

Rapid Communication**First report on the natural breeding of river cooter, *Pseudemys concinna* Le Conte (1830), in the Republic of Korea**Kyo Soung Koo¹, Hakyung Kang², Ajoung Kim³, Sera Kwon³, Ming-Feng Chuang⁴, Jae Young Seo¹ and Yikweon Jang^{2,3,*}¹Research Institute of EcoScience, Ewha Womans University, Seoul 03760, Republic of Korea²Division of EcoScience, Ewha Womans University, Seoul 03760, Republic of Korea³Interdisciplinary Program of EcoCreative, Ewha Womans University, Seoul 03760, Republic of Korea⁴Department of Life Sciences, National Chung Hsing University, Taichung 40227, Taiwan

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OPEN ACCESS**Abstract**

Pseudemys concinna (River cooter) is native to the United States. Although the turtle is invasive to many countries around the world, successful breeding in the wild is confirmed only in the Iberian Peninsula. River cooters have been imported into the Republic of Korea, hereafter Korea, since early 2000s and sold nationwide. Due to discovery in the wild, they were designated as an invasive species in March 2020, and the import and trade of this turtle were banned. This paper reports two cases that serve as evidence for the successful settlement of the river cooter introduced in Korea. On June 27, 2019, a female *P. concinna* and her nest were found at a public park in Yangcheon-gu, Seoul, the Republic of Korea. Two out of 12 eggs were on the verge of hatching. On October 17, 2019, however, all eggs were found dead. On April 6, 2022, two hatchlings of *P. concinna* presumed to be born in 2021 were found in Geumho Reservoir, Jinju City. One of the hatchlings was captured on April 27, 2022. Successful breeding in the wild suggests that *P. concinna* has settled in Korea's natural environment.

Key words: invasive species, reptile, turtle, natural nesting, East Asia**Introduction**

The river cooter, *Pseudemys concinna*, is a non-native turtle that was actively imported after the import ban of *Trachemys scripta elegans* in the Republic of Korea, hereafter Korea. *Pseudemys concinna* is native to the central and eastern parts of the United States, and the species has been introduced to many countries, including Germany, Portugal, Spain, Mexico, Taiwan, Singapore and Korea (<https://GBIF.org>). The breeding of *P. concinna* outside of its native country was only reported in Portugal and Spain. In Portugal, a *P. concinna* laid 21 eggs in the wild, but 16 failed to hatch, and five were hatched artificially (Alves et al. 2016). Six young *P. concinna* were found in a private garden in Braga, Portugal (Alves 2012), and young turtles (40–55 mm in length) were found in Spain (Alves et al. 2016). However, there has been no report of successful breeding, outside of the Iberian Peninsula until now.

Pseudemys concinna is found in habitats similar to those inhabited by *T. s. elegans* (Alves et al. 2016). Moreover, *P. concinna* can grow to a size larger than *T. s. elegans*, which has possibly become a bigger threat to the surrounding ecosystem. They were sold at low prices of about 10 dollars in Korea and can easily be bought from supermarkets throughout the country (Koo et al. 2020a). According to a recent survey, *P. concinna* was the second most common non-native turtle found in the wild in Korea, after *T. s. elegans* (Koo et al. 2020b). In March 2020, the Korean government designated the species as invasive, considering its potential spread and impacts on the natural ecosystem (Ministry of Environment 2020).

Typically, the invasion of a non-native species is caused by natural factors such as climate change, but also by the development of transportation and the expansion of pet trade (Sung and Fong 2018; Koo et al. 2020a, b). Non-native species have great impacts on indigenous ecosystems (Weitzman et al. 2019), through competition (Cadi and Joly 2003) and predation (Savidge 1987; Lovich et al. 2011). They can even lead to population decline or extinction of native species (Gurevitch and Padilla 2004). In addition, the social and economic costs in managing the problems caused by non-native species are enormous (Bacher et al. 2018).

The increased import of non-native species leads to increased influx into natural ecosystems (Koo et al. 2020a). One of the main reasons for non-native turtle's introduction into the wild is the abandonment by former pet owners (Ministry of Environment 2001; Sung and Fong 2018). Turtles are small and cute when they are young but can grow to large sizes which become hard to accommodate in term of space and cost. Snapping turtles, such as *Chelydra serpentina* or *Macrochelys temminckii*, grow to be very large and aggressive (Elsley 2006). Many owners release such large turtles into the wild rather than killing or taking them to appropriate wildlife rescue centers.

Here, we report the first case of the natural breeding of *P. concinna* in Korea. Our results represent warning to many countries where *P. concinna* has been imported and provides a basis for establishing management strategies for non-native turtle species.

Materials and results

The breeding of *Pseudemys concinna* was discovered at a public park (37.528413°E; 126.830580°N, 34 m a.s.l.) located in Yangcheon-gu, Seoul, which is a metropolitan city with a population of about 10 million. The park has a reservoir with a circumference of 0.59 km and an area of 15,080 m², surrounded by shrubs and trees (Figure 1A). This park was frequented by people for a walk along the path around the reservoir and on the lawn where the turtle was found.

On June 27, 2019, we discovered the nesting of *P. concinna*. We initially found a female *P. concinna* (straight carapace length: 266.0 mm, straight carapace

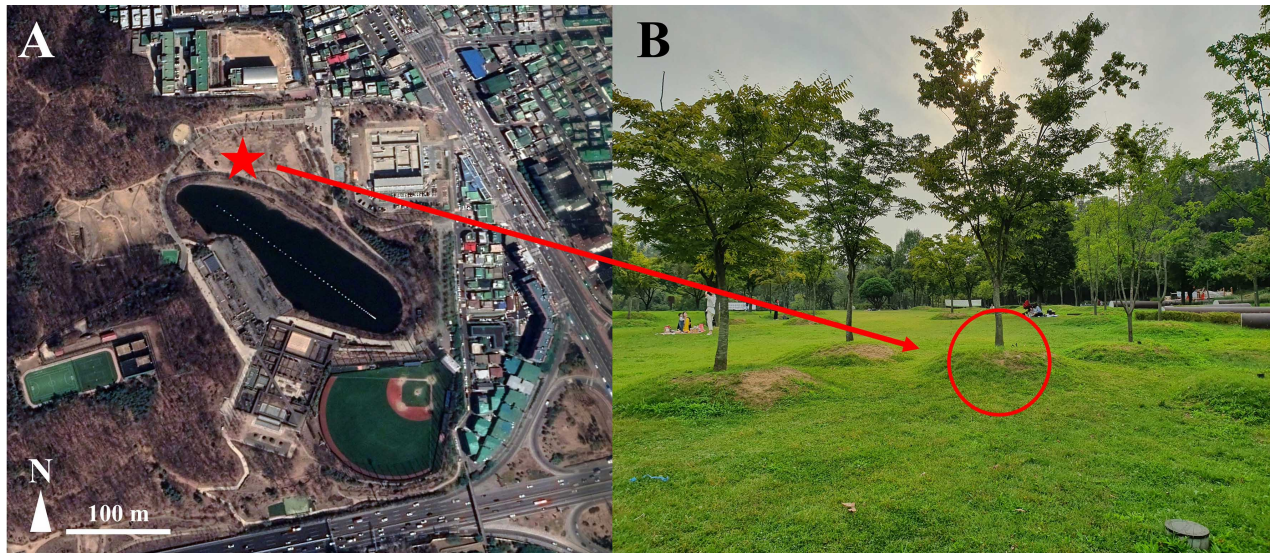


Figure 1. A nest (red star) of *Pseudemys concinna* in a public park, Seoul, the Republic of Korea (A). The nest was found at the base of a tree (red circle) in the northern part of the park (B). Photograph by Kyo Soung Koo.

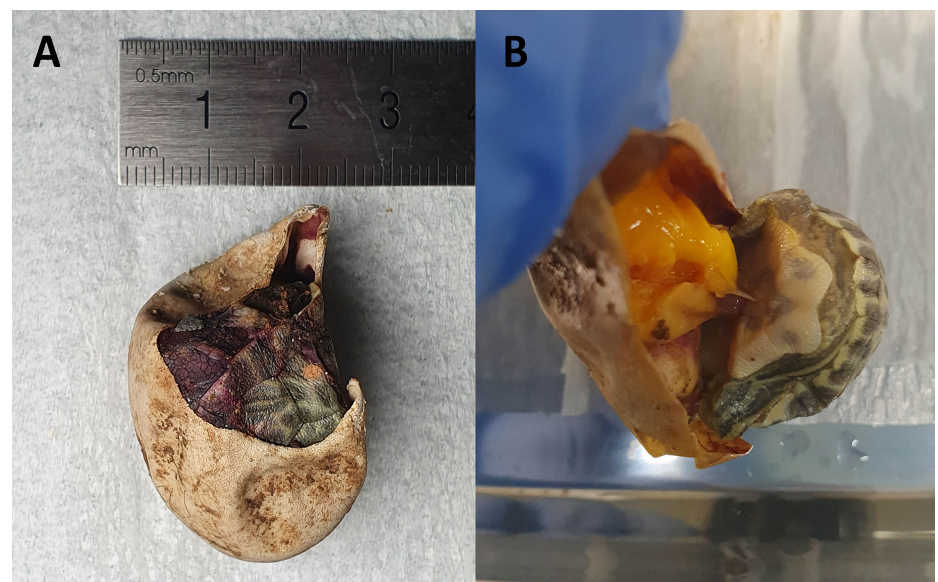


Figure 2. A specimen found from the nest of the *Pseudemys concinna* (A). A dead turtle has an unabsorbed yolk (B). Photographs by Sera Kwon.

width: 184.0 mm, carapace height: 97.0 mm) returning to the reservoir after laying eggs, and then discovered a nest nearby (Figure 1B). The turtle nest was in the mound of soil at the base of a tree in the northern part of the park (Figure 1B). The nest was located on a lawn, about 37 meters away from the reservoir, and the depth was about 10 cm deep underground. The nest was marked and left alone for further examination. Afterwards, we visited the site periodically to check the condition of the nest. On September 25, 91 days after the discovery, many ants were found inside the nest and on the eggshells, albeit there was no damage on the outside of the nest. One specimen at the top of the clutch was found dead (Figure 2A). The dead turtle had blood on its surface and the eggshell was slightly torn off (Figure 2A). The collected specimen was developed enough to distinguish

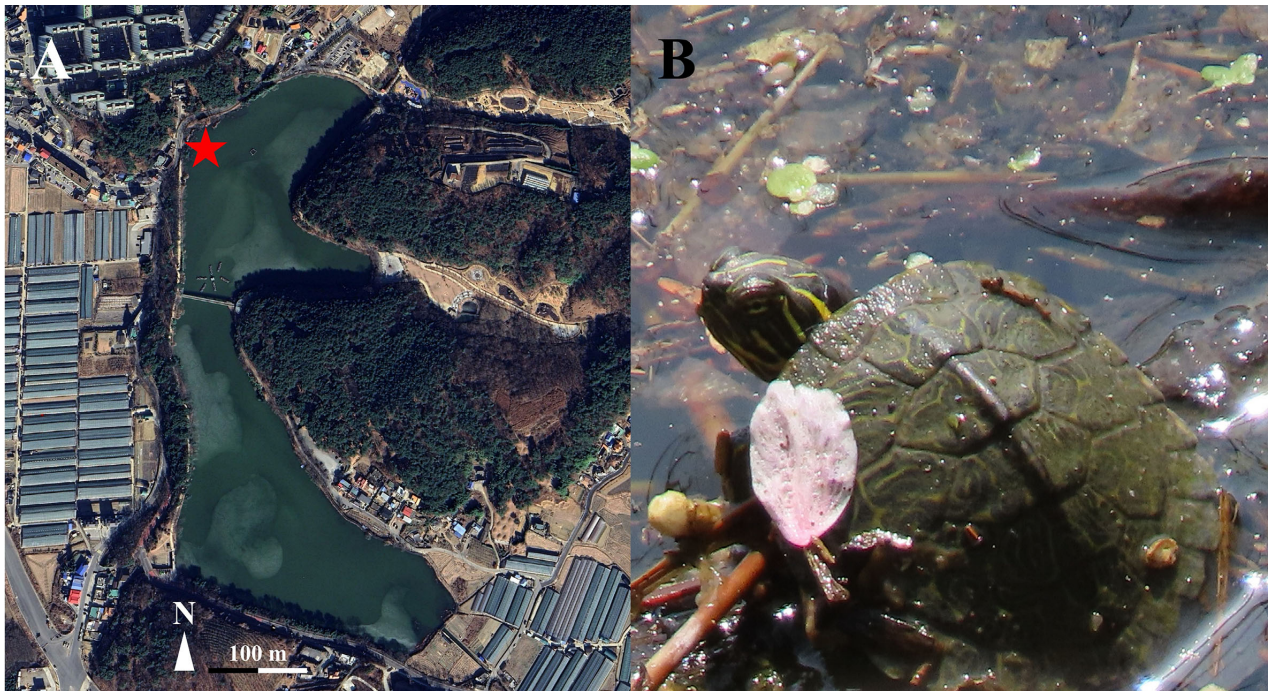


Figure 3. The map of Geumho Reservoir in Jinju (A) and the hatchling of *Pseudemys concinna* (B). The red dot indicates the discovered point of the turtle. Photograph by Kyo Soung Koo.

the species, but the yolk was not fully absorbed (Figure 2B). On October 17, 2019, 113 days after the first discovery of egg-laying, apprehensive of the sudden drop in temperature, we checked the inside of the nest, and found the rest had all died (two individuals in the developmental process and ten eggs). All the dead specimens were collected and kept in 70% alcohol for further study.

On April 6, 2022, we found two *P. concinna* hatchlings in Geumho Reservoir (35.209761°N; 128.152433°E, 37 m a.s.l.; Figure 3A). They were sunbathing on the north shore of the reservoir. The turtle's carapace length was estimated to be about 36.0 mm, given that the vertical length of the pink leaf with the turtle on it was about 12.0 mm (Figure 3B). Based on size, this turtle was presumed to be born in 2021. More than 20 hatchlings and juveniles of *T. s. elegans* were found nearby. A few weeks after, on April 27, we captured one hatchling with straight carapace length 40.1 mm, straight carapace width 36.5 mm, carapace height 21.8 mm and body weight 13.0 g in the same reservoir.

Discussion

We report the first case on the successful breeding of *Pseudemys concinna* in the Republic of Korea. There is a possibility that the hatchlings were recently released to the reservoir by pet owners. However, since import and trading of *P. concinna* were banned in March 2020, the possibility of release by pet owners is unlikely. Instead, this finding is a strong evidence of the settlement of *P. concinna* in Korea.

This study suggests that natural breeding may also occur in other turtles that inhabit similar environments. Red-eared sliders are successfully breeding and spreading out in Korea (Koo and Sung 2019; Koo et al. 2019). Moreover, the *Trachemys* genus (yellow-bellied slider, cumberland slider) and the *Pseudemy* genus (red-bellied cooter, peninsula cooter) are similar in habitats as those of the *P. concinna* and are found all over the country (Koo et al. 2020b). Recently, an individual *Macrochelys temminckii* succeeded at breeding in a semi-natural environment of a privately owned zoo in Korea (National Institute of Ecology 2014). Our results show that additional successful breeding of invasive turtles will be possible, since more than twenty non-native turtle species were found in the wild (Koo et al 2020b; *unpublished data*).

One of the main reasons for *P. concinna* introduction in the wild is that they are easily accessible in Korea (Koo et al. 2020a). They were available for purchase at cheap prices in numerous online and offline pet shops all around the country until the import ban in March 2020 (Koo et al. 2020a). *Trachemys s. elegans*, the first invasive turtle successfully bred in the wild in Korea, were also sold at very cheap price and widely available across the country (Ministry of Environment 2009). In addition, a vicious cycle is repeated where new species are imported, if a previously imported species is banned. Accordingly, a comprehensive ban of importing all turtles is required, followed by limited import through risk assessment.

The fertilized eggs were laid and developed in a park in Seoul, but they failed to hatch. There are possible reasons for hatching failure. First, the *P. concinna* nest might have been attacked by wild animals, such as stray dogs, raccoons or weasels that are often found near the park. However, this was unlikely because the nest was not dug up, so the chance of direct attack by animals seems low. Second, ant attack may be responsible for hatching failure. Although we found many ants in the turtle's nest, the ant attack may occur only after the nest was disturbed by other unknown causes (Buhlmann and Coffman 2001). Third, the *P. concinna* nest may have been disturbed by parkgoers or park keepers. Furthermore, herbicides are periodically sprayed for the management of grasses. These anthropogenic stresses may have prevented the eggs from hatching successfully. Lastly, the interference by researchers may be an underlying cause for hatching failure. We dug up the nest to check the number and condition of eggs, which might have changed the optimal condition for hatching in the nest. We could not clearly explain how and why the eggs failed to hatch. However, understanding the cause of this failure is helpful for developing effective management strategies of invasive turtles.

In this study, we confirmed the successful breeding of a non-native species, *P. concinna*, in the Republic of Korea. This case shows *P. concinna* settling in the natural environment of Korea. As the world is becoming

globalized, the problem of invasive species continues to rise. We hope that this study serves as a warning to other countries with similar problems, leading to an opportunity for countries to work together to find management practices for non-native species.

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Authors' contribution

Research conceptualization; KSK, YJ, Sample design and methodology; KSK, YJ, Investigation and data collection; HK, AK, SK, MFC, JYS, Data analysis and interpretation; KSK, HK, MFC, Funding provision; YJ, Roles/writing – original draft; KSK, Writing – review and editing; KSK, YJ, Supervision: YJ.

References

- Alves A (2012) Tartarugas exóticas ameaçam biodiversidade. *Revista Parques e Vida Selvagem* 41: 37
- Alves A, Martínez-Silvestre A, Alves A, Martins JJ (2016) Are the invasive species *Trachemys scripta* and *Pseudemys concinna* able to reproduce in the northern coast of Portugal? In: International Symposium on Freshwater Turtles Conservation (Vila Nova de Gaia, 22-24 May 2013). Águas e Parque Biológico de Gaia, Portugal, pp 15–24
- Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkillä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roy HE, Saul WC, Scalera R, Vilà M, Wilson JR, Kumschick S (2018) Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution* 9: 159–168, <https://doi.org/10.1111/2041-210X.12844>
- Buhlmann KA, Coffman G (2001) Fire ant predation of turtle nests and implications for the strategy of delayed emergence. *Journal of the Elisha Mitchell Scientific Society* 117: 94–100
- Cadi A, Joly P (2003) Competition for basking places between the endangered European pond turtle (*Emys orbicularis galloitalica*) and the introduced red-eared turtle (*Trachemys scripta elegans*). *Canadian Journal of Zoology* 81: 1392–1398, <https://doi.org/10.1139/z03-108>
- Elsley RM (2006) Food habits of *Macrochelys temminckii* (alligator snapping turtle) from Arkansas and Louisiana. *Southeastern Naturalist* 5: 443–453, [https://doi.org/10.1656/1528-7092\(2006\)5\[443:FHOMTA\]2.0.CO;2](https://doi.org/10.1656/1528-7092(2006)5[443:FHOMTA]2.0.CO;2)
- Gurevitch J, Padilla DK (2004) Are invasive species a major cause of extinctions? *Trends in Ecology and Evolution* 19: 470–474, <https://doi.org/10.1016/j.tree.2004.07.005>
- Koo KS, Sung HC (2019) Analysis on the important environmental factors for reproduction of *Trachemys scripta elegans* in Jeju Island, South Korea. *Korean Journal of Ecology and Environment* 52: 378–384, <https://doi.org/10.11614/KSL.2019.52.4.378>
- Koo KS, Beak HJ, Kim SH, Jang HJ, Kim DI, Sung HC (2019) First report on the natural movement of introduced turtle, *Trachemys scripta elegans*. *Korean Journal of Ecology and Environment* 52: 9–12, <https://doi.org/10.11614/KSL.2019.52.1.009>
- Koo KS, Park HR, Choi JH, Sung HC (2020a) Present status of non-native amphibians and reptiles traded in Korean online pet shop. *Korean Journal of Ecology and Environment* 34: 8–16, <https://doi.org/10.13047/KJEE.2020.34.2.106>
- Koo KS, Song S, Choi JH, Sung HC (2020b) Current distribution and status of non-native freshwater turtles in the wild, Republic of Korea. *Sustainability* 12: 4042, <https://doi.org/10.3390/su12104042>
- Lovich JE, Yasukawa Y, Ota H (2011) *Mauremys reevesii* (Gray 1831) - Reeves' turtle, Chinese three keeled pond turtle. *Chelonian Research Monographs* 5: 1–10, <https://doi.org/10.3854/crm.5.050.reevesii.v1.2011>
- Ministry of Environment (2001) Encyclopedia of the environment. Ministry of the Environment, Seoul, Republic of Korea, 781 pp

- Ministry of Environment (2009) Ecosystem disturbing wildlife sourcebook. Ministry of Environment, Sejong-si, Republic of Korea, 138 pp
- Ministry of Environment (2020) Ecosystem disturbance organism designation notice 2020-61 In: vol. Biodiversity Conservation and Use Act (21-2). 30 Mar 2020, Republic of Korea
- National Institute of Ecology (2014) Ecological studies of alien species (I). Ministry of Environment, Seochoun, Republic of Korea, 101 pp
- Savidge JA (1987) Extinction of an island forest avifauna by an introduced snake. *Ecology* 68: 660–668, <https://doi.org/10.2307/1938471>
- Sung YH, Fong JJ (2018) Assessing consumer trends and illegal activity by monitoring the online wildlife trade. *Biological Conservation* 227: 219–225, <https://doi.org/10.1016/j.biocon.2018.09.025>
- Weitzman CL, Kaestli M, Gibb K, Brown GP, Shine R, Christian K (2019) Disease exposure and antifungal bacteria on skin of invasive cane toads, Australia. *Journal of Emerging Infectious Diseases* 25: 1770, <https://doi.org/10.3201/eid2509.190386>