the white sub-species (*Proteus anguinus anguinus*) and were housed in a tank in the former Zoology Department at the University of Bristol (Chapman, 1993). During the 1940s the olms had apparently outstayed their welcome and two students were tasked with releasing the olms into a suitable cave in the Mendip Hills (Chapman, 1993). There is no record of how many olms were released.

Chapman (1993) speculates about whether any of the olms could have survived the ordeal in the Mendips. To confirm their presence by direct manual searching would be very difficult as access to some caves may not be possible. It has been suggested that the detection of eDNA could be used in this case (Vörös et al., 2017; Gorički et al., 2017), but the use of this method assumes that acceptable error rates could be maintained (Griffin et al., 2019) which may well not be the case. However, there are several reasons for thinking that olms would no longer be present in the Medips. First, it seems likely that they would have perished soon after release due to the significant difference of the hydrophysico-chemical conditions between the karst water in the Mendips and those in their native range. In the Mendips the water is contaminated due to farm waste runoff, recreational activity, and agrochemical contamination probably rendering Mendip karst water uninhabitable for the olms (Atkinson, 1971: Hardwick & Gunn, 1996). Second, the olms were released some 80 years ago and as they were likely collected from the wild as adults, which would have been easier to catch than larvae and juveniles, they were at least 10 years old when originally caught making them at least 95 years of age as we write and are therefore close to the maximum observed age. Thirdly, British caves generally are quite poor in stygobitic biodiversity, so their food supply would also have been very limited (Maurice et al., 2016). The whole scenario points to the probable rapid demise of the olms.

More recently due to incorrect information circulated online, Kent's Cavern in Torquay, Devon has been subject to hearsay as a place where olms may potentially be seen. But to the best of our knowledge, no *P. anguinus* have ever been released into caves in Devon. However the William Pengelly Cave Studies Centre at Buckfastleigh did once have a small aquarium in one of its demonstration caves during 1977, containing a small number of Mexican axolotls (*Ambystoma mexicanum*). Axolotls are superficially similar to olms with pale coloration and retained gills (Fig. 2) so that the two species could easily be confused by non-specialists. It is therefore likely that these individuals were either mislabelled or visitors have wrongly identified them and attributed them to Kent's Cavern.

To conclude, the conditions needed to sustain olms are unlikely to be present in English cave systems. Although some individuals were released in the first half of the 20th century,

Figure 2. An albino axolotl (Ambystoma *mexicanum*) showing its similarities with the olm, such as a pale coloration and the presence of external gills. These features could lead to confusion between the two.

these individuals almost certainly expired very rapidly soon after. Since then other suggestions have been made for the presence of olms but there is no evidence to support these. Despite the exploration of such systems by recreational cavers as well as keen herpetologists, the evidence for any *P. anguinus* remains at zero. Whilst *P. anguinus* may have made a brief entry to the introduced herpetofauna of England, it is almost certain that they are long gone.

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SHORT COMMUNICATION

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Deaths of mugger crocodiles *Crocodylus palustris* falling from small dams in Gujarat, India

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The mugger or marsh crocodile (*Crocodylus palustris*) is one of the most adaptable and widely distributed crocodilian species in south Asia (Choudhury & de Silva, 2013). In India it is considered 'Vulnerable' under IUCN Red List criteria and is protected under Schedule I of the Wildlife (Protection) Act, 1972. In the Indian state of Gujarat, the mugger population is facing various threats, including water pollution, habitat loss and encroachment, river-side developments, tourism, and the pet trade (Vyas, 2010). Some of the recently noted direct threats to the species involve the trade of crocodile parts as aphrodisiacs (Vyas, 2017), crocodile-vehicle collisions (Vyas, 2011, 2014; Vyas & Vasava, 2019; Vyas et al., 2020a), and entanglement or ingestion of discarded plastic waste (Vyas et al., 2020b).

In this account we document the sudden and tragic deaths from 2000 to 2020 of 11 mugger crocodiles at five small dams (Table 1 & Table 2) in the Saurashra region of Gujarat State. It would appear that these deaths resulted from falls caused by flash-flood waters over the dam walls. In 2019, five cases were recorded at the Willingdon Dam involving individuals (2M:3F) ranging in length from 1.66 to 2.51 m (snout to tip tail length) which were found dead having fallen from the reservoir (Table 1; Fig. 1). Earlier, on 25th August 2018, a large male mugger, measuring 2.4 m in length was found in a severely injured condition near the base of the Willingdon dam. The injured animal had a large hump on its back and its snout covered in blood clots. Due to the severity of injuries, the animal was unable to move and given the location where it was found it can be assumed to have fallen from the dam. This is consistent with the fact that on the previous night water had overflowed the 13 m retaining wall of the dam. Soon after the injured animal was found, it was shifted to a nearby local veterinary facility for further treatment and clinical care (Dr Vaibhasingh Dodiya, College of Veterinary Science and Animal Husbandry Junagadh, with advice from a renowned crocodile expert veterinarian Dr Gowri Mallapur). An X-ray showed signs of multiple injuries and fractures to vertebrae and ribcage (Fig. 2A to C). Unfortunately, the injured animal did not recover and died after three weeks of intensive care and treatment.

In the past, similar mugger deaths have been recorded at three other man-made water bodies (Vyas, unpublished records); Dhola Dhuna dam, Gothadad dam (Barda hills) and Singoda dam (Gir forest) (Table 1). The last two water bodies are known to hold breeding populations of the species;

Table 1. Dead or injured mugger crocodiles (*C. palustris*) found at various small dams in Gujarat (India)

No	Date	Mugger total body length in cm	Gender	Condition
	Dhola Dhuna dam			
1	2nd September 2000	200	Female	Dead
	Gothadad dam			
2	20th August 2001	250	Male	Dead
	Singoda dam			
3	8th August 2012	300	Male	Dead
4	14th September 2015	210	Female	Dead
	Willingdon dam			
5	25th August 2018	240	Male	Badly injured*
6	7th August 2019	185	Female	Dead
7	9th August 2019	200	Male	Dead
8	11th August 2019	180	Female	Dead
9	17th August 2019	251	Male	Dead
10	27th August 2019	166	Female	Dead
	Hasnapur dam			
11	27th August 2020	227	Female	Dead

*animal died after 3 weeks of intensive treatment

Gothadad dam contains over 12 muggers and Singoda dam contains over 66 muggers. This makes Singoda dam home to the second-largest mugger population within Gir Wildlife Sanctuary & National Park (Vyas, 2019). Victims may have been washed out during flooding and been killed when washed over the high dam walls. In the absence of roller brackets, or where the brackets are damaged, these muggers seem likely to have hit the hard ground directly leading to trauma and ultimately death.

Crocodile movements across aquatic habitats are influenced by water level and are seasonal (Campos et al., 2006; Campbell et al., 2013). Large hydroelectric dams modify water-level regimes (Magilligan & Nislow, 2005) but there hasn't been any specific research demonstrating the impact of fluctuations in the water-levels of large-dams on the movement of crocodilian fauna. However, there have been reports of the movement patterns of Nile crocodile (*Crocodylus niloticus*) after the construction of Pongolapoart dam, South Africa (Champion & Downs, 2017) and the effects of dam construction and operation in the Brazilian Amazon on

Table 2. Salient features of small dams in Gujarat (India) where dead or injured muggers (*C. palustris*) have been found

Name of the Dam, District	Geo-coordinates	Height (m)	Area of reservoir (km²)	River	Use of water body	Remarks
Dhola Dhuna Check dam, Jamnagar	21°50'43.24"N; 69°44'18.02"E	7.5	0.6	Kileshwari River	Percolation, water conservation	Barada Wildlife Sanctuary, no water roller backets
Gothadad dam, Porbandar	21°46'44.64"N; 69°43'57.27"E	8.5	2.5	Bileshwari River	Percolation, water conservation	Barada Wildlife Sanctuary water roller backets damaged
Singoda dam Juna-gadh	21° 1'21.52"N; 70°46'37.06"	14.7	5.5	Singodi River	Percolation, water conservation, irrigations	Gir Sanctuary & National Park, water roller backets damaged
Willingdon dam, Junagadh	21°30'16.82"N; 70°28'49.16"E	12.9	1.5	Kalwa River*	Water supply for Junagadh City	Girnar Wildlife Sanctuary, water roller backets damaged
Hasnapur dam, Junagadh	21°34'13.16"N; 70°31'8.03"E	11.5	4.25	Lol River*	Water supply for Junagadh City	Girnar Wildlife Sanctuary, water roller backets damaged

*a tributary of Uben River

Figure 1. A. Willingdon dam on the outskirts of Junagadh city, on 17th August 2020, **B**. A 2.5 meter-long mugger (*C. palustris*) found dead after falling over 13 m from the dam wall, **C.** Local forest staff and volunteers of an NGO making efforts to recover the crocodile's dead body for postmortem diagnosis

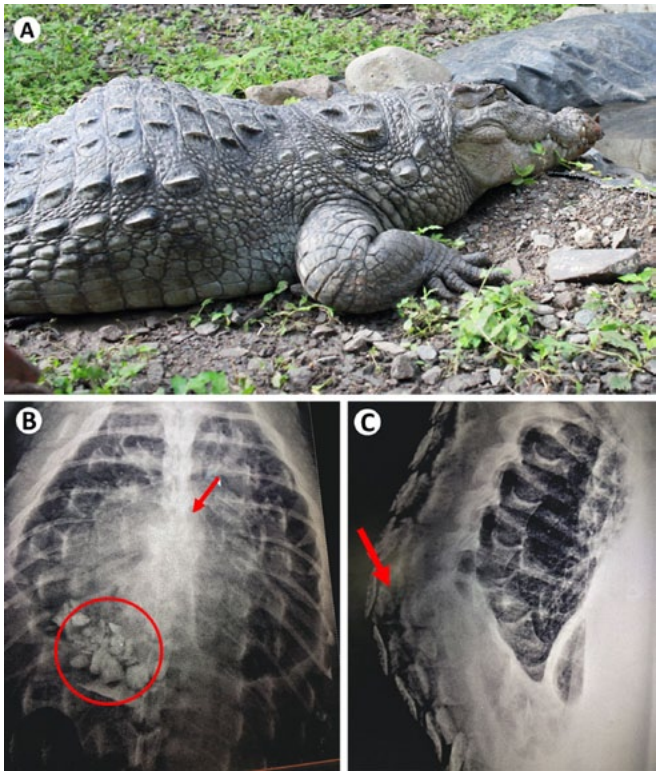

Figure 2. The injuries of a 2.4-meter-long male mugger (*Crocodylus palustris*) that fell from the Willindon dam in 2018 **A.** The crocodile with a humped back, **B.** X-ray in dorsal view (red arrow shows bones facture and red circular marks gastroliths), **C.** Lateral view of multiple fractures on the spinal vertebrae and rib-cage (red arrow shows same bone facture as in B.)

the movements of the dwarf caimans *Paleosuchus trigonatus* and *Paleosuchus palpebrosus* (Campos et al., 2017) and black caiman *Melanosuchus niger* (Campos, 2019). Crocodilians are long-lived and most species are strongly territorial by nature (Lang, 1987). Consequently, dam construction may severely disrupt home ranges, possibly resulting in individuals dispersing into nearby water bodies or catchment areas where they are at increased risk of death from dam turbines or floodgates (Campos, 2015). Furthermore, changes in water levels may reduce opportunities for nest building (Magnusson & Lima, 1991; Mourão & Campos, 1995; Campos, 2019). Even though the water-filled dams displace crocodilians from their home ranges, most individuals eventually re-established themselves near their original sites which increases their risk of mortality from encounters with dam turbines and floodgates.

Larger dams, certainly those in Amazonia, directly affect local populations of crocodiles (Benchimos & Peres, 2015). And yet, the impact of smaller dams or man-made reservoirs on crocodilians remains little known. In the case of our study, the numbers of accidental deaths associated with such dams is relatively small but this is an emergent threat that requires further research so that it can be properly quantified and appropriate conservation actions identified.

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SHORT COMMUNICATION

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Deformities in the Cuban spotted toad *Peltophryne taladai*: A rare case of abnormal eyes

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In the last decade, around the world observations of individuals in amphibian populations with some type of physical anomaly has become increasingly frequent (Lannoo 2008; Lunde & Johnson, 2012). In Cuba the occurrence of abnormal anurans has been sporadic, anecdotal, and has usually involved single specimens (García-Padrón & Alonso Bosch, 2017, 2019), which suggests that the rate of anomalous frogs in nature could be low. However, Alonso Bosch et al. (2017) reported that 45 % of 113 tadpoles of *Peltophryne fustiger*, collected in five localities of Pinar del Río and Artemisa provinces, had abnormal mouthparts such as missing tooth rows and lack of dark keratinisation of mouthparts. The cause for these anomalies remains unknown.

Peltophryne taladai (Schwartz, 1960) is one of fourteen native bufonids from the Caribbean islands (Hedges et al., 2019). It is a Cuban endemic toad, which has a disjunct distribution in Central, Central East and Eastern Cuba, from the sea level to 850 m a.s.l. (Díaz & Cádiz, 2008; Rivalta et al., 2014). This species is common in mesic and broadleaf forests, banana and cacao plantations; it has been sighted also in open cultivated areas. Usually, it occurs associated with small streams, rivers and ponds where it reproduces (Díaz & Cádiz, 2008; Henderson & Powell, 2009).

On 19th September 2012, during a short visit to Pinares de Mayarí region, Mayarí municipality, Holguín province, Cuba, we undertook a rapid nocturnal survey (21:00 h-23:00 h) along a small stream in the surroundings of Los Exóticos farm (20° 31´29.61" N 75° 49´14.20" W, WGS 84). Our sample included ten adult *P. taladai* (eight males, one female and one juvenile). Two individuals of these had facial or skeletal deformities. The sex was determined based on sexually dimorphic and behavioural characters (size, nuptial pads, vocal sac, advertisement calls). We collected data on snout-vent length (SVL) that was measured with a Vernier calliper (0.05 mm error) and mass (BM) with Pesola dynamometers (±2 g). The first specimen, an adult male *P. taladai* (SVL=128.55 mm, BM=132 g) exhibited rare anomalies in both eyes (Fig. 1A). This animal had an apparent hyperxanthism (overabundance of yellow pigments) in the right eye, and opacity (opacification of the eye lens or cataracts) of the left eye (Fig. 1B & C). The second malformed individual was also an adult calling male (SVL = 114.40 mm, BM=132.0 g) which had a case of polydactyly in the right foot, one of the most common skeletal anomalies reported in urodeles and anurans (Henle et al., 2017). Both animals were released at the site of capture.

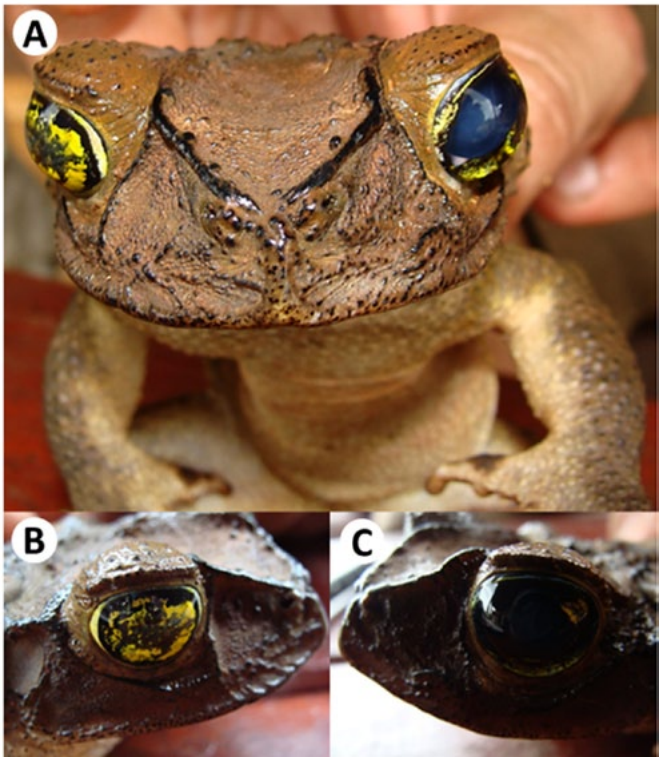

Figure 1. Malformed eyes of a male *Peltophryne taladai* - **A.** Front view showing anomalies in both eyes, **B.** Hyperxanthism of the right eye, **C.** Opacity or whitened left eye

Reports of ocular abnormalities (duplication, microphthalmia and anophthalmia) in adults and tadpoles of anurans have been widely documented (Henle et al., 2017; Brassaloti & Bertoluci, 2018; Mônico et al., 2019). Two of the most detailed studies have been on island populations of introduced toads (Anura, Bufonidae). In the Brazilian oceanic archipelago of Fernando de Noronha, Toledo & Ribeiro (2009) reported that the rates of malformed individuals of *Rhinella jimi* reached about 45 % of post-metamorphic (adult) individuals. About 20 % of the malformation cases were related to eye deformities, such as anophthalmia, palpebrae

malformation, and lack of coloured iris; inbreeding has been argued as a causative agent (Toledo et al., 2016). In the case of *Rhinella marina* introduced into the Bermuda islands, the incidence of abnormalities was high and widespread (Bacon et al., 2006) and included external facial, eye and limb abnormalities. In this case, environmental pollutants in pond sediments such as petroleum hydrocarbons, polycyclic aromatic hydrocarbons, metals (Al, As, Sn, Cd, Cr, Cu, Fe, Pb,Hg, Mn, Ni, and Zn), and ammonia, appear to be responsible (Fort et al., 2006; Bacon et al., 2013). In the two cases, the authors reported different types of ocular abnormalities; at least one of them (whitened eye) is similar to that reported for *P. taladai* in this study. To the best of our knowledge our observation of hyperxanthic eyes in an anuran has only been reported previously for *Rana arvalis* in Penza region of Russia (Svinin et al., 2018). However, this anomaly is probably widespread but usually occurs in combination with other more externally visible ocular malformations.

In spite of these malformations, no alteration in behaviour was detected in any of these toads. According to Tolledo & Toledo (2015), sight loss can impact the frequency of food acquisition and the prey types consumed, consequently blind toads may be handicapped in relation to normal ones in size and mass. However, according to our observations the body condition in the 'blind' Cuban spotted toad appeared to be optimal as its size and mass corresponded closely to the mean value (±SD) obtained for the males in this population (SVL=119.54 ± 8.75, BM=143.71 ± 35.03).

Further visits to the area will allow estimation the prevalence of these and other anomalies, as well as providing more information on the ecology, natural history and behaviour of the individuals of this population. An adequate research design that includes the analysis of water quality and the search for aquatic molluscs that could be intermediate hosts of encysted trematodes (*Ribeiroia*), recognised as responsible for the abnormalities in several amphibian species around the world (Johnson et al., 1999; Stopper et al., 2002), are needed. *Ribeiroia* has not been reported in any fresh water bodies in Cuba, but studies are required to determine whether or not Cuba fresh water snails are infected.

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Ocular anomalies in four species of European toad

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Physical anomalies in frogs and toads (anurans) were first described in a scientific manner in the year 1554 (Mônico et al., 2019). However, with intensification of human impact, anomalies have become ever more common (Garcia-Muñoz et al., 2010; Johnson et al., 2010). Moreover such anomalies are associated with population declines (Cohen, 2001).

Vision is crucial to the fitness and survival of adult anurans (Ingle, 1976). Nevertheless when ocular deformities, such as microphthalmia (an unusually small eye), anophthalmia (absence of an eye), dyscoria (abnormally shaped pupil) or corectopia (abnormally placed pupil), are unilateral, fitness may be relatively unaffected. Data compiled by Henle et al. (2017) shows that anophthalmia and microphthalmia taken together constitute more than one fourth of non-skeletal morphological anomalies in anurans. The prevalence of anophthalmia has been recorded as 0.036 % in a healthy population of *Bufo bufo* (Wolf, 1994) while in two populations of *Lithobates sylvaticus*, in which 7260 and 5243 individuals were examined, the prevalence was somewhat greater, at 0.07 % and 0.15 % respectively (Eaton et al., 2004). It would appear that microphthalmia is several times less common than anophthalmia (Henle et al., 2017).

Causes of deformities can be environmental and/or genetic. The environmental causal factors are teratogens, irradiation (e.g. Nishioka et al., 1981), pathogens, physical injury, egg retention time, temperature (Briggs, 1941; Witschi, 1952; Mikamo & Hamaguchi, 1975) and the effects of predators (Caldwell, 1982) or disease (Bradford, 1991). The genetic causal factors are hybridisation (Delarue, 1982) or inbreeding (Humphrey, 1948). Some cases of anophthalmia are related to thyroid carcinoma (Cheong et al., 2000). Dyscoria and corectopia in amphibians have so far not received much attention, which suggests that they are either rare, overlooked, or both. Colour aberrations and other anomalies of amphibians in Poland are known to include eye depigmentation, partial eye depigmentation, and black eye (Kolenda et al., 2017). Here I describe cases of ocular anomalies in three anuran species from western Poland (Gorzów Wielkopolski) and in one species from Croatia.

On 1st June 2011 at 17:51 h an adult *Bufo bufo* was rescued from a gully pot in Poland (52° 45’15” N, 15° 13’28” E). The individual had unilateral microphthalmia (Fig. 1). Its behaviour was normal and it had no other anomalies.

On the 8th October 2011 at 22:12 h an adult *Bombina bombina* was rescued from another nearby gully pot in Poland (52° 45’16” N, 15° 13’19” E). It showed unilareral anophthalmia (Fig. 2). Nevertheless it was lively and seemed healthy. Several other normal conspecifics were seen in the area.

Figure 1. *Bufo bufo* with unilateral microphthalmia in Poland

Figure 2. *Bombina bombina* with unilateral anophthalmia in Poland

On the 13th April 2012 at 14:52 h in a garden in Poland (52° 45’55” N, 15° 14’24” E) a pair of *B. bufo* in amplexus was seen migrating to a breeding pond. The female had unilateral microphthalmia (Fig. 3). The individual was in good condition and had no other anomaly. Many other conspecifics, both juvenile and adult, have been observed for years in this specific location but the individual with the anomaly was not seen again and neither were any other malformed *B. bufo*.

On 11th June 2013 at 22:55 h in a garden in Poland (52°

Figure 3. A female of *Bufo bufo* with unilateral microphthalmia in amplexus in Poland

Figure 5. *Bombina variegata* with unilateral anophthalmia in Croatia

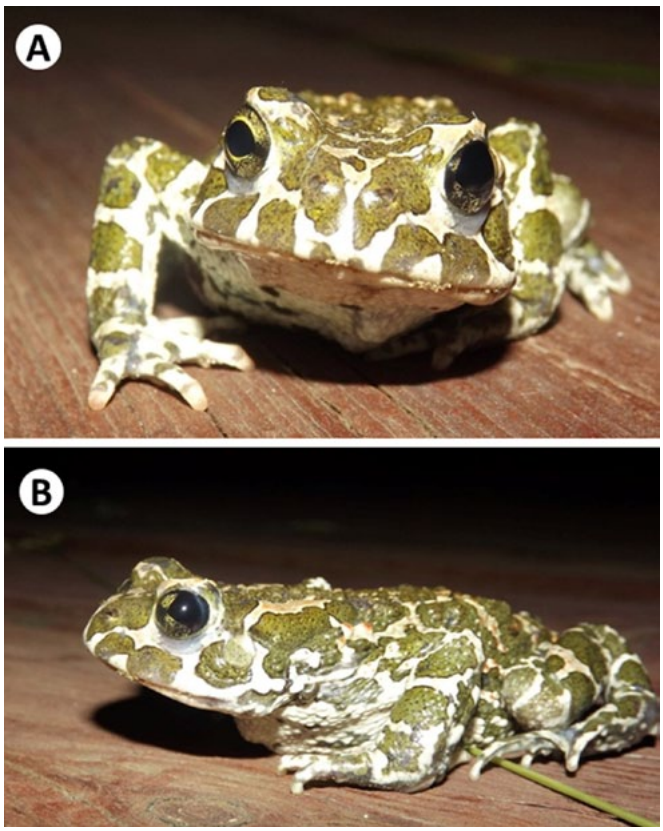

Figure 4. An adult *Bufotes viridis* with unilateral corectopia and dyscoria in Poland – A. Frontal view, B. lateral view

45'55" N, 15° 14'24" E) a single adult individual of *Bufotes viridis* was observed with corectopia and dyscoria (Fig. 4A & B). The skin around the eye had some grey discoloration. To my knowledge this is the first case of corectopia and dyscoria in the family Bufonidae. The individual was not observed again despite searches.

Finally, on 26th July 2012 at 08:12 h one individual of *Bombina variegata* with unilateral anophthalmia was found in a puddle in a dried stream bed in Medveja, Istra, Croatia (45° 16'16" N, 14° 15'09" E) (Fig. 5). In that habitat it was syntopic with many conspecifics, *Natrix natrix* and *Salamandra salamandra* larvae. Probably the same individual was also seen the next day at 10:58 h. It seemed not to have other problems but it was smaller than conspecifics, probably because of difficulties in hunting caused by the malformation. There was no injury or scar visible, suggesting that the individual had either not developed the eye at all or that a trauma happened in an early larval developmental stage.

All but one observation were made in urban or suburban areas so it is possible that these malformations are of indirect anthropogenic origin - for example pollution in an early developmental stage (Fort, 2006) or irradiation (Henle et al., 2017). Amphibians are good bioindicators since they are sensitive to water pollution because their early development occurs in the aquatic environment (Duellman & Trueb, 1986; Dunson et al., 1992; Blaustein et al., 1994). In turn, the aquatic environment easily becomes polluted as water drains from the land. Future exotoxicological, developmental, epidemiological and genetic studies are needed to explain the interactions of factors leading to ocular deformities. Furthermore, the significance of such anomalies in amphibian declines and the role of anthropopressure on the frequency of such anomalies need to be explained.

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SHORT COMMUNICATION

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An anomalous phenotype of the Italian Aesculapian snake *Zamenis lineatus* from Mt. Etna, Sicily

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Zamenis lineatus (Camerano, 1891) is a semi-arboreal colubrid snake (Harrington et al., 2018) endemic to Italy where it occurs in southern Lazio, Campania, Calabria, Molise, Basilicata as well as in Sicily (Di Nicola, 2019).

The body of adult *Z. lineatus* is usually grey, olive, beige or brown with four dark stripes, two dorsally and two laterally. The head is characterised by a dark band starting from the post-ocular and terminating on first labial corresponding to the angle of the jaw (Di Nicola, 2019), but possibly the most notable trait of *Z. lineatus* is the copper red or orange iris, a diagnostic feature that is generally used to distinguish it from the Aesculapian snake *Zamenis longissimus* (Laurenti, 1768) (Salvi et al., 2017). Individuals of *Z. longissimus* presenting aberrant colour patterns are known (Cattaneo, 2015), and dark coloured individuals are found regularly in Primorsko, Bulgaria (Speybroeck et al., 2016) but no colour anomalies of *Z. lineatus* have been published. The authors and other volunteers of the Sicily Wildlife Fund (SWF - a Wildlife protection NGO) communicate here their discovery of individuals of *Z. lineatus* presenting an anomalous phenotype in Sicily.

The Sicily Wildlife Fund is a non-profit NGO with the objectives of monitoring and conserving wildlife in eastern Sicily. As part of its mission, recovery facilities are provided for animals rescued in urban and suburban areas by the local population and institutions. In 2010, a citizen brought to SWF three *Z. lineatus* found stuck in a water tank on his property located at Etna under Bronte municipality (Catania); these individuals showed a peculiar colour, appearing overall grey and lacking the typical red iris. These animals were underfed and thus they were kept under observation, fed and rehydrated until fully recovered. After one week, as per our animal management protocol, these individuals were then returned to their original wild area.

Figure 1. A rescued adult and a juvenile *Zamensis lineatus* showing abnormal coloration – **A.** Full body coloration and pattern of the adult as it looks on a substrate, **B.** Full body coloration and pattern of the juvenile as it looks on a substrate, **C.** Close-up of the head of the adult, **D.** Close-up of the head of the juvenile

In the following years, there have been surveys of the area, leading to other sightings of similar individuals of *Z. lineatus* confirming their presence in the wild. Unfortunately, only starting from 2020 has SWF implemented a cataloguing protocol for rescued individuals (in the field or when admitted at the wildlife centre); for this reason we cannot exclude the possibility that these animals are the same ones that were observed previously. Here we present only the data for an adult and a juvenile observed in 2020.

The adult (SVL = 89.6 cm, weight = 275 g) and juvenile (SVL = 26.8 cm, weight = 14 g) were found on two different occasions in September 2020 (Fig. 1). The area surveyed is a sparse forest over 1000 m a.s.l. on Mt. Etna, presenting leaf litter on volcanic soil. We have not indicated the exact position of these snakes in order to discourage poaching activity. Instead, the precise GPS coordinates have been uploaded to the ORNITHO platform (https://www.ornitho.it/) which is managed by many wildlife conservations agencies and scientific bodies (including the Societas Herpetologica Italica - the Italian Herpetological Society). The users of this platform are vetted routinely and consequently we have full trust in this system. The GPS data can be requested through the ORNITHO platform or directly by contact with the corresponding author of this paper.

Both individuals have been identified as *Z. lineatus* following Di Nicola (2019). The body of the adult was grey (Fig. 1A) and lacked the red-coloured iris, showing a clearly grey iris instead (Fig. 1C) while the colour aberration is even more pronounced in the juvenile. This individual preserves the chequered pattern of the body but completely lacks any other colour other than shades of grey and black (Fig. 1B) including the eyes which are grey (Fig. 1D). As with *Z. longissimus* (Cattaneo, 2015), we consider these individuals to be a variation of the normal colour pattern of *Z. lineatus*. This might be due to the absence or malfunctioning of xanthophores for the body and erythrophores for the eyes, but further studies are needed to confirm this suggestion.

The distribution of ectotherms is critically limited by temperature and exposure to the sun. For this reason, it has been suggested that individuals showing a darker body coloration, compared to lighter coloured individuals, may have an adaptive advantage by warming more quickly during basking, especially at higher altitudes, in what has been called the thermal melanism hypothesis (Fernando Martínez-Freiría et al., 2020; Clusella-Trullas et al., 2007). However, it has also been proposed that a darker colour might make these snakes stand out on lighter backgrounds, thus increasing predation risk (Clusella-Trullas et al., 2008). In the case of the individuals presented here those with a darker colour pattern might have an advantage in thermoregulation while still blending well with the background of the black-dark brown volcanic soil. The observations between the period of 2010-2020, the presence of an adult and a juvenile in the area surveyed, and the correspondence of the dark coloration with the dark soil of the habitat, all suggest that the individuals reported here are part of a population of *Z. lineatus* that has genetically fixed the anomalous colour pattern, thanks to the ecological advantages it may provide. Nevertheless, individual *Z. lineatus* with a normal colour have been observed in the same area, leaving our hypothesis in need for further surveys to establish i) What is the percentage of individuals presenting the colour anomaly over the whole *Z. lineatus* population in the area, and ii) Whether the two different phenotypes are somehow separated spatially or ecologically (i.e. do they occupy a different niches?).

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Tail vibration – a newly described defensive behaviour of the Aesculapian snake *Zamenis longissimus*

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The defensive behaviour of numerous snake species may include tail raising or tail vibration. Defensive tail displays generally function as a warning signal, a decoy, or both. The role of the tail display as a warning or intimidating signal is usually associated with the presence of bright colours of the tail, which serve to warn the predator of a potentially venomous bite, or a noxious discharge of the cloacal scent glands (Bogert, 1968; Greene, 1973; Parker & Grandison, 1977; Gibbons & Dorcas, 2002; Araújo & Martins, 2006). The decoy role of the tail display is observed in numerous venomous and non-venomous species, which use tail vibration to divert the predator's attack from the head, leaving it time to escape or attack the predator (Greene, 1973; Johnson, 1975; Jackson, 1979; Arnold & Bennett, 1984; Kochva & Golani, 1993; McCallum, 2006). Additionally, the tail display may serve as a flash display, which disorients the predator, allowing the snake to escape (Robinson, 1969; Greene, 1973).

The Aesculapian snake, *Zamenis longissimus* (Laurenti, 1768), is distributed from the north-east of the Iberian Peninsula and southern Europe, through Central Europe to the Carpathians and some isolated locations east of them, and south to the central part of the Apennines and southern parts of the Balkan Peninsula, the northern parts of Asia Minor and the Caucasus region (Speybroeck et al., 2016). In Bulgaria, the species is found throughout the country, most commonly in areas up to 1500-1600 m a.s.l. (Stojanov et al., 2011). In the present study the author describes a novel defence behaviour for the species.

An adult specimen of *Z. longissimus* was captured on 29 August 2015 near Karlukovo Village in north-western Bulgaria (43° 10'46" N, 24° 3'32' E) during an ecological study of snakes in the country. The specimen was measured (SVL = 77 cm, TL = 17.9 cm), weighed (W = 41.04 g), photographed (Fig. 1) and then released at the site of capture. Immediately after capture, the snake made several attempt to bite. During the photo session, while the snake was restrained by the author, it started a rapid lateral vibration of the tip of its tail. This behaviour was exhibited while the head and the anterior part of the body were gently covered with the palms of the author's hands in order to try to keep the snake still. During the vibration, the snake's tail was placed on the ground. While vibrating its tail, the snake's body was partially coiled with the head positioned in one end and the tail at the other. Vibration of the tail ceased a few seconds after the head and the anterior part of the body were uncovered by the author's palms. The behaviour was exhibited again on both a second and the third attempt to cover the anterior part of the snake's body.

Figure 1. The individual *Zamensis longissimus* in which defensive tail vibration was observed

Similar defensive tail vibration is well documented in numerous snake species (Greene, 1973; Johnson, 1975; Jackson, 1979; Arnold & Bennett, 1984; Kochva & Golani, 1993; Mullin, 1999; McCallum, 2006). Predators have been shown to respond to tail behaviours by attacking the tail instead of the head (Jackson, 1979). Defensive tail vibration is well documented for another representative of the *Zamenis* genus – *Zamenis situla* (Linnaeus, 1758) (see Speybroeck et al., 2016) as well as for species of the closely related genus *Elaphe* (e.g. *Elaphe schrenckii* Strauch, 1873, *Elaphe quatuorlineata* Lacepede, 1789, *Elaphe suromates* (Pallas, 1811) and *Elaphe dione* (Pallas, 1773) (Bannikov et al., 1977; Speybroeck et al., 2016)). However, at least to the author's knowledge, this behaviour has never been documented for *Z. longissimus*. The usual defence behaviours of this species include trying to escape, hissing, biting and expulsion of the content of the cloacal scent glands (the author's personal observations; Rubio & Gosá, 2010; Stojanov et al., 2011; Speybroeck et al., 2016). It seems that tail vibration may be used as a last resort by *Z. longissimus*, when the snake is unable to escape. This behaviour likely diverts the attention of the 'attacker' from the vulnerable head area of the snake, using the tail as a decoy. This statement could be supported

by the fact that this behaviour was observed after each of the several attempts of approaching and covering the snake's head with the author's palm. By diverting the attacker's attention to the tail area, the snake could have more time to escape, cover its head or attack the predator (Greene, 1973; Johnson, 1975; Jackson, 1979; Arnold & Bennett, 1984; Kochva & Golani, 1993; McCallum, 2006). Additionally, by attacking the tail, the predator could be exposed to the noxious scent of the cloacal scent glands (Greene, 1973). However, this behaviour seems to be very rare for this species as it was observed in only one individual of a total of 45 captured and measured individuals (frequency of occurrence = 2.22 %). In contrast, this behaviour seems to be very common for *Z. situla*: frequency of occurrence = 50 %; total individuals captured and measured = 8 (the author's personal observations).

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NATURAL HISTORY NOTE

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Tentative confirmation that the common mussurana *Clelia clelia* has low susceptibility to the bufotoxins of the marine toad *Rhinella marina*

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ARTICLE WITHDRAWN OWING TO AN ERROR IN SPECIES IDENTIFICATION

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First record of piebaldism in the Munoa worm lizard (*Amphisbaena munoai*)

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The pigmentation of reptiles is determined by the different types of chromatophore embedded within the skin. Chromatic anomalies are not uncommon and result from the inactivity or the absence of one or more chromatophores types (Prüst, 1984; Bechtel, 1991). The terminology for such anomalies tends to be confused. The anomaly most frequently reported in the literature is hypopigmentation since this is the easiest to detected (Kazilas et al., 2018; Kornilios, 2014; Lucati & López-Baucells, 2017; Zalapa et al., 2016). One form of hypopigmentation is albinism which refers to the complete absence of pigment in the skin or eyes (Prüst, 1984; Bechtel, 1991). When the absence of pigment isn't total, the term 'partial albinism' is used, nevertheless this condition can be better classified as leucism or piebaldism (Prüst, 1984; Bechtel, 1991; Lucati & López-Baucells, 2017). Leucism refers to absence of any skin pigment, except in the eyes; while piebald specimens have coloured eyes and lack pigments only on some parts of the body, frequently resulting in spotted colour patterns (Prüst, 1984; Bechtel, 1991; Grouw, 2006, 2013; Abreu et al., 2013; Fertl & Rosel, 2009).

In this report we present the first record of piebaldism in *Amphisbaena munoai* Klappenbach 1960 (Amphisbaenidae). This is a small and slender worm-lizard distributed in areas of the Uruguayan savannah ecoregion that comprises subtropical open areas of southern South America, in the Brazilian state of Rio Grande do Sul and eastern Uruguay (Dinerstein et al., 2017). The species reaches 151 mm snout-vent length (102 mm to 151 mm in adults) and normally has a light brown colour that is intense dorsally, extends laterally and then fades in the center of the ventral region (Perez & Borges-Martins, 2019).

During a field survey on 27th October 2015, in the municipality of Bagé (Rio Grande do Sul, Brazil) we encountered two specimens of *A. munoai* under a fallen tree trunk in an open field (-54.0189 longitude, -31.3195 latitude: WGS84). These have been deposited as voucher specimens in the collection of the Departamento de Zoologia, Universidade Federal do Rio Grande do Sul (UFRGS). One of the specimens (UFRGS 7417) was piebald (Fig. 1) while the other (UFRGS 7418) had quite normal coloration. The piebald amphisbaenian was a juvenile and had a snout vent length of 97 mm and a tail length of 12 mm. The eyes had coloration typical for this species but the body had non-pigmented areas giving a typical piebald pattern (Fig. 1).

Figure 1. Piebald specimen of *Amphisbaena munoai* (UFRGS 7417) from Bagé municipality, Rio Grande do Sul, Brazil

There are three earlier records of pigment deficiency in amphisbaenians. A case of piebaldism was recorded as partial albinism in *Amphisbaena trachura* (Chalkidis & Di-Bernardo, 2004), and cases of piebaldism have been reported in *Blanus strauchi* (Kazilas et al., 2018) and *Blanus cinereus* (Malkmus, 1997). Reptiles with chromatic anomalies are normally rare in nature, mostly because there are associated with defective vision, an inability to thermoregulate, or they are easily predated (Krecsak, 2008; Hupfeld & Hoffmann, 2006; Kornilios, 2014). However, as amphisbaenians are fossorial species these problems may not affect their ability to survive (Kornilios, 2014; Kazilas et al., 2018) and so may increase the frequency with which this abnormality is observed in nature.

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NATURAL HISTORY NOTE

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Behavioural interactions between barred grass snake *Natrix helvetica* and northern viper *Vipera berus*

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This note documents behavioural interactions between barred grass snakes (*Natrix helvetica*) and northern vipers or adders (*Vipera berus*) observed during the spring breeding season in 2020. Observations were made from 9th to 16th April in a small clearing, amongst heather and gorse, a typical early spring basking site at this location in Norfolk, England.

During the first two days three male and two or three female vipers were present, mostly basking communally. Some courtship and brief spells of combat were observed and during the latter one of the males appeared to establish dominance.

On 11th April, over a period of approximately ten minutes, three grass snakes arrived and mingled with the vipers. Two of the grass snakes engaged in intertwining their tails, indicating that at least one was male and one female and that their relatively synchronous arrival was due to a mating pursuit. Three interspecific behaviours were also observed. A male viper followed alongside a moving grass snake (Fig. 1). At least one male grass snake initiated courtship behaviour with a female viper (Fig. 2). Male vipers behaved aggressively towards grass snakes, raising their foreparts (rising, both without and with contact, as described by Andrén (1986)), in the initial stages of combat (Figs. 3 and 4).

Both grass snakes and vipers were present the following day and showed further interspecific mating and combat behaviour. No further interspecific interactions were observed after this. Weather was unfavourable to activity from 13th to 14th April. On 15th April two male and two female vipers were observed but only a single grass snake and by the 16th April only a single, courting pair of vipers remained.

Figure 1. Male viper tracking the movement of a grass snake

Figure 2. Grass snakes and vipers at a communal basking site. The grass snake on the left is initiating courtship with a female viper.

Figure 3. A male viper behaving aggressively towards a grass snake, raising its foreparts (rising without contact)

The close proximity of snakes in this mixed species aggregation seems likely to have prompted these unusual interspecific interactions. It is difficult to determine the specific cues involved. Male vipers have been prompted to attempt combat with model snakes, or even a stick moved to replicate another male, but both visual stimuli and female pheromones could have been involved (Kelleway, 1982). Similarly, both visual and vomeronasal cues may have prompted the current observations. As the snakes were in physical contact, pheromones may have been transferred between species, provoking interspecific interactions.

Figure 4. A male viper in contact with a grass snake, raising its foreparts in the early stages of combat (rising with contact)

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NATURAL HISTORY NOTE

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Arboreal foraging and ambush by grass snakes *Natrix natrix* on European treefrogs *Hyla arborea*

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In 2011 and 2012, I observed foraging and the use of arboreal ambush sites by grass snakes (*Natrix natrix*) in a melaphyre quarry in Tłumaczów (SW Poland; 50˚ 33'10" N, 16˚ 25'56" E; 350 m a.s.l.) (Fig. 1A). The bottom of the quarry contained a pond (ca 1 ha in area) and around the pond shoreline willow shrubs up to 3 m high were growing partly out of the water in clusters (Fig. 1A). As the only tall objects at the edge of the pond, these shrubs were being used by European treefrogs (*Hyla arborea*) as diurnal hiding places from which they began to vocalise after dark. There were birch (*Betula* spp.) and the Eurasian aspen (*Populus tremula*) near the pond but neither *N. natrix* nor *H. arborea* were observed on them.

On my first visit to the quarry, on 28th June 2011, several juvenile snakes (not exceeding 40 to 50 cm) foraged, ambushed, and swallowed adult tree frogs which had been resting on the branches of willows (*Salix* spp.) at heights ranging from 0.5 to 2 m.

More detailed studies were undertaken in 2012. From 21 March to 29th April 2012, using drift fences, 71 specimens of *H. arborea*, all of them male, were caught. Also present at the site was a large populations of newts – the Alpine newt *Ichthyosaura alpestris*, the smooth newt *Lissotriton vulgaris*, the great crested newt *Triturus cristatus* (all newts together totalling about 3000 adults) – and a breeding population of the common toad *Bufo bufo* (no more than 100 adults) (Kaczmarski et al., unpublished data). Three further visits to the site (18th May, 19th May & 23rd June 2012) where made which allowed further observation on the grass snakes and treefrogs. During the day and on warm nights, grass snake adults and juveniles were observed regularly searching for

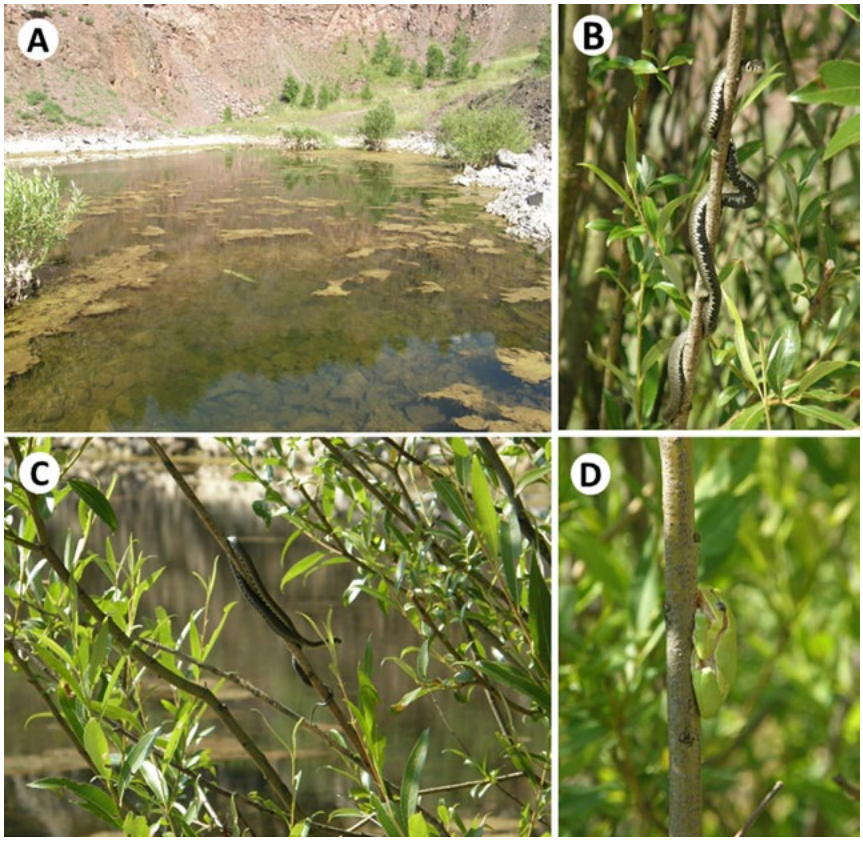

Figure 1. A. Study site in Tłumaczów quarry (Poland) 28 June 2011, B. & C. Ambush by grass snakes (*Natrix natrix*), D. European treefrog (*Hyla arborea*) on the branches of a willow *Salix* spp.

amphibians and consuming newts near the pond and the drift fences. However, grass snakes were observed on shrubs only after the start of the *H. arborea* mating season, i.e. after 20 April. Grass snakes were often observed on branches as high as 2 m above the ground, either actively looking for resting *H. arborea* or remaining in an ambush position (Fig. 1B & C). All these grass snakes were both timid and vigilant and after detection by an observer moved rapidly along the branches and sometimes directly into the water. Consequently, I was unable to photograph the moment when these snakes swallowed treefrogs. Most of these grass snakes were approximately 40–50 cm in length, and thus should be considered juveniles or young males. Adult females and males were mainly observed foraging among boulders and stones, but never on willow branches.

The grass snake is a generalist predator, feeding largely on various amphibians and, much less often, on other vertebrates (Gregory & Isaac, 2004) or invertebrates (Consul, Eger & Kwet, 2009). Treefrog species (*Hyla* spp.) have been reported relatively rarely as prey for *N. natrix* but the Sardinian grass snakes (*Natrix natrix cetti*) is reported as an active hunter in water with the adults and tadpoles of *Hyla sarda* as their main prey (Capula, Rugiero & Luiselli, 1994). There are previous reports of *N. natrix* climbing, where the authors speculate that this enabled the snakes to warm up in the sun and/or search for prey (Bringsøe & Aastrup, 2017). However, the current report appears to be the first description of several relatively small specimens of *N. natrix* regularly hunting adult *H. arborea* on branches and displaying an ability to balance on thin, flexible willow branches when searching for food.

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NATURAL HISTORY NOTE

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Davian behaviour in the threatened California red-legged frog *Rana draytonii*: more than just a waste of time

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Davian behaviour, also variously referred to as necrogamy (Bettaso et al., 2008), necrophilia (Cortés Bedoy et al., 2014), and misdirected copulation (Ayres, 2010), is an event during which a live individual attempts to mate with a dead individual for reproductive gain (Ayres, 2010). This behaviour has been observed in amphibians (Bettaso et al., 2008), reptiles (Costa et al., 2010), birds (Lehner, 1988), and mammals (Dickerman, 1960), but appears to be most common among anurans (Pearl et al., 2005). Alvarez (2011) reported Davian behaviour between a western toad (*Bufo boreas*) and California red-legged frog (*Rana draytonii*); that observation, however, would have been more appropriately referred to as interspecific amplexus because neither individual was dead. Herein we report two observations of Davian behaviour in the threatened California red-legged frog.

In 2001, while conducting daytime monitoring surveys to assess reproduction in California red-legged frogs within mitigation wetlands in Contra Costa County, California, USA, the senior author encountered a live adult male California red-legged frog in pectoral amplexus with a dead adult female conspecific (Fig. 1). The pair was photographed but not handled. Amplexus occurred along the water's edge (approximately 5 cm from the pool edge and in water 2 cm deep), and adjacent to a patch of cattail (*Typha* sp.). When encountered, the male was clasped tightly to the female's thoracic region. The female was in a very early state of decomposition, and showed evidence of having been ovipositing at death, or that eggs had been forced outward by the compressive force of the male.

Figure 1. An adult male California red-legged frog engaged in Davian behavior with a dead adult female conspecific in the early stages of decomposition (Contra Costa County, California, 2001)

In 2016, we were again conducting daytime monitoring surveys in a drain adjacent to the first observation when we similarly encountered a live adult male California red-legged frog in pectoral amplexus with a dead adult female conspecific. Amplexus was observed along the water's edge (approximately 30 cm from the pool edge and in water 20 cm deep), amidst a patch of dead cattail (*Typha* sp.). The small adult male was clasped very tightly to the female's thoracic region. The female was partially decomposed, with a thin film of fungal hyphae covering the majority of her body (Fig. 2). Despite handling and photography, the male did not disengage from the female.

Figure 2. An adult male California red-legged frog engaged in Davian behaviour with a dead adult female conspecific in 2016. The female is partially decomposed and acquiring a film of fungal hyphae.

Davian behaviour has been considered a possible ecological trap because persistent necrophilic males may lose or experience diminished opportunities to successfully reproduce during the (often brief) breeding season (Ayres, 2010). Magnhagen (2003) suggested that the risk of predation may also increase during Davian behaviour due to the lengthy hyperfocus of the male. This contention is supported by our observation, in that neither the proximity of the four observers (in the 2016 event) nor a brief period of photography (2001) disturbed the respective males. Risk of predation rises even more if, as in these examples, the behaviour occurs during daylight and in shallow water.

Under some circumstances there might be potential gains from Davian behaviour as at least in the beaked toad (*Rhinella proboscidea*) necrophilic males may be able to squeeze eggs from dead females and fertilise them (Izzo et al., 2012). This occurrence may be rare as it has not been reported for other species. Our 2001 observation did include a small (20-25) number of ejected eggs at the cloaca of the female California red-legged frog. We made no attempt to determine if these eggs were fertilised. In the case of California red-legged frogs, however, females typically attach the egg mass to vegetation at or near the surface (Storer, 1925; Alvarez et al., 2013) in water that is, on average, 38 cm deep (Alvarez et al., 2013). In this case, the ejected eggs, which would typically number 2,000 to 6,000, were resting on the hind legs of the dead female in water approximately 2 cm deep. If this small number of eggs were fertilised, we contend that the conditions were not appropriate for their development, resulting in no fitness gains for the male or female.

Alvarez (2011) reported male western toads, a sympatric species with California red-legged frog, in amplexus with a variety of objects, including a root ball, cattle dung, a dead conspecific, and a live female *R. draytonii*. Bateson (1983) suggested that an explosive breeding reproductive strategy, as in the western toad, may contribute to misdirected amplexus, including necrogamy (i.e., Davian behaviour). As the California red-legged frog is not considered an explosive breeder, it follows (sensu Bateson, 1983) that Davian behaviour would be expected to be less common in this species. Our temporally-spaced observations of Davian behaviour in 2001 and 2016, on a site where breeding-season California red-legged frog surveys are conducted annually, suggests that it is not common; we calculated a rate of observation at less than 0.0003 %. Alvarez (2011) suggested that temporally compressed breeding events, which periodically occur at this site due to prolonged drought, may result in increased breeding pressure from conspecifics and sympatric anurans, thereby contributing to misdirected amplexus behaviour (i.e., non-conspecifics) by males.

Inasmuch as Davian behaviour may represent an ecological trap for some individuals, it also represents a confounding stressor on a threatened species.

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NATURAL HISTORY NOTE

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Self-inflicted bites by two venomous snake species: Medo's pit viper *Trimeresurus medoensis* and lesser black krait *Bungarus lividus*

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Cases of self-envenomation in snakes are not uncommon. However, deaths in most cases were associated with stress or internal disease, as evident from necropsies, rather than envenomation alone (Peterson, 1990). Of the cases considered by Peterson (1990) the deaths of *Crotalus atrox* and *Ophiophagus hannah* following their own bites were not solely due to venom, while *Coniophanes fissidens*, *Micrurus fulvius tenere*, and *Bungarus flavicep* all survived their bite despite some ill effects. In a case of self-envenomation by *Boiga irregularis* death appeared to be due to envenomation alone (Hill & McKillop, 2017). In this report we describe two cases of self-inflicted bites by two venomous snakes both of which subsequently died.

Medo's pit viper *Trimeresurus medoensis* Zhao, 1977

On 21st August 2011, an adult *Trimeresurus medoensis* was rescued from a kitchen garden in the Malki area (25° 33'37.09"N, 91° 53'24.01"E) of Shillong, Meghalaya, India at around 08:00 h. The snake was bagged and was to be released into the nearby forested area the next day. The following morning when the bag was opened to examine the snake, it was found dead, biting its midbody (Fig. 1). The dead specimen was then preserved in 4 % formalin but after 3 days it was noticed that the body posterior to the bite was significantly decomposed while the area anterior to the bite was relatively well preserved. This suggests that death occurred soon after the bite since the venom appears not to have spread throughout the body but was confined. This provides some evidence that the envenomation was the cause of death and that this species is not immune to the effects of its own venom.

Figure 1. A dead *Trimeresurus medoensis* following a self-inflicted bite

Figure 2. A dead *Bungarus lividus* following a self-inflicted bite (left); 3rd infralabials punctured by the fangs (right)

Lesser black krait *Bungarus lividus* Cantor, 1839

On 4 March 2020, a sub-adult *Bungarus lividus* was rescued from the Geetanagar area (26° 10'15.15"N, 91° 47'19.65"E) of Guwahati, Assam, India. On the way back from the rescue site, the snake was found dead within the bag. Initially we believed that the snake died due to stress or because of coming in contact with carbolic acid sprayed at the rescue location. On closer examination we spotted two puncture marks on the lower lip of the snake just below the fangs (Fig. 2). Apart from the puncture marks, no other visible damage was seen on the snake. It is unclear whether the envenomation was the actual cause of death.

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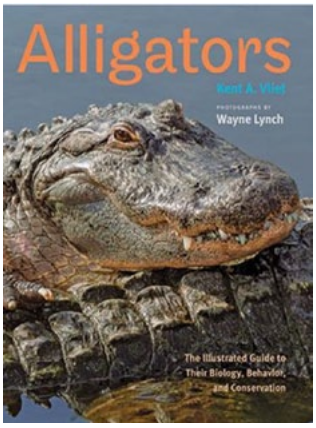
Alligators – The Illustrated Guide to Their Biology, Behaviour, and Conservation

Kent A. Vliet with photographs by Wayne Lynch
John Hopkins University Press, ISBN 9781421433370 (hard cover), pp 293.



Biologist, educator, and crocodilian researcher, Dr. Kent Vliet, combines his expertise in American alligator biology and behaviour with his communication skills to create a comprehensive work on the American alligator that unravels many of the mysteries of alligator natural history. He teams up with talented photographer, Wayne Lynch, who connects many of the biological traits presented in the book with outstanding photographs. 'Alligators' covers all aspects of alligator biology, including conflicts with humans, and targets the general public and enthusiast rather than professional scientist.

The book provides one of the best accounts of the European discovery, classification, and scientific naming of the American alligator with the most complete description of its historical range that I have read, particularly at the range extremes in Virginia and the Rio Grande. Ten common myths and misconceptions about alligators are listed and thereafter debunked or clarified. In Chapter 2, there are outstanding accounts of both paleohistory and the more recent association between alligators and indigenous Americans, after which there is an interesting review of the relationship between early European settlers and alligators. Chapter 3 delivers a broad and detailed study of alligator anatomy and an excellent examination of the alligator's sensory system, including an explanation of how these senses have helped alligators to thrive for millions of years. Chapter 4 offers an overview of alligator habitats, salt tolerance, shaping of microhabitats, movements, and navigation. Chapter 5 gives an in-depth treatment of thermoregulation including response to cold weather and a short assessment of possible climate change impacts on distribution and population viability. Chapter 6 details feeding and predatory behaviour while Chapter 7 presents the evolution and systematics of the Crocodilia supported by an exceptionally clear account of the most recent findings of DNA analysis, accessible to a general audience. Vliet's ground-breaking research and observations on alligator courtship, mating, and copulation are presented in Chapter 8 while Chapter 9 presents detailed descriptions of nest construction, egg laying, embryo development, and hatching. Chapter 10 covers the early life of alligators and the high mortality suffered at this stage, alligator longevity in captivity, and an account of the debate about the maximum size of alligators. Chapter 11 describes the general social behaviour of alligators from birth to adulthood, including social hierarchies, breeding behaviour, vocalisations, and other fascinating aspects. Chapter 12 assesses the problems encountered as alligator country becomes more populated with humans and in Chapter 13 the history of alligator exploitation and conservation is discussed. Finally, there is a nice appendix, 'Where to See Wild Alligators', for those readers wanting to follow up with an in-person experience of these creatures.

Those familiar with Vliet's scientific research on alligator behaviour by might be disappointed that this book has no bibliographical references. Consequently, some readers will be unsure whether statements are based on scientific studies by others or on Vliet's interpretation of previous works. Nevertheless, Vliet does an admirable job of presenting various sides of arguments for most of those issues that are still being debated by the scientific community.

There are several concepts presented in the book that are either scientifically equivocal or have been dispelled. Among those is a central theme that the American alligator was "… close to extinction in the 20th Century" (dustcover), "… reduced to rarity by the 1950s and 1960s" (p. 7), "… concern about the alligator's pending extinction." (p. 40), and "… we might have seen the American alligator go extinct" (p. 248). Since the 1970s, as our understanding of alligator population dynamics has advanced the view that alligators were on the brink of extinction has been widely refuted. Population estimates of 250,000 – 400,000 alligators remaining in the late 1960s, presented in Chapter 13 entitled 'From Slaughter to Salvation', do not match up with the notion of near extinction. Neither does a population estimate presented in the section entitled "The Comeback" of 734,000 alligators remaining shortly after they received federal protection in 1970. But the misconception that alligators were close to extinction is planted early in the book and will likely stay with the reader, despite subsequent information that weakens this notion. In addition, Vliet's estimates of pre-Ponce de Leon alligator populations, late 1960s populations, and current population are also debatable.

Several other less important concepts and debates about crocodilians are presented that appear to be factually incorrect. But these should not overshadow the overall reliability of the book. All in all, 'Alligators' is a wonderful introduction to all aspects of alligator natural history for the general public and an enjoyable read for professional scientists interested in alligators and their relatives.

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THE HERPETOLOGICAL BULLETIN

Contents: Issue 154, Winter 2020

RESEARCH ARTICLES:

SHORT NOTES:

SHORT COMMUNICATIONS:

NATURAL HISTORY NOTES:

BOOK REVIEW:

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