

Cockroach fauna in the Ogasawara Chain Islands of Japan and analysis of their habitats

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Abstract. A survey of cockroach fauna was carried out on the 3 inhabited islands of the Ogasawara chain island of Japan, namely, Chichijima island, Hahajima island and Iwo island. Seven species, namely, *Periplaneta americana* (Linnaeus, 1758), *Periplaneta australasiae* (Fabricius, 1775), *Blattella lituricollis* (Walker, 1868), *Onychostylus vilis* (Brunner von Wattenwyl, 1865), *Supella longipalpa* (Fabricius, 1798), *Pycnoscelus surinamensis* (Linnaeus, 1758) and *Opisthopteria orientalis* (Burmeister, 1838), were collected on Chichijima island. Four species, namely, *P. americana*, *P. australasiae*, *O. vilis* and *P. surinamensis* were collected on Hahajima island and 6 species, namely, *P. americana*, *P. australasiae*, *B. lituricollis*, *O. vilis*, *P. surinamensis* and *Neostylopyga rhombifolia* were collected on Iwo island. This is the first record of *N. rhombifolia* and *Onychostylus orientalis* on the Ogasawara chain islands. Our study increases the recorded taxon of cockroaches on the Ogasawara from 3 families, 5 genera 10 species to 4 families, 7 genera, 12 species. A list of the cockroach species on Ogasawara islands reported to date as well as a key for their identification is also presented. *Periplaneta americana* and *P. australasiae*, being the dominant species, together with *S. longipalpa*, were collected mostly in the indoor environment, indicating their preference for this habitat. *Pycnoscelus surinamensis*, which is considered as an outdoor insect has been found in semi-household environments such as greenhouse and shed, indicating their new adaptation to the changing environment.

INTRODUCTION

The Ogasawara chain islands, also known as Bonin islands, consists of over 100 subtropical and tropical islands in the Pacific Ocean, some 1,000 kilometers directly south of Tokyo, Japan (Fig. 1A). It has been designated as a world natural heritage site in July 2011, albeit with the exception of Iwo island. Since the islands have never been connected with a continent, its flora and fauna were considered to have undergone unique evolutionary processes. Cockroach fauna in the Ogasawara archipelago islands was first reported in 1930 by Esaki (1930) and

Furukawa (1930). Their reports were later followed by those of Monzen, (1951), Wada *et al.* (1969), Nakane (1970), Takahashi (1973), and Saito & Hori (1973) in the three decades after the Second World War. All these studies focussed on the sanitary importance of the insect and the need to clarify their prevalence and distribution on the Ogasawara chain islands.

In recent years Kusui *et al.* (2004), carried out a survey of the indoors cockroaches on Chichijima and Hahajima islands of the Ogasawara chain islands. They reported the presence of 3 families, 5 genera and 10 species of the cockroaches, namely,

Periplaneta fuliginosa Serville, 1838, *Periplaneta americana* (Linnaeus, 1758), *Periplaneta australasiae* (Fabricius, 1775), *Onychostylus pallidiolus boninensis* Asahina, 1985, *Onychostylus vilis* (Brunner von Wattenwyl, 1865), *Supella longipalpa* (Fabricius, 1798), *Periplaneta brunnea* Burmeister, 1838, *Pycnoscelus surinamensis* (Linnaeus, 1758), *Blattella germanica* (Linnaeus, 1767) and *Blattella lituricollis* (Walker, 1868). *Supella longipalpa* was first recorded by Takahashi (1973) on the Ogasawara chain islands. This species is unique to these islands and has not been found elsewhere to date. About three decades later, Kusui *et al.* (2004), also reported the presence of this species on Chichijima island, confirming the permanent establishment of this cockroach in that area. Nevertheless, this species of cockroach has not yet been reported on Hahajima island, which is about 50 km south of Chichijima island, despite that there is an almost daily ferry service connecting the two islands. Presently, there has been no report of *P. fuliginosa* and *P. brunnea* on the Ogasawara Chain islands since that of Nakane (1970), and also of *B. germanica* since that of Takahashi (1973). For an integrated pest control program to be successful, so as to be less dependent on insecticides, a greater understanding of the cockroach ecology and taxonomy is indispensable. Thus, the results of a routine survey of the cockroach population in a certain area will greatly contribute to the success of the control program.

We report in this paper the results of our survey from 2008 to 2011, on cockroaches on Chichijima island, which serve as the gateway to the flow of goods and humans to the Ogasawara chain island, as well as on Hahajima island and Iwo island, which are all part of the archipelago (Fig. 1B).

MATERIALS AND METHODS

Area and period of survey

Chichijima island (27N 142E) (Fig. 1C): Cockroaches were collected in the outdoor area of Shuzaki district in April 2008, in 3 buildings in Omura district, one building in

Kiyose district and one building in Ogiura district in June 2008, as well as in the kitchen of a restaurant in Omura district and residential houses in May 2009.

Hahajima island (25N 142E) (Fig. 1D): Surveys were carried out in the outdoor of Hyogihira district in June 2010, two buildings in Okimura district and residential houses from December 2010 to January 2011.

Iwo island (24N 141E) (Fig. 1E): Cockroaches were collected in the outdoors in June 2010 and indoors in August 2010. In the case of outdoor, the spot is more than 50 meters away from the nearest housing.

Trapping methods

For the outdoor collection, the cockroaches were caught on sight using hands. For the indoor collection of the insects, traps with baits on sticky tapes were set in the boiler room, in the vicinity of fish-rearing tub, fish-processing raw materials storage room and feeds storeroom. Between one to 5 traps were set for 3 to 60 days, depending on the efficiency of the trappings. In addition, between two to 5 glass bottle traps were also used for 3 days in the buildings on Chichijima island. The bottle trap has an opening of 100 mm diameter and a height of 100 mm. The inner surface of the bottle was coated circumferentially with a 50mm width of butter to prevent the cockroaches from climbing out. The outer surface of the bottle was wrapped around with black paper.

Processing and identification of the collected cockroaches

The collected adult specimens were killed using ethyl acetate $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$ and then their sex and species identified. For the nymphs, they were first identified and some were kept alive for later research purposes. Representative specimens were selected and preserved in a mothball-containing wooden box using insect pins. The cockroaches were identified based on the criteria as described by Asahina (1991).

Statistical analysis

Statistical analysis was carried out using the statistical package SPSS 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Differences

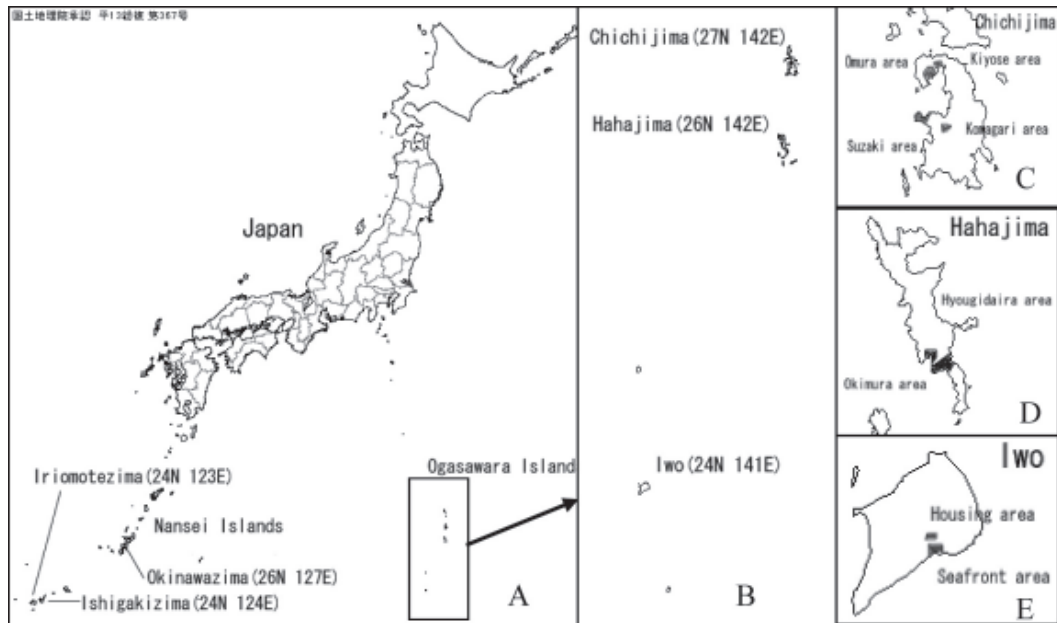


Figure 1. **A.** Map showing the location of the Ogasawara chain islands, which is 1,000 km south of Tokyo. **B.** Map showing the 3 islands which are inhabited by humans, namely, Chichijima Island (27N 142E), Hahajima Island (26N 142E) and Iwo (24N 141E). **C.** Chichijima island (27N 142E): Cockroaches were collected in the outdoor area of Shuzaki district in April 2008, in 3 buildings in Omura district, one building in Kiyose district and one building in Ogiura district in June 2008, as well as in the kitchen of a restaurant in Omura district and residential houses in May 2009. **D.** Hahajima island (26N 142E): Surveys were carried out in the outdoor of Hyogihira district in June 2010, two buildings in Okimura district and residential houses from December 2010 to January 2011. **E.** Iwo island (24N 141E): Cockroaches were collected in the outdoor of Seafront area in June 2010 and indoors of Housing area in August 2010. In the case of outdoor, the spot is more than 50 meters away from the nearest housing

Table 1. Total number of cockroaches collected at Ogasawara chain islands

Species	Survey area						Total (%)
	Chichijima Is.		Hahajima is.		Iwo Is.		
	Adult	Instar	Adult	Instar	Adult	Instar	
<i>Periplaneta americana</i>	29	27	18	29	6	3	112 (37.97%)
<i>Pij australasiae</i>	18	22	1	13	5	5	64 (21.69%)
<i>Blatella lituricollis</i>	1	0	0	0	8	0	9 (3.05%)
<i>Onychostylus vilis</i>	5	5	1	2	9	0	22 (7.46%)
<i>Supella longipalpa</i>	7	15	0	0	0	0	22 (7.46%)
<i>Pycnoscelus surinamensis</i>	8	18	4	8	19	8	65 (22.03%)
<i>Neostylopyga rhombifolia</i>	0	0	0	0	1	0	1 (0.34%)
Total	68	87	24	52	48	16	295 (100%)

among the number of cockroaches caught indoor, semi-indoor and outdoor were analyzed using the Chi-square test. When the groups differed ($P \leq 0.05$), post-hoc test using the Fisher's exact test was performed.

RESULTS

The total number of cockroaches collected was 295 specimens consisting of 6 genera and 7 species (Table 1). Comparison of

percentages of the species of cockroaches captured in the household area (completely indoor), semi-household area (storeroom, shed, greenhouse, workshop) and outdoor area, is shown in Table 2. A list of the cockroach fauna on the Ogasawara chain islands as reported to date, including those of the present study, is presented in Table 3. Figure 2 shows the photographs of the various species of cockroaches collected in the Ogasawara chain islands. A binomial key to the species identification of the cockroaches found in the Ogasawara chain islands is presented in Table 4.

A female adult specimen of *Opisthoptilia orientalis*, collected on Chichijima island on July 28, 1989 by Mr. Kimura Johnson, was found preserved in the Sub-tropical Agriculture Research Center. This finding is also added in this paper for the first record of this species on this island.

Chichijima island

Shuzaki district: Two nymphs of *P. australasiae*, 7 adults and 8 nymphs of *Pycnoscelus surinamensis* were collected in the outdoors. Five adults & 5 instars of *Onychostylus vilis* were collected under the bark of a fallen tree trunk.

Omura district: No cockroaches were caught in Building A. One adult of *B. lituricollis*, 6 adults and 6 nymphs of *S. longipalpa* were collected in the boiler room

of Building B. In Building C, 2 nymphs of *S. longipalpa* in the boiler room, 5 adults & 5 nymphs of *P. americana*, 1 nymph of *P. australasiae* and 1 nymph of *S. longipalpa* in the kitchen, were caught, respectively. Moreover, 2 adults and 3 nymphs of *P. americana* in kitchen of restaurant A, and 4 nymphs of *S. longipalpa* in restaurant B, and 15 adults and 10 nymph of *P. americana*, 3 adults and 5 nymphs of *P. australasiae*, 1 adult and 1 nymph of *S. longipalpa* in restaurant C were collected, respectively. In the collective residential homes, 3 adults of *P. americana*, 3 adults of *P. australasiae* and 1 nymph of *S. longipalpa*, were caught.

Kiyose district: No cockroaches were caught in the boiler room or the office space in the building. However, 2 nymphs of *P. americana*, 1 adult and 1 nymph of *P. australasiae* were caught in the fish-rearing room.

Ogiura district: No cockroaches were caught in the boiler room or the office space in the building. However, 4 adults & 7 nymphs of *P. americana*, 11 adult & 13 nymphs of *P. australasiae*, 1 adult & 10 nymphs of *Pycnoscelus surinamensis* were caught in the greenhouse.

Hahajima island

Two nymphs of *P. americana*, 3 nymphs of *P. australasiae*, 4 adult and 8 nymphs of *P. surinamensis* were caught in the outdoor

Table 2. Comparison of the number of cockroaches caught in various environments

Species	*Indoor (%)	**Semi-indoor (%)	#Outdoor (%)
<i>P. americana</i>	94 ^a (57.0%)	14 ^b (22.6%)	4 ^c (5.9%)
<i>P. australasiae</i>	24 ^a (14.5%)	36 ^b (58.1%)	4 ^c (5.94)
<i>B. lituricollis</i>	1 (0.65)	0.0	8 (11.7%)
<i>O. vilis</i>	3 (1.8%)	1 (1.6%)	18 (26.5%)
<i>S. longipalpa</i>	22 (13.3%)	0.0	0.0
<i>Py. surinamensis</i>	21 ^a (12.7%)	11 ^a (17.7%)	33 ^b (48.5%)
<i>N. rhombifolia</i>	0.0	0.0	1 (1.5%)
Total	165 (100%)	62 (100%)	68 (100%)

^{a,b,c}Numbers in the same row with different superscript alphabet denotes significant difference (P<0.05)

*Indicates inside the household like kitchen or boiler room

**Indicates areas like shed, greenhouse and workshop

#Percentage indicates the percentage of that species caught in a specific environment

P.: *Periplaneta* *B.*: *Blattella* *O.*: *Onychostylus* *S.*: *Supella* *Py.*: *Pycnoscelus* *N.*: *Neostylopyga*

Table 3. List of cockroach species on Ogasawara chain islands reported to date.

Locality	Species	References
Chichijima	<i>Periplaneta americana</i>	Furukawa (1930), Ezaki (1930), Takahashi (1973), Nakane (1970), Saito & Hori (1973), Asahina (1991), Kusui & Ichikawa (2002), Present study
	<i>P. australasiae</i>	Furukawa (1930), Ezaki (1930), Takahashi (1973), Nakane (1970), Saito & Hori (1973), Asahina (1991), Kusui & Ichikawa (2002), Present study
	<i>P. brunnea</i>	Asahina (1991)
	<i>P. fuliginosa</i>	Nakane (1970)
	<i>Blattella germanica</i>	Furukawa (1930; on ship), Takahashi (1973)
	<i>B. lituricollis</i>	Takahashi (1973), Nakane (1970), Asahina (1991), Present study
	<i>Onychostylus vilis</i>	Takahashi (1973), Nakane (1970), Kusui & Ichikawa (2002), Present study
	<i>O. pallidolus boninensis</i>	Asahina (1991)
	<i>Supella longipalpa</i>	Takahashi (1973), Kusui & Ichikawa (2002), Present study
	<i>Pycnoscelus surinamensis</i>	Furukawa (1930), Ezaki (1930), Takahashi (1973), Nakane (1970), Asahina (1991), Kusui & Ichikawa (2002), Karube <i>et al.</i> (2004), Present study
	<i>Opisthoptatia orientalis</i>	Present study
Hahajima	<i>P. americana</i>	Nakane (1970), Saito & Hori (1973), Kusui & Ichikawa (2002), Present study
	<i>P. australasiae</i>	Saito & Hori (1973), Kusui & Ichikawa (2002), Present study
	<i>O. vilis</i>	Nakane (1970), Kusui & Ichikawa (2002), Karube <i>et al.</i> (2004), Present study
	<i>O. pallidolus boninensis</i>	Kusui & Ichikawa (2002)
	<i>P. surinamensis</i>	Nakane (1970), Saito & Hori (1973), Kusui & Ichikawa (2002), Present study
Mukoshima	<i>P. americana</i>	Kusui & Ichikawa (2002)
	<i>P. australasiae</i>	Kusui & Ichikawa (2002), Karube <i>et al.</i> (2004)
	<i>O. vilis</i>	Karube <i>et al.</i> (2004)
	<i>O. pallidolus boninensis</i>	Karube <i>et al.</i> (2004)
	<i>P. surinamensis</i>	Kusui & Ichikawa (2002), Karube <i>et al.</i> (2004)
Minamijima	<i>P. americana</i>	Kusui & Ichikawa (2002)
	<i>P. surinamensis</i>	Kusui & Ichikawa (2002)
Nakoudojima	<i>P. surinamensis</i>	Kusui & Ichikawa (2002)
Nishijima	<i>P. australasiae</i>	Karube <i>et al.</i> (2004)
	<i>P. surinamensis</i>	Karube <i>et al.</i> (2004)
	<i>O. pallidolus boninensis</i>	Karube <i>et al.</i> (2004)
Higashijima	<i>O. vilis</i>	Kusui & Ichikawa. (2002)
Mukoushima	<i>P. australasiae</i>	Karube <i>et al.</i> (2004)
Ototojima	<i>O. pallidolus boninensis</i>	Karube <i>et al.</i> (2004)
	<i>P. surinamensis</i>	Karube <i>et al.</i> (2004)
Anejima	<i>O. pallidolus boninensis</i>	Karube <i>et al.</i> (2004)
Anijima	<i>P. surinamensis</i>	Kusui & Ichikawa (2002)
Imoutojima	<i>O. pallidolus boninensis</i>	Karube <i>et al.</i> (2004)
Kitaiwo	<i>P. australasiae</i>	Karube <i>et al.</i> (2004)
	<i>P. surinamensis</i>	Karube <i>et al.</i> (2004)
Iwo	<i>P. americana</i>	Present study
	<i>P. australasiae</i>	Tomioka & Shibayama (1998), Present study
	<i>B. lituricollis</i>	Asahina (1991), Tomioka & Shibayama (1998), Present study
	<i>O. vilis</i>	Asahina (1991), Present study
	<i>P. surinamensis</i>	Takahashi (1969), Asahina (1991), Tomioka & Shibayama (1998), Present study
	<i>Neostylopyga rhombifolia</i>	Present study
Minamiwo	<i>P. australasiae</i>	Asahina (1991), Karube & Matsumoto (2008)
	<i>P. surinamensis</i>	Asahina (1991), Karube & Matsumoto (2008)

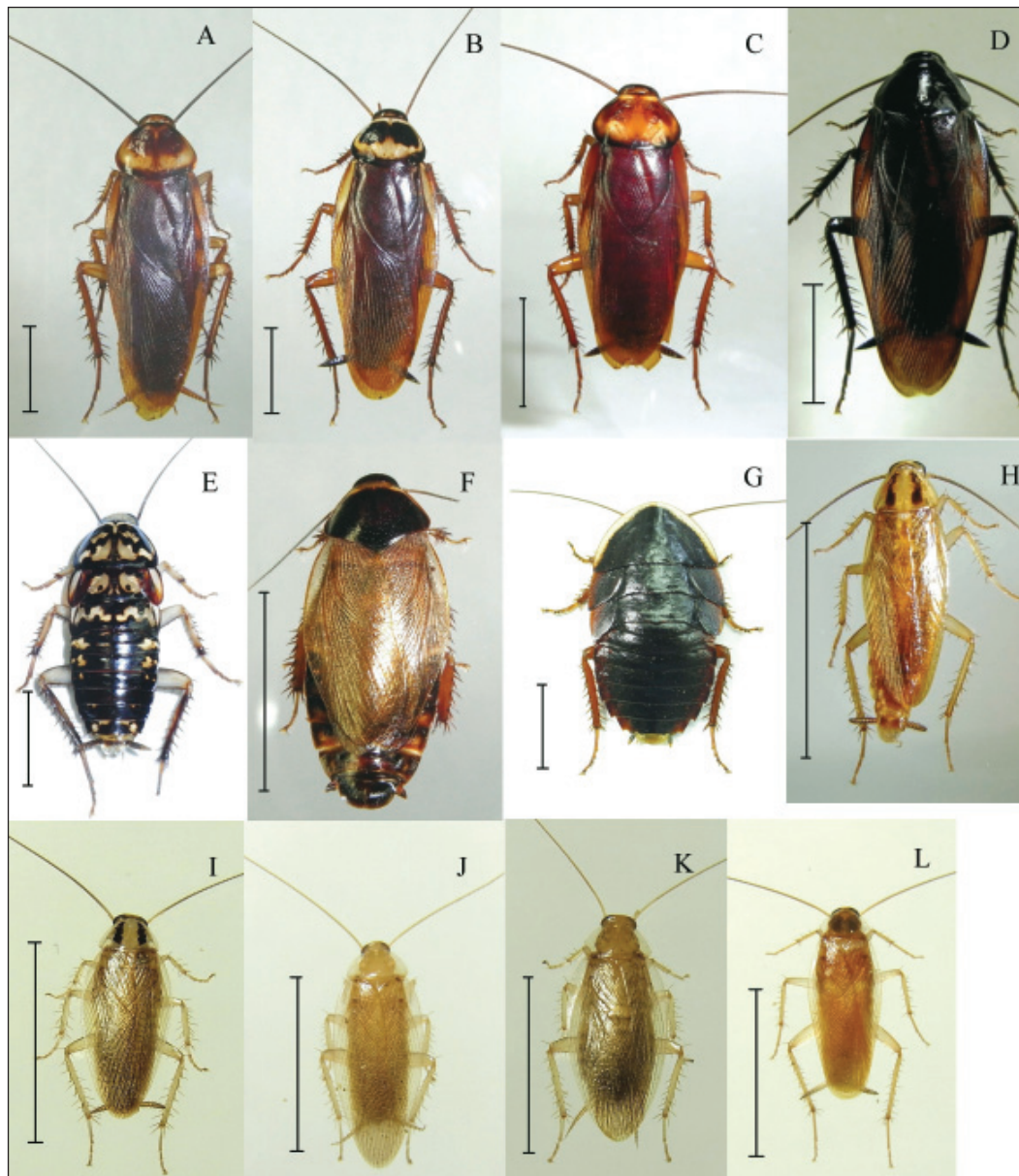


Figure 2. Species of cockroaches found in Ogasawara chain islands. **A.** *Periplaneta americana*; **B.** *Periplaneta australasiae*; **C.** *Periplaneta brunnea*; **D.** *Periplaneta fuliginosa*; **E.** *Neostylopyga rhombifolia*; **F.** *Pycnoscelus surinamensis*; **G.** *Opisthoptatia orientalis*; **H.** *Blattella germanica*; **I.** *Blattella lituricollis*; **J.** *Onychostylus vilis*; **K.** *Onychostylus pallidiolus boninensis*; **L.** *Supella longipalpa*. Scale bars: 10mm for A–L.

area. In residential house A, 3 adults and 14 nymphs of *P. americana*, in house B, 1 adult of *P. americana*, in house C, no cockroaches, and in the shed of house D, 1 nymph of *P. americana*, 1 adult and 10 nymphs of *P. australasiae* and 1 nymph of *O. vilis*, were

caught. Ten adults and 11 nymphs of *P. americana* were collected in a pension. One adult and 1 nymph of *P. americana* in Building A, and 3 adults of *P. americana* and 1 adult and 1 nymph of *O. vilis* in Building B, were collected.

Table 4. Key to the species identification of adult cockroaches found on Ogasawara islands

1.	Length of cockroach including the tegmina, 15 mm long or less	2
	– Length of cockroach including the tegmina, longer than 15 mm	6
2.	Pronotum with two longitudinal dark bars	3
	– Pronotum without two longitudinal dark bars	4
3.	Dark bars on pronotum almost pointed at both anterior and posterior ends, ending with inward pointing. Presence of a short seta on the dorsal surface of the 7 th segment of abdomen	<i>Blattella lituricollis</i>
	– Dark bars on pronotum rounded at both anterior and posterior ends, with the space between the two posterior portions increasingly becoming bigger, like forming an inverted open-end “v” figure spreading outward. Absence of short seta on the dorsal surface of the 7 th segment of abdomen	<i>Blattella germanica</i>
4.	Periphery of pronotum translucent, center to posterior portion light brown. Presence of two black-brown cross bands on tegmina at position of metanotum and dorsal surface of abdomen	<i>Supella longipalpa</i>
	– Both pronotum and tegmina uniformly light brown in colour	5
5.	Presence of 2 pairs of brown dots at the central area near to the posterior margin of pronotum	<i>Onychostylus pallidiolus boninensis</i>
	– Absence of 2 pairs of brown dots at the central area near to the posterior margin of pronotum	<i>Onychostylus vilis</i>
6.	Tegmina long, extending to cover the apex of abdomen or extending a little beyond	7
	– Tegmina degenerated, leaving only a fish-scale-like structure	8
7.	Whole body, dark brown. Pronotum with yellowish brown markings or with yellowish brown edging at the anterior	9
	– Whole body, black brown. Pronotum uniformly black brown without markings	<i>Periplaneta fuliginosa</i>
8.	Whole body, black brown with striking bright yellow pattern at pronotum, mesonotum and metanotum	<i>Neostylopyga rhombifolia</i>
	– Whole body, black brown. Yellowish brown semi-circular band lining the anterior edging of pronotum	<i>Opisthoplatia orientalis</i>
9.	Presence of pale yellowish brown streak at the anterior edging of tegmina	<i>Periplaneta australasiae</i>
	– Tegmina uniformly dark brown, with no markings whatsoever	10
10.	Whole body length, including tegmina, less than 20 mm	<i>Pycnoscelus surinamensis</i>
11.	Whole body length, including tegmina, longer than 20 mm	12
12.	Pronotum with prominent yellowish brown circumferential marking. Male supra-anal plate protruding conspicuously to the posterior, with deep bifurcation at the tip	<i>Periplaneta americana</i>
	– Pronotum without prominent yellowish brown circumferential marking. Male supra-anal plate daishape and not protruding conspicuously to the posterior	<i>Periplaneta brunnea</i>

Iwo island

Two adults of *P. americana*, 1 adult of *P. australasiae*, 8 adults of *Blattella lituricollis*, 8 adults of *O. vilis*, 15 adults and 6 nymphs of *P. surinamensis*, 1 adult of *Neostylopyga rhombifolia* were caught in the outdoor area. In Dormitory A, 1 nymph of *P. australasiae* and 1 nymph of *P. surinamensis*, and in Dormitory B, 4 adults and 3 nymphs of *P. americana*, 4 adults and 5 nymphs of *P. australasiae*, 1 adult of *O. vilis*, and 4 adults and 1 nymph of *P. surinamensis*, were caught, respectively.

Periplaneta americana and *P. australasiae* were significantly caught in the indoor or semi-indoor rather in the outdoor, whereas, *P. surinamensis* were significantly caught in the outdoor area (Table 2).

DISCUSSION

To date, a total of 10 species of cockroaches on the Ogasawara chain islands has been reported (Monzen, 1951; Wada *et al.*, 1969; Nakane 1970; Takahashi, 1973; Saito & Hori, 1973; Kusui *et al.*, 2004). Of these 10 reported species, we were able to collect 6 species in the present study. However, we also collected 2 new species that has not yet been reported. The major species of cockroaches found indoors on the Ogasawara chain islands are *P. americana*, *P. australasiae*, *P. surinamensis* and *B. lituricollis*. Since these same species had also been reportedly caught indoors on Okinawa islands by Shimojana & Kishimoto (1974), it implied that the cockroach fauna of both Okinawa islands and the Ogasawara chain islands share much similarity. Each of the individual islands has its unique cockroach fauna, with 10 species having being reported on Chichijima alone (Table 3). However, of these 10 species, three, namely, *P. fuliginosa*, *P. brunnea* and *B. germanica* have not been observed on that island since the last report by Asahina (1991). Chichijima island is considered as the gateway to the Ogasawara chain islands for the goods coming from Japan proper. These 3 aforementioned species of cockroaches might have entered in Chichijima island together with the goods but might not have

established a permanent colony on the island. However, further study is warranted. Nevertheless, *S. longipalpa* is thought to have established its habitat on Chichijima island because since its first report by Takahashi (1973) on this island, this species has been caught in all the subsequent surveys, including the present study. In our present study, a specimen of *O. orientalis* was found preserved in the Sub-tropical Agriculture Research Center. This represents a new geographical record for this species in the Ogasawara chain islands.

Our present study confirms the presence of 4 species of cockroaches, namely, *P. americana*, *P. australasiae*, *P. surinamensis* and *O. vilis*, on the Hahajima islands. These 4 species on this island had been reported previously by Nakane (1970), Saito & Hori (1973), and Kusui & Ichikawa (2002). Among the Ogasawara chain islands, only 3 islands, namely, Chichijima island, Hahajima island and Iwo island are inhabited by humans. Among these 3 islands, the cockroach fauna on Hahajima island has the least number of species present. It is noteworthy that *B. lituricollis*, which is found distributed widely in Chichijima island, Iwo island and the Spratly chain islands, has not yet been reported on Hahajima island.

Four species of cockroaches, namely, *P. australasiae*, *B. lituricollis*, *O. vilis* and *P. surinamensis*, have been reported to date on Iwo island (Asahina, 1991; Tomioka & Shibayama, 1998). Besides the four species, we also observed the presence of *P. americana* and *N. rhombifolia*, on this island in the present study. This represents a new geographical record for these two species. *Neostylopyga rhombifolia* is widely distributed in the tropical areas south of the Spratly islands. It is considered a pest that invades household. Although we caught *N. rhombifolia* specimen in the outdoor in this study, we postulated that this species will establish itself in the indoor environment on this island.

As seen in Table 2, most of the specimens caught in the household area or indoor environment were that of *P. americana*, accounting for 63%, followed by *P. australasiae*, and *S. longipalpa*, both at

15%, respectively. However, most of the specimens caught in the semi-household area, such as in the shed, greenhouse, storeroom or workshop, consisted of *P. australasiae* at 58%, followed by *P. americana* at 22% and *P. surinamensis* at 17%. Most of the specimens collected in the outdoor area comprises of *P. surinamensis* at 57%, followed by *O. vilis* at 21% and *B. lituricollis* at 8%. Since all specimens of *S. longipalpa* were collected only in the indoor environment, it might be possible that this species is very much adapted to the household area. The environment in which most the specimens of a specific species are collected might reflect on the optimal niche for that species. However, further study is needed to elucidate this phenomenon, including the consideration on the exposure to predators in open space.

Although *P. americana* were caught in both semi-household and outdoor environments, 94 (83.9%) out of 112 specimens were collected in the household environment, indicating the high preference and adaptation to the latter environment. This observation conforms to the reports on the behavior of the same species on Okinawa islands (Shimojana, 1973, 1975; Shimojana & Kishimoto, 1974; Shimojana *et al.*, 1977). However, on the Ogasawara chain islands, many specimens of this species can be seen in the outdoors even at night and as well as under the dried leaf mold during daytime, indicating that the insects had adapted to all the different types of environment there.

On the other hand, just like *P. americana*, *P. australasiae* has also been caught in all the indoor, semi-household and outdoor environments, 56.9% (37/65) of the specimens were caught in the semi-household environment, such as in the greenhouses, shed and workshop. Majority of the specimens of *P. australasiae* has been reportedly caught in the semi-household environment such as greenhouse and storage shed in various places in Japan proper (Yamauchi & Kato, 2009; Tomioka *et al.*, 2009; Nakano, 2009). It is thus suggested that *P. australasiae* might originally be an outdoor species but has adapted to the semi-household environment.

On Chichijima island, since *B. lituricollis* inhabit areas in the vicinity of residential houses, there had been complaints that these insects invade into the houses, as that reported for *Blattella nipponica* (Kamo & Kawashima, 1960; Harunari *et al.*, 2007). Since these two species are able to fly, and they look like *B. germanica*, they have been considered as invading pests. These same characteristics had also been observed for *O. vilis*.

The normal habitat of *P. surinamensis* is usually under the compost of decaying organic foliage. Occasionally, these cockroaches invade into the household along with the soil being brought indoors, resulting them being considered as an indoor pest (Shimojana & Kishimoto, 1974). In our study, this species was caught in the greenhouse.

In our present study, although only one specimen of *N. rhombifolia* was caught at the outdoor area, we think that this species will invade the household and establish a colony because it has been reported to be an indoor species (Shimojana & Kishimoto, 1974).

One of the objectives of the present study is to determine whether *B. germanica*, *P. fuliginosa* and *P. brunnea* has permanently established themselves on the Ogasawara chain islands or not. In our present study, none of these species were collected. As no sighting of *P. fuliginosa* has been reported by the islanders, and the differentiation of *P. americana* from *P. brunnea* is quite difficult, it is suggested that further survey is still needed to clarify the permanent establishment of these aforementioned species on the islands. Our results are similar to that of Kusui *et al.* (2004), who conducted a survey 8 years ago, indicating a low possibility that the 3 aforementioned species might have established themselves on the islands. This might be due to the progress in pest control methods and the drastic decrease in the number of cockroaches inhabiting on the boat. Such measures will work to the advantage of preventing the introduction of new species to the Ogasawara chain islands, which has been designated as a natural world heritage site.

We propose that *S. longipalpa* has not yet invaded or established a colony on the Hahajima island, as evidenced by our failure to collect them. However, due to the large volume of goods in cardboard boxes being transported to the Ogasawara islands on a daily basis, it might just be a matter of time that the endemic species of cockroaches of Japan proper will find their way to these islands. Moreover, the daily ferry service between Chichijima and Hahajima islands also provide the impetus for people to move houses between the islands. All these activities warrant the need to continue with the survey on the fauna of cockroaches on the Ogasawara chain islands.

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REFERENCES

- Asahina, S. (1991). *Blattaria* of Japan. Nakayama Shoten Publsiher, Tokyo, pp. 1-253 (In Japanese).
- Esaki, T. (1930). Uebersicht uber die insektenfauna der Bonin (Ogasawara) Inseln, unter besonderer Berucksichtigung der zoogeographischen Fannen charaktere. *Bulletin of the Biogeographical Society of Japan* **1**: 205-226 (In Japanese).
- Furukawa, H. (1930). Orthopteroid of Bonin Islands. *Bulletin of the Biogeographical Society of Japan* **1**: 225-237 (In Japanese).
- Harunari, T., Kutukake, M., Tanikawa, T. & Tomioka, Y. (2007). An indoor invasion and seasonal changes of *Blattella nipponica* Asahina (Blattaria: Blattellidae) in a food factory. *House and Household Insect Pests* **29**: 55-59 (In Japanese).
- Kamo, H. & Kawashima, K. (1960). On the comparative study of two related species of *Blattella*- *B. germanica* and *B. sp.* *Medical Entomology and Zoology* **11**: 62 (In Japanese).
- Karube, H. & Matsumoto, K. (2008). Insects of Minami-Iwo-To Island. *Ogasawara Research* **33**: 135-141 (In Japanese).
- Karube, H., Takakuwa, M., Suda, S., Matsumoto, K., Kishimoto, T., Nakahara, H. & Suzuki, W. (2004). List of insects collected in the Ogasawara Islands mainly through the special research expedition organized by the Kanagawa prefectural museum of natural history during 1997-2003. *Research Reports of Kanagawa prefectural Museum of Natural History* **12**: 68-86.
- Kusui, Y. & Ichikawa, A. (2002). Ophthopteroidea of Ogasawara Islands in 1972 to 1973, with a list of group of islands. *Tettigonia* **4**: 35-44.
- Kusui, Y., Shimamura, H., Oomatu, T., Savory, N. Jr., Suzuki, S., Iizuka, S. & Aoki, H. (2004). Surveys on the mosquitoes and cockroaches in the Bonin (Ogasawara) islands, Southern Japan. *Journal of Japanese Quarantine Medical Association* **6**: 62-68 (In Japanese).
- Monzen, K. (1951). A revision of the insect-fauna of the Bonin Islands with unrecorded species. *Annual Reports of the Department of Liberal Arts, Iwate University* **2**: 21-33.
- Nakane, T. (1970). The insects of the Bonin and the Volcano Islands. The arts and sciences, the natural monument survey of Ogasawara Islands. The Ministry of Education Agency for Cultural Affairs publication, Tokyo, 15-32 (In Japanese).
- Nakano, K. (2009). Distribution records on Australian Cockroach at greenhouse in Tokyo. *House and Household Insect Pests* **31**: 51-52.
- Saito, K. & Hori, E. (1973). Cockroaches of Bonin Islands. *The Nature and Insects* **8**: 23-25 (In Japanese).

- Shimojana, K. (1973). The habitation population estimate law of the cockroach in the lunch kitchen and an extermination laboratory finding report. *Annual Reports of Okinawa Prefecture Institute of Public Health* **7**: 74–79 (In Japanese).
- Shimojana, K. (1975). Extermination experiment of the *Periplaneta americana* by the residual coating method. *Annual Reports of Okinawa Prefecture Institute of Public Health* **9**: 59–66 (In Japanese).
- Shimojana, K. & Kishimoto, T. (1974). The northern part of Okinawa Island, a cockroach aspect of Noha. *Annual Reports of Okinawa Prefecture Institute of Public Health* **8**: 109–115 (In Japanese).
- Shimojana, K., Kishimoto, T. & Haga, Y. (1977). Extermination experiment of the German cockroach by the smoking method. *Annual Reports of Okinawa Prefecture Institute of Public Health* **11**: 90–93 (In Japanese).
- Takahashi, S. (1973). Insects of medical importance in Ogasawara (Bonin) islands. *Medical Entomology and Zoology* **24**: 143–148 (In Japanese).
- Tomioka, Y. & Shibayama, J. (1998). Distribution records on 12 species of cockroach in Japan. *House and Household Insect Pests* **20**: 10–16 (In Japanese).
- Tomioka, Y., Shibayama, J. & Tanikawa, T. (2009). Distribution records of Australian cockroach, *Periplaneta australasiae* (Fabricius), from Chiba prefecture. *House and Household Insect Pests* **31**: 53–55 (In Japanese).
- Wada, Y., Fujita, K., Sasa, M., Ishii, A. & Shirasaka, A. (1969). Hygiene pest investigation of Bonin Islands. *Japanese Journal of Tropical Medicine and Hygiene* **4**: 57–61 (In Japanese).
- Yamauchi, T. & Kato, H. (2009). Cockroaches inhabiting greenhouses of a botanical garden in Toyama Prefecture, Japan. *Medical Entomology and Zoology* **60**: 305–310 (In Japanese).