



New Record of Two Non-Native *Sternotherus* Turtles in The Wild of South Korea

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ABSTRACT

The remarkable economic growth achieved in the modern era has revitalized various industries, including pet trade. More than 2,000 species of non-native species have been introduced to South Korea and approximately 7.7 tonnes of alien turtles are imported annually. Turtles belonging to the family Kinosternidae. They are mostly small and popular pets, although they are designated as Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) species. In the present study, we present the first two species of musk turtles found in the wild in South Korea. On April 5, 2023 and July 8, 2023, an eastern musk turtle (*Sternotherus odoratus*) and a razor-backed musk turtle (*Sternotherus carinatus*) were captured in Ilsandong-gu, Goyang-si, Gyeonggi-do and Jung-gu, Daejeon, respectively. The carapace length was 88.6 mm for *S. odoratus* and 105.68 mm for *S. carinatus*. They were identified based on their morphological characteristics and mtDNA cytochrome b gene. These turtles were found in waterfront areas with over 1.4 million annual visitors. Both sites were found to have threatened amphibians and reptiles. There is an urgent need to continue monitoring and conducting risk assessments for the protection of endemic species in Korea.

Keywords: CITES, Ecological park, Invasive turtle, Pet release, *Sternotherus carinatus*, *Sternotherus odoratus*

Introduction

Invasive alien species (IAS) are organisms that have been artificially or naturally introduced from foreign regions. They have come to exist in an environment outside their natural origin or habitat. In general, they pose a serious threat to the ecological integrity of ecosystems worldwide.

They are major causes of biodiversity loss (Adams *et al.*, 2018; Pyšek *et al.*, 2020). IAS can affect native species diversity through competition, disease transmission, and hybridization with native species. They can also increase the risk of native species extinction and alter ecosystem functions as well as the provision of ecosystem services (Pyšek *et al.*, 2020). The number of IAS introduced into South Korea has been steadily increasing, with 894, 1,109, 2,160, and 2,653 species in 2009, 2011, 2018, and 2021, respectively. They are mainly imported and traded as pets (NIE, 2021a).

According to the Kunming-Montreal Global Biodiversity Framework, Target 6 aims to reduce the rate of introduc-

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tion and establishment of invasive alien species by 50% by 2030. The rapid development of the Internet since the 20th century has made it easier to obtain a wide variety of information and conduct international transactions between individuals. On average, more than 20 countries have exported alien turtles to South Korea. About 7.7 tonnes of alien turtles are imported annually (Baek *et al.*, 2023). Most of them are distributed as pets. Some are distributed as food (Baek *et al.*, 2023). Of these, 110 species are sold as pets, of which 47 species are Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)-registered (Koo *et al.*, 2020a). As international trade between individuals increases, the number of invasive species that can be imported into Korea is also expected to increase.

Freshwater turtles are popular pets around the world. While they are small and relatively easy to care for when they are juveniles, mature ones are often abandoned in the wild because of their distinctive odor and difficulty in caring for them. Some are released in religious ceremonies (Sung *et al.*, 2021; Esposito *et al.*, 2022). Unlike native turtles, which are found in South Korean rivers and other more natural environments, exotic turtles found in the wild are more likely to be found in urban ecological parks with high human traffic. A total of four new species (*Chelydra serpentina*, *Chrysemys picta*, *Chrysemys dorsalis*, and *Podocnemis unifilis*) have been discovered in the wild in the last 10 years. It is estimated that there are more turtles in the wild. Based on previous studies, about 14 species of non-native turtles are found in the wild in South Korea, including *Graptemys ouachitensis*, *Graptemys pseudogeographica*, *Macrochelys temminckii*, *Mauremys sinensis*, *Pelodiscus sinensis*, *Pseudemys concinna*, *Pseudemys nelsoni*, *Pseudemys peninsularis*, *Pseudemys rubriventris*, *Trachemys scripta*, and the four newly discovered species. Only two native species of freshwater turtles, *Mauremys reevesii* and *Pelodiscus maackii*, are naturally occurring in South Korea. It is believed that native turtles are outnumbered by alien species in terms of species, number of individuals found, and habitat area (Koo *et al.*, 2020b; Baek *et al.*, 2023).

Abandoned turtles in South Korea are currently a severe problem, with 109 of 161 cities reporting abandonment. Moreover, some populations have successfully resettled. They can maintain their populations through breeding (Cheon *et al.*, 2023; NIE 2021b; NIE 2021c; NIE 2022). Control methods for invasive non-native turtles that have established themselves in natural ecosystems include destroying their nesting sites and removing their eggs and adults. However, these methods do not provide complete control. Therefore, preventing the establishment of invasive non-native species is more cost-effective than eliminating the species after it has already established (Allendo-

rf & Lundquist, 2003; Green & Grosholz, 2021). Continuous monitoring of new non-native species found in the wild is therefore an important task to prepare early management plans for their invasion in South Korea. This study reports two newly identified *Sternotherus* turtles in the wild in South Korea.

Materials and Methods

One individual of *S. odoratus* was captured on April 5, 2023 during a field survey of alien species in Ilsan Lake Park, Goyang-si, Gyeonggi-do (37°39'47.1" N 126°45'33.37" E). One individual of *S. carinatus* was found on July 8, 2023, after a daily precipitation measurement of 68.7 mm during the manager's pass in Ppuri Park (36°17'00.6" N 127°23'30.7" E), Daejeon Metropolitan City (Fig. 1.A, B).

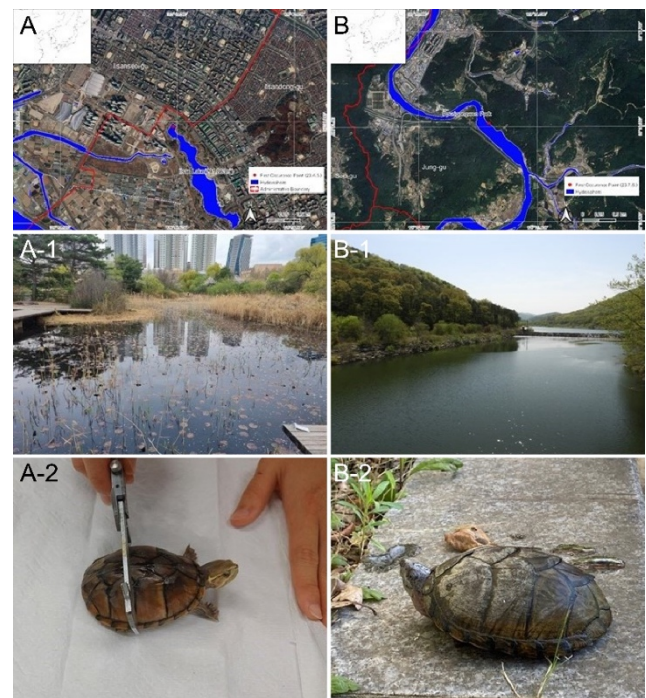


Fig. 1. The first occurrence points and pictures of the two non-native *Sternotherus* turtles captured in the wild of South Korea. (A) The first occurrence point in Ilsan Lake Park; (B) the first occurrence point in Ppuri Park; (A-1) view of Ilsan Lake Park; (B-1) view of Ppuri Park; (A-2) picture of the eastern musk turtle (*Sternotherus odoratus*); (B-2) picture of the razor backed musk turtle (*Sternotherus carinatus*).

Captured individuals were identified primarily based on their external characteristics. Sex was determined based on positions of their genitalia. The carapace length was measured in a straight line using Vernier calipers. Turtles were weighed using an electronic balance (AND CB-3000) with an accuracy of 0.1 g. Individuals were measured. They are

currently being managed by the National Institute of Ecology's Invasive Alien Species Team. Field surveys were conducted around discovery sites to determine whether additional individuals could be identified. Koo *et al.*, (2020b) have found that the introduction of non-native turtles into the wild is associated with changes of population compositions and abundance. To assess the potential for abandonment of non-native turtles, populations, households, kindergartens, primary schools, middle schools, and high schools in the ward where the individuals were found were identified.

For a more definitive identification, molecular analysis was performed. Blood samples were collected from the tail vein of each individual for DNA extraction and stored in a freezer at -20 °C until use. Total DNA was extracted using a Qiagen DNeasy Blood and Tissue Kit (Qiagen Korea Ltd., Seoul, South Korea). Samples were deposited at the National Institute of Ecology. They were maintained by the Invasive Species Team. Two sets of primers were used to amplify the mitochondrial cytochrome b gene (Table 1), which was sequenced commercially (Macrogen, South Korea) with an ABI3730XL DNA Analyzer. To construct the phylogenetic tree, two relevant species belonging to the same genera, *Stemotherus* and *Dermatemys mawii* (KF301357), from the family Kynosternidae were used as an outgroup. DNA molecular phylogeny was analyzed by bootstrapping with the maximum likelihood (ML) methodology using MEGA 7.0 at 1,000 replications (Kumar *et al.*, 2016). The best-fitting model was determined using the Akaike information criterion in MEGA 7.0 and the TN93+G model was selected (Kumar *et al.*, 2016).

Table 1. The two sets of primers used in this study

Primer	Sequences (5'→3')	References
f	TGACTTGAARAACCAAYCGTTG	Shaffer <i>et al.</i> , 1997
r	TCTTCTACTGGTTGCCTCCGATTCA	Shaffer <i>et al.</i> , 1997
CytbJSr	CCTGTTGGGTTGTTTGATCC	Spinks <i>et al.</i> , 2004
THR-8	GGTTTACAAGACCAATGCTT	Spinks <i>et al.</i> , 2004

Results

We analyzed 570 bp of the cytochrome b gene, performed an NCBI BLAST search, and found that it shared >99% sequence identities with *S. odoratus* and *S. carinatus*. This was also confirmed by constructing an ML tree (Fig. 2). The genus *Stemotherus* comprises six species (*S. carinatus*, *S. depressus*, *S. intermedius*, *S. minor*, *S. odoratus*, and *S. peltifer*), with *S. carinatus* native to the United States

and *S. odoratus* native to Canada and the United States. These are small turtles with a maximum carapace length <20 cm. They are popular as pets worldwide (Kopecký *et al.*, 2013). In South Korea, they are sold in the pet market at \$60 per individual. Their sales in traditional markets have also been confirmed (Baek *et al.*, 2023).

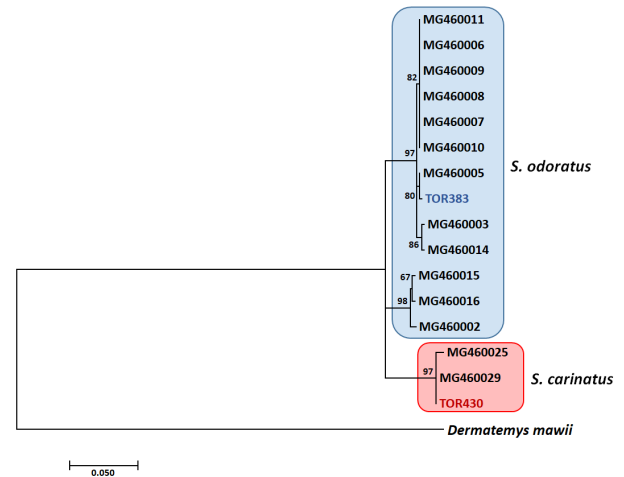


Fig. 2. Maximum likelihood (ML) tree reconstruction with 570 bp of the cytochrome b gene. Each individual is clustered with *S. odoratus* and *S. carinatus*. Node values indicate bootstrap values.

Female *S. odoratus* was measured. Its external morphology showed a carapace length of 88.6 mm with a weight of 130.2g (Fig. 1. A-2). Ilsan Lake Park is situated in Goyang-si, Gyeonggi-do between Ilsan Dong-gu and Ilsan Seo-gu along Route 731. Goyang-si is a large city with a population of 1,090,738 in 448,574 households, making it a metropolitan area with over 10 million residents. Its surrounding areas are urbanized, with Ilsan Dong-gu and Ilsan Seo-gu having populations of 296,122 and 289,852 residents, respectively. The number of households is 128,567 in Ilsan Dong-gu and 116,097 in Ilsan Seo-gu. There were 40 kindergartens, 24 elementary schools, 10 middle schools, and 11 high schools in Ilsan Dong-gu. There were 45 kindergartens, 24 elementary schools, 13 middle schools, and 12 high schools in Ilsan Seo-gu. Considering these demographics, the population living near Ilsan Lake Park might have individuals capable of keeping turtles as pets, suggesting a possibility of pet abandonment.

The *S. carinatus* that was found was a female based on measurements of the external shape of the captured turtle, with a carapace length of 105.6 mm and a weight of 176 g (Fig. 1. B-2). The individual was captured at the manager's road located southeast of the center of Ppuri Park. It is a paved road that extends from Sanseoro and leads to Ppuri Park along Yudeungcheon. Ppuri Park is located at

79 Purigongwon-ro, Jung-gu, Daejeon Metropolitan City. It is equipped with facilities such as a waterside stage, lawn plaza, observatory, and forest baths. It is situated on the mid-slope of Mt. Manseong, on the southern side of the stream, whereas Yudeungcheon and Bomunsan are located toward the north. The Daejeon Metropolitan City is large with a population of 1,445,126 in 679,151 households. The population of Jung-gu is 224,799 and the number of households is 107,336. There are 38 kindergartens, 27 elementary schools, 14 middle schools, and 14 high schools around Ppuri Park. Individuals who raise turtles as pets might live around Ppuri Park. It is possible for them to abandon their pets in this area.

Discussion

Kinosternidae is one of the most vulnerable taxa in Testudines and includes most of the species designated as CITES. Particularly the species belonging to *Stemotherus* and *Kinosternon* are designated as CITES II except *K. cora* and *K. vogti*, which are designated as CITES I. Under the CITES Agreement, CITES II species can be traded commercially and academically, whereas CITES I species can only be traded for academic research purposes and require an export license that must be issued by the CITES authority of the exporting country. To trade CITES species in captivity in South Korea, prior notification is required, along with a legal acquisition report and certification of the breeding facility. Owing to these legal restrictions and the difficulty of keeping turtles in captivity, the number of turtles abandoned in the wild is increasing. Baek *et al.*, (2023) retrieved 169 freshwater turtles from the wild over three years. All the retrieved turtles were non-native species, including *S. carinatus*.

The introduction of alien turtles into natural habitats has been confirmed to be related to anthropogenic factors (Koo *et al.*, 2020b). The occurrence of alien turtles is more frequent in areas with larger populations and high per capita incomes of local residents. The two *Stemotherus* turtles identified in the present study were also found in a large city with a population of more than one million. The detection site was an urban ecological park with more than 100,000 visitors per month, which is consistent with the results of Koo *et al.*, (2020b). In particular, Ilsan Lake Park has a high frequency of detection of exotic turtles, including *C. picta*, *P. concinna*, *P. nelsoni*, *P. peninsularis*, and *T. scripta*, and was also the site of a new confirmation of *C. picta bellii* in 2020 (Park *et al.*, 2020).

Ilsan Lake Park, where the *S. odoratus* female was captured, is also known as the habitat of *Kaloula borealis*, an endangered species in Korea. Daejeon Ppuri Park, where the *S. carinatus* female was found, is the habitat of *M.*

reevesii, an endangered species that is managed as a natural monument; therefore, these are priority sites for habitat protection. *Stemotherus odoratus* and *S. carinatus* are omnivorous and have been known to live for up to 28 years in the wild and 29 years in captivity. IAS affect the native biodiversity by competing with native species or introducing pathogens (Polo-Cavia *et al.*, 2008; Pearson *et al.*, 2015; Demkowska-Kutrzepa *et al.*, 2018; Chinchio *et al.*, 2020; Martínez-Ríos *et al.*, 2022). They also change the composition and structure of the ecosystem, reducing the services provided by it (<https://www.cbd.int/gbif/targets/6/>). To date, no study has been conducted on the ecological risk of *Stemotherus* in South Korea. Therefore, an assessment of its possible impact on the domestic ecosystem should be conducted. Furthermore, the status of turtles of the genus *Stemotherus* introduced into South Korea should be identified and continuous monitoring should be conducted in natural ecosystems. In addition, public awareness is needed to prevent the release and dumping of non-native turtles in urban reservoirs and rivers with high annual visitation, and the designation of 'priority management points' for sites where non-native species are frequently introduced.

Currently, the provisions of the Wildlife Act address many issues for CITES species for which artificial propagation is permitted, and there is no equivalent legislation for other species, many of which are the most common and widespread. As a result, it is impossible to accurately estimate the reproduction and distribution status of CITES species and effective management is not possible. CITES species are internationally endangered wildlife and require regulations to improve their conservation and welfare, and basic breeding regulations and management measures should be in place for individuals produced and sold domestically.

Conflict of Interest

The author declare that they have no competing interests.

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