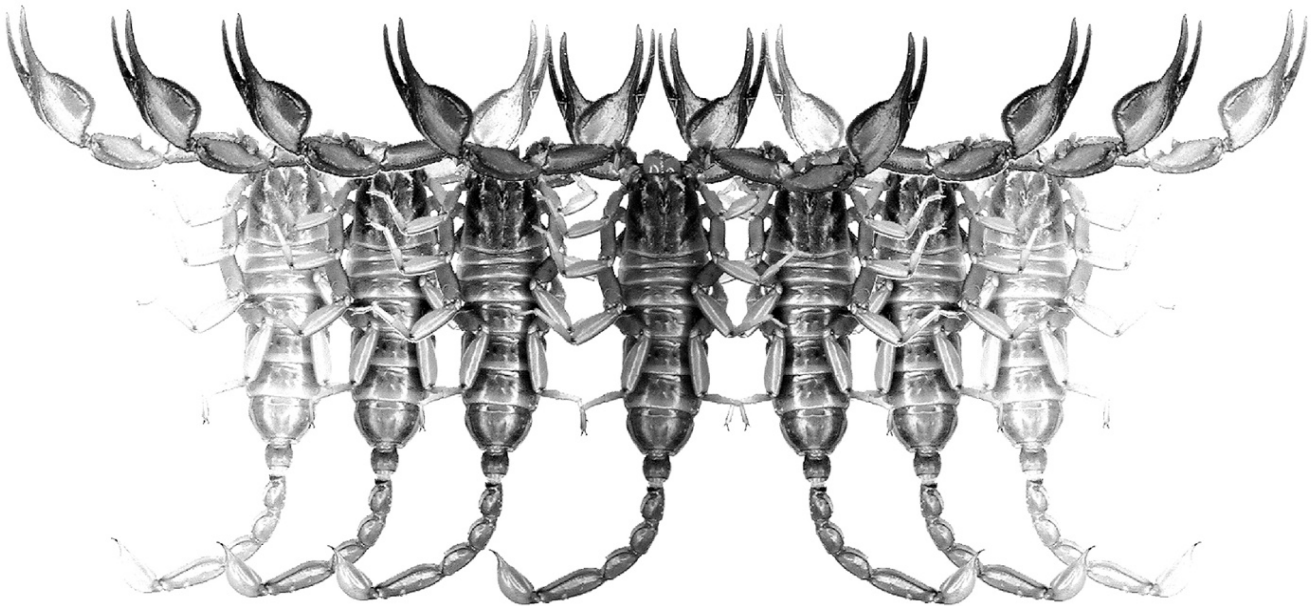


Euscorpius

Occasional Publications in Scorpiology



**Habitat characteristics of two scorpion species,
Liocheles australasiae (Fabricius, 1775) and
Isometrus maculatus (De Geer, 1778)
in Miyako Islands, Japan**

Kazusa Kawai

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Habitat characteristics of two scorpion species, *Liocheles australasiae* (Fabricius, 1775) and *Isometrus maculatus* (De Geer, 1778) in Miyako Islands, Japan

Kazusa Kawai

The Japan Scorpion Laboratory, 4-7, Motomachi, Gifu-shi, Gifu-ken, 500-8185, Japan;
email: kawai.k.scorpion@gmail.com

<http://zoobank.org/urn:lsid:zoobank.org:pub:899DB2B0-E072-410F-9C0E-CE1D32D37391>

Summary

Scorpion surveys were conducted in the five islands: Miyakojima, Ikemajima, Kurimajima, Irabujima, and Shimojishima (Miyako Islands, part of Nansei/Ryukyu Islands of Japan). Eight individuals of *Liocheles australasiae* (Hormuridae) and 16 individuals of *Isometrus maculatus* (Buthidae) were observed in a total of 10 points on four islands, except Ikemajima. The localities of both species are recorded in this survey, focusing on altitude, distance from the nearest coast, and sunlight. The lowest temperatures in the habitat are also examined, and the cold tolerance of the species is discussed.

Introduction

Liocheles australasiae (Fabricius, 1775) (Hormuridae) and *Isometrus maculatus* (De Geer, 1778) (Buthidae) are the only two species of scorpions found in Japan, specifically in its southern chain of islands, usually referred to as “Ryukyu Islands” in English literature. Both species have been historically recorded in the Ryukyu Islands (Iwakawa, 1906), and *I. maculatus* has been later introduced to the Ogasawara Islands (Bonin and Volcano Islands; Takashima, 1945). Both species have a very wide range of distribution outside Japan, with *L. australasiae* distributed from South Asia to East Asia, Southeast Asia, Australia and Oceania (Fet et al., 2000), and *I. maculatus* is thought to be the most widely distributed scorpion in the world, be found in tropical and subtropical areas worldwide (Fet et al., 2000; Lourenço & Cloudsley-Thompson, 2012).

The Japanese distribution area of *L. australasiae* is the Ryukyu Islands (Iwakawa, 1906), and it has been confirmed on 11 islands: Miyakojima, Irabujima, Shimojishima, Taramajima, Ishigakijima, Iriomotejima, Kohamajima, Taketomijima, Kuroshima, Haterumajima, and Yonagunijima (Shimojana, 1972, 2015; Takashima, 1942; Chigira & Tanaka, 2004; Tanaka, 2012; Karasawa & Kawazoe, 2005; Kawai, 2020a, 2020b) (Fig. 2). We surveyed this species in the Miyako Islands (Miyakojima, Kurimajima, and Irabujima).

Isometrus maculatus has been previously recorded from eight islands in Japan: Ishigakijima, Iriomotejima, Kamijijima, Haterumajima, Yonagunijima, Chichijima, Hahajima, and Ioto (Shimojana, 1972; Kawai, 2020b; Yokotsuka, 2011; Yamazaki et al., 2016; Muramatsu, 2007; Takashima, 1943, 1945, 1948, 1949; Kubo, 2001) (Fig. 3).

The populations on Chichijima and Hahajima (Ogasawara Islands) are thought to be invasive (Takashima, 1945). Geographic information suggests that the Ioto population may also have been introduced. However, this species has not been seen in Chichijima and Hahajima in recent years, and it is not clear whether it is still established there.

We surveyed this species in the Miyako Islands (Miyakojima, Irabujima, and Shimojishima).

The subgrouping of Japanese Islands (Fig. 1) is given below.

NANSEI ISLANDS

SATSUNAN ISLANDS, no scorpions recorded

RYUKYU ISLANDS

Okinawa Islands, no scorpions recorded

Sakishima Islands

Miyako Islands

Ikemajima Island, no scorpions recorded

Irabujima Island, *L. australasiae* (see Kawai, 2020a; this survey), *I. maculatus* (this survey)

Shimojishima Island, *L. australasiae* (see Kawai, 2020a), *I. maculatus* (this survey)

Miyakojima Island, *L. australasiae*, *I. maculatus* (see Shimojana, 1972; this survey)

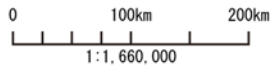
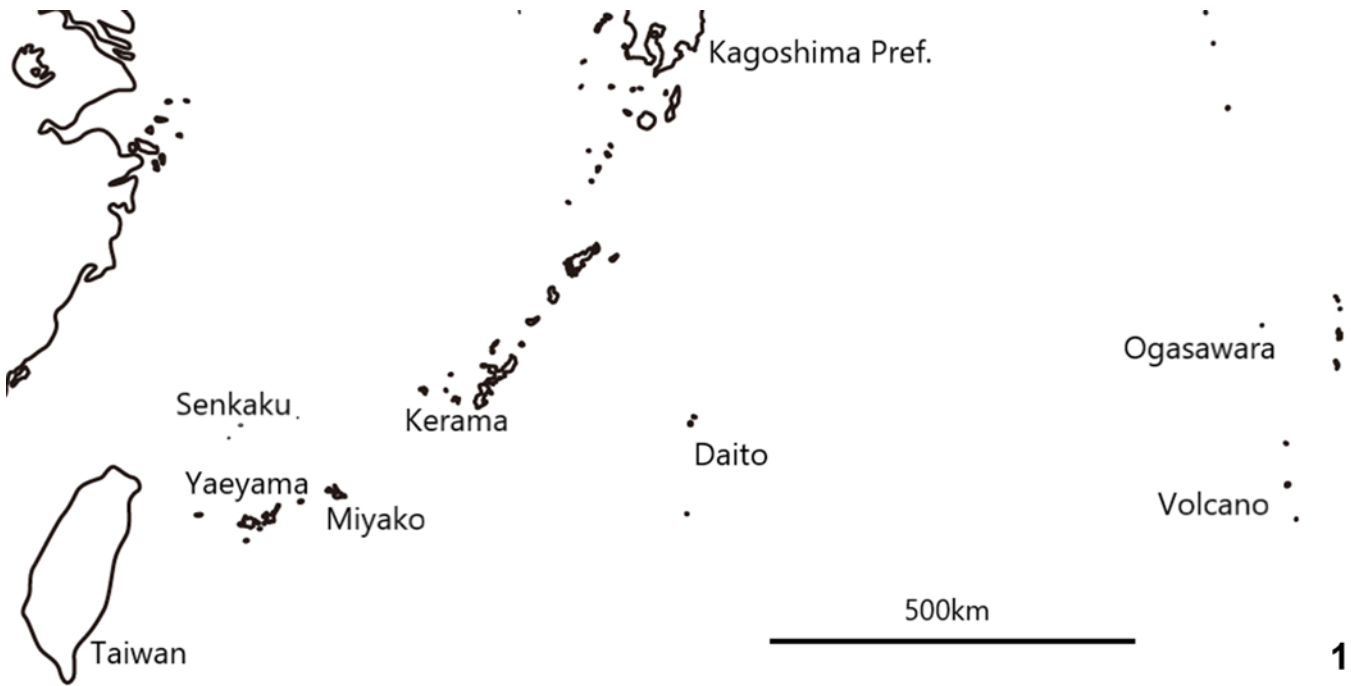
Kurimajima Island, *L. australasiae* (this survey)

Taramajima Island, *L. australasiae* (see Shimojana, 1999)

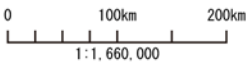
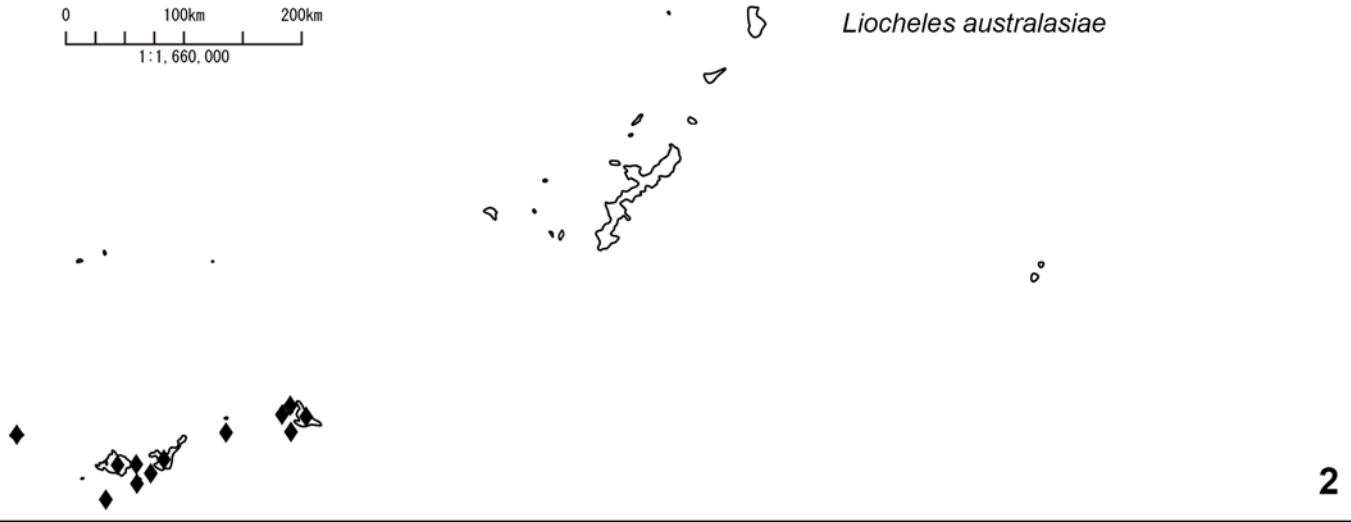
Yaeyama Islands

Ishigakijima Island, *L. australasiae* (see Shimojana, 1972), *I. maculatus* (see Takashima, 1948)

Iriomotejima Island, *L. australasiae* (see Takashima, 1942), *I. maculatus* (see Yokotsuka, 2011)



Liocheles australasiae



Isometrus maculatus



Figures 1–3: Figure 1. Location of Nansei Islands and Bonin Islands. Figure 2. Distribution of *Liocheles australasiae* (Fabricius, 1775) in the Nansei Islands. Figure 3. Distribution of *Isometrus maculatus* (De Geer, 1778) in the Nansei Islands.

	Location	Species	Figure	A	Date/time	Quantity	Density	Microhabitat	D
1	Kurimajima, NE	<i>L. australasiae</i>	Fig. 4	47 m	12/29/2020, 17:30-18.00	4 ♀ ad.	4 / fallen tree	Under a bark of a fallen tree	160 m
2	Irabujima, SE - A	<i>I. maculatus</i>	Fig. 5	70 m	12/29/2020, 20:15-20:45	3 ♀ ad., 2 second instars	1 / tree	Under bark of <i>Pinus luchuensis</i> and on the surface of a sign	520 m
3	Irabujima, SE - B	<i>L. australasiae</i>	Fig. 6	74 m	12/29/2020, 20:15-20:45	1 ♀ ad, 1 ♀ sbad	2 / m ²	Under a bark of decayed wood and in the grass	380 m
4	Irabujima, S	<i>L. australasiae</i>	Fig. 7	59 m	12/29/2020, 12:00-12:15	1 ♀ ad	1 / m ²	Under a stone in a cave	730 m
5	Shimojishima, NE	<i>I. maculatus</i>	Fig. 8	10 m	12/29/2020, 22:00-22:15	1 ♀ ad	1 / tree	Under bark of <i>Pinus luchuensis</i>	35 m
6	Shimojishima, NW	<i>I. maculatus</i>	Fig. 9	13 m	12/29/2020, 22:30-22:45	1 ♂ ad	1 / fallen tree	On a fallen tree	170 m
7	Shimojishima, SW	<i>I. maculatus</i>	Fig. 10	18 m	12/29/2020, 23:00-23:15	1 second instar	1 / branch	On a branch in the grass under <i>Pandanus odoratissimus</i>	170 m
8	Shimojishima, center	<i>I. maculatus</i>	Fig. 11	7 m	12/30/2020, 11:30-11:45	7 ♀ ad	7 / fallen tree	Under bark of a fallen tree	960 m
9	Miyakojima, SE	<i>L. australasiae</i>	Fig. 12	76 m	12/31/2020, 01:15-01:30	1 ♀ ad	1 / tree	Under bark of <i>Pinus luchuensis</i>	400 m
10	Miyakojima, SW	<i>I. maculatus</i>	Fig. 13	4 m	12/31/2020, 02:10-02:45	1 ♀ ad	1 / tree	Under bark of <i>Pinus luchuensis</i>	75 m

Table 1. The survey sites. Abbreviations: A – altitude, D – distance from nearest coast.

Kohamajima Island, *L. australasiae* (see Chigira & Tanaka, 2004)

Taketomijima Island, *L. australasiae* (Tanaka, 2012)

Aragusukujima (Kamijijima) Island, *I. maculatus* (see Yamazaki et. al., 2016)

Kuroshima Island, *L. australasiae* (see Karasawa & Kawazoe, 2005)

Haterumajima Island, *L. australasiae*, *I. maculatus* (see Kawai, 2020b)

Yonagunijima Island, *L. australasiae* (see Kawai, 2020a), *I. maculatus* (see Muramatsu, 2007)

Senkaku Islands, no scorpions recorded

DAITO ISLANDS, no scorpions recorded

OGASAWARA ARCHIPELAGO

Ogasawara Islands (Bonin Islands)

Chichijima Island, *I. maculatus* (see Takashima, 1949)

Hahajima Island, *I. maculatus* (see Takashima, 1943)

Volcano Islands

Ioto Island, *I. maculatus* (see Kubo, 2001)

Material and Methods

In this survey, scorpions were searched for in Miyako Islands: Miyakojima, where both species are known to be distributed, and four surrounding islands (Ikemajima, Irabujima, Shimojishima, and Kurimajima). *Liocheles australasiae* has been previously recorded from Miyakojima, Irabujima, and Shimojishima but not from the remaining two islands. *Isometrus maculatus* has been previously recorded only from Miyakojima but not from the remaining four islands.

Sex determination for *L. australasiae* was done according to the fact that genital operculum is divided into two in hormurid males (Monod & Volschenk, 2004). The *Isometrus maculatus* was considered a male if the pedipalp segments were long vs short in females (Kovářík, 2003).

The search continued from the evening of December 29, 2020 to the early morning of December 31, 2020. On December 30, there was a full moon. In the Miyakojima Island, December 29 had a maximum temperature of 23.0°C (73.4°F), a minimum

<i>Liocheles australasiae</i> Quantity: 8 Sex: Female 8			
	Altitude	Density	Distance from the coast
Point 1	47 m	4/tree	160 m
Point 3	74 m	1/tree	380 m
Point 4	59 m	1/m ²	730 m
Point 9	76 m	1/tree	400 m
Average	64 m	—	418 m

Table 2. Summary of records of *Liocheles australasiae* in this survey.

<i>Isometrus maculatus</i> Quantity: 16 Sex: Male 1, Female 12, Juvenile 3			
	Altitude	Density	Distance from the coast
Point 2	70 m	1/tree	520 m
Point 5	35 m	1/tree	35 m
Point 6	13 m	1/tree	170 m
Point 7	18 m	1/tree	170 m
Point 8	4 m	7/tree	960 m
Point 10	4 m	1/tree	75 m
Average	24 m	—	322 m

Table 3. Summary of records of *Isometrus maculatus* in this survey.

temperature of 20°C (68°F), an average of 21°C (70°F), and was rainy. December 30 was also rainy with a maximum temperature of 21°C (69.8°F), a minimum temperature of 11°C (51.8°F), and an average of 16°C (60.8°F). December 31 was rainy and had a maximum temperature of 15°C (59.0°F), a minimum temperature of 11°C (51.8°F), and an average of 13°C (55.4°F) (Table 4). Photographs were obtained with an Olympus Tough TG-6 camera. These photographs were slightly processed by the editing function in an Apple iPhone, only to optimize the brightness and contrast for print. Illustrations were created using Microsoft Paint 3D software. The website of the Japan Meteorological Agency was referred to for the temperature.

Results

Scorpions were observed in a total of 10 locations on the four Miyako Islands: Miyakojima, Kurimajima, Irabujima, and Shimojishima. In this survey, *L. australasiae* and *I. maculatus* were found in Miyakojima and Irabujima. Only *L. australasiae* was found in Kurimajima, and only *I. maculatus* was found in Shimojishima. *Liocheles australasiae* has been previously recorded from Shimojishima but was not found in this survey. *Isometrus maculatus* was searched for in Kurimajima but was not found. In this study, Ikemajima was also surveyed, but neither species was found. Table 1 lists the altitude, date and time of the survey, species recorded, number of individuals recorded, density (number of individuals recorded per tree), environment, and distance from the nearest port at each site. Photographs of the environment and the scorpions found are included in our figures. Although scorpion feeding was not observed during this survey, organisms that were likely preyed

upon were found, including *Porcellio scaber* Latreille, 1804 (Crustacea: Isopoda) (Fig. 4D) and *Balta vilis* (Brunner von Wattenwyl, 1865) (Insecta: Blattodea) (Fig. 8D).

In addition, the lowest temperatures ever recorded on the island were examined, and the cold tolerance of these two species was estimated.

Discussion

Liocheles australasiae

Liocheles australasiae was found in Miyakojima, Kurimajima, and Irabujima Islands. It was the first record of this species from Kurimajima. However, it was not found in Shimojishima, where it had been previously recorded, or in Ikemajima, where it has never been recorded. Eight individuals were found, all females. Only females of this species have been found in Japan thus far, likely due to the fact that this species is capable of parthenogenesis (Yamazaki & Makioka, 2005). Since males have been found in Australia, Papua New Guinea, and Thailand (Koch, 1977; Monod & Prendini, 2014), it is likely that Japan is not the country of origin, but it is unclear when the species became established in Japan. There were no individuals of this species giving birth, but there were adults whose bodies were slightly swollen, with late embryos faintly visible; therefore, it is expected that they would have given birth approximately 1–2 months later.

The altitude ranged from 47–76 m, with an average of 64 m, suggesting that this species is found in the environments that are located neither too low nor too high. In terms of density, approximately one individual per tree was recorded in most places. However, the data also suggest that they are not actively cannibalistic, as four individuals were found in a single tree at

Date	Maximum	Minimum	Average	Weather
12/29/2020	23°C	20°C	21°C	Rainy
12/30/2020	21°C	11°C	16°C	Rainy
12/31/2020	15°C	11°C	13°C	Cloudy

Table 4. Meteorological data at Miyako Island on the day of the survey.

Island Name	Species	Maximum	Minimum
Irabujima	<i>L. australasiae</i> & <i>I. maculatus</i>	35.1°C (8/20/1980)	5.1°C (3/1/1987)
Shimojishima	<i>L. australasiae</i> & <i>I. maculatus</i>	36.1°C (7/5/2016)	6.8°C (2/14/2018)
Miyakojima	<i>L. australasiae</i> & <i>I. maculatus</i>	35.3°C (7/16/1971)	6.9°C (1/24/2015)
Taramajima	<i>L. australasiae</i>	35.4°C (8/2/2009)	6.1°C (12/28/2010)
Ishigakijima	<i>L. australasiae</i> & <i>I. maculatus</i>	36.1°C (7/8/2012)	5.9°C (2/19/1918)
Iriomotejima	<i>L. australasiae</i> & <i>I. maculatus</i>	35.7°C (7/6/2014)	6.7°C (1/28/1963)
Haterumajima	<i>L. australasiae</i> & <i>I. maculatus</i>	35.7°C (8/5/2009)	7.8°C (3/1/1987)
Yonagunijima	<i>L. australasiae</i> & <i>I. maculatus</i>	35.5°C (7/23/2020)	7.7°C (1/16/1967)
Chichijima	<i>I. maculatus</i>	34.1°C (7/30/2006)	7.8°C (2/8/1969)

Table 5. Maximum and minimum temperatures at the habitats.

the Kurimajima point of record. The distance from the nearest coast ranged from 160 to 730 m, with an average of 418 m. The species was not present in the windbreaks on the coast, nor was it present in the center of the island. At Point 1, this species was located in the middle of the forest, and the ground was damp with little sunlight. Several *P. scaber* isopods were found in the tree where this species was found, and a large number were found in the nearby leaf litter. This suggests that this species was feeding mainly on *P. scaber* at the time of the survey. In fact, when both species were brought back to the laboratory and kept together, *L. australasiae* preyed upon *P. scaber*. At Point 3, scorpions were found in the grass and rotting wood, and the ground was as damp as that at Point 1. Point 4 was located in a cave, and the ground was moist. Point 9 was a tree on the south side, which was a relatively drier site, though on the northern side it was relatively more humid. Based on the tree locations, this species appears to inhabit only humid places.

Isometrus maculatus

This species was found in Miyakojima, Irabujima, and Shimojishima; this is the first record from Irabujima and Shimojishima. *I. maculatus* was not found in Kurimajima or Ikemajima, from where it had not been recorded previously. Sixteen individuals were found during this survey, of which only 1 was male, 12 were female, and 3 were juveniles whose sex could not be determined. One female was carrying first-instar juveniles on her back, suggesting that the juveniles had just been born. Another female was carrying second-instar juveniles on her back. The fact that second-instar juveniles were found in the same tree suggests that they were in the process of being separated from their parents. Several females had bellies swollen enough that the late embryos could be seen, indicating that they were close to giving birth. Late

December to early January is considered the time when this species gives birth.

The altitude of their habitat was low, averaging 24 m (4–70 m range). The distance from the nearest coast ranged from 35–960 m, with an average of 322 m. Excluding the value of 960 m (Point 8), the average altitude was 194 m, therefore the species was found relatively close to the coast. Generally, their density was one per tree; however, considering that seven scorpions were recorded from the same tree at Point 8, it is likely that they are not actively cannibalistic. The females remained still under the bark of the trees, even at night when they were active, but the single observed male was moving around the tree, probably looking for a female to mate with. At Point 2, *I. maculatus* was found on a tree and a sign along a road to the south or west, respectively. On the day it was found, the area was wet from rain; however, during the day it was dry from prolonged exposure to sunlight. At Points 1, 5, and 6, they were found in trees along roads to the south or southeast, and at Point 8 they lived in decaying trees in sites where there were no large trees around them. At Point 7, it was found at a considerable height from the ground at a relatively dry location. Thus, it appears that relatively dry habitats are suitable for this species. *Liocheles australasiae*, which prefer wet environments, and *I. maculatus*, which prefer dry environments, were not found in the same place, suggesting that they occur in distinctly different habitats. A *Balta vilis* cockroach was found together with this species at Point 5. It is likely that *I. maculatus* preys on *B. vilis*.

On the day of the survey, the temperature had dropped to a minimum of 11°C (51.8°F). We reviewed the record low temperatures on each island where the scorpion presence has been confirmed so far (Table 5). The lowest temperature ever recorded on Irabujima, where both species are found, was

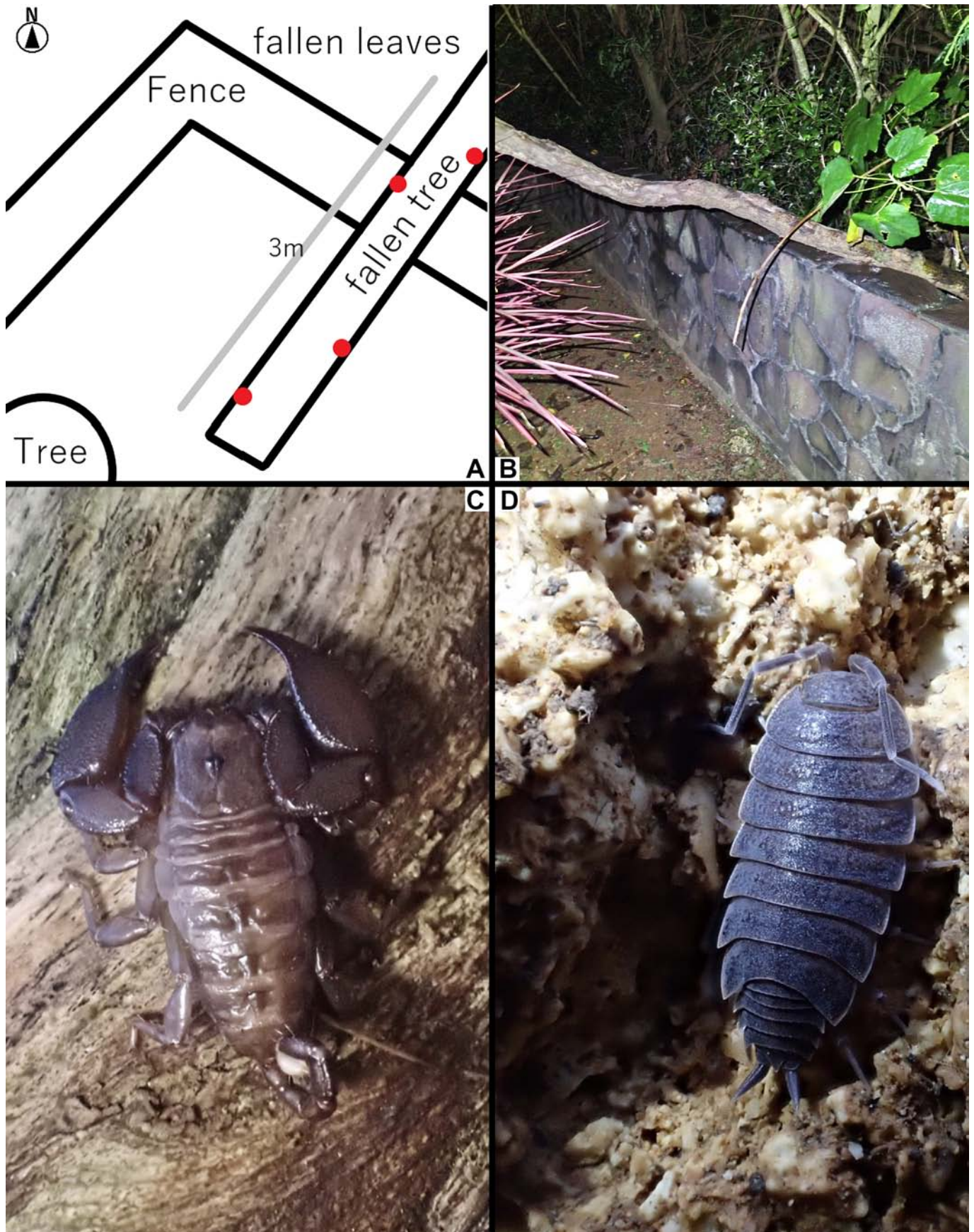


Figure 4: **Figure 4A.** Northeastern part of Kurimajima Island, location. Red point: place of discovery. **Figure 4B.** Environment. **Figure 4C.** A discovered female of *Liocheles australasiae*. **Figure 4D.** A discovered *Porcellio scaber*.

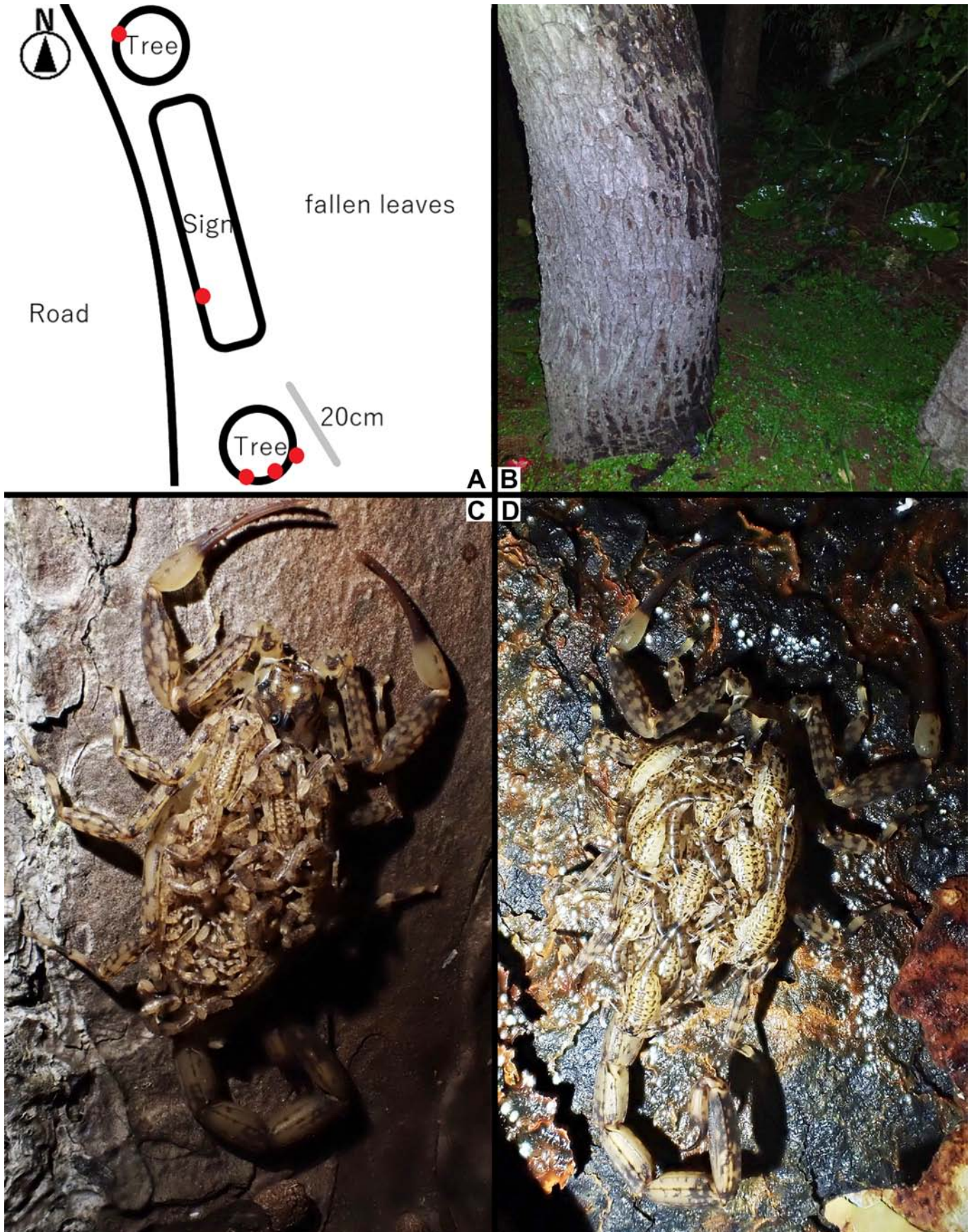


Figure 5: **Figure 5A.** Southeastern part of Irabujima Island, location. Red point: place of discovery. **Figure 5B.** Environment. **Figure 5C–D.** A discovered female of *Isometrus maculatus* with juveniles after the first ecdysis (the second instar) (C) and with newborns (the first instar) (D).

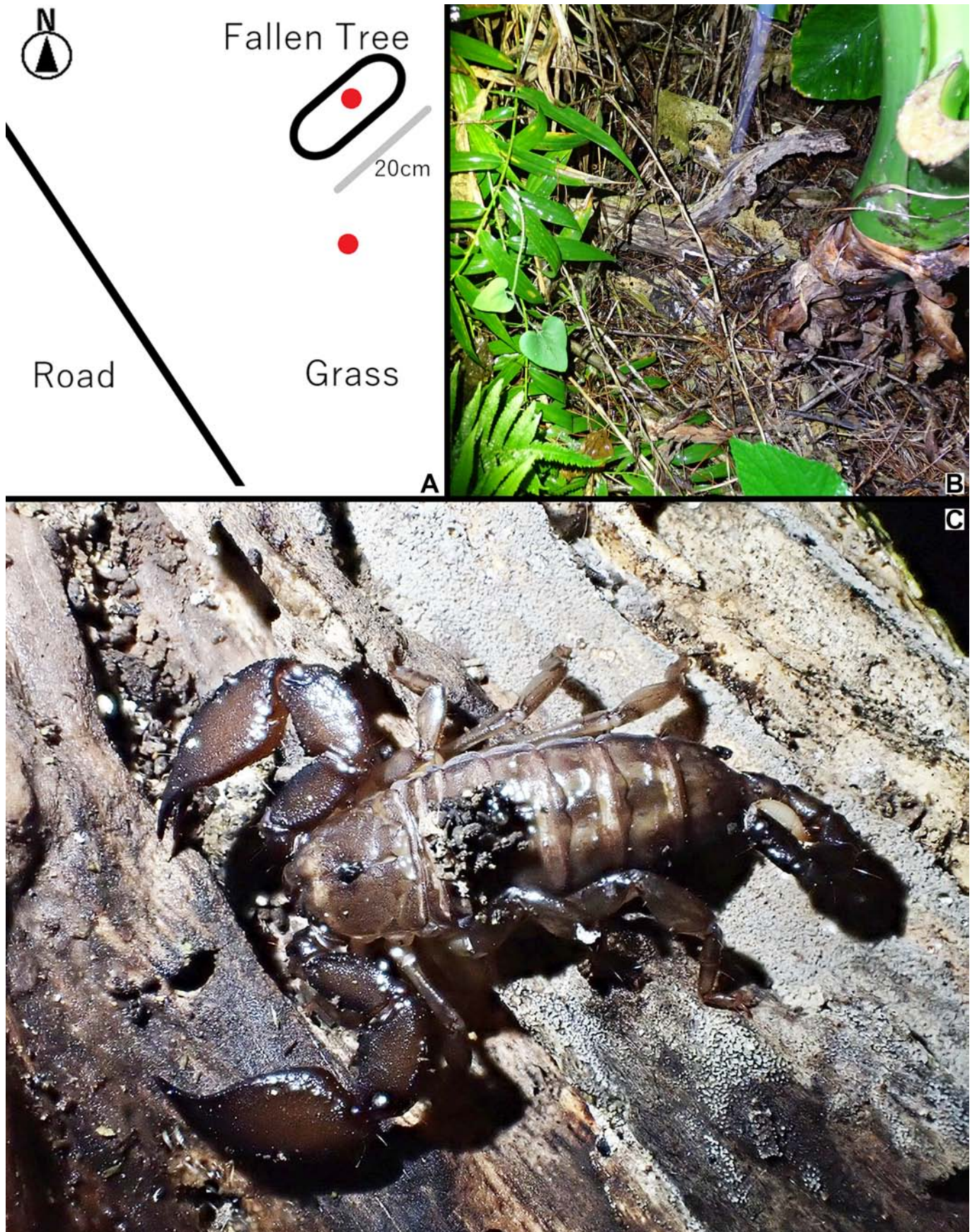


Figure 6: **Figure 6A.** Southeast part of Irabujima Island, location. Red point: place of discovery. **Figure 6B.** Environment. **Figure 6C.** A discovered female of *Liocheles australasiae*.

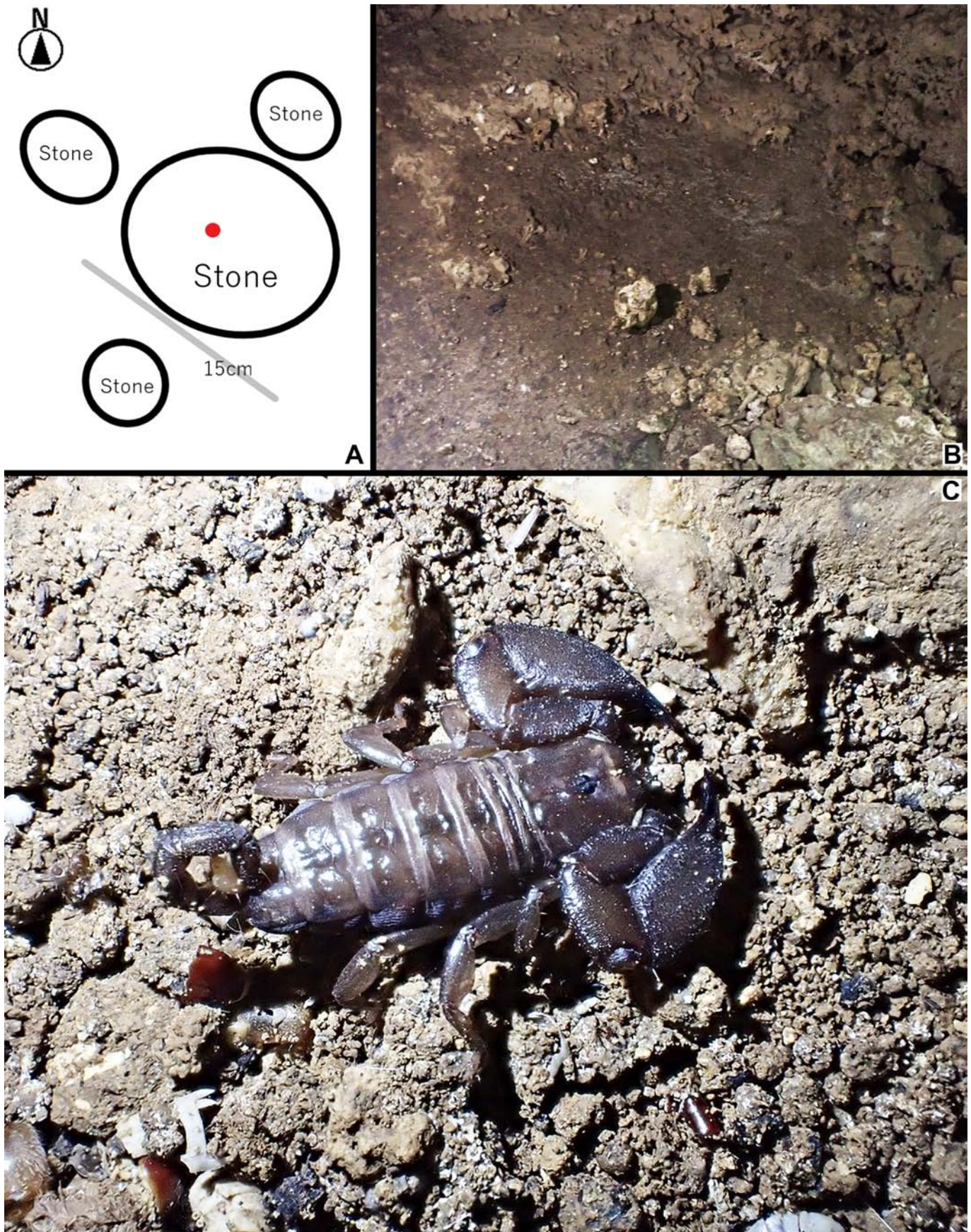


Figure 7: **Figure 7A.** Southern part of Irabujima Island B, location. Red point: place of discovery. **Figure 7B.** Environment. **Figure 7C.** A discovered female of *Liocheles australasiae*.

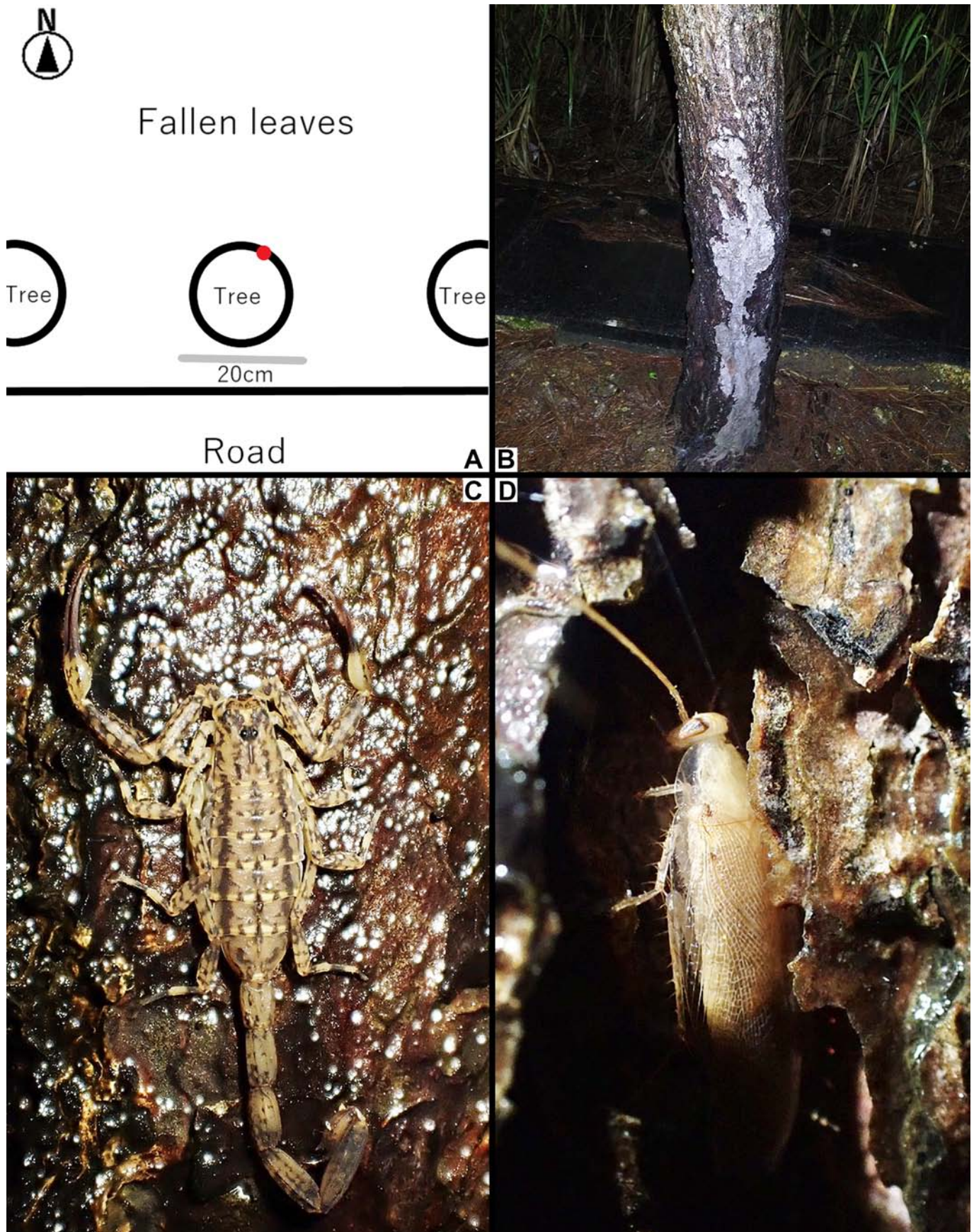


Figure 8: **Figure 8A.** Northeastern part of Shimojishima Island, location. Red point: place of discovery. **Figure 8B.** Environment. **Figure 8C.** A discovered female of *Isometrus maculatus*. **Figure 8D.** A discovered *Balta vilis*.



Figure 9: **Figure 9A.** Northwestern part of Shimojishima Island, location. Red point: place of discovery. **Figure 9B.** Environment. **Figure 9C.** A discovered male of *Isometrus maculatus*.

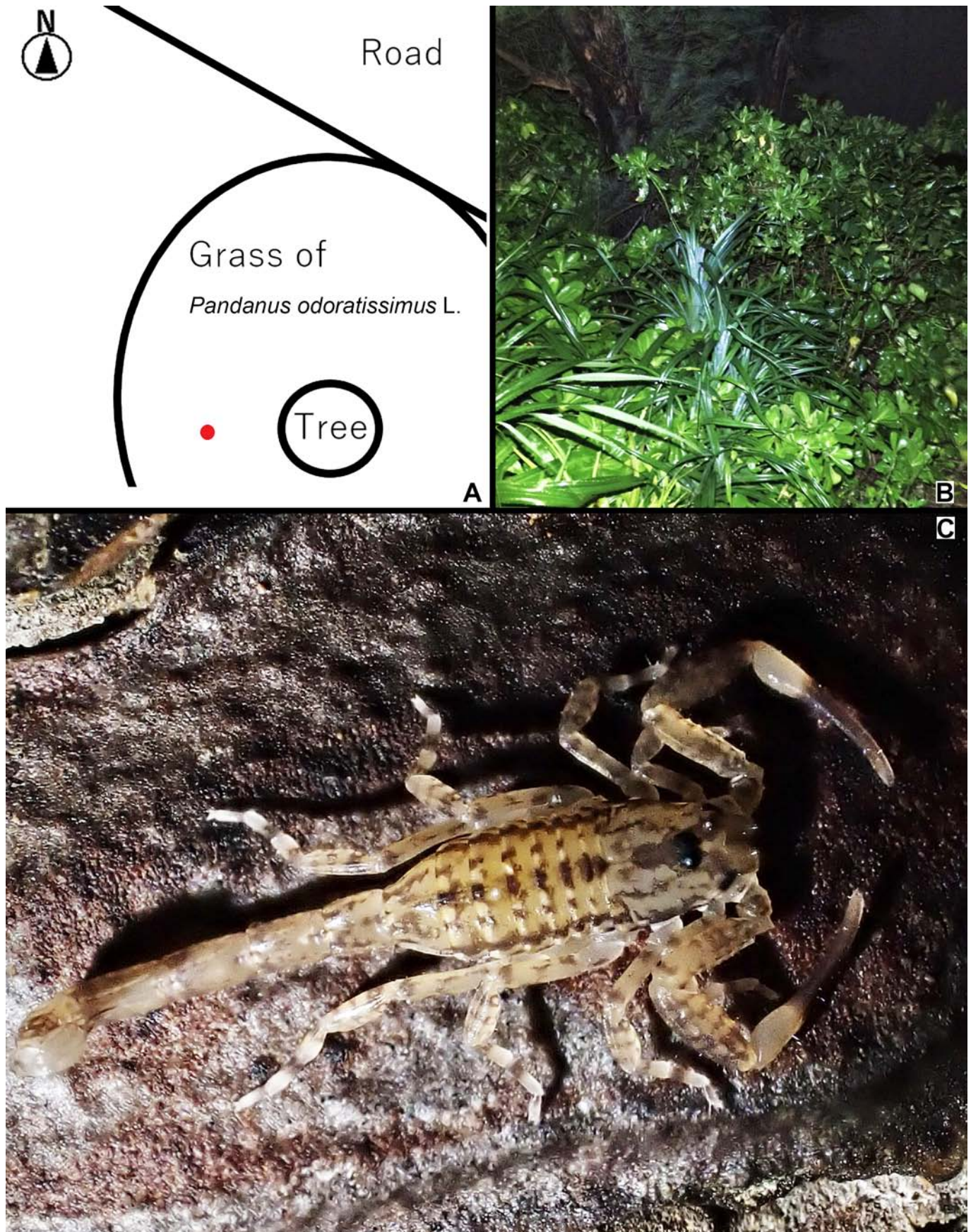


Figure 10: **Figure 10A.** Southwestern part of Shimojishima Island, location. Red point: place of discovery. **Figure 10B.** Environment. **Figure 10C.** A discovered juvenile of *Isometrus maculatus*.

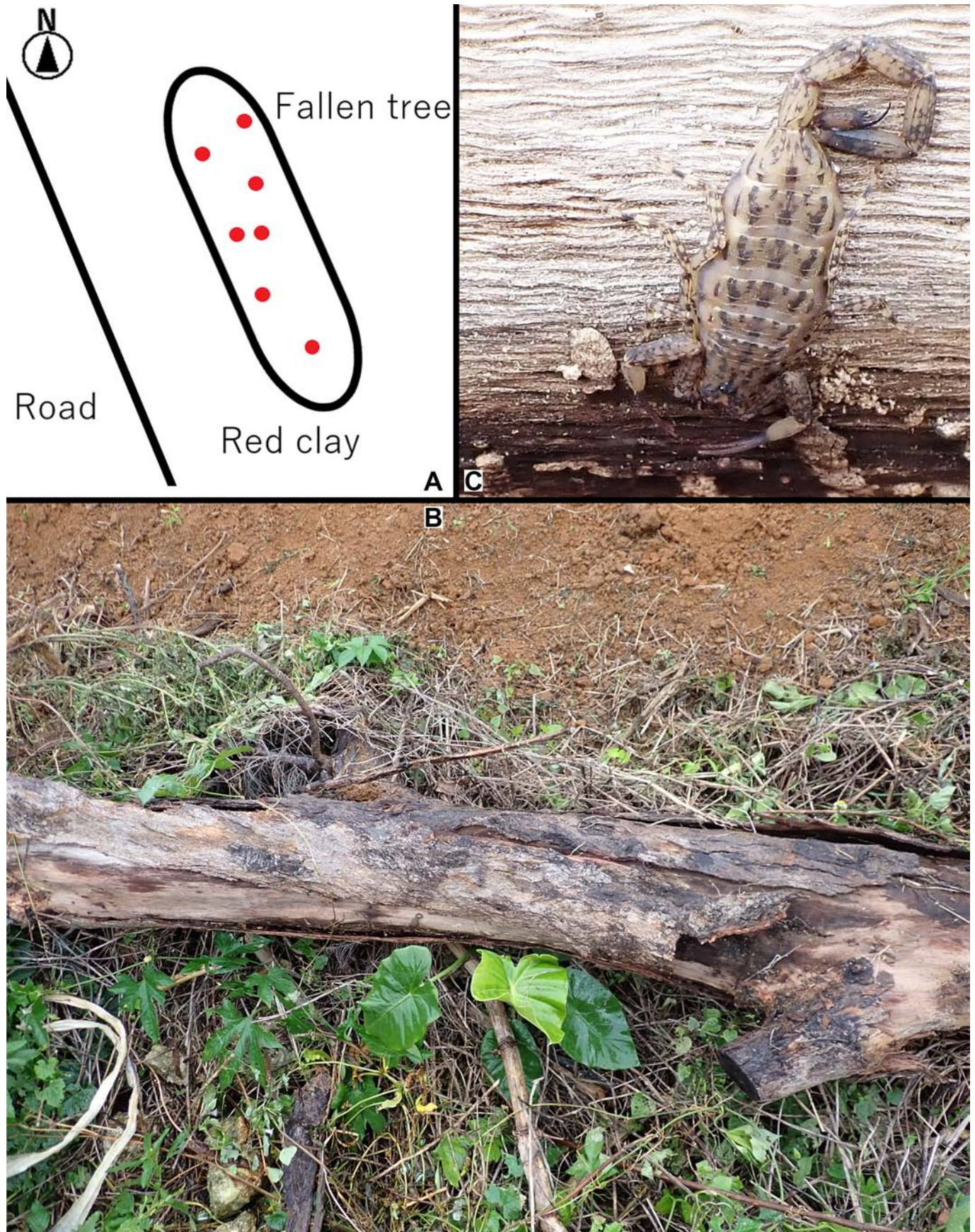


Figure 11: **Figure 11A.** Central part of Shimojishima Island, location. Red point: place of discovery. **Figure 11B.** Environment. **Figure 11C.** A discovered female of *Isometrus maculatus*.

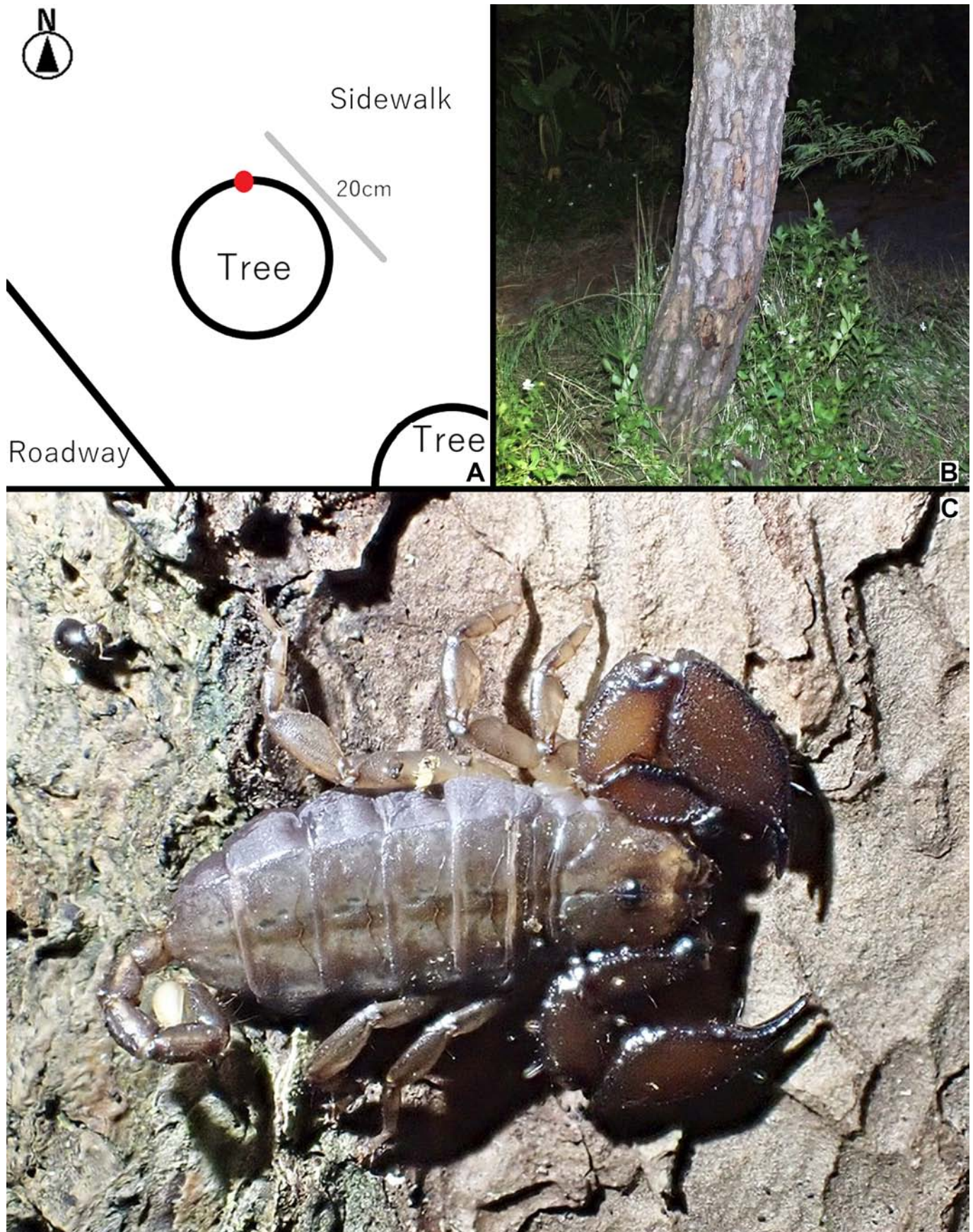


Figure 12: **Figure 12A.** Southeastern part of Miyakojima Island, location. Red point: place of discovery. **Figure 12B.** Environment. **Figure 12C.** A discovered female of *Liocheles australasiae*.

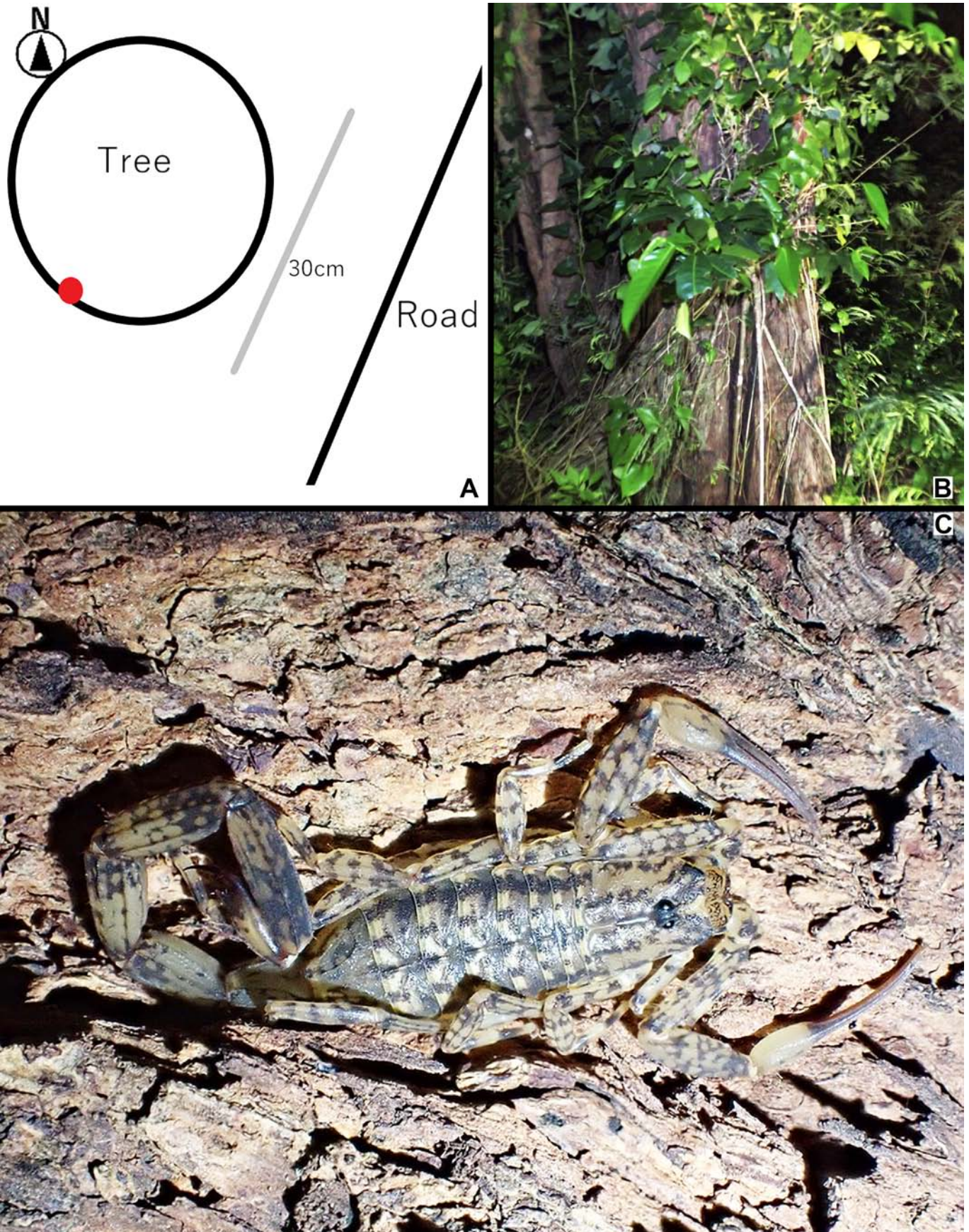


Figure 13: Figure 13A. Southwestern part of Miyakojima Island, location. Red point: place of discovery. Figure 13B. Environment. Figure 13C. A discovered female of *Isometrus maculatus*.

5.1°C (41.2°F) in 1987. It is unclear when the two species were established on Irabujima; however, since a low of 6.1°C (43.0°F) was recorded in 2010 on Taramajima, where *L. australasiae* was recorded in 1999 (Shimojana, 1999), it is known that the species can survive even when the temperature drops to approximately 6°C (43°F). *Isometrus maculatus* was discovered in 1972 in Miyakojima (Shimojana, 1972), and a temperature of 6.9°C (44.4°F) was observed in 2005 and 2015. This shows that this species is also able to survive when the temperature drops to the 6°C range. In most of the distribution areas, the annual minimum temperature occurred in late December and early January, and in this survey, there was no indication that both species tolerated the cold temperatures by inhabiting artificial urban construction during that period. Moreover, *I. maculatus* gave birth, so it can be expected that even juveniles can tolerate such temperatures.

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