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Repeated Visitation by a Sesarmid Crab to Male Inflorescences of *Piper* sp.

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Abstract Here I report an example of repeated visits to male inflorescences of *Piper* sp. (Piperaceae) by a sesarmid crab, which has been previously unappreciated as a flower visitor. The flower-visiting animals were monitored using time-lapse digital photography with 2 min intervals. During the nighttime, the crab species, most likely *Scandarma lintou*, visited 11 times in total onto five inflorescences of the plant. The inflorescences exerted anthers and the crab was feeding on the anthers during the visits. Notably, some of the anthers were attached onto the ventral surface of the crab, suggesting short-distance pollen transfer by the crab is possible. Although the present observation is not extensive, it has shed light on the potential significance of the terrestrial crabs for the plant life histories in tropical coastal forests.

Key words: coastal forest, Luzon Island, *Piper*, pollination, *Scandarma lintou.*

Introduction

It is believed that the evolutionary success of flowering plants is partly associated with their various ways of utilizing diverse animals as pollinators (Crepet and Niklas, 2009). The recent estimation showed that among the 352,000 species of flowering plants, more than 80% are animal pollinated (Ollerton *et al.*, 2011). Pollinating animals can be assigned to as different functional groups, depending on their characteristics and behaviors, and the floral adaptation to each of the functional groups are often visible as the evolutionary trends referred to as a pollination syndrome (Fenster *et al.*, 2004). Therefore, to understand the evolutionary mechanisms shaping diverse sets of floral traits present in certain biomes and habitats, it is crucial to illustrate the overall picture of animal diversity that can potentially be pollinators.

The association between several types of floral morphs and the specific pollinating animals, especially insects, birds, and small mammals has been recognized (Proctor *et al.*, 1996), and obviously these pollinators have contributed largely to the formation and maintenance of most of the floral forms in nature. Nevertheless, much of the floral diversity, especially in tropics, remains to be investigated in terms of their relationships to the pollinating animals. Specifically, very few reports have been available about the contribution of terrestrial invertebrates other than insects to pollination.

Here, I report the floral visitation and pollen foraging by a sesarmid crab in coastal forest in Luzon Island, Philippines.

Materials and Methods

During the botanical survey in Sierra Madre Mountains, Isabella state, Philippines on March 3, 2012, I have encountered the flowering male

individual of *Piper* sp. near Divilacan village at 17°20′52.0″N, 122°22′32.7″E (elevation of 15 m above sea level). In order to monitor flower visitors of this plant using time-lapse photography, I set a digital camera (Optio W90, Pentax, Tokyo, Japan) in front of the five inflorescences (ca. 30 cm distance) mounted on a flexible tripod (Gorillapod, Joby, San Francisco, USA) fixed at 1.5 m above the ground level. The interval between shots was set to 2 min and the monitoring was conducted overnight from 1505 pm on March 3 to 0843 on March 4. The resultant 531 shots were subjected for visual inspection of any flower-visiting animals. To understand the visitation sequence of the animals, the five inflorescences were numbered sequentially from near ground (right) to the left (Fig. 1A).

The plant specimen was deposited at herbarium at National Museum of Nature and Science (TNS) under the temporal collection number GK14625 (Fig. 2A).

Results

The monitored *Piper* species had somewhat an unusual characteristic of the male flower. That is, the anthers were exerted on the spadix-like inflorescences at maturity yet they did not appear to dehisce and be releasing pollen grains throughout the monitoring period, although it is not conclusive as the resolution of the pictures taken in this study was not sufficient to determine this. This observation was also partly supported from the heat-dried specimen of the same plant which retained most of the anthers indehiscent (Fig. 2B).

Throughout the monitoring, I only observed two flightless invertebrate species visiting on the inflorescences of the *Piper* plant. One of these was a sesarmid crab, which is likely *Scandarma lintou* (Fig. 1A), a species reported from southern Taiwan (Schubart *et al.*, 2003) and Okinawa, Japan (Maenosono and Naruse, 2011). The other was a cockroach nymph (Blattodae: Fig. 1B). The flower visits by the two invertebrates occurred only during the nighttime.

Both of the flower visitors repeatedly visited the inflorescences and actively moved among them, mostly between neighboring inflorescences (Table 1). At least once during the move between the inflorescences, the crab attached some anthers on the ventral surface of the crab (Fig. 1C).

Discussion

The present observation revealed that the sesarmid crab, most likely *Scandarma lintou*, might be a major flower-visiting animal for some plant species in a coastal forest as in the *Piper* sp. studied here. The flower visiting behavior of this relatively small crab species is consistent with the original description of *Scandarma lintou*, where it is reported to be mostly arboreal, and feeds on flowers (Schubart *et al.*, 2003). Most notably, the crab can attach anthers or clusters of pollen grains on its body surface (Fig. 1C), indicating that at least the short-distance pollen transfer can occur with the crab.

Although the present observation is only on a single plant individual, the visitation occurred repeatedly and the inflorescences were located $>$1.5 m above the ground, it is most likely that the crab has specifically searched on the inflorescences of the *Piper* species. One of the questions arisen is how the crabs could locate themselves toward the specific flowers. Because the crab is nocturnal (Schubart *et al.*, 2003) as also observed in the present study, the most probable cues are olfactory. It is notable that some terrestrial crustaceans are reported to have developed sophisticated olfactory systems parallel to those of insects (Stensmyr *et al.*, 2005). Thus, it is possible that some plant species with flowers accessible to general nocturnal insects with scents are also accessible to this crab species.

Although scarce, there are several reports about the contribution of pollination by terrestrial invertebrates other than insects. Kato (1995) reported that *Aspidistra elatior* flowers are pollinated by amphipods feeding on pollen, and Suetsugu *et al.* (2014) reported a *Clubiona* spider frequently visits on a orchid species *Neottianthe*

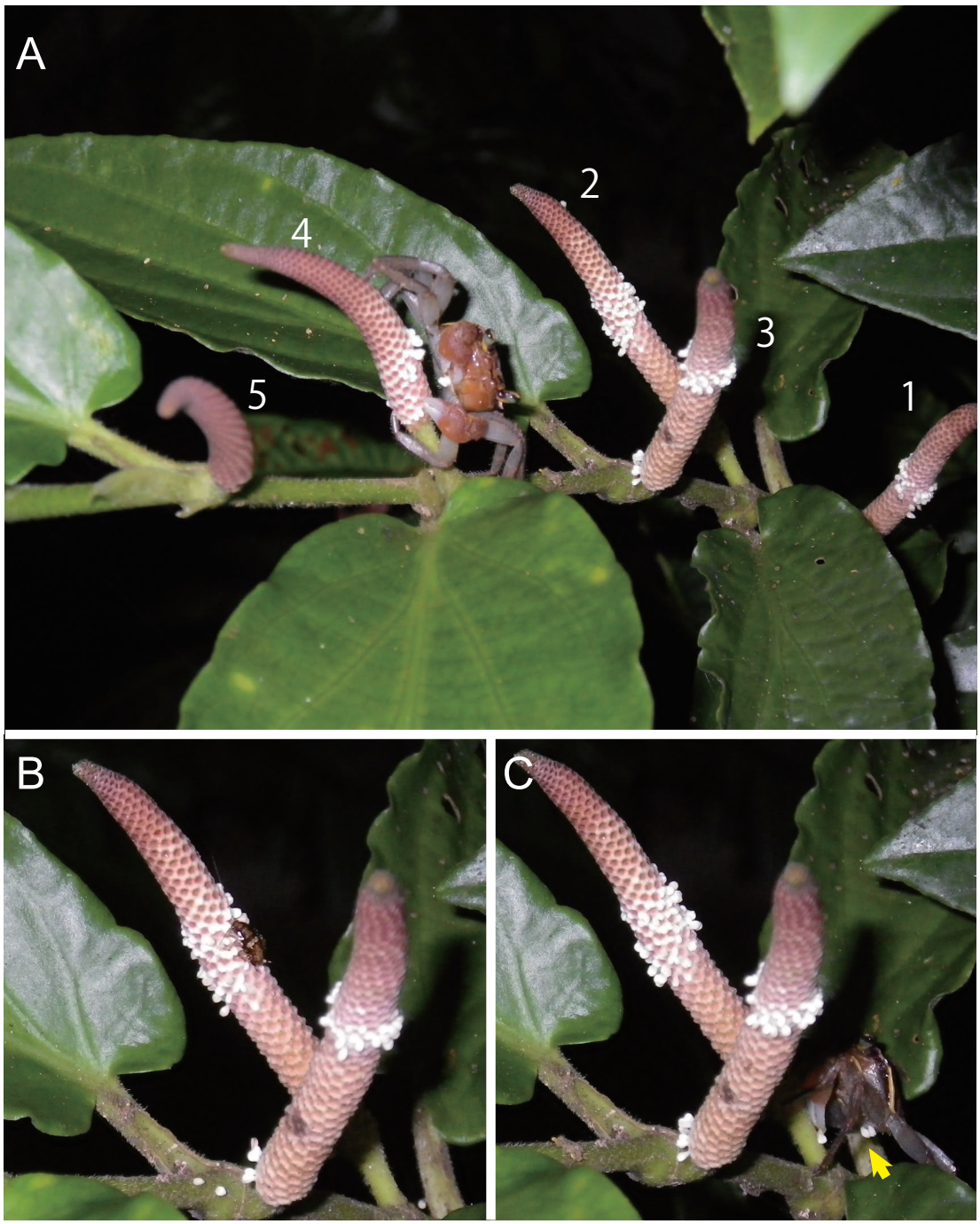

Fig. 1. The animals observed visiting on *Piper* sp. A, A sesarmid crab *Scandarma lintou* feeding on anthers of the *Piper* sp. The numbers are the inflorescence IDs used for Table 1. B, A cockroach nymph staying on the male inflorescence of the *Piper* sp. C, A *Scandarma lintou* moving between the inflorescences. Note that some anthers, or the clusters of pollen grains are attached onto the ventral surface of the crab (yellow arrow).

cucullata to feed on nectar and contribute to its pollinarium transfer. The more notable observations have been made by Higashi *et al.* (2014) in the coastal vegetation in Ryukyu islands, Japan. The terrestrial hermit crabs of the genus *Coenobita* frequently visited and fed on the nectar of the flowers of several plant species there. Because the pollen grains were often observed to attach onto the shell surface and the head and thoracic appendages, the flower-visiting hermit crabs are likely contributing to the pollination as well (Higashi *et al.*, 2014). Based on the present study, it might be appropriate to add the sesarmid crab such as *Scandarma lintou* to these examples, because of its consistent behavior toward flowers. Further observations will clarify whether the sesarmid crab is important as the flower visitor so that it affects the plant evolution in the tropical coastal forests. The relatively robust flower or inflorescence, which is sufficient to

Table 1. Flower visitors observed in the present study

Time on an inflorescence	Species	Inflorescence No.
1921–1925	*Scandarma lintou*	1
1929–1945	*Scandarma lintou*	2
1949–1951	*Scandarma lintou*	4
1953	*Scandarma lintou*	5
1955–1957	*Scandarma lintou*	4
1959–2005	*Scandarma lintou*	3
2011–2013	*Scandarma lintou*	2
2017–2019	*Scandarma lintou*	4
2025	*Scandarma lintou*	1
2045	*Scandarma lintou*	4
2243	*Scandarma lintou*	2
2249–2305	Blattodea (nymph)	1
2309–2353	Blattodea (nymph)	2
2355–0021	Blattodea (nymph)	3
0025–0029	Blattodea (nymph)	4
0041–0057	Blattodea (nymph)	3
0050–0101	Blattodea (nymph)	2
0105–0111	Blattodea (nymph)	2
0149	Blattodea (nymph)	1
0153–0155	Blattodea (nymph)	2

Fig. 2. The herbarium specimen (GK14625) of the *Piper* sp. searched in the present study. A, A whole image. B, A magnified male inflorescence, which is indicated with red square in Fig. 2A. Note that only the anther indicated with black arrow is releasing pollen grains.

support the body of the crab, with exposed anthers and stigmas would be the plant traits necessary to pollination by the crab, as observed in the *Piper* sp.

Lowland forests in tropics are one of the most extensively destroyed biome by the human activities. Under such challenges, it is noteworthy that the Sierra Madre Mountains studied here remains largely unaffected by an intensive exploitation so that the population of the terrestrial crab species such as *Scandarma lintou* can sustain, as they require healthy continuity between coast and forest. Therefore, special cares are necessary for conserving this globally important area also in the light of its potentially unique plant-animal interactions.

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