Rapid Communication

New record of the invasive red-eared slider *Trachemys scripta elegans* (Wied, 1838) on the Qinghai-Tibetan Plateau, China

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Abstract

Freshwater organisms are facing rapid population declines and substantial extinction risks, and invasive species represent one of the significant drivers of freshwater biodiversity declines. Aquaculture practices and trade activities in China are expansive, and the establishment of nonnative freshwater species is widespread. The red-eared slider *Trachemys scripta elegans* (Wied, 1838) is one of the world's worst invasive species, and this species is traded nationally both in food and pet markets in China. Red-eared sliders had entered native ecosystems through escapes and intentional releases in China. However, investigations mostly have focused on eastern and central China. Here, we present results of a field survey reporting a new distribution of red-eared sliders on the Qinghai-Tibetan Plateau, which is a conservation priority area located in western China. Forty-one individuals in three plots were observed in 2019 and 2020. Four individuals were captured, and no individual was sexually mature. The average carapace length and body weight of the specimens were 70.57 (± 13.071) mm and 50.70 (± 8.087) g, respectively. Red-eared sliders might negatively influence biodiversity since there are no native testudine species in this region. Thus, we suggest putting more effort into monitoring red-eared sliders and other nonnative species, discouraging unscientific animal release, and emphasizing the threat of releasing nonnative species to the public.

Key words: inland waters, testudines, Asia, nonnative, animal release

Introduction

Freshwater ecosystems (not including wetland ecosystems) host almost 9.5% of the Earth's recorded animal species, including one-third of the vertebrates (Balian et al. 2008), and indicators such as the World Wide Fund for Nature (WWF) Living Planet Index (LPI) showed freshwater organisms are facing rapid population declines and substantial extinction risks (Collen et al. 2014; WWF 2016). Invasive species represent one of the significant drivers of freshwater biodiversity declines (Dudgeon et al. 2006; Reid et al. 2019), and biological invasions are increasing as a result of international trade and globalization (Simberloff et al. 2013). Developing countries undergoing rapid economic growth can be especially vulnerable

to such introductions that are driven by new commercial opportunities (Pelicice et al. 2014). China is the largest developing country, and it has been severely affected by alien species invasions, for example, imported red fire ants (*Solenopsis invicta*) have caused hundreds of human injury events and crop damage every year (Zhang et al. 2007). More than 500 invasive alien species have been identified on the mainland, and they have caused substantial environmental and economic losses (Ministry of Ecology and Environment PRC 2014a). Aquaculture practices and trade activities in China are expansive and have resulted in the widespread establishment of nonnative freshwater species and fundamental changes in biodiversity (Liu et al. 2017).

The red-eared slider (RES) *Trachemys scripta elegans* (Wied, 1838) is one of the 100 world's worst invasive alien species, and the only testudine species listed on the IUCN SSC Invasive Species Specialist Group's Global Invasive Species Database (GISD 2020). It is native to the southeastern United States but has been introduced in many countries outside its natural range (Kraus 2009). The threats caused by RES are especially worrisome in Asia since massive numbers of individuals are imported, sold and released while many indigenous testudine species are threatened in Asian countries such as Singapore, China, Vietnam and Japan (Ramsay et al. 2007). RES was introduced to mainland China in the 1980s (Shi et al. 2009) to meet a demand for food and traditional Chinese medicine, following which it became popular and the dominant species in the pet market, too (Gong et al. 2009). National (i.e. domestic) trade and large-scale captive breeding made RES easy to purchase in China, followed by widespread release and escape of this species, through which many individuals entered urban and rural habitats in China (Gong et al. 2018).

After the RES entered native ecosystems through escapes and intentional releases, the Ministry of Ecology and Environment of the People's Republic of China listed the RES in the List of alien invasive species in China (the third batch) (Ministry of Ecology and Environment PRC 2014b). However, there is no specific restriction on farming and trading of RESs, and the species is still successfully entering the market and natural environments (Gong et al. 2018). In 2010, RESs were captive bred in 17 provinces (34 provincial-level administrative regions), sold nationally, released in 18 provinces and distributed within natural environments in 22 provinces in China (Liu 2011). Although studies have investigated the distribution of RESs in eastern and central China, few reports have focused on the western region, especially the Qinghai-Tibetan Plateau (QTP).

The QTP is located in Central and East Asia, with an area of approximately 2,500,000 km^2, and is renowned as "the roof of the world" or "the third pole" for its high elevation (over 4,000 meters above sea level on average) (Kang et al. 2010). The extensive variation in the topography and climate of the QTP generates a number of different habitats and supports abundant

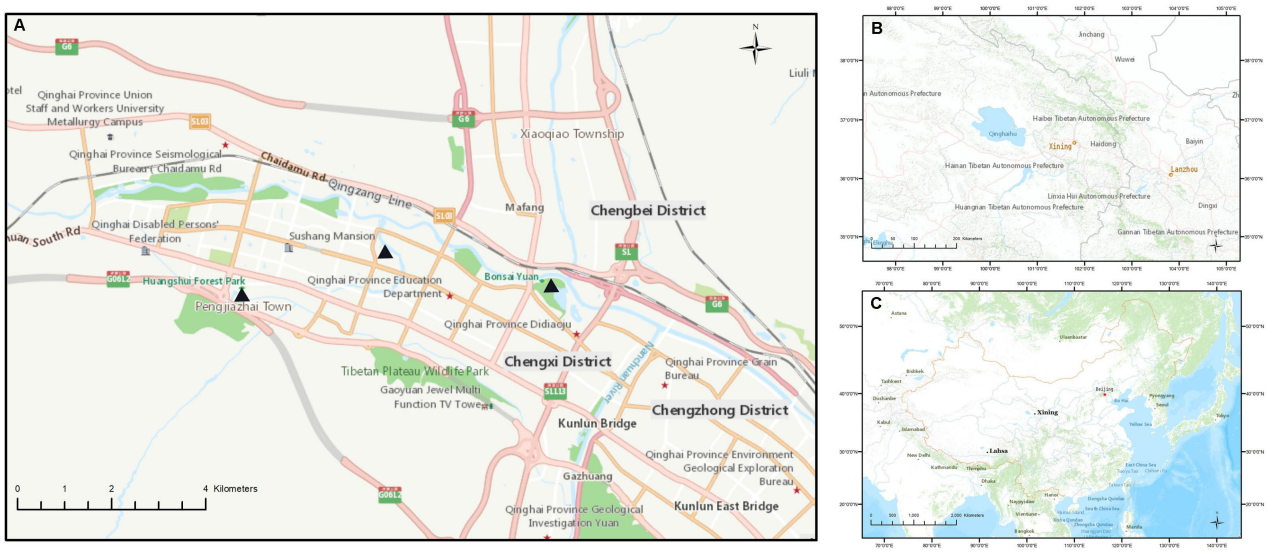

Figure 1. Distribution of three plots with RESs (*Trachemys scripta elegans*), in Xining, Qinghai Province, China. The black triangles in (A) represent the plot with RESs, (B) indicates the location of Xining in Qinghai Province, (C) indicates the location of Xining and Lahsa.

species diversity, and biodiversity in the QTP is threatened by biological invasions (Mittermeier et al. 2011; Li et al. 2016). American bullfrogs (*Rana catesbeiana*), topmouth gudgeon (*Pseudorasbora parva*) and other alien species have established populations in this area (Migmar et al. 2014; Xiong et al. 2015), with nonnative fishes having been documented to cause biodiversity changes in several major basins (Liu et al. 2015). However, few field surveys have reported on alien reptiles, with the exception of one RES individual found in Lhasa (Figure 1C) (Fan et al. 2016). Here, we report on new occurrences of invasive RESs in the QTP.

Methods and results

The field survey was conducted through visual observations from 25 June to 4 August 2019 and from 5 July to 4 August 2020. The survey was implemented in nine major cities that across two provinces Qinghai and Tibet. The line transect method was used in both natural and artificial habitats, including rivers, wetlands, lakes, and canals. The transect lines were set at 200 to 400 meters in length depending on the habitat conditions, and every sample plot contained 3 to 5 lines, with the survey of each line completed in 10 to 20 minutes (i.e. approximate rate of 1.2 km/h). Transect survey in each plot was conducted continuously each time, and it occurred once to three times during different days (between 10:00 and 16:00) and was repeated at least once during the night (between 20:00 and 24:00). For each plot, the sum on each occasion was counted and took the highest number as final result. Two to three researchers constituted a team, one of the members observed and photographed the animals, and the others confirmed and recorded the observations. No binoculars were used in the survey, but a digital camera (focal length:18–135mm) was used to capture

Table 1. Occurrences of RESs and details of each plot.

Plot		Renmin Park	Renmin Park	Huangshui Forest Park	Baishatan Park
Number of RESs	Small	3	12	1	3
	Middle	2	10	2	1
	Large	0	5	2	0
Date		02.08.2019	07.07.2020	20.07.2020	18.07.2020
Latitude		36.6422°N–36.6455°N	36.6422°N–36.6455°N	36.6437°N–36.6446°N	36.6504°N–36.6538°N
Longitude		101.7682°E–101.7705°E	101.7682°E–101.7705°E	101.7069°E–101.7080°E	101.7347°E–101.7391°E
Altitude (meters above sea level)		2228.52–2237.91	2228.52–2237.91	2291.35–2298.68	2249.97–2273.66
Acreage		5.17 ha	5.17 ha	0.98 ha	2.91 ha
Number of line		4	5*	3	4
Habitat		Lake	Lake	Lake	River

Illustration: * the transect lines in Renmin Park 2020 are the same lines with 2019, one line was added in the adjacent bank of the Huangshui River, no RESs is found in this line. Although this line located outside the park, it is linked with the lake and the distance is short (about 150 m), the line is calculated in the Plot.

images and magnify details. Identification was based on the following morphological characters: red stripe on each side of the head; elongate and pointed snout; absence of an elongated, black-bordered yellow spot on chin at corner of mouth; plastron with either a dark blotch on each scute, with a dark, elongated, medial blotch; and green skin (Ernst et al. 1994). Photographs were taken of each individual; every stationary RES in the transect lines was counted, while moving RESs were not counted to avoid double-counting. Five types of information were recorded: time of observation, location, habitat, species and size of each individual. Since we could not measure each one accurately, the RESs were divided into three categories by the carapace length: Small individuals were under 100 mm, Middle individuals were about 100 mm to 150 mm, and Large individuals were over 150 mm (Fish and Stayton 2014; Taniguchi et al. 2017). Specimens were captured with fyke nets after all the surveys were performed in the affirmed plots.

RESs were observed in three plots, Renmin Park, Huangshui Forest Park and Baishatan Park, and all the plots were located in Xining (Figure 1A). Five individuals were observed in 2019 (6 to 8 August), and 36 individuals were recorded in 2020 (6 to 19 July), including 19 small individuals, 15 middle individuals and 7 large individuals (Table 1). All individuals were observed in the day, and the density was 1.374 individuals/ha (Baishatan), 5.102 individuals/ha (Huangshui) and 5.222 individuals/ha (Renmin). Four specimens were captured in total, no specimen was sexually mature (Figure 2C), and the average carapace length and body weight of the specimens were 70.57 (± 13.071) mm and 50.70 (± 8.087) g, respectively.

Discussion

All three plots with RESs are influenced by humans; two are artificial lakes, and the other plot is in a branch of the Huangshui River, which is utilized

Figure 2. RESs in Renmin Park, Xining (A), the habitat of Huangshui Forest Park (B), one RES specimen caught by fyke net (C). Photographs by Teng Deng.

for its scenic value. To investigate the source of RESs, three officers and five frequenters (citizens who are familiar with the three plots, and visit the park to fish or exercise regularly or frequently) were interviewed, the interviewees stated most of the mature RESs were released, while the source of juveniles is not clear. Four pet markets and seven food markets were surveyed, and RESs were frequently found, with the lowest price (ranging from 5 Yuan to 150 Yuan or approximately 0.7 US dollars to 20 US dollars), with approximately 3,000 individuals recorded on sale at the four pet markets. Two vendors stated that they sold over a thousand RESs every year, and the majority of the RESs were released.

For reptiles, the total number of introduction events and the total number of successfully established introductions show that intentional release is the most important introduction pathway (Kraus 2009; Kikillus et al. 2012). Although we could not confirm that the population in QTP is self-sustaining since we did not find any evidence of reproduction, the RES nevertheless threatens the local biodiversity. The three habitats where they are found are linked to rivers, and the individuals could easily reach more habitats. RESs have caused serious biodiversity losses worldwide, and carry pathogens (*Salmonella* spp.) that are infectious to many species, including humans (Woodward et al. 1997; Shen et al. 2011). Research has shown that RESs ingest animal material more frequently than plant material on mainland China (Zhang et al. 2020), indicating that they might enhance predation pressure on local aquatic organisms and change ecosystems.

The climate conditions on the QTP are different from those in RES native habitats (Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia) (Rhodin and Carr 2009), and Species Distribution Models (SDMs)

have also predicted this area to be not suitable for RESs (Rödder et al. 2009). Localised differences might explain the occurrences of RESs in QTP; the urban habitat and climate condition in the city might be more suitable than other parts of the QTP region (Wei et al. 2003; Shen et al. 2018). Another possible explanation for RES occurrence in QTP could be niche shift, where a release from biotic and abiotic constraints, such as the absence of competitors, predators or pathogens or the availability of empty niches, may lead to a niche shift in an introduced range (Mitchell and Power 2003; Torchin et al. 2003; Hierro et al. 2005; Li et al 2016). Previous studies showed that the RES nonnative realized niche is greater than its native niche, and its entire temperature tolerance range is not fully used (Espindola et al. 2019). This is particularly true in Asia, where the species has been shown to occur in an area with a broader range of precipitation conditions than the ranges on all other continents (Rodrigues et al. 2016). To prevent further invasion of RESs and other nonnative species in this area, we suggest: 1) putting more effort into monitoring RESs and nonnative species both in natural environments and at the markets in this region; 2) discouraging unscientific animal release, or at least supervising the release of animals to ensure that only native species are released into nature rather than nonnative; and 3) emphasizing the threat of releasing nonnative species to the public.

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Authors' contribution

Teng Deng, Yu Li, Jiaqi Zhang, Wenhao Li and Chunxia Xu conducted the survey, Teng Deng and Yiming Li wrote the paper.

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