

## SHORT COMMUNICATION

### Notes on the feeding habits of the Okinawan fishing spider, *Dolomedes orion* (Araneae: Pisauridae), in the southwestern islands of Japan

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**Abstract.** Fishing spiders, *Dolomedes* Latreille, 1804 (Pisauridae), are thought to be important predators in semi-aquatic ecosystems, but relatively few studies have investigated feeding ecology of Asian species. Here, we report on the diet of the Okinawan fishing spider, *Dolomedes orion* Tanikawa, 2003, the largest cursorial spider in Japan, based upon field observations on Amami Oshima Island in Kagoshima Prefecture and a literature review. A total of 13 predation events were observed in field surveys and 10 records were found in the literature. Together, these indicate the consumption of a broad range of food items from arthropods to vertebrates, e.g., insects, harvestman, conspecific spiders, crustaceans (freshwater crab and prawn), two species of endemic frogs (*Rana ulma*, *Odorrana narina*), and an Okinawa tree lizard (*Japalura polygonata polygonata*). Because this species has substantial energy demands for growth, large prey items such as crustaceans and vertebrates seem to be its primary food resources with 10 of 23 prey items [= 43%] belonging to these two large-sized prey groups.

**Keywords:** Amami Islands, Asia, predator-prey interaction, subtropical, white leg patches

Spiders are some of the most abundant generalist predators in terrestrial ecosystems (Riechert & Lockley 1984; Provencher & Riechert 1994). Because spiders use various food resources derived from different ecological systems, they play an important role in linking food webs as a shared consumer (Wise 1995; Wise et al. 1999). Therefore, information on their diets can provide a basis for understanding food web structuring and ecological linkages in transition zones between different ecosystems (Shimazaki & Miyashita 2005). Many studies have focused on the feeding habits of web-spinning spiders in semi-aquatic ecosystems, where water subsidies can have substantial impacts on food web dynamics (e.g., Kato et al. 2003; Akamatsu et al. 2004), but few studies have done the same for non-web-spinning spiders.

Fishing spiders (Pisauridae, mainly of the genera *Dolomedes* Latreille, 1804 and *Nilus* Pickard-Cambridge, 1898) are common cursorial spiders in semi-aquatic ecosystems. Because these spiders are frequently found at the land–water interface, they are thought to use prey resources derived from both terrestrial and aquatic ecosystems. This includes the frequent consumption of vertebrate prey such as fish and frogs (Menin et al. 2005; Toledo 2005; Nyffeler & Pusey 2014). Therefore, these spiders occupy a relatively higher trophic position and may play ecological roles different from those of web-spinning spiders, which consume mainly flying insects. Despite the ecological importance of fishing spiders worldwide, most of the reports on their feeding habits are derived from North and South America; there are few reports from other regions such as Africa, Asia, Australia, and Europe (reviewed by Nyffeler & Pusey 2014). Furthermore, individual records of prey items have been obtained from studies of different species and different regions around the world, and there have been few systematic studies of the feeding habits of single species in a certain region (but see Zimmermann & Spence 1989). If we are to gain a comprehensive understanding of the feeding habits and ecological role of the fishing spiders worldwide, it is important to study a species that is distributed outside the Americas.

In this research, we focused on the diet of the Okinawan fishing spider, *Dolomedes orion* Tanikawa, 2003. This species is distributed in the central and northern Ryukyu Islands (the Tokara Islands, Amami Islands, and Okinawa Islands, located between 26°N and 30°N) in subtropical Japan. It reaches a body length of 30–40 mm, which is comparable to that of the Neotropical giant fishing spiders of the genus *Ancylometes* Bertkau, 1880 (Ctenidae) (15–40 mm), and it is the largest species of pisaurid. Because of its large body size and excellent diving ability, this species is thought to consume large aquatic and semi-aquatic organisms (Kosuge & Sasaki 2002). Interestingly, it has a white hair patch on its first and second legs; in the closely related species *Dolomedes raptor* Bösenberg & Strand, 1906 this patch visually attracts terrestrial prey insects (Lin et al. 2015; Tso et al. 2016). *Dolomedes orion* is therefore expected to have a broad diet that includes both aquatic and terrestrial organisms. Additionally, the Ryukyu Islands are a habitat for many endemic aquatic and semi-aquatic species (Nishida et al. 2003), and *D. orion* may interact with these species. Investigating the feeding habits of *D. orion* will therefore provide useful information for understanding ecological interactions in the unique freshwater ecosystems of the Ryukyu Islands.

We investigated the dietary composition of *D. orion* on the basis of field observations. Our field survey was conducted mainly in the forested area on Amami Oshima Island, Kagoshima Prefecture, Japan, which is dominated by evergreen trees. The surveys were conducted at the same time as a night census conducted between 2005 and 2015 to investigate endemic organisms (described by Iwai & Watari 2006; Watari et al. 2008). All observations were occasional, and predation events were recorded with a digital camera. To collect data on predation events on other islands, we conducted an extensive literature review and contacted researchers conducting field surveys on Okinawa Island. Prey items were visually identified as far as possible to the species level, and the growth stage of the spiders was roughly classified as juvenile or adult based on body size, body coloration and presence of mature pedipalp of males. The predator/

Table 1.—Observational records of predation by *Dolomedes orion* under natural conditions, as determined from field surveys, a literature review, and unpublished data. Length estimates used to calculate predator/prey length ratios are based on photographs depicting predation event.

ID	Location	Date	Growth stage of spider	General name	Species	Predator/prey length ratio*	Source
1	Amami-Oshima	7-IV-2015	Juvenile	Insect/Moth	unidentified	1:1.30	This study (Y.G. Baba)
2	Amami-Oshima	15-II-2006	Adult	Insect/Cockroach	<i>Rhabdoblatta guttigera</i>	1:1.27	This study (Y. Watari)
3	Amami-Oshima	14-VII-2005	Adult	Insect/Grasshopper	<i>Psyrana amamiensis</i>	1:1.17	This study (Y. Watari)
4	Amami-Oshima	8-IV-2015	Adult	Insect/Crane-fly	Tipulidae gen. sp.	1:0.50	This study (Y.G. Baba)
5	Amami-Oshima	14-VIII-2006	Adult	Insect/Cockroach	<i>Periplaneta suzukii</i>	1:0.48	This study (Y. Watari)
6	Amami-Oshima	20-X-2005	Adult	Insect/Camel cricket	<i>Diestrammea gigas</i>	1:1.08	This study (Y. Watari)
7	Amami-Oshima	20-V-2009	Adult	Insect/Cockroach	<i>Periplaneta suzukii</i>	1:0.48	This study (Y. Watari)
8	Amami-Oshima	21-V-2006	Adult	Arthropod	unidentified	1:0.37	This study (Y. Watari)
9	Amami-Oshima	10-VIII-2006	Adult	Arthropod/Diptera?	unidentified	1:0.48	This study (Y. Watari)
10	Amami-Oshima	25-X-2006	Adult	Harvestman	<i>Pseudogagrella amamiana</i>	1:0.15	This study (Y. Watari)
11	Amami-Oshima	15-VII-2005	Adult	Spider	<i>Dolomedes orion</i>	1:0.71	This study (Y. Watari)
12	Amami-Oshima	15-II-2006	Adult	Freshwater crab	Potamidae gen. sp.	1:0.59	This study (Y. Watari)
13	Amami-Oshima	4-III-2007	Adult	Freshwater crab	Potamidae gen. sp.	1:0.76	This study (Y. Watari)
14	Amami-Oshima	19-III-2016	Adult	Okinawa tree lizard	<i>Japalura polygonata polygonata</i>	1:1.51	Nishi 2016
15	Kume-jima	Unknown	unknown	Freshwater prawn	Palaemonidae gen. sp.	1:1.66	Kosuge and Sasaki 2002
16	Okinawa-jima	Unknown	unknown	Okinawa tip-nosed frog	<i>Odorrana narina</i>	1:1.43	Kosuge and Sasaki 2002
17	Okinawa-jima	9-VI-2012	Adult	Spider	<i>Dolomedes orion</i> (male)	1:0.66	T. Komatsu (unpubl.)
18	Okinawa-jima	9-VI-2012	Adult	Spider	<i>Dolomedes orion</i> (juvenile)	1:0.66	N. Murayama (unpubl.)
19	Okinawa-jima	14-IV-2012	Adult	Anura/Tadpole	unidentified	1:0.71	T. Komatsu (unpubl.)
20	Okinawa-jima	14-XII-2008	Adult	Ryukyu brown frog	<i>Rana ulma</i>	1:0.86	T. Shiroma (unpubl.)
21	Okinawa-jima	12-XII-2008	Adult	Ryukyu brown frog	<i>Rana ulma</i>	1:1.57	T. Komatsu (unpubl.)
22	Okinawa-jima	12-XII-2008	Adult	Ryukyu brown frog	<i>Rana ulma</i>	1:1.41	T. Komatsu (unpubl.)
23	Okinawa-jima	8-XII-2007	Adult	Ryukyu brown frog	<i>Rana ulma</i>	1:1.14	T. Sasaki (unpubl.)

\* Prey length = total body length, excluding legs in insects, harvestman and spiders, carapace width in crabs and snout-vent length in amphibian and reptiles

prey length ratios were roughly estimated by the photographs depicting predation events.

We obtained 13 predation observations in the field, along with 3 additional records reported in two articles and seven records via personal communications (Table 1). Of these 23 observations, seven predation events were of insects, one was of a harvestman, three were cannibalism of a conspecific, three were of crustaceans (freshwater crab and shrimp), seven were of vertebrates (five frogs and one Okinawa tree lizard), and two were of unidentified arthropods. With the exception of one record (record 1), all predation events were by adult spiders. Further details for each taxonomic group are described below.

Lizard predation has been reported in some wandering spiders around the world (Maffei et al. 2010; Nyffeler et al. 2017), but there are very few reported cases of wandering spiders eating reptiles in Japan (e.g., Nishi 2016; Tokuyama et al. 2017; Fig. 1A). The body size of the Okinawa tree lizard, *Japalura polygonata polygonata* (70–90 mm) is generally larger than that of *D. orion*, and the lizard's habitat does not overlap spatiotemporally with that of *D. orion*: the tree lizard is active on tree trunks during the day, whereas *D. orion* waits for prey on rocks at night. Therefore, the predation event we observed seems to have been opportunistic, but our findings do suggest that an arboreal lizard can potentially become a food resource for large spiders even if the lizard (snout-vent length) is 1.5 times larger than the spider (Table 1).

Frog predation by large fishing spiders seems to be very common in the Neotropics (Menin et al. 2005; Toledo 2005; Moura & Azevedo 2011), but few cases have been reported in Asia (e.g., Nakajima 2014; Nyffeler & Pusey 2014). Records of predation of frogs (*Rana ulma* and *Odorrana narina*, both belonging to the Ranidae family) and tadpoles were collected by literature review (record 16) and personal

communications (records 19–23, Figs. 1B, C). These two frogs usually live on the forest floor, but a large number of individuals gather in streams and rivers for spawning in winter (Matsuhashi & Okuyama 2002). Due to the shortage of spider food resources during winter (from December to February) in subtropical region, these frogs may be important food resources for fishing spiders. Indeed, all predation records of *Rana ulma* were observed in the winter and the prey frogs were larger than the spiders in three cases of the four records (predator–prey length ratios ranging from 0.86 to 1.57; Table 1). On the other hand, juvenile fishing spiders seem to be suitable prey for the frogs themselves (Toft 1980; Santos et al. 2004). Because the density of fishing spiders is high in mountain streams, predator–prey interactions involving *D. orion* are likely to be ecologically important for frog assemblages. Therefore, elucidating these predator–prey interactions may shed light on the fundamental ecology of these endemic frogs.

Spider predation on crustaceans has previously been reported (Bristowe 1941; Van Berkum 1982; Kosuge & Sasaki 2002; Bhukal et al. 2015; Suzuki 2018), but the number of observational records is relatively small. In our field survey, we observed two cases of crab predation (records 12, 13, Fig. 1D) and one case of freshwater prawn predation (record 15). In our study, the crustaceans in the prey of *D. orion* could not be identified to taxon; but the related species *Dolomedes raptor* – likewise occurring in the Okinawa region – was observed feeding on the crab *Geothelphusa minei* (see Kosuge & Sasaki 2002).

Although *D. orion* is found on rocks close to streams, it frequently preys on terrestrial insects, including moths, cockroaches, and grasshoppers (records 1–7). Many of the insects captured by *D. orion* were of large size (e.g., camel crickets, katydids and cockroaches, Figs. 1E–G), reflecting the ability of *D. orion* to subdue large-sized

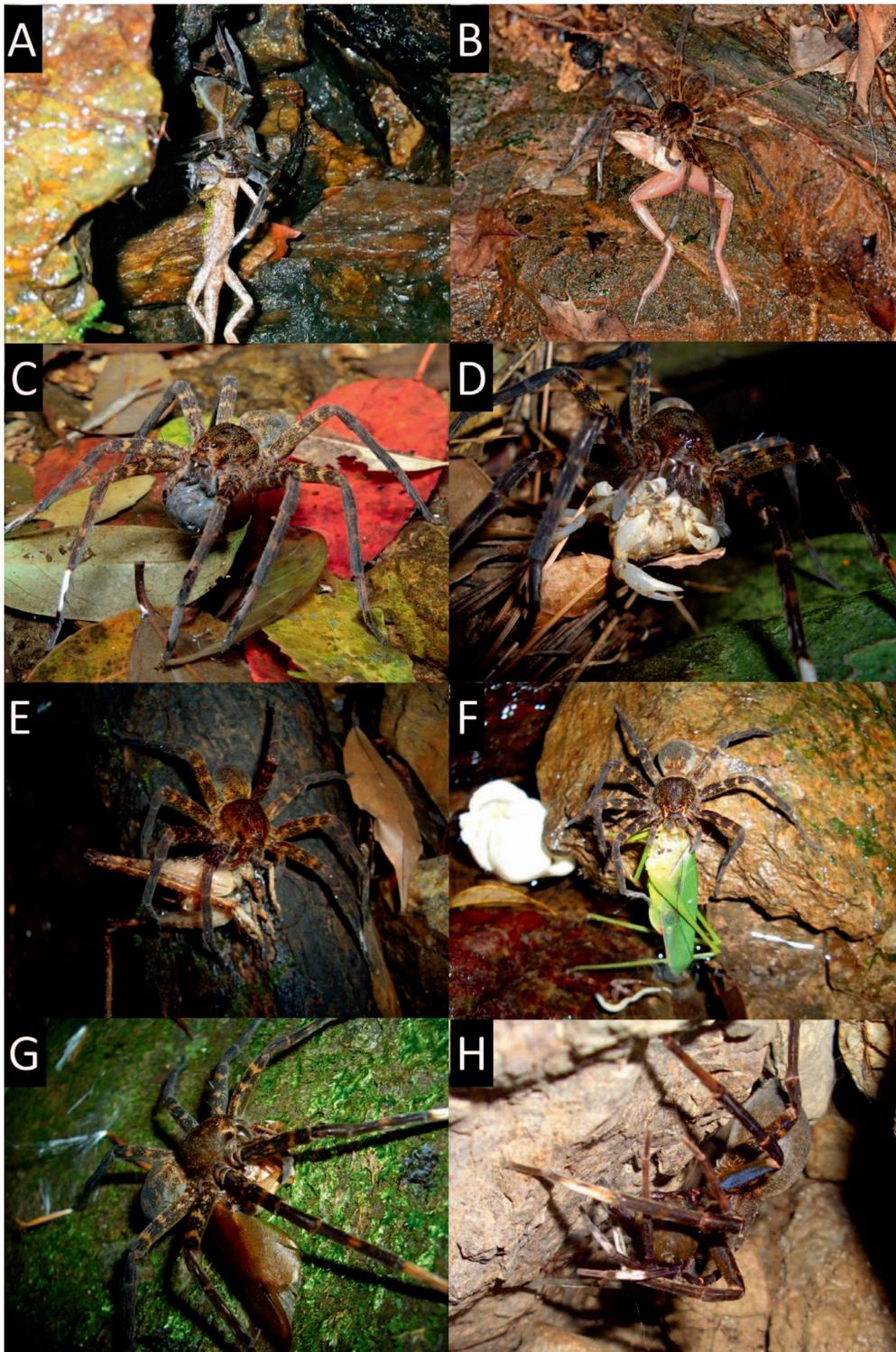


Figure 1.—Prey items of *Dolomedes orion* observed in field. A. Okinawa tree lizard *Japalura polygonata polygonata* (record 14). B. Ryukyu brown frog *Rana ulma* (record 23). C. Tadpole (record 19). D. Freshwater crab Potamidae gen. sp. (record 12). E. Camel cricket *Diestrammena gigas* (record 6). F. Katydid *Psyrana amamiensis* (record 3). G. Cockroach *Rhabdoblatta guttigera* (record 2). H. Conspecific spider (record 11).

prey. The closely related species, *D. raptor*, captures insects such as grasshoppers by visually attracting them with the white patches on its legs (Lin et al. 2015; Tso et al. 2016). In *D. orion*, the presence or absence of white leg patches differs among islands: they are present on most individuals on Amami Oshima and Okinawa Island but are

lacking on many individuals on Kume Island (A. Tanikawa, pers. comm., Fig. 2). Whether the presence of white leg patches on individuals of *D. orion* on Amami-Oshima and Okinawa Island plays a role in prey capture needs to be investigated in a future study. In addition, we observed 3 cases of cannibalism (records 11, 17–18, Fig.



Figure 2.—Geographic variation in the presence or absence of white hair patches on the legs of *D. orion*, which are thought to function as visual lures to attract insect prey. A. An individual with white hair patches (arrow) from the Amami Oshima population, Kagoshima Prefecture. B. An individual without white hair patches (arrow) from the Kume Island population, Okinawa Prefecture (photograph by A. Tanikawa).

1H). Cannibalism appears to be a common phenomenon in pisaurids (Zimmermann & Spence 1989), and this may also apply to *D. orion*.

Our study revealed that *D. orion* has a broad diet including terrestrial insects, crustaceans, and even vertebrates such as tree lizards and frogs. Our finding that *D. orion* is capturing prey of considerable size in the form of crustaceans and vertebrates is consistent with the high energy demands expected in a spider species of this large size (see Brose et al. 2006).

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