

New discovery and review of termitophile fauna in Taiwan

by

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Abstract

The termite fauna in Taiwan has been studied since the early 20th century. However, termite-associated animals, termitophiles, in Taiwan has received little attention. This study summarizes the fragmented termitophile faunal data and reports a new discovery in Taiwan. We provide a preliminary check-list with 21 species or morphospecies of termitophiles from 7 insect families for Taiwan.

Key words: symbiont, social insect, Coleoptera, Diptera, Thysanura

Introduction

The termite fauna in Taiwan has been studied since early 20th century (Zhu 2005), and termite taxonomic studies and biodiversity surveys continue (Li et al. 2015). However, significantly less attention has been given to the termitophiles of Taiwan. Termitophiles refer to the symbionts that have obligatory relationship with termite societies (Kistner 1969). Depending on the relationship between symbionts and their host termite, the social insect symbionts can be divided into two categories, the integrated and non-integrated species (Kistner 1979). The biology of termitophiles was reviewed by Kistner (1982) and Wilson (1971) while the current study provides an overall review of termitophiles in Taiwan and reports a new finding. This study is the first step in our investigation of termitophile biology in Taiwan.

Materials and methods

We examined the termite specimens deposited in the National Chung Hsing University (NCHU) Termite Collection, Taichung, Taiwan to begin our investigation of the termitophile fauna in Taiwan. The NCHU Termite Collection was established by the second author in 2005. At the time of this investigation there were 3,341 termite colony specimens and associated animals deposited in NCHU Termite Collection, representing 4 termite families: Termitidae, Rhinotermitidae, Kalotermitidae, and Archotermopsidae. These specimens were collected through numerous termite biodiversity surveys in various regions of Taiwan. In addition, a comprehensive search for termitophiles in termite nest as well as field observations of termitophile behavior were conducted by the first author over the past two years. Termitophile collecting methods varied depending on the termite taxon (Kistner 1969).

Results and discussion

According to specimen examination and field survey, we discovered 13 morphospecies of termitophiles belonging to 10 genera. Coleoptera represented the greatest number and the rest were dipteran and thysanuran. A total of 21 termitophile species or morphospecies were found in Taiwan using the combination of new data and previous records (Table. 1). Six termite species, *Coptotermes formosanus* Shiraki, 1909, *Hodotermopsis sjöstedti* (Holmgren, 1911), *Nasutitermes kinoshitai* (Hozawa, 1915), *N. parvonasutus* (Nawa, 1911), *Odontotermes formosanus* (Shiraki, 1909), and *Reticulitermes flaviceps* (Oshima, 1908) are the hosts to termitophiles.

Table. 1. The list of termitophiles in Taiwan.

Termitophile species and taxonomic position	Host termites	References
Order Coleoptera		
Family Cerylonidae		
<i>Cycloxenus</i> sp.	<i>C. formosanus</i>	New record for Taiwan
Family Hydrophilidae		
<i>Oreomicrus</i> sp. 1	<i>N. kinoshitai</i>	New record for Taiwan
<i>Oreomicrus</i> sp. 2	<i>N. parvonasutus</i>	New record for Taiwan
Family Staphylinidae		
<i>Termophiloholus formosanus</i> Naomi & Hirono, 1996	<i>H. sjöstedti</i>	Naomi & Hirono (1996)
Corotocini sp.	<i>N. parvonasutus</i>	New record for Taiwan
<i>Zyras</i> sp.	<i>O. formosanus</i>	New record for Taiwan
<i>Sinophilus</i> sp.	<i>C. formosanus</i>	New record for Taiwan
<i>Japanophilus</i> sp.	<i>C. formosanus</i>	New record for Taiwan
<i>Trichopsenius</i> sp. 1	<i>R. flaviceps</i>	New record for Taiwan
<i>Trichopsenius</i> sp. 2	<i>R. flaviceps</i>	New record for Taiwan
<i>Trichopsenius</i> sp. 3	<i>R. flaviceps</i>	New record for Taiwan
Family Tenebrionidae		
<i>Ziaelas formosanus</i> Hozawa, 1914	<i>O. formosanus</i>	Hozawa (1914)
Order Diptera		
Family Keroplatidae		
<i>Ioneuromyia</i> sp.	<i>O. formosanus</i>	New record for Taiwan
Family Phoridae		
<i>Achaetophora aristafurca</i> Disney, 1996	<i>O. formosanus</i>	Disney (1996)
<i>Bolsiusia spatulasetaeis</i> Disney, 1996	<i>O. formosanus</i>	Disney (1996)
<i>Clitelloxenia formosana</i> (Shiraki, 1925)	<i>O. formosanus</i>	Shiraki (1925)
<i>Clitelloxenia audreyae</i> Disney, 1997	<i>O. formosanus</i>	Disney (1997)
<i>Pseudotermtoxenia nitobei</i> Shiraki, 1925	<i>O. formosanus</i>	Shiraki (1925)
<i>Horologiphora sinensis</i> Disney, 1997	<i>O. formosanus</i>	Disney (1997)
<i>Selenophora shimadai</i> Maruyama & Disney, 2011	<i>O. formosanus</i>	New record for Taiwan

Order Thysanura

Family Nicoletiidae

Nicoletiidae sp.

O. formosanus

New record for Taiwan

1. Coleoptera**1.1. Cerylonidae**

The adults of Cerylonidae were commonly found in leaf litter, rotten debris or under the fungus infested bark, and a few species are associated with ants and termites. The termitophilous species belong to the genus *Euxestoxenus* or *Cycloxenus* strictly associated with fungus growing termites, mostly *Odontotermes*. (Kistner 1982, Leschen et al. 2011). Several species were found nesting in the fungus garden (Kistner 1982).

We found termitophilous Cerylonidae belonging to the genus *Cycloxenus*. These specimens were found in the fungus garden of *O. formosanus* and in the company of termite larvae. These beetles secrete a white waxy substance from pores on their dorsal body surface, a phenomena also mentioned by Kistner (1982).

1.2. Hydrophilidae

The beetle family Hydrophilidae are mainly found in aquatic environments but nearly a third of the species are terrestrial (Short and Fikáček 2013) with a few species known to be associated with ants (Fikáček et al. 2015). Recently, the genus *Oreomicrus* had been confirmed to be a termitophilous group and several new species including Taiwanese species are on the way to being described (Fikáček et al., in prep.). Numerous samples were found inhabiting in the foraging tunnels of *N. kinoshitai* and *N. parvonasutus* in rotten wood.

1.3. Staphylinidae

The family Staphylinidae is one of the most diverse termitophile taxon. However, termitophilous Staphylinidae are poorly studied in Taiwan. The only related study was when Naomi and Hirono (1996) described, *Termophiloholus formosanus*, associated with *H. sjöstedti*.

A total of 7 morphospecies of termitophilous Staphylinidae were found in our investigation. One, *Corotocini* sp., was collected in the foraging tunnels of *N. parvonasutus* on bark. Two species, *Japanophilus* sp. and *Sinophilus* sp., belonging to the Termitohospitini were collected from the nest of *C. formosanus*. Three morphospecies of genus *Trichopsenius* were collected from the nests of *R. flaviceps*. One species in the genus *Zyras* was confirmed to be an obligate predator of *O. formosanus* in laboratory choice tests (Liang et al. unpublished data).

1.4. Tenebrionidae

Fairmaire (1892) established the genus *Ziaelas* with one species, *Z. insolitus*. Hozawa (1914) described a second species, *Z. formosanus*, based on three specimens collected in Heng-Chun

Peninsula, southern Taiwan from an *O. formosanus* fungus garden. Bremer (2014) indicated that these species might be synonyms according to their similarity morphology. However, the proper status should be determined using additional specimens of *Z. formosanus* from Taiwan.

We frequently observed *Z. formosanus* inside the fungus garden and walking on the chamber walls of *O. formosanus* nests in the field. This species is very integrated into the termite society without any aggressive behavior between termites and beetles. We successfully reared one beetle in an *O. formosanus* nest in the laboratory where the *Z. formosanus* probably feed on the fungus without damage to the media (Liang et al. unpublished data).

2. Diptera

2.1. Keroplatidae

The larvae of Keroplatidae were found in the foraging tunnels of *O. formosanus* in rotten wood. These larvae make webs from oral secretions and use the webbing to navigate the tunnel and catch termites. The larvae are probably specialized obligate predators of termites (Liang et al. unpublished data). Some larvae were successfully reared to adult, and identified to the genus *Isoneuromyia*. This is the first record of termitophilous Keroplatidae.

2.2. Phoridae

Shiraki (1925) described *Clitelloxenia formosana* and *Pseudotermitoxenia nitobei*, collected from the fungus garden of *O. formosanus* in Taiwan. The fauna of the termitophilous subfamily Termitoxeniinae in the oriental region was further investigated by Disney and Kistner (1997), and they described two more species, *Clitelloxenia audreyae* and *Horologiphora sinensis* from Taiwan. Disney (1996) described two species belonging to the subfamily Phorinae, *Achaetophora aristafurca* and *Bolsiusia spatulasetaeis*. The host termite of *C. audreyae*, *C. formosana*, *Horologiphora sinensis*, and *A. aristafurca* collected from Taiwan were identified as *Odontotermes hainanesis* (Disney 1996, Disney and Kistner 1997). However, according to our survey and identification with molecular tools, *O. formosanus* is the only fungus-growing termite found in Taiwan (Li at al. unpublished data). We believed *O. formosanus* is the only termite host of these phorid termitophiles in Taiwan.

Our investigation of *O. formosanus* fungus gardens resulted in discovering the fifth species of Termitoxeniinae, *Selenophora shimadai*, in Taiwan. *Selenophora shimadai* was recently described by Maruyama et al. (2011) based on specimens from Ishigaki-jima and Iriomote-jima, Japan.

3. Thysanura

3.1. Nicoletiidae

Nicoletiidae had been reportedly associated with numerous termites (Kistner 1982). In Taiwan, we recorded one morphospecies inhabiting the fungus garden of *O. formosanus*.

Conclusions

Based on a literature review and survey our new discovery brings the total species or morphospecies of termitophiles in Taiwan to 21 representing 7 families from 3 insect orders. Coleoptera, with 12 termitophile species, is the most diverse and species-rich order associated with termites. Along with understanding the nest structure and ecology of Taiwanese termites we expect to find additional, new termitophiles. Further investigation of the biology of these termitophiles and their interaction with their termite hosts will be our focus.

References

- Bremer, H. J. 2014 Revision of *Azarelius* Fairmaire, *Ziaelas* Fairmaire and related Oriental termitophilous genera, with description of two new genera and remarks on tribal placement (Coleoptera: Tenebrionidae: Amarygmini). *Stuttgarter Beiträge zur Naturkunde A, Neue Serie* **7**, 163-182.
- Disney, R. H. L. 1996 Two new termitophilous Phoridae (Diptera) from Taiwan. *Sociobiology* **28**(1), 1-10.
- Disney, R. H. L. and D. H. Kistner 1997 Revision of the Oriental Termitoxeniinae (Diptera: Phoridae). *Sociobiology* **29**(1), 3-118.
- Fairmaire, L. 1892 Nouveau genre de Coléoptère hétéromère. *Bull. Soc. Entomol. Fr.* **61**, CX-CXI.
- Fikáček, M., M. Maruyama, T. Komatsu, C. von Beeren, D. Vondráček, and A. E. Short 2015 Protosternini (Coleoptera: Hydrophilidae) corroborated as monophyletic and its larva described for the first time: a review of the myrmecophilous genus *Sphaerocetum*. *Invertebr. Syst.* **29**(1), 23-36.
- Hozawa, S. 1914 Note on a New Termitophilous Coleoptera found in Formosa (*Ziaelas formosanus*). *Annot. zool. jpn.* **8**(3), 483-488.
- Kistner, D. H. 1969 The biology of termitophiles. 525-557pp. in: K. Krishna & F. M. Weesner (eds.), *Biology of Termites*, vol. 1. Academic Press, New York.
- Kistner, D. H. 1979 Social and evolutionary significance of social insect symbionts. 339–413pp. in: Hermann, H. R. (ed.) *Social Insects*, Vol. 3. Academic Press, New York.
- Kistner, D. H. 1982 The social insects' bestiary. 1–244 pp. in: Hermann, H. R. (ed.) *Social Insects*, Vol. 3. Academic Press, New York.
- Leschen, R., R. Beutel, and J. Lawrence 2011 *Coleoptera, Beetles. Vol. 2. Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim)*. *Handbook of Zoology, Arthropoda: Insecta*. Walter de Gruyter GmbH & Co. KG, Berlin/New York, xiii.
- Li, H.-F., Y.-C. Lan, I. Fujisaki, N. Kanzaki, H.-J. Lee, N.-Y. Su 2015 Termite assemblage pattern and niche partitioning in a tropical forest ecosystem. *Environ. Entomol.* **44** (3): 546-556.
- Maruyama, M., T. Komatsu, and R. H. L. Disney 2011 Discovery of the termitophilous subfamily

- Termitoxeniinae (Diptera: Phoridae) in Japan, with description of a new genus and species. *Entomol. Sci.* **14**(1), 75-81.
- Naomi, S., and Y. Hirono 1996 A new genus and species of a termitophilous Staphylinidae (Coleoptera) associated with *Hodotermopsis japonica* (Isoptera: Termopsidae) from Taiwan. *Sociobiology* **28**(1), 83-89.
- Shiraki, T. 1925 Some insects living in the nest of *Odontotermes formosanus*. *Trans. Nat. Hist. Soc. Formosa, Taihoku* **15**, 208-210.
- Short, A. E. Z. and M. Fikáček 2013 Molecular phylogeny, evolution and classification of the Hydrophilidae (Coleoptera). *Syst. Entomol.* **38**(4), 723-752.
- Wilson, E. O. 1971 *The Insect Societies*. 548pp. Harvard University Press, Cambridge, MA.
- Zhu, Y. I. 2005 *Insects into focus: entomology in Taiwan, 1684-1945*. 616 pp. Taiwan Interminds Publishing Inc., Taipei (in Chinese).