Chapter

Ecology of Red-Tongue Viper (*Gloydius ussuriensis*) in Jeju Island, South Korea

Hong-Shik Oh and Maniram Banjade

Abstract

Understanding the ecology of species at risk is extremely important for their conservation and management. Due to land clearing for urban expansion, agriculture, and the import of pets, several snake species including the red-tongue viper (*Gloydius ussuriensis*) on Jeju Island of South Korea, have become threatened. We studied morphology, distribution, habitat characteristics, diet, and reproduction of red-tongue viper to provide a higher understanding of species ecology. This species on average reach 242–580 mm snout-vent length and is found in a wide range of habitat from mountain forest to lowland areas. Adult snakes prey almost entirely on amphibians followed by mammals and centipedes. The mating usually takes place in spring and birth takes place in autumn. This study points out the major threats and ill-information if addressed will not only contribute to the conservation efforts but also improve the negative attitudes that people hold toward these fascinating animals. The ecological data of *G. ussuriensis* herein provides basic information which assists in designing the management technique for conservation. Similar applications may be generalized and used to other vulnerable species to detect and quantify population ecology and risks, bolstering conservation methods that can be used to optimize the efficacy of conservation measures.

Keywords: *Gloydius ussuriensis*, viperidae, ecology, Jeju Island, threats

1. Introduction

Snakes have fascinated people for millennia. They have been integrated into a variety of myths and civilizations [1]. Despite having a limbless ectothermic body, snake species have spread throughout the Earth's biomes except for the polar area. Some species may still be found within the Arctic circle (e.g., *Vipera berus*; [2]). Snakes are one of the most misunderstood and mistreated animal species [3, 4]. Snake conservation has significant hurdles due to widespread unfavorable views of snakes and a lack of awareness of their basic biology [5]. Unfortunately, we frequently know the least about the species that are the most in need of protection because of their seeming scarcity. These difficulties are most evident for vipers (Family Viperidae, ~330 species). Vipers are species with a broad range of habitats. Only a few places such as Antarctica, Australia, New Zealand, Madagascar, the Arctic Circle, and island clusters like Hawaii are free of vipers.

Vipers are among the most poisonous family of snakes. They belong to the family Viperidae. All vipers are known for their long, hollow fangs that are hinged on a highly flexible maxillary bone. Vipers are also known for their phylogenetically extensive viviparity, parental care, and ambush forager behavior [6, 7]. In a study of 1500 randomly selected reptile species, Böhm et al. [8] have discovered that vipers are much more endangered than predicted. Even though vipers make up just 9% of all snakes [9], they account for 20% of 226 snakes classified as endangered on the International Union for Conservation of Nature (IUCN) Red List [10]. Twenty viper species are classified as vulnerable, 23 as endangered, and 11 as critically endangered globally [10].

1.1 Snakes in South Korea

Snakes in South Korea live like in any Asian country. The location of the country is in a temperate climatic zone that provides a territory with rich flora and fauna. The country's heterogeneous landscape is represented by plains, mountains, and sea coast. Rich forests are found not only in the plains, but also in the foothills and mountainous regions which provide excellent feeding, resting, and spawning habitats for a variety of animals as well as various herpetofauna, particularly snakes. South Korea is home to 20 species of both poisonous and non-poisonous snakes (**Table 1**). Of 600 species of venomous snakes worldwide, South Korea is home to nine species [11, 12]. These venomous snakes include three pit vipers (*Gloydius brevicaudus*, *G. ussuriensis*, and *Gloydius intermedius*) belonging to Viperidae, *Rhabdophis*

S. No	Scientific name	Common name
1	*Dinodon rufozonatum*	Red-banded snake
2	*Elaphe davidi*	David's rat snake
3	*Elaphe dione*	Steppe rat snake
4	*Elaphe schrenckii*	Korean rat snake
5	*Elaphe taeniura*	Korean beauty snake
6	*Amphiesma vibakari*	Asian keel back
7	*Hydrophis platrrus*	Yellow-bellied sea snake
8	*Hydrophis cyanocinctus*	Annulated sea snake
9	*Hydrophis melanocephalus*	Slender-necked sea snake
10	*Vipera berus*	Common viper
11	*Oocatochus rufodorsatus*	Frog-eating rat snake
12	*Hierophis spinalis*	Slender racer
13	*Pelamis platurus*	Yellow-bellied sea snake
14	*Rhabdophis tigrinus*	Tiger keelback.
15	*Sibynophis chinensis*	Black-headed snake
16	*Gloydius brevicaudus*	Short-tailed mamushi
17	*Gloydius saxatilis*	Rock mamushi
18	*Gloydius ussuriensis*	Ussuri mamushi/Red tongue viper
19	*Laticauda semifasciata*	Chinese sea snake
20	*Laticauda laticaudata*	Blue-banded sea krait

Table 1.
List of snake species in South Korea.

tigrinus belonging to Colubridae, and five marine species belonging to Elapidae [13]. Red-tongue viper (*G. ussuriensis*) has the highest venom toxicity among pit vipers based on LD_{50} (lethal dose that kills 50% of the population) values, followed by *G. intermedius* and *G. brevicaudus* [14]. The venom of *G. ussuriensis*, like those of other viperids, is hemotoxic, causing hemorrhages, thromboses, and severe necrosis [14]. *G. ussuriensis* and *G. brevicaudus* are the two species responsible for the majority of snakebite incidents in South Korea, particularly the former. According to large data from Korea's Health Insurance Review & Assessment Service, poisonous snake bites impact 2315–4143 patients on average each year in South Korea.

In South Korea, *G. ussuriensis* (**Figure 1**) has a wide distribution, including the mainland of South Korea and its associated islands. Jeju, the largest Island that is rich in biodiversity, is located 73 km south of the Korean Peninsula. It is a well-known habitat for this species. However, rapid urbanization and industrialization have posed a threat to this species. In the previous two decades, Jeju Island has seen significant urbanization and industrialization, undergoing a large-scale change from agricultural land to industrial land for civilization [15]. The use of heavy equipment for farming, land clearance, and road construction has caused their high mortality. Moreover, they are killed by humans despite their important roles as prey and predators in the ecosystem. These species account for a substantial proportion of middle-order predators that keep our natural ecosystem working.

However, a comprehensive understanding of its ecology and population biology is lacking. Such gaps in our understanding hinder our capacity to design effective conservation and management plans. They also prevent us from arguing that conservation is even necessary. This seems to be because there is a lack of communication between scientists due to publications written in various languages. Most publications about *G. ussuriensis* are in the Korean language, attracting little attention from researchers who write in western languages. In an attempt to bring Korean research focusing on *G. ussuriensis* to the attention of researchers worldwide, we reviewed various publications and major findings of Kim and Oh from 2014 to 2016. Effective conservation of snakes nearly always requires answers to specific questions regarding their distribution, diet, habitat requirements, and reproduction.

1.2 Jeju Island

Jeju Island is a typical volcanic island formed about 2 million years ago by a volcanic eruption. It is located in the most southerly portion of the Korean

Figure 1.
G. ussuriensis *individual observed in Jeju Island.*

Peninsula. Its topography is smooth with an oval form extending in an east-northeast direction [16]. There is a wide range of volcanic topographies. There are about 360 small volcanoes known as "Oreum". Oreums are distributed mainly in the middle mountain zones [17] that provide retreat sites for snakes. The highest peak on the island is 1950 m above sea level. Despite its small size (1833.2 km^2), a total of 830.94 km^2 (about 45%) land area was designated as a "Biosphere Reserve" by UNESCO (United Nations Education Scientific Cultural Organization) in 2002 [18].

The climate on Jeju Island is highly seasonal with cool, dry winters and warm, wet summers. The hottest month is August (average temperature of 26.5°C) and the coldest month is January (average temperature of 6°C). It contains various habitat types ranging from evergreen broadleaf forest, deciduous forest, and coniferous forest to grassland and wetland habitats [19]. The Island supports 4764 species of land flora [19]. Vertebrate species include 43 species of mammals (including sea mammals), 418 species of birds, 7 species of amphibians, and 14 species of reptiles [20].

2. Description

2.1 Morphology

G. ussuriensis is a small-sized, highly venomous snake belonging to the family of Viperidae [21]. Its adults have short, moderately slender bodies not exceeding 650 mm (rarely more than 680 mm). Its tail length is 80 mm [22]. Males are generally larger than females (**Table 2**). The Head is large and often triangular because of the lateral projection of quadrate bones. Its very small eyes have typical vertical pupils with a fine bright edge. Its mouth has paired hollow fangs connected to venomous glands located behind the eye at the back upper part of the jaw. The tongue is pink or red and bifurcated. Scales are located in 21 rows on each side of the body. There are also abdominal scutes (16–66 pairs) and sub-caudal scutes (about 51 pairs).

The general ground color of the body is brown or brown of varying intensity, sometimes almost black. On the side of the body starting from the head, there is a row of elliptical or rounded dark spots with a light middle and darker edges. In the middle of the back, rings of opposite sides are often joined. The belly is yellow-gray with black marks anteriorly. In the central part, there is a combination of black and yellow-gray spots such that the snake is well camouflaged both in arboreal and terrestrial situations. Posteriorly, the belly is uniformly black. The melanistic individual from Jeju Island has been reported [24], with remarks on color variations of this species.

SVL (mm)	Population		
	Male (n = 61)	Female (n = 99)	SSD (Sexual size dimorphism)
Mean	434.5	422.0	
SD	51.7	46.7	−0.03
Range	296–580	242–532	
			Kim and Oh [23]

Table 2.
Snout-vent length (SVL) comparison between male and female of G. ussuriensis *in Jeju Island.*

3. Life history

3.1 Distribution

G. ussuriensis is a species of a venomous snake having limited distribution worldwide. Currently, the known range of this species cover the following regions: Russian Far East, northwards to the lower Amur River, westwards to the Argun River, eastwards limited to the coast of the Sea of Japan and Tatarskiy Strait, the Korean peninsula, and northeastern China [21, 25]. In Korean Peninsula, it is commonly found in mainland South Korea, Jeju Island, and its associated islets. In Jeju Island, its distribution is homogenous (**Figure 2**) and it is one of the most commonly encountered snakes. In Jeju Island, it utilizes various habitats ranging from mountain forests to low altitude areas containing swamps and marshes [26, 27]. They are frequented more open microhabitats that had rocks or fallen logs that served as a refuge or basking spots. Agricultural land, grasslands, and freshwater streams are the areas of most frequent records. More commonly they were recorded from wetland sites adjacent to forested habitats as; Dongbaekdongsan, Muljangori, Mulyeongari, and Sumeunmulbaengdui wetland areas. Being hygrophilous, it is not uncommon on the sea. It is also recorded at an altitude up to 1947 m. However, until recently no information is available about population size.

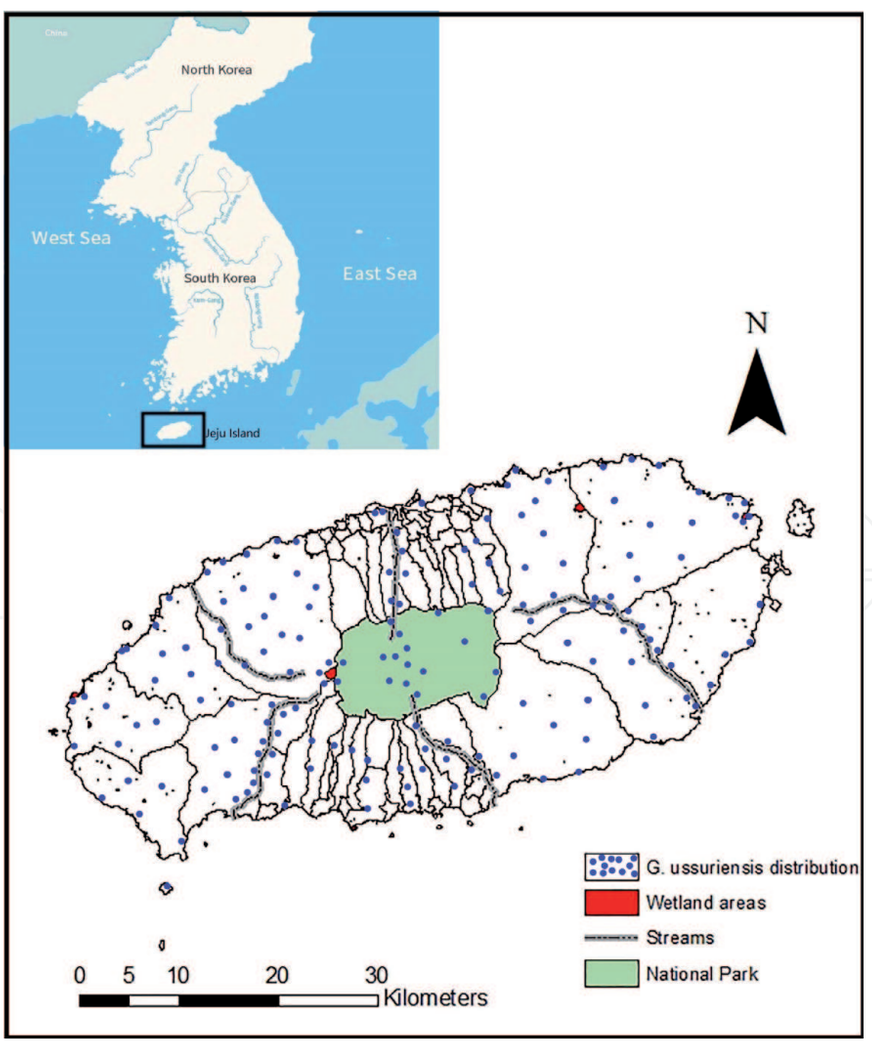

Figure 2.
Distribution of G. ussuriensis *in Jeju Island.*

3.2 Habit and habitat

Each species has its own unique behavior. Some spend most of the day foraging for food or basking in the sun, while others are most active at dusk and dawn or during the night. *G. ussuriensis* has plasticity in its diet, which allows this species to spread widely and survive in various landscape zones. Prey is identified by heat, followed by a sudden and rapid attack and bite. Basking in the sun is a common daytime activity in early summer. Hibernation begins from October to the middle of May of the following year. Each individual has its own hunting territory, beyond which it does not go. *G. ussuriensis* generally engages in limited movements. They may remain for long period in relatively small areas of approximately 64 m^2 [28], where they can be repeatedly observed. They shed their skin from time to time during molting. Bites are excruciatingly painful, producing internal organ hemorrhages as well as bleeding at bite sites.

Most animals have their preferred habitats [29, 30], which may be influenced by species-specific temporal and spatial constraints. Vipers can live in different ecosystems including woodlands, forests, rocky areas, coasts, wetlands, swamps, mountainous regions, scrubs, and others. Habitat is an essential part of their survival and life history because it allows snakes to protect themselves from predators and it can be used for hibernation, breeding ground, and ambush. They can take refuge in burrows of rodents, among rocky slopes, boggy vegetation, and dense bushes. In Russia, *G. ussuriensis* usually adheres to forest edges, rocky taluses, abandoned settlements, ruins of old houses, and cemeteries. It is frequently observed on the coast of the Sea of Japan. In Jeju Island, it is common in cultivated land, low mountain areas, and forest areas. It can be seen hiding under stones. It is often found along banks of water bodies, dried-out ditches, and low-lying damp areas that provide more humidity. As a rule, it adheres to open space covered with grass or shrubs required for successful hibernation.

3.3 Diet

Every snake is zoophagous (consuming other creatures). All snakes are carnivorous. They eat animals, not vegetables. Some prefer specific prey, while others will eat just about everything they can grab and swallow. Snakes hunt different prey items, including rats, mice, rabbits, frogs, insects, lizards, other snakes, birds, bats, squirrels, and so on.

The diet of *G. ussuriensis* in its distribution range is not well documented. It has been stated that this species feeds primarily on frogs and other amphibians. They also feed on small mammals and other animals [31]. Thus, the diet of *G. ussuriensis* is typically broad. Kim and Oh [23] have studied prey items of *G. ussuriensis* in Jeju Island through manual palpation methods (**Figure 3**). Through the analysis of 177 individuals from 46 locations, a variety of prey items ranging from centipedes to amphibians, reptiles, and mammals were observed (**Table 3**). Among these prey, amphibians had the highest frequency of occurrence (55.2%), followed by mammals (20.7%), centipedes (13.8%), and reptiles (10.3%). The highest occurrence of the amphibian diet of *G. ussuriensis* is related to a higher abundance of herpetofauna at swampy (wetland) areas as good habitats of *G. ussuriensis* whose subsequent mimicry can kill the prey. The choice of prey differs in response to local and geographical variation in prey availability or abundance. At Gapado Island (Islets of Jeju Island, located 5.5 km off the Jeju coast), where prey items of *G. ussuriensis* were limited only to centipedes and lizards [23]. They concluded that the shift in diet was related to the lower density of favorable prey items.

Figure 3.
Prey detection of G. ussuriensis *through manual palpation method.*

Preys		**Number**	**Remarks**
Sorts	**Scientific name**		
Centipede	*Scolopendra subspinipes mutilans*	4	
	Hynobius quelpaertensis	2	
	Hyla japonica	9	
Amphibians	*Kaloula borealis*	2	
	Rana dybowskii	1	
	Rana nigromaculata	2	
	Scincella vandenburghi	1	
Reptiles	*Amphiesma vibakari*	1	
	Colubridae sp.	1	Skin of snakes
	Crosidura shantungensis	1	
Mammals	*Sorex caecutiens hallamontanus*	1	
	Apodemus chejuensis	2	
	Deomyinae sp.	2	Fur of rodent

Table 3.
Prey items of G. ussuriensis *identified through manual palpation in Jeju Island.*

Head size and shape are not static, and however, most snake species have shown substantial flexibility in head shape [32, 33]. In a wide range of snakes, head form is surprisingly varied and has been hypothesized to be adaptive, with relative head width, in particular, is connected to the maximum prey size that may be eaten [34]. In general, larger snakes eat larger prey whereas smaller consumed smaller prey. In Jeju Island, a positive correlation was found between the size of the head of *G. ussuriensis* and the diameters of prey items [23].

3.4 Reproduction

Reproductive behaviors and rates vary drastically based on the species. Reproduction in snakes is controlled by the natural cycle of ambient warmth and cold [35] and red tongue vipers are no exception. Seasonal changes in light and rainfall, which impact food availability, might potentially play a role in reproduction for these ectotherms. Reproduction is dioecious. Mating takes place in April and May. The mating strategy of *G. ussurisensis* is not well documented yet but incidences of 2–3 males mating with a single female have been frequently observed (**Figure 4**).

Figure 4.
The group mating of G. ussuriensis *in Jeju Island. Two male and one female participating in group mating.*

However, one incidence of multiple males competing for a single female (forming mating ball) was observed within Jeju Island (personal communication). Like other members of the viper family, *G. ussuriensis* is ovoviviparous. They retain eggs inside their bodies until they hatch and give "live" birth.

Much like other snake species, [36] red tongue viper reproduce annually. In Jeju Island, seasonal cycles based on size and histological examination of testes and follicles in ovaries have been reported by Kim and Oh [23]. The change in the monthly average value of the Testis Index (TI) was large between June and July. It was relatively stable between July and August, while it was the largest between August and early September (**Figure 5**). The average length of the largest follicle in a female's ovary was at its largest in May and smallest in June (**Figure 6**). After intensive vitellogenesis in May, ovulation and fertilization seem to occur since June. Most births occur between the end of August and September when females give birth to 2–10 offspring in one brood.

Newborn babies completely repeat the color of their parents. With the analysis of 146 newborns, the mean weight of neonates was 4.3 ± 0.7 g (range, 1.1 g–6.6 g) and the mean length (NS) of neonates was 174.3 ± 12.6 mm (range, 110–203 mm). They reach sexual maturity at a body length of 400 mm, possibly after the second or third hibernation. Before hibernation, newborn snakes have time to molt 5–6

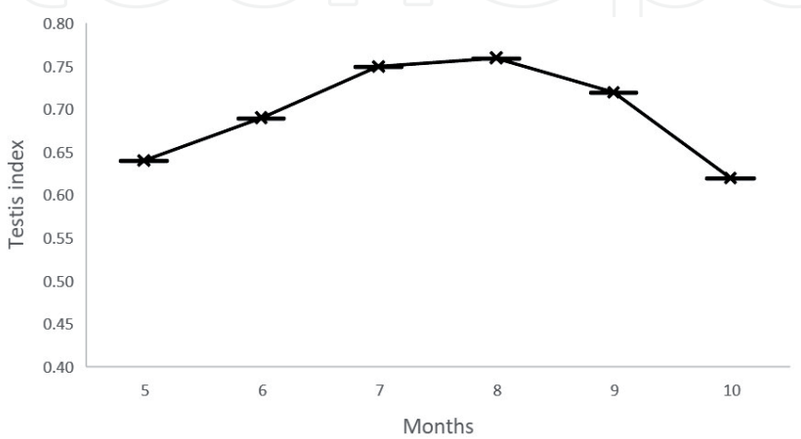

Figure 5.
Monthly pattern of male testis index. Cross line represent means and horizontal lines represent standard deviation.

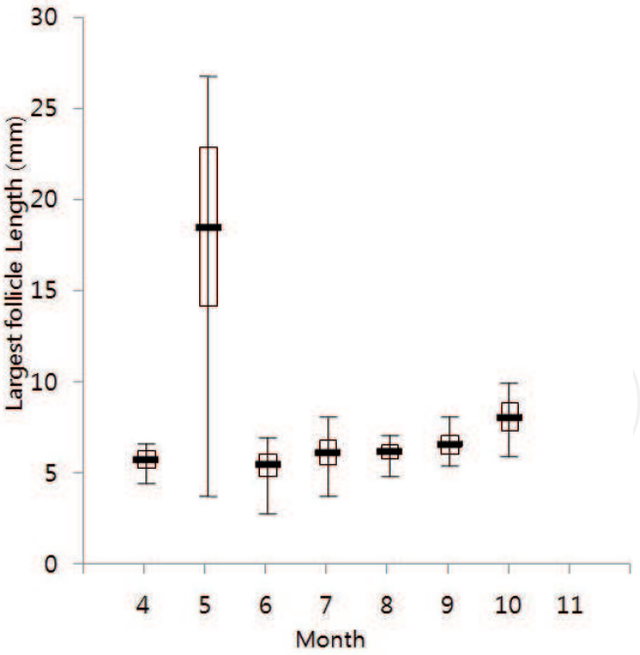

Figure 6.
Annual pattern of ovarian largest follicle length in female G. ussuriensis *in Jeju Island. Horizontal thick lines represent means and horizontal thin lines and vertical bars represent standard deviation and ranges.*

times. The first molt occurs after 6–7 h and the second molt occurs after 2–3 days. At first, newborns feed on insects and invertebrates. Later, they switch to normal food. Life expectancy on average ranges from 9 years to 15 years. In captivity, this may increase.

Adult females of many snake species breed on a less-than-annual basis, indicating the requirement of a long foraging period to accumulate sufficient reserve for offspring production [37]. *G. ussuriensis* females have a one-year breeding cycle [23]. According to indirect data, in the north of Primorsky and the Khabarovsk Territory in Russia, this species may have a two-year breeding cycle. Depending on factors such as prey densities and favorable weather conditions, some degree of synchrony is observed during clutch or litter production by females within a population.

3.5 Natural predators and competitors

G. ussuriensis members, particularly young ones, have someone to fear. They are frequently attacked by birds of prey (hawk, white-tailed eagle, and black kite), large-billed crow and jay, and predatory mammals (badger, Siberian weasel). Competition from other vipers does not seem to be occurring in Jeju Island. In many parts of the world, humans hunt vipers for food [38]. The genus Gloydius, has long been known for its medicinal value in Asia. Dried *G. ussuriensis* meat is eaten for medical treatment by inhabitants of Japan and Korea. Thus, hunting for them has made people their main enemy.

4. Threat

4.1 Habitat loss and fragmentation

The most serious risks to biodiversity are habitat loss and fragmentation. It is reasonable to believe that habitat loss and fragmentation will be the most serious

dangers to snake populations worldwide [39, 40]. Where the natural forest is destroyed and replaced with intensive agriculture, coniferous plantations, or urban development, *G. ussuriensis* faces a particularly serious threat. Such changes will definitely have a detrimental effect on the prey abundance of snake species, decreasing predators' chances of long-term survival [41].

As vehicle ownership and traffic levels increase, many new roads are being built everywhere in Jeju Island, with a greater proportion of them being broad, fast highways. Snakes usually travel a certain distance in search of a mate and seek nesting sites, which force them to cross roadways. As a result, many individuals are killed on the roads. Some others interact with threats such as humans, farm equipment, vehicles, and pets (dogs and cats), which put *G. ussuriensis* populations at serious risk.

4.2 Introduction of invasive species

Invasive species frequently have immediate and widespread detrimental consequences for populations, natural groups, and biodiversity [42]. The impact of invasive alien species on native snakes species in the world has been recorded, including the introduction of Cane Toad (*Thinella marina*) in Australia [43], Indian Mangoose (*Herpestes javanicus*) in some Antillean Islands [44], and three species of fire ants (*Solenopsis invicta, S.geminata,* and *Wasmannia auropunctata*) in Africa and New-Zealand [45].

In 2017, a red fire ant (*S. invicta*) was discovered in South Korea. Since then, it has subsequently spread to various states within the country [46]. This species is of high concern because it has caused severe damage to many aspects of human life and wildlife [47] due to its aggressiveness and toxicity [48, 49]. Quantitative evaluation of climate suitability of the invasive red fire ant suggests that this ant has a high possibility of settlement after its introduction in Jeju Island [50]. Invasive red fire ants have the potential to harm *G. ussuriensis* indirectly through their negative effects on their prey and directly by predation facilitated by their potent stings.

4.3 Human persecution

The persecution of snakes by humans is widespread, especially among venomous snakes. Many snakes are killed regardless of whether they are venomous because people tend to have an irrational fear of these creatures. *G. ussueriensis* is often intentionally killed by hikers and hunters, although such an act is considered illegal. Building new roads can bring more people to formerly inaccessible places, increasing the danger of snakes being killed as a result of misinformation. Even experienced field biologists have limited knowledge of this snake's behavior and biology. It is difficult to establish a positive public perception of poisonous snakes. However, an adequate legislative framework can alleviate such issues. It is essential to educate people about the importance of snakes to modify their attitudes regarding venomous snakes.

5. Conclusion

G. ussuriensis is the most widespread species in Jeju Island and has suffered greatly, due to habitat loss, fragmentation, and increased mortality from roads and human persecution. The ecology of *G. ussuriensis* in Jeju Island was studied which aids in understanding the general biology of the species. *G. ussuriensis* is the small-sized, highly venomous viperidae having widespread distribution within Jeju Island.

Through the manual palpation method, *G. ussuriensis* was identified in consuming amphibian, centipede, reptiles, and mammals. Being dioecious, mating takes place in April and May and gives birth to live young's toward the end of August and September. A complete understanding of ecology could help in implementing the conservation and management plans. Increasing people's knowledge and understanding about snake and snakebite treatment and prevention through educational interventions like snake parks and snake museums is a low-cost method to promote a snake-friendly mindset.

Here, we attempt to provide useful knowledge to locals, scientists, and conservation agencies. Because this field is in its infancy, we are forced to rely heavily on results published in other languages, personal communication, and results of unpublished experiments. We believe that successful initiatives, even if limited in their impact are informative and might well prove broadly applicable for snake conservation.

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Appendices and nomenclature

IUCN	International Union for Conservation of Nature
UNESCO	United Nations Education Scientific Cultural Organization

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