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Biology of the Japanese Crabroninae (Hymenoptera, Sphecidae)*

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The aim of the present paper is to provide a general biological knowledge concerning the Crabroninae of the world with some material from Japan as well as to give informations to the Japanese entomologists on the present state of the taxonomic and biological knowledge of the indigenous species.

Crabroninae, because of their variety in habits, have attracted attentions of a number of the entomologists and a comparatively large number of papers have been published pertaining their biology. These have been summarized at the respective time by F. F. Kohl (1915) on the Palaearctic species, by L. Berland (1925) on the French species, by A. H. Hamm and O. W. Richards (1929) chiefly on the British species and very recently by J. Leclercq (1954) on the world species. Despite the comparatively abundant contributions in this field, how insufficient remains still at present the recorded knowledge concerning the biology, in order to attempt the phylogenetic consideration between and among species known so far, is well related in Capture 4 of the recent monographic work of J. Leclercq.

Japan, as compared with its tiny land areas, seems very prominent in the abundance of species of Crabroninae. The number of species known to occur until now attains as many as 70[1]! And their biological records have been comparatively well accumulated through the efforts of K. Iwata, K. Sibuya, E. Tanaka and some others. I had an opportunity to investigate these interesting wasps chiefly during my residence in Sapporo, Hokkaido, and have published some of the observations in a fragmental or rather summarized form. In the present paper they will be given in detail, together with some unpublished notes on several species.

GENERAL BIOLOGY OF THE JAPANESE SPECIES

a) Nesting substratum. In the Japanese species, as in general, four types can be divided concerning their nesting substratum, namely, i) decayed wood, ii) pre-existing narrow tubes such as the pith hollow of dried reed-canes, grass-halms and the like, iii) the living sappy stem of herbs and, iv) the earth.

The species that burrow in decayed wood are most common and abundant. Most of them are apparently indifferent to whether it lies in horizontal or stands vertically and whether it is thick or thin. Some species, for instance *Crossocerus* (*Coelocrabro*) *walkeri*, however, seems to have preference of the not thick branches to the main trunk. On the contrary, species belonging to *Metacrabro* of *Ectemnius* seem to prefer the big stems.

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To the second type belong the elongate or small species such as *Rhopalum* spp. and *Crossocerus congener*, *cinxius* and *capitosus*. In the third type is included in our country *Ectemnius rubicola nipponis* only. Among the exotic species it is konwn that *Dasyproctus bipunctatus* makes its nest in the stem of *Gladiolus* in Transvaal (Berland, 1932). The fourth type in Japan comprises, as in general, the species belonging to *Crossocerus* (*Crossocerus*) and *Lestica alata*. Probably *Nesocrabro* of *Ectemnius*, *Entomognathus* and *Crabro* known to occur in this country also make their nests in the ground.

b) Types of the structure of the nest. C. Verhoeff divided the nest structure of Hymenoptera into six types : Einzelbauten (Monoecien), Linienbauten (Orthoecien), Zweig- oder Traubenbauten (Dendroecien), Freibauten (Eleutheroecien), Gewölbebauten (Trogloecien) und Wabenbauten (Melessoecien). Of the six Linien- and Zweigbauten only can be met with in Crabronid wasps. Indeed, Kohl (1915) related that the nest of Crabronids can be ascribed either to Reihentypus (oder linear Typus) or to Zweigtypus (Zweigsystem). Hamm and Richards called these the single system (the nest consisting of a burrow containing a linear series of cells) and the double system (the nest with main tunnel giving off small lateral galleries containing or occasionally two or more cells in linear series) respectively and presented as a third type in which a number of females simultaneously use the same main tunnel.

In the Japanese species the first two types of the last-mentioned authors can be found. I called them the linear type and the branched type respectively, because the single type seems to be confused with Einzeltypus. In the branched type there are various degrees of complexity in structure. The simplest is the form wherein the main tunnel gives off several short branches, in each of which is contained a single brood-cell at the end (Simple branched type). In the Japanese Crabronids this is the commonest type of the nest structure (see figures, especially the nests of *Ectemnius cavifrons*, *nigrifrons*, *nigritarsus*). In the next simplest type (Compound branched type) the branch contains, as a rule, two brood-cells linearly arranged. The tendency toward this type is most marked in the nests of *Ectemnius spinipes* (Figs. 29–31), *E. konowii* (Figs. 20–27) and *Lestica reiteri* (Figs. 55–57). Between the above two every transitional state can be observed. On the other hand, the case of the branch containing three brood-cells or more is rather rare, as far as my observations go (*Blapharipus vagabundus* and *Crossocerus pubescens*). The most complex type is seen in the nest of *Lestica collaris* (Figs. 46–48) in which the branch bifurcates twice or thrice and there is no clear difference between the main and the branch tunnels. Moreover, each branch contains as many cells as possible when the nest is accomplished and the main tunnel, too, is sectioned into several linearly arranged cells. Thus, sometimes the branch is apparently given off from a certain cell. On the other hand, in both the simple and the compound branched types a comparatively complex dichotomy of the tunnel is sometimes observed. But this is mainly due to the reutilization of the old nest (Figs. 10, 11, 19 and 53).

From the point of view of evolution the type of the nest made in the earth is considered primitive as compared with those burrowed in wood. As to the burrowing and non-burrowing types the latter is originally primitive (cf. Wheeler, 1923). In the actual

state, however, it is rather difficult to determine that this is the case, since there is a secondary reversion to the primitive type. In the comparison between the simple (unicellular) and the compound (multicellular) types, the former is of course primitive. But there may be no superiority between the linear compound and the branched compound types, because this may originally be determined by the state of the substratum. In some cases, however, we encounter with the instances in which some of the linearly arranged cells are half produced from the main burrow, showing the very initial state of the branched type, e.g. a case given by Iwata (1938) on *Rhopalum nipponicum* and some branches of the nest described in the present paper on *Blepharipus vagabundus*, *Crossocerus walkeri* and *pubescens*. Such instances may be a suggestion that the branched type is more advanced than the linear type. At any rate, it is evident that the linear branched compound type is more advanced than the simple branched compound.

The species nesting in the earth always dig the tunnel by themselves. And there has been no instance known of the linear compound type. Always they belong to the branched compound type. Once accomplished, however, the branch tunnel leading to each cell is so compactly closed with earth that we can hardly distinguish the tunnel from the surrounding earth. From the state of distribution of the contained cells the nest is supposed to belong to the simple branched type.

Hamm and Richards say that the first cell to be constructed is always that which is farthest from the surface, and the other cells follow in regular sequence so that the last is nearest to the entrance. This statement can be accepted as a general rule, but the exception against this rule is not necessarily few. Such exceptional instances are met with in some nests of *Ectemnius spinipes* (Fig. 29) and nearly all the nests of *E. konowii* (Figs. 20-26 and Table 5).

Most of the species do not make a temporary closure in the tunnel leading to the cell just being provisioned. But some, for instances *Ectemnius konowii* as a rule and *Lestica reiteri* occasionally, temporarily closed the tunnel behind the entrance with saw-dust.

c) *Prey*. It is a well known fact that the prey hunted by the wasps of Crabroninae distribute over a wide range of insect orders. But the Dipterous insects occupy the main part.

Hamm and Richards considered that when the other insects are stored there is some evidence to show that this is a secondary habit.

Insofar as our observations go, the Japanese species of Crabroninae prey, beside the Dipterous insects, upon Orthoptera (*Ectemnius furuichii*), Lepidoptera (*Lestica* spp. without exception, *Ectemnius spinipes* exclusively and *Crossocerus vagabundus* exceptionally), Hemiptera-Homoptera (*Crossocerus ambiguus* and *C. tanakai*), Ephemeroptera (*Crossocerus walkeri*), Trichoptera (*Crossocerus amurensis*, in part), Psocoptera (*Rhopalum* spp., *Crossocerus amurensis* in part and *Cr. wesmaeli* exceptionally) and Mecoptera (*Crossocerus aino*). Among the above listed insect orders the Orthoptera and the Mecoptera are the very interesting prey not known so far from any regions other than Japan. The instance recorded to catch the Trichoptera is also very rare. On the other

hand, the Lepidoptera-hunter among the members of the genus *Ectemnius* forms quite an exception. But *Ectemnius spinipes*, though not endemic in Japan, exclusively stores the Lepidopterous insects (imagoes) in the brood-cells. Similarly, the Lepidoptera captured by a member of *Crossocerus* seem of considerable interest, although they are found mingled rather exceptionally (according to Adlerz *Crossocerus ovalis* hunts exceptionally the Microlepidoptera).

In the Japanese species, however, the hunters of the Hymenoptera and the Coleoptera have not as yet been ascertained to occur. But the Coleoptera are probably collected by *Entomognathus brevis* occurring in Hokkaido. The habits of this species, however, remain still uninvestigated in this country.

As already clearly pointed out by Hamm and Richards, the range of the prey, as a rule, does not directly correlate with the taxonomic affinity among the hunters. However, in some cases the presence of such a correlation can not definitely be denied. For instance, the members of *Lestica* prey nearly exclusively (*L. clypeata* of the Continent forms a single exception) upon the Lepidopterous insects and the Lepidoptera are preyed upon by the members of *Lestica* alone, with the single exception of *Ectemnius spinipes*.

NESTING HABITS OF EACH SPECIES

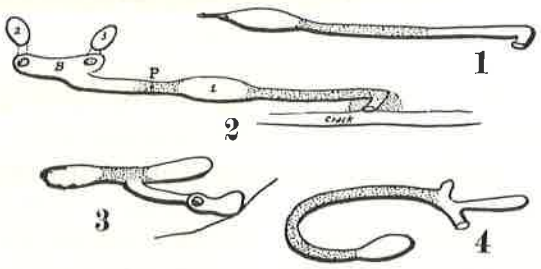
1. *Ectemnius* (*Nesocrabro*) *shimoyamai* Tsuneki, 1959

On the biology of this rare species no observation has ever been made. But the following account described on *Nesocrabro compactus* var. *lanaiensis* Perkins in Hawaii by the original author himself will afford us some suggestion :

"... preying upon Diptera of moderate size, and forming burrow in trodden pathway and bare banks in the forest."

2. *Ectemnius* (*Ectemnius*) *dives* (Lepeletier et Brullé, 1834)

On September 24, 1946, at the natron-spring in Jozankei, Hokkaido, I found several nests of this species made in the rotten log placed as a railing on a bridge. The main tunnel of all the nests observed penetrated along the crack of wood stuffed with sawdust and from the mid-way or the bottom of the crack the wasp dug herself the continuation of the tunnel. After running for about 5–8 cm in wood it reached the first brood-cell.



Figs. 1–4. Nests of *Ectemnius dives* (Lepeletier et Brullé),

Judging from the structure of four nests examined (Figs. 1–4) that were all considered incomplete the nest of this species belonged to the branched linear type. The cell was normal in form, 13×5–5.5 mm in size. The contents of the nests were as shown in Table 1.

Nest 2 seems interesting in showing that cell 1 is formed by packing débri in the wedge-shaped bottom of the crack and by loosely partitioning the interior and exterior of

Table 1. Contents of the nests of *E. dives*.

Nest No.	Cell No.	Prey	Wasp's young
1	1	Syrphidae 4	No egg
2	1	Syrphidae 5	Egg
	2	Empty	
	3	Empty	
3	1	Remains	None
	2	Remains	Larva
4	1	Remains	Larva

the space also with débri, but the ceiling remained half opening. While space B is burrowed by the wasp herself and cells 2 and 3 were simultaneously completed prior to provisioning either of the cells. In cell 1 five prey were loosely packed in and on the one located interiormost was attached the egg of the wasp. It was cylindric in form with both ends rounded, about 2.3 ×0.6 mm in size, wax white in colour and normally attached to the neck beneath of the victim and laid crosswise to its length axis. The larva is characteristic of having the lateral processes of the abdominal segments markedly large and produced (Fig. 5). The prey were as follows :

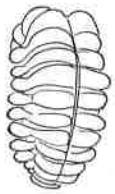


Fig. 5. Lateral processes of the larva of *Ectemnius dives*.

(1) *Sphaerophoria menthastri* Linné (2) *S. taeniata* Meigen. (3) *S.* sp. (4) *Chilosia luteipes* Shiraki. (5) *Syrphus lasiophthalmus* Zett. (6) *Ischirosyrphus laternarius* Müller. (7) *Paragus jezonicus* Mats.

In Europe and North America some fragmental observations were made on this species. The wasp makes the nest in decayed wood and, according to Richards (1944), preys on Syrphidae and Larvaevoridae.

Mode of transportation of the prey was observed by plugging the entrance by a rolled leaf. It captured the fly from the back, holding it by the neck with her middle pair of legs.

3. *Ectemnius* (*Ectemnius*) *nigrinus* (Herrich-Schaeffer, 1841)

Nothing has been known with regard to the nesting habits of this species, the occurrence of which is confined to the Chishima or the Kurile Islands in Japan. In Europe also no observation has ever been made.

4. *Ectemnius* (*Clytochrysus*) *lapidarius* (Panzer, 1799)

E. Tanaka observed a wasp of this species nesting in decayed wood of a fallen tree at Senjogahara, Nikko. The nest was still in the course of construction and only three larval cells were included. The prey stored in the cells were 3, 5 and 7 in number respectively. They all belonged to small species of Syrphidae.

In Europe and North America numerous records of observations have been reported as to the habits of this species. The victims hunted by the wasp belong most usually to Syrphidae, but sometimes also to Stratiomyidae, Calliphoridae, Muscidae, Empidae and Therevidae.

5. *Ectemnius* (*Clytochrysus*) *cavifrons* (Thomson, 1870)

On Septenber 13, 1946, I found at the Otane-valley in Jozankei, Hokkaido, a dead fallen tree in which six nests of *Ectemnius continuus* F. and a nest of this species had been made. The nest was made in a branch, about 13 cm in diameter and the entrance was concealed under the half-lifted dried bark. The structure was as shown in Figure 6. The tunnel ran about 10–20 mm below the surface and the size and the contents of

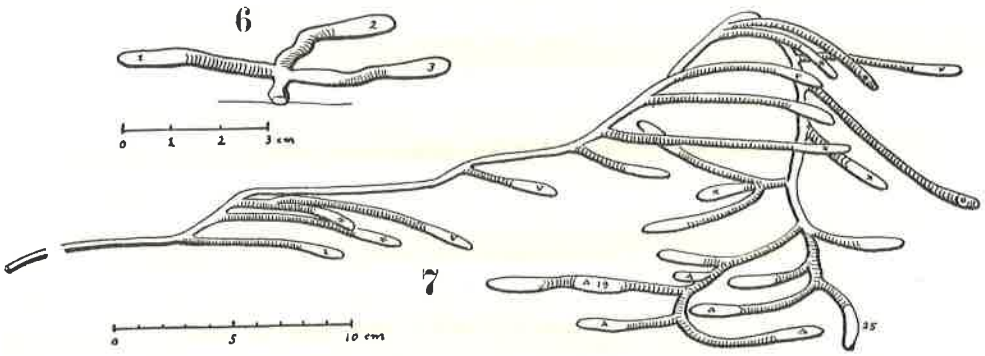
each cell were as given in Table 2.

Table 2. Contents of nest 1 of *E. cavifrons* Thomson

Cell No.	Size	Prey	Number	Young
1	19×7.5 (mm)	*Olbiosyrphus sapporensis* Mats. *Syrphus confrater* Wiedem.	1 1	Just hatched larva
2	16×7	*Syrphus cingulatus* Mats. *Epistrophe balteatus* de Geer	2 1	Egg
3	16×7	*Syrphus cingulatus* Mats.	1	Parasitic fly maggot

Judging from the state of cell 3 this wasp makes a temporal closure in front of the larval cell every time of her provisioning, since the cell was, of course, incompleted.

Nest 2. A complicate nest of this species was observed by me at a valley in Sounkyo, Hokkaido, on September 18, 1946. It was burrowed in one of the decayed logs piled up at the road side. The entrance was opened beneath the log and after running through a more complicate nest of *Ect. spinipes* (Fig. 30) which was also made in the middle of the same log, the nest reached near the upper surface and widely extended the group of cells (Fig. 7). The distal portion of the nest attained beyond the nest of *E. spinipes* and occupied a more interior portion of the log. Thus the state of their distribution seems to show the habitat segregation in the micro-condition within a log. As regards the nest the following facts could be confirmed :



Figs. 6 and 7. Two nests of *Ectemnius cavifrons* (Thomson)

1) The main tunnel running through the log from beneath was 37 cm in length (the cut portion in the Figure) and the main tunnel was clear throughout, that is, no tampon of saw dust anywhere.

2) No doubt the nest was the result of cooperation of two wasps at least of successive genetations, since some cells were stuffed with saw dust including remains of victims and of the cocoon (denoted with a circlet) and some cells were empty (shown with an asterisk).

3) Four cells with a ×-mark were invaded by the parasitic fly maggot, in five cells with a ∨-mark the egg did not hatch and five cells with a △-mark were stuffed

partly with remains of food. But most remained unknown whether the state was effected by the parasitic fly invaded that year (in cell 19 probably this was true) or by the emerged wasp of the previous year.

4) The portion of the cell was sometimes as wide as the tunnel, sometimes slightly enlarged. The size of the cell measured was 16×8, 23×8, 22×8, 24×7.5, 20×8.5, 23×8.5, 20×8, and 22×9.5 mm.

5) In cell 1 a cocoon was flattly pressed and a larva in a prepupal stage lay upon it. In cell 25 a nearly full-grown larva was feeding on the prey. In the other unmarked cells were found newly spun cocoons. They were typical in form, having a papilla on the cephalic end and yellowish brown in colour.

6) The following species of the prey could be ascertained :

Epistrophe baltheatus de Geer, *Syrphus cingulatus* Mats., *S. ribesii* L., *Chrysotoxum festivum* L.

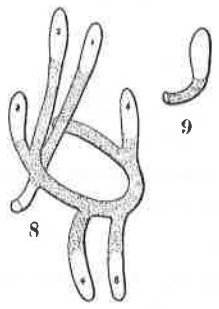
Nest 3. This was observed on September 30, 1947 at Ebetsu, near Sapporo, in a log. The structure was as given in Figure 8 and the contents in Table 3.

Table 3. Contents of nest 3 of *E. cavifrons* Thomson

Item	Cell					
	1	2	3	4	5	6
Size of cell (mm)	20×7	20×8	23×7	23×8	22×8	23×8
Prey *Epistrophe balteatus* de Geer	2	2	3	2	1	1
Prey *Zelima coquilletti* Hervè-Bazin	1	1	1	2	3	4
Prey *Sargus niphonensis* Bigot	1	1	1	1	1	1
Egg of wasp	–	–	–	–	+	+
Waspling (Size, mm)	8	6	4	3*	–	–

* ..... Just hatched larva.

The prey were all placed in the cell with their heads directing inwards, showing, however, a tendency of directing their wings towards the cell-wall, thus forming an envelop with them, as usually seen in the moth hunting Crabronids. The egg or the young larva was always found on the interior-most victim at its neck and placed, as usual, crosswise.



Figs 8 and 9. Two nests of *Ectemnius cavifrons* (Thomson)

Nest 4. Found in the same log as that with nest 3. It was a very simple unicellular (probably incomplete) nest. The main tunnel was only 20 mm in length and the cell stood almost vertical (Fig. 9). In the cell 2 *Sargus* and 1 *Epistrophe* were provisioned, but with no egg. Notwithstanding, the tunnel throughout was fairly compactly stuffed with débri.

Nest 5. July 17, 1949, in the Otane-vally, Jozankei, Hokkaido. The nest in a dead fallen tree, heavily moistened. The wasp was provisioning. The structure of the nest : Figure 10. This was a reutilized nest, the dotted portions in the Figure were the old one and the hatched portions were newly burrowed by the wasp. As was supposed from the Figure the wasp only utilizing the old entrance and a part of the tunnels alone, not re-using the old cell. This was confirmed by examining the state

of the cell wall. In cell 7 were stuffed 6 flies of *Eristrophe balteatus*, with the first instar larva on the one placed interiormost. In cells 10 and 11 the larvae were almost full-grown, in cell 12 the cocoon was being spun, in cell 13 were found 4 flower flies (*Eristrophe balteatus* 2, *Neoascia longiscutata* Shiraki 1 and a species near this 1) with the wasp's egg.

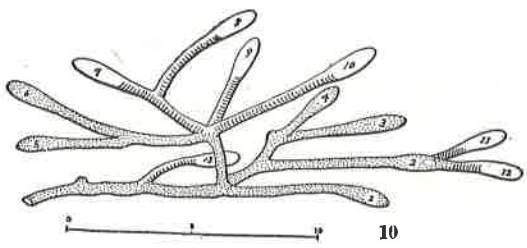


Fig. 10. A reutilized nest of *Ectemnius cavifrons*. Dotted parts show the old nest.

In general the following may be summarized as to the biology of this species in Japan :

1. The nest is made in a branched type in decayed wood, each branch containing, as a rule, a single cell (very rarely two cells) and the number of cells attains more than 10. The cell is 16–23 mm in length and 7.5–9.5 in width.

2. The same nest is sometimes utilized and extended by the wasps of the successive generations.

3. The prey mainly belong to Syrphidae, containing sometimes Stratiomyiidae.

4. The egg is always found on the victim lying innermost in the cell, but the egg is not laid on the first prey just after being carried in, since in the cells not adequately provisioned no egg is found on any of the victims stored.

5. Mode of attaching of the egg follows the general rule in this group of wasps.

6. The cocoon has a papilla on the cephalic end.

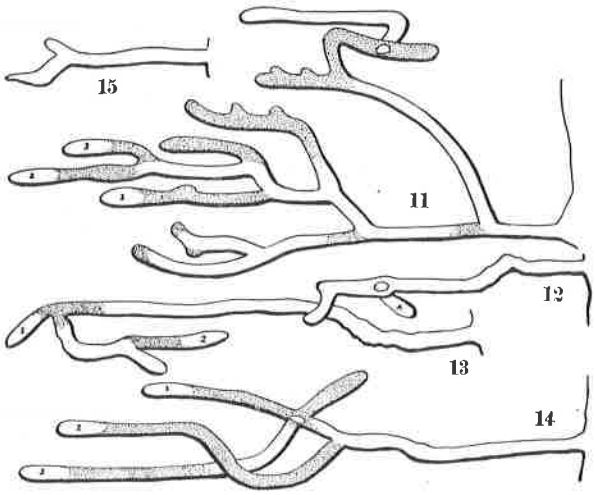
A number of observations have been made upon the habits of this species in Europe. According to these, the prey belong mainly to Syrphidae, but Calliphoridae, Stratiomyiidae and Tabanidae are also recorded. In Japan a single nest has been observed by Iwata (1941) in which the prey were all Syrphidae.

6. *Ectemnius* (*Clytochrysus*) *nigrifrons* (Cresson, 1865)

Biology of this species has been recorded by only two investigators, one in Europe (Faester, 1944) and one in North America (Krombein, 1936). According to these authors the wasp of this species nests in decayed wood and provisions the brood cells with flies belonging to Syrphidae. At the road-side in the Hoheikyo-valley, Jozankei, I happened to observe, on September 18, 1945, several wasps of this species and a wasp of *E. iridifrons* making their nests in a wood which was almost decayed. As it was the possession of a cooper I bought and cut off the portion of the wood and carried it back to my laboratory at that time in Hokkaido University to investigate with a sufficient time and the instruments. The block of wood, 40 cm in diameter and 60 cm in length, contained 7 nests of this species, exhibiting various stages of construction (Figs. 11–17 and Pl. II, Fig. 2). The data were as given in Table 4.

From the Figures and the data we may summarize the habits of this species as follows :

1. Hither and thither in the tunnel a small hollow is present, probably these are the trace of trials of the wasp to make the branch tunnel. The tunnel is unevn in width,



Figs. 11–15. Nests of *Ectemnius nigrifrons* Cresson.

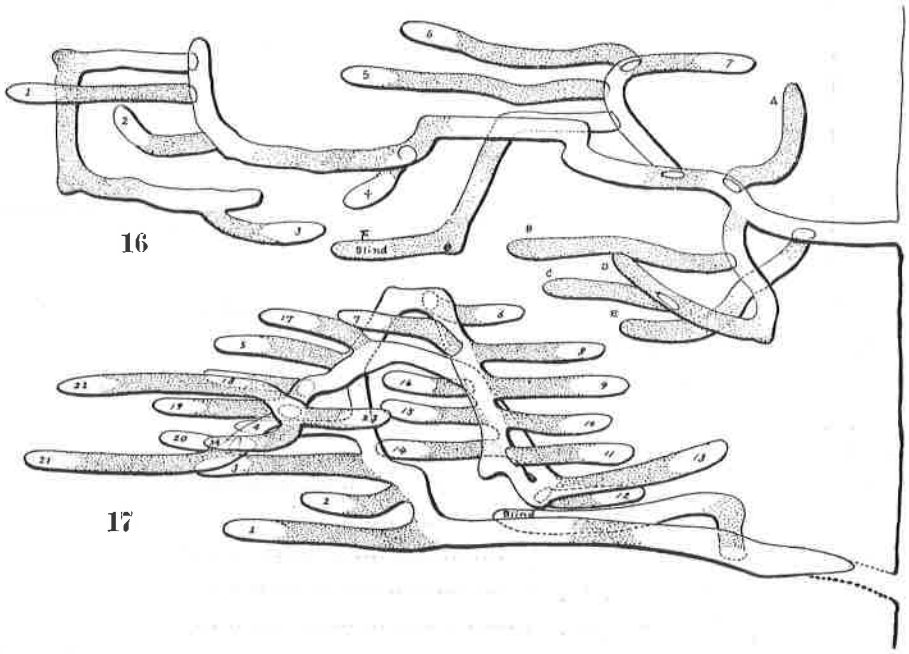
usually 5–6 mm, but in some places it enlarges to about 10 mm.

2. The structure of the nest belongs to the branched type, each branch containing a single cell at the end. It is as wide as the tunnel and its length is determined by the location of the partition of saw dust. This is markedly compact and usually stuffs whole the length of the branch.

3. Nest 7 (Fig. 17) is considered representing a nicely completed one and made by a single wasp, since there was no unused cell containing fragments of the old prey and cocoon within the nest. This seems to show, therefore, that 24 may be the limit of the number of cells made by a single wasp in this species.

4. There is no doubt that sometimes the old nest is reutilized (e.g. Nest 6 — Fig. 16).

5. Species of the prey corroborated (parenthesized letter at the head of each species



Figs. 16 and 17. Other complicate nests of *Ectemnius nigrifrons*.

Table 4. Contents of nests observed of *E. nigrifrons* Cresson

Nest No.	Cell No.	Size (mm)	Contents: Prey (number)	Egg (mm)	Larva (mm)	Cocoon (mm)	Remarks
1	1	11×5.5	C(1) S(1) T(1)	–	–	5.5×2*	* Some parasite's cocoon ?
	2	17×6	S(1) + *x*	–	–	–	
	3	20×6	S.c(1) + *x*	–	–	14×4	
2	1	–	–	–	–	–	Incomplete
3	1	12×6.5	I(3)	–	4	–	
	2	12×6.0	I(1) Sp(2)	–	5	–	
4	1	15×5	E(2) S.r(1)	3×1.0	–	–	
	2	16×5	E(5)	–	–	–	Maggots 2
	3	15×5.5	E(3) Sp(1)	–	–	–	
5	1	–	–	–	–	–	Incomplete
6	1	16×5.5	S.r(1) P(1)	–	–	13×4	
	2	15×5.5	E(2) S.c(1)	–	–	–	
	3	8×6	P(1)	–	–	–	Abnormal
	4	16×5.5	P(1) E(1) Sp(1)	–	–	15×5	
	5	14×6	E(1) Sp(2) S.r(1)	–	–	–	1 pupalium
	6	15×5.5	I(1) + *x*	–	–	–	1 pupalium
	7	16×5.5	P(1) E(1) + *x*	–	–	–	
7	1	16×6	P(1) + *x*	–	–	–	
	2	15×5	P(2) E(1) + *x*	–	–	–	1 pupalium
	3	16×4.7	?	–	–	12×3.5 (♂)	
	4	14×4.7	?	–	–	13×4.3 (♂)	
	5	16×5	?	–	–	13×4 (♂)	
	6	15×5	?	–	–	15×4.3 (♀)	
	7	16×5	E(2) Sp(3)	–	–	–	
	8	16×5	?	–	–	14×4 (♂)	
	9	18×6	?	–	–	13×4 (♂)	
	10	17×5	?	–	–	12×3 (♂)	
	11	16×5.5	?	–	–	14×3.8	Ichneumon
	12	16×5.5	?	–	–	13×5 (♀)	
	13	18×5.5	?	–	–	14×3.5 (♂)	
	14	16×5	?	–	–	14×4 (♂)	
	15	15×4.8	?	–	–	12×3.5 (♂)	
	16	14×5	?	–	–	13×3.7 (♂)	
	17	15×5	E(2) Sp(2)	–	–	–	
	18	14×5	?	–	–	–	1 pupalium
	19	15×5	E(3) + *x*	–	–	–	
	20	14×4.5	E(3) Sp(2)	–	–	–	
	21	18×6	P(2) Sp(1)	–	–	–	
	22	13×6	?	–	–	–	
	23	14×5	E(1) + *x*	–	–	7×3	Chrysididae
	24	16×4.7	E(2) P(1)	–	–	–	

Abbreviation of the prey name is given in text.

name is the abbreviation used in Table 4.) :

(C)	*Chilosia yesonica* Matsumura	1	
(S.c.)	*Syrphus corollae* Fabricius	2	
(I)	*Ischilosyrphus laternarius* Linné	5	
(Sp)	*Sphaerophoria menthastri* Linné 14		Syrphidae
(E)	*Epistrophe balteatus* de Geer 26		
(S.r.)	*Syrphus ribesii* Linné	3	
(S)	Syrphidae gen. sp.	1	
(S)	Syrphidae gen. sp.	1	
(T)	*Tachytrechus genualis* Loew	1	Dolichopodidae

(P) *Phasia separata* Matsumura ..... 8 Anthomyiidae

6. The cocoon is fairly variable in size, 12–15 mm in length and 3.5–5 mm in width, always provided with a papilla at the cephalic end. The two exceptionally small cocoons obtained from nest 3 might be those of some parasite. Unfortunately, however, the imagoes did not come out of the cocoons, while a small cocoon found in cell 23 of nest 7 contained a dead larva, probably of Heteronychine Chrysididae.

7. The egg is cylindric with the ends rounded, about 3.0×1.0 mm in size and milky white; as seen usually, it attaches with the cephalic end to the neck beneath of the innermost prey and produces crosswise with the other end. But in this species, too, the egg is not laid just after the first prey is carried in, but probably after the completion of provisioning.

8. Transportation of the prey is also as usually observed in this group of wasps : catching it, venter to venter, with the mid legs and transporting on the wing.

9. As parasites, besides the cuckoo wasp above stated and the Tachinid flies, the Ichneumon fly, *Perithous japonica* Uchida has been obtained from the preserved cocoons.

7. *Ectemnius* (*Cameronitus*) *flavohirrus* Tsuneki, 1954

The specimens of this species have hitherto been collected only at Ichinose, at the foot of Mt. Haku, on the flowers of Umbelliferae and in the bush of the bamboo grass. Nothimg has been known about their nesting habits.

8. *Ectemnius* (*Cameronitus*) *radiatus* Pérez, 1905

(= *mizuho* Tsuneki, 1952)

On July 31, 1954, at Ichinose, I captured a wasp of this species coming out of a burrow made in one of the logs piled up at the road side for firing material. Upon cutting, I could made out the structure of her nest as given in Figure 18. It contained two completed cells and the wasp was provisioning in the 3rd cell.

The prey found in each cell were 5, 5 and 2 in number, in the 1st and 2nd cell the prey laid at the interiormost portion carried respectively the wasp's egg. While in the 3rd cell on none of the prey was found the egg. The prey belonged to small flies of Anthomyiidae, Muscidae and Calliphoridae. According to this observation, this species follows the usual habits of Crabroninae in its mode of burrowing, provisioning and oviposition.

9. *Ectemnius* (*Cameronitus*) *nigritarsus* (Herrich-Schaeffer, 1841)

Only once I had a chance of investigating the nest of this species. It was made in a big fallen tree lying in the forest on the river-side in Otane-valley, Jozankei. The wood was heavily decayed, without the bark, and fairly moistened. The entrance to the nest was opened on one side of the trunk and the wasp was working at her provisioning.

Mode of her carrying the prey followed the usual fashion, namely capturing it venter to venter with the middle pair of legs with the prey's head directing forward and crept in the entrance which was left opened during the time of her absence.

The nest was doubtlessly the old one and the wasp was reutilizing some of the old cells after cleaning them up. It had the structure as shown in Figure 19. The undermentioned cell number was assigned according to the order of examination, that is to say, accord-

ing to the depth from the surface of the wood, the amaller the shallower. Because of the fact that the biology of this species remains unknown to the scientific world the contents of the cells will be described in detail.

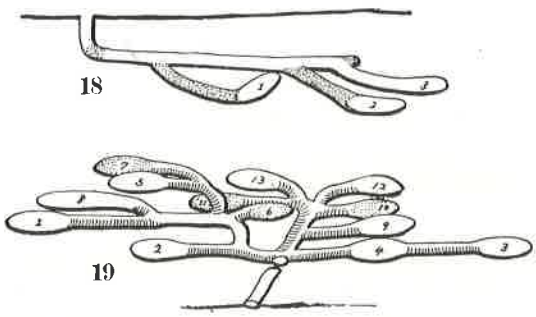


Fig. 18. A nest of *Ectemnius radiatus* (Pêrez.)
Fig. 19. A reutilized nest of *Ectemnius nigritarsus* (Herrich-Schaeffer). Old cells are dotted.

Cell 1. Size : 16×6.5 mm, distinctly wider than the tunnel. Prey : From the interior outward, a fly of Terevidae with the wasp's egg, 1 Syrphidae (*Epistrophe balteatus* de Geer), 3 middle-sized Tachynidae, all with the head directing inward and with the wings to the cell wall to form the external wrapping layer to include the eatable portions of the prey, as usually observed in the moth-hunting group of the Crabronids.

Cell 2. Size : 15×6 mm. Prey : Rotten and covered with mould, including 2 puparia of the parasitic fly.

Cell 3. Size : 18×6 mm. Prey : From the interior, Tachinidae 1, Anthomyiidae 1 and Terevidae 1, the first two being rotten and the egg of the wasp also rotten.

Cell 4. 16×6.5 mm. Prey : Musty and decomposed, with two empty puparia of the parasitic fly.

Cell 5. 22×5.5 mm. Prey : All covered with mould, but Syrphidae (*Sphaerophoria menthastri* L.) 1, Muscidae 1 and Tachynidae 1 were defined.

Cells 6, 7, 10, 11, 12 and 13. Old cells, as yet unused, stuffed with saw dust, remains of flies and an empty cocoon.

Cell 8. Only the entrance to the cell was loosely closed with saw dust and in the interior which was very large, 35 mm in length, were scattered four prey, all belonging to the same species of Terevidae, but on none of them the egg of the wasp was found. This cell is clearly the one just in the course of provisioning.

Cell 9. 20×5.5 mm. Prey : Anthomyiidae 1 carrying the waspling, Terevidae 1, Syrphidde 1 (*Epistrophe balteatus*), already beginning to rotten.

Summary of the habits : Nest simple branched type, rarely containing two cells within a branch; cell distinctly wider than the tunnel, 15–22 mm in length and 5.5–6 mm in width. Old nest (sometimes ?) reused. Prey : Diptera including Terevidae, Syrphidae, Anthomyiidae and Tachinidae (Pl. I, Fig. 2). Transportation of the prey, provisioning habit and oviposition as usual.

10. *Ectemnius* (*Yanonius*) *martjanowii* (Morawitz, 1892)

No record of observation upon this species has been taken up to the present.

11. *Ectemnius* (*Metacrabro*) *konowii* (Kohl, 1905)

I have investigated up to now eight nests of this species in Hokkado and examined some prey collected at Towada, Aomori Pref. The nests were all made in decayed wood and provisioned with flies belonging mainly to Syrphidae and exceptionally to Phasiidae

(Pl. I, Fig. 3). The structure of the nests were as shown in Figures 20–27 and the data concerning them in Table 5. Rearing of the larvae : Pl. II, Fig. 3.

a) Some remarks on the nests observed

Nest 1 (Fig. 20). The entrance was made in the wood-pecker's hollow. Branch E, a tunnel of some boring beetle larva, was compactly packed with saw-dust probably by the wasp. Branches A, H and I were respectively a blind tunnel and stuffed compactly with débri. They were probably the dust tunnel for the use of reception of the débri from the newly burrowed tunnel, though it is uncertain whether they were originally intended so or casually utilized during the course of burrowing of the wasp.

Nest 2 (Fig. 21). At x a wasp was found dead with saw-dust between her mandibles, probably the original owner of the nest and the constructor of all the cells of the nest. She would have died prior to the completion of cell 16. On the other hand, at y another living female wasp of *konowii* was hiding. She would have entered the nest for the purpose of utilizing the tunnel to make her own nest and possibly removed the saw-dust from the tunnel leading to cell 14 and in part from that to cell 15. On the other hand, tunnel s was decidedly being constructed by a wasp belonging to *Ectemnius spinipes* Mor., since there were scattereed 6 paralysed moths within the range of 35 mm from the interior.

Nest 3 (Fig. 22). This is considered a case of reutilization of the old nest. Because the blind tunnels found in the nest contained a fragments of dried flies and old cocoons.

Nest 5. This was the nest that I dug for the purpose of obtaining the larvae of *konowii* to use for my experimental study on *Bembix niponica.* I cut open five cells (Fig. 24, cells 1–5) and left alone the wasp and cell 5 which was incomplete. The next year when I investigated a nest of another Crabronid on the same trunk I found a tunnel was dug from the entrance to cell 5. So I cut the wood and discovered three branch tunnels including totally 5 broken cocoons. The wasp that I knew must have continued her work thereafter and constructed the 5 cells.

b) Structure of the nest

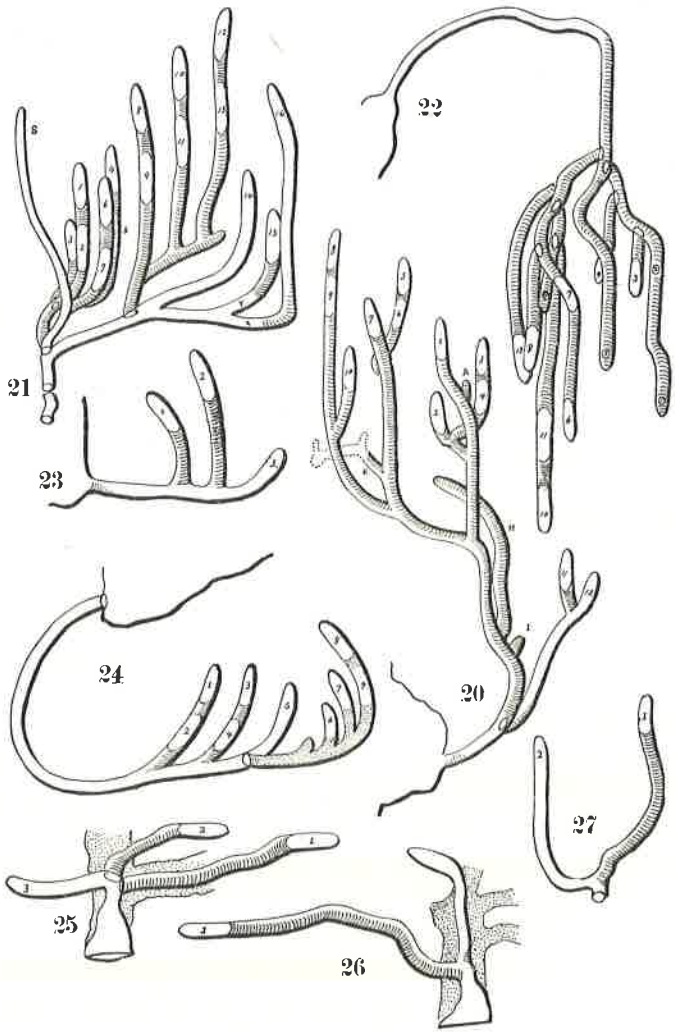
It is preferred by the wasp to dig her burrow from some hollow naturally present on the trunk, such as the excavation of the wood-pecker or the abandoned hole of the boring beetle larva in order to avoid the hard work of boring through the hard tissue under the bark. As for the tunnel and cell, except for the two nests (Nos. 6 and 7) which were made in the fallen trees, all those burrowed in the standing dead trees had the branch tunnels running upwards and the cells located vertically. In one branch usually one or two cells were made, in the latter case with interval of saw-dust wall varying in length. As a rule, the cell is the same in width as the tunnel, usually 7–9 mm in diameter and 18–25 mm in length. The maximum number of cells contained in one nest constructed by a single wasp is considered as many as about 16. The tunnel leading to the cell is compactly closed after it is fully provisioned with prey and the egg is laid.

c) Provisioning

During the course of provisioning of the wasp the tunnel just behind the entrance is, as a rule, closed temporarily with a loose partition of saw dust, but sometimes not. Similarly the tunnel leading to the provisioning cell is sometimes loosely closed at the bifurcation.

The presence or absence of such a closure may be determined by the length of time the wasp is out in the field.

As the brood-chamber is vertically consturcted victims carried in are strongly pressed against the wall or against the other victims so as not to drop off during the absence of the wasp. Notwithstanding, in no case of the provisioning cell can be discovered the egg of the wasp on any of the victims already stored. No doubt, the wasp, after finishing her hunting activity for one cell, loosens the packed victims and lays her egg on the insect then placed innermost. The fashion seems to be the rule among the Crabonine wasps.



Figs. 20–27. Nests of *Ectemnius konowii* (Kohl).

d) Observation of the provisioning activities

August 31, 1946. In the stock-farm of the Hokkaido University, Sapporo, stood a big dead tree of *Phellodendron amurense* in which some ten nests of various species of Crabronids and Pemphredonids have been made. Among the wasps at work I found an individual of *E. konowii*, upon which I took some records of her provisioning activity :

13:13 (at 13 past 1 p.m.). The owner of nest 1 came back with a flower fly belonging to *Eristalis cerealis*, alighted near the entrance which was located at the bottom of a hollow, 140 cm above the level of the ground, walked there about and then penetrated through the débri with which the entrance was closed, with the fly slightly pushed backward and dragging it almost behind her abdomen. It was confirmed that the fly was grasped by the neck from backward with the middle pair of legs of the wasp. After 3 minutes she appeared at the entrance, closed there by scratching together the saw-dust

Table 5. Contents of nests of *E. konowii* Kohl

Nest No.	Cell No.	Size (mm)	Prey: Species (number)	Prey: Total	Waspling: Egg	Waspling: Larva (mm)	Waspling: Cocoon	Remarks
1	1	30×9	Remains	?	–	18	–	Aug. 31, '46.
	2	24×8.5	Remains	?	–	17	–	Sapporo
	3	23×9	Remains	?	–	17	–	
	4	20×10	Remains	?	–	17	–	(Fig. 20)
	5	22×9	E.c(2) E.t(1)	3	–	12	–	
	6	22×9	E.c(3)	3	–	10	–	
	7	32×9	E.c(2) E.n(2) E.t(1) C.f(1)	6	–	8	–	
	8	25×9	E.c(3)	3	–	8	–	
	9	22×9	E.c(1) E.n(1) E.t(1)	3	–	6	–	
	10	23×8	E.c(2) E.n(1)	3	–	5	–	
	11	28×9	E.c(4)	4	+	–	–	
	12	–	E.c(4)	4	–	–	–	Incomplete
2	1	19×8.5	Remains	?	–	–	+	Sept. 15, 1946.
	2	22×9	Remains	?	–	–	+	Sapporo
	3	23×8.5	Remains	?	–	18	–	
	4	29×9	Remains	?	–	18	–	(Fig. 21)
	5	18×7	Remains	?	–	–	Spinning	
	6	22×9.8	Remains	?	–	17	–	
	7	22×9	Remains	?	–	17	–	
	8	20×8	Remains (including E.c)	?	–	14	–	
	9	20×8	Remains (including E.c)	?	–	17	–	
	10	35×9	Remains (including E.c, En)	9	–	17	–	
	11	18×9	Remains	?	–	13	–	
	12	21×9	E.c(3) E.n(1)	4	–	13	–	
	13	19×9	E.c(4) C.f(1)	5	–	13	–	
	14	No wall	E.c(2) E.n(2)	4	–	8	–	
	15	23×8	E.c(5)	5	–	4	–	
	16	No wall	E.c(3) E.n(2)	5	–	–	–	Incomplete
3	1	–	Saw-dust and remains	–	–	–	–	Sept. 15, 1946.
	2	–	Saw-dust and remains	–	–	–	–	Sapporo
	3	25×9.5	Remains	?	–	–	+	
	4	24×9	Remains	?	–	–	+	(Fig. 22)
	5	–	Saw-dust and remains	–	–	–	–	
	6	16×10	Remains including E.n.	?	–	18	–	
	7	19×9	Remains	?	–	17	–	
	8	18×9	Remains	?	–	17	–	
	9	–	Saw-dust and remains	–	–	–	–	
	10	25×8	E,c(2) E.n(1) S.b(1)	4	–	–	–	Larva unhatched
	11	22×8	Remains	?	–	16	–	
	12	23×9	E.c(3) C.f(1)	4	–	–	–	
4	1	20×8.5	E.n(6)	6	–	+	–	(Fig. 23)
	2	22×8.5	E.c(4)	4	+	–	–	
	3	–	E.c(2)	(2)	–	–	–	Incomplete
5	1	–	E.c(2) E.n(1) S(1)	4	–	15	–	Sept. 11, 1947.
	2	–	E.c(2) E.n(1)	3	–	12	–	Sapporo
	3	–	E.c(2) E.n(2)	4	–	12	–	
	4	–	E.n(4)	4	–	8	–	(Fig. 24)
	5	–	E.c(3)	(3)	–	–	–	....Incomplete
	6	–	Saw-dust and remains	–	–	–	–	
	7	–	Saw-dust and remains	–	–	–	–	Cells 6–9
	8	–	Saw-dust	–	–	–	–	examined on
	9	–	Saw-dust	–	–	–	–	Oct. 29, '48.
6	1	22×9	E.c(4)	4	Just hatched larva			(Fig. 25)
	2	17×7	E.c(3) P.a(1)	4	+	–	–	
	3	–	E.c(2) E.s(1)	3	–	–	–	Incomplete
7	1	18×6	E.c(3)	3	+	–	–	(Fig. 26)
	2	–	E.c(2)	(2)	–	–	–	
8	1	20×8	Remaints including E.c	?	–	–	–	1 pupalium
	2	–	–	–	–	–	–	(Fig. 27)

E.t ... *Erystalomyia tenax* L. E.c ... *Eristalis cerealis* Fabr. E.n ... *Eristalis nigricans* Mats. C.f ... *Chrysotoxum festivum* L. S ... A species of Syrphidae. P.a ... *Phasia analis* F. E.s ... *Eristalinus sepulchralis* L.

scattered there and flew off.

13:32. She returned with a flower fly of apparently the same species as above, catching it as before. Four minutes later she came out, loosely closed the entrance and flew away.

13:44. She took in another *Eristalis cerealis* after hesitating a while near the entrance and stayed inside up to 14:27. During the time she might have rearranged the flies and laid her egg on one of them. When she apperared at the entrance she found a flower fly that had been killed and placed by the observer in the entrance gallery, showed an appearance of taking it in, but suddenly stopped the work, dropped it off and flew away wihout closing there.

14:43. The wasp came back with another flower fly of the same species. Mode of capturing as before. The fly raised a long screeching sound. Four minutes later she came out, closed the entrance and at once started off without taking a glance at the flower fly that was replaced in front of the orifice.

14:57. The wasp turned back with a fly of the same species. Mode of capturing and of entering was as before. Five minutes later, she came out, closed the entrance and flew away.

15:36. Returned with the same species of the victim, stayed in the nest until 15:45, when appeared, closed the entrance and started off. She did not return up to 17:00 when the observation was stopped.

Two days later, I was digging the above mentioned nest at 13:15, when the wasp came back empty-handed and after searching for the entrance that had already been destroyed flew off. At about 16:00 she turned back once more without a prey. Judging from the state of the final cell (cell 12) it seemed possible that she came to the nest to lay her egg for the cell.

The next day I found two wasps of *konowii* working on the same dead tree and recorded their provisioning activities. It was as given in Figure 28. Whether one of them was the same wasp observed a couple of days before I could not say with certainty. But they were respectively the owner of nest Nos. 2 and 3. The state of nest 3 examined afterward, however, seems to suggest that the wasp of nest 3 might be the same individual as that of nest 1.

Judging from behaviour of the wasps represented in Figure 28 it is presumable that wasp 2 made one and wasp 3 two cells in that day. During the time between 13:12 and 14:17 wasp 2 must have arranged her victims in the cell and laid her egg on one of them and during 12:39 and 13:31 wasp 3 similarly laid her egg and prepared the next cell which must have been done with ease in this case, since the wasp reused the old nest.

e) Orientation flight

At 10:52 wasp 3 came back from her foraging excursion with a prey and went to the entrance. In her removing work of the temporary closure at the door she happened to drop off the prey (Fig. 28). She searched for the prey a very little while and at once started for her new hunting journey. After 17 minutes she returned with another fly and provisioned it. In her next starting-off she made the so-called orientation flight. She

started, but did not go far away, turned back from a distance of about 5 meters to the nest. She alighted at the entrance but at once flew off and came back from a distance of 3 meters. She then repeated twice more the same behaviour, the distance being from 3 to 5 m and the direction from south-west to north-west. This is decidedly the so-called orientation flight and suggested, together with the structure of the nest later made clear, that the wasp might be the same as wasp 1 whose nest had been destroyed the previous day.

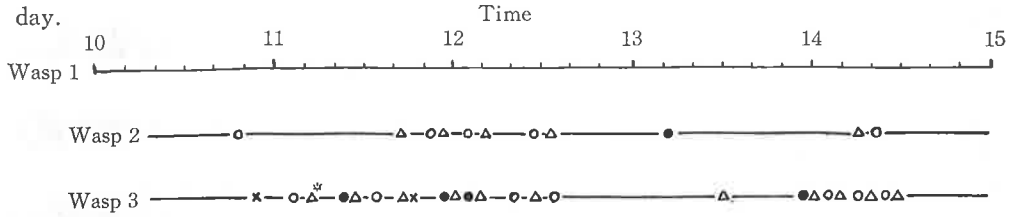


Fig. 28. Provisioning activity of two wasps of *Ectemnius konowii*.
○ Came back with a fly. △ Flew away from the nests.
● Returned without a fly. × Dropped off the fly and started for hunting.

f) Prey

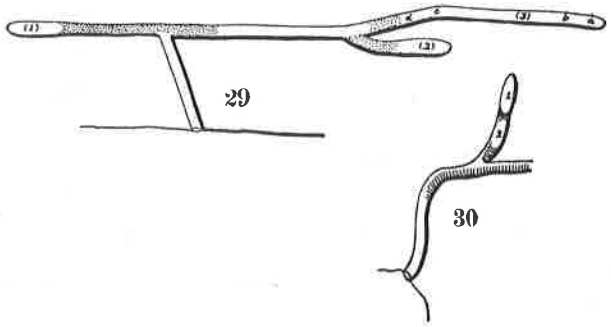
The prey of this species consisted mainly of Syrphidae, mixing a few specimens of Phasiidae. Among Syrphidae *Eristalis cerealis* F. occupied the main part, among others *Eristalomyiia tenax* L, *Chrysotoxum festivum* L. etc. were included. Of the Phasiidae *Phasia analis* F. made the main part.

12. *Ectemnius* (*Metacrabro*) *spinipes* (A. Morawitz, 1866)

Amongst a number of the nests of this species discovered by me only three instances have practically been investigated. The structure of these nests was as given in Figures 29–31. Besides the above the early stage of construction of a nest is illustrated with Figure 21 (S).

a) Some remarks on each nest

Nest 1. On August 19, 1945, at Sounkyo, Hokkaido, I found at a pile of logs several wasps of *Ectemnius* – *konowii*, *spinipes*, *iridifrons* and *nigrifrons* – busily engazing in their nesting activities. Several *spinipes* were seen flying back, each carrying a moth under their abdomen. A nest of the wasp that twice provisioned for about 10 minutes was selected to be dug open.



Figs. 29 and 30. Two nests of *Ectemniuss pinipes* (A. Morawitz)

The wood was decayed and could easily be crambled with my pen-knife. The entrance was located beneath one of the logs and the tunnel went upward and joined with a horizontal branch (Fig. 29). The portion of the cell is slightly enlarged than the tunnel with the maximum width 7–8 mm and the length 22–25 mm.

Cell 1 contained 7 moths, the innermost one being attached with the waspling just hatched out. Cell 2 was stored with 10 moths and contained the egg of the wasp attached similarly on the one placed innermost. Cell 3 was incomplete and acattered with 4 moths at a, b, c and d in the figure, but there was no egg. The prey belonged to a species of Pyralidae

Nest 2. This nest was found in a log of the same pile as that contained nest 1, but after a year. It was on September 18 and already off season. The nest was very complicate, involving as many as 44 cells (Fig. 31). It lay horizontal and at A a dead wasp of *spinipes* was discovered, probably the constructor of the nest. The nest was, without doubt, an old one and reused by the wasp, since in some cells fragments of old cocoons could be disclosed stuffed among saw-dust. It was uncertain, however, whether the nest was made by the single wasp, or the result of cooperation of several wasps that successively arrived at the hollow, though to me it seemed possible that the latter might be the case.

Among the cells 12 contained the intact moths, probably in these chambers the egg of the wasp unhatched. In cell 8 was a larva of about 13 mm in length, still feeding; and in each of other cells was found a completed cocoon. This fact seems to indicate that the cell group distantly located was made earlier than the one placed near the entrance. Some of the cells measured possessed the following dimension :

Cells 1, 4, 5 and 41 : 20×7 mm. Cell 18 : 22×7 mm. Cell 35 : 23×7.5 mm. Cell 37 : 25×8 mm. Cells 35 and 40 : 25×7 mm.

The portion of the tunnel was mostly 6-6.5 mm in width and in some places it was irregularly enlarged.

Nest 3 (Fig. 30). This nest was dug for the purpose of obtaining the larva of *E. konowii* and was stopped after finding cocoons wrapped with the wings of moths.

b) General structure of the nest

In this species the nest belongs to the simple or compound branched type, each branch containing one or two cells whthin. The general structure, excepting for the somewhat smaller scale, well coincides with that of *E. konowii*.

c) Mode of carrying the moth

The wasp with a moth when scooped in the net did not let it drop off. So I repeatedly compelled such a wasp to

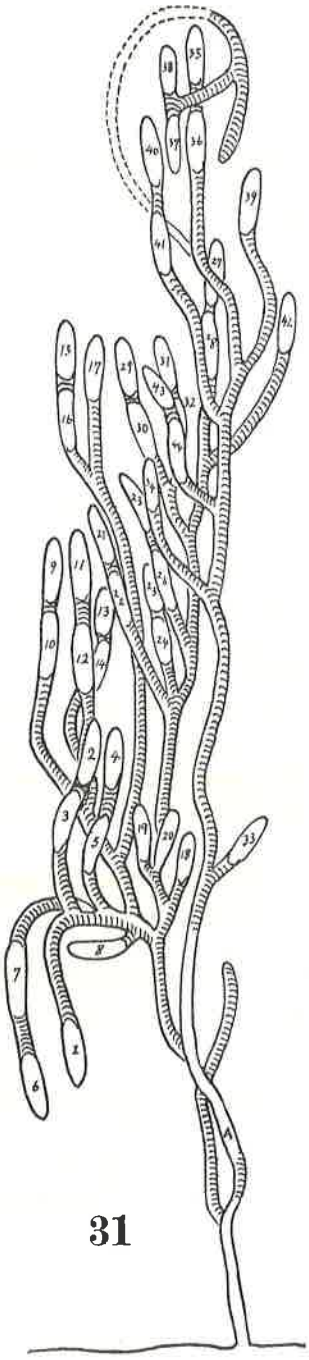


Fig. 31. A very complicate nest of *Ectemnius spinipes*.

creep in a glass tube from the net and observed the mode of her capturing the Lepidoptera. By such means it was clearly confirmed that the wasp of this species did not use both the middle pair of legs in catching the prey, but only one of them, with which she held the neck of the prey and dragged it about in the glass tube. During the time the prey became frequently rotated with its venter sometimes up and sometimes down. At first I thought that the wasp held the legs of the victim bundled together between her hind coxae, but later it was ascertained that this was not the case. In the glass tube the prey used to be dragged about with its venter up.

d) The time of oviposition

In two unaccomplished cells observed four and six moths were respectively discovered, but no egg on any of them. This tells us that this species, too, lays its egg after the full provisions are stored, though the egg is always laid on the victim stuffed innermost.

e) Mode of packing the victims in the cell

In the cell wherein the egg of the wasp is discovered mode of placing the moths seems of interest. The victims are all placed with their heads directing inwards, but with their ventral side directing toward the longitudinal axis of the chamber. Thus the wings of the moths are gathered along the wall of the cell as if to wrap the bodies of the prey. The moths brought in later are inserted inside of the cylinder made of wings of the prey previously stored, lengthening the cylinder as much by itself. The egg is laid on the throat of one of the victims placed at the interiormost portion of the cylinder or rather a sausage. Therefore, it is presumed that the oviposition must be done after the full store of the prey but before the complete formation of the wing cylinder. This peculiar mode of accumulation of the prey is clearer than in *E. konowii*, the fly catcher.

f) Prey

The prey of this species observed by me consisted mainly of the moths belonging to Pyralidae. Sometimes, however, moths of the families Noctuidae and Tortoricidae were included. According to the information of Mr. K. Shimoyama, Towada, the wasp he observed in his region stored exclusively the moth, *Trichobaptria exsecuta exsecuta* Felder, a species of Geometridae. The writer examined the specimens. Iwata recorded Noctidae, Geometridae, Pyralidae, Drepanidae, Uranidae and Lycaenidae.

g) Parasite

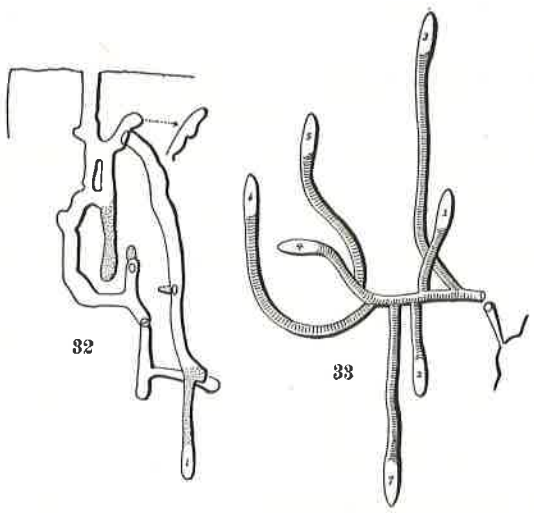
Besides the parasitic fly I obtained about 10 Ichneumons belonging to *Exeristes* sp. from the cocoons of nest 2.

13. *Ectemnius* (*Metacrabro*) *iridifrons* (Pérez, 1905)

The block of wood mentioned in reference to the nests of *Ectemnius nigrifrons* Cresson (p. 8) contained also a nest of *E. iridifrons*. It had a comparatively complicate tunnel but involved but a single cell (Fig. 32) which had already been parasitized by two maggots of the parasitic fly. The cell was comparatively small, only 14 mm in length and 7 mm in width and included remains of two flies that could be determined, mainly by the wingvenation and a part of the thorax and abdomen, as belonging to Tachinidae (probably *Crossocosmia sericaria* Corn.) and Stomoxyidae (probably *Stomoxys calivitrans* L.). This nest had been marked by me by means of painting during the activity of the

mother wasp. Therefore, there is no question as to that the nest was made by a wasp of this species. But I had some doubt from the size of the brood-cell whether the cell belonged truly to the wasp I observed. If the wasp-ling was the male, however, there is no question.

During her burrowing work this wasp was observed to push forward the saw dust from the interior of the nest, instead of backing with the débri. Near the nest, I once saw a wasp of this species dash upon a fly (*Sarcophaga* sp.) crouching on the ground, but she failed in capturing it.



Figs. 32 and 33. Nests of *Ectemnius iridifrons* (Pérez)

The 2nd nest that I could examine of this species was found in that decayed log which I mentioned in connection with the complicate nest of *Ectemnius spinipes* (Fig. 31) and that of *E. cavifrons* (Fig. 7). It was made entangled with the above-mentioned two nests and from the prey left in some cells I thought it to belong to a wasp of *E. nigrifrons* or of *cavifrons*. On July, the next year, however, a female of *iridifrons* emerged from a preserved cocoon. The structure of the nest was as shown in Figure 33. The entrance was located beneath the log. The nest contained 7 larval cells, all of which must have made several days before :

Cell 1 contained 4 dried flies belonging to Syrphidae (*Eristrophe balteatus* de Geer 1, *Syrphus ribesii* L. 3). Probably in this cell the egg did not hatch. Cell 2 was invaded by larvae of some parasitic fly, including remains of some Syrphidae. Cell 3 : With a cocoon, similar in form to that of *konowii*, having the papilla on the cephalic end. Cell 4 : Empty. Cell 5 : Invaded by some Tachinid fly, with remains of Syrphidae. Cell 6 : Including 4 dried Syrphid flies (*Eristrophe balteatus* 2, *Syrphus* sp. 2). Cell 7 : Empty.

In this nest the prey belonged all to Syrphidae. In the first nest they were flies of Tachynidae and Stomoxyidae. Sibuya observed a nest of this species in Osaka Pref. in which the pry consisted of Tabanidae only, with a single exception of a fly of *Sarcophaga*. According to these records, the prey of this species seem to include various Families of Diptera.

14. *Ectemnius* (*Metacrabro*) *nitobei* (Matsumura, 1912)

Nothing has been known up to the present as to the habits of this species.

15. *Ectemnius* (*Metacrabro*) *chrysites* (Kohl, 1892)

No record of observation has ever been published concerning this species.

16. *Ectemnius* (*Iwataia*) *furuichii* (Iwata, 1934)

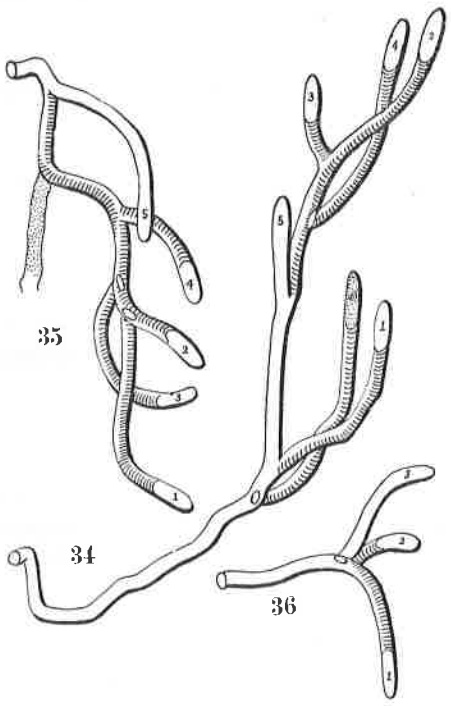
In 1941 Iwata reported the first and a single record of observation on this Orthoptera-

hunting Crabronid. Such a prey makes a strange exception among the various insects captured by the members of Crabroninae. This quite interested me and I have waited for a chance that may allow me to know behaviour of this species through my own eyes. However, this species was so rare that I could have even captured only two specimens up to that time, one in Japan and one in Korea and it seemed impossible to have my desire fulfilled unless a good fortune smiles upon me.

But the fortune has come quite unexpectedly. In 1957 I could find *several* specimens of this rare species among the wasps sent to me for identification from Mr. Shimoyama, Towada. I at once asked him to find out the nesting place of this curious wasp, informing him every possible condition of nidification in this species. He soon could find some nests, as he was an enthusiastic student of the life history of boring beetles.

With such an aid given by him, on August 15, 1956 I could examine three nests of this species in the mountain region of Towada, situated about 800 km north of my laboratory. I must express my heartiest appreciation for his kind help.

The nesting ground was a big rotten tree of *Fagus sieboldi* still standing, about 80 cm in diameter. Upon the trunk of this dead tree were opened entraces of about 7 nests of this species, which were scattered from about 30 cm above the surface of the ground to about ten m high. In another two big dead trees several other nests of *furuichii* had also been discovered.



Figs. 34–36. Three nests of *Ectemnius furuichii* (Iwata).

At 11:30 awasp came back flying to her nest with a green prey, *Conocephalus* sp., a species of Tettigoniidae. It was a female and was held by its neck with the mid legs of the wasp from the back, but its long antennae were left free. The wasp alighted near the entrance of her nest, but flew off and after several minutes turned back again and this time directly entered the nest from in the air holding the prey. In the tunnel the prey was pushed backward and dragged behind the wasp. Eight minutes later she appeared at the orifice and flew away without making a temporary tampon there. The nest cut open had the structure as given in Figure 34. I examined two further nests (Figs. 35 and 36). The data obtained from these nests were given in Table 6.

The nest of this species seems to belong to the simple branched type, each branch involving a single cell at the end. The tunnel goes sometimes upward, sometimes downward. No temporary closure at the entrance and the tunnel leading to the cell just provisioning is always clear throughout. The number of the prey per cell varies from 1

to 3. The egg laid in the cell that was provisioned with only one prey may be destined to become a male. Despite the great difference in the kind of the prey, mode of oviposition is consistent with the case in the fly-hunting congeners. It is laid after whole the provisioning of the cell is over and on the prey lying innermost, being attached to the neck, somewhat deviating to the left or right from the median line and produced sideward with its caudal end.

Table 6. Contents of nests of *Ectemnius furuichii* Iwata

Nest	Cell	Prey					Wasp's young			Remarks
		♀	♂	Imago	Nymph	Total	Egg	Larva(mm)	Cocoon	
1	1	1	1	2	–	2	–	12	–	(Fig. 34)
	2	–	3	–	3	3	–	7	–	
	3	2	1	–	3	3	–	6	–	
	4	–	3	–	3	3	?	?	–	
	5	1	1	–	2	2	–	–	–	Incomplete
	6	–	–	–	–	–	–	–	–	Old cocoon
2	1	1	2	–	3	3	–	14	–	(Fig. 35)
	2	1	2	–	3	3	–	10	–	
	3	1	1	2	–	2	–	7	–	
	4	1	2	2	1	3	–	5	–	
	5	–	–	–	–	–	–	–	–	Empty
3	1	1	2	1	2	3	–	5	–	(Fig. 36)
	2	–	1	1	–	1	+	–	–	
	3	–	2	2	–	2	–	–	–	Incomplete

I brought to my laboratory the eggs and the larvae above tabled, together with several others obtained from some unrecorded nests. The journey was one of more than 1500 km. During the time various severe shocks must have been given to the delicate eggs and larvae in my rucksack through walking, runing, climbing and riding in trains, ships, and especially motor-buses. Nevertheless, when I examined them at my laboratory, most of them were peacefully feeding in glass cells separated with cotton plugs. Later, they, excepting 3, succeeded in spinning the cocoon and the next year emerged as imagoes, 5 ♀♀ and 8 ♂♂. The cocoon is, as usual, provided with a papilla (nipple) at the broader end.

17. *Ectemnius* (*Hypocrabro*) *laevigatus* (De Stefani, 1884)

The occurrence of this species in Japan, at least in Honshu, is quite doubtful. The specimens hitherto recorded as this species seem to me a subspecies of *E. robicola* (*E. r. nipponis* Tsuneki). At any rate, no record of observation under this specific name has been published in Japan.

18. *Ectemnius* (*Hypocrabro*) *schlettereri* (Kohl, 1888)

According to Iwata (1937, 1941) this species makes a nest of the compound branched type, containing in one branch 1. 2 and 3 cells linearly arranged. The nesting ground is also decayed wood. The prey are all Dipterous insects, consisting of Stratiomyiidae, Stomoxidae, Muscidae, Calliphoridae, Anthomyiidae, Rhagionidae and Syrphidae. The number per cell varies with the size of the prey, being 2–14. Mode of attaching of the egg follows the general rule in this Subfamily.

19. *Ectemnius* (*Hypocrabro*) *rubicola nipponis* Tsuneki, 1960

I have but one incomplete record of observation on the nesting habits of this subspecies. The nest was made in the living stem of *Artemisia vulgaris* and I observed the wasp enter her nest with a fly. It was done in the early days of my investigation (1928) in Saitam Pref. and I did not examine the nest, for the plant was cut down and taken away during my observation. However, when I found the accident a wasp, probably the one I had been observing, came there flying, holding a fly and I captured and preserved both in my box. Later it was identified with *E. rubicola nipponis* and the fly with a species of Muscidae.

The habits of this subspecies is well investigated in Japan by Iwata (1938, 44), Maruyama (1951) and Ohgushi (1955). They informed that the Japanese *rubicola* always choices as the nesting place the green sappy stem of herbs, such as *Sophora*, *Macleya*, *Gladiolus*, *Erigeron* and *Aster*. The entrance is particularly excavated on the stem and the larval cells are linearly arranged in the burrowed hollow in pith. The prey comprize various Families of Diptera, viz. Stratiomyiidae, Dolichopodidae, Syrphidae, Muscidae, etc. Exceptionally, however, Ephemeroptera is also hunted. Provisioning and oviposition are done as is usual in the members of the group.

20. *Ectemnius* (*Hypocrabro*) *continuus* (Fabricius, 1804)

This common species seems to represent one of the best studied among Crabronids. Since J. O. Westwood (1840) about 20 investigators of Europe and North America have touched upon the habits of this species. In Japan, however, rather curious to say, the habits of this species which is common in mountain regions of Middle and Northern Japan have escaped the eyes of the earnest inverstigators of wood-boring wasps. There are indeed some fragmental observations and a comparatively detailed one reported under the name of *Crabro vagus* (Ishii, 1935), but the latter must be *E. rubicola nipponis* as already pointed out by Iwata.

On September 17, 1945, in Hoheikyo, Jozankei I saw twice a wasp of this species walking on the ground with a victim under her abdomen. The nest was made in a sleeper of the simple railway and could not be examined. So I caught the wasp and obtained the flies which were *Musca domestica* L. and *Fannia canicularis* L.

On July 12, 1946, at Sapporo, Mr. M. Munakata brought for me a block of decayed wood that he found at the road-side and was nidified by some wood-boring Hymenoptera. Soon it was confirmed that the borers were the wasps of the species now concerned. By sawing and cutting I could make out three nests (Figs. 37–39) and their contents (Table 7).

Amongst the Anthomyid-flies stored I could ascertain the presence of *Chortophila cinerella* Fallén and amongst the remains fragments of *Sarcophaga* sp. and *Solva* sp. In cell 6 a number of prey were compactly packed, all with their heads directing inwards, but with their venter irregularly directed. In the 2nd nest the cells were measured : 16 ×6, 17×6, 20×6, 16×6 and 16×6 mm.

On September 13, 1946. in the Otane-valley, Jozankei, I found 4 nests of this species made in a big fallen tree of *Fagus sieboldi*, the wood of which was favourably decayed.

Their structure was shown in Figures 40–43 and contents in Table 8.

Table 7. Contents of nests of *Ectemnius continuus* Fabricius

Nest	Cell	Prey	Waspling	Sex	Emergence
1 (Fig. 37)	1	Remains	Spinning cocoon	♀	24. VII. 1946
	2	Remains	Spinning cocoon	♀	24. VII. 1946
	3	Remains	Spinning cocoon	—	Larva died
	4	Remains	Larva 13 mm	♀	26. VII. 1946
	5	〃 with 10 Anthomyidae	Larva 8 mm	—	Larva died
	6	〃 and 19 Anthomyidae	Larva 5 mm	♀	Pupa died
	7	Empty	—	—	
2 (Fig. 38)	1	Remains	Cocoon	♀	24. VII. 1946
	2	Remains	Cocoon	♀	23. VII. 1946
	3	Remains	Cocoon	♀	Pupa died
	4	Remains	Cocoon	♀	Pupa died
	5	Remains	Cocoon	♀	23. VII. 1946
3 (Fig. 39)	1	Remains	Spinning cocoon	♀	24. VII. 1946
	2	Remains	Spinning cocoon	♀	26. VII. 1946
	3	Empty	—	—	

Table 8. Contents of nests of *Ectemnius continuus* Fabricius

Nest	Cell	Size	Prey(number)	Total	Waspling			Remarks
					Egg	Larva(mm)	Cocoon	
4	1	15×7	T(1)	1	–	–	–	
	2	15×7	S(1)	1	–	–	–	
	3	–	–	–				Ant queen
5	1	17×7	S(2) A(2)	4	–	6	–	
	2	15×7	S(2) A(2)	4	+	–	–	
	3	15×6.5		–	–	–	–	
	4	–	S(1) A(1)	2	–	–	–	Incomplete
	5	–	S(2) A(3)	5	–	–	–	10 pupalia
6	1	15×7.5	L(1) A(2) T(2)	5	+	–	–	
	2	15×7.5	A(3) T(1)	4	+	–	–	
	3	–	Remains and saw-dust	–	–	–	–	
7	1	16×6.5	A(9)	9	+	–	–	
	2	16×6	A(2) T(2)	4	–	–	–	
8*	1	15×7.5	L(1) T(1)	2	–	–	–	Maggots
	2	14×7.5	A(9)	9	+	–	–	
	3	–	A(5)	5	+	–	–	
9*	1	14×8	A(2) S(2)	4	+	–	–	
10	1	–	A(3) M(2) P(1) Sy(1)	7	–	–	–	

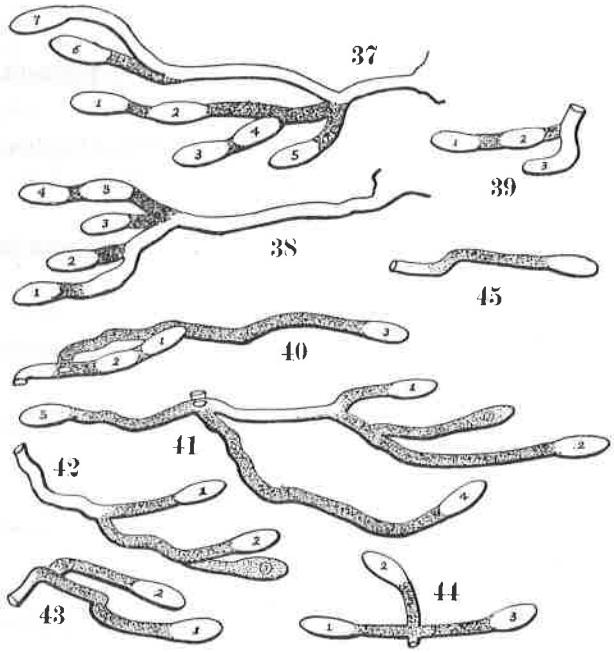
* ... See remarks in text.
T ... Tachynidae. S ... *Sarcophaga*. A ... Anthomyidae. L ... *Lucilia*.
M ... Muscidae. P ... *Phagocarpus* sp. Sy ... Syrphidae.

a) Remarks on some nests

Nest 4 (Fig. 40). At noon the wasp brought a middle-sized Tachynid fly to her nest, holding it, venter up, by the neck with her middle pair of legs. On cutting open

the nest I discovered the fly, venter up, in cell 1, both ends of which were tightly packed with saw-dust, but the fly was not attached with the egg. In cell 2 a single *Sarcophaga carnaria* with no egg was packed in with saw-dust. This is a very curious case of provisioning. Probably the *Sarcophaga* might be transported afterward to cell 1, but the presence of the tightly packed partition walls is quite exceptional. In cell 3, 15 cm apart from cell 2, was a dead queen ant of *Camponotus herculeanus obscripes* Mayr covered with mould and the tunnel leading to it was very compactly stuffed with saw-dust.

Nest 5 (Fig. 41). Packing in the tunnel leading to cell 5 was mixed with fragments of old cocoon and in the cell about 10 maggots of parasitic fly were present.



Figs. 37–45. Nests of *Ectemnius continuus* (Fabricius).

Nest 6 (Fig. 42). After the nest was destroyed, the owner came back with a fly, holding it, venter to venter, with her middle pair of legs. In the nest it had been ascertained that there was no preparation of the brood-cell to receive the fly. The wasp, therefore, may lay aside such a fly in the tunnel until the next cell is prepared.

Nest 7 (Fig. 43). In the 2nd cell which was considered sufficiently provisioned and accomplished(because the tunnel leading to it was compactly closed throughout with débri)there was no egg. Had the egg in the ovary already been exhausted ?

Nests 8 and 9. When nests 4–7 were dug open the owners of nests 5 and 7 were left free. A week later when I revisited the place two newly made nests were discovered opening close to the site of the previous nests. These were nests 8 and 9 and probably the results of the extended work of the above mentioned two wasps. In cell 2 of nest 8 (Eig. 44) nine small Anthomiid flies were stored, two of which had been quite recovered from the paralysis they received. One of them was even able to beat violently the wings and could fly away when tossed in the air.

In nest 9 (Fig. 45) there was found a remarkable fact that the egg was laid on a 2nd fly from the interior.

Nest 10 was an incomplete one, discovered in Jozankei on August 11, 1960.

Summary. Structure of the nest that is made in decayed wood belongs to the simple branched type, rarely some branches being bicellular. The cell is slightly enlarged than the

tunnel, 14–17 mm in length and 6–8 mm in width. No temporary closure at the entrance. Mode of provisioning is as usual and mode of oviposition also follows the general rule in this group. But the egg which is 3.0–3.2 mm in length and strongly curved seems more markedly attenuate toward apex than usual, producing backward after half surrounding the neck of the prey. The victims observed in Japan belong to Anthomyiidae, Muscidae, Sarcophagidae, Tachinidae and exceptionally Solvidae and Syrphidae. The number stored per cell varies from 2 to 9 with the size of the prey.

21. *Crabro* (*Dascolocrabro*) *chalybeus* (Kohl, 1915)

It seems quite doubtful that this curious species really occurs in Japan. There has been no record of capture since it wad described by Kohl (1915).

22. *Lestica* (*Lestica*) *collaris* (Matsumura, 1912)

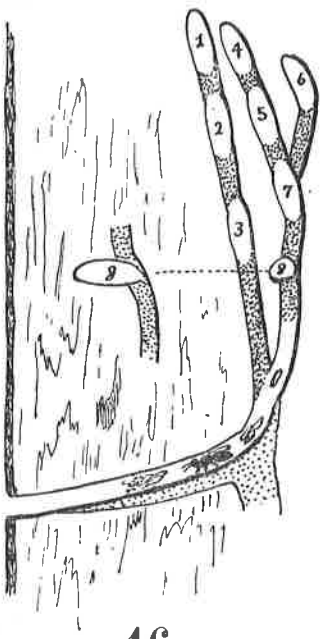
Nest 1. On August 30, 1946, at noon on the trunk of a big standing dead tree, the same as contained nests of *Ectemnius konowii*, etc., in the farm-yard of Hokkaido University, Sapporo, I saw a wasp of this species come flying with an apparently Trichopterous insect and enter her nest which was opened on the bark, about 1 m above the ground. Thenceforth I watched her going and coming for about an hour and confirmed that the prey was not the Trichopterous insect, but a species of moth belonging to Tortoricidae. It was held by the neck with the middle pair of legs of the wasp with its venter up or more frequently venter down. At 14, I returned there equipped with cutting tools and found that another two wasps of the same species were also working on the same trunk at their provisioning. The nest found first had been closed at the entrance and the wasp did not turned back for a while. So I thought it was accomplished and began to cut open.

Table 9. Contents of nests of *Lestica collaris* Matsumura

Nest	Cell	Prey	Larva(mm)
1	1	5	6
	2	7	3
	3	7	55
	4	6	5
	5	6	2.5
	6	5	Egg
	7	4	Egg
	8	5	Egg
	9	6	–
2	1	4	5
	2	4	4
	3	4	3
	4	3	3
	5	0	–

The tampon at the door was only 3 mm in thickness and it was at once understood that an abandoned beetle burrow which was compactly packed with débri was utilized by the wasp to cut through the tunnel of her nest. At about 25 mm from the entrance the tunnel was almost closed with saw dust and the wing of a moth came in sight from the aperture. It lay on its back and soon another moth, lying on its venter, was discovered behind it. There the wasp was present, with its head directing toward the entrance. Upon cutting on, the wasp flew away and 4 more moths were found scattered in the tunnel between 30 and 55 mm from the entrance. On these prey, though carefully examined under a high power magnifying glass, no egg of the wasp was attached. Thence the tunnel turned upward, leaving the beetle burrow and divided into three branches containing totally 8 larval cells as given in Figure 46. Their contents were shown in Table 9.

The egg is 2.0–2.1×0.5 mm, semitransparent white, attached to the neck of the innermost prey and produced sideward as usually the case in this group. The prey are



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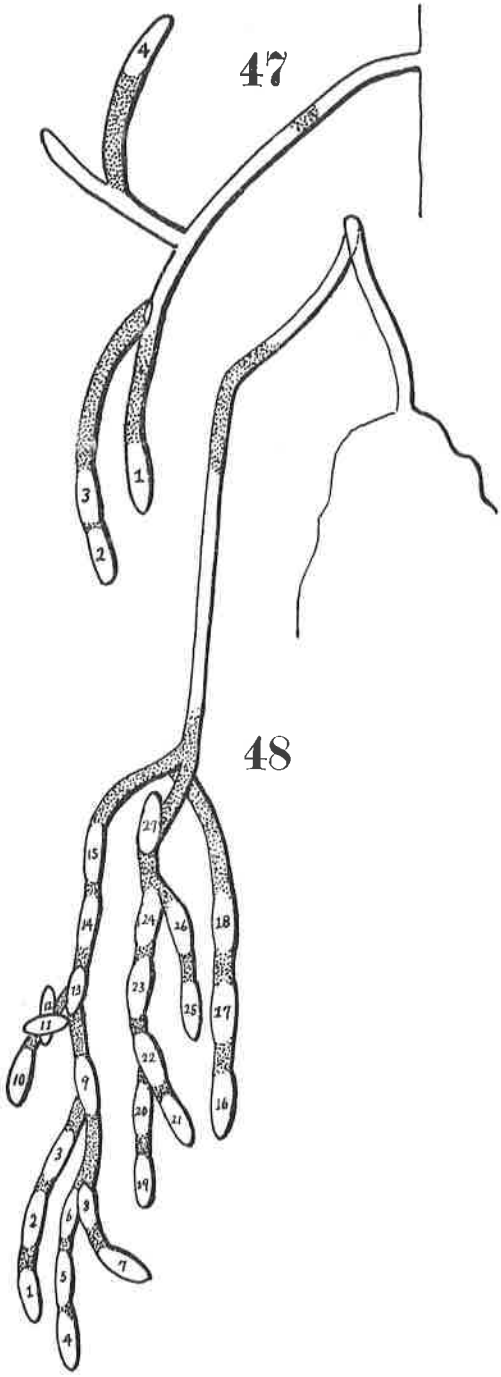
weaved into a cylinder with their wings, the later brought moth being inserted inside of the cylinder previouly formed. But as the wings of the prey are narrowly folded in this case formation of the wing-cylinder and contents of moth bodies — or the sausage of moths, wrapped by their own wings — is not so nice as in *Lestica alata* or *Ectemnius spinipes*. The prey belongs to a single species of Tortoricidae, most of which were females with eggs. The brood-cell is not particularly enlarged as compared with the tunnel, 7–12 mm in length and 2.5–2.7 mm in width. The state of the moths weaved into a sausage of the prey and the accumulation of 6 prey in the tunnel before being arranged in the larval cell suggest that the wasp lays her egg after a necessary number of prey is stored in the tunnel, but at the same time before the sausage of moths is accomplished. Therefore, she must lay



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Figs. 46–48. Three nests of *Lestica collaris* (Matsumura).

her egg just after the first prey is arranged in the cell and then pack the remainder into a sausage. When I found the wasp amongst the 6 prey scattered in the tunnel she might be preparing to lay her egg.

This wasp was left alone. She soon returned to her nest already destroyed and after searching about a while she penetrated a near-bye hole where she was observed working on the following days. On September 3, in the forenoon I observed her take in her prey 4 times, namely, 10:35, 10:56, 12:09 and 12:26. Two days later, that is after 5 days from the beginning of her reconstruction, I cut open the nest. It contained 4 cells (Fig. 47). The number of the prey found in each cell and the state of the wasp's young were as given in Table 9.

Nest 3. The entrance of this nest was situated on the back of the same tree as above, 1.7 m above the ground. I cut it open on the 31st, August, 1946, at 13 o'clock. The wasp did not appear during the operation and from the state of the nest observed her work was considered to have already finished. The structure of the nest were as illustrated in Figure 48. It involved as many as 27 larval cells, of which 4 contained the cocoon, 6 the larva, 4 the egg and 3 the prey covered with mould. The other 10 were either crushed by my chisel or blown down by the wind during the excavation. The number of the prey in a cell made clear was 4, 4, 5, 6, 6, 6, 6, 8, 9, 9, 10, 10 and 11. The cocoon is yellowish brown, more brownish than in *continuus* or *nigrifrons* and possesses a small mammilla on the cephalic end. Its size measured was : 9.0×3.2, 8.2×3.0, 8.5 ×3.0 and 8.0×2.8 mm.

It is characteristic of this species to make cells not only in the branch tunnel, but also in the main tunnel leading to such branches.

23. *Lestica* (*Solenius*) *heros* (Kohl, 1915)

On August 14, 1956, while I was collecting wasps in the bush at Ichinose (about 1000 m high) at the foot of Mt. Haku (2700 m) I was fortunate enough to become an eye-witness of hunting manoeuvre of this rare species. At about 15 o'clock a wasp suddenly appeared within my sight and while being persued by my eyes she took that characteristic posture which is usually observed in the members of the Crabronids when they took aim at the prey. She began that stationary flight in front of a thickset of a shrub, very slowly proceeding and retreating a little as if the cat aims at the rat; then suddenly rushed upon a booty and succeeded in capturing it between her legs. I could not see whether she used her sting at that moment, but when I scooped the insects together in my net the wasp was still holding down the prey from its side. The wasp was confirmed to be *heros* and the prey afterward *Abraxas suspecta latifasciata* Warren, a species of Geometridae, Lepidoptera. The prey was already immobile, but three days later she was still alive and remained soft after a week.

24. *Lestica* (*Ceratocolus*) *alata* (Panzer, 1797)

On the promenade of Tendan, in the city of Peking, North China, I observed, on June 16, 1938, a wasp of this species hunt a moth. Mode of its hunting was much the same as mentioned in regard to *L. heros*. On July 10 of the same year I found a nest of this species made in the ground of the same promenade. I attempted to observe the inside

of the nest. But the tunnel drawing a curve penetrated more than 40 cm in depth and refused to dig further with my pen-knife only (at that time I was a soldier). On August 21, however, at the same place I found another nest, around a small entrance mound of which were discarded four small moths. I wondered and at once began to dig. The burrow went for about 5 cm aslant and then penetrated nearly vertically to about 15 cm below the suface and stopped by being prevented by a very hard layer of earth and there the wasp was present. From the end of the tunnel I broadly extended the excavation to find out the concealed brood-cells, but none of them could be discovered there. Why the moths had been discarded out of the nest I could not say.

Three years later when I as in Korea, I found a large colony of this species, mixed with that of *Cerceris navitatis* Sm. in a chestnut plantation near the aerodrome of Keijo. At the entrance of every nest, unless trodden over by passers-bye, there was a lovely little mound of earth. The entrance is not concealed, in contrast to *Cerceris navitatis*, and always left open. On June 29, 1941 I dug a nest. The tunnel was missed on the way but the feature disclosed was as shown in Figure 49. Irregular bending of the tunnel is not due to the obstacle but is considered made by the wasp's intention. No brood-cell could be discovered. Mode of transportation of the prey was observed by letting a wasp dragging a moth enter a glass tube and it could confirmed that she used the same method as mentioned in reference to *Ectemnius spinipes*.

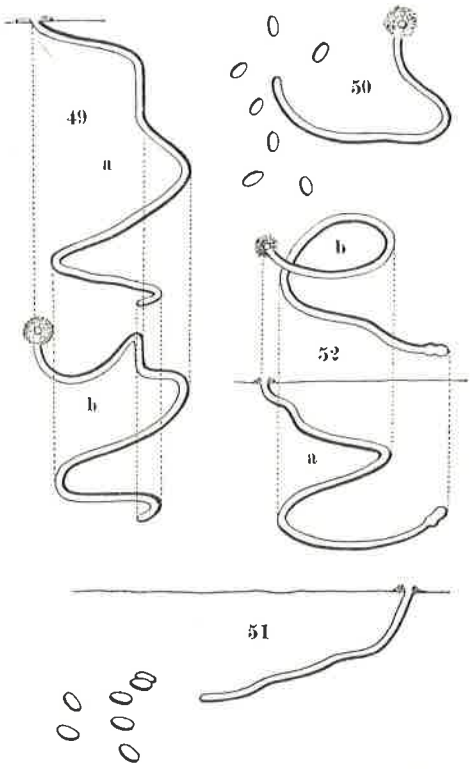
The next day (30. VI.) I dug two nests with success. They had the structure as given in Figures 50 and 51. The main tunnel, 5-6 mm in diameter, nearly circular in cross section, ended at about 15 and 8 cm respectively below the surface of the ground. The branch tunnel when the cell at the end was accomplished was so compactly closed with earth that it could not be followed. The brood-cell was 15-17 mm in length and 7-7.5 mm in width, always located with the interior more or less high. Thus the longitudinal axis of the cell was always inclined and in the remarkable case the inclination attained more than 45°. I can not say whether the inclination has something to do with the peculiar mode of storing the prey in the cell. The prey belonged to a single species of Microlepidoptera of the Family Noctuidae, the number per cell ranged from 4 to 9 (actual number : 4, 9, 7, 6, 2, 7 and 7; 2 being obtained from an incomplete cell). They were packed into a sausage, with their wings forming the outside epidermis and with their bodies constituting the inside meat, just as mentioned in relation to *E. spinipes* and *L. collaris*, but mode of manufacturing was subtler than the latter. In one of the nests were found the wasp's larvae of various developmental stages, in the other all cocoons. Young larvae were attached on the neck of the innermost prey. More developed ones were feeding the meat of the sausage in a condition completely wrapped with the epidermis of the moths' wings. The cocoons were completely concealed under the layer of the wings of the moths, that is to say, the larvae utilized the epidermis of the sausage of the prey as the outermost layer of their cocoons (Pl. Ⅲ, Fig. 4).

Near the close of activity of the 1st generation of this species, on July 5, I went again to the same place and excavated one more nest. Its structure was given in Figure 52. In this nest the larval cell showed exceptionally an constricted form and the cell it-

self and the tunnel adjacent to it were slightly elevated inwards. The prey stored were 7 in number, loosely packed in the cell, some ones with venter up and some down, but none of them carried the wasp's egg.

On July 18, 1943, I dug a nest of this species at Shoyozan, 40 km north of Keijo and found 2 brood-cells from 7 cm below the surface of the ground, both of which contained 7 prey, consisting mainly of Pyralidae, Noctuidae and exceptionally Zygaenidae (*Artona gracilis* Walker).

In 1946 I was in Sapporo and was continuing the experimental work with *Bembix niponica*. My working ground was a sand plane sparsely covered with grass and was rich in the symaptric sand wasps, such as *Cerceris, Oxybelus, Tachysphex* and many species of Pompilidae. Amongst these wasps *Lestica alata* was also found nidificating at somewhat clayish area.



Figs. 49–52. Nests of *Lestica alata* (Panzer).
49a, 51 and 52a ... Lateral view.
49b, 50 and 52a ... Surface view.

By closing the entrance of the nest and by nipping and gently pulling the moth that was carried by the wasp while she was walking to search for her lost nest, I attempted to induce the wasp to sting her victim again. By such means I succeeded in observing several wasps repeatedly conduct the hunting manoeuvre. On feeling the movement of the prey the wasp suddenly recaptured the moth from its back turned her abdomen sidewards, or held it crosswise from the side, inserted the tip of her abdomen beneath the thorax of the prey and stung it.

I dug a nest, but the cells were intricated with those of two other nests located nearbye and could not clearly be distinguished at the bordering region. They were all located from 3 to 7 cm below the surface of the ground, markedly shallow as compared with those investigated in Korea and especially so with those in China. Totally I discovered as many as 71 cells within the range of 25×35 cm, including cocoons, feeding larvae, eggs and some having prey only. The following could be ascertained :

1) In three incomplete cells with some prey there was always no egg.

2) Mode of attaching of the egg was as usual (Pl. Ⅲ, Fig. 3), but some eggs laid crosswise, some obliquely and others nearly parallel with the length axis of the moth body.

3) The prey were combined together in the same fashion as repeatedly mentioned above, the number in each cell being 5–8. They were identified by Dr. H. Takahashi

with some species of Noctuidae, most of which, however, could not be distinguished to species because of the serious loss of the wing scale, but some were made out to belong to *Chloridea dispacea* L.

4) Most of the cells obliquely lay, keeping the length axis usually more than 45° and sometimes nearly 90°, always with the interior lifting high. They were 13–17 mm in length and 6–7 mm in width with the inner wall slightly smooth.

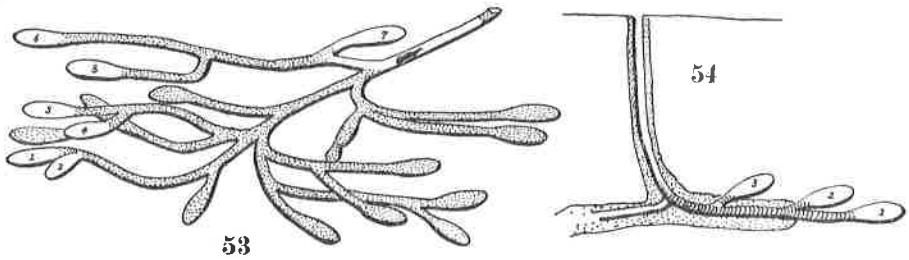
Later at Nopporo, near Sapporo, on the ground of a shrine I found a large colony of this species and dug open several further nests (Pl. Ⅲ, Figs. 1–4), but could not find no particularity that should be added to the avove description.

25. *Lestica* (*Clypeocrabro*) *reiteri* (Kohl, 1915)

Only a single report concerning this species has been published up to the present (Iwata, 1941). My papers touching on this point were all fragmental or summary. Here I will mention in detail the observations on 6 nests of this species. All of them were made in the Otane valley of Jozankei, of which 4 were burrowed in the same decayed stump of a tree.

nest 1. At 14 o'clock on August 1, 1949, my attention was attracted by a wasp carrying her prey and entering a hole made on a dead fallen tree of about 60 cm in diameter. It was heavily decayed and already without the bark. Mode of her entering the hole was quite characteristic. She flew swiftly along the fallen trunk and on arriving at the hole sliding into the tunnel without alighting at the entrance. I observed the same behaviour twice more. This was probably due to the tunnel of the nest being inclined in the direction of the extention of the way along which the wasp used to come back flying. I covered the entrance with a glass-tube and ascertained that the wasp was *reiteri*. Then I set her free. At 16 (4 p.m.) I dug the nest (Fig. 53). The branches of the tunnel and the cells were spread beneath the surface of the wood, all being located 20–25 cm below the surface, without entering deep toward the center of the trunk. It was clearly an old nest reused. In the old cells saw-dust, remains of prey and of the wasp's cocoon were packed, and only 7 newly constructed cells of the wasp could be disclosed.

In cells 1, 2, 3 and 4 were contained the cocoon, but the wrappage of the moth-wings was not complete in this species. In cell 5 the larva was spinning the cocoon and



Figs. 53 and 54. Nests of *Lestica reiteri* (Kohl).

in cell 6 there were stored 16 small moths, but not so subtly combined together into a sausage of prey as in *alata* and most of which the scales of the wings were dropped off.

On the neck of the innermost prey were found two maggots of a parasitic fly, probably they had just eaten up the egg of the wasp. In cell 7 eight moths were scattered within the range of 27 mm, on no one of which was there the egg of the wasp. The wasp was found in the empty tunnel, 25 mm from the entrance, with her head directing outwards. The brood-cell was 10-16 mm in length and 4.5-5 mm in width, slighly enlarged than the tunnel, while the cocoon was 10-12 mm long and 4 mm wide, provided with the so-called respiratory tubercle, as usual, at the broader end.

Nest 2. August 9, 1946. Another dead fallen tree in the same valley. Activity of the wasp observed :

Coming back with a prey ····· 11:20 11:46 12:00 12:10
Going out for hunting ····· 11:31 11:56 12:07 ——

By plugging the entrance mode of holding the prey was observed. The wasp captured the moth by the neck from above with one or two of her middle legs.

At 12:10 the wasp laid aside the moth in the tunnel near the entrance and at once started for her next hunting excursion.

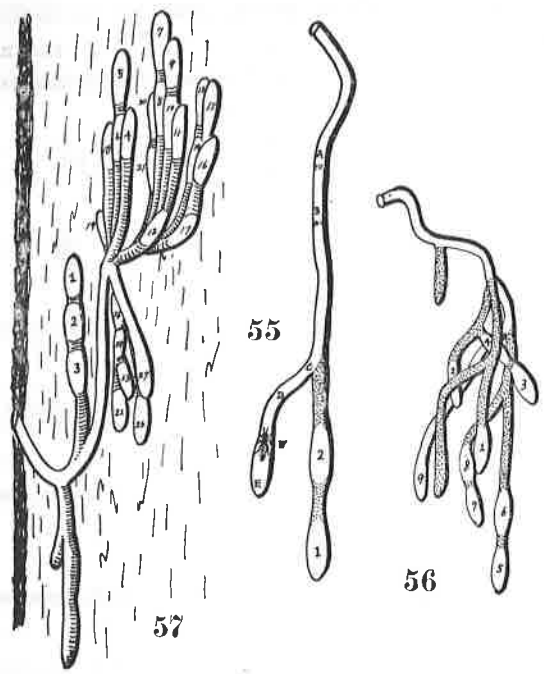
The nest (Fig. 54) was burrowed, utilizing the abandoned tunnel of a boring beetle larva which was compactly stuffed with débri. It penetrated up to 14 cm in depth and turned horizontal and included 3 cells, comprizing respectively 15, 13 and 13 moths. Mode of packing of the prey in this nest was so nice as in *spinipes* and in *alata* and so compact that it was hardly possible to separate the combined prey intact. In each cell was found the egg attached to the prey as in *alata*.

Nest 3-6. July 31, 1951. A big stump of a tree, about 1 m high, heavily decayed and partly covered with a bed of *Homes*-fungi. It contained 4 nests of this species, each on the side facing west, north, east and south.

Nest 3. Already accomplished (Pl. Ⅱ, Fig. 1), including 9 cells of which 4 were invaded by the larvae of Dermestidae, Coleoptera, usually 2-4 larvae in one cell. One of them was very large and had destroyed two cells linearly arranged. This is a curious enemy against the nest of the wood-boring hunting wasp.

Nest 4. Figure 55. The wasp was provisioning, carried in a moth to the tunnel at 11:07, :13 and :15 respectively. Entrance among the fungi. Two completed cells (8 and 7 prey, each with the egg of the wasp) and one provisioning cell. The provisioning cell gave an interesting suggestion that the wasp might gather a large number of moths at a time and later might divide them in two cells, because I found at E 3 prey, at D 2, at C 4, at B 4 and at A 1, totally 14 prey without the wasp's egg. Of course, the number was not necessarily too large for one cell (cf. nest 2); but in this case the other two cells involved only 8 and 7 prey respectively and moreover, just below B and A a thin partition of saw-dust had been placed. If this supposition be true (as in some species of *Cerceris* and *Astata* in our region) it seems highly of interest. The wasp was at W, and apparently preparing cell 3 with 9 prey at E, D and C.

Nest 5 (Fig. 56). Including 2 blind tunnels stuffed with saw-dust and 8 complete and 1 incomplete cells. The number of the prey made clear : 6, 6, 8, 6 and 8; in cell 3 a maggot of a parasitic fly, in cells 1, 2, 4, 5 and 6 a larva of the wasp respectively,



Figs. 55–57. Another nests of *Lestica reiteri*.

in cells 7 and 8 an egg and in the incomplete cell without partition (cell 9) 7 prey without the wasp's egg.

During the excavation the wasp came back carrying a moth. She succeeded after several trials in finding the continuation of the tunnel in the largely destroyed hole and entered there. She laid aside the prey soon and disappeared empty-handed in the tunnel, but at once turned back to the prey and dragged it backing into the nest. This mode of carrying in of the prey which was previously made clear on *Bembix* is considered a general rule also in the group of the Crabronids.

Nest 6. This nest was dug on August 11. It had the most labyrinthine structure as given in Figure 57. During digging I took 5 photographs (Pl. Ⅳ, Figs. 1–5) to indicate the states of the nest progressively disclosed. Figure 57 was recomposed from the records of the depth and the distance from a certain standard point of each cell. In this nest parts of the tunnels were a reutilization of a nest or nests of some *Osmia*, the inside of which being painted with yellow of the once stored pollen. The nest included as many as 27 larval cells of which 15 (Nos. 1–15) contained the cocoon (Pl. Ⅰ, Fig. 5), 2 (Nos. 16, 17) the just spinning larva and 8 (Nos. 18–25) the larva of various developmental grade (progressively reduing in length toward the cell of larger number), 1 (No. 26) the egg and 1 (No. 27) no egg. So far as distinguished, the number of the prey per cell was 7, 6, 7, 8 and 7; in cell 27 there were 5 moths but with no egg of the wasp. The developmental stages of the wasp's young were so regularly arranged that the nest is considered constructed by a single wasp.

Summary. The nest is made in decayed wood and belongs to the simple or more frequently the compound branched type, each branch containing one, two or three cells linearly arranged. Sometimes the old nest is reutilized. The cell is slightly enlarged than the tunnel and 10–16 mm in length and 4.5–5 mm in width. The numer of the brood-cell per nest attains as many as 27. The prey belongs chiefly to small moths of Noctuidae and Tortoricidae, the number per cell varies from 4 to 16, usuall 6–8. They are tightly combined to form a sort of sausage made of the wings (wrappage) and bodies (meat), but sometimes the manufacture is not so nice as in *alata*. Mode of oviposition and the utilization of the wing wrapper as the outermost layer of the cocoon are as in *alata* and *Ect. spinipes*.

26. *Lestica* (*Clypeocrabro*) *camelus* (Eversmann, 1849)

In the farm-yard of the Hokkaido University, Sapporo, on October 2, 1951, I saw a wasp enter a hole which was made on the trunk of a dead tree and captured her by covering the hole with a glass-tube. It was a female of *Lestica camelus* Eversmann of which no record of observation has ever been published up to that time. So I cut open the nest. The tunnel was made in the saw-dust packing of an abandoned burrow of some boring beetle larva (Fig 58). It had the inner wall fairly hardened and old, showing that the tunnel had once been utilized by some wasp. It was fairly broadly and loosely closed with saw-dust in the middle. At the end of the tunnel a small moth was stored with its head directing inwards. It belonged to a species of Tortoricidae.

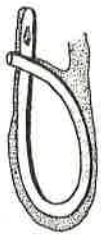


Fig. 58. A nest of *Lestica camelus* Eversmann (incomplete).

Incomplete as it was, the observation informs us that *Lestica camelus* follows the rule in its genus and hunts moths as food for the young. As the egg was not found on the prey mode of its provisioning and oviposition must be the same as in other members of the genus.

27. *Crossocerus* (*Cuphopterus*) *monstrosus suzukii* (Matsumura, 1912)

On September 15, 1945, in a valley of Jozankei, Hokkaido, I saw several females of this species searching for the nesting site on the wood piled up at the road-side. One of the wasps came back carrying a fly and was caught in my net. The prey was *Musca* sp. On the 29th of the same month, I caught a female of this species returned with a fly to her nest which was made in a standing dead tree at the farm-yard of the Hokkaido University, Sapporo. The nest was situated too high to investigate and I repeatedly captured and set free the wasp only to deprive her of her prey. The prey thus obtained were all small flies belonging to Muscidae, Anthomyiidae and Sarcophagidae.

28. *Crossocerus* (*Cuphopterus*) *hakusanus* Tsuneki, 1954

I caught another female with her prey on the same day and on the same dead tree as above mentioned. At that time I thought that she was also a wasp assigned to *monstrosus*. Later, however, it was made out that the wasp belonged to another species that had been named *hakusanus* upon the basis of the male. Fortunately the prey was pinned with the wasp. It is a fly belonging to Anthomiidae (*Fannia canicularis* Linné).

29. *Crossocerus* (*Cuphopterus*) *dimidiatus sapporoensis* (Kohl, 1915)

On the same pile of wood as mentioned in relation to *Cr. monstrosus* found in a valley of Jozankei, two wasps of *dimidiatus sapporoensis* were also discovered nesting. They walked on the wood, holding the prey, venter to venter, by the neck with their middle pair of legs. It was not allowed to cut open the wood and I captured the wasps and the prey. The prey were the flies belonging to Anthomyiidae and Muscidae. Later, in the same valley I caught four females of this species carrying the prey which were all flies of Anthomyiidae.

On August 8, 1944, near the surmit of Kurodake-peak of Mt. Taisetsu, Hokkaido, I saw several females of this species hunting the prey around the twigs of *Alnus alnobetula fruticosa*. When found a favourable fly the wasp aimed at it from a distance of about

30–40 cm behind it and then suddenly dashed upon it. She caught the fly and instantly stung it and soon flew away carrying the booty beneath her abdomen. The wasps repeatedly turned back to the place, but I could not find their nests.

30. *Crossocerus* (*Cuphopterus*) *yanoi* (Tsuneki, 1947)

Nothing of the observation on the habits of this species has been made up to now. But I captured several specimens on dead tree trunks in the farm-yard of the Hokkaido University. They must, therefore, burrow in the decayed trees.

31. *Crossocerus* (*Ainocrabro*) *aino* (Tsuneki, 1947)

A female specimen preserved at the Takeuchi Entomological Laboratory, Kyoto, was pinned with a paper triangle containing the prey which was carried by the wasp at the moment of collection. The prey was a species of Mecoptera, and was kindly identified by Dr. S. Isshiki, with *Parnopa bicornuta* MacLachlan. The kind of the prey is so curious that it is desirable to make further observation upon the prey of this species.

32. *Crossocerus* (*Blepharipus*) *vagabundus yamatonicus* (Tsuneki, 1947)

Several nests of this subspecies have been observed by the writer.

Nest 1. The nest was made on the dead tree trunk at about 1.5 m above the surface of the ground. The prey robbed of the wasp was the daddy-long-legs, *Nephrotoma cornicina* Linné. (July 22, 1944 at the farm-yard of the Hokkaido University)

Nest 2. The nest was burrowed in the same tree as above at about 2 m above the ground. The prey that I obtained from the wasp was a small moth belonging to Tortricidae.

Nest 3. The entrance to the nest was opened on a telegraph pole at about 10 cm from the earth. The prey that I robbed of the wasp was a crane fly of an unknown species. (July 27, in same farm-yard as mentioned above.)

Nest 4. On June 16, 1946, at 15:30, I saw a wasp of this species carrying a crane fly to her nest which was burrowed in the same dead tree as contained nests 1 and 2. When the wasp alighted on the entrance it was ascertained that the fly was held, venter to venter, with the middle pair of legs of the wasp. It was also caught by the antennae with her mandibles. She dragged it in the tunnel by about 2 cm, dropped the prey, turned round and carried it backing into the burrow. Soon she started for her next foraging excursion. Ten minutes later she came back with another crane-fly and alighted near the entrance which had been closed roughly with a cotten plug to observe mode of her carrying. At this time she did not catch the prey by the antennae and held it from the side with her middle legs.

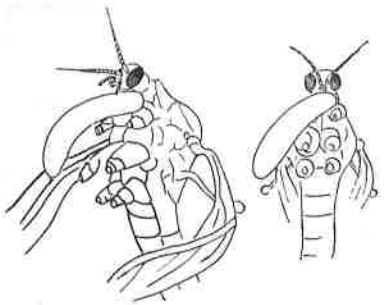


Fig. 59. Mode of attaching of the egg of *Crossocerus vagabundus yamatonicus* Tsuneki.

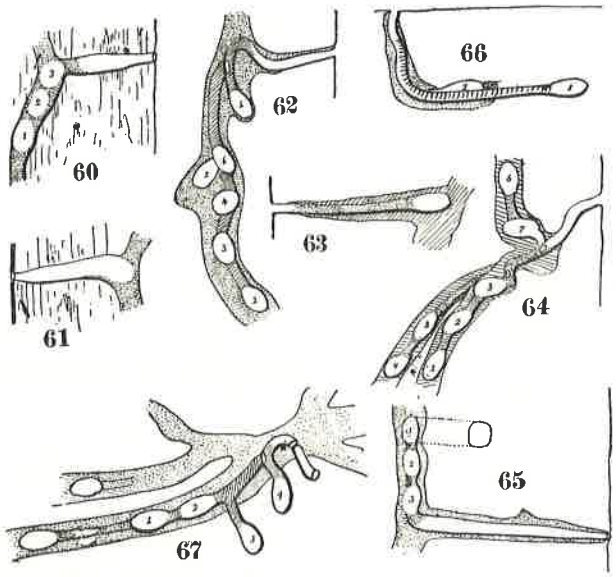
The next day at 16:30 I dug the nest. The burrow was made utilizing an old tunnel of some Cerambicid beetle and dug through the débri of the beetle-larva filled in the tunnel. It entered straight for about 3 cm and inclined downward. There I found 5 crane-flies stored, the interiormost one ly-

ing on its back, the next three on their sides and the outermost one on its belly, as if to make the outer crust of the wings of the prey. On the neck beneath of the innermost prey was laid an egg (Fig. 59). The entrance was 4 mm in diameter and the tunnel was enlarged to 6–7 mm in diameter and the portion of the cell was somewhat more broadened. There was no stoppage in the tunnel up to the cell. Judging from the absence of the wasp and from the state of the cell it seems supposable that she might lay her egg before full provision for the brood-cell.

Nest 5. I found the other nest close to the above-mentioned. It has the structure as given in Figure 60. The prey found in each cell were all crane flies, their number being from the interior 4, 6 and 4 respectively. To the innermost prey of cell 1 was attached the egg of the wasp. In spite of my careful observation, however, no egg was discovered on any of the crane flies in cells 2 and 3. The partition walls between the cells were fairly compact and about 3 mm in thickness. The bodily orientation of the prey was various, but the tendency as mentioned with regard to nest 4 was clearly observed. The long legs of the prey were mostly amputated and the bodies and the wings of the prey were irregularly folded.

I can not give explanation as to the absence of the egg in cells 2 and 3.

Nest 6. This nest was also discovered near the above two. I saw the owner of the nest provisioning on the 16th. On the 17th p. m., I saw again the wasp carrying a crane-fly in her nest three times more. At 17, I dug the nest open (Fig. 61). The wasp was in the tunnel with her head directing toward the entrance and when cutting was progressed she retreated little by little and at last went into the collection of the prey. I caught her only to let her free. The bodily orientation of the prey was quite uncertain and in spite of the fact that as many as 10 prey had already been accumulated, there could be found no egg on any of them.



Figs. 60–66. Nest 1–7 of *Crossocerus vagabundus yamatonicus* Tsuneki.

The prey of nests 4, 5 and 6 were as follows :

Nest 4,	cell 1	*Limnophila japonica* Alexander	3 ♂♂	Total 1 ♀ 4 ♂♂.
		Tipulidae, sp. No. 1	1 ♀ 1 ♂	
Nest 5,	cell 1	*Limnophila japonica* Alexander	1 ♀ 2 ♂♂	Total 1 ♀ 3 ♂♂.
		Tipula yamata Alexander	1 ♂	
	cell 2	*Limnophila japonica* Alexander	1 ♀ 3 ♂♂	Total 3 ♀♀ 3 ♂♂.
		Tipulidae, sp. No. 1	1 ♀	
		Tipulidae, sp. No. 2	1 ♀	

	cell 3	*Limnophila japonica* Alexander 3 ♂♂ *Epiphragma subfascipennis* Alex. 1 ♂	Total 4 ♂♂.
Nest 6,	cell 1	*Nephrotoma minuticornis* Alex. 1 ♀ 2 ♂♂ Tipulidae, sp. No. 1 2 ♀♀ 1 ♂ Tipulidae, sp. No. 3 1 ♀ 1 ♂ Tipulidae, sp. No. 4 2 ♀♀	Total 6 ♀♀ 4 ♂♂.

The state of the prey. The prey except the following two were with all the legs amputated at the tip of the trochanters.

Limnophila 1 ♂ in cell 2 of nest 5 with the left hind leg. Tipulidae No. 3, 1 ♀ in nest 5 with the left front and the right hind leg.

Of the prey in nest 4, 3 ♂♂ were dead, others being all alive, with their antennae, palpi, wings, genitalia, abdomen trembled or pulsate. In some specimens the visceral movements could be observed through semitransparent ventral skin. Of the 10 in nest 6 all were alive.

The egg were 2.3 mm in straight length (slighly curved) and 0.7 mm in width, wax white with a slight tint of yellow.

Nest 7. On June 27, 1947, I dug this nest together with the following two which were all burrowed in the same dead tree trunk in Hokkaido University as mentioned above repeatedly.

The wasp of nest 7 was observed provisioning since the 18th of that month. In carrying the prey she did not catch the antennae of the prey with her mandibles, but holding it, venter to venter, with the middle pair of legs alone.

The nest structure : Fig. 64. The brood-cell was distinctly enlarged than the tunnel, 8×12–13 mm in dimension. The prey were packed in the cell with their bodies and wings bent or folded. Their bodily orientation except heads was uncertain, but with the tendency as previously described. The contents of the cells were given in Table 10.

Nest 8. In this nest only a single cell was contained at the end of the straight tunnel of about 5 cm (Fig. 63). The interior wall of the cell was darkened by being attached with remains of food. The contents : Table 10.

Nest 9. This nest involved 6 cells (Fig. 62 and Table 10). In this nest two species of the intruders were discovered, one being a species of the mite and the other a small species of Histeridae, Coleoptera, both devouring the egg or the young of the wasp.

Nest 10. On July 12, the same year, I found on the same dead tree trunk as mentioned above another nest of this species which was being provisioned. It had the structure as given in Fig. 65. In cell 1 was found a cocoon, in cell 2 a full-grown larva and cell 3 had been destroyed by two maggots of the Tachinid fly. Among the prey that remained intact Limoniidae No. 1 was most abundant. From the cocoon in cell 1 a female wasp emarged on the 29th of the same month.

Nest 11. On June 29, 1949, I found a female of this species carry in a fly other than the daddy-long-legs to her burrow which was made in the decayed wood of a big fallen tree near the brook-side of the Otane-valley in Jozankei, Hokkaido. After catching the wasp to ascertain the species to which she is assigned I dug the burrow. It was made through the abandoned tunnel of a beetle hollow and had two brood-cells dug by herself, one of which was still in the course of provisioning. Nevertheless, the tunnel leading to

Table 10. Contents of nests 7, 8 and 9 of *Crossocerus vagabundus* Pz.

Nest	Cell	Prey		Waspling	Result of rearing
7	1	*Nephrotoma cornicina* L. Tipulidae No. 1. Tipulidae No. 5.	1 wing 1 wing 1 ♂ (intact)	Cocoon	♂, July 15.
	2	*Limnophila japonica* Alex. Tipulidae No. 1.	wings wings	Cocoon	♂, July 15.
	3	*Limnophila japonica* Alex. Tipulidae No. 1.	wings 5 wings	Full-grown larva	♀, July 21.
	4	Tipulidae No. 1. Tipulidae No. 4. Limoniidae No. 1. Limoniidae No. 2.	3 ♀ 2 ♂ 1 ♂ 2 ♀ 3 ♂ 1 ♀ 1 ♂	6 ♀ 7 ♂ 2nd instar larva	Died
	5	Tipulidae No. 1. Limoniidae No. 1. Tipulidae No. 4. Limoniidae No. 2.	1 ♀ 5 ♀ 1 ♀ 1 ♂ 2 ♀	9 ♀ 2 ♂ Egg	Died
	6	Tipulidae No. 4. T. No. 6 (*Nipponomyia* sp.) Limoniidae No. 1. *Dicranomyia takeuchii*	1 ♀ 1 ♀ 4 ♀ 11 ♂ 1 ♀	7 ♀ 11 ♂ Egg	Died
	7	Tipulidae No. 1. Limoniidae No. 1. Limoniidae No. 3. *Antoma* sp.	2 ♀ 1 ♂ 3 ♀ 4 ♂ 1 ♀ 1 ♀	7 ♀ 5 ♂ Egg	Died
8	1	*Limnophila japonica* *Nephrotoma cornicina* Lepidopt. Tortricidae Limoniidae No. 5. *Antoma* sp.	1 wing 1 wing 1 thorax 1 ♀ (intact) 1 wing wings	Nearly full-grown larva	♂, July 21.
9	1	Lepidopt. Tortricidae Tipulidae No. 4. Chironomidae No. 1. Remains	1 ♀ 1 ♀ 1 ♀	Final instar larva	♂, July 21.
	2	Chironomidae No. 2. Limoniidae No. 1. Limoniidae No. 2.	5 ♀ 1 ♀ 10 ♂ 1 ♀ 2 ♂	7 ♀ 12 ♂ Second instar larva	♀, July 21.
	3	Lepidopt. Tortricidae Limoniidae No. 1. Limoniidae No. 2. *Antoma* sp. *Pseudolimnophila inconcussa*	1 3 ♀ 12 ♂ 1 ♀ 1 ♂ 1 ♀	6 ♀ 13 ♂ Egg	Killed by parasites.
	4	Tipulidae No. 1. Tipulidae No. 4. Limoniidae No. 1. *Nephrotoma virgata*	2 ♂ 1 ♀ 3 ♂ 1 ♂ 1 ♂	1 ♀ 7 ♂ Egg	Died
	5	Tipulidae No. 1. Tipulidae No. 4. Tipulidae No. 6. Limoniidae No. 1.	1 ♀ 2 ♀ 1 ♂ 1 ♂ 2 ♀ 4 ♂	5 ♀ 6 ♂ Egg	Eaten by a parasite
	6	Limoniidae No. 1.	5 ♀ 11 ♂	Egg	Died

it was loosely closed with particles of wood (Fig. 66). The kind of the prey found in the cells was quite interesting :

Cell 1. A moth belonging to Tortricidae, Lepidoptera.
A species of the fly belonging to Rhagionidae, Diptera. 5 ♂♂.
A fly of undetermned Family. (Pl. I, Fig. 1)

Cell 2. The same species of Rhagionidae as found in cell 1. 3 ♂♂.

In cell 1 the egg of the wasp was laid on a third fly from the interior. In cell 2 the egg was not as yet laid.

Nest 12. Two years later I found another nest of this species in the same decayed wood as contained nest 11. It was on September 12, 1951. At that time the wood was so heavily moistened by the rain of the previous day that water exudated by the pressure of my cutting tools. Four brood-cells were discovered at the depth of 15 mm below the surface of the wood (Fig. 67). The nest excepting cells 3 and 4 was tunneled through the débri of a boring beetle larva, and deeply in the interior two other cells containing a cocoon were dug open. These cocoons must have belonged to other species of the Crabronid, since in the cells remains of Muscidae could be observed. Therefore, this wasp must have utilized the tunnel of the already completed nest of other Crabronid.

The prey belonged to a single species of Limoniidae, about 8 mm in size and the number in each cell was as follows :

Cell 1, 18; cell 2, 16; cell 3, 20; cell 4, 18.

The prey were all alive, moving the mouth parts, antennae and genitalia. In some of them the visceral movement was also observed. In each cell an egg of the wasp discovered deposited as usual on one of the innermost prey. Of the prey only two possessed two legs intact, others all missing them from the tip of the trochanters.

Summary, The nest of this species was usually dug in the débri of the abandoned beetle burrow. Masuda observed, however, that the wasps of this species made their nests in the reed-canes horizontally placed and linearly arranged their brood-chambers. When the nest is burrowed in wood the tunnel is usually somewhat enlarged than the entrance and the cell than the tunnel. In structure it belongs to the compound branched type and in the linear arrangement of cells in the tunnel it shows sometimes the primitive state of branching pattern, that is to say, part of a cell is slightly produced from the tunnel. The prey belongs usually to Diptera, Orthorrhapha, Nematocera, including Tipulidae, Limoniidae, sometimes also Chironomidae. In some cases, however, they also include Brachyceran Diptera of the family Rhagionidae. In one instance a specimen of an uncertain family of probably Cyclorrhapha was included. It is interesting that this species stores sometimes Lepidoptera, the moth of Tortricidae, in the cell. The number of the prey per cell varies with the size of the insects, ranging from 4 to 20. Mode of carrying the prey is the type of venter to venter, holding it with the middle pair of legs, rarely holding it further by the antennae with the mandibles. Mode of storing the prey in the cell shows the same tendency as mentioned in regard to the moth-hunting species. The egg is laid beneath the neck of the innermost prey (sometimes on the prey lying more exteriorly), with its length axis obliquely placed against the body axis of the pedestal

fly, not encircling the neck. The time of oviposition is considered to follow the general rule of the group. Nest 4, however, affords an interesting instance suggesting that the egg is laid before full provisioning of the cell. There were two instances wherein the egg of the wasp could not be discovered, though the cell was, without doubt, accomplished.

33. *Crossocerus* (*Ablepharipus*) *assimilis* (Smith, 1856)

No record has been published from Japan on the habits of this species. Only a single incomplete observation was recorded in German by F. Rudow (1912). According to this author, *C. assimilis* nests in the branch of *Morus* and stored the Dipterous insects.

34. *Crossocerus* (*Ablepharipus*) *shibuyai* (Iwata, 1934)

Accrding to the simple record of Iwata (1954) this species makes the nest in the abandoned beetle tunnel and stores the flies belonging to Fungivoridae.

35. *Crossocerus* (*Ablepharipus*) *congener* (Dahlbom, 1845)

On July 7, 1936, at the road-side in Okorogawa, near Nikko, I found a bundle of old hemp-canes once used for the roof piled up and occupied by a number of wasps belonging chiefly to the genus *Psenulus*. Among them a wasp with a somewhat different appearance having yellow maculated legs took my attention and was captured. Fifteen years later it was identified with *Crossocerus congener*. The nest of the wasp was collected and recorded. According to my note book it had three completed brood-cells and a provisioning one which were linearly arranged in a hemp-cane. The entrance was about 2,5 mm in diameter but the tunnel was somewhat enlarged to about 4.5 mm in diameter. The cells and the contents were as given in Table 11.

Table 11. A nest of *Crossocerus congener*.

Cell	Length	Prey	Number	Location of the fly carrying the egg
1	8 mm	midges	27 ♀	Egg on the innermost prey
2	7	〃	22 ♀	Egg on a fourth prey from the interor
3	8	〃	23 ♀	Egg on the innermost prey
4	Incomplete	〃	19 ♀	No egg

The partition wall between the cells was made of particles of pith gnawn off from the inner wall of the next cell. Therefore, the portion of the cell was more or less enlarged. The innermost wall was 4.5 mm in thickness, the next three were all 1.5 mm, with the outer surface made somewhat concave. The prey attached with the egg of the wasp were all having one of the wings opened toward which the end of the egg was produced (Fig. 67). Judging from the figure drawn at that time the prey must have belonged to Diptera, Orthorrhapha, Nematocera, probably Fungivoridae. In my note book was also recorded the presence of Empidae among the prey.

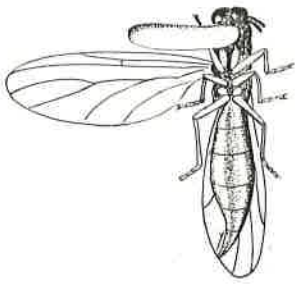


Fig. 67. The egg on the prey of *Crossocerus congener* Dahlbom.

Recently, in Fukui Prefecture, I found a large colony of this wasp at Hatogayu situated in a valley in the mountain region. The thatched roof of a barn was abundantly inhabited by various species of tube-renting Hymenoptera of

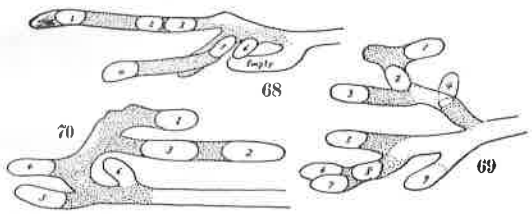
which *Cr. congener* was the most prosperous. About a hundred or more wasps were every year nesting there. From May to August more or less of them were seen provisioning. From time to time I pulled out some of their nesting canes and examined the contents. Also I obtained a number of their prey when I cellected necessary specimens of the wasps. They belonged chiefly to one species of Fungivoridae, probably *Phorodonta flavipes* Meigen, sometimes including specimens of Empidae. The flies were exclusively the females. In one cell they were stored from 14 to 23 in number. The egg was usually found on the innermost prey, but sometimes on the one lying slightly before. The number of the linearly arranged cells was from 5 to 12, as far as my examination has gone.

36. *Crossocerus* (*Ablepharipus*) *podagricus* (Van der Linder, 1829)

Nothing has been known on the habits of this species occurring in Japan and its adjacent regions. In Europe this species is known to nest in decayed wood and stores the brood-cells with Nematoceran Diptera.

37. *Crossocerus* (*Coelocrabro*) *walkeri* (Shuckard, 1837)

Late in March, 1955, I examined three nests of this species which I had collected the previous year with Mr. Tanaka from the dead branches of *Malus toringo* growing at the shore of the brook, Yugawa, Nikko. At that time we could discover only a single wasp nesting, but we found a number of dead branches occupied by the wasp. They were located in various height, low from 40–50 cm to as high as 2 m above the surface of the ground. The branches preferred by the wasp were 15–40 mm in thickness, but apparently the twigs of 20 mm or so in thickness were most preferred. The nests were easity discovered by the the small heap of wood-particles on or below twigs. They could be discovered only on the trees growing near the brook and there was no nest found on trees growing more than 10 m far from the stream.



Figs. 68–70. Nests 1–3 of *Crossocerus walkeri* Shuckard.

Nests 1, 2 and 3 : Figs. 68, 69 and 70 and the data : Table 12.

Some remarks. (1) There were some cells that have not the outer wall. In these cells the size was measured by the clumps of food. Some of these cells must have lost the outer wall or packing by the shock received during the trans-

Table 12. Three nests of *Crossocerus walkeri*.

Nest	Cell	Size	(mm)	Prey	Waspling
1	1	7.5	4.0	Remains	Cocoon
	2	7.0	4.2	〃	〃
	3	7.0	3.4	〃	〃
	4	7.0	3.5	6	Died
	5	6.5	3.5	Remains	Cocoon
	6	–	4.0	〃	Died
2	1	6.0	3.7	9	Died
	2	5.5	3.7	6	〃
	3	6.0	3.5	7	〃
	4	5.5	4.0	–	–
	5	6.0	3.5	7	Died
	6	5.2	3.5	4	〃
	7	6.5	3.5	7	〃
	8	–	3.7	7	?
	9	–	3.5	–	–
3	1	8.0	3.5	6	Died
	2	6.0	3.5	–	–
	3	15.0	3.3	10	Died
	4	7.0	3.3	6	〃
	5	8.0	3.5	11	〃
	6	6.0	3.5	–	–

portation from Nikko to Fukui, a journey of about 600 km. (2) The prey contained at least 4 species of Ephemeroptera. The long front legs were usually amputated, but sometimes left in situ. They were all laid with their heads directing toward the interior of the cell. (3) Mode of storing the prey showed the same tendency as repeatedly mentioned in regard to that of moth-hunting species. (4) There was no papilla (or the so-called rerpiratory process) on the top (broader side) of the cocoon.

According to Tanaka (Tsuneki et Tanaka, 1955) the brood-cells were sometimes arranged in a simple branched pattern. The maximum number of cells he examined in a nest was sixteen, though the nest was still in the course of provisioning. Out of 28 prey specially examined 23 were cut off of both their four legs, 5 of one of the fore legs, 6 of both the middle legs and 2 of one of the middle legs, but the hind legs were all left intact. An interesting finding made by him is that the wasp has the habits of collecting a number of prey at a time which are later divided to provision two or three cells that are constructed in succession. Such curious habits have hitherto been known only in some members of the genera *Aphilantops*, *Cerceris* and *Astata*. The number of prey per cell ranges from 4 to 7.

38. *Crossocerus* (*Coelocrabro*) *barbipes* (Dahlbom, 1837)

According to Tanaka a nest of this species was found in a dead tree still standing. It belonged to the simple branched type in structure, containing 4 brood-cells which were packed with small Dipterous insects, varying in number from 3 to 6.

39. *Crossocerus* (*Coelocrabro*) *amurensis* (Kohl, 1892)

Mr. Tanaka sent to me two specimens of insects which he obtained from a provisioning wasp of this species. One of the insects was a species of Chironomidae and the other belonged to Trichoptera. According to him the wasp made a nest in so hard a tissue of a dead tree trunk that he could not cut open. The prey robbed of the wasp included, besides the Diptera and Trichoptera, some Psocopterous insects.

40. *Crossocerus* (*Coelocrabro*) *cetratus* (Shuckard, 1837)

I saw several times in Hokkaido that the wasp of this species carried in some Dipterous insects to her burrow which was made in the dead tree or in the telegraph pole. Tanaka observed at Tyuzendzi, Nikko, that the nest of this species was made in decayed wood of the dead tree and contained 3–4 larval cells linearly arranged and the cells were stored with Dipterous insects belonging mainly to Empidae and Fungivoridae. In Europe this species has been recorded to hunt Stratiomyidae, Empidae, Ceratopogonidae, Bibionidae and some Hemiptera, Homoptera.

41. *Crossocerus* (*Coelocrabro*) *ambiguus hokkaidoensis* Tsuneki, 1954

In decayed wood of a big fallen tree in the dense forest of the Otane-valley, Jozankei, I found 3 nests of this specics which were all in the course of provisioning. The prey were, as in the nominate race, the insects belonging to Hemiptera, Homoptera. During their activities I observed mode of their carrying the prey by inducing the wasp to enter the glass tube. It held the prey, venter to venter, with the middle pair of legs and besides, caught it by the short antennae with the mandibles. Usually they did not alight near the entrance to the nest, but slid into the tunnel from in the air with the prey. The nests

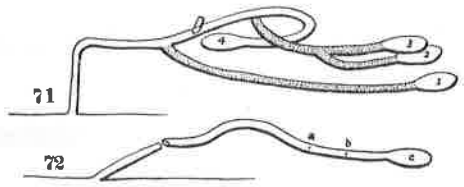
had the structure as given in Figs. 71–72 and the data on the contents were shown in Table 13.

Table 13. Nests of *Crossocerus ambiguus hokkaidoensis*

Nest	Cell	Size (mm)	Prey			Waspling
			Nymph	Imago	Total	
1	1	7.0 × 3.0	4	10	14	Larva, killed by P.
	2	7.5 × 3.3	2	9	11	lst instar larva
	3	8.0 × 3.0	–	18	18	Egg
	4	– × 3.0	2	14	16	No egg
2	1	– 3.2	–	14	14	No egg
3	1	– 3.0	–	–	–	Incomplete

P. ... Parasitic fly maggots

The prey belonged all to a single green species of Jassidae. Most of them were packed in the cell with their heads directing inwards, but several of them lying in the opposite direction. The orientation of their ventral side was uncertain. Mode of attachment of the egg was slightly different from each other in two instances observed. In one it attached to the neck, somewhat deviating from the median line to the right and obliquely crossed the thorax of the prey, attaining with the other end to the outside of the left hind coxa. While in the other it attached to the neck at its center as usual with its anterior end, but lay parallel with the body axis of the prey, attaining with the posterior end to between the hind coxae (Pl. Ⅲ, Fig. 5). The egg was milky white with a faint tinge of yellow, 1.2×0.3 mm in dimension.



Figs. 71–72. Nests 1 and 2 of *Crossocerus ambiguus hokkaidoensis* Tsuneki.

In nest 2, 11 prey were stored at the end cell and two were scattered in the tunnel, one at a and the other at b shown in Figure 72.

The nominate race is known to hunt also Hemiptera, usually Homoptera, but sometimes Heteroptera, as food for their young.

42. *Crossocerus* (*Coelocrabro*) *leucostoma* (Linné, 1758)

No observation has been made oe this species in Japan. The Enropean representative is known to make the nest in decayed wood of the dead tree and stores with cell with small Dipterous insects.

43. *Crossocerus* (*Coelocrabro*) *tanakai* Tsuneki, 1954

On August 10, 1954, I walked along the shore of Lake Tyuzendzi, Nikko, with Mr. Tanaka, collecting and observing the wasps. Under the dense forest we found a small heap of saw-dust on the heavily decayed wood of a fallen tree, half-buried along the lane. My comrade crambled the wood around the heap with his fingers and soon found a brood-cell fully stored with Homopterous insects. The tunnel of the burrow was only 15 mm in length and closely packed with débri. He cut off a block including the nest from the wood and took it to his house. Later he informed me "The prey stored in the cell were

15 in number. About a week later I examined the cell to find a cocoon and on crambling the wood further I could discover another cell made below the above-stated which also included a cocoon. The cells were 12 mm in length and 5 mm in width." He also wrote that he had investigated before another nest of this species found under the similar condition which contained a single brood-cell at the end of about 10 mm in length and the cell was stored with 11 Homopterous insects.

From the nests above-mentioned three wasps emerged the next year and they were identified with *tanakai*. The prey were all insects of Jassidae, bright green in colour and 3–4 mm in length, but they were all devoured by the larvae during rearing.

44. *Crossocerus* (*Coelocrabro*) *tyuzendzianus* Tsuneki, 1954

The type specimen of this species was captured at Shobugahama, Nikko, when she came out of a burrow made in the dead part of the trunk of a very big tree of *Quercus crispula* Bl., but the nest could not be examined.

45. *Crossocerus* (*Coelocrabro*) *nikkoensis* Tsuneki et Tanaka, 1955

I captured some specimens of this species at Senjugahama, Nikko, on the trunks of some dead trees. The nests were made from the abandoned tunnel of some small boring beetle. But the trees could not be cut open. Mr. Tanaka told me that he obtained several of his specimens from nests in the pith cavity of *Diervilla japonica*.

46. *Crossocerus* (*Coelocrabro*) *heydenii* Kohl, 1880

A specimen preserved at the Entomological Institute, Hokkaido University, collected by E. Gallois is accompanied by a midge (Fungivoridae ?) pierced on the same insect pin.

47. *Crossocerus* (*Coelocrabro*) *pauxillus* (Gussakovskij, 1933)

Nothing has been known concerning biology of this species.

48. *Crossocerus* (*Coelocrabro*) *cinxius* (Dahlbom, 1838)

On June 4, 1948, at Sapporo, I captured two wasps of this species, each carrying a small Dipterous insect. One of the victims beloged to Chironomidae and the other to Anthomyiidae.

According to Tanaka the wasps of this species nest in *Rubus palmatus* at Tyuzendzi, Nikko. The prey stored in the larval cell were chiefly the flies of Empidae, but sometimes some Hemipterous insects (Pentatomidae and Psillidae) were exceptionally included.

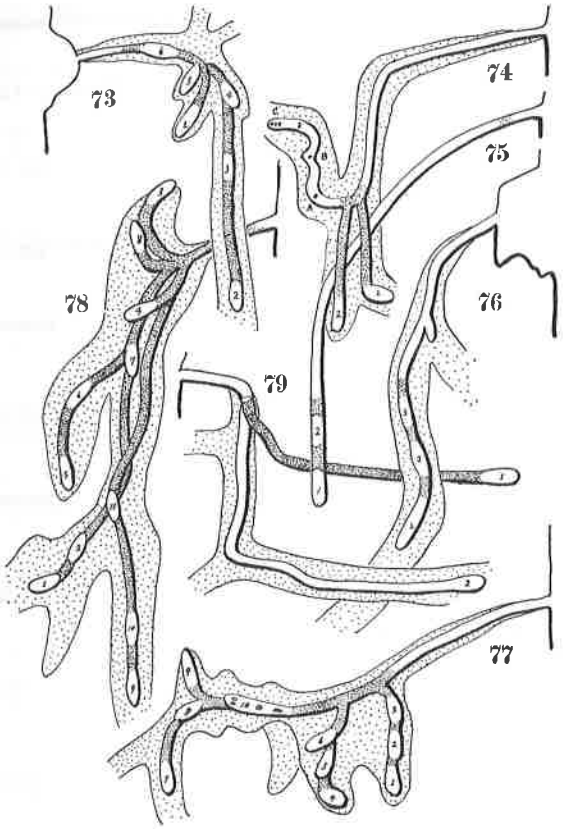
49. *Crossocerus* (*Coelocrabro*) *capitosus* (Shuckard, 1837)

Tanaka reported that the nest of this species was made in *Sambuccus*-trees at Tyuzendzi, Nikko, and stored with small Dipterous insects.

50. *Crossocerus* (*Coelocrabro*) *pubescens* (Shuckard, 1837)

I have examined seven nests of this species in Hokkaido (Figs. 73–79). The contents of these nests were as given in Table 14.

Hunting. On June 25, 1947, in the farm-yard of the Hokkaido University, Sapporo, a wasp of this species aimed at and dashed upon a fly which alighted on a leaf of a *Sambuccus*-tree and succeeded in capturing it. She held herself on the leaf with her anterior four legs, capturing the prey with her hind legs only. The fly was on its legs and



Figs. 73–79. Nests 1–7 of *Crossocerus pubsecens* Shuckard.

the wasp obliquely mounted upon it, with the apical portion of her abdomen bent under the belly of the prey, taking the posture of stinging. The body axes of both the hunter and the prey thus came to be nearly crossed. The wasp, however, did not whip out her dagger at once, but moved herself little by little toward the head of the prey, with the tip of her abdomen moving along the median line of prey's underside and finally the tip attained to beneath the thorax. During the course the prey wriggled and struggled, violently and irregularly moving its legs in vacant. The apex of the abdomen of the wasp reached at last the middle of the prey's neck. There it pushed up the head of the fly and inserted the sting into the throat. The manoeuvre of the wasp was carried out comparatively slowly and allowed me to observe in detail.

Character of the nest structure. The nest of this species is of the compound branched type, including linearly arranged cells in a branch. But the cells arranged in such a manner shows hither and thither a primitive state of the branched pattern, that is to say, they include some cells slightly deviating from the row, with the distal end somewhat produced laterally. The cells are sometimes as wide as the tunnel, sometimes slightly wider than the tunnel. Usually the tunnel leading to the just provisioning cell is closed either in front of it or at the entrance.

Oviposition. Judging by the state of the provisioning cell, it seems concluded that in this species, too, the egg is laid after the full store of food is finished.

51. *Crossocerus* (*Coelocrabro*) *flavitarsus* (Tsuneki, 1947)

52. *Crossocerus* (*Crossocerus*) *uchidai* (Tsuneki, 1947)

53. *Crossocerus* (*Crossocerus*) *opacifrons* (Tsuneki, 1947)

54. *Crossocerus* (*Crossocerus ?*) *leclercqi* Tsuneki, 1959

Nothing has been known on these species in reference to their biology.

55. *Crossocerus* (*Crossocerus*) *varus* Lepeletier et Brullé, 1834

Near the summit of the peak, Kurodake, of Mt. Taisetsu, Hokkaido, I found on

Table 14. Prey of *Crossocerus pubescens* observed in Hokkaido.

Nest	Cell	Waspling	Prey: Anthomyiidae	Empidae	Chironomidae	Agromyzidae	Dolichopodidae	Trypetidae	Phoridae	Neriidae	Others	Total
1	1	4th i.1.										Remains
	2	〃										〃
	3	3rd i.1.	1♀	5♀ 3♂	3♀							9♀ 3♂
	4	1st i.1.		3♀ 9♂	3♀							6♀ 9♂
	5	Egg	2♀ 1♂	3♀ 7♂								5♀ 6♂
	6	None		3♀ 5♂								3♀ 5♂
2	1	2nd i.1,	1♀	2♀ 5♂	2♀ 1♂		2♀ 1♂ 1♀					8♀ 7♂
	2	Maggots	2♀	3♂	1♀		1♀ 1♂					1♀ 5♀ 4♂
	3	None	1♂	10♀ 7♂								10♀ 8♂
3	1	Cocoon										Remains
	2	None	3♀									–
4	1	3rd i.1.	1♀ 2♂	1♂						3♀ 3♂		4♀ 6♂
	2	2nd i.1.	2♀	1♀ 4♂			2♀		1♀	1♀ 2♂		7♀ 6♂
	3	1st i.1.	1♀ 3♂	1♀ 2♂			1♀			1♀ 4♂		4♀ 6♂
5	1	Cocoon										Remains
	2	〃										〃
	3	–	2♀	11♂		2♀		1♂				4♀12♂
	4	4th i.1.										Remains
	5	〃										〃
	6	〃										〃
	7	2nd i.1.	2♂	1♀ 1♂	3♀					1♀ 1♂		5♀ 4♂
	8	1st i.1.	1♀	2♀ 1♂						4♂		3♀ 5♂
	9	〃	1♂		2♀					1♀ 4♂	1♀ 4♀ 5♂	
	10	None			1♀					4♂		–
6	1	Cocoon										Remains
	2	〃										〃
	3	Spin. 1.										〃
	4	4th i.1.										〃
	5	〃										〃
	6	2nd i.1.	2♀ 1♂	1♀ 1♂	2♀					2♀		7♀ 2♂
	7	1st i.1.		3♂	1♀ 1♂		1♀			1♂		2♀ 4♂
	8	〃	1♀	3♀ 1♂						3♂		4♀ 4♂
	9	Egg	1♀	2♀ 3♂	1♀					1♀		5♀ 3♂
	10	〃		2♀ 2♂				1♀		2♀		5♀ 2♂
	11	〃	1♀ 1♂	1♀ 1♂	1♀					1♂		3♀ 3♂
7	1	Egg	1♀ 2♂	10♀14♂		2♀						13♀16♂
	2	None		1♂		6♀ 1♂						–

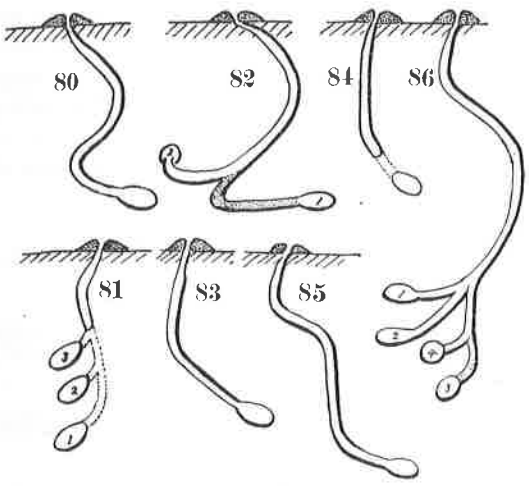
the path a number of the nests of this species. It was on August 24, 1947. I dug seven of them (Figs. 80–86), all being not the accomplished nests.

Nest. The entrance was 2.0–2.5 mm in diameter, with around it a small rounded mould. The tunnel, soon after penetrating the earth, distinctly enlarged to about 3.0–3.5 mm in diameter (in one instance it was elliptic in cross-section with the size of 3×4 mm) and went in a steep slope to about 5–7 cm. The

Table 15. Nests of *Crossocerus varus*

Nest	Cell	Prey		Waspling Remarks
1	1	Anth. Emp.	12	No egg Provis.
2	1	Remains (Anth. Emp.)		Cocoon
	2	〃 (〃 〃)		4th i.1.
	3	〃 (〃 〃)		〃
3	1	Anth. Emp.	14	Egg
	2	No prey		None
4	1	Anth. Emp.	12	No egg Provis.
5	1	Anth. Emp. Fungiv.	22	Egg
	2	Anth. Emp. Fungiv.	24	Egg
6	1	Remains & Emp. (20)		Larva
	2	Empidae	32	Egg
7	1	Remains		4th i.1.
	2	〃 & Empidae		3rd i.1.
	3	Empidae	20	Egg
	4	Anth. Emp.	14	No egg Provis.

Anth. ... Anthomyiidae. Emp. ... Empidae. Fungiv. ... Fungivoridae. Provis. ... Provisioning.



Figs. 80–86. Nests 1–7 of *Crossocerus varus* Lepeletier et Brullé.

cells were connected with the main tunnel usually by a short horizontal branch. They were 8–9×4–4.5 mm in dimension, with the inner surface smooth but not polished.

Transportation of the prey: Catching the fly from the back with one of the middle pair of legs.

Prey: Chiefly a small species of Empidae, mixing Anthomyiidae and Fungivoridae. The data of the nests are as given in Table 15.

Locality of the egg and the form of the cocoon. The egg is usually found on the innermost prey, but sometimes on the one lying uppermost and locating in the middle of the chamber. Mode of attaching is as usual. The cocoon which was spun in the glass-tube partitioned with cotton plugs was light yellowish brown in colour, slightly stumy (6×2.7 mm), with the so-called respiratory process on the broader side, not markedly produced and usually covered with remains of flies.

56. *Crossocerus* (*Crossocerus*) *denticrus* Herrich-Schaeffer, 1841

57. *Crossocerus* (*Crossocerus*) *yasumatsui* (Tsuneki, 1947)

These species have been several times observed by the author flying about low on the ground, but he could not succeeded in finding the nest of them out.

Cr. denticrus is known by a single record by Adlerz (1912) to make the nest in the clayey soil and to store small flies as food for the larva.

58. *Crossocerus* (*Crossocerus*) *emarginatus* (Kohl, 1915)

Tanaka (1952) reported that the wasp of this species nested in the neighbourfood of Tyuzendzi, Nikko, in the lump of earth which was attached to the root-complex of the fallen tree. The nest belongs to the simple branched type, containing usually 8–10 cells inside. In transportation the prey is held by the wasp by its neck with one of the middle legs, usually with the ventral side upward, sometimes sideward. The number of the prey stored in one cell ranges from 6 to 10. The prey include small flies of Anthomyiidae, Syrphidae, Empidae and Trypetidae. Mode of attachment of the egg and the time of oviposition are as usual. During the provisioning the wasp makes a temporary closure in front the cell. In closing the tunnel finally, the wasp uses the pygidial area as a pounding tool of the earth.

59. *Crossocerus* (*Crossocerus*) *wesmaeli* (Van der Linden 1829)

Sibuya (1957, 58) published the results of his extensive studies on the habits of this species in Japan. But it was in Japanese (with English summary). The important points can be summarized as follows :

The nest is made from the surface of clay cliffs. It belongs to the simple (probably an in-

complete one), linear (usually 2) and simple branched types. All but one (Psocoptera) of the prey were small flies belonging to Chironomidae, Ceratopogoniidae, Cecidomyiidae and Fungivoridae, the number per cell being 16–39. The egg is usually found buried among the compactly stuffed prey, but not in the cells which are during the course of provisioning. (The auther concludes from the facts that oviposition will be taken place after several prey is carried in, but to me it seems that the time of oviposition follows the general rule of the group.) State of attachment of the egg is as usual. Mode of hunting the prey is similar to that described by the present writer as regards *Cr. varus*. In trasporting the prey the wasp catches it by the neck with one of its middle pair of legs. The prey, by turning around the axis of its neck, takes posture sometimes with the ventral side upward, sometimes downward. In closing the tunnel finally, this species also uses the tip of the abdomen as done by the members of the burrowing Pompilidae. The cocoon is on its outer layer embeded with grains of sand or particles of earth.

On a small clay cliff facing north which was situated along the road of Asuwa-hill in the city of Fukui I found, in June, 1959, a population of this species nesting. The habits of the wasps were observed and several nests were dug open. Mode of carrying the prey was the same as descscribed by Sibuya, namely holding the fly by the neck with one of the middle pair of legs, sometimes venter up and sometimes venter down. In two points, however, our wasps showed a slight difference from his observation. In the kind of the prey the wasps of the hill confined the range to a single family of Diptera, namely Agromyzidae only. Fragments of insects attached to the old cocoons as well as the insects stored in the cells belonged all to three species of the leaf-mining fly. In the second place the cocoon is not always embeded with particles of earth. Some cocoons including an old one were normal in structure, yellowish brown in colour and wrapped with remains of food only. This may be, however, an unusual cocoon in this species. In the greater part inumerable particles of earth are woven into silk of the cocoon. In both cases the so-called respiratory process can be observed at the cephalic end.

The nests were not deep, the brood-cells being scattered from 2 to 5 cm below the surface of the cliff. The structure is considered to belong to the simple branched type. The maximum number of cells included in an accomplished nest was 9. In the cells not yet included the wasp's egg I found 12, 3, 10, 8, 5 and 13 midges accumulated. While in the old cells made in the previous year the number of the prey calculated mainly from the remains of the thoraxes was 15, 14, 11, 8, 19, 16 and 14. Judging from such data this species is considered to lay its egg after full provision of a cell.

60. *Rhopalum* (*Latrorhopalum*) *latronum* (Kohl, 1915)

Several wasps of this species were observed to hunt the prey on the tuft of flowers of *Polygonum polymorphum* in the ground of the Hokkaido University, Sapporo. The wasp darted on a fly, carries it on to a near-bye leaf and stung it on the underside of its thorax. Sometimes it stung the prey whilest it hung from the flower with one of its hind legs. The prey robbed of the wasps belonged to Neriidae (*Terepidaria dentigena japonica* Hennig), Dolichopodidae and Drosophilidae.

According to Tanaka, at Tyuzendzi, Nikko, this species nests in dead or living twigs of *Deutzia scabra*. The prey belonged to small Dipterous insects of the families Anthomyiidae, Chironomidae, etc. The number of prey stored per cell attained as many

as 38. The nest was of the linear type, with cells of 3–5 in number. In the brood-cells which were still being provisioned the presence of an already hatched or a half-developed larva was always ascertained. Judging from the fact it seems certain that the wasp has a habit of the so-called progressive provisioning. Moreover, in one nest Tanaka discovered that the egg had already been deposited, though the prey stored was but one. This is quite an exceptional habit among the members of Crabroninae.

61. *Rhopalum* (*Rhopalum*) *nipponicum* (Kohl, 1915)

On June 4, 1953, a number of wasps of this species were found nesting in the reed-canes used for the roof of a barn located at the shaded place in Hosonoguchi, Fukui Prefecture. I deprived the homig wasps of their prey. Four of them were the daddy-long-legs belonging to Limoniidae and all of their legs except 2 hind legs of one of them were amputated. I collected 6 nests and examined them at my laboratory.

Nests 1–5. Including one cell only, which was in the course of provisioning and there was no egg laid.

Nest 6. Two cells. In the 1st which was 14×2.7 mm in dimension the egg of the wasp was laid on a 2nd prey from the interior. The 2nd cell was in the course of storing food. The prey were as given in Table 16. Most of the prey examined were alive not only when captured at the entrance to the wasp's nest, but on the next day.

Table 16. Prey of *Rhopalum nipponicum* (numerals within parentheses : number of species)

Nest	Cell	Chironomid.	Simulid.	Cecidomiid.	Phorid.	Limoniid.	Psocoptera	Tatal
1	1	(6) 5♀ 8♂	(1) 1♀	(2) 1♀ 1♂				(9) 7♀ 9♂
2	1	(6) 1♀ 7♂	(1) 2♂	(1) 1♀			1♀[1]	(7) 2♀ 9♂
3	1	(6) 3♀ 5♂[2]	(1) 1♀[3]	(1) 1♀ 1♂	(1) 1♂			(9) 5♀ 7♂
4	1	(6) 6♀11♂[4]				(1) 1♀[5]		(7) 7♀11♂
5	1	(2) 1♀ 1♂		(1) 1♀				(3) 2♀ 1♂
6	1	(2) 3♀ 2♂	(1) 1♀					(5) 8♀ 3♂
	2	(1) 2♀ 1♂	(1) 1♀	(1) 2♀ 1♂		(1) 2♀ 1♂	(1) 2♀	(3) 5♀ 2♂
Total		(6)22♀34♂	(2) 4♀ 2♂	(3) 6♀ 3♂ (1)	1♂	(2) 3♀ 1♂	(1) 3♀	(15)38♀41♂

1) *Graphopsocus cruciatus* L. 2) Including *Critopus metatibialis* Tokunaga and *Critopus* sp. 3) *Prosimulium yezoense* Shiraki. 4) Including *Critopus metatibialis* Tokunaga and *C. trimaculatus* Macquart. 5) *Eritoptera asiatica* Alexander.

In Hokkaido I captured a wasp (subsp. *hokkaidense*) carrying a crane fly beloning to Limoniidae. Anterior four legs of the prey were amputated.

According to Iwata (1938) he observed the species nesting in dead and wet twigs of *Sambuccus* and *Diervilla*. The nest was either of the linear or of the branched type. In the latter case curious transitional types from the linear to the branched were observed. The prey were the flies belonging to Tipulidae, Chironomidae and Culicidae. He found the egg deposited on the prey placed nearest to the entrance (the prey brought in last accrdingly, he says), but he also discovered that 2–7 prey were stored without an egg.

62. *Rhopalum* (*Rhopalum*) *nigrinum* Kiesenwetter, 1849

Munakata (1948) reported that the wasp of this species makes the nest of the linear type in the reed-canes stood around the house against the winter snow in Hokkaido. The prey captured by the wasp belonged chiefly to Psocoptea (*Psocus tokyoensis* Enderlein, *Ptelodela* sp.) and the Diptera of the family Dolichopodidae (*Dolichopus nitidus* Fállen).

When I examined the wasp of this species and its prey obtained from the nest made in the dead stem of *Solidago occidentalis* collected in Tochigi Prefecture, the prey were all Dipterous insects belonging to Dolichopodidae, Trypetidae and Psychodidae.

63. *Rhopalum* (*Rhopalum*) *succineicollare* Tsuneki, 1952

I have once observed at Koike, Fukui Prefecture, that a wasp of this species made the nest in an old beetle burrow opening on a railing of a barn.

64. *Rhopalum* (*Rhopalum*) *guttatum* Tsuneki, 1955

The wasps belonging to this species have been observed at Koike making their nests in the hollow of thatches used for the roof of a barn. The prey robbed of the wasps consisted of several species of small Diptera belonging mainly to Chironomidae.

65. *Rhopalum* (*Rhopalum*) *clavipes jessonicun* (Bischoff, 1921)

66. *Rhopalum* (*Rhopalum*) *venustum* Tsuneki, 1955

The nesting site of the above listed two species is similar to the case of *guttatum*, but no special attention has been paid as to their biology.

67. *Rhopalum* (*Rhopalum*) *ebetsuense* Tsuneki, 1952

This species was observed to make the nest in dried thaches stood around the house against the winter snow in Hokkaido. But no observation has been made.

68. *Rhopalum* (*Calceorhopalum*) *calceatum* Tsuneki, 1952

69. *Rhopalum* (*Calceorhopalum*) *kuwayamai* Tsuneki, 1952

70. *Rhopalum* (*Calceorhopalum*) *watanabei* Tsuneki, 1952

Some of the specimens of the above listed 3 species have been obtained from the nests made in the pith hollow of *Diervilla japonica*, but no detailed observation has been conducted up to the present.

71. *Entomognathus* (*Entomognathus*) *brevis* (Van der Linden, 1829)

Addendum

Very recently Mr. Y. Haneda published the results of his investigation on the nests of four species of *Rhopalum*, viz. *nipponicum*, *nigrinum*, *venustum* and *calceatum*, all made in the pith cavity of reed-canes standing in the natural habitat. He described the structure of the nests, size of the cells and cocoons, thickness of the partition walls and the distribution of sexes in the nests, but none on the prey. It seems interesting that the cocoon of *calceatum* is not attached with remains of prey, while in others it is covered with remains and that the cocoon of *venustum* lacks the so-called respiratory process, while in all others it is always provided.

Literature

In this list the references are confined mainly to those published in Japan, with the exception of the first four. Those who wants to know the full catalogue should refer to J. Leclercq (1954). To the Japanese entomologists more easily acceptable Tsuneki et Tanaka (1955) will afford most of the literature on the related species.

Berland, L. 1925. Faune de France, 10. Hyménoptères Vespiformes, I. Paris.

Hamm, A. H and Richards, O. W. 1926. The biology of the British Crabronidae. Trans. Ent. Soc. London. 74.

Kohl, F. F. 1915. Die Crabronen der paläarktischen Region. Lebensweise der paläarktischen Crabronen. Ann. k. k. naturh. Hofmus. Wien, Vol. 29, S. 352–440.

Leclercq, J. 1954. Monographie systématique, phylogénétique et zoogéographique des Hyménoptères Crabroniens. Liège.

Haneda, Y. 1960. Nests of four species of *Rhopalum* in Japan. Life Study (Fukui), Vol. 4, No. 3, pp. 1–3.

Iwata, K. 1935. Nesting substratum and the prey of Crabronids. Fukui-ken Hakubutsu-Gakkai-Kaiho, No. 2, pp. 1–10. (In Japanese)

——— 1937. Habits of four species of the Japanese hunting wasps that burrow in rotten wood. Mushi, Vol. 10, No. 2, pp. 129–140.

——— 1938. Habits of some Japanese Pemphredonids and Crabronids. Ibid., Vol. 11. No. 1, pp. 20–41.

——— 1940. The life of bees and wasps. Kobunsha. Tokyo. (In Japanese)

——— 1941. Habits of some Japanese Grabronids. Mushi, Vol. 14, No. 1, pp. 1–7.

——— 1942. Comparative studies on the habits of solitary wasps. Tenthredo, Vol. 4, pp. 1–146.

——— 1944. From the field book of a nature observer. (In Japanese)

——— 1947. Insects and their nests. Suida. (In Japanese)

——— 1950. A hypothetic dentrogram of the habit-types in the Aculeate Hymenoptera. Tech. Bull. Kagawa Agr. Col,. Vol. 1, No. 3, pp. 75–81. (In Japanese)

——— 1954. Sphecoidea (In Insecta Japonensia). Chukai Sokuho, Extra Issue, No. 1. (In Japanese)

——— 1955. Evolution in the habits of insects. Shizen (Tokyo), Vol. 10, No. 8, pp. 22–29 et No. 9, pp. 46–55. (In Japanese)

——— 1957. Memorandum on the life of *Anthrax distigma* Wiedermann. Ins. Ecol. (Tokyo), Vol. 6, No. 14, pp. 25–32. (Including the record of parasitization upon *Ectemnius spinipes*) (In Japanese)

Iwata, K. and S. Yoshida. 1957. Gladiolus damaged by *Ectemnius* (*Hypocrabro*) *rubicola* (Dufour et Perris) in Shikoku. Trans. Shikoku Entom. Soc., Vol. 5, Pars 4, pp. 53–54.

Maruyama, K. 1951. Takenigusa no Ginguchibachi (The Crabronid nesting in the living stem of the noxious plant, *Macleya cordata* Br.) Shin-Konchu, Vol. 4, No. 8, pp. 10–11. (In Japanese)

Masuda, H. 1940. Biological notes on *Crabro* (*Acanthocrabro*) *vagabundus* Panzer. Mushi, Vol. 13, No. 1, pp. 33–39. (In Japanese)

Munakata, M. 1948. Notes on *Crabro* (*Rhopalum*) *kiesenwetteri* A. Morawitz. Matsumushi, Vol. 3, No. 2, pp. 56–57. (In Japanese)

Ohgushi, R. 1955. On the environmental resistances of *Ectemnius* (*Hypocrabro*) *rubicola* (Dufour et perris). Trans. Shikoku Ent. Soc., Vol. 4, Pars 5–6, pp. 83–86.

Shimoyama, K. 1960. Notes on the biology of *Ectemnius* (*Iwataia*) *furuichii* Iwata. Life study (Fukui), Vol. 4, No. 1, pp. 11–12. (In Japanese)

Sibuya, K. 1938. Notes on the nesting habits of *Odynerus* (*Ancistrocerus*) *shibuyai* Yasumatsu and *Crabro* (*Crabro*) *iridifrons* Pérez from Japan. Mushi, Vol. 11, No. 1, pp. 1–10.

——— 1957. Studies on the habits of the hunting wasp, *Crossocerus* (*Crossocerus*) *wesmaeli* Van der Linden, from Japan (1). Ins. Ecol. (Tokyo), Vol. 6, No. 15, pp. 65–79. (In Japanese with English summary)

——— 1958. Ibid. (2). Ibid., Vol. 7, No. 2, pp. 82–91. (Ibid.).

Tanaka, E. 1952. Nesting habit of *Crabro* (*Crossocerus*) *emarginatus* Kohl. Ins. Ecol., Vol. 4, No. 11, pp. 90–93. (In Japanese)

——— 1953. Biology of the may-fly-hunting Crabronid, *Crossocerus* (*Coelocrabro*) *walkeri* (Shuckard). Shin-Konchu, Vol. 6, No. 10, pp. 10–13. (In Japanese)

Tsuneki, K. 1942. Nesting habit of *Crabro* (*Crossocerus*) *alatus* Panzer. Trans. Kansai Ent. Soc., Vol. 13, Pt. 1, pp. 54–58. (In Japanese)

——— 1942. A naturalist at the front. Osaka. 424 pp. (In Japanese)

——— 1946 a. Prey records of some Crabronids. Matsumushi, Vol. 1, No. 1, p. 23 (In Japanese)

——— 1946 b. Oecological observations on hunting wasps. III. *Crabro* (*Crabro*) *spinipes* A. Mor. and *Crabro* (*Clytochrysus*) *planifrons* Thoms. Seibutsu, Vol. 1, Nos. 5–6, pp. 290–294. (In Japanese)

——— 1947. On the wasps of the genus Crabro s. l. from Hokkaido, with descriptions of new species and subspecies. Jour. Fac. Sci. Hokkaido Univ., Ser. VI, Zool., Vol. 9, No. 2, pp. 397–435.

——— 1948. Oecological observations on hunting wasps. IV. *Crabro* (*Crabro*) *konowii* Kohl. Seibutsu, Vol. 3, No. 1, pp. 22-26. (In Japanese with English summaary)

——— 1952 a. Some Crabronids from Shikoku, Japan. Trans. Shikoku Ent. Soc., Vol. 3, Pars 3–4, pp. 63–70.

——— 1952 b. The genus *Rhopalum* Kirby (1829) of Japan, Korea, Saghalien and the Kuriles, with a suggested reclassification of the subgenera and descriptions of four new species. Jour. Fac. Sci. Hokkaido Univ., Ser. VI, Zool., Vol. 11, No. 1, pp. 110–125.

——— 1954 a. The genus *Crossocerus* Lepeletier et Brullé (1834) of Japan, Korea, Saghalien and the Kuriles. Mem. Fac. Lib. Arts, Fukui Univ., Ser, II, Nat. Sci., No. 3, Pt. 3, ref. p. 78 (Biology of *Cross. tanakai*)

——— 1954 b. Descriptions and records of wasps of the families Chrysididae and Sphecidae of Japan. Ibid., No. 4, Pt. 5, ref. p. 47. (Nesting site of *Cross. tyuzendzianus*)

——— 1959 a. Guide to the study of the Japanese Hymenoptera (5). Biology of the genus *Ectemnius*. Life Study, No. 8, pp. 10–13. (In Japanese)

——— 1959 b. Ibid. (7). V. Biology of the genera *Crabro* and *Lestica*. Ibid., Vol. 3, No. 2, pp. 12–13. (In Japanese)

——— 1960 a. Ibid. (10). Biology of *Crossocerus* in Japan (1). Ibid., Vol. 4, No. 1, pp. 15–17. (In Japanese)

——— 1960 b. Ibid. (11). Ibid. (2), Ibid., Vol. 4, No. 2, pp. 27–29. (In Japanese)

Tsuneki, K. et Tanaka, E. 1955. Crabroninae of Nikko, Japan, with notes on their biology and description of a new species. Kontyu, Vol. 22, Nos. 3–4, pp. 65-70.

——— 1955. Ibid. Kontyu, Vol. 23, No. 1, pp. 21–27.

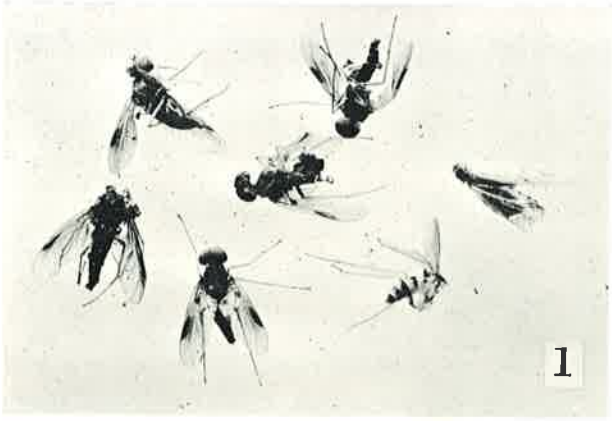
Explation of the Plates

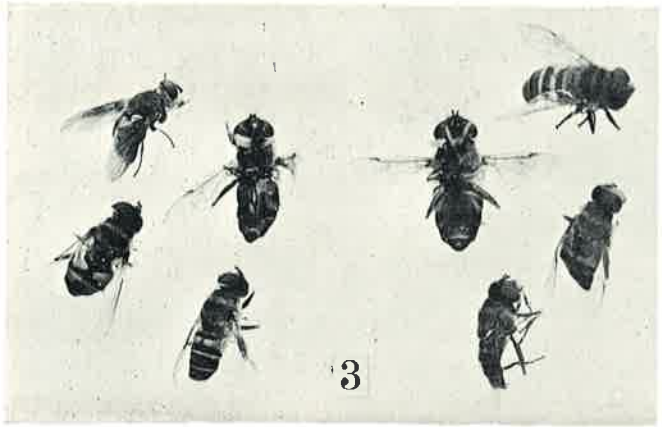
Plate I.

Fig. 1. Unusual prey of *Crossocerus vagabuudus yamatonicus* Tsun. from a single brood-cell, the central fly carrying a young larva of the wasp.

Fig. 2. The prey of *Ectemnius nigritarsus* Her.-Schaef., the central one with the wasp's egg.

(continued to p. 53)





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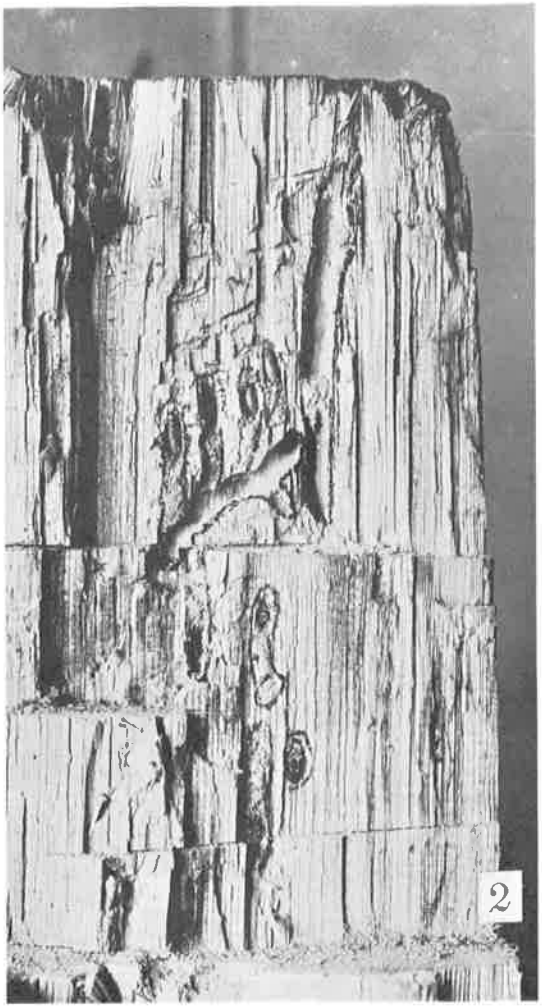

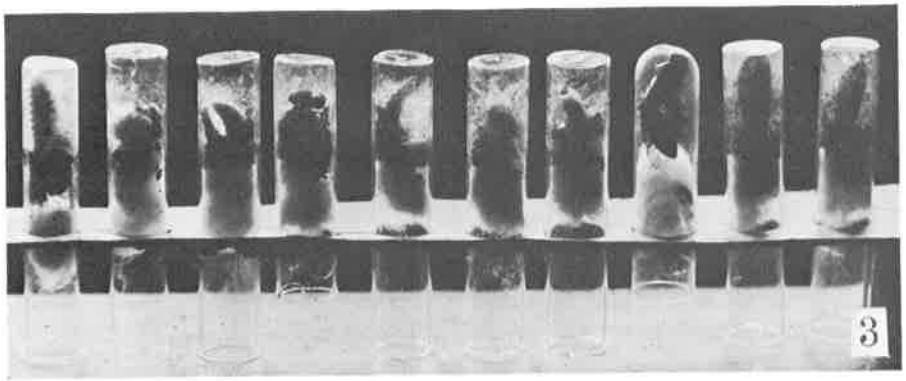

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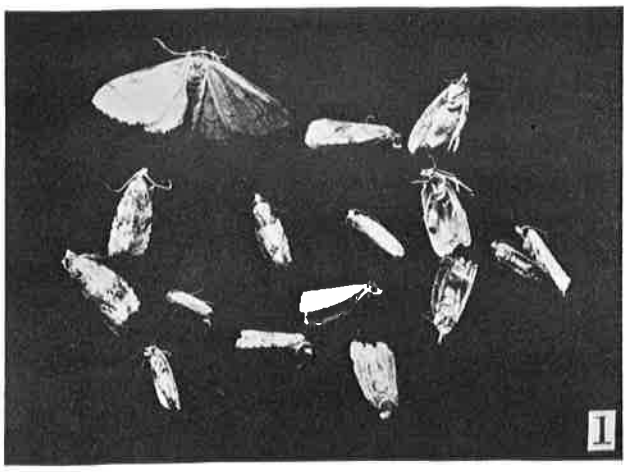

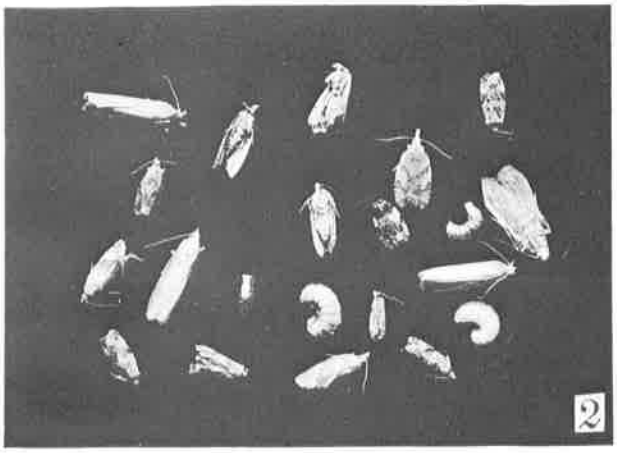

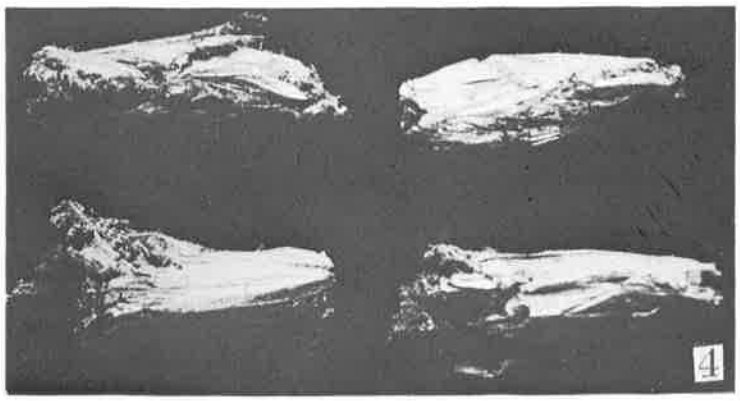

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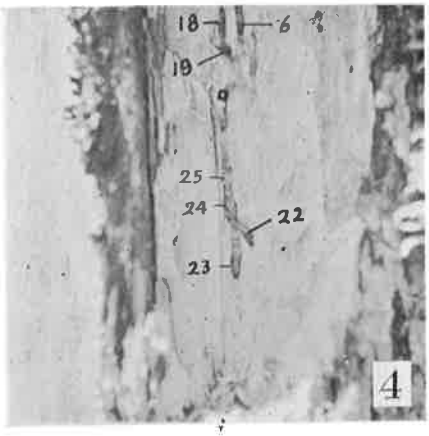

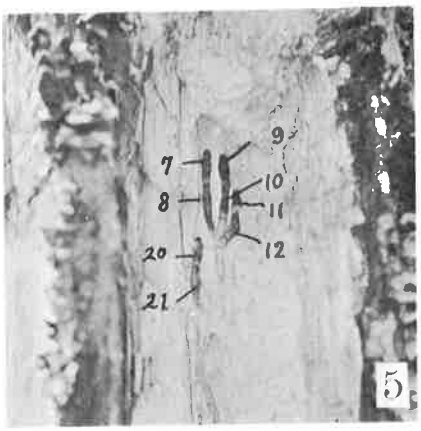

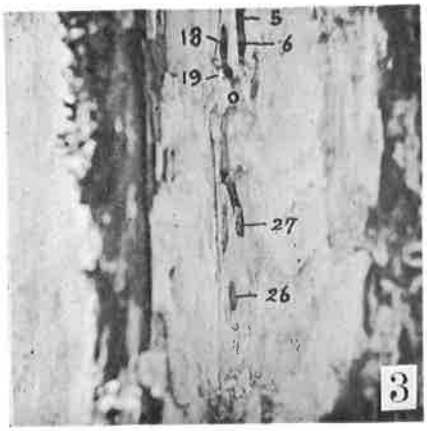

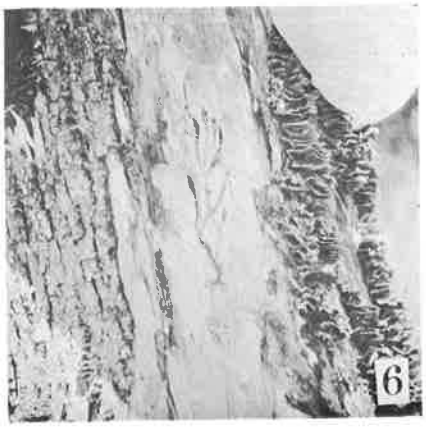

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Fig. 3. The prey of *Ectemnius konowii* K. from two brood-cells, the central two being attached with the wasp's egg.

Fig. 4. The prey of *Lestica reiteri* K.

Fig. 5. The cocoons in the brood-cells of *Lestica reiteri* K.

Plate II.

Fig. 1. A nest dug open of *Lestica reiteri* K.

Fig. 2. A nest made in wood of *Ectemnius nigrifrons* Cres., the same as shown in Fig. 17 in the text.

Fig. 3. Rearing of larvae of *Ectemnius konowii* K.

Plate III.

Fig. 1. The prey of *Lestica alata* Pz.

Fig. 2. Ibid., with larvae of the wasp.

Fig. 3. Ibid., attached with the wasp's egg.

Fig. 4. Cocoons of Lestica alata covered with the wings of the prey.

Fig. 5. A prey carrying a young larva of *Crossocerus ambiguus hokkaidoensis* Tsun.

Plata IV.

Figs. 1–5. The states of a nest of *Lestica reiteti* K. successively disclosed by digging. Fig. 6. Another nest of *L. reiteri*, the same as given in Pl. II, Fig. 1.

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