Journal of Coastal Conservation (2021) 25: 29
https://doi.org/10.1007/s11852-021-00820-9

Effect of coastal dune restoration on the population of endangered Mongolian racerunner (*Eremias argus*) in the Republic of Korea

Min Ho Chang[1] · Jae Young Song[2] · Kyo Soung Koo[3]

Received: 8 June 2020 / Revised: 16 February 2021 / Accepted: 22 February 2021 / Published online: 1 March 2021

Abstract
The endangered species Mongolian racerunner (*Eremias Argus*), with a limited distribution in South Korea, is found only in sand dunes near waterside and forests. Therefore, species trends in this particular habitat are directly affected by habitat contamination and destruction. In this study, we examined the effects of coastal sand dune restoration on the distribution and population of *E. argus*. We conducted a field survey in Baramarye special protection zone, called Baramarye Coast, a part of the Taeanhaean National Park, during April and June 2016. We searched and recorded the location of *E. argus* and tagged them using the toe clipping method. The size of the *E. argus* population was estimated using the Peterson method. After the restoration of coastal sand dunes in Baramarye Coast, the population size of *E. argus* increased by 126–137 (21.1–55.7%) compared with that in 2008. The home range of *E. argus* in coastal sand dunes was significantly expanded by 4.8-fold for 95% Kernel density (KD) and 3.6-fold for 50% KD compared with that in 2008. Moreover, we confirmed that the distribution of *E. argus* was expanded to the restored area. Our study showed that in situ conservation is effective for endangered *E. argus,* distributed in particular environments such as coastal region. This study provides one more reason why coastal region must be conserved.

Keywords Endangered species · Lacertidae · Sand lizard · Habitat restoration · In situ conservation

Introduction

The Mongolian racerunner, *Eremias argus*, is a small lizard found throughout China, Mongolia, and Korean peninsula (Do et al. 2017; Orlova et al. 2019). In contrast to other Korean reptiles, *E. argus* only inhabits certain environments, such as coastal dunes and sandy banks along rivers and sea (Kim et al. 2011a). Given the limited habitat of *E. argus*, habitat disturbance can be fatal for members of this species. For example, species richness, species diversity, functional richness, functional dispersion, and the number of functional groups of lizards in the disturbed sites are lower than those in undisturbed sites (Berriozabal-Islas et al. 2017). This lizard is currently found in limited areas and there is an urgent need for its protection and management (Song et al. 2010, 2013). In South Korea, *E. argus* is an endangered species owing to its limited distribution and decreasing population size, and therefore, it is managed (Kim et al. 2011b). Research on *E. argus* is centered on population restoration by focusing on reproduction, home ranges, and food resources (Kim et al. 2010; Song et al. 2010; Jeong and Song 2010; Kim et al. 2012). Although there are several studies on restoring the population of *E. argus*, limited data are available on protecting and managing the habitat of this lizard in South Korea.

The Baramarye Coast includes one of the largest coastal sand dunes in Taean-gun, South Korea (Kim et al. 2011a; Park et al. 2013). Many of the coastal plants found in the coastal dunes act as both refuges and habitat for endangered *E. argus* (Kim et al. 2011a; Park et al. 2013). In 2008, a study on the distribution and population size of *E. argus* in Baramarye Coast was conducted (Song et al. 2013). The Taeanhaean National Park management designated this site as a natural protected area in 2009. The coastal dune restoration project removed concrete structures and sand trap installations from the area in 2013 and 2014 (Yu et al. 2016). As a result, coastal grasslands, which are the primary habitats of *E. argus*, increased by approximately 190%, from 8314 m^2 in 2008 to

Min Ho Chang and Jae Young Song contributed equally to this work.

✉ Kyo Soung Koo
flqpfj@hanmail.net

1 National Institute of Ecology, 33657 Seocheon, Republic of Korea

2 Korea National Park Research Institute, 26441 Wonju, Republic of Korea

3 Interdisciplinary Program of EcoCreative, Ewha Womans University, Seoul 07804, Republic of Korea

15,829 m^2 in 2016 (Song et al. 2016). Furthermore, previous studies predicted continuous sand sedimentation in Baramarye Coast and Halmi Island due to wind direction and speed data (Park et al. 2013; Yu et al. 2016). The environmental conditions of Baramarye Coast are changing, and the subsequent effects on the different organisms present in the area, including *E. argus*, are unknown.

In this study, we sought to evaluate the hypothesis that the restoration of *E. argus* habitat, namely coastal dunes and grasslands, will affect the population expansion of Mongolian racerunner. The number of *E. argus* present in 2008 (Song et al. 2013) and 2016 was compared to evaluate the effect of habitat expansion on the lizard's population size and determine the effects of restoration efforts. We predicted that the expansion of *E. argus* habitat, specifically the coastal grassland area, would lead to an increase in habitable area and consequently increase the size of *E. argus* population. Second, we analyzed the changes in *E. argus* habitat use and distribution due to habitat expansion. We predicted that the observed changes in habitat would increase the distribution of *E. argus*. This study not only identifies the effect of in situ conservation efforts on *E. argus*, but also provides important evidence for the future protection and management of organisms that are found in restricted habitats.

Materials & methods

Research area

Baramarye special protection zone (36.412417°N, 126.384440°E, WGS84, 3 m a.s.l.) is located at the southern end of Anmyeon-eup, Taean-gun. Baramarye Coast is characterized by well-developed sandy beaches and the presence of grassland patches. The lowest height from the sea level of the coast is normally 3–5 m, and the maximum height is 17 m (Park et al. 2013). A previous study reported 49 native and 8 non-native plants distributed in the Baramarye special protection zone, including the following communities: 5 arbors, 10 halophytes and sand dune plants, and 4 mixed plants (Park et al. 2013). Most plant communities form small patches and are usually distributed between 100 and 150 m from the coastline (Park et al. 2013). This zone is a part of the Taeanhaean National Park and therefore is well managed and preserved.

Field research

Considering the main activity season of *E. argus*, we conducted the field survey between April and June 2016 following the methodology of Song et al. (2013). To reduce the methodological difference between two studies in 2008 and 2016, we used exactly the same methods as in the previous study (Song et al. 2013): three researchers, capturing methods, survey time, and individual labeling. Usually, lizards immediately move as humans approach. We marked the initial discovery points of an individual animal with an iron stick to record the lizard's original point. We used a portable GPS (Oregon 650, Garmin, USA) to obtain the coordinates of each location. To prevent repeated counting, all lizards were captured and kept in an ecorium until the completion of the field survey (Fig. 1).

Individual tagging

Repeated capture of the same individual during a day could be a problem in estimating the population size; therefore, we used the tagging method. Typically, two tagging methods are used for the study of small lizards: inserting a passive integrated transponder microchip or partially clipping either a scale or toe (Langkilde and Shine 2006). Previous studies showed that toe clipping does not substantially affect lizard mobility, and thus we employed this method in the present study (Dodd 1993; Borges-Landáez and Shine 2003; Langkilde and Shine 2006). In a previous study, researchers clipped many toes for numbering (Song et al. 2016). In this study, however, we clipped only one joint of the longest fourth toe of the left foot to identify recaptured individuals. We released individual animals to the same location of their capture after tagging. We followed the guidelines for field research of live reptiles by Beaupre et al. (2004).

Population size estimation

We compared the total number of individuals, number of individuals per sampling month, and number of recaptured individuals in 2016 with those of a previous study (Song et al. 2013). To estimate the population size of *E. argus* in Baramarye Coast in 2016, we used the Peterson method (Begon 1979), and compared the result with those of the previous study (Song et al. 2013). The Peterson method is the most effective and simple method to estimate population size from two studies (Begon 1979). A few experimental assumptions are required for the Peterson method: 1) the population is closed, 2) all animals have the same chance of being caught in the first sample, 3) marking of individual animals does not affect their catchability, 4) animals do not lose their marks between the sampling periods, and 5) all marks are reported on discovery in the second sample (Begon 1979; Krebs 1998). We considered that the *E. argus* population was closed given that their habitat was limited to coastal dunes, and we found no *E. argus* individuals in other nearby regions. The number of researchers, duration of the investigation period, and sampling effort were the same in 2008 and 2016. We estimated the

Fig. 1 Endangered Mongolian racerunner, *Eremias argus*, in Baramarye coast, South Korea

size of the *E. argus* population using the Peterson method with the following equations:

$$N = \frac{M(C+1)}{(R+1)} \text{(and)}$$

$$Variance\ (N) = \frac{M^2(C+1)(C-R)}{(R+1)^2(R+2)},$$

where, N refers to group size, M refers to the number of marked individuals in the first sample, R refers to the number of recaptured individuals in the second sample, and C refers to total number of individuals identified in the second sample. For population size estimation, we calculated $N \pm 1.96\sqrt{(N)}$ to obtain the 95% confidence interval.

Changes in the distribution of *E. argus*

To estimate the home range of *E. argus* in 2008 and 2016, we used the Kernel density (KD) method. It is well known that distinct boundaries such as cliffs, river, and ponds considerably affect the results of the Kernel method (Getz and Wilmers 2004; Getz et al. 2007). In our study site, there are no physical barriers to prevent the movement of lizards. Based on locations in which we captured *E. argus* in 2008 and 2016, the characteristics of their distribution and changes in their distribution were compared with the changes in their size of habitat area. For the KD analysis, the following options were set: area unit, square map unit; output value, density; and method, planar. We used ArcGIS ver 10.6 (ESRI, USA), and represented the result as 95% KD and 50% KD.

Results

During the field survey in the previous study (Song et al. 2013), 152 *E. argus* individuals were recorded (Fig. 2). In our study, we identified 147 *E. argus* individuals in April and 197 individuals in June, 2016 (Table 1). In the previous study, 15.1% (23 individuals) of *E. argus* were recaptured, while we recaptured 13.6% individuals (20 individuals; Table 1). We found no individual animals that were marked in 2008 during this study.

Population size estimation using the Peterson's method predicted that the *E. argus* population in Baramarye Coast comprised 352–787 individuals in 2016. This estimation represents an increase by 126–137 (21.1–55.7%) lizards compared with that in the previous study (Song et al. 2013).

The distribution of the *E. argus* population was highly limited to dune grasslands near Baramarye Coast and northern Halmi Island in the 2008 study (Fig. 2). After habitat restoration efforts, the distribution of *E. argus* in the research site increased, and we found individuals in a larger area of dune grasslands near Baramarye Coast, northern Halmi Island, and the southern coast of Halmi Island in 2016 (Fig. 3).

Table 1 Number of captured *Eremias argus* from field surveys in Baramarye coast, South Korea. Recapture = recaptured lizards from second survey / lizards from first survey. *: Song et al. 2010

Survey	Year	
	2008*	2016
First	152	147
Second	–	197
Recapture	23 (15.1%)	20 (13.6%)

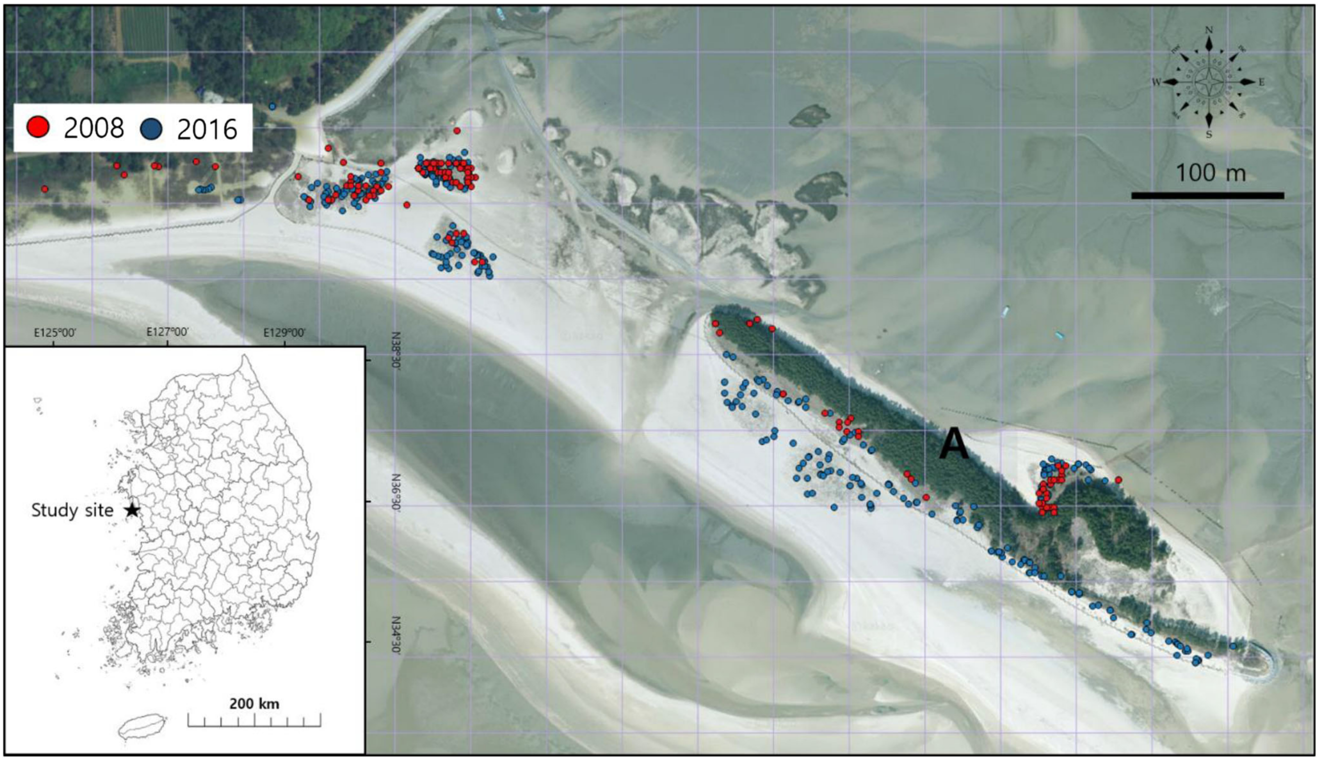
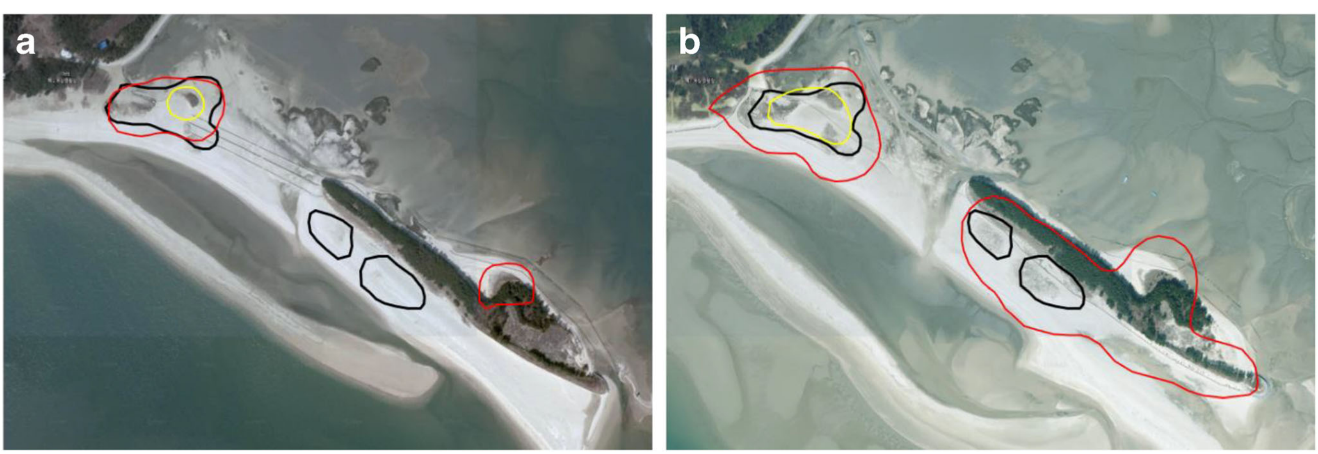


Fig. 2 The location of Baramarye coast and the Halmi island (A). The spots (red: 2008, blue: 2016) indicated the points of discovery the Mongolian racerunners

The home range of *E. argus* was 12,092 m^2 for 95% KD and 1329 m^2 for 50% KD in 2008 (Fig. 3a). In 2016, after the restoration of coastal sand dune, the home range of 95% and 50% KD increased by 58,000 m^2 (4.8-fold) and 4737 m^2 (3.6-fold) compared with that in 2008 (Fig. 3b).

Discussion

In this study, we examined the effects of coastal sand dune restoration on the distribution and population of *E. argus*. We found evidence to support our hypothesis that the expansion of coastal dunes and grasslands can lead to an increase in the size of the *E. argus* population. Habitat expansion and restoration, such as the removal of threats within habitats, can lead to an increase in population (Towns 1994; Pike et al. 2011). In particular, species found only in certain habitats may be greatly affected by habitat restoration efforts (Amo et al. 2007). As a result of a habitat restoration project in Baramarye Coast that was carried out in 2013, the dunes and dune grasslands expanded, and may have resulted in an expansion in the distribution of *E. argus*. In other words, the changes in population size that coincide with habitat



restoration, as identified in this study, present a meaningful case study for the effect of habitat restoration efforts on the presence of organisms.

Recently, the coastal region has high pressure from human actions such as tourism, building resorts, and public beach (Bramwell 2004; Nordstrom 2004). This pressure leads to overgrazing, deforestation, and exploitation and finally destroys the habitat of endemic species in coastal regions. However, the population of *E. argus* has been decreasing, because their habitats are mainly in coastal dunes vulnerable to human pressure (Song et al. 2010; Kim et al. 2011a; NIBR 2019). However, our results showed that the restoration and expansion of coastal sand dunes could recover the population of *E. argus* and even expand their home range. In other words, habitat restoration is an effective way of conserving species that inhabit a specific environment such as coastal dunes.

The introduction of invasive plant is another threat to *E. argus* populations. Recently, the abundance of invasive plant has been continually increasing in coastal dunes, resulting in negative effects on dune environments and the biodiversity present (Choi et al. 2006; Wouters et al. 2012). In general, the presence of invasive plants in coastal dunes is a result of topological changes and artificial introduction by visitors (Song and Cho 2007). Furthermore, the invasive plants change insect biodiversity and population dynamics in coastal dunes, which may also affect food availability for *E. argus* (Taean 2016a, b). Invasive plant removal and plant cover rate regulation are important for reptiles including *E. argus*, because open areas are necessary for basking (Kim et al. 2011a; Pike et al. 2011). Therefore, a consistent increase in invasive plants can have both direct and indirect effects on *E. argus* populations; thus, continuous management and removal of invasive species are required.

Vegetation cover of habitats is critical for *E. argus* (Kim et al. 2011a). The cover rate is related to the availability of moving and refuge spaces, degree of sun exposure, and availability of nearby food sources associated with dune vegetation (Kim et al. 2011a). In particular, the extent of light transmission by rice (Gramineae) plants makes the areas associated with these plants important refuges that protect from sun exposure; thus, these plants affect the presence and distribution of *E. argus*. However, the introduction of invasive plant could result in not only an increase in vegetation cover in coastal sand dunes but also reduce the available habitat of the lizards (Seo 2012).

In the 2008 study, all sampled *E. argus* individuals had their toes clipped (Song et al. 2013). In the current study, which was conducted in the same area, we did not find any previously marked *E. argus* individuals. It is possible that previously marked individuals died owing to various causes, such as disease, predation, and old age. A previous study estimated the life expectancy of *E. argus* to be 8–10 years (Kim et al. 2010), suggesting that 8 years is roughly equal to one generation. Generational changes are another important consideration for habitat or population restoration efforts.

In this study, we found that the expansion of habitat due to coastal dune restoration in Baramarye Coast can lead to an increase in the population size of *E. argus*, which is an endangered species. Our findings provide evidence that in situ conservation in the form of habitat expansion can be effective in preserving organisms that inhabit limited environments, such as coastal dunes.

Acknowledgments This work was supported by a grant from the National Institute of Ecology (NIE), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIE-C-2019-04). Also, our study includes the results of "Taeanhaean National Park monitoring" by Korea National Park Research Institute. We would like to thank Editage (www.editage.co.kr) for English language editing.

Authors' contributions Conceptualization: Kyo Soung Koo; data collection and field survey: Min Ho Chang, Jae Young Song, and Kyo Soung Koo; draft writing: Min Ho Chang; reviewing and editing: Jae Young Song and Kyo Soung Koo; funding acquisition: Min Ho Chang.

Funding This work was supported by a grant from the National Institute of Ecology (NIE), funded by the Ministry of Environment (MOE) in South Korea (NIE-C-2019-04). Also, our study includes the results of "Taeanhaean National Park monitoring" by the Korea National Park Research Institute.

Availability of data and material Not applicable (*Eremias argus* is an endangered species. Therefore, the permission from the Korean Government is needed for using data).

Code availability Not applicable.

Declarations

Conflicts of interest/competing interests There are no conflicts of interest to declare.

Ethics approval Not applicable.

Consent to participate All members agreed to participate in this study as author.

Consent for publication All members agreed with the publication of this paper.

References

Amo L, López P, Martín J (2007) Habitat deterioration affects body condition of lizards: a behavioral approach with *Iberolacerta cyreni* lizards inhabiting ski resorts. Biol Conserv 135:77–85

Beaupre SJ, Jacobson ER, Lillywhite HB, Zamudio K (2004) Guidelines for use of live amphibians and reptiles in field and laboratory research. American Society of Ichthyologists and Herpetologists. Miami, FL

Begon M (1979) Investigating animal abundance: capture-recapture for biologists. Edward Arnold Ltd.

Berriozabal-Islas C, Badillo-Saldana LM, Ramírez-Bautista A, Moreno CE (2017) Effects of habitat disturbance on lizard functional diversity in a tropical dry forest of the Pacific coast of Mexico. Trop Conserv Sci 10:1940082917704972

Borges-Landáez PA, Shine R (2003) Influence of toe-clipping on running speed in *Eulamprus quoyii*, an Australian scincid lizard. J Herpetol 37:592–595

Bramwell B (2004) Mass tourism, diversification and sustainability in southern Europe's coastal regions. Coastal mass tourism: Diversification and sustainable development in Southern Europe: 1–31

Choi CH, Seo BS, Park WJ, Park SH (2006) The flora of coastal dune area in Shinduri, Korea. Kor J Plant Res 19:209–217

Do MS, Lee JW, Jang HJ, Kim DI, Park J, Yoo JC (2017) Spatial distribution patterns and prediction of hotspot area for endangered herpetofauna species in Korea. Korean J Environ Ecol 31:381–396

Dodd CK (1993) The effects of toe-clipping on sprint performance of the lizard *Cnemidophorus sexlineatus*. J Herpetol 27:209–213

Getz WM, Wilmers CC (2004) A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. Ecography 27:489–505

Getz WM, Fortmann-Roe S, Cross PC, Lyons AJ, Ryan SJ, Wilmers CC (2007) LoCoH: nonparameteric kernel methods for constructing home ranges and utilization distributions. PLoS One 2:e207

Jeong JC, Song JY (2010) Diet composition of the Korean leopard lizard, *Eremias arugus* (Reptilia:Lacertidae) in Taeanhaean National Park. J Nat Park Res 1:9–12

Kim BN, Kim IH, Kim JK, Park D (2010) Characteristics of oviposition and egg hatching of the Mongolian racerunner (*Eremias argus*) in the laboratory and field. Korean J Herpetol 2:27–34

Kim JK, Kim IH, Kim BN, Ra NY, Park D (2011a) Characteristics of *Eremias argus* habitat in coastal sand dunes and mountain areas. Korean J Herpetol 3:11–18

Kim JB, Min MS, Park DS, Song JY (2011b) Red data book of endangered amphibians and reptiles in Korea. National Institute of Biological Resources, Incheon, South Korea, p 125

Kim BN, Kim JK, Park D (2012) Mating behavior of the Mongolian racerunner (*Eremias argus* Lacertidae, Reptilia). Anim Cells Syst 16:337–342

Krebs CJ (1998) Ecological methodology. Harper and Row, Publishers. New York

Langkilde T, Shine R (2006) How much stress do researchers inflict on their study animals? A case study using a scincid lizard, *Eulamprus heatwolei*. J Exp Biol 209:1035–1043

NIBR (2019) Red data book of Republic of Korea. Volume 2: Amphibians and Reptiles. National Institute of Biological Resources, Ministry of Environment, Incheon, Republic of Korea.

Nordstrom KF (2004) Beaches and dunes of developed coasts. Cambridge University Press, Cambridge, UK, p 352

Orlova V, Terbish K, Zhao W, Guo X (2019) Eremias argus. The IUCN red list of threatened species 2019: e.T47755847A47755852. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T47755847A47755852.en

Park J, Seo J, Kim J, Oh HS, Park J (2013) A study on topography and plant distribution characteristics in the Baramarye special protection zone. J Nat Park Res 4:111–119

Pike DA, Webb JK, Shine R (2011) Removing forest canopy cover restores a reptile assemblage. Ecol Appl 21:274–280

Seo JC (2012) Sustainable management duidances for Sindu coastal dunefield, natural monument no.431: on the focus of a new ecological observation trail course and the long-term moniteringmonitoring programs. Geo J Korea 46:25–37

Song HS, Cho W (2007) Diversity and zonation of vegetation related micro-topography in Sinduri coastal dune, Korea-focused on the natural monument area. Korean J Environ Ecol 21:290–298

Song JY, Koo KS, Chang MH (2010) Movement and home range of the Mongolian racerunner, *Eremias argus* (Squamata: Lacertidae): a preliminary result. Korean J Herpetol 2:17–21

Song JY, Chang MH, Koo KS (2013) Estimating the size of a Mongolian racerunner *Eremias argus* (Squamata: Lacertidae) population at Baramarae beach, Taeanhaean National Park. Korean J Herpetol 5: 9–13

Song JY, Chang MH, Koo KS (2016) Fluctuating size of Mongolian racerunner, *Eremias argus* (Squamata: Lacertidae) population at Baramarae beach, Taeanhaean National Park. Korean J Herpetol, p 10

Taean (2016a) A study on coastal sand dune monitoring in Sindu coastal dune, Taean, South Korea. pp. 188. (published in March 2016)

Taean (2016b) A study on coastal sand dune monitoring in Sindu coastal dune, Taean, South Korea. pp. 220. (published in December 2016)

Towns DR (1994) The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertilia: Scincidae). N Z J Zool 21:457–471

Wouters B, Nijssen M, Geerling G, Van Kleef H, Remke E, Verberk W (2012) The effects of shifting vegetation mosaics on habitat suitability for coastal dune fauna—a case study on sand lizards (*Lacerta agilis*). J Coast Conserv 16:89–99

Yu JJ, Kim JS, Jang DH (2016) A time-series analysis of the erosion and deposition around Halmi-island, Baramarae. J Korean Geomorphological Assoc 23:47–60

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.