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# THE BIOLOGY OF EAST-ASIATIC *CERCERIS* (HYM., SPHECIDAE) WITH SPECIAL REFERENCE TO THE PECULIAR SOCIAL RELATIONSHIPS AND RETURN TO THE NEST IN *CERCERIS HORTIVAGA* KOHL

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# THE BIOLOGY OF EAST-ASIATIC *CERCERIS* (HYM., SPHECIDAE) WITH SPECIAL REFERENCE TO THE PECULIAR SOCIAL RELATIONSHIPS AND RETURN TO THE NEST IN *CERCERIS HORTIVAGA* KOHL*

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## Synopsis

TSUNEKI, Katsuji (Fukui Univ., Japan): The biology of East-Asiatic *Cerceris* (Hym., Sphecidae), with special reference to the peculiar social relationships and return to the nest in *Cerceris hortivaga* Kohl. Etizenia (Fukui), No. 9, pp. 1–46, 1965.

Chiefly the nesting biology, in some species the prey records, of the following species occurring in Japan, Korea, North China and East Mongolia is described:

*Cerceris hortivaga* Kohl, *lybyensis japonica* Ashmead, *arenaria* Linné, *albofasciata* Rossi, *nipponensis* Tsuneki, *carinalis* Pérez, *sobo* Yasumatsu et Okabe, *bupresticida* Dufour, *bicincta* Klug, *pekingensis* Tsuneki, *rufipes evecta* Shestakov and *sabulosa nupta* Shestakov.

Special reference: In a colony of *hortivaga* a common possession of the colony nests by the members of the colony due to random entering, provisioning aud oviposition was observed which was probably dependent upon the weak descriminating capacity of the wasps regarding their own nests. In the homing experiments the wasps could not return to their nesting area from the places that were considered unknown to them, even when the place was not distantly apart from their home ground.

## INTRODUCTION

The study on the bionomics of the genus *Cerceris*, as in most other biological investigations, was initiated as early as the beginning of the 19th century by the European entomologists. The investigations were most flourishingly carried out during several decades centering around the turn of the 19th century and the life of a number of the species was brought to light either fragmentarily or in some detail. In recent years, however, in Palaearctic region excepting Japan the papers published dealing with the subject mentioned are few, though the species known as to their habits are far smaller in number than those uninvestigated. While in Nearctic region, especially in the United States, the significance of the study of this sort has become reestimated and the biological studies on Aculeate Hymenoptera are very actively carrying out (Table 1).

The species of *Cerceris* are all terricolous insects, digging their nests in the ground. The female wasp makes the tunnel, constructs the first cell, provisions it with some prey insects, lays an egg on them, closes the tunnel in front of the cell, then constructs a second cell and repeats the same procedure as in the first cell. Thus the cells are successively constructed and completed one by one. Usually in one group of *Cerceris* the cells later constructed are located in front of those made earlier, while in the other reverse is usually the case. The nest thus formed is compound in structure, having from several to some twenty larval cells within, which are led by comparatively short branch tunnels from the main burrow. Each branch tunnel and finally the greater part of the main burrow are compactly closed by the wasp with the soil when her work for the cell or the cell group to which it leads is com-

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Table 1. The number of the papers or books dealing with the biology of *Cerceris*.

| 1800 — 33 | | 1834 — 66 | | 1867 — 99 | | 1900 — 33 | | | | 1934 — 64 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E | N.A | E | N.A | E | N.A | E | A | S | N.A | E | A | N.A |
| 0 | | 9 | 0 | 12 | 1 | 38 | 5 | 2 | 10 | 5 | 8 | 18 |

Remarks. E, Europe. N.A, North America. A, Asia. S, South America.

pletely finished.

It is characteristic of the nests of *Cerceris* that we find (1) several prey insects provisionally stored in the main burrow before the cell wherein they are to be received is prepared, and (2) the main burrow fairly compactly closed with the soil for a considerable distance every time when the wasp is out or at the entrance gallery.

## TWO GROUPS BASED ON THE SORT OF PREY

The species of *Cerceris* can biologically be divided into two groups, the group in which the prey given to the larva consist of the insects of Coleoptera, and the group wherein the prey consist of the insects of Hymenoptera, mainly of Apoidea. Once this fact, together with the morphological distinctions considered in those days parallel to the biological characters above mentioned, was dealt with as a base of subdivision of the genus *Cerceris*. Later studies, however, discovered that the biological and morphological characters do not always run parallel to each other. From the biological point of view only there is no doubt that the members of the genus is very clearly divided into the Coleoptera-hunting group and the Hymenoptera-hunting group. None of the species does mix the two groups of prey and none of the species hunts insects other than the two orders. In the number of the species the Hymenoptera hunters occupy only a small part of the genus and, moreover, they do not occur in Nearctic region.

### A. Coleoptera capturing group

The Coleopterous insects captured by the wasps of the first group are restricted taxonomically to ten families, namely Phalacridae, Nitidulidae, Buprestidae, Tenebrionidae, Coccinellidae, Chrysomelidae, Bruchidae, Cerambycidae, Curculionidae and Anthribidae, of which Curculionidae occupy the greater part of the reported species of the prey and Phalacridae, Nitidulidae, Tenebrionidae, Coccinellidae and Cerambycidae form exceptions. Amongst the remainder Chrysomelidae involve forms very divergently structured in appearance, as in *Coptocephala*, *Hispa* and *Cassida*. On the other hand, Bruchidae and Anthribidae had sometimes been dealt with roughly as weevils and confused with Curculionidae. It is interesting, however, that the confusion occurs also in the wasps themselves. No species of *Cerceris* collects the insects of Bruchidae or Anthribidae exclusively. The insects of these families are only occasionally mingled with the Curculionid prey that form the main part of the provision of the wasps. The same is true with reference to Phalacridae and Nitidulidae as against Chrysomelidae.

Two Tenebrionid hunters are recently discovered in U.S.A. In one of them, however, it was made clear that capturing of such an insect is rather unusual, and in the other the observation is restricted to only a single instance in which the prey was transported by the wasp and not found in the nest. Probably the Tenebrionids are also of exception.

According to the data above mentioned it seems that the types of Coleoptorous prey captured by *Cerceris* are divisible into three classes, Curculionid-, Buprestid-, and Chrysomelid types, others being deviations from some one of these types or a mistake made by the wasps.

Tenebrionidae, Bruchidae (though taxonomically nearly related to Chrysomelidae) and Anthribidae may be deviations from Curculionidae; Phalacridae, Nitidulidae and Coccinellidae from Chrysomelidae and Cerambycidae either from Curculionidae or Buprestidae. Such a concept seems to be given evidence by the fact that the insects considered exceptional are usually mingled with others that belong to one of the above mentioned three main prey sources. Only *rubida* group which forms the morphological exception among the Coleoptera-hunters shows also exception in this respect. The members of this group captures both Chrysomelidae and Curculionidae. Similar exceptions are also presented by *blakei* (Curculionidae and Chrysomelidae), *fumipennis* (Buprestidae and Curculionidae), *spiniger* and *quinquefasciata* (both Curculionidae and Chrysomelidae).

It seems not of no use to arrange the species so far known of their biology according to the sort of prey they capture at the present date. In this list the species of *Cerceris* (*Eucerceris*) of Nearctic region were also included, since they fall within the same category as far as their biological characters are concerned. Within parentheses are given the zoogeographical regions they occur. The abbreviations: PA, palaearctic; NA, nearctic; O, oriental; NT, neotrpical.

**I. (1) Curculionidae**

(1) *C. archites* Mickel (NA)
(2) *C. arenaria* L. (=*quinquecincta* Ashmead, nec Fabr.) (PA)
(3) *C. atramontensis* Banks (NA)
(4) *C. bicornuta* Guéin (nec Smith) (NA) (incl. ssp. *fidelis* V. et C.) (NA)
(5) *C. blakei* Cresson (NA)
(6) *C. carinalis* Pérez (PA)
(7) *C. chilensis* Spinola (NT)
(8) *C. clypeata* Dahlbom (NA)
(9) *C. deserta* Say (NA)
(10) *C. eustylicida* Williams (NT)
(11) *Eucer. flavocincta* Cresson (NA)
(12) *C. flavilabris* Fabr. (= *ferreri* v. d. L.) (PA)
(13) *C. frontata* Say (NA) (incl. ssp. *raui* Rohwer) (NA)
(14) *C. fumipennis* Say (NA)*
(15) *C. halone* Banks (NA)
(16) *C. interrupta* Panzer (PA)
(17) *C. nigrescens* Smith (NA)
(18) *C. nipponensis* Tsuneki (PA)
(19) *C. otomaria* Sausure (NT)
(20) *C. quadricincta* Panzer (PA)
(21) *C. quadrifasciata* Panzer (PA)
(22) *C. quinquefasciata* Rossi (PA)
(23) *C. rhois* Rohwer (NA)
(24) *C. rubida* Jurine (PA)
(25) *Eucer. ruficeps* Scullen (NA)
(26) *C. ruficornis* Fabr. (= *rabiata* F., = *cunicularia* Schrank) (PA)
(27) *C. rufinoda* Cresson (NA)
(28) *C. rufipes* Fabr. (incl. ssp. *evecta* Shest.) (PA)
(29) *C. sobo* Yasumatsu et Okabe (PA)
(30) *C. spiniger* Rohwer (NT)
(31) *Eucer. superba* Scullen (NA)
(32) *Eucer. triciliata* Scullen (NA)

**(2) Anthribidae**

(1) *C. spiniger* Rohwer (NT)

**(3) Tenebrionidae**

(1) *C. athene* Banks (NA)
(2) *C. blakei* Cresson (NA)*

**(3) Bruchidae**

(1) *C. rubida* Jurine (PA)*
(2) *C. specularis* Costa (PA)*

**II. (1) Buprestidae**

(1) *C. argyrotricha* Bohwer (NA)
(2) *C. bupresticida* Dufour (PA)
(3) *C. californica* Cresson (NA)
(4) *C. fumipennis* Say (NA)

Some species

**III. (1) Chrysomelidae**

(1) *C. albofasciata* Rossi (=*luctuosa* Costa. = *navitatis* Smith) (PA)
(2) *C. bicincta* Klug (=*qudrimaculata* Duf.) (PA)

(3) *C. blakei* Cresson (NA)*
(5) *C. flavofasciata* Smith (NA) (incl. ssp. *floridensis* Banks (NA)
(8) *C. insolita* Cresson (NA)
(10) *C. quinquefasciata* Rossi (PA)*
(12) *C. rubida* Jurine (PA)*
(13) *C. spiniger* Rohwer (NT)

**(2) Coccinellidae**

(1) *C. gayi* Spinola (NT)*

**(3) Phalacridae**

(1) *C. rubida* Jurine (PA)*

**(4) Nitidulidae**

(1) *C. rubida* Jurine (PA)*

**(5?) Cerambycidae**

(1) *C. angularis* Costa (PA)
(4) *C. finitima* Cresson (NA)
(6) *C. fukaii* Rohwer (O)
(7) *C. gayi* Spinola (NT)
(9) *C. nipponensis* Tsuneki (PA)*
(11) *C. robertsonii* Fox (NA) (incl. ssp. *emmiltosus* Scullen) (NA)
?(14) *C. arenaria* Linné (PA)*[1)]

Remarks.

Besides the above, *C. mexicana* Saussure (NT) belongs to the first group, since it was recorded to capture some Coleopterous prey.

* indicates the hunter not mainly capturing the prey group.

As briefly touched upon in the foregoing page some species collect varied types of prey belonging to two or more different families. Such instances seem very interesting, because they are suggestive, on the one hand, of the distinguishing ability of the insects in question, and on the other hand, of a certain cross section of the evolutionary development of the instinctive behaviour. The instances are represented by the following species:

(1) *C. blakei* Cresson. Chiefly Curculionidae, occasionally Chrysomelidae and Tenebrionidae.

(2) *C. fumipennis* Say. Chiefly Buprestidae, rarely Curculionidae.

(3) *C. gayi* Spinola. Chiefly Chrysomelidae, sometimes Coccinellidae.

(4) *C. nipponensis* Tsuneki. Chiefly Curculionidae, occasionally Chrysomelidae.

(5) *C. rubida* Jurine. Chiefly Curculionidae, but sometimes Bruchidae, Chrysomelidae, Phalacridae and Nitidulidae.

(6) *C. specularis* Costa. Curculionidae as a rule, sometimes Bruchidae.

(7) *C. spiniger* Rohwer. Curculionidae mainly, but occasionally Chrysomelidae and Anthribidae.

(8) *C. quinquefasciata* Rossi. Mainly Curculionidae, rarely Chrysomelidae.

? (9) *C. arenaria* Linné. Believed exclusively Curculionidae, but a single report recorded Chrysomelidae mixed[1)].

On the other hand, in most of the species the range of the prey is limited to one family alone. Even in such species, however, the dispersion of the prey genera is a very common phenomenon. But sometimes there are species in which the insects captured are confined to a single genus or even to a single species, in so far as a given district is concerned, for instance of the genus, *C. albofasciata* Rossi, and of the species, *C. rufipes* Fabricius (= *tuberculata* Vill.).

Morphologically the species of the Coleoptera hunting group were formerly believed to have no raised area (platform) on the second ventral plate of the abdomen. As our knowledge proceeds, however, exceptions to this rule came to appear. The taxonomic *rubida* group and *sobo* group represent such species. In the former the platform is distinct and in the latter it is represented by two tubercles.

1) Amongst a number of authors recording Curculionids as prey Lucas (1858) alone reported a few specimens of Chrysomelids (*Bromius* ... Eumolpinae) mixed with Curculionids.

### B. Hymenoptera capturing group

The insects that fall into the victims of these wasps except *C. stratoties*, belong to the solitary bees of the families, Halictidae, Andrenidae, Colletidae and Apidae, The genera are also limited to a small number. *Halictus* (Halictidae) forms the greater part of the victims to these wasps. The remaining small part is filled by such genera as *Hylaeus* (Colletidae, Hylaeinae), *Panurgus* (Andrenidae, Panurginae), *Andrena* (Andrenidae, Andreninae), *Sphecodes* (Halictidae), *Dufourea* (*Halictoides*) (Halictidae, Nominae), *Epeolus* (Apidae) and *Nomada* (Apidae, Anthophorinae).

Very rarely, however, some aberrant prey have been observed:

In his report on the biology of *C. quadrifasciata* that usually preys upon Curculionidae J. H. Fabre (1856, p. 184) recorded to have observed a wasp carrying a fossorial wasp, *Alysson bimaculatus* Panzer (=*fuscatus* Pz.). L. Berland (1925, Faune de France p. 61) gives comment to this record, saying "On peut se demander s'il n'y a pas là un fait isolé et exceptionnel, ou une erreur de détermination, d'autant que seuls sont connus comme chasseurs d'Hyménoptères les *Cerceris* du groupe de *rybyensis*". In my opinion this is not necessarily unacceptable provided a certain species of *rybyensis*-group was misidentified as such as suggested by Berland, though a fossorial wasp as the prey of *Cerceris* is a very aberrant exception and may throw much doubt accordingly. I have, however, two instances of such aberrant prey captured by species of the bee-hunting *Cerceris*.

I obtained once a specimen of the Pemphredonid wasp, *Psen* (*Mimumesa*) *dahlbomi pacificus* Tsuneki placed among the Halictid and Andrenid bees in a cell of a nest of *C. hortivaga* Kohl found in Sapporo. Further, in Peking I observed a wasp of *C. pekingensis* Tsuneki carry in her burrow *Pisn* sp. (probably *P. insigne* Sickmann), a Trypoxylonid wasp, though I failed in recapturing the specimen from the nest.

These instances indicate that Fabre's observation is not absolutely improbable, provided the wasp he saw belonged to the second biological group designated in this paper.

In this group of *Cerceris* there is no differentiation in the particular preference for a certain group of the prey, as very distinctly observed in the first group. All of them are the hunters of *Halictus* mixing occasionally some specimens of other genera.

Only four species, sometimes under different specific names, have been on record as to their biology:

(1) *C. rybyensis* Linné (=*ornata* Fabr., *variabilis* Schr. *magnifica* s. Ferton, *japonica* Ashm.) (PA)

(2) *C. hortivaga* Kohl (=*harmandi* auct.) (PA)

(3) *C. sabulosa* Panzer (=*emarginata* Panz.) (PA) incl. ssp. *nupta* Shest.)

(4) *C. pekingensis* Tsuneki (PA)

Among the Hymenoptera-hunters, *Cerceris stratiotes* Schletterer occupies a particular or rather exceptional position. According to Grandi (1957, 61), the wasp of this species captures solely the Chalcidid wasp, *Stilbula cynipiformis* (Rossi), which is well known by the habits of parasitizing the larvae of the ants bolonging to the genus *Camponotus*.

## THE STATE OF THE PREY

*Cerceris*, though any of them even when grasped between fingers of a human being would not whip out a sword, does sting the prey into paralysis when it captures them as food for the young. Generally, the Coleopterous prey fall into deep permanent paralysis and they show

very faint signs of life or, rather more usually, completely none of the sign. Under magnifying glass we can sometimes find the trembling tarsi or slowly moving palpi or legs, but more of the insects are as motionless and still as the dead. This is true either upon the insects snatched from the wasps during their transportation or upon those dug out of their nests.

To the contrary, on the prey of Hymenopterous insects it is very common to observe a fairly active movement, save those that were taken out of the completed cells. The bees that were taken from the transporting wasps or that were dug out of the tunnel where they were provisionally laid are used to show a disordered movement of the legs and wings and sometimes they can even walk or fly, though they cannot normally proceed, either circling or soon turning over. No doubt they are alive. But they have lost the harmony of movement and behaviour.

> I have frequently observed that a bee after having been taken in the burrow while the wasp was clearing the tunnel crawled out of the opening by itself, walked disharmoniously around it and then crawled in the burrow again. This is an evidence that the central nervous system controlling the behaviour succession has been destroyed or at least harmed.

The bee just after being stung is unable to move, lying quite as motionless as a dead insect. But after a while it becomes somewhat recovered from the poison and gradually reaches the state above mentioned, though there is a marked variation in the degrees of recovery. However, once it is packed and arranged in the larval cell of the wasp it turns into a complete paralysis and can not move even the tip of the leg. The question how and why is this state brought about was experimentally clarified as early as 1887 by P. Marchal with *Ceiceris rybyensis* under the name of *Cerceris ornata*.

## A BRIEF REVIEW OF THE BIOLOGICAL STUDIES IN EAST ASIA

The studies hitherto made on the biology of species of *Cerceris* have piled up a vast smount of literature (*vide* p. 42), but more than a half of them concern only kinds of the prey and the parasites. The remainder go far up to deal with the nest structure, provisioning activity and prey species. A few investigators, however, such as Paul Marchal (1887), Jean Henry Fabre (1856) and Guido Grandi (1926), carry out particular studies, taking up the problem of either the manipulation given to the prey, stinging and paralysis or recognition of the nest site.

In Japan several reports on the biology of *Cerceris* (Yano, 1926; Yasumatsu, 1931 and 39; Kuribara, 1931; Hamatake and others, 1931; Katayama, 1933, 35, 37; and myself) have been published. But most of them were also fragmental.

In 1937 I recorded the nesting biology of four species of this genus occurring in Japan based on my observations. Later in 1942 in my 'A Naturalist at the Front' several East Asiatic species were described with respect to their biology and in 1947 and 48 peculiar social relationships found in a colony of *C. hortivaga* Kohl were also reported by me.

Very regret to say, all the reports above mentioned except one of the Katayama's were given in Japanese and could not be taken into the general biological knowledge of the genus of the world.

In the present paper I have rearranged my own data and put forwards all the records so far published by me, adding some unpublished notes on some species. Among them the peculiar social relationships found in *C. hortivaga* seem to be worthy of notice from the viewpoint of socio-biology. The observations on the Continental species were performed in Peking, China and in Apaka, East Mongolia, during my stay in military service, others being carried out mostly in Japan and partly in Korea.

## THE BIOLOGY OF THE SPECIES IN JAPAN

### 1. *Cerceris hortivaga* Kohl

This is one of the commonest species of the fossorial wasps in Japan. They are most frequently found nesting in the well trodden and moderately moistened earth of the rural paths, the garden of the city houses and parks. They are widely distributed over Japan from the Ryukyus to Hokkaido and from the low land to mountains as high up as 1500 m in Central Japan. They can be seen from July to October and repeat two generations a year in most of the districts. It is therefore well-known among the Japanese people who are more or less interested in observing the natural phenomena that this wasp makes the nest in the earth and takes in bees to it. However, the detailed observation at a colony of this seemingly most patent species reveals a quite unexpected and very significant phenomenon that has not ever been known in the world of bees and wasps. Before touching upon the phenomenon the general nesting biology will first be given as an introducing account to the life of *Cerceris* in general.

#### (1) General nesting biology

**Habitat.** As given in the foregoing lines the wasps of this species make their nests by preference on the ground of the sun-baked path, but they also nest in the shaded place such as the grounds of shrines and temples covered with the canopy of tall trees or on the mountain path running through the forest where the sunshine reaches through the leaves only a part of the day. Sometimes they burrow into the steep slope of the banks.

**Colony.** They usually assemble to a certain restricted area and form the so-called colony. The members of a colony range from several to over a hundred according to the environmental conditions and the years passed since the colony foundation. Sometimes, however, we can find an isolated nest made by a pioneer of the future colony.

The nest is dug, as a rule, by the inhabitant of the time from the beginning. Sometimes, however, the old nest is hereditarily reused by one of the offsprings. Early in the season when the young wasps, males and females, successively emerge in the nest of the preceding generation, it is not an unfrequent matter to observe several wasps go in and out one and the same nest. This is due to the fact that the young wasps do not disperse at once, but live for the first several days after emergence in the nest in which they were born. They turn back in the evening to their nest and they stay in it when the weather is unfavourable. Gradually, however, they turn out to the other place to make their own nests or to pass the time in chasing the female. The female that remains last utilizes the abandoned tunnel as her burrow. She does not, however, reuse the old cells for her own. In some instances, however, one of the sisters begins to dig her own cell while her brothers and sisters still live together in the nest. These reused nests when dug up by the observer are used to furnish some old cells scattered among the newly constructed ones, each containing an abandoned cocoon and the remains of the prey.

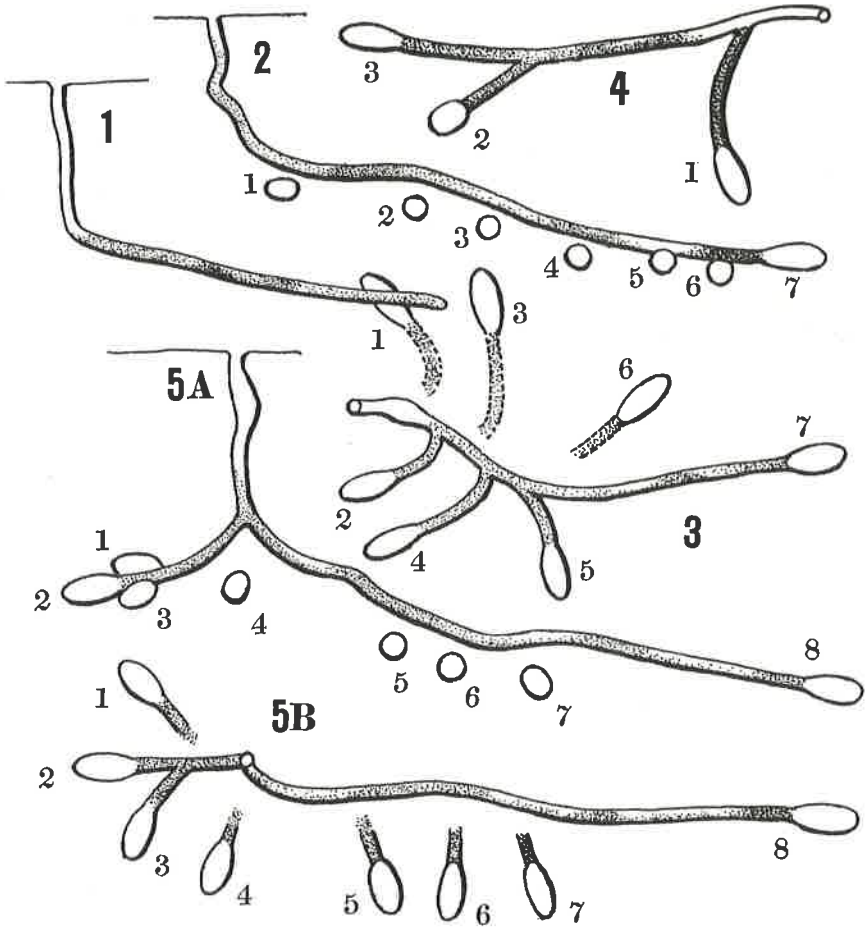
Among the out-leaving wasps of the brood the females do not disperse far away, as a rule. They return to their native place and determine the nesting sites, not far from their mothers' nests. This is the cause of their colony formation.

In the colony the female wasps pass the time at night and in bad weather in their own nests, possibly digging tunnels and cells during the time. Therefore, if one visits the colony early in the morning he can always find the wasps in the nest, usually at the entrance gallery preparing to go out. The behaviour of the wasp at this time was very finely narrated by Peckhams (1898) with *C. clypeata* and by Krombein (1952) with *C. robertsonii*.

**Nest structure.** At the entrance of the nest a mound of soil, about 2 cm in radius, is

observed early in the season. But as the time passes on it becomes more frequent that such an accessary disappears. This is probably due to that a larger amount of the soil taken out of the new cell is used to close the branch tunnel leading to the cell just accomplishid. Further, *Cerceris* has not a habit of taking out the dug up soil from the burrow, but leaves it in the tunnel packed either loosely or fairly compactly, except at the beginning of the nest construction.

In this species the burrow does not penetrate deep into the earth. It usually goes down for about 3–6 cm perpendicularly or in a very steep slope, then turns at about a right angle and runs in a gentle inclination for about 10–15 cm in the accomplished nest. Therefore, the burrow at the deepest place lies 10–15 cm down from the earth surface. Usually the main tunnel is not branched, but occasionally it is made so; in such a case, however, a single dichotomy is the rule.




Figs. 1–5. Nests of *Cerceris hortivaga* Kohl.
Figs. 1, 2 and 5A lateral view, 3, 4 and 5B vertical view. In some nests the entrance gallery is enlarged.

As above mentioned in the nest of *Cerceris* the tunnel is always more or less compactly packed with soil either thoroughly or intermittently. This makes the pursuance of the tunnel very difficult. We must find out by probing somewhat soft portion in the earth to follow after the tunnel. In the accomplished nest it is almost impossible to make clear the detailed structure of the burrow.

The burrow is 4 mm or so in diameter at the opening and enlarged near the entrance more

often than the other, sometimes for about 10 mm in length, but sometimes for 30–50 mm, especially in such a nest as is the entrance used in common by some companions.

The first cell is made close to the bottom of the entrance gallery. After it is provisioned, oviposited and the portion of the branch tunnel is closed the main burroow is extended and the second cell with its branch tunnel is made from the end of the burrow newly dug, a short distance beyond the first, the portion of the branch tunnel later closed being more or less turned to one side. Similarly are made the third and the fourth cells and so on from near the entrance towards the interior, always the branch tunnels, 2–5 cm in length, being compactly packed with soil after each end cell is completed.

Some wasps, after making a few cells along a comparatively short main burrow, cease to extend it further and dig a new main tunnel in other direction. Most of them, however, extend the burrow more or less straight, without forming the nest of the branched type. It seems that the wasp deposits all her eggs, as a rule, in a nest. Those wasps that make a second nests are considered to have lost their nests, owing probably to heavy rain during her absence or to the entrance disturbance caused mainly by men.

Table 2. Nests of *Cerceris hortivaga* Kohl.

| Nest No. | Cell No. | State | Prey | Offspring | Remarks |
|---|---|---|---|---|---|
| 2 | 1 | complete | 6 | larva 15 mm | Examined on June 12, 1931. |
| | 2 | complete | 9 | larva 13 mm | Depth of the cells: From 7 to 12 cm. |
| | 3 | complete | 8 | larva 10 mm | |
| | 4 | complete | 10 | larva 8 mm | |
| | 5 | complete | 7 | larva 6 mm | |
| | 6 | complete | 8 | egg | |
| | 7 | complete | 0 | — | |
| 3 | 1 | complete | ? | Mutillid ♂ | Examined on June 12, 1932. |
| | 2 | emerged | ? | old cocoon | Depth of the cells: From 7 to 10 cm. |
| | 3 | emerged | ? | old cocoon | In cell 4 an emerged wasp still remained in |
| | 4 | complete | ? | *Cerceris* ♀ | the cell. |
| | 5 | complete | ? | Mutillid ♂ | |
| | 6 | emerged | ? | old cocoon | |
| | 7 | emerged | ? | old cocoon | |
| 4 | 1 | complete | 5 | larva 10 mm | Examined on July 3, 1932. |
| | 2 | complete | 3 | none | Depth of cells: 5–7 cm. |
| | 3 | complete | 3 | none | |
| 5 | 1 | complete | ? | larva 15 mm | Examined on July 3, 1932. |
| | 2 | complete | 9 | larva 15 mm | Depth of cells: 10–13 cm. |
| | 3 | complete | 10 | larva 13 mm | Larvae in cells 1 and 2 nearly full-grown. |
| | 4 | complete | 5 | larva 13 mm | Prey were counted from remains. |
| | 5 | complete | ? | larva 10 mm | |
| | 6 | complete | ? | larva 10 mm | |
| | 7 | complete | 10 | larva 6 mm | |
| | 8 | complete | 1 | none | |
| 6 | 1 | complete | ? | larva 15 mm | Examined on Aug. 20, 1945. |
| | 2 | complete | 5 | larva 12 mm | |
| | 3 | incomplete | 1 | none | |
| 7 | 1 | complete | 6 | egg | Examined on Aug. 24, 1945. |
| | 2 | complete | 2 | none | Depth of cells: 10 cm. |
| | 3 | incomplete | 0 | none | |

The cells contained in a nest reach 8 in numder, as far as my digging results show. But they were all in the course of provisioning. The cell is 13–16 mm in maximum length and about a half in widh, with the inner wall smoothed and mostly polished. Some instances of the nest structure examined by myself were given in Figures 1–6.

In the nest-making activity of this species it seems worthy of notice that the cells are con-

structed from exterior (Table 2. cf. Figs. 1–7). Whether this is the rule in the Hymenoptera hunting *Cerceris* or merely a characteristic of this species remains still uncertain.

**Prey.** The prey consist mainly of solitary bees of the genus *Halictus*, sometimes containing also those of *Panurgus*, *Hylaeus*, *Sphecodes*. As related earlier I once obtained a female specimen of *Psen* (*Mimumesa*) *dahlbomi pacificus* Tsuneki, a Pemphrenid wasp, from a nest dug up in Sapporo.

The method of paralyzing the prey in the Hymenoptera-capturing *Cerceris* was described in detail by P. Marchal (1887) with *C. rybyensis* under both natural and experimental conditions. The method of *hortivaga* is much the same. In this species the prey is hunted by the wasp usually on the flowers of mostly wild Compositae and Umbelliferae. In our country it is not difficult to the nature observer, if he has a little perseverance, to witness the hunting manoevre of this species at the flower of *Aster fastigiatus*, one of the common wild Compositae with white petals. One's mere following after the wasp for a while will do. The wasp in hunting is used to visit from one flower to another, moving very slowly around each of them and when she finds a proper bee she suddenly dashes to it. She grasps it from the back, bent her abdomen and gives a sting or two very rapidly to the ventral side of the prey's thorax. During the time the wasp supports herself with her hind legs, sometimes hanging herself with one of the legs only and holding the bee with other pairs of legs. She then turns round the prey so as to hold it venter to venter and flies to some foothold near the place, carrying the prey with her mid pair of legs only. Usually she takes a rest a while and then goes to her nest with the prey.

The bees robbed of the wasps or found in the tunnel while they are stored temporarily are able to move their legs, antennae and mouth parts fairly actively, but with no coordination at all. Sometimes they can fly off by themselves or had they been thrown up in the air. But they can only draw disordered spirals and sooner or later drop to the ground. These bees are covered more or less with pollen and their crops are filled more or less with nectar.

On the other hand, bees found arranged in the cells of the wasps are quite motionless, without the covering pollen and with their crops empty. This is decidedly due to the manipulation performed by the wasp in her burrow. Experimental study carried out by Marchal showed the fact.

The number of the prey stored in one cell is from 5 to 11, as far as my observations go.

**Provisioning habits** It is the common habits observed in the members of *Cerceris* that prey hunting precedes cell construction. In this species also the wasp begins to collect the prey soon after the tunnel is somewhat deepened, without preparing the enlarged cell at its end. When the nesting schedule is fairly progressed, however, the wasp of this species usually digs the cell first and later brings the prey in it. In this case the manipulation given to the prey is considered carried out soon after taking it in the burrow, since even a single bee found in such a cell is almost completely motionless. Probably in such a stage of nesting work the wasp has much time to dig a cell during her stay in the burrow at night or in bad weather before her starting to hunt the prey.

The observations described below will indicate such relationships.

(No. 1) June 21, in Chiba near Tokyo. The tunnel goes perpendicularly down in the ground for 6 cm, then turns at a nearly right angle and proceeds further for about 10 cm with a very gentle inclination. The tunnel is here and there packed with soil and contains between the soil-plugs two fairly vividly moving bees. At the end of the tunnel where not the least trace of enlargement is observed four further bees are stocked, all being more or less movable (Fig. 1).

(No. 2) June 27, the same place. This nest contained 7 larval cells, 6 of which were

provisioned and completed. The last one was situated at the end of the main burrow. It was distinctly enlarged and had the inner wall polished. But there I could not find even a single prey stored. Also there was none of the prey stored in the tunnel (Fig . 2).

(No. 3) June 12, the same place. The tunnel penetrates into the ground at an angle of about 45° to the earth surface. Then, it turns to nearly herizontal and runs for about 5 cm in the same gentle inclination up to the end. Of course, no brood cell has been formed, yet in the tunnel there are three bees stuffed in the loosely packed soil.

(No. 4) July 3, the same place. I saw the wasp of this nest go in the opening with a prey on June 26. It was the rainy season and from that date the wasp was not favoured by good weather. When I examined the nest after a week at 9:00 she was staying below the entrance which was temporarily closed from within. The nest contained only 3 cells, the most proximate one of which was the accomplished, involving 5 bees and an egg attached to one of them and the other two were the unaccomplished. It is very interesting that the two unaccomplished cells contained respectively 3 bees without the egg of the wasp. Probably the wasp dug the cells during she was confined to her nest by unfavourable weather and the occasional booties obtained during the time were provisioned mechanically in either of the cells (Fig. 4 ).

(No. 5) The same place and date. This nest contained 8 cells 7 of which contained each a larva of the wasp and the remains of the prey. In the eighth cell located innermost was placed only a single bee without the wasp's egg and there was no temporary store of the prey in the tunnel. The stop of her work between the constructions of the last two cells must be due to the bad weather above mentioned (Fig. 5).

(No. 6) August 24, Sapporo. The structure of the nest is as given in Figure 6. The tunnel was loosely packed with aoil and at *a*, *b* and *c* is buried in the soil a bee of *Halictus* respectively, each could move fairly actively its legs and wings. One of them successively thrust its sting reflexively.

**Parasites.** ( 1 ) *Parasitic fly.* As frequently seen at the side of the nests of the digger wasps it is commonly observed that one to several parasitic flies crouch near the nests of this species. When the owner of the nest comes back with a prey they fly up and obstinately follow after the wasp. The manner is just the same as excellently narrated by J. H. Fabre with respect to *Bembix rostrata.*

In the literature we can find a number of reports recording a heavy damage of *Cerceris'* nests suffered from the invasion of the parasitic flies belonging to Tachinidae. It seems strange to me, however, that why the exotic congeners are so heavily molested by such flies, because the habitual soil packing of their tunnel is considered to be a distinct adaptive acquisition defensive of the parssitic flies. Moreover, they must have another defensive instinct relating to such behaviour that will be mentioned below regarding the species of our region. At least in the nests of *Cerceris* examined by me I have found none of them destroyed by the flies. The species of *Cerceris* of our regions, therefore, do not suffer any damage from them. The reasons for this seem to me: ( 1 ) They do not leave aside the prey before entering the nest. The entrance to their nests is always left open while the owners are out and the wasps when come back with the prey plunge into the opening dircetly from in the air after performing a short pendent flight a few times above it, without leaving the prey. ( 2 ) The tunnel of their nests is always stuffed more or less compactly with soil which does not permit the flies to penetrate, because the legs of the flies are too delicate to do so. Reason 1 is effective to prevent the flies from larvipositing directly on the prey, which is the most usual way of the parasites to send their maggots in the cells of the wasps. While reason 2 is useful in keeping the flies away from directly entering the larval

cells.

(2) *Ruby-tailed wasps.* It has been known in the European species that the ruby-tailed wasps belonging to the genus *Hedychrum* are the common parasites of *Cerceris*. In this species the same is the case. It is not rare to observe several individuals of the small rounded and flattened cuckoo wasps of the brilliant coloration crouching on the ground or alighting on the grass near the nests of this species. This is *Hedychrum gerstaeckeri japonicum* Cameron, a geographical race of a common species of *Hedychrum* occurring in Europe having the emerald green head and thorax and the fiery red abdomen, both with a metallic shimmer. This beautiful species of the cuckoo wasp does not follow after the prey-carrying wasps as the parasitic flies do, but it boldly penetrates into the nest of the host wasp while she is away. Apparently it has not an apprehension nor fear of the nest owner and it is not frightened when it encounters it, only rolling itself into a ball if attacked. No record has been reported until now on the actual obtainment of this cuckoo wasp from the nest of this *Cerceris*. But there is no doubt that it is parasitic on this species.

In Korea, I observed also *Hedychridinm roseum* frequently sitting on the ground of the colony of this species. Near the area, however, there was always a colony of another digger wasp, *Astata boops* Schrank, so that it was uncertain whether it was parasitic on either or both of the wasps.

(3) *Mutillids.* The third enemy of this digger wasp is the Mutillid, *Smicromyrme lewisi yanoi* Mickel. This species frequents the colony of *C. hortivaga* and the fact of their parasitizing the *Cerceris* was confirmed by the following observation:

June 12, 1932. Having dug up a nest it was made clear that it was the nest of the previous year and the opening was the emergence hole of the new born wasps. Seven cells were discovered which were distributed as given in Figure 3. (The numbers are conventional, not showing the order of the construction.) In cell Nos. 2, 3, 6 and 7 there were empy cocoons, yellowish brown in colour, and pushed backwards to the inner wall. Cell Nos. 1, 4 and 5 contained a cocoon respectively of which that of No. 4 involved a female adult wasp still remained in it and in those of Nos. 1 and 5 the Mutillid wasps, both males, were discovered. One of them had already shed its pupal skin and was beginning to tear open the cocoon, while the other had just gotten rid of the pupal skin. The cocoons that covered the Mutillids were apparently completely identical with those of *Cerceris*. The fact indicates that in this Mutillid also the egg is sent through the cocoon of the host insect and the hatching larva devours either the prepupa or pupa in the dormant state, as was formulated by C. E. Mickel (1928) as a typical case of the parasitizing method of the Mutillid wasps.

The Mutillid wasp is a powerful insects and it is not difficult to them to penetrate into the packed gallery of *Cerceris* to reach the host larval cell, probably led by the sense of smell[1].

**(2) Peculiar social relationships among the inhabitants of the colony**

It seems to be the general habit of the biological Hymenopterists to call the solitary wasps and bees that form the so-called colony 'subsocial'. In reality, however, in most of the cases there is no social relationships among the inhabitants, save those that are called protocooperation which

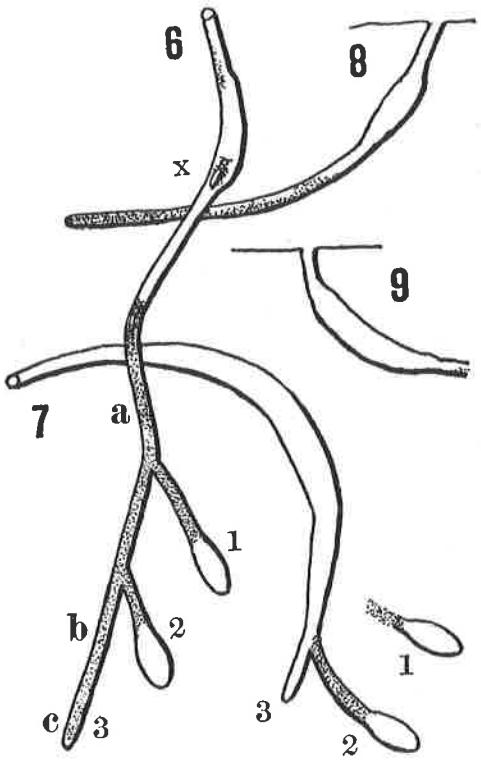
1) It was observed by me that the female Mutillid, *Squamulotilla ardescens* Smith, found the nest of a digger wasp by examining elaborately with her antennae the sand grains one by one that were taken out of the nest by the host wasp and scattered around the entrance of it. The delicately trembling antennae, their manner of encircling the sand grains gave me the impression that she was led by the density distribution of the smell of the host wasp transmitted to the grains while they were held by the wasp. To such parasites as these, therefore, the elavorate levelling behaviour of the spoil heap around the nest performed by some digger wasps every time of their departure is considered utterly of no use, since these parasites do not depend upon the sense of vision in the search of the nests of their host wasps.

arises mechanically as a result of mere grouping. In fact, the so-called colonies of the wasps anp bees are only a form of aggregations.

I thought the colony of *Cerceris hortivaga* to be the case. But when I saw two wasps live in one and the same nest and, moreover, make provisioning together at the Botanieal Garden in Sapporo I began to pay attention to the mutual relationships among them, because it was clear that they were not the sisters living in the mother's nest.

August 24, 1945. I dug a nest (Fig. 6) the tunnel of which was markedly widened at the first turning point (x) where a female wasp was at rest. Strange to say, in the interior of the nest, in front of the temporary store of bees (a) I found another wasp hidden. This was also a female.

The same place and date. In another nest I could confirm the presence of two wasps. They were seen from the opening to come out and to go in the burrow alternately. Later I saw two wasps carry in a prey respectively to the nest. Two days later when I dug the nest one of the wasps was out and the remaining one was the smaller of the two and it was a female. The entrance of the nest was 4 mm in diameter, but from a short distance below the opening the burrow was enlarged to about 8–9 mm in diameter and went in the similar broadness for about 7 cm (Fig. 7). Then it was narrowed again and soon became undiscernible from the surroundings. Search digging brought to me two cells, one of which was complete including 6 prey and the wasp's egg and the other incomplete inovlving 2 prey without the egg. In this nest it seems interesting that the burrow was so constructed as to adjust the movement of the two wasps in the nest (Fig. 7). Similar structure was observed in some of the other nests in which two wasps were present (Figs. 8 and 9).




Figs. 6–9. Nests of *Cerceris hortivaga* observed in the colony found in the Botanical Garden in Sapporo. The entrance gallery is markedly enlarged.

**The first observation.** On September 5, 1945. I began to follow the behaviour of the wasps of the colony by giving each of them an individual mark by means of the coloured shellac. The place of observation — the colony area — was a promenade between the flower gardens used at that time just after the war as kitchen gardens near the southwestern corner of the Botanical Garden in Sapporo. It was about 150 cm in wide and about 15 m in lenght and a large number of the Cerceris' nests were scattered densely over the area.

At 10:40, a female came back with a prey (*Sphecodes simillimus* Sm.) and went in nest A (Fig. 10). The nest had been closed from within, showing that the owner was inside. But the wasp penetrated carrying the prey.

At 10:43, a wasp came out of the nest. It was distinctly smaller than the one just observed. I caught it, marked it with a green spot on the back of the propodeum and released. She went to a shrub a meter away, rested for about a minute and returned to the entrance of nest A. At this moment the head of the other wasp was seen through the opening. As I had covered it with a small bottle *Green* turned round from there, landed on the ground a meter away, soon flew up and visited successively the openings of two other nests, entered there a little but soon came out,

walked and flew about until 10:45, when she entered nest B (Fig. 10) and stayed inside.

At 11:07. The wasp in nest A came out. I caught it and marked it with a vermilion spot. She flew away.

At 11:08, a wasp with a prey came back and entered nest B without showing the least confusion, in spite of the fact that there was *Green* inside. After a minute this wasp appeared empty-handed. She was caught, marked with a red spot and set free. At this moment a face of a wasp was seen in the opening, probably *Green*.

At 11:27, *Green* crawled out of the nest and flew about low over the colony area.

At 11:40, *Red* turned back without carrying a prey. She searched for the nest at western end of the cololy which was about 6 m away from nest B. She entered the nests of other wasps one after another, gradually approaching nest B. Finally she reached the nest, but to my surprise, she did not enter there, but passed over it and continued the apparent nest searching behaviour. Until this moment she had examined over 10 nests, sometimes reappeared after a moment, sometimes stayed for about a minute or more within. Finally, at 11:47, she penetrated into the tunnel of nest C and did not come out for a long time.

At 12:05, a wasp appeared in the colony with a prey. She flew to nest C and entered there without hesitation. After a second or two she came out leaving the prey inside. I caught her and marked with a white spot. *Red* did not come out of the nest.

At 12:10, *Green* returned empty-handed and searched about the nest to enter. After 4 min. she went in the opening of nest D which was situated only 25 cm from nest A, in which she went at the onset of this observation. I saw at this time that the *Sphecodes* which *Green* took in nest A about an hour and a half before crawled out of it by itself, but, curious to say, it turned back and entered the nest again.

At 12:20, *Green* came out of nest D and flew about in confusion in the bottle with which I had covered the opening. Soon, however, she happened to touch the earth with her legs and at once ceased flying to turn back into the nest.

At 12:46, *Green* came out again in the bottle and this time she was at once set free. *Red* was also seen struggling in the bottle that covered the burrow opening of nest C. She was also released.

At 13:15, *White* returned to the colony area carrying a bee. She went straight to nest C which was again covered with a bottle. She turned aside, hovered over the nearby ground or rested on the earth. After a minute *Green* appeared at the colony without a prey. *Red* also came back empty-handed. Both of them did not enter either nest B or nest C, though the entrance cover of the bottle had been removed. During the time *White* was already out of sight.

At 13:26, *Green* returned without carrying a prey and after hovering for 3 min. entered nest A.

At 13:30, *Red* reappeared with a prey. She searched for her (?) nest by examining from nest to nest, thrusting her head in the opening successively. Finally at 13:35 she went in nest E which was 60 cm apart from nest C, left the prey in it, reappeared at once, as if she was frightened by encountering other wasp hidden within. She hovered over the colony area for a long while and at 13:43 again turned back to nest E, reentered it and stayed in it.

At 13:45, *Vermilion* returned with a victim. She hovered low over the ground for about 2 min. and finally entered nest E, came out again leaving the bee in it, flew about a while, but again returned to this nest and went in again. This time she did not come out until I turned my eyes towards other wasps.

At 13:50. *Red* came out of nest E and flew off.

At 13:53, *White* appeared over the ground of the colony area, carrying a prey. She continued

slow hovering over the ground until 13:58 when she reached nest F which was situated 50 cm apart from nest C (Fig. 10) and which was closed at the entrance. The wasp left her prey aside, cleared the soil plug with her front legs, entered there, but at once turned back to the entrance, caught the prey, flew up and began to hover again. After 2 min. she apparently happened to come over nest F, landed and entered at once carrying the prey.

A moment later another unmarked wasp came straight to this nest with a prey and entered it without hesiation. She, however, reappeared at the entrance at once leaving the bee in the burrow, flew up and hovered low over the ground very slowly. After a while she landed again on the entrance of nest F and penetrated into the burrow. After a moment, however, she hurried up to the opening as if she was attacked from inside. She was caught and marked with blue.

At 14:04, *Blue* went to nest G which was 1 m apart from nest F, entered and pushed out of the opening the lamps of loose soil.

From the opening of nest F was also pushed out the soil plug, probably by *White*.

At 14:06, an unmarked wasp came flying with a prey and entered nest D smoothly.

A minute later *Vermilion* returned carrying a prey and flew about over nest A which was covered with a bottle. After a while she flew away and when I noticed her again she became empty-handed and flew about over a small area including nest A. I removed the bottle and she at once went in. Instantly, however, she turned back to the entrance, flew up, moved about over the ground in flight and again went to the entrance of nest A and penetrated into the burrow. This time she stayed inside.

When I turned back to the area after an hour I saw *Red* and *White* hovering over the ground very slowly, as if they were searching for their own nests.

According to the observations above described the five marked wasps went in the following nests and stayed for a considerable time:

Wasp *Green* ····· Nest A(twice), B(once), D(once).
Wasp *Vermilion* Nest A(twice**), E(once*).
Wasp *Red* ····· Nest B(once*), C(once), E(once*).
Wasp *White* ····· Nest C(once*), F(once*).
Wasp *Blue* ····· Nest F(once*), G(once).

An asterisk in the above list indicates that a prey is taken in at that time.

**The second observation** The next day, the weather was fine and I began a further observation at 9:30. Greater part of the nests of *Cerceris* had been opened, showing that the wasps had already gone out. The ground

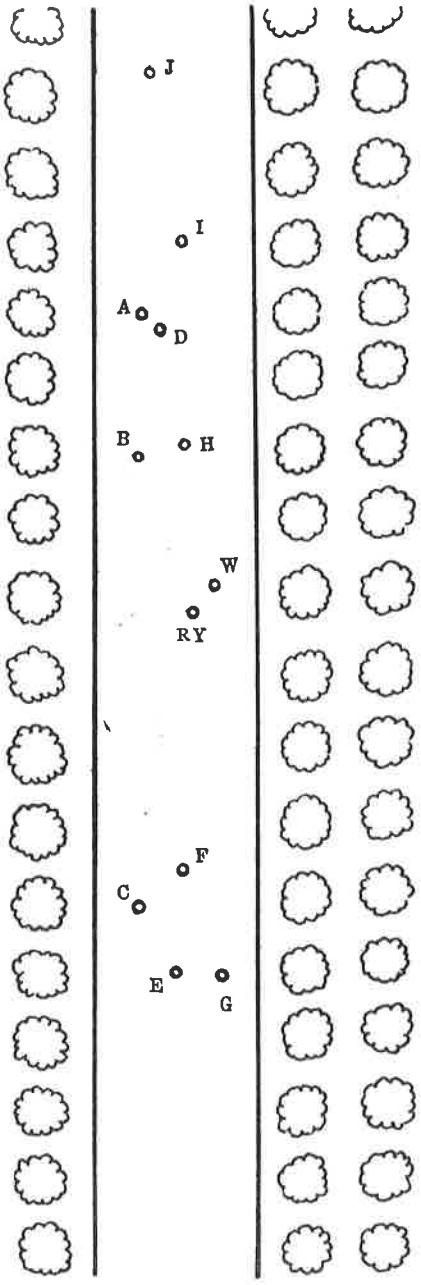



Fig. 10. Distribution of the nests which more than two wasps entered or provisioned.

of the area was, strange to say, inhabited also by a flourishing population of the Halictine bees in common with the *Cerceris*. The bees busily flew about over the area with their legs already turned yellow with pollen and their parasites, the red-banded *Sphecodes*, flew and walked about among them in a considerable number. Strange to say, the hunters did not attack the prey at their nesting place, although it would be the easiest way of capturing them if they wanted. Probably the instinct demanded them to attack the prey on the flower and nowhere else.

At 10:04, a female without a marking came flying carrying a bee, landed at the side of the closed entance of a nest and tried to enter. Suddenly, however, a confusion occurred. The prey was thrown aside and the wasp began to struggle moving violently her legs and wings in disorder. I approached and saw the yellow face of another wasp below the opening whose powerful mandibles caught the nape of the first wasp. She continued to struggle to free herself from the assailant's holding and the latter strived so as not to be pulled out by the struggling intruder. The fight appeared to be lasted forever. So I caught the wings of the attacked with a pincette and tried to pull her out. She kicked and rampaged more violently and succeeded in slipping out of the attacker's hold. Probably the latter, by feeling something unusual, loosened her hold. The attacked, as soon as she could roll out of the opening, caught the thrown out prey very promptly and reflexively and flew away eastwards. She, however, turned round at about 5 m from the nest and came straight to the opening, though her flight was very slow and was performed in a searching manner. She landed at the side of the nest again and tried to enter, as if she was confident of her justice. Again, however, she wes caught from inside. But this time she did not strive to set herself free from hold of the attacker, but strived to elbow in by force. Again the victim was thrown out to the entrance and struggled in the dust. The competition between the two wasps was lasted for two min. Finally the intruding wasp succeeded in proceeding a little, but she was again grasped by the defender by the constricted waist (the base of the abdomen) with her mandibles. The intruder also clasped the defender by the waist. They thus wrestled, venter to venter, head to tail. At last the competitors moved out of the entrance of the nest, bent each abdomen ventrally and they thus turned into a ball. A moment they whirled round in a mass. Then they were separated and the defender flew 50 cm westwards, landed and walked slowly towards the nest. During the time the intruder also flew off, but she did not forget to recapture the thrown out victim before flying up, and gave it a quick sting to the ventral side of the thorax. She turned round in the air, dashed at the competitor walking, gave her a violent body blow and flew away eastwards, carrying the victim under her body. The defender stood up from the attack, very promptly flew to the nest and penetrated. After half a min. the intruder returned to the nest again. The entrance had already roughly closed with the pushed out spoil, but she forced in it and this time succeeded in entering with the prey without receiving resistance.

I covered the entrance with a bottle. After a while a female came out and then the other female. From the slight difference in size it was made out that the former was the intruder and the latter was the defender. I caught them and marked the former with a yellow spot and the latter with two red spots. The nest was called RY.

At 10:15, *Red* came back with a prey, hovered low over the ground, landed from time to time at some openings of the nests to try to enter, but every time the trial was ceased on the way to fly up carrying the prey. Sometimes she rested on the ground for a while. During the time she came twice over the opening of nest B which was provisioned by her the previous day, but passed it over each time without paying the least attention.

At 10:20, she finally entered nest H which was 50 cm away from nest B. After a min. she came out free-handed, flew up and resumed hovering. Soon, however, she turned back to

H again, entered it and stayed inside. Two min. later the head of the wasp was seen in the burrow through the opening. After staying there a while the wasp came out of the opening, flew up, circled round twice over the opening and flew away eastwards. Soon, however, she turned back to the colony area, slowly hovered and finally entered nest I which was situated 170 cm westwards from nest H.

10:25, the weather suddenly became clouded and began to rain. It continued till 14:30.

**The third observation**. September 7. The weather was fine. But when I arrived at the colony area at 10:30, I could see only a few of the unmarked wasps from time to time make their appearance, although a larger part of the nest entrances were already cleared up. The insects that actively walked about on the ground were the parasitic bees of the genus *Sphecodes* alone who were searching for the proper nests of *Halictus*.

At 10:58 I saw a wasp without carrying a prey came flying from the east. I approached and could confirm that she was *White*. She flew about hither and thither for a long while and at last entered nest G and stayed in it.

At 11:40 *Yellow* came back without a prey. After a considerable while of hovering low over the ground she went to an opening of a nest (W) located 25 cm towards NW of nest RY which was closed probably by the rain of the previous day, entered there and at once pushed out the soil mass.

At 12:10, *Red-red* came back empty-handed and searched about the nest to enter. At this moment *Green* also made her appearance, carrying a prey. She went to a nest (J) located 2 m westwards of nest A, entered there at once and pushed out the earth from within.

12:15, search behaviour of Red-red on and over the colony area was still lasting.

At 12:20, however, she was disappeared from the area and an unmarked wasp without a prey entered nest G and pushed out débri from the entrance.

12:23, another unmarked wasp appeared from nest F and flew away.

12:25, *Yellow* came out of nest W and flew about slowly over the ground. I opened the entrance of nest RY. At 12:30 she came to the entrance, thrust her head in it, but retreated and resumed her search flight. The range of her flight was mainly confined to an area of 50 cm in radius around nest RY.

12:31, *Green* came out of nest J, bathed the sun a while and reentered the nest. *Yellow* still continued her search flight, resting occasionally on the ground or on the leaf of the shrub nearby, but at 12:35 she flew off.

12:37, *White* returned without the prey. As the entrance of nest G was not covered with a bottle the time of her departure was not observed. At 40, she entered nest E, but soon appeared at the opening and flew about over the ground.

12:41, *Yellow* made her appearance at the colony. After flying about a while she went in nest W, but at once came out. At the entrance she turned round and crept in again. However, after a moment she returned to the opening and flew off, visiting from nest to nest. At 43 she disappeared from the area but soon reappeared over the colony ground, without carrying the prey and went in nest E. After a minute she crept out and flew about again over the area until 12:47 when she flew away.

At 12:50, *White* also flew away.

Probably because of the comparatively low temperature of the day activity of the wasps was not heightened and it was regretted that the prey carrying wasps were very few. However, it was clarified that *Green* entered and provisioned a nest other than the ones she entered the previous day, and that *White* also entered and stayed a long while in nest G. Further, nest F was occupi-

ed by an unmarked wasp. The same was the case with nest G. Still further, it seems strange that either *Yellow* or *Red-red* did not pay the least attention to nest RY around which they developed so furious a battle the previous day.

**Consideration.** Judging from the observations above mentioned at least in the members of the colony dealt with here the memory on the site of one's own nest is very weak. It is very strange as compared with other fossorial Hymenoptera wherein the site memory is generally so strong and accurate that it seems rather marvellous. However, as a general outcome of such an inferior ability of the site memory of the wasps concerning their own nests the interesting and very peculiar social relationships come to appear. Most of the wasps observed here do not possess such a nest as is definitely descriminated from others as its own. It seems that they enter and provision any favourable nest having probably a general similarity in structure as well as in site. Some individual that happens to stay in some uncertain nest at night may dig a brood-cell at the end of the burrow, and some individual that happens to be in the nest which has been provisioned with a considerable number of the prey insects by some uncertain wasps may arrange them in the cell and may deposit her egg upon them.

Therefore, the result is that a mass of nests and cells are made, provisioned and oviposited by a mass of uncertain wasps quite indiscriminately. Accordingly the wasps emerged from one and the same nest are not always, or rather usually not, brothers and sisters. Taking a single cell as an instance, it is completed by the cooperation of a lot of wasps.

This is a very peculiar social relationships, never known among the insect world and has somewhat a resemblance with the so-called promiscuity, believed by some sociologists to have developed in the primitive human society, in which there are a mass of wives and a mass of hnsbands and the offsprings born amongst them are indiscriminately brought up by all as common children.

**( 3 ) Return to the nest**

The study on return to the nest in insects has mainly been carried out with honeybees and ants. A bulk of results hitherto accumulated and are still expanding with these insects can not simply been summarized. The purpose of the present short report is not to place my result upon the general summary of the problem, but to present a record as a material of such a problem with respect to the digger wasp.

On the other hand, the studies of the problem made heretofore with digger wasps or solitary bees are not always few*. But it seems rather curious that the majority of the studies concern mainly to the final phase of the problem, namely the recognition of the nest site or the nest itself, and did not touch upon the fundamental aspect as to what range the insects concerned can return from.

Apart from the mysterious problem how some insects find about their ways for their nests at a certain place that lies so far apart that it ts considered quite unknown to them, the study of this sort will have at least an ecological significance to determine the home range of the insects that have no ability to return to their nesting site from the territory unknown to them.

**Fabre's experiments with *Cerceris rufipes*** (= *tuberculata*). The studies on the problem of orientation using the wasps of the genus *Cerceris* have hitherto been made by four investigators, namely Fabre (1879), Peckham (1898), Grandi (1926) and Marquenie (1954). Among

* J.H. Fabre (1882), E.L. Bouvier (1900), P. Marchal (1893), E. Marchand (1900), C. Ferton (1905, 08, 10), C.H. Turner (1908a and b), C.N. Ainslie (1920), N. Tinbergen (1932, 35, 38a and b), G.P. Baerends (1941), J.J. van Iersel (1952), J.A. Chmurzynski (1953, 59, 60, 64), J. G. M. Marquenie (1954), K. Tsuneki (1936, 46, 50, 56).

these investigators Fabre alone dealt with the problem of return to the nest. In his first experiment he moved 12 females, without giving sight of the external world, to the field, 2 km northwards, and released. All the wasps started directly southwards and he found after 5 hours 4 wasps re-

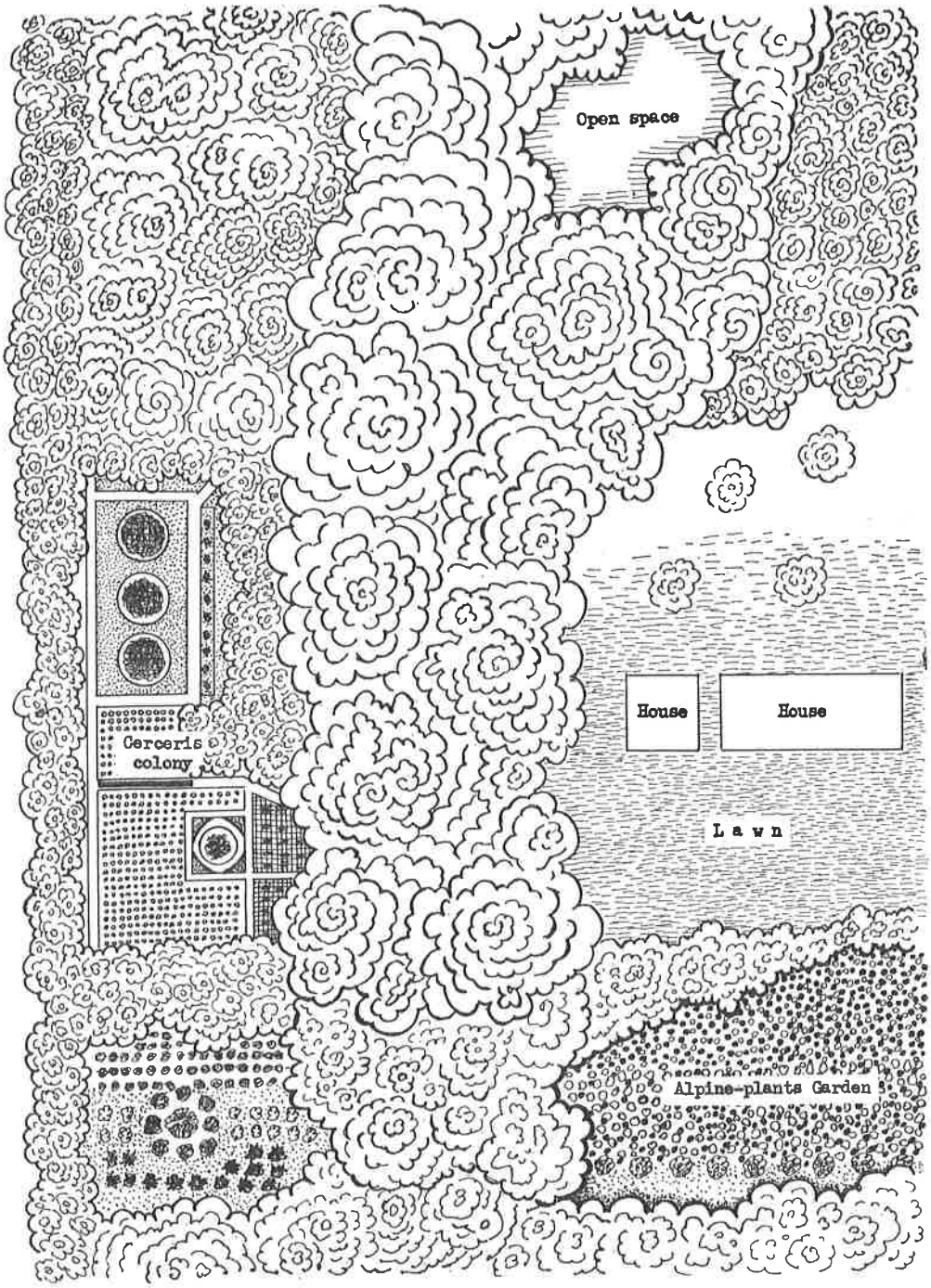



Fig. 11. Environment of the *Cerceris* colony in the Botanical Garden. The path occupied by the colony was indicated by a black bar at the left hand of the Figure.

turned to their nesting area.

Succeedingly he captured 9 females, including 3 that were resued, transported them 3 km northwards and released in the street of a town the next day. All the wasps set free flew high up between the rows of houses and as soon as they reached the open sky they directly flew away towards the south. After several hours when he examined their nesting place none of the wasps had returned. But the next day, he could find out 5 of them already returned and working.

From such results he concluded that the *Cerceris* had capacity of finding their way home from the areas quite unknown to them.

In my experments using *Cerceris hortivaga* the results were quite another thing. It remains uncertain, however, whether the difference is dependent upon the difference in the capacity of the species concerned, or upon the difference in the environmental conditions of the nesting areas of the two species.

**Place and time of my experiments.** The Sapporo Botanical Garden; the colony dealt with in the preceding section; August 21–September 4, 1945. Namely, this experiment preceded the observation mentioned in the foregoing section. The topography of the habitat of the *Cerceris*-colony at that time was roughly as given in Figure 11. A space of about 3 ares was considered their home range, since within the area there were abundant flowering plants that furnished them the necessary nectar for themselves and rich prey for their young. The space was bordered westwards by a narrow belt of trees, about 5 m in averaged height and 5 m in width and adjacent to the city houses having more or less wide gardens across a 10 m road. To the south and north it had thickets of shrubs and trees, 5–10 m high, and eastwards it was separated from the main portion of the Garden by a wood of tall trees, 15–20 m in height and about 40 m in width. The thicket lying north of the space was broad and deep and the wasps were considered not to go over there. On the other hand, those bordering west and south of the space were comparatively low and narrow and they might go out in some occasions.

**Expariment 1.** August 21. During 9:30–10:30, I captured 30 female individuals at the entrances to their nests when they came back there with the prey. Each of them was put in a tube bottle, 10 cm long and 1 cm across. These bottles were again placed in a card-paper box and the box was enclosed with a sheet of black cloth. The box was given a series of complex rotation before departure and then it was transported during 10: 35–10:50 to the Faculty of Science of Hokkaido University, situated about 500 m toward NNE of their habitat. Until 11:00 they were all marked with a white spot of shellac on the mesonotum. At 12:00 the box was carried to the top of the building about 15 m above the ground, and the wasps were released one by one. At that time the mild wind from the south, about 3 m per sec., was blowing. Of the 30 wasps 25 flew off southwards against this wind, some ones directly and others after circling once or twice above the experimenter, 2 went westwards, 2 landed nearby and after taking a short rest flew away southwards and only 1 could not fly up.

I arrived at their settlement at 12:20, but not a single marked individual could be found there. I waited till 15:00 but none of them did turn back. From that day on till the 25th of the same month I went to the Garden every day, but could not find any of the white spotted wasps on the road occupied by the colony.

**Experiment 2.** During 14:00–15:00 of the same day I collected further 27 female wasps of which 23 carried the prey. They were imprisoned in the separate bottles which were again enclosed in a card-paper box and brought to the laboratory at Hokkaido University, because it was too late to perform experiments. The next day (the 22nd) the weather was unfavourable for the experiments. A half of the wasps were antennae amputated and marked with a red spot and the

other half were left intact and marked with a vermilion spot. All were fed with sugar solution and kept in the dark.

August 23. The weather became fine. There was mild SE wind of about 2 m per sec.

At 9:30 I was at the centre of the lawn of the Botanical Garden with the box of wasps, about 70 m eastwards from their colony area. As above stated, between the two places lay a belt of tall trees, about 15–20 m high and 40 m or so wide, It was considered that the majority of the wasps of the colony would have no experience whatever of visiting the lawn, since the space they lived was surrounded by the thickets of trees and shrubs and, moreover, it had rich sources of not only their nourishment but also their prey, and they had no need of going out of the space as far as they would pass the usual life. It must particularly be noted, however, that the belt of tall trees lying between their colony area and the lawn could be passed by them if they wanted, since above the bamboo-grass floor there rested comparatively broad passable space between trunks of trees. But the place is gloomy owing to the dense canopy of trees and had nothing to attract the wasps. This is the reason why I thought that the lawn is the unknown place to the majority of the wasps.

I selected from each group of the imprisoend wasps 10 healthy and vigorous individuals and set them free one after another. Most of them flew towards the southeast (probably due to anemotaxis), some after trying the so-called orientation flight. One of the red marked wasps was canght dy a robber fly as soon as she started from the bottle opening. The rest all flew away.

I at once went to their colony area and waited till 10:20, but none of them, either the intact nor the antennae amputated did make their appearance.

I then captured another 10 females, all carrying the prey and marked each of them with a yellow spot. Then the wasps were taken directly eastwards through the wood to the same spot of the lawn where the foregoing release was carried out. During the transportation the wasps were put in the dark box. The time of imprisonment was, in this case, far shorter than that of the preceding experiment and the fact seemed far more favourable to the wasps to return.

At 10:40 I began to set them free. The wind was almost still, with a very mild breeze from the southeast. The behaviour of the wasps at the time of departure was as follows:

No. 1. Soaring high up in the sky to about 10 m, then flew to the east.

No. 2. Circling above the experimenter and flew to the northwest.

No. 3. Started directly to the northwest.

No. 4. Flying high up to about 15 m, then flew off to the east.

No. 5. Slowly flew to the east.

No. 6. Soon landed on the nearby grass leaf and did not start after all, though she was again and again caught and thrown up in the air.

No. 7 and No. 9. Circling twice above the place and flew to the southeast.

No. 8 and No. 10. Flew directly to the southeast.

Thus among the nine wasps released, 3 flew to the east, 2 to the northwest and 4 to the southeast and none of them started directly in the homeward direction.

I went at once back to their nesting site and waited till 12:30 but not a single of them and not a single of the wasps previously released could be found on their colony area.

The next day (Aug. 24) at 11:00, I went to their nesting place and found that the following wasps had turned back to their home ground:

2 wasps marked with the red spot (antennae removed).

2 wasps marked with the vermilion spot (antennae intact).

5 wasps marked with the yellow spot (antennae intact).

No further wasp returned until 17:00.

But the next day (Aug. 25) at 10:00 I could confirm the presence of 6 wasps with a yellow spot on their mesonotum, that is to say, one further wasp could come back to her nesting area. However, untill evening of the day no other wasp used in the experiments appeared on their nesting ground.

**Experiment 3.** August 24, at 12:00. I captured 7 female wasps and took them to an open space, 100 m northeast of their colony. The place was surrounded by the dense wood, covered sparsely with weed and there was no flowering plant within the area.

The method of transportation was as before. They were marked with a blue sopt on the thorax and at once released. All of them landed on the nearby place and after resting a while flew off. This is due probably to the treatment for marking. The direction in which they flew was quite uncertain. Some went to the south, some to the west, and others to the northeast or to the east.

They did not return to the site of their nests, though I waited unted 17:00 of the day. On 25, slso I cound not discover any of the blue marked wasps on their colony ground.

**Experiment 4.** September 3. At 10:30, I caught 3 females that came back with the prey and marked each of them with a green spot. They were separately imprisoned in a tube bottle and carried in my pocket to the southeastern corner of the open space they lived, 25 m away from their nests. The place was considered to be within their home range and well known by the wasps. Before they were set free, both antennae were amputated from them. During 10:33–10:35 they were released.

At 10:38, one of the wasps came back to the colony area.

At 11:35, a second wasp made her appearance.

At 11:55, the last wasp appeared on the nesting area.

**Summary of the result.** The materials were all females that were in the course of provisioning their nests. During transportation the external world was shut out.

Of the 30 wasps released soon after being caught in the town, 500 m away from their nesting place none could return to their colony area.

Of the 20 wasps, half with the antennae amputated, released at the place, 70 m away from their nests but was separated by a belt of tall trees, and after imprisonment of 42 hours 2 of each group could return the next day.

Of the 10 wasps released at the same place but soon after capturing, 6 were found returned the next day, of which 5 came back the same day.

Of the 7 wasps released soon after being caguht from the place only 100 m away from the colony but separated by the wood none could turn back to their nesting site after all.

On the other hand, 3 wasps with the antennae amputated and released at a corner of the open space they lived, 25 m away from their nests, all returned soon.

**Consideration.** The general result obtained seems to show that the wasps used in the experiments can not return to their nesting area from the places that are considered unknown to them, even when it lies quite close to it (Experiment 3). While they can turn back very easily from the spot lying withing an area that is considered to be their home ground. Among the releasing places the lawn in the Botanical Garden alone seems to pose a question. It lies quite adjacent to their nesting area, only being separated by a belt of wood, As mentioned in the foregoing page, however, the spaces between tree trunks are broad and easily passable if they want. Moreover, another tree belt bordering the south of the space of their nesting place is comparatively low, about 5 m in height, so that they can fly over the trees to go to the southern open place where flowering plants are more or less cultivated. Still further, the eastern tree belt of this open area,

the extention of tall wood bordering the east of their nesting site, is not so high. Therefore, if the wasps fly over these two zones of trees they can reach the Alpine Vegetation Garden that lies adjacent to the south of the lawn on which the wasps were released in Experiment 2. Taking these matters into consideration, it seems not necessarily undue to suppose that some of the wasps employed in the experiment had experience to be on the Alpine Plant Garden where various kinds of flowers bloomed. The results in experiment 2 are explicable on the basis of this assumption. On the other hand, the place where Experiment 3 was performed was a flowerless patch of open space surrounded by the dense thickets of tall trees. It had no nest of the Halictine bees. Therefore, it seems natural to suppose that the wasps had no experience whatever of visiting such an unattractive place. The result obtained here, however, seems to be rather casual, since the distance the wasps were transported was so small that at least an eighth of them must be able to return to their nesting area even if they disperse at random. Moreover, if a half of them had an experience to have visied the Alpine-plant Garden situated south to southeast of the release point across a tree belt (depending on the results of experiment 2), return of at least a quarter of them is probable under the random dispersion. Therefore, the result of experiment 3 must be said to represent an extreme case out of various probabilities.

### (4) Behaviour of the antennae-amputated wasp.

In the experiments described in the preceding section some of the wasps employed were amputated their antennae from the base. This was done in connection with other problem regarding the homing mechanism.

While observing their behaviour at their colony ground I found that none of them turned back carrying the prey. When such a wasp comes back to the nesting area she enters this or that nest, sometimes staying a while in it and sometimes comes out to search for another. The behaviour appears not substantially different from that of the normal wasp, except that she is always empty-handed. These antennae-lost wasps disappear after a while from the area, but soon fly back from anywhere. But none of them, so far observed by me, came back with the prey, though they were found flying about over the colony ground, entering from time to time this or that opening during subsequent one or two days.

In order to confirm the fact, on September 3 at 10:00 I captured 10 females anew that were in the course of provisioning their nests. Their antennae were amputated at the base. They were numbered by means of the coloured shellac and liberated.

All the wasps disappeared from the area, but after 30 min. or so they came back one by one. I stayed at the colony area until 15:00 observing their behaviour. But I could not find any one of them carry the prey. The next day I continued the observation from 9:00 to 16:00. Nos. 1, 2, 4, 7 and 10 were observed. But none of them was with the prey.

Similar loss of hunting behaviour was confirmed later in *Bembix niponica* Smith from which the antennae were cut off (Tsuneki, 1956).

It is not certain, however, whether this is due to loss of sensation (tactile and olfactory) necessary for searching for the prey, or due to loss of something relating psychic entity.

## 2. *Cerceris rybyensis japonica* Ashmead

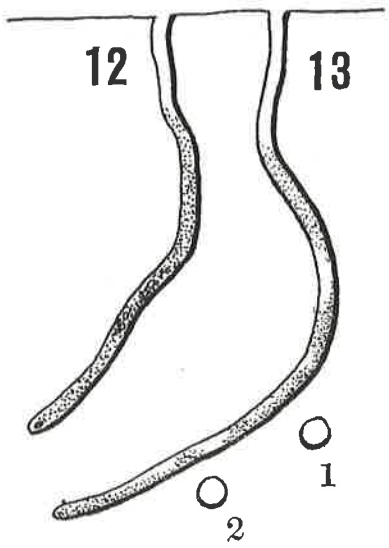
Unfortunately the seven nests that I dug up were all imcomplete. I therefore cannot give the detailed comparison of the nest structure of this species with that of *C. hortivaga*. But, in the nesting site, in the appearance of the nest from outside, in the structure of the nest as far as observed excepting for the fact that it is more deeply penetrated into the earth, in the mode of capturing the prey, in the range of the prey species (mainly *Halictus*, occasionally *Andrena*,

*Panurgus* observed), in the methods of provisioning and oviposition, the habits of the present species are very similar to those of the species compared.

In this species also we can find some struggling prey stuffed in the loosely packed soil of the incomplete burrow. The egg of the wasp is similarly laid on the ventral side of the thorax of the prey which is placed, venter up, on top of the prey mass in the cell. The manner of oviposition is also similar to the case in *C. hortivaga*, and the number of the prey stored per one cell is from 4 to 7 according to their body size. The cells in a nest are made from exterior to interior, thus in the endless type, as far as my observations go.

I once had a chance of observing the hunting behaviour of this species:

A wasp rushed furiously on the back of a bee that was sucking honey from the flower of a Chrysanthemum. As soon as she grasped the prey her abdomen was bent and instantly stung it at the central region of the ventral plate of the thorax. She then carried the bee on to a leaf of a shrub and nibbled and malaxated the nape of it leisurely.




Figs. 12 and 13. Nests of *Crecreis rybyensis japonica* Ashmead. Both incomplete.

So far as I have observed the colony of this species is, however, not so large as in some cases of *C. hortivaga*. Further, it has been left uninvestigated whether or not there is a similar curious social relation among the members of the colony.

Two instances of the nest structure of this species are given in Figures 12 and 13.

The nominate race of this species occurs widely in Europe and its nesting biology has been touched upon by a number of investigators such as Walckenaer (1817), Goureau (1834), Shuckard (1837), Lepeletier (1841), Dahlbom (1843), Schenck (1857), Smith (1858), Lucas (1867), Thomson (1874), André (1886), Marchal (1887), Sickmann (1891), Borries (1897), Barnes (1902), Adlerz (1903), Alfken (1899), (1913), Ferton (1905), Fahringer (1922), Perkins (1923), Berland (1925), Bristowe (1927), Hamm and Richards (1930), Minkiewicz (1932), and Olberg (1957), mostly under the name *ornata* Fabr, and the majority dealing with the prey species only. Amongst the above the investigation of P. Marchal (1887), though it belongs to the classical work, is outstanding.

According to these authors the structure of the nest of this species is considerably varied with the condition of the place. The depth to which it reaches is from 5 to 15 cm. The prey are mainly *Halictus*, but contains also bees of the genera *Andrena*, *Hylaeus*, *Panurgus* and *Halictoides*.

The Japanese subspecies seems to differ in no essential aspect from the typical race in biology, except that the burrow is sometimes dug much deeper, reaching 20–25 cm in depth.

*Taxonomic note*: *Cerceris interruptus* Matsumura, Thous. Ins. Jap., Suppl. IV, p. 168, 1912 (nec *interrupta* Panzer, 1799); Ibid., Ed. II, p. 152, 1930, is a synonym of this subspecies.

### (3) ***Cerceris arenaria*** Linné

This species has long been known as *C. quinquecincia* Ashmead (nec Fabr.) among the Japanese entomologists and its nesting habits were fragmentally recorded under this specific name (Kuribara, 1931; Hamatake and others, 1931, Tsuneki, 1937). This species is, however, one of

the commonest representatives of *Cerceris* in Europe and its nesting biology has long since been studied and recorded by many investigators (Kirby, 1815; Westwood, 1836; Dahlbom, 1843; Lucas, 1858; Smith, 1858; Thomson, 1874; Fabre, 1879; Kohl, 1880; Sickmann, 1891; Alfken, 1899, 1915; Adlerz, 1903, Hallett, 1914; Feytaud, 1914; Fahringer, 1922; Perkins, 1923; Berland, 1925; Grandi. 1926, 61; Chevalier, 1927; Hamm and Richards, 1930; Olberg, 1959). Most of the records made, however, concern mainly the kind of the prey, but some deal with the general biology in considerable detail.

According to Adlerz the female more often steals the burrow of the bee, *Trachusa serratulae* Pz. than digging by herself. It begins hunting before preparing its first cell. The cells are made comparatively shallowly in sand, the majority lying at a depth of 7 cm. In one cell are stored 5–12 (usually 8) weevils. As a rule the prey can move more or less some of the appendages. In this respect Hamm and Richards record that the state is fairly varied, including one with no sign of life.

Grandi (1926) studied the site recognition in this species. Richards (1930) made the following interesting observation: The males pester the females when the latter were returning to their nest with prey. By clinging to their back, the males made it impossible for the females to enter the burrows. The females got rid of the males by walking between two pine-needles and so scraping them off.

The following genera belonging mostly to Curculionidae have been known to be captured by the wasps as prey for their young:

Eumolpidae: *Bromius* (Lucas, 1858), but ?

Curculionidae: *Otiorrhychus, Strophosomus, Phytonomus, Balaninus, Brachyderes, Cneorrhinus, Geonemus, Sitona, Tanymecus, Lepyrus, Caulostrophus, Peritelus.*

According to Richards, the nests of some individuals observed at Oxshott were stocked almost entirely with *Balaninus*, while other nests contained mainly *Strophosomus*. He considered that further observations may show that there is a tendency for some of these wasps especially to attack either weevils on pines or on deciduous trees and shrubs.

In a Sphecid, *Sphex argentatus fumosus* occurring in Japan I observed a similar differentiating tendency of prey selection (Tsuneki, 1946, 63).

As parasites are known the Chrysid, *Hedychrum nobile* Scopoli and several species of parasitic flies. These flies follow after the females when they turn back to their nests with prey.

* * *

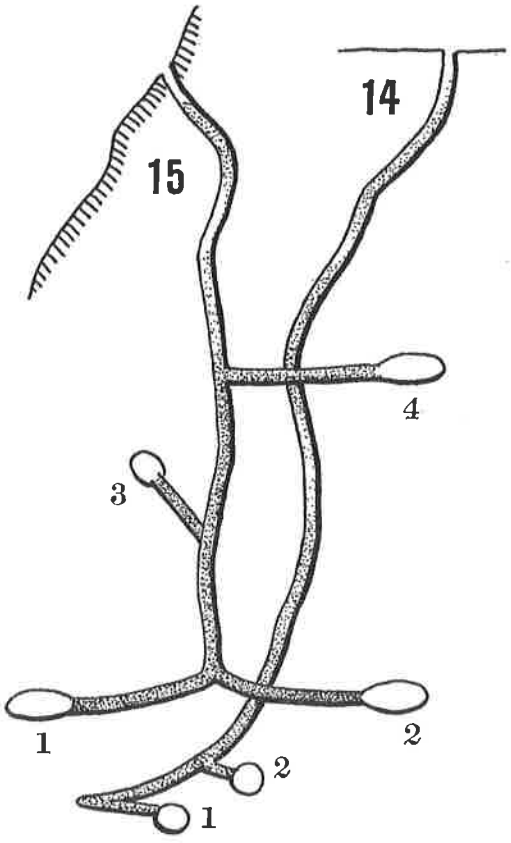
In Japan this species is distributed over wide regions of four main Islands, but their habitat is rather restricted to the sandy areas near the sea shore. Sometimes, however, they live in the loamy ground of considerable hardness.

**Nest.** So far as I have observed the wasp of this species in Japan digs its nest, as a rule, by itself. But in the suburbs of Sapporo I also observed some wasps enter the nests of the solitary bees that burrow in the same area. However, they did not steal completely the burrow, but after entering a short distance they dug their own tunnels. At first the entrance gallery was used in common (but not simultaneously), but after a few days a new tunnel with its own opening was made from the main burrow by the bee (probably because the tunnel is packed with sand by the wasp) and the two nests became completely separated.

All the nests that I dug up while they were provisioned were constructed very deep, the main burrow penetrating up to 40–50 cm into the earth. But in the course of excavating I frequently discovered sets of old cells located much shallower. Therefore, it is supposed that the depth of the cells made by this species is varied not with the condition of the ground, but with the in-

dividual. Further, as I dug the nests both early in July (the first generation) and late in September (the second generation) the difference in the depth does not depend upon the instinctive precaution of the wasps concerning the climatic condition.

The nests observed on July 3, 1932 in the suburbs of Chiba (near Tokyo): 25 cm (no cell), 40 cm (no cell), 47 cm (no cell), 10–12 cm (old cells), 17–20 cm (old cells), 13–15 cm (old cells) in depth. While the nest dug up on September 20 in the same place was 35 cm in depth; those studied on September 28 in the suburbs of Sapporo, Hokkaido, had the cells located 25–58 cm and 28–45 cm in depth. Two instances of the nest structure are given in Figures 14 and 15.




Figs. 14 and 15. Nests of *Cerceris arenaria* Linné. Both in the course of construction.

The cell is comparatively large, 15–17 mm in length and 9–11 mm in maximum width, with the wall smoothly pressed.

**Hunting**. On September 10, at Momiji-yama, in the suburbs of Sapporo. At about 13:30 I saw a wasp of this species fly swiftly to the plant, *Artemisia vulgaris*, carrying a prey insect. She hung down from a leaf with one of her hind legs, venter up, holding the prey on her breast. It was held venter up, that is to say, caught from the back by the wasp, and head to head. The wasp quickly bent her sbdomen and stung the prey at the junction of pro and mesosternum. She then turned round the prey, held it venter to venter and flew away.

**Prey**. The prey are all Curculionids. Those collected in Chiba are *Scepticus griceus* Roelofs and *Scepticus* sp (det. Dr. H. Yuasa) and those obtained in Sapporo are all *Scepticus tigrinus* Roelofs (det. Mr. H. Kamiya). They are all almost immovable, without sign of life.

**Provisioning**. Following the general rule in this genus, this species also begins hunting before preparing the cell in which the pery captured are to be stocked. This is not only with respect to the first cell, but also to the cells later constructed:

(1) July 3, Chiba. The burrow after turning several times ended at a depth of 25 cm (20 cm from the entrance in the horizontal distance) and there was placed one Curculionid. No cell could be found below and around the spot.

(2) July 3, Chiba. The tunnel penetrated to a depth of 40 cm and towards the end there were stored 7 weevils in the loosely packed sand in the burrow. But no cell could be found in the nest.

(3) The same place and date. The burrow reached 47 cm below the surface and in the tunnel 11 weevils were stocked, mostly single, some in twos, with intervening sand-packing in between.

(4) September 20, Chiba. The main tunnel penetrated up to 35 cm in the earth and contained 2 completed cells. In the tunnel there were intermittent sand-packings and in some of them

near the entrance there were 8 prey provisionally stocked.

(5) September 28, 1948, Sapporo. The nest (Fig. 15) contained 4 cells already, but in the tunnel, about 10–12 cm in depth, 4 weevils were buried in the packed sand.

(6) The same date and place. There were 3 cells in the nest already completed. But in the tunnel 7 prey were laid in the sand packing.

The unmber of the prey collected in one cell is from 4 to 17, according to the size of the prey:

New cells observed in Chiba: (6 and 8).

New cells observed in Sapporo: (5, 5, 4 and 6) and (5, 7 and 7).

Old cells observed in Chiba: (14, 15, 7, 13, 6, 6, 9, 11, 13, 17),

In the placement of the prey some confusion is observed.

Nest No. 5 observed in Sapporo (Fig. 15) contained 4 cells completed. In cell 4 out of 5 prey collected 3 were head in, while the remaining 2 head out. In cell 3, all but one head in; in cell 2 2 out of 4 prey head out and in cell 1, of the 4 prey left untouched by the larva one head out. But all the prey were laid venter up.

The disorder observed with respect to the head orientation of the prey seems to be due to the random placement of them in the tunnel when the wasp stores them provisionally there. While the regularity in the dorso-ventral direction of the prey is considered to be dependent upon the fixed mode of catching the prey, venter to venter, by the wasp. Further the fact seems to show that the wasp does not use the mouth part in carrying the prey at least in the burrow.

**Order of cell construction.** In *Cerceris hortivaga* the cells are constructed from near the entrance towards the interior, that is to say, in the endless type. In *C. arenaria* the order of cell construction is completely reverse. The first cell is made from the bottom of the main tunnel, the second is excavated in front of the first. Thus the 3rd, 4th and so on are constructed gradually towards the entrance. Therefore, it belongs to the limited type. As for instance, nest No. 5 observed in Sapporo will be cited (Fig. 15):

Cell 1, 58 cm in depth, contained 6 prey partly eaten by the larva. The larva was about 8 mm in length. Cell 2, 56 cm in depth, involved 4 prey, with the larva of about 7 mm attached to one of the prey. Cell 3, 38 cm in depth, was stocked with 5 prey, the uppermost one of which carried a just hatched larva. In cell 4, 25 cm in depth, 5 prey were stocked, to the uppermost one of which was glued the egg of the wasp.

In the other instances that contained the larval cells, it was the rule that the deeper the cell the larger the larval wasp found in it.

**Egg, larva, larval growth and cocoon.** The egg is always found deposited to the prey placed uppermost. It is cylindric in form with the ends rounded, $3.2 \times 1.0$ mm in a measured instance, attached to the middle of the ventral side of the thorax with its anterior end and reaches the middle of the abdomen with its posterior end. It is milky white in colour, with a faint tint of yellow. Apparently it is glued to the body of the prey with its total length.

The larva when hatched is attached with its caudal end to the middle of the ventral side of the abdomen and its head is slightly lifted from the prey's thorax. It begins to eat the prey from the thorax, with its posterior end fixed on the prey's abdomen.

The larva in cell 3 of nest No. 5 observed in Sapporo was in such a state when dug up on September 28. It was reared in an artificial cell without the ceiling made on the wet sand in a basin. Until October 2, it devoured up the five prey stored in the cell, leaving apparently the solid integument and horny elytra alone. I then gave it further three weevils snatched from the homing wasps. It continued to eat until the 9th when it reached 15 mm in length and was still

gnawing the small pieces of flesh left attached to the inside of the integument. On the llth it became fully 22 mm in length when stretched the body. The next day the larva began to cramble the sand walls of the cell. As a rasult the remains of the prey were covered with sand grains and the cell became shallower. Then it began to spin the cocoon. I covered the cell with a piece of a half cylinder of glass so as to give it the upper support. By the evening it has spun a thin cocoon with the anterior broader end still open. From this opening it stretched out its anterior body and searched about the support to glue its thread. Frequently it caught a sand grain between the mandibles, but soon threw it off without inlaying the cocoon, as done by the larva that forms a sand cocoon. The next day the opening of the cocoon was closed and it turned pale yellow. But it is still semitransparent and the movement of the larva inside was well visible. On the 18th, the cocoon became orange yellow, thick and was apparently completed. It measured 18 mm in length and 5 mm in width.

The very slow pace of its growth depends certainly upon the cold climate of the time.

The full grown larva before cocoon spinning seems to have the anus already open. Its caudal end is not rounded, but pointed, with the apex slightly bifurcate. The body is markedly slender as compared with the larvae of other fossorial wasps and the body segments on the posterior portion are very distinct. The same structure of the body was also confirmed upon the larva of *Cerceris albofasciata* Rossi (Fig. 22).

**Life cycle.** In Chiba, this species repeats without doubt two generations a year, appearing in June-July and in August-September. while in Sapporo it seems to pass a single generation a year. In the suburbs of Fukui where the climatic conditions are rather similar to those of Hokkaido the emergence of this species seems confined to a single time during July-August.

**Parasite.** On September 20, 1932, I was on patrol as the commander of the guard in the barrack ground during my military service, when I found several small tumuli scattered on the earth. While I was watching a female wasp of this *Cerceris* came out of a tumulus and flew away. After a while, a Chrysid, wholly dark blue in colour, penetrated into the burrow and soon after crept out. I caught it and imprisoned it in the cap of my fountain pen.

Later when I studied the Chrysididae of Japan the specimen was identified with *Hedychrum simile* Mocsáry, known from Manchuria and Korea. It is the sole specimen of this species that I have capturd to date in Japan.

### (4) *Cerceris albofasciata* Rossi

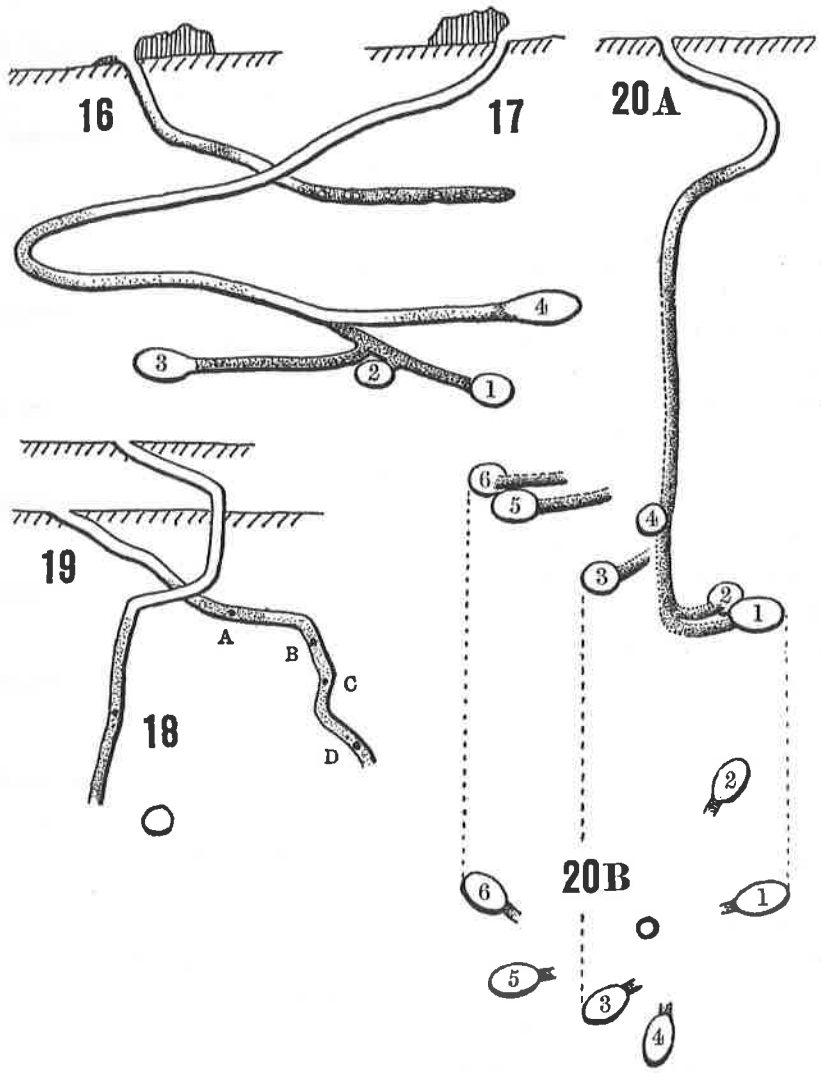
In Japan this species has long been known as *Cerceris navitatis* F. Smith and the general biology of the species was already recorded in fair detail by Kamayama (1933, 35) and myself (1937, 42) under this specific name. In Europe Roth (1923) recorded to see the wasp of this species (under the name of *C. luctuosa* Costa) carrying *Hispa testacea*.

I have observed the nesting biology of this species first in Chiba while I was in the military service and later in Seoul, Korea. In the former this species settled their colony on fairly hardly trodden sandy earth near the sea-shore, while in the latter they lived in the clayey soil mixed with numberless broken gravels derived from the gneissic matrices. In Chiba they were sym patric with *Bembix niponica*, *Cerceris arenaria*, *C. lybyensis japonica* and *Oxybelus* sp. and in Seoul their neighbours were *Stizus pulcherrimus*, *Philanthus coronatus* and *Lestica alata*.

**Nest structure.** The entrance to the nest is left open while the wasp was out and while she is inside it is usually closed either with the pushed out soil or her own head, as is the rule in the members of this genus. Following the general rule the tunnel is also fairly compactly packed with soil and tracing in digging not unfrequently ends in failure. Therefore, in spite of

my frequent attempts the nests that could thoroughly be examined are rather a few.

The nest of this species has a tendency of concealing the entrance. Most usually it is open half covered with scattered objects such as gravels, chips of wood, fragments of metals and so on, or it is excavated at the base of weeds. The tunnel is irregularly turned and bent as given in Figures 16–20, and the larval cells, 13–14 mm by 7–8 mm in dimensions are located usually at the depth of 10–15 cm, sometimes of 20–30 cm below the earth surface. The maximum number of cells examined by me is 6. But, as this nest was still being previsioned by the wasp the full number must be much larger.




Figs. 16–20. Nests of *Cerceris albofasciata* Rossi. 20B is the vertical view of 20A.

**Prey, modes of carrying and provisioning,** The prey of this species belong all to Chrysomelidae, the curious flattened Chrysomelids belonging to the genus *Cassida*. The insects derived from Chiba were *Cassida neburosa* L. and *C. piperata* Hope (det. by the late Dr. H. Yuasa) and those from Seoul were *C. neburosa* and *C.* sp. (*C.* sp. was more abundant).

In carrying the prey the wasp grasps the insect venter to venter, catching it by the antennae with her mandibles and holding its body from both sides with her mid legs. The wasp with the prey landed on the ground near the entrance, walked to it and, different from the usual mode of other species, she usually lays the prey aside at the entrance, enters the burrow head first, turned round at once, protrudes its anterier body from the opening, caught the prey with the mandibles and pulls it backing into the burrow. This exceptional mode of taking in the prey may be dependent upon the flattened and broader body structure, like a tortoise, of the prey.

Temporary storing of the prey in the tunnel is always observed during the provisioning activity of the wasp is going on, that is to say, not only before the first cell is constructed, but also before any later cell is prepared. The states were perceived in the following instances:

No. 1. Chiba, 9. VII. 1932; the nest: Fig. 17. The prey contained in the cells were 8 (with a larval wasp), 10 (ibid.), 7 (ibid.) and 3 (no egg). In the tunnel were buried in the packed soil 2, 1 and 1 prey separately. The wasp was probably arranging the temporarily stocked prey in the cell newly constructed.

No. 2. Chiba, 17. VII. 1932. No larval cell was prepared in the burrow, but in the tun el were stocked 9 prey, collected in 2 or 3, or sometimes singly in the packed soil.

No. 3. Chiba, the same date. As yet no cell was made. In the tunnel 9 prey in four groups were found packed in the soil, 5–10 cm below the earth surface.

No. 4. Chiba, the same date. No larval cell, yet in the tunnel 2 prey were stocked.

No. 5. Chiba, 12. VII. 1932. In this instance (Fig. 16) as many as 12 prey were stocked in the tunnel, packed in the soil, though it contained no larval cell as yet.

No. 6. Chiba, 2. VIII. 1931. The tunnel entered the earth perpendicularly for 3 cm, then suddenly turned to the east, becoming almost horizontal, ran for about 8 cm, turued again to the north and soon ended in the cul-de-sac. There a victim was placed half buried in the soil. No larval cell could be discovered around and below the tunnel.

No. 7. Seoul, 5. VII. 1941. The tunnel went in the earth in a gentle inclination for 4 cm, then penetrated perpendicularly for 5 cm and again turned as given in Figure 18. At a depth of 12 cm tracking became completely impossible and there one *Cassida* sp. was discovered. I then excavated around and below the point and could find a larval cell. It lay at a depth of 14 cm and included 8 prey with a larval wasp, 8 mm in length, attached to the upper one of them. Other cells must have been constructed, but could not be found after all.

No. 8. The same place and date. The prey, 2, 1 and 2 in separate groups were buried in the soil loosely packed in the tunnel, 9, 6 and 5 cm from the entrance. No larval cell was constructed as yet.

No. 9. Ibid. The tunnel was missed at D of Figure 19. At A two Chrysomelids and the wasp of the nest, at B one at C two and at D three prey were hidden in the soil packing the burrow.

No. 10. Ibid. The entrance was surrounded by a tuft of grasses and the tunnel was soon missed owing to the hard packing of soil. In the tunnel 3 prey were discovered one by one. I dug the place broadly and deeply, expanding the hole centrifugally and could find 6 larval cells scattered as given in Figure 20.

Table 3. Nests of *Cerceris albofasciata* Rossi

| Nest No. | Cell No. | Depth | State | Prey | Offspring | Remarks |
|---|---|---|---|---|---|---|
| 1 | 1 | 18 cm | complete | 8 | larva 13 mm | Chiba, 9. VII. |
| | 2 | 17 cm | complete | 10 | larva 10 mm | In the tunnel 4 prey. |
| | 3 | 17 cm | complete | 7 | larva 8 mm | |
| | 4 | 15 cm | complete | 3 | none | |
| 10 | 1 | 13.7 cm | complete | ? | cocoon | Seoul, 5. VII. |
| | 2 | 13.5 cm | complete | ? | cocoon | In the tunnel 3 Prey. |
| | 3 | 13.0 cm | complete | ? | cocoon | |
| | 4 | 12.0 cm | complete | ? | cocoon | |
| | 5 | 9.5 cm | complete | ? | cocoon | |
| | 6 | 9.0 cm | complete | ? | larva spinning cocoon | |

From the instances above described, it is clear that the wasps of this species have a strong tendency of capturing the prey and stocking them temporarily in the tunnel before they form the cell to receive the prey.

The number of the prey stocked in one cell is, so far confirmed, 6, 7, 8, 10, 13, 17, 14, 15, 15 and 17. The last listed four were counted from the remains of the old cells in which the larvae did not hatch.

**Order of cell construction.** In the nest observed in Seoul, Korea, that contained 6 larval cells, the cells located deeper from the surface of the earth involved cocoons already spun by the larvae, while those found at the shallower place either the just cocoon spinning larva or the larva still eating the prey (Fig. 20, Table 3). The fact indicates that the wasp first digs the tunnel up to its end and distributes the cells from the interior to the exterior. In all the other nests that contained more than one larval cell the same was the case (Fig. 17, Table 3).

**Egg, larva and cocoon.** The egg is laid on the insect placed on top of the prey pile (Fig. 21), all laid venter up. It is 3.5 mm in length and 1.0 mm in width, milky white and glossy. The period needed for the growth of the larva remains unknown. The full-grown larva reaches 16–17 mm in length. Its caudal end is not rounded, but attenuate towards the apex. The posterior portion of the body very distinctly segmented. Apical segment is characteristic in form as given in Figure 22. The cocoon is yellowish brown in colour, 15–17 by 5–6 mm in dimensions. In the natural state it is completely covered with remains of the prey.

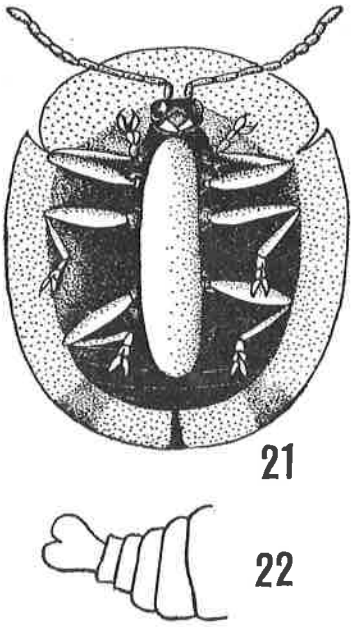



Fig. 22 and 23. the egg of *C. albofasciata* attached to the prey, *Cassiba nebulosa* L. 22, posterior portion of the full-grown larva.

### 5. *Cerceris nipponensis* Tsuneki

This species is not rare in the montane regions of Japan from Kyushu (incl. Tsushima) to Hokkaido. Despite the fact, the nest of this species remains still undiscovered. During my collecting excursions, however, I could obtain four females carrying the prey. The prey belong to two different families of Coleoptera, namely Curculionidae and Chrysomelidae. They are as follows (det. by H. Kamiya):

1. *Curculio aino* (Kôno, 1930). (アイヌシギゾウムシ) Yumoto, Nikko, 12. VIII. 1955.

2. *Macrocorynus viridulus* (Roelofs, 1873). (ミドリクチブトゾムシウ) Hatogayu, Fukui Pref., 28 VII. 1954.
3. *Basilepta bulyi* (Harold, 1877). (チヤイロサルハムシ) Jozankei, Hokkaido, 10. IX. 1945.
4. *Basilepta ruficolle* (Jacoby, 1885). (ムネアカサルハシム) Arashi, Fukui Pref., 4. VIII. 1965.

According to my study *Cerceris nipponensis* belongs to the *rubida* group in taxonomy. With regard to *C. rubida* the prey records have been published by Fabre (1879), Aptel (1931) and Grandi (1926 and 1961). Fabre recorded 2 genera, *Bruchus* (Bruchidae) and *Apion* (Curculionidae), Aptel 12 genera, *Olibrus* (Phalacridae), *Meligethes, Pria, Cypocephalus* (Nitidulidae), *Epithrix, Mantua, Chaetocnema, Longitarsus* (Chrysomelidae), *Bruchidius* (Bruchidae), *Apion, Tychius, Napophyes* (Curculionidae) and Grandi 10 genera, *Olibrus* (Phalacridae), *Meligethes* (Nitidulidae), *Psylloides, Longitarsus* (Chrysomelidae), *Bruchus* (Bruchidae), *Apion, Exapion, Sitona, Tychius* and *Miccotrogus* (Curculionidae). These are totaled as 5 families and 15 genera.

It is not strange, therefore, that our *nipponensis*, a related species of *rubida*, hunts insects belonging to two different families. Future studies will increase much the number of the family, genus and species of the insects captured by this species of *Cerceris* as food for the young.

### 6. *Cerceris carinalis* Pérez

This species also belongs to the *rubida* group and the nest investigation has similarly been left untouched. The species widely occurs in Japan from the Island of Yaku, Kyushu through Honshu up to Hokkaido. Probably it is distributed also in Shikoku, though as yet not confirmed.

I have a single specimen of this species captured during the transportation of the prey. It is a Curculionid, having a very slender proboscis:

*Curculio aino* (Kono, 1930) (det. H. Kamiya). Koike, Fukui pref., 6. IX. 1958.

The fact that the nests of wasps of *rubida*-group remains undiscovered is considered due to that their colonies are not founded on the path or the open area, but probably among grasses and are well concealed by the leaves.

Yasumatsu (1939) recorded that this species captures 'bees', but probably it is due to misapprehension.

### 7. *Cerceris sobo* Yasumatsu and Okabe

The distribution of this species is confined in Japan to certain districts of Central Kyushu. It is, however, not rare in Korea. Taxonomically it forms a separate group, occupying a position somewhat near to *rubida*-group.

I captured a female of this species in Korea which was flying with a prey. It was a Curculionid beetle belonging to the genus *Myllocerus* (det. H. Kamiya), but the species is unknown.

Yasumatsu (1939) recorded that this species lives at the foot of Mt. Sobo, Kyushu, and hunts *Anosinus decoratus* Roelofs, *Myllocerus castaneus* Roelofs, *M. fumosus* Faust, *M. griseus* Roelofs. In 1926 Yano reported that a species of *Cerceris* makes nests in the ground of a shrine at Naidaijinyama, Kyushu, and stores Curculionid beetles belonging to the genus *Phyllobius* in the cells. He mistook it to be *C. harmandi* (=*hortivaga*), but later Yasumatsu

presumed it to belong to the present species.

As parasites, besides the Tachynid fly, the Coleopterous insect of the family Rhipiphoridae is known.

## BIOLOGY OF SOME SPECIES OF NORTH CHINA AND EAST MONGOLIA

During my stay on the Continent as a called up soldier in Chino-Japanese conflict from 1930 to 1940 I passed a year in Peking, N. China and another year in Apaka, E. Mongolia. During the time I was used to pass my leisure hours in observing and collecting bees and wasps. After my return I published a book entitled "Sensen no Hakubutsu-gakusha", meaning A Naturalist at the Front, and included in it my observations of the life of the solitary wasps and bees living in the above mentioned two regions. I wrote at the same time an abbreviated records on these insects and sent the manuscript to the Editorial Board of the Entomological Society of Japan. Unfortunately, however, it was burnt up in the bombardment to Tokyo and since then I idled to redescribe my observations except those concerning the genus *Sphex*.

On this occasion I reread my old notes on the biology of *Cerceris* and rearranged them to make accessible to the western entomologists.

### 1. ***Cerceris pekingensis*** Tsuneki

A small species, with the maculation somewhat resembling *C. hortivaga* Kohl, but much smaller in size and more broadly yellow in coloration. In taxonomic this species is close to *hortivaga* or *rybyensis*, having the so-called platform at the base of the second sternite of the abdomen. Such structural characters make us suppose that this is a hunter of the solitary bees.

On July 18, while I was rambling on the circular road in Tiendang, Peking, I saw a wasp of this species come back with a prey to her nest that was open on the road. She left the prey on the ground by the side of the entrance to her nest and entered it empty-handed. To my surprise, the prey was a Sphecoid wasp, *Pison* sp. which was, soon after my corroboration, caught by the wasp turned back there and pulled backing into the burrow.

Awaiting a while, I captured the wasp when she came out and at once dug up her nest. The tunnel was soon missed, however, owing to the very compact packing of soil, and in spite of my great effort of expanding and deepening the hole none of the cells nor any of the stored prey could be discovered after all.

According to my consideration the prey that I observed was an exceptional insect, just as I found a specimen of *Psen* from a nest of *C. hortivaga* and this species of *Cerceris* must be hunters of the solitary bees in their normal ways of life.

I could not recapture the prey-wasp, but later study of the wasps collected in the same place led me to suppose that it was a specimen of *Pison insigne* Sickmann.

### 2. ***Cerceris buprestícida*** Dufour

The wasps of this species are so well-known through the biological studies of L. Dufour (1841) which was reproduced by J. H. Fabre (1879) in his "Souvenirs entomologiques".

The circular road of Tiendang was in those days an abandoned passage rarely visited by the Chinese bird-catchers and was overwhelmed by the thick vegetation powerfully advanced from both sides like waves. The lonely road was occupied by the solitary wasps and bees that nest in the ground and they are so numerous not only in individual but also in species that I

was at times apt to forget their rariness and curiousness in other places.

**The first observation** made on this species was also quite unexpected one and not particularly interested one at that time.

On June 5, 1938, while walking with an insect net I saw a wasp carrying the prey and very slowly hovering over the ground. I approached her and found at once an opening there. So I began to take notes on her behaviour. She soon landed by the side of the opening, but did not enter there, flew up again with the prey and resumed same flying about over the area as before. During the time she repeatedly passed over the opening and from time to time alighted on the road, most frequently near the opening. The cause of her hesitation might have been the presence of a man. There was no other opening around the place and there was no doubt it was her nest. But her behaviour was too phlegmatic and slow that I could not wait her to enter. At last I captured her with her prey. The wasp was about 12 mm or so in length, black with yellowish maculae scattered. The prey was a small black Buprestid of about 12 mm and showed apparently no sign of life.

I at once began to dig the nest. The clayey ground was so hard that excavation with a penknife, the sole digging tool for me, was rather difficult and needed much time. The tunnel entered perpendicularly for 10 cm and turned horizontal. It ran for 2 cm further to reach the larval cell. At the turning point the tunnel was loosely plugged with soil. The cell was 15 by 7 mm in dimensions, with the inner wall polished as frequently the case in this genus. But the cell was empty. This seemed rather strange.

I enlarged the hole and found another cell constructed obliquely below the first cell. It contained four Buprestids, the same species as carried by the wasp, which were laid head in and venter up and on the uppermost one was glued the egg of the wasp. It was cylindric, about 3.5 mm long and 1.3 mm wide, milky white in colour and glossy. It was attached to the neck of the prey, laid along the median axis of ventral plates of the thorax and reached with its caudal end between the hindcoxae.

Particular mention is needed to the fact that I found and captured another female wasp at the bottom of the perpendicular tunnel. Probably she was a sister of the wasp caught by me, as suggested from the similar common use of the old burrow by *Cerceris hortivaga*, since the time was the beginning of the season of *Cerceris*.

**The second observation.** The next year when I came back from the front at Siansi I had a few days of free time before I departed for East Mongolia. I revisited Tiendang expecting meeting with the offsprings of the Buprestid-killers of the preceding year. It was the 14th of May, 1937.

Fortunate enough, as soon as I reached the place of observation of the previous year I could at once find a wasp of this species flying low over the ground carrying the prey. From the manner of her flying the nest was soon discovered. It was open on the ground without the mound of soil. But the wasp did not quickly enter the opening, probably because of my sitting close by with a camera. So I retreated a few steps backwards to let her in, giving up to take photographs. The wasp at once entered the opening. Without waiting the wasp to come out I dug up the nest.

The tunnel was about 4 mm in diameter and entered the earth at an angle of about 30° to the surface of the ground. It ran for 5 mm towards the south, then suddenly turned at a right angle to the east without any apparent obstacle. From the turning point the inclination of the tunnel became somewhat steeper. It proceeded for 10 cm further and was stuffed with soil. Having cleared up the soil plug of about 3 cm I found a larval cell in which a cocoon wrapped

with remains of Buprestid-beetles was suspended. The cell was laid horizontal, 6.7 cm in depth from the earth surface to its ceiling and 14 by 7 mm in dimensions. The cocoon was 12 mm in length and 4.5 mm in width, ashy brown in colour with a yellowish tint. From the remains it was clarified that the prey were three in number. From in front of the soil plug a branch tunnel went in below the cell and the wasp was digging the tunnel at its end, leaving aside the Buprestid in the tunnel behind her.

In the cocoon there was a dead larva covered with mould. The nest was doubtlessly an old one made in the previous year and reused by the offspring. I searched for another cell from which the wasp that I knew had emerged by expanding the dug up hole and finally I could uncover an empty cocoon from the earth. But the cell could not distinctly be examined.

This nest might include further cells undiscovered. But they could not be confirmed with the poor digging tool that I had.

The prey that I collected were later identitied by H. Kamiya with *Sphenoptera* sp. (This genus is included by some authors in *Budrestis*).

It seems interesting that in both instances the wasps reused the old nests from which they had emerged. In the first nest the wasp prepared the cell before bringing the prey, while in the second the prey was taken in the burrow prior to the construction of the larval cell.

### 3. *Cerceris bicincta* Klug (=*quadrimaculata* Dufour)

Probably there has been no record of the biological observation concerning this species which has a wide range of distribution from Europe as far east as Korea.

On the loop road of Tiendang, Peking, I happened to discover a nest of this species. It was July 4, 1939.

By pursuing a while with the eyes a flying wasp with a prey I succeeded in finding out her nest. The opening was without the tumulus of soil. After confirming her entering I went to the opening and found that a plug of soil was being pushed out from within. In the soil pushed out an insect of the prey was moved out. It was a Chrysomelid beetle, about 5 mm in length, having the blue head and pronotum and the yellow elytra.

The wasp continued to push out the soil from the burrow. Probably the tunnel must have been compactly stuffed with soil during the time of her absence. She did not come back to the entrance to take the prey for a long while. The day was sunny and very hot. I covered the entrance with my insect net and took shelter under a tree.

After a while I found the wasp trapped in the net. I captured it and began to excavate her burrow. The tunnel at the entrance is about 4 mm across, penetrated into the earth at an angle of 40°–60° up to the depth of 6 cm. The ground for the surface 2 cm was very hard like concrete, then gradually softened. At the bottom the burrow turned horizontal and slightly enlarged and included in it 3 prey, 2 of which were the same species of the Chrysomelid as obtained at the entrance, while the other was smaller, having the blackish head and the yellow pronotum and elytra with 4 blackish spots. In spite of my careful handling on none of them was found the egg of the wasp.

The pocket in which the three prey were stocked was narrower as compared with the normal cell and, moreover, the inner wall was not polished. Judging from these conditions it was not the formal cell of the larva. It was rather a part of the tunnel wherein the prey were placed provisionally, although the place might be reformed later into a formal cell. Therefore it is clear that this species also begins to hunt the prey before preparing the first cell.

It was later determined that the larger ones of the Chrysomelids hunted by the wasp were

*Lobidostomis tridentata* and the other one *Coptocephala* sp.

I searched for another larval cell but the search ended in vain.

### 4. *Cerceris rufipes evecta* Shestakov.

The typical race of *C. rufipes* Fabricius, 1787, occurs in South Europe and commonly known as *C. tuberculata* Villers, 1789. This specific name became familliar among the insect loving people through the splendid narration of J. H. Fabre.

The East-Asiatic race was first described as a valid species by the Russian author, but later transferred by me under the Fabrician species. But the difference between the two races are fairly large and distinct in some characters, *evecta* has been treated by some authors as a separate species. In connection with this it seems interesting to me that the Asiatic race that I convince captures the same genus of the Curculionid prey alone as done by the typical species in Europe and shows the similar nesting biology.

This subspecies is the largest of all the congeners in East Asia and attracted my particular attention in N. China and E. Mongolia.

**(1) The first observation.**

**Nesting site and behaviour of the wasp.** The first of my encounters with this species was on July 10, 1939, on the loop road of Tiendang, when I found one of the wasps landed on the ground near the wayside grass, carrying a prey under her body. She was walking among the stalks of tall grasses with comparatively prompt foot-steps, without letting the prey off. Suddenly, however, she stopped. Her antennae were put together and stretched forwards, as if she were gathering her attention towards something in front. I also paid my attention and found at once a small parasitic fly suspended at a spot in the air, 10 cm in front of her. Probably the fly was following after the wasp, but her sudden turn led the fly to be face to face with the wasp. After a moment the wasp with the prey rushed upon the fly, running swiftly for about 10 cm at a breath. The fly flew back and alighted on the grass nearby, as if it gave up to pursuit her.

It was very pleasant to me to see the wasp violently attack the hateful enemy to which the most other fossorial wasps are quite incompetent, only struggling to dodge their pursuit, as if they were frogs aimed at by snakes.

The wasp turned back, walked at slow pace for about 30 cm and plunged into a hole, quite shapeless as if to be an earthworm hole, carrying the prey. She did not let the prey off at the entrance, so I could not ascertain what kind the prey was. In order to distinguish this wasp from others I call it hereafter *A*.

As soon as *A* entered her burrow the other wasp (*B*) of the same species landed on the nearby ground. A parasitic fly at once began to follow her. But *B* also soon took notice of it, turned round and dashed at it to drive it away. After walking about a while, B entered her nest which had also very clumsy opening at the foot of a tall grass, 20 cm apart from that of *A*. I found another three wasps (*C*, *D* and *E*) nesting within a small area that included the nests of *A* and *B*. Therefore, this species was considered to have gregarious habits, but not so dense and crowded as in *Cerceris hortivaga* observed in Sapporo. So far I have observed, the inhabitants of a colony are only a few in number. In this instance the nests of *A*, *B* and *C* were made at the west side of the road, while those of *D* and *E* at the east side and slightly apart from each other, all being burrowed near the base of the tall grasses.

Since then the five wasps carried in the prey to their nests at the hours given in Table 4, as far as my eyes caught them.

The entrances of all the nests examined were quite shapeless, without exception. They were large, irregular in form and always without the mound of earth around them. The opening resembles rather the cricket's hole, or rain-beaten hollow of the earthworm, or of the mole cricket. It could not be reflected to the eyes of the experienced observers as an opening of the nest of the fossorial wasp.

Table 4. Hunting activities of the wasps.

| Wasp | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *A* | 14:34 | 15:00 | 15:17 | 15:33 | 15:56 |
| *B* | 14:34 | 15:00 | 15:12 | 15:25 | ? |
| *C* | 15:38 | 15:53 | ? | ? | ? |
| *D* | 15:50 | 16:03 | 16:11 | ? | ? |
| *E* | 16:20 | | | | |

Remarks. Standard time of Peking.
The time of staying in the nest was usually 1-2 min.

**Prey carriage.** At the time when wasp *A* came back at 15:17 I intimidated her to let her off the carrying prey. She dropped the prey on the ground and fled away. But her attitude was by no means timid and nervous as seen in the majority of the spider wasps, but rather dignified or dull. In fleeing she did not fly or run away, but walked away in the normal tempo among the grasses. The prey was a species of the Curculionid, about 10 mm in length, having whitish streak-like maculae on the thorax and elytra. It was later determined to belong to the genus *Cleonus* (*Coniocleonus*), the same genus as captured by the typical species of *C. rufipes*.

I replaced the Curculionid on the ground. The wasp came back, searched about and soon found out the prey. She grasped it from its dorsal side, head to head, bent her abdomen, directing the tip to the center of the ventral plates of the thorax and was about to sting. But she did not sting it, turned it round to be venter to venter and carried it in her burrow. During the time she supported the prey with her middle pair of legs alone, her mandibles being free from catching it.

After observing prey-storing a single time I dug up the nest of wasp *E*.

**Temporary provisioning.** The entrance was left open and just below the opening the tunnel was enlarged and there (a) two Curculionids were stored. Then the tunnel (or rather aperture) was closed with soil and soon another prey was discovered in the soil (b). Thereafter 16 Curculionids belonging to a single species were uncovered. They were separated in three groups with the following numbers and intervals:

Table 5. Temporary storing of the prey.

| (a)-2～3mm-(b)-10mm-(c)-20mm-(d)-20mm(e) | | | | | Total |
|---|---|---|---|---|---|
| 2 | 1 | 6 | 4 | 6 | 19 |

Between the insects collected at a place there was inserted a more or less amount of soil. The portion of the tunnel used for storing the prey was slightly inclined, about 6 cm in length and was also enlargld and shapeless.

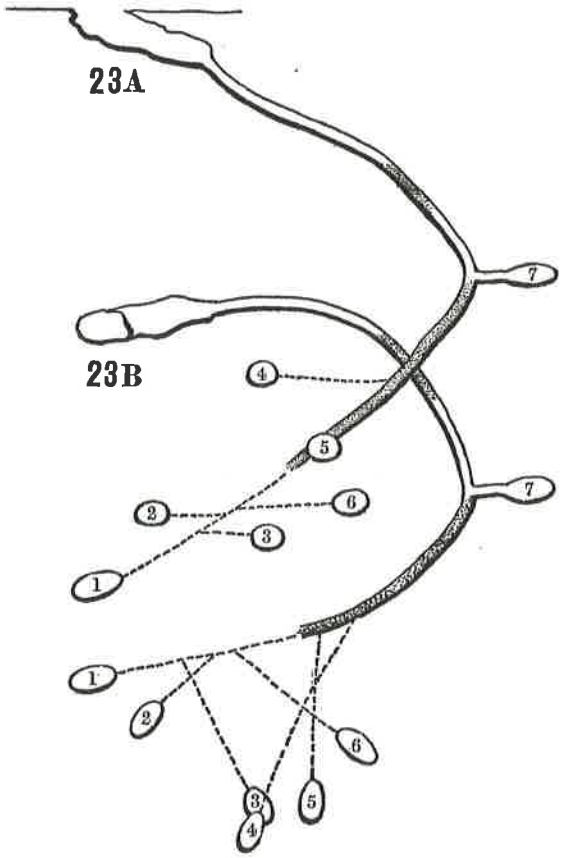
This instance shows that this subspecies has also the habits of collecting the prey prior to preparing the first brood-cell to receive them and the tendency is very remarkable, because judging from the large size of the prey, the number collected in this instance is considered far surpassing the normal provision of a single cell.

In order to satisfy myself I dug the place more deeply and broadly below and around the tunnel, but I could not find any of the cells.

**Structure of the nest.** On July 18, I dug up the nest of wasp *A*. It was extended so far down in the earth as compared with the nests of other congeners living in Tiendang that it needed much time and labour to examine the cells. So much so that I lost completey my working volition to examine the remaining nests of wasps *B*, *C* and *D*. The structure of the nest of wasp *A* was as follows:

The first 7–8 cm of the tunnel was not the formal one, broader, irregular and shapless in form. Probably the portion of the tunnel was a burrow of other insect and utilized or stolen by

the wasp. Then it turned into a normal rounded smooth passage about 6–7 mm in diameter. It proceeded for 15 cm drawing a gentle curve to the right. The next 5 cm of the tunnel was packed with soil and at its end the tunnel reached 16 cm in depth. Then it turned at nearly a right angle to the right and ran for 7 cm, the last 3 cm of which was loosely packed with soil and included in it 3 paralyzed prey. From this point a short branch was horizontally shot off and led to a hollow, 20 mm long, 8–9 mm wide and high, wherein 2 Curculionid beetles were stocked, but without the egg. The wall of the hollow was not polished and it seemed somewhat doubtful whether it was a completed hollow for the brood-chamber or not. From this depth below the tunnel was very compactly stuffed with soil. I could hardly follow it by the difference in colour of the packed soil. It entered deeper and deeper and continued to draw the rightward curve, until at last it came to run completely in the opposite direction. The depth of the point of the tunnel was 23 cm from the earth surface. Finally I missed the tunnel. But by digging around and below the spot I could find successively six larval cells. However, it seemed probable that several more larval cells might be made more below in the earth which I could not discover.




Figs. 23 A and B. A nest of *Cerceris rufipes evecta* Shestakov. A, lateral view, B, vertical view.

The first larval cell that I found was situated 15 cm apart from the end point of the tunnel and by 3 cm deeper. The branch tunnel leading to the cell was completely closed and could not be followed up. Seven prey stored in the cell were covered with mould and no egg nor larva could be found among them.

Cell 2 was placed by the side of cell 1 and contained 8 prey, half of which were already wrapped with the white hyphae and among the remaining 4 a poor larva, about 10 mm in length, was eating the victims. It gnawed in the body of the prey from the neck region and ate up the contents, leaving the hard sclerites untouched.

In cell 3 also 8 prey were collected. But they were also wrapped completely with hyphae. Among them I found a 12 mm larva already dead.

From cell 4 to cell 6 each contained 7 prey. But all of them were completely invaded by the mould and the egg or the larva of the wasp could not be discovered among them.

The depth of these cells was from 1 successively 28, 25, 26, 20, 23 and 25 cm respectively. The distribution of these cells were given in Figures 23.

**Consideration and summary.** It was very strange and unexpected that in this nest all the completed larval cells were destroyed by the invasion of the mould. Of course, the instance does not represent the normal state of their nests, since if so they can not survive. Probably

the wasp that made this nest —wasp *A*— was exceptionally a bad operator. Some of the prey stung by her must have deen killed, instead of being paralyzed. The dead insect soon becomes putrefied under such proper conditions of humidity and temperature, and soon invites the mould. One dead prey among the 6 or 7 paralyzed leads to the eventual destruction of whole the insects in the cell. .

The case in this nest may be such and it shows very clearly the process of the instinctive evolution that the offsprings of a bad operator become extinct and those of the skillful one survive.

It is very regret that I did not examine any of the three remaining nests that I knew in Tiendang, but later when I was in East Mongolia I had a chance to investigate one further nest of this species. But the investigations in Peking brought to light the following facts concerning the biology of this subspecies:

(1) The wasp begins hunting prior to preparing the first brood-cell; the number of the temporarily stored prey sometimes surpasses the number needed for the provision of two cells.

(2) Storing temporarily of the hunted prey in the tunnel is also observed even in the later course of the nest making activity.

(3) The wasp may utilize the hollow made by other insect as an entrance gallery of her nest, but the main portion of the burrow is constructed later by herself.

(4) The nest is compound in structure, including many cells in it, and the cells are constructed from interior to exterior: cell $1 \rightarrow 3 \rightarrow 2 \rightarrow 6 \rightarrow 5 \rightarrow 4 \rightarrow 7$.

(5) The number of the prey per one cell is 7-8. The prey belonged to one species of the genus *Cleonus*, in the family Curculionidae.

(6) The larval cell is ellipsoid in form, 20 by 8-9 mm in dimensions and considerably deeply distributed in the earth.

**( 2 ) The second observation.**

From May 1939 to March 1940 I was in East Mongolia and was enjoying in my free hours the splendid world of animals and plants. A fair number of wasps' life were recorded in my note books. Among them was the life of *Cerceris rufipes evecta*.

The specimens of this subspecies collected in E. Mongolia were considerably larger in general than those of Peking and there was sometimes a marked variation in the maculation and colour of the abdomen.

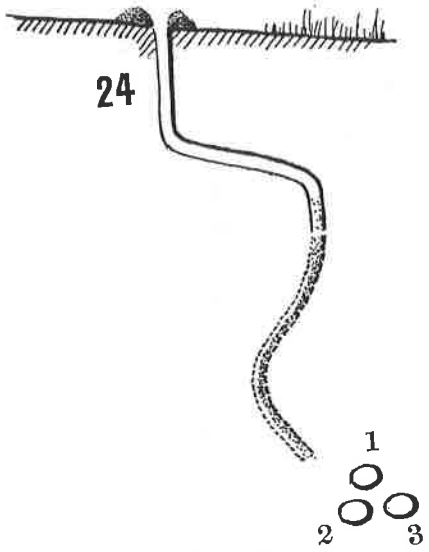
On a patch of the bare ground of gentle inclination amid the vast grass land I found two nests of this species. The soil of the place was derived from the eroded gneiss and mixed with a considerable amount of sand and gravels at the surface area.

On the way to the hilly region in Apaka, in the middle of August, I took notice of two wasps of this subspecies nesting. During my observation I saw the wasps from time to time carry in her nest a large Curculionid. They held the victim venter to venter with the mid legs, as their colleagues in Peking did. They landed near the entrance and walked to it and ran into it without letting the prey off. This behaviour was much the like that of the Peking wasps. Twice I robbed the wasps of their prey. They were much larger than those of Peking, measuring almost 15 mm or so in length and in weight they were probably more than thrice as heavy as the Peking prey. Later, when I came back to Japan they were determined to belong to the genus *Cleonus* (*Coniocleonus*) also, but to a different species.

I excavated the nests on August 22. In these instances the burrows were formed from the beginning by the wasps themselves. The entrance was rounded, with the diameter of 10–11 mm. In one of them a tumulus of the débri ornamented the entrance, while in the other completely

without such.

The tunnel was as broad as the entrance. It entered the ground perpendicularly for 6 cm, then turned at an angle of approximately 120° towards the west, went for 7 cm, running nearly in parallel with the downwards inclination of the earth surface, and turned again perpendicularly. After proceeding a short distance from the second turning point I missed the continuation of the tunnel, since it was so compactly packed with soil. From near the turning point downwards three large Curculionids of the same species were stored in the tunnel.




Figs. 24. A nest of *Cerceris rufipes evecta* Shestakov observed in East Mongolia.

I bored a hole of about 20 cm in length perpendicularly into the ground below the point where I missed the tunnel. Then by gradually enlarging the hole in all directions I succeeded in finding three larval cells. They were very slightly different in depth, No. 1 being 23 cm, Nos. 2 and 3 both 24 cm from the earth surface. The three cells were collectively constructed and all were laid with the length axis directing SSE-NNW. If the cells were connected with the end of the main burrow by the straight branch tunnels, the compactly stuffed portion of the main burrow must have been bent as given by the dotted line in Figure 24.

The brood-cells were very large, measuring 25 mm long, 13 mm wide and 11 mm high, with the inner wall smoothed but not polished, owing probably to the soil nature of the place. They were laid nearly horizontal, very slightly raised inwards. In cell 1 four prey, in cell 2 five prey and in cell 3 three prey were cellected, all being one and the same species. They were laid head in, venter up and on the one placed on top was laid the egg of the wasp.

In cell 2 the egg was about to hatch, and the larval segments became visible through the chorion. In the eggs of cells 1 and 3 there was no sign of hatching.

The hatching larva of cell 2 was attached with its anterior end to the middle of the 2nd ventral segment of the abdomen, laid along the medial line of the body and reached with its posterior end between the front coxae. This is probably an exception and inverse to the general rule, since in two other instances the anterior end of the egg was glued between the front coxae.

The egg is comparatively very large, measuring 6.5 mm in length, 1.2 mm in width, with a pale yellowish tint.

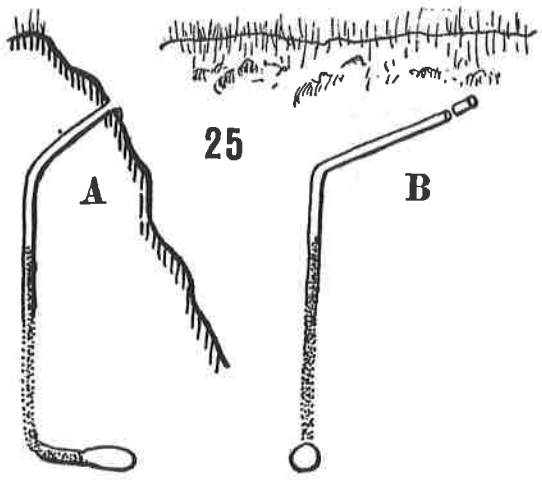
From the developmental degree of the eggs it was made out that cell 2 was constructed first. Therefore, it became that the wasp followed the general rule in the order of cell construction in this group.

A second nest was burrowed among the short grasses. It was dug into the groud at an angle of about 30° at first and after running for about 20 cm it was plugged with soil, first loosely then gradually compactly. I gave up further excavation by the severe attack of numberless mosquitoes, biting midges and stinging flies that appeared like a cloud in the steppe of Mongolia during summer. I had excavated and examined the first nest with utmost perseverance and could not endure further irritation and hindrance.

### 5. ***Cerceris sabulosa nupta*** Shestakov

Septemder 29, 1939, East Mongolia (Apaka). The entrance to the nest was open on the upper edge of a bank facing the south of a rain valley running from the east to the west. The climate of East Mongolia on that day was already like that of the winter season* in Central Japan. Notwithstanding, a crowd of solitary wasps and bees were still very actively working on the sunny areas of the bank during the daytime.

The opening of the nest was provided with a half crambled mound of earth. The tunnel was missed after being followed for about 10 cm, as often the case in this genus. The search digging brought to me one larval cell located 15 cm below the entrance. The general structure of the nest, partly presumed, was given in Figure 25.




Figs. 25. An incomplete nest of *Cerceris sabulosa nupta* Shestakov. A, lateral view; B, frontal view.

The cell was 13 by 6 mm in dimensions with the inner wall smoothed and contained 4 prey. They were laid venter up, head in and on the top one was laid the egg of the wasp. The method of the egg attachment was much the same as in *Cerceris hortivaga*. The cephalic end was glued to the neck of the prey, slightly deviated to the front of the right fore coxa, and the caudal end after crossing the ventral plates of the thorax reached the postero-external point just outside of the left hind coxa. Fore and mid pairs of legs of the insect were so bent as to embrace the wasp's egg from both sides.

Of the prey, two were *Halictus*, one *Sphecodes* and the remaining one *Nomada*, but the species names were still undetermined.

According to the literature (Ferton, 1905, 1910; Grandi, 1929, 1961; Berland, 1928; Hamm and Richards, 1930) the typical race of *Cerceris sabulosa* Pz. (=*emarginata* Pz.) is much the same in the nesting biology as in *C. rybyensis*. The genera of the prey recorded by these authors were as follows:

*Halictus, Hylaeus* (=*Prosopis*), *Andrena* ..... Ferton, C., 1905, 10.
*Halictus* only ..... Grandi, G., 1929, 61.
*Epeolus, Halictus* ..... Berland, L., 1928.

Though the wasp observed in Mongolia was a geographical race, *Sphecodes* and *Nomada* form the prey records new to the species.

* According to the meteorologic records we took the air temperatures of the day were: average, 5°.4, the highest, 15°.4 and the lowest, -4°.6 C; while the earth temperatures at 10 cm in depth were: average, 12°.3, the highest 17°.8 and the lowest, 7°.6 C; at 30 cm in depth, average 13°.9. (Remarks. The day was slightly colder than the averaged temperature of the time.)

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