Rapid Communication

Distribution status for invasive alien freshwater turtles *Trachemys scripta* (Thunberg *in* Schoepff, 1792) on Jeju Island, Republic of Korea

Seon-Mi Park[1], Sang-Hyun Han[2], Jun-Won Lee[3], Sung-Hwan Choi[4], Young-Hun Jung[4], Maniram Banjade[1], Hong An Nguyen[4] and Hong-Shik Oh[3,4,*]

[1]*Practical Translational Research Center, Jeju National University, Jeju Special Self-Governing Province, 63243, Republic of Korea*
[2]*Department of Ecological Conservation, Korea National Park Research Institute, Korea National Park Service, Gurye-gun 57616, Republic of Korea*
[3]*Faculty of Science Education, Jeju National University, Jeju Special Self-Governing Province, 63243, Republic of Korea*
[4]*Interdisciplinary Graduate Program in Advanced Convergence Technology and Science, Jeju National University, Jeju Special Self-Governing Province, 63243, Republic of Korea*

**Corresponding author*
E-mail: *sciedu@jejunu.ac.kr*

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Abstract

Several alien species of freshwater turtles have been imported to the Republic of Korea from various countries, and then released to the wild by breeders and as a part of religious practices throughout Korea. Here, we evaluated the number of subspecies of the alien freshwater turtle *Trachemys scripta* in the wild on Jeju Island, Korea. We confirmed the presence of three alien subspecies of freshwater turtles with higher number and broader distribution compared to previous studies in 2007 and 2015. There were 134 adult and 48 juvenile *Trachemys scripta elegans* in 41 locations; nine adult *Trachemys scripta scripta* in seven locations; and two adult *Trachemys scripta troostii* in two locations. Illegal release by humans and potential reproduction in the wild probably contributed to the increase in their numbers. Early detection of invasive alien species is crucial for preventing their spread. Therefore, to minimize their negative impacts on the natural ecosystem of Jeju Island, we suggest the continuous monitoring of invasive freshwater turtles (including the evaluation of their survival, growth, and reproduction) and the strengthening of regulations to prevent continued releases to the wild.

Key words: Emydidae, expansion, invasive species, island biodiversity

Introduction

The development of transportation has become an important means of connecting the world, with active trading occurring across most countries. The widespread increase in international trade of wildlife has become an important vector of invasive alien species introduction (Wilson 1995; Williamson and Griffiths 1996; Banks et al. 2015). Several alien species have been introduced to the Republic of Korea for agriculture, pet trade, religion, and education. Annually, approximately 400,000 reptiles are imported to Korea (Ministry of Environment 2010, 2019; Information of Korean Alien Species 2021). Recently, exotic pets become more population, leading to an increasing number of imported turtle (Ministry of Environment

2010; Lee et al. 2016). Within the last 10 years, several freshwater turtle species have been imported to Korea, including *Pseudemys concinna* (Le Conte, 1830), *Mauremys sinensis* (Gray, 1870), *Chrysemys picta* (Schneider, 1783), and *Chelydra serpentina* (Linnaeus, 1758) (National Institute of Ecology 2015; Koo et al. 2020b). According to Lee et al. (2016), 73 species of turtles, across 9 families, have been introduced to Korea as of 2016. The number of imported alien turtles of different species is increasing every year, with many turtle species being introduced to Jeju Island. In Korea, turtles are being sold to people without strict restrictions through the pet market, and CITES species are also traded (Koo et al. 2020a). This behavior requires special attention and management, as it implies that many turtle species could be easily released into the wild in Jeju Island by many owners and breeders.

Trachemys scripta is a freshwater turtle native to the USA, with distribution extending from northern Florida to southeastern Virginia (Rhodin et al. 2017). This species has three subspecies, namely, red-eared slider [*Trachemys scripta elegans* (Wied, 1839); TSE], yellow-bellied slider [*Trachemys scripta scripta* (Thunberg *in* Schoepff, 1792); TSS], and cumberland slider [*Trachemys scripta troostii* (Holbrook, 1836); TST] (Bonin et al. 2006; Rhodin et al. 2017). This species is a popular pet worldwide, resulting in its introduction to the wild (except in Antarctica) through natural and anthropogenic causes (Platt and Fontenot 1992; Ramsay et al. 2007). TSE is listed in the World's 100 most invasive alien species by the International Union for Conservation of Nature (IUCN) (Lowe et al. 2000). In the 1970s, TSE was introduced to the Republic of Korea for religious, pet, food, and medicinal purposes (Oh and Hong 2007). However, many individuals have since been released to the wild, and have spread into domestic water systems, threatening native species. Therefore, in Korea, TSE was registered as an ecosystem-disrupting species in 2001, and imports and trade of all species belonging to the genus *Trachemys* were banned in 2005 (Ministry of Environment 2006; National Institute of Ecology 2016). To prevent the spread of invasive alien species such as TSE, the local government invested heavily on a project that aimed to capture and remove individuals from the wild, $108,000 in 2016 and $182,000 in 2017. Despite the efforts of the government, TSE is still illegally released as abandoned pets, due to odor problems, diseases, and economic burden.

Trachemys scripta adapts well to the environment in Korea, with successful breeding individuals easily observed in the wild. The continued release and breeding of *Trachemys scripta* have resulted in population growth, threatening *Mauremys reevesii* (Gray, 1831), a native species in Korea. To protect the natural ecosystem of Korea from further damage by the introduction of invasive species, monitoring is urgently required to evaluate the current situation. In Korea, extensive efforts are being made to manage and eradicate invasive species. However, Jeju Island is separated from the Korean Peninsula; therefore, it is difficult to investigate and manage

invasive species there. This study was conducted to identify the extent of introduction and distribution range for *Trachemys scripta* in Jeju Island.

Materials and methods

Study area

Jeju Island, the largest island in the Republic of Korea, was formed by volcanic activity. It has a subtropical climate and is situated at the center of the Pacific Sea Route for shipping goods between China and Japan. The island is approximately 73 km wide (east to west), and 31 km long (north to south), with an oval shape and as area of approximately 1,848 km^2. Mount Hallasan (1,950 m high) is located in the center of the island and is the highest mountain in Korea. The east-west slope is gentle, whereas the north-south slope is steep. Many rare species are distributed on the island, including *Sibynophis chinensis* (Günther, 1889), which is designated as an endangered species in Korea, and the globally rare bird, *Pitta nympha* (Temminck & Schlegel, 1850). The island was designated as a Biosphere Reserve by the United Nations Education Scientific Cultural Organization (UNESCO) in 2002. It was also registered as a World Natural Heritage Site in July 2007 and certified as a Global Geopark in October 2010. There are approximately 320 inland wetlands on Jeju Island, of which five of them are registered to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat and have been designated as wetland protected areas.

Monitoring and analysis

To confirm the distribution by *Trachemys scripta* on Jeju Island, a field survey was conducted in 46 inland wetlands from March 2016 to April 2021. Considering the ecological characteristics of sunbathing freshwater turtles, surveys were conducted during daylight hours from 09:00 to 16:00 h. The survey team consisted of two or more people; the line census method was used to traverse the survey area, with observations being made using binoculars and a camera. In locations where freshwater turtles were expected to be sighted, the point census method was used, with observers staying at one point for > 1 h. By combining the results of multiple observers, we regarded the maximum number of individuals counted by one observer as the result of a site. Species identification was conducted from the morphological characteristics (Bonin et al. 2006). TSE was identified from the noticeable red color in the temporal region behind the eye and black spots scattered on the plastron. Some adults had blackened shells and skin, whereas the young individuals had clearer and brighter stripes than the adults. TSS had bright yellow stripes connected to the back of both eyes, extending diagonally from the neck. TST had a near-yellow stripe with a pale red color behind the eye; the chin had a wider yellow stripe than the

Figure 1. Invasive species of freshwater turtles (*Trachemys scripta*) were observed on Jeju Island, Republic of Korea. (A) Adult *Trachemys scripta elegans* basking on a rock; (B) juvenile *Trachemys scripta elegans* and (C) adult of *Trachemys scripta scripta* sunbathing on a piece of wood; (D) adult *Trachemys scripta troostii*. Photographs by Seon-Mi Park..

other subspecies and large dark blotches on the plastron. Turtles with a carapace length of 15 cm or more were classified as adults (Bonin et al. 2006; Rhodin et al. 2017; The Reptile Database 2020). The coordinates of the locations where the turtles occurred were recorded using a handheld GPS (GPSMAP 64s, GARMIN, USA). A species distribution map was prepared using QGIS 3.18.3 (Supplementary materials Table S1). We compared the results of previous studies (Oh and Hong 2007; Ministry of Environment 2015) with the findings of this study to analyze the changes in the number of *Trachemys scripta* individuals in Jeju Island.

Results and discussion

Three subspecies of *Trachemys scripta* were observed in Jeju Island, with a total of 193 individuals: TSE, TSS, and TST (Figure 1). We observed 182 TSE individuals, of which 134 were adults and 48 were juveniles. For TSS and TST, nine and two adults were identified, respectively, with no juveniles. A previous study recorded 92 TSE individuals in Jeju Island (Oh and Hong 2007) (Figure 2). Approximately 50 TSEs were captured and removed by Ministry of Environment in 2015, causing a temporary decrease in the population size (Ministry of Environment 2015). However, the number of

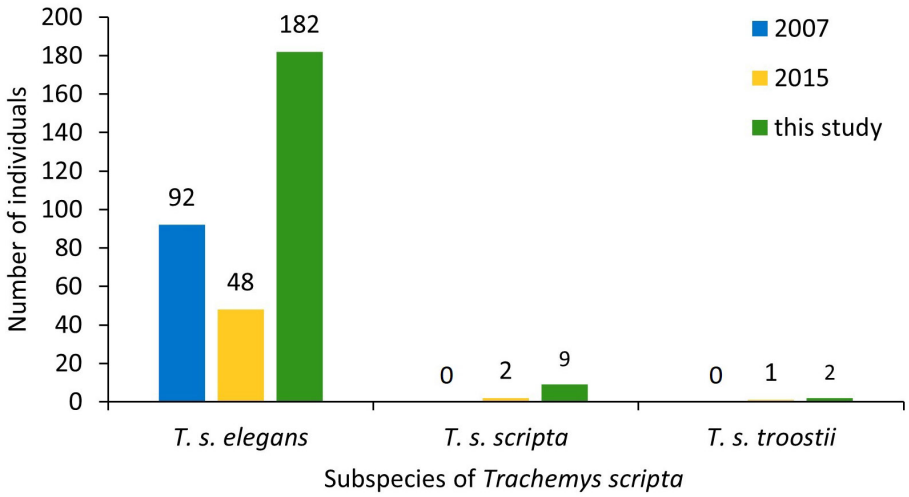

Figure 2. Change in the number of individuals for three subspecies of *Trachemys scripta* on Jeju Island, Republic of Korea, in 2007, 2015, and at present (Table S2).

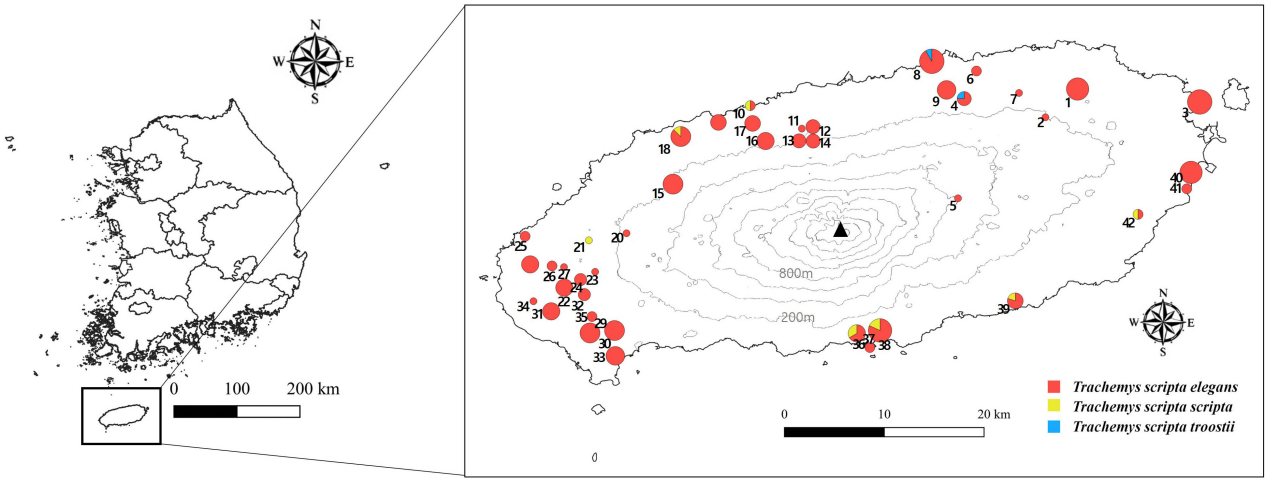

Figure 3. Distribution sites of *Trachemys scripta* on Jeju Island, Republic of Korea. The black triangle represents Mount Hallasan, which is located at the center of Jeju Island. Red indicates the TSE was observed. Yellow is the site where the TSS was found. Blue represents the area where the TST was found. Numbers show observation location (Table S1).

individuals rapidly increased through subsequent releases and breeding activities. Oh et al. (2017) and Koo and Sung (2019) reported that 133 and 180 TSE were observed in Jeju Island respectively. The increase in number of individuals may be caused by release after 2015. Further, this may also be attributed to successful reproduction in the wild as juveniles were observed. Although the import and trade of all species of *Trachemys* were banned in South Korea 16 years ago (2005), the problem of *Trachemys scripta* being the release of *Trachemys scripta* being released into the wild has persisted. Juveniles of TSS and TST were not found, suggesting no breeding in the wild has happened. However, the results of this study cannot be considered completely conclusive. Continuous monitoring of this species is required to establish its breeding status.

TSE was observed in 41 locations and was the most widely distributed of the three subspecies (Figure 3). TSS and TST inhabited seven and two locations, respectively. The individuals were observed in ponds, reservoirs, streams,

and crater lakes (Table S1). Most individuals were found in residential areas, villages, parks, and promenades, with large volumes of human and vehicular traffic. The number of alien species tends to increase with increasing human population size or density (Spear et al. 2013). Similarly, in this study, many species and individuals were observed in densely populated villages or in ponds frequented by people. There are no native turtles on Jeju Island, and we estimated that all *Trachemys scripta* recorded in the wild on the island were illegally abandoned by people. We confirmed that TSE coexisted with either TSS or TST in 8 out of 42 sites (Table S1).

Biodiversity is threatened worldwide; considerably more species have become extinct on islands than on continents with the introduction of invasive species being the most common cause (Whittaker 1998; Hong 2014). Owing to the development of marine and air transport of goods, there is a high possibility of introducing alien species alive, with a greater number of individuals being transported. This has been exacerbated by the liberalization of trade and increased preference of consumers for exotic animals and plants as pets (Office of Technology Assessment 1993). The effect of invasive species on island ecosystems is expected to increase over time (Dulloo et al. 2002; Russell et al. 2017). Therefore, it is necessary to implement long-term monitoring programs of invasive species and the associated indicators. The introduction, invasion, and spread of alien species on island, as well as their effect on indigenous species, should be closely monitored (Russell et al. 2017). Jeju Island has a unique environment and topography, with many species inhabiting it. Environmental changes, such as the introduction of alien species to the natural environment, are dangerous to native species inhabiting islands, because of limited refuges (Tershy et al. 2015; Bellard et al. 2016). Here, we confirmed the widespread distribution of three subspecies of *Trachemys scripta* in the inland wetland of Jeju Island, causing the wetland ecosystem of Jeju Island to be threatened by invasive species. The early detection of invasive alien species is essential to prevent their proliferation (Tobin et al. 2012). Therefore, we suggest the establishment of a management plan to mitigate the threats posed by invasive species to Jeju Island in order, to preserve its natural diversity.

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Authors' contributions

SMP and HSO conceived the study, field design and methodology. SMP, SHH, JWL, SHC, YHJ, MRB, and HAN and carried out the field study, data collection and analysis. SMP wrote the original manuscript and was reviewed/edited by HSO.

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Supplementary material

The following supplementary material is available for this article:
Table S1. Location and number of *Trachemys scripta* individuals found in this study.
Table S2. Number of individuals for three subspecies of *Trachemys scripta* on Jeju Island, Republic of Korea, in 2007, 2015, and at present.
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