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Discovery of a Bird-Parasitic Fly, *Carnus orientalis* (Diptera: Carnidae), in Japan, With Bionomic Remarks and a Key to *Carnus* Species

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ABSTRACT A bird-parasitic fly, *Carnus orientalis* Maa, 1968, is recorded for the first time from Japan, and it is taxonomically reexamined on the basis of specimens collected in Okinawa Prefecture. Adult flies were found from nestlings of Ryukyu scops owl (*Otus elegans* Cassin, 1852), which is a new host for *C. orientalis*. Bionomic remarks regarding *C. orientalis* are presented, and a key to the world species of *Carnus* is also provided.

KEY WORDS Carnidae, *Carnus orientalis*, Japan, new avian host, new record

The species of the genus *Carnus* are distributed in the Holarctic and Oriental regions and now comprise one Holarctic, three Nearctic, and one Oriental species excluding unidentified species (Grimaldi 1997, Papp 1998). Adults are blood feeders and usually are found in nests and nestlings of various bird species (Fitzner and Woodley 1983, Cannings 1986, Kirkpatrick and Colvin 1989, Grimaldi 1997). In Japan, a Holarctic *Carnus hemapterus* Nitzsch was first found in the external auditory meatus of a woman who was sleeping under a tree in Hokkaido (Iwasa et al. 2000). Thereafter, avian hosts and infestations of *C. hemapterus* in Hokkaido and Honshu were reported, along with a case of human dermatitis caused by the adult fly (Iwasa et al. 2008). However, there has been no record of *Carnus* in Kyushu and the Ryukyu Islands of southern Japan.

During the course of research on relationships of nesting habits of birds and ectoparasites in 2012, the third author (K. Asahi) collected some adults belonging to the genus *Carnus* from nestlings of Ryukyu scops owls (*Otus elegans* Cassin; Strigiformes: Strigidae) in Okinawa Prefecture, Japan. On close examination, this species was identified as *Carnus orientalis* Maa, 1968 described from Malaysia. This Oriental species has not been recorded since its original description based on the specimens from Fish owl (*Ketupa ketupa* Horsfield; Strigiformes: Strigidae). We believe this species is valid, but diagnostic features of male genitalia could not be deciphered (Grimaldi 1997). In the present article, we report this species for the first time from Japan with a rede-

scription of the Japanese specimens obtained from new host bird, and we present taxonomic and bionomic remarks, with a key to the world species of *Carnus*.

Materials and Methods

In June of 2012, during a survey of bird ectoparasites in the Experimental Forest of the Ryukyu University, Kunigami Village, Okinawa Prefecture, some small flies were collected from nestlings of Ryukyu scops owl in artificial nest boxes. As a result of the examination, this species was identified to be *C. orientalis* of the Family Carnidae based on the characteristics described by Maa (1968). All adult flies collected were preserved in 99% ethanol and examined for states of wings in both sexes and gravid distension of female abdomens. Morphological terminology follows McAlpine (1981) and Grimaldi (1997), except that we use the term “postpedicel” for “antennal flagellomere 1” (Stuckenberg 1999).

Taxonomy

Genus *Carnus* Nitzsch

Carnus Nitzsch, 1818: Germar's Mag. Ent., 3:305. Type-species *Carnus hemapterus* Nitzsch, 1818.

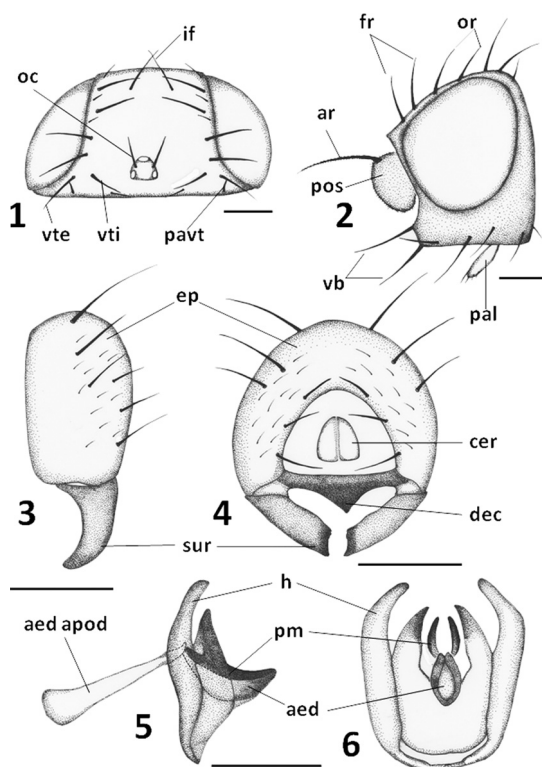
Diagnosis. Head more or less round; frons with two medioclinate and two laterocline orbitals; postvertical setae absent; two pairs of vibrissae present; proboscis heavily sclerotized and bulbous; scutum with one pair of dorsocentrals; wings present only in young specimens; vein A₁ and crossvein dm-cu absent; abdominal tergites reduced in both sexes; in female, sternites I–V indistinct; lateral membranes of abdomen densely with setiferous sclerotized spots; surstyli not fused to epandrium.

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Figs. 1–6. *C. orientalis* Maa. 1, male head, dorsal view; 2, male head, left lateral view; 3, male genitalia, left lateral view; 4, male genitalia, posterior view; 5, male hypandrium and phallic complex, left lateral view; 6, male hypandrium and phallic complex, posterior view. Abbreviations: Head: fr, frontal setae; or, orbital setae; pal, palpus; pavt, paravertic setae; vb, vibrissae; pos, postpedicel; vte, outer vertical setae; vti, inner vertical setae. Male genitalia: aed, aedeagus; aed apod, aedeagal apodeme; cer, cercus; dec, decasternum; ep, epandrium; h, hypandrium; pm, paramere; sur, surstylus. Scales: Figs. 1–4, 0.1 mm; Figs. 5–6, 0.05 mm.

Carnus orientalis Maa, 1968

[Japanese name: Minami-tori-chisui-kobae]

Figs. 1–10

Carnus orientalis Maa, 1968:33.

Type Locality. Selangor, Rantan Ranjang, 8 km N of Klang, Malaysia.

Specimens Examined. 3♂, 11♀, Kunigami village, Okinawa Prefecture, Japan, ex Ryukyu scops owl (*Otus elegans* Cassin, 1852), 10–30. VI. 2012, K. Asahi leg.

Male. Head (Figs. 1 and 2): black; eye slightly ovoid and reddish brown; frons black and shining; face black; gena (Fig. 2) narrowed forward, ratio of narrowest width to height of eye ≈ 0.25 – 0.29 ($n = 3$); genal setae strong; vibrissal angle with two strong vibrissae; postpedicel oval and black; arista pubescent; palpus clavate and light brown; proboscis bulbous, heavily sclerotized and labial theca slightly longer than wide; Chaetotaxy: one interfrontal (cruciate with each other); two frontals (mediocline); two orbitals (laterocline), one ocellar, one inner vertical, one outer vertical, one paravertic; postvertical setae absent. Thorax: mesonotum, scutellum, anepisternum, and katepisternum black; anepimeron and meron blackish brown. Chaetotaxy: one postpronotal, one presutural,

two notopleural, one postsutural supra-alar; one postsutural dorsocentral, one basal scutellar, one apical scutellar. Legs: femora black; fore femur with two to three distinct posteroventral setae; tibiae brown to light brown, and yellow apically; tarsi yellow. Abdomen: tergites I–V (Figs. 7 and 8) heavily sclerotized and rectangular, clothed with strong setae; sternites I–IV sclerotized and square or rectangular shaped; lateral membranes with numerous setiferous sclerotized spots which are fewer in second and third segments; epandrium (Figs. 3 and 4) strongly sclerotized and rounded; surstylus (Figs. 3 and 4) curved innerside in lateral view and broad trapezoidal in posterior view; decasternum (Fig. 4) strongly sclerotized and protruded triangularly; hypandrium (Figs. 5 and 6) simple and horseshoe form; cercus small and unsclerotized; aedeagus (Figs. 5 and 6) short, bulbous, and membranous; aedeagal apodeme not pigmented and thickened apically; paramere (Figs. 5 and 6) slender and its dorsal projection well developed.

Female. Like male, except abdominal tergites (Fig. 9) reduced to narrow and sclerotized; sternites (Fig. 10) inconspicuous, clothed with setulae; sixth sternite sclerotized and square with obtuse angles;



Figs. 7–11. *C. orientalis* Maa. 7, dealate male, dorsal view; 8, abdomen of dealate male, lateral view; 9, dealate female (gravid), dorsal view; 10, abdomen of dealate female (gravid), ventral view; 11, dealate female just after oviposition, left lateral view, see arrow. Scale bar: 0.5 mm.

terminalia slender and unsclerotized with hair-like setulae.

Body Length. ♂, 1.5–1.6 mm; ♀, 1.5–2.2 mm.

Taxonomic Remarks. This species is extremely similar to *C. hemapterus* Nitzsch.

According to Maa (1968) and Grimaldi (1997), this species is separable from *C. hemapterus* Nitzsch in having narrower interocular distance, narrower gena, epistoma with parallel inner lateral margins, labial theca shorter and wider, and male abdominal sternites almost square shaped. However, these characteristics are very subtle, and some of them vary according to body sizes. As a result of our closer examination, in male *C. orientalis* is distinguishable from *C. hemapterus* by a combination of the following characteristics: narrower gena, ratio of narrowest width to height of eye ≈ 0.25 – 0.29 (in *hemapterus*, 0.35 – 0.38); triangular deacasternum strongly protruded ventrally, its triangular height over $2/3$ of broadest width of surstylus or the same width (in *hemapterus*, $\approx 1/2$ of broadest width of surstylus). In females, *C. orientalis* may be distinguishable from *C. hemapterus* in number of setiferous sclerotized spots on second and third abdominal pleural membranes; both have few spots on the lateral sides, but only *C. hemapterus* has spots visible on ventral surface (Maa 1968; p. 36).

Grimaldi (1997) found three new species of *Carnus* (*C. occidentalis*, *C. floridensis*, and *C. mexicana*) in southwestern and southern North America, and their male surstyli and parameres are clearly different each

other. However, it is difficult to separate *C. orientalis* from *C. hemapterus* by the characteristics of surstyli and parameres in males. Close similarity of *C. orientalis* including male genitalia with *C. hemapterus* suggests that these two are vicariant species resulting from geographical isolation in the Eurasian Continent.

Distribution. Japan (Okinawa Is.) and Malaysia.

Bionomic Remarks

C. hemapterus Nitzsch is Holarctic and has a wide variety of avian hosts, comprising 38 species in 18 families (Grimaldi 1997, Iwasa et al. 2008). Hitherto *C. orientalis* Maa was recorded only from Fish Owl belonging to Strigidae in original description by Maa (1968) in Malaysia. Ryukyu scops owl is a new host for *C. orientalis*. Though knowledge of distribution and avian hosts of *C. orientalis* are limited, it is suggested that this species preferably parasites on owls in the Oriental region.

It is known that in *C. hemapterus* dealate flies (Figs. 7 and 8) are most frequently observed on nestlings and almost all female's abdomens were distended with egg (Bequaert 1942, Capelle and Whitworth 1973, Iwasa et al. 2008). The male and female specimens were all dealate, and 10 of 11 females found were gravid (Table 1; Figs. 9 and 10). Infestations of *C. hemapterus* on hosts were mainly observed in nestlings aged 2–3 wk with downy hairs (Kirkpatrick and Colvin 1989, Iwasa et al. 2008). In the current study, ages of nestlings

Table 1. Data for adult flies of *C. orientalis* collected from nestlings of Ryukyu scops owl in Okinawa, Japan, in 2012

Nests ^a	Sampling dates	States of wings (no.)		States of female abdomen (no.)		Ages of nestlings (days)
		Alate	Deplete	Gravid	Not gravid	
1	10 June	0	1[♂], 4[♀]	4	0	9
2	23–25 June	0	3[♀]	3	0	21
3	25–30 June	0	2[♂], 2[♀]	2	0	19–24
4	27 June	0	2[♀]	1	1	11

^a Data represent four different nests.

parasitized by flies were 12–14 d old (Table 1). These suggest that infestations and parasitizing habits of *C. orientalis* in subtropical and tropical zones are similar to those of *C. hemapterus*. However, little is known of behavior of *Carnus* species after infestation (Kirkpatrick and Colvin 1989). Our discovery of one female with undistended abdomen, having extended ovipositor immediately after oviposition (Table 1; Fig. 11: arrow) is interesting, because it suggests that deplete females remain and feed on blood in the same host after oviposition.

Nordberg (1936) found in Finland that a fair number of puparia remained to yield flies the next spring after birds left the nests. In the current study, however, all nest boxes were used for the first time in spring. It has been reported that the brooding birds do not harbor adult *C. hemapterus*; therefore, flies never disperse with their avian hosts (Bequaert 1942, Kirkpatrick and Colvin 1989, Grimaldi 1997). It is conceivable that adult flies of *C. orientalis* can reach the nest boxes from other natural nests in spring. In Europe, North America, and Japan, infestations of *C. hemapterus* on nestlings start in mid May and continue until the end of July (Capelle and Whitworth 1973, Walter and Hudde 1987, Kirkpatrick and Colvin 1989, Iwasa et al. 2008). Maa (1968) recorded *C. orientalis* from nestling on 11 November, which is not supposed in northern temperate regions. It is noteworthy how life cycle of *C. orientalis* including hibernation is different from that of northern species of *Carnus*.

Kirkpatrick and Colvin (1989) found some protozoan infections from the blood of owls during the higher infestations of *C. hemapterus*. Further surveys are necessary on life history and vectorial role in transmission of avian blood pathogens for *Carnus* species in various regions.

Grimaldi (1997) showed the presence of unidentified species (*Carnus* sp. A, *Carnus* sp. B, and African *Carnus* sp.) in his world revision of *Carnus*, but they are excluded in the following key.

Key to the World Species of *Carnus* (Male)

1. Surstylus roughly triangular with two blunt apical teeth (Grimaldi 1997; p. 8) *C. mexicana* Grimaldi
- 1' Surstylus squarish without such apical teeth (Grimaldi 1997; p. 9) 2

2. Surstylus almost square; paramere much shorter, almost triangular. (Grimaldi 1997; p. 9 and 12) *C. occidentalis* Grimaldi
- 2' Surstylus rectangular or trapezoidal; paramere much longer than wide 3
3. Surstylus almost rectangular; paramere simple and triangular (Grimaldi 1997; p. 8 and 12) *C. floridensis* Grimaldi
- 3' Surstylus trapezoidal; paramere much slender posteriorly 4
4. Gena narrower, ratio of narrowest width to height of eye 0.25–0.29 (Fig. 2); triangular decastrum strongly protruded, its triangular height over 2/3 of broadest width of surstylus or the same width (Fig. 4) *C. orientalis* Maa
- 4' Gena wider (Maa 1968; p. 35), ratio of narrowest width to height of eye 0.35–0.42; triangular decastrum not strongly protruded, its triangular height $\approx 1/2$ of broadest width of surstylus (Maa 1968; p. 36) *C. hemapterus* Nitzsch

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