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Spatial Ecology of Translocated and Resident Amur Ratsnakes (*Elaphe schrenckii*) in Two Mountain Valleys of South Korea

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Abstract The translocation of snakes has been viewed as a useful tool to augment declining populations and to mitigate human-wildlife conflicts, even though released snakes often exhibit relatively high mortality. We radio-tracked 13 Amur Ratsnakes (*Elaphe schrenckii*) in the Woraksan National Park in South Korea from July 2008 to May 2009. Two of these snakes were residents, and 11 had been illegally captured in areas remote from the study site and were donated by the park office. During the study period, six of the translocated snakes were lost: two were killed by predators, one died of unknown causes, and the radio signals of three of the snakes were lost. In the field, the ratsnakes laid eggs in early August, moved into hibernacula in late November, and moved away from the hibernacula in mid-April. Compared to the resident snakes, five of the translocated snakes traveled approximately 1.3 times farther per week, and the home ranges of the translocated snakes were three to six times larger than those of the resident snakes. In addition, the translocated snakes were found underground more frequently than the resident snakes. The management recommendations resulting from this study will guide biologists and land use managers in making appropriate decisions regarding release sites and the use of gravid females in the translocation of this endangered ratsnake.

Keywords Amur Ratsnake, conservation, *Elaphe schrenckii*, radiotelemetry, translocation

1. Introduction

Reptile populations are declining worldwide, and reintroduction, supplementation and translocation techniques are currently being applied to encourage snake populations to recover (Fischer and Lindenmayer, 2000; Armstrong and Seddon, 2008; Mullin and Seigel, 2009; Reading *et al*., 2010). Translocation has been viewed as a useful tool for supplying snakes to declining populations and mitigating human-wildlife conflicts (Reinert, 1991; Brown *et al*., 2010). However, translocation often produces abnormal behavior and high mortality in the affected snakes (Dodd and Seigel, 1991; Fischer and Lindenmayer, 2000; Roe *et al*., 2010). According to a recent review of reptile translocations, several snake, lizard, and turtle species in North America, Europe, and Australasia have been translocated (Germano and Bishop, 2008). However, no studies on the translocation of Asian snakes have been published to date.

The Amur Ratsnake (*Elaphe schrenckii*) is the largest snake in Korea. It is found in Russia, from Siberia to Manchuria, Northeastern China, and most of North and South Korea (Kang and Yoon, 1975; Schulz, 1996). Several taxonomic studies (Zhou, 2005; Woo *et al*., 2009; An *et al*., 2010) and basic ecological studies on its feeding, mating, and oviposition in captivity have been conducted (Paik, 1979; Zhou and Zhou, 2004). In South Korea, the ratsnake has traditionally been recognized as a divine animal, with the power to protect a house (Paik, 1979). However, field populations have declined to critically low levels as traditional rural towns have modernized; furthermore, stream systems have been modified by replacing rocky banks with concrete banks, reducing the snakes' available habitat (Paik, 1979).

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Since 2005, the Amur Ratsnake has been classified as a Category I endangered species by the Korean Ministry of Environment. The endangered status of the Amur Ratsnake indicates an urgent need for field studies aiming to conserve and rehabilitate the remaining populations.

During the planning phase of our radio-tracking study of the Amur Ratsnakes in the Woraksan National Park in July 2008, we were given 11 (five females and six males) adult Amur Ratsnakes by the park office. A local policeman and park rangers found the snakes, which had been illegally collected in areas remote from the study site between April and July 2008 and kept in a private residence. Hereafter, we will refer to these 11 ratsnakes as the "translocated snakes". The goal of this study was to investigate the basic spatial ecology of resident and translocated Amur Ratsnakes in mountain valleys in the Woraksan National Park using radiotelemetry. The results could be used to design translocation projects for this endangered ratsnake in the future.

2. Materials and Methods

2.1 Study area We conducted our study in two neighboring small mountain valleys, the Golmoe and Guraegol valleys, which are approximately 2.5 km apart (36° 52' N, 128° 04' E) in the Woraksan National Park. The park occupies an area of 288 km^2 in three administrative districts in the central region of the Korean Peninsula (Jecheon-si, Moonkyeong-si, and Danyang-gun), and it includes more than five mountains that are over 1000 m above sea level. The mountains surrounding the study valleys are generally covered by deciduous woodlands, and have many rock cliffs and rocky outcrops. The dominant trees in the mountains are Mongolian oak (*Quercus mongolica*), Oriental cork oak (*Q. variabilis*), and Korean red pine (*Pinus densiflora*), and the dominant shrubs are Japanese spicebush (*Lindera obtusiloba*), fragrant snowbell (*Styrax obassia*), and Korean rosebay (*Rhododendron mucronulatum*), listed in order of their relative abundance. The mountain habitats are bordered by small areas of grassland, crop fields with rock fences, and stream banks; a paved road follows the mountain streams in the valleys of the study site. In some locations, the stream bank is immediately adjacent to the roadside.

2.2 Radiotelemetry We conducted radiotelemetry between 14 July, 2008, and 15 May, 2009. We captured two female resident ratsnakes with a snake-stick in the Golmoe and Guraegol valleys in the National Park during the first week of July, and received 11 additional adult ratsnakes (five females and six males) from the park office. The translocated ratsnakes were caught at three different sites in the park: at Deoksan-myeon, Cheongpung-myeon, and Susan-myeon, which are 9.0 km, 16.5 km, and 15.3 km from the study site, respectively. Considering the average distance traveled and the home range size of other ratsnakes (Durner and Gates, 1993; Sperry and Taylor, 2008), it is unlikely that any of these ratsnakes were native to the study site. The surviving ratsnakes were collected at the end of the study and are now being used in the captive breeding program for the Amur Ratsnakes that is conducted at the Chiaksan National Park. Before implanting the transmitters for radio-tracking, we measured the snout-vent length (SVL) of each ratsnake to ± 0.1 cm and weighted the snake to ± 0.1 g with a field balance (ELT4001, Sartorius, NY, USA). For individual identification, we used a needle to insert a passive, integrated transponder tag (TX1411L, Biomark, Boise, ID, USA) under the dorsal skin of each ratsnake.

We surgically implanted an SI-2 transmitter (18 g; Holohil Systems Ltd., Carp, Ontario, Canada) into the abdominal cavity of each ratsnake (Lee *et al*., 2011). The weight of the transmitter averaged 2.7% (ranging between 2.0% – 3.1%) of the body weight of the snake. Following the implantation, the ratsnakes were individually allowed to recover for approximately one week in a plastic cage (60 cm long × 40 cm wide × 17 cm high) (Lee *et al*., 2011). The ratsnakes were released once they had been recovered from the surgery.

Because we speculated that the areas where we caught the resident ratsnakes could be appropriate translocation sites, we released each resident snake along with several translocated snakes in each valley. A female resident snake, No. 590, was released with five translocated snakes, two females (No. 830 and No. 900) and three males (No. 890, No. 531, and No. 810), at the mouth (three snakes) and in the middle (three snakes) of the Golmoe Valley, where No. 590 was caught. Another female resident snake, No. 782, was released in the middle of the Guraegol Valley, where she was caught, with six translocated snakes, three females (No. 390, No. 970, and No. 991) and three males (No. 270, No. 510, and No. 760). We tried to maintain a 1:1 ratio of males and females released into each area. After release, we began the radio-tracking of these ratsnakes.

To follow the transmitter signals, we used a TR-1000 receiver combined with a three-element Yagi antenna (Wildlife Materials Inc., Murphysboro, IL, USA). We radio-tracked the ratsnakes weekly between 14 July and 9 December, 2008; monthly, between January and March 2009; and resumed weekly tracking between 3

April and 5 or 10 May, 2009. The last two radiotelemetry sessions were conducted to determine whether the snakes had survived the hibernation period. When we detected a snake's signal, we determined the coordinates of its location using a hand-held GPS unit (Vista CX, Garmin, New Taipei, Taiwan, China) and described the structural features of the site (See below). When we could not observe the snake directly, we determined its approximate location using triangulation (Lee *et al.*, 2011).

During the radio-tracking, we found that three females (two translocated and one resident) were gravid. We described the characteristics of the oviposition sites used by these females, including their altitudes and aspects, which was defined as the compass direction that a topographic slope faces, usually measured in degrees from north, and recorded the duration (in weeks) of the egg incubation period, which was defined as the number of weeks during which a gravid ratsnake remained at a specific site without any detectable movements. When the female moved away from the site, we confirmed that she had laid eggs. All of the snakes moved into hibernacula prior to 9 December, 2008. We judged the snake to be in hibernation if it did not move in an underground site for more than 2 weeks during November and/or December. We obtained the GPS coordinates of the hibernation sites and recorded the altitude, aspect, and structural features of each hibernaculum.

To analyze the structural features of the habitat used by the snakes, we classified the features used by each snake as ground, rock, underground, tree and bank. The ground features included grassland, bare ground and leafy places that were not near a rocky area or bank. The rock feature was designated when the snake was found on or inside a rocky outcrop or rock fence. The underground feature was designated if we detected a signal that originated from underground. The tree location meant that the snake was observed on a tree above the ground. Lastly, the bank location indicated that a snake was found on or under a stream bank or on a paved road along a mountain stream.

We plotted the coordinates of the relocated snakes on a digital map of the area in Arc-View GIS (v. 3.2, Environmental Systems Research Institute Inc., Redlands, CA, USA). We examined the distances that the released ratsnakes traveled during one week between 14 August and 9 December, 2008. The distance was measured as the minimum distance between two sequential locations plotted on the digital habitat maps in ArcView GIS. The home range of each ratsnake between the periods was estimated using both the minimum convex polygon (MCP) and the fixed kernel density techniques using the animal movement extension for ArcView GIS. For the kernel method, we obtained fixed 50% and 95% estimates by applying the least squares cross-validation criterion to choose the smoothing parameters (Row and Blouin-Demers, 2006; Lee *et al.*, 2011). The size of the home range was defined as the area that the ratsnake used between 14 July and 9 December, 2008. We excluded the data from the period between January and April or May, 2009 because the ratsnakes stayed in their hibernacula during this period. The hibernacula locations were determined prior to 9 December, 2008.

Because the sample size was relatively small, we did not perform any statistical analyses. The data are presented as the mean ± standard error throughout the text.

3. Results

Of the 11 translocated ratsnakes (two gravid females, three non-gravid females, and six males), five snakes were lost within the first 10 days of radio-tracking (two to predators, one to an unknown cause of death, and two whose signals were lost); the signal from one additional snake was lost later in the tracking period. Neither of the resident snakes was lost in the study. The translocated snakes that died included one of the two non-gravid females and two of the five males. We did not include the six lost translocated snakes in the further analysis (Table 1).

Two of the ratsnakes released at the mouth of the Golmoe Valley (No. 590 and No. 900) made relatively short-distance movements from the release site (Figure 1 A). The five ratsnakes that were initially released in the middle of the Golmoe Valley or Guraegol Valley (No. 270, No. 390, No. 782, No. 830, and No. 890) traveled long distances toward the mouth of the valley. After they reached that area, they generally made only short-distance movements (Figure 1 B). Two of the five snakes released in the middle of the valleys (No. 270 and No. 760) made return movements toward the release site, but they ultimately moved to the mouth of the valleys (Figure 1 B).

During our study, the three gravid females (two translocated snakes and one resident snake) laid eggs. From 6 August to 11 or 18 September, the gravid snakes stayed at a site for an average of 4.3 weeks (n = 3). One gravid snake was found inside a rock fence, and two gravid snakes were found in stream banks (Figure 1). The mean altitude and aspect of the oviposition sites (n = 3) were 269.7 m ± 34.7 m and 44.1° ± 1.4°, respectively.

The ratsnakes moved into hibernacula between 1 November and 9 December and left them between 12

Table 1 The weekly distance traveled and home range sizes of five translocated and two resident Amur Ratsnakes (*Elaphe schrenckii*) in the Golmoe and Guraegol Valleys, Woraksan National Park, between 14 July and 9 December, 2008.

Individual No.	Sex and gravid status	SVL (cm)	Body weight (g)	Radio-tracking period (2008–2009)	No. of relocations	Weekly distance traveled (m)	Home range (ha)		
							MCP	Kernel 50%	Kernel 95%
Translocated snakes									
900	Gravid female	127.4	692.4	7/18 – 5/5	28	51.9 ± 16.7	5.4	2.5	15.4
830	Gravid female	146.4	772.8	7/28 – 5/5	26	69.6 ± 25.5	5.5	4.5	31.9
390	Non-gravid Female	152.4	584.7	7/15 – 5/5	28	184.0 ± 46.0	87.6	17.8	186.3
270	Male	128.8	614.8	7/15 – 5/10	29	141.7 ± 39.9	11.4	6.3	37.9
890	Male	134.5	882.4	7/28 – 5/5	26	135.1 ± 69.6	36.4	15.7	110.5
Mean ± SE						116.5 ± 24.4	29.3 ± 15.7	9.4 ± 3.1	76.4 ± 32.0
Resident snakes									
590	Gravid female	113.8	585.2	7/17 – 4/18	26	40.3 ± 13.2	2.7	0.9	6.5
782	Non-gravid female	138.2	639.8	7/17 – 4/18	26	162.1 ± 44.4	21.4	5.4	50.7
Mean ± SE						101.2 ± 60.9	12.1 ± 9.4	3.2 ± 2.3	28.6 ± 22.1

SVL: Snout-vent length; MCP: Minimum convex polygon.

April and 1 May. The mean period of hibernation was 21.4 weeks (n = 7). The hibernaculum sites of the snakes varied; the three gravid females selected rock cliffs of mountains, one non-gravid female used rocks near an agricultural field, and one non-gravid female and two males hibernated in stream banks (Figure 1). The mean altitude and aspect of the sites (n = 7) were 258.5 m ± 88.0 m (176.5 m – 397.2 m) and 188.6° ± 78.4° (83.8° – 337.1°), respectively.

Between 14 July and 9 December 2008, the five translocated and two resident snakes traveled for mean weekly distances of 116.5 m ± 24.4 m (n = 5) and 101.2 m ± 60.9 m (n = 2), respectively (Table 1). The gravid translocated female traveled 1.5 times farther than the gravid resident female, and the non-gravid translocated female traveled 1.1 times farther than the non-gravid resident female. The 95% kernel estimates of the home ranges of the translocated and resident snakes were 76.4 ha ± 32.0 ha (n = 5) and 28.6 ha ± 22.1 ha (n = 2), respectively (Table 1). The home ranges of both the gravid

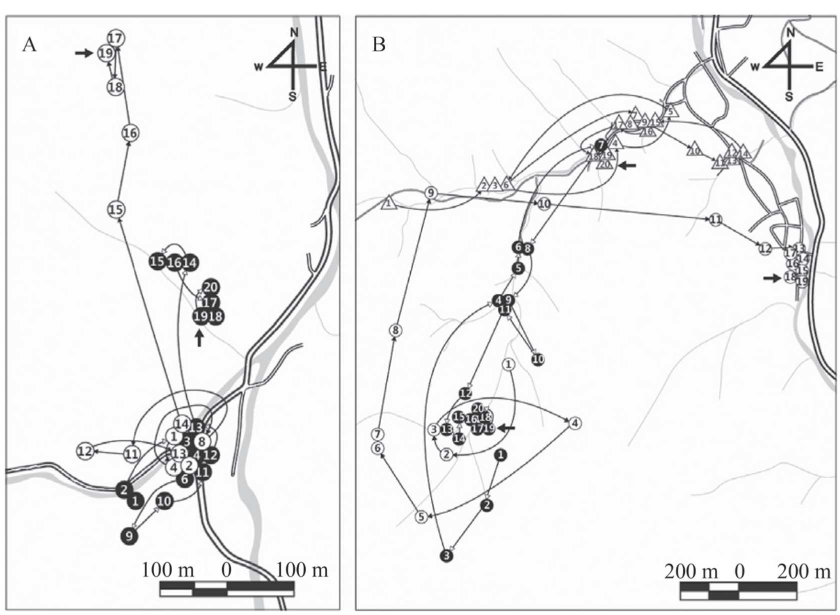

Figure 1 The movement patterns of the translocated and resident Amur Ratsnakes (*E. schrenckii*) in the Golmoe (A) and Guraegol (B) valleys of the Woraksan National Park between 14 July and 9 December, 2008. A: translocated (○: No. 900) and resident (●: No. 590) gravid females; and B: translocated (○: No. 390) and resident (●: No. 782) non-gravid females, and a translocated male (△: No. 270). The hibernacula are indicated by arrows. The paved road and mountain streams are indicated by a double line and a solid gray line, respectively.

and non-gravid translocated females between 14 July and 9 December, 2008, were 3.7 times larger than those of the corresponding resident females. Our comparison of structural feature usage showed that the translocated snakes were more frequently found underground and less frequently found in or on banks than the resident snakes (Figure 2).

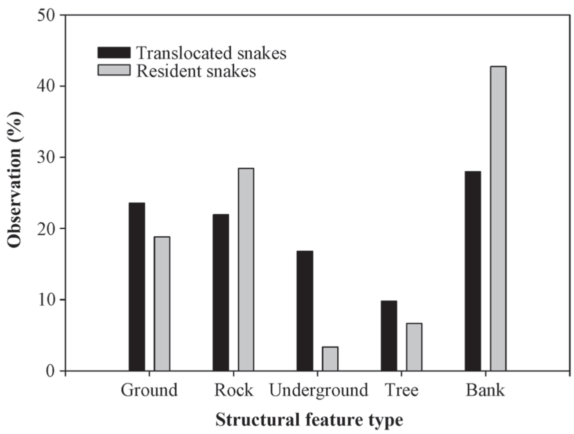

Figure 2 The use of structural features by the translocated and resident Amur Ratsnakes (*E. schrenckii*) in the Golmoe and Guraegol valleys of the Woraksan National Park between 14 July and 9 December, 2008.

4. Discussion

These results enhance our knowledge of the basic spatial ecology of the endangered Amur Ratsnake and reveal several important aspects associated with the use of translocation in snake conservation. However, our results should be interpreted with caution due to our small sample sizes. The Amur Ratsnakes in this study moved away from their hibernacula in mid-April, laid eggs in early August, and moved into their hibernacula in late November. Captive Amur Ratsnakes (*E. schrenckii*) in China were also reported laying eggs between middle July and early August and hibernated in late November (Zhou and Zhou, 2004). The activity of the Black Ratsnake (*E. obsoleta*) in Maryland, USA was found to begin in April, and the animals moved into their hibernacula in November (Stickel *et al.*, 1980). These results indicate that the activity and hibernation periods of ratsnakes are closely related with the timing of their reproductive periods. In the present study, the Amur Ratsnakes preferred the edges or mouths of mountain valleys, areas that often contain stream banks, as habitats. Because *E. schrenckii* prefers water, it is often called the Manchurian Water Snake (Schulz, 1996). A preference for edge habitats has also been reported for other ratsnakes, such as *E. obsoleta* and the Great Plains Ratsnake (*E. guttata emoryi*) (Blouin-Demers and Weatherhead, 2002; Sperry and Taylor, 2008), and it has been shown that edge habitats can provide effective basking sites for *E. obsoleta* (Blouin-Demers and Weatherhead, 2002).

The gravid *E. schrenckii* females that we tracked laid their eggs in stream banks or rock fences. Paik (1979) reported anecdotal information indicating that *E. schrenckii* laid eggs in heaps of dead leaves or compost in the vicinity of farms, but our results indicated that they prefer stream banks as oviposition sites. These sites might be beneficial because they allow effective basking and facilitate escape from possible predators. Because the Amur Ratsnakes incubate their eggs (Schulz, 1996), the open habitat offered by stream banks and rock fences could facilitate thermoregulation. Moreover, because ratsnakes prefer to remain primarily at the edges of habitats such as banks (Blouin-Demers and Weatherhead, 2001), an oviposition site located at or near the main activity site could benefit the offspring after hatching and possibly improve their chances of survival.

The Amur Ratsnake *E. schrenckii* in our study hibernated inside the stream banks at the mouth of mountain valley or in the rock cliffs of mountains from late November to middle April. In China, ratsnakes have been reported to hibernate beneath old trees or inside farmers' houses between October and April (Schulz, 1996). Similar to *E. obsoleta* (Prior and Weatherhead, 1996; Sperry and Weatherhead, 2009), *E. schrenckii* in our study preferred the sites that offered deep places for hibernation and were oriented toward the south or southwest. Considering that the three snakes hibernating in the mountains were all oviposited females, it might be interesting to inquire whether a breeding experience in the preceding summer affects the hibernacula selection in female Amur Ratsnakes (i. e., favors the selection of mountains rather than stream banks).

During their active period, the weekly distance traveled and the home range size was smaller for gravid females when compared to males and non-gravid females. The one-month incubation period for the eggs of the gravid females and the short-distance movements after their incubation might be responsible for these small values. The large distances traveled weekly by the non-gravid females and their large home ranges may be attributed to an active pursuit of nutrition to compensate for the previous year's expenditure of energy for breeding. It is well known that after oviposition or parturition, snakes travel farther during foraging to compensate for the energy used for reproduction (Shine, 1985; Lee *et al.*, 2011).

Meanwhile, the large home ranges of the males could be explained by their tendency to search actively for mates during July and August, as has been demonstrated in other ratsnakes (Durner and Gates, 1993). In *E. obsoleta*, the reproductive conditions are more important than a mere sex difference for predicting movement patterns (Blouin-Demers and Weatherhead, 2001). This could also be true of the Amur Ratsnakes.

The translocated Amur Ratsnakes traveled greater weekly distances and had larger home ranges compared to the resident ratsnakes. Similar behavioral trends have also been reported for some other snakes (Reinert and Rupert, 1999; Plummer and Mills, 2000; Roe *et al*., 2010). The increased movements and home range sizes might simply reflect the exploration of unfamiliar habitats or an active adaptation to the new habitats (Reinert and Rupert, 1999). In this study, the weekly distance traveled by the translocated Amur Ratsnakes was approximately 1.3 times greater than that of the resident snakes. This difference is similar to the 1.4-fold increase in the daily distance traveled that was reported for translocated Northern Water Snakes (Roe *et al*., 2010). However, these increases are much smaller than the 2-fold increase in daily distance traveled found for the translocated Tiger Snakes (Butler *et al*., 2005a) and the 3- to 6-fold increase in the daily distance traveled that was found for the translocated rattlesnakes (Reinert and Rupert, 1999). In our study, the home ranges of the translocated Amur Ratsnakes were 2.7 times larger than the home ranges of the resident snakes, similar to the 2.8-fold increase in home range size found in the study of Northern Water Snakes (Roe *et al*., 2010) but smaller than the 6-fold increase found for Tiger Snakes (Butler *et al*., 2005a) and the 5-fold increase found for rattlesnakes (Reinert and Rupert, 1999). The relatively small difference in home range size between the translocated and resident ratsnakes might be explained by the limited habitat use during the periods of activity; the home ranges of most of the Amur Ratsnakes were restricted because they were located in a mountain valley. Moreover, most of the snakes preferred edge habitats at the mouth of the valley, and the snakes were frequently observed in association with stream banks.

The structural features used by the translocated ratsnakes differed from those used by the resident ratsnakes. Translocated timber rattlesnakes exhibit similar habitat use patterns as those shown by resident snakes (Reinert and Rupert, 1999), whereas translocated and resident Tiger Snakes exhibit divergent habitat preferences (Butler *et al*., 2005b). Translocated and resident Northern Water Snakes also display different habitat preferences (Roe *et al*., 2010). In the present study, the translocated Amur Ratsnakes were found more frequently underground and less frequently on stream banks. A similarly decreased use of ground features was also reported in captive-bred Northern Water Snakes released in the field (Roe *et al*., 2010). Our frequent observation of the ratsnakes in underground sites implies that the ground activity of the translocated *E. schrenckii* individuals might be limited. This abnormal structural feature use could have long-term negative effects on the health of individual snakes and would probably produce high mortality for translocated snakes.

5. Conclusion

Despite the small sample size, this study revealed several important aspects of the basic spatial ecology of Amur Ratsnakes, including their oviposition and hibernation period. In addition, our results showed: 1) the translocated Amur Ratsnakes experience high initial mortality; 2) the use of structural features in the habitat is affected by translocation; and 3) the translocated snakes travel farther and have larger home ranges than resident snakes. However, 1) some of the translocated males and females released in the middle or at mouth of mountain valleys survived the winter; and 2) the translocated gravid females survived at a particularly high rate. These results could guide biologists and land use managers in making appropriate decisions regarding release sites and the use of gravid females for the translocation of this endangered ratsnake in the future.

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