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Occasional Publication of the Biological Laboratory
Fukui University, Japan

No. 42.

GLEANINGS ON THE BIONOMICS OF THE EAST-ASIATIC NON-SOCIAL WASPS (HYMENOPTERA)

V. Some species of Pemphredoninae

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FEBRUARY 20, 1970

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V. Some Species of Pemphredoninae*

By K. TSUNEKI
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PSENULUS (EOPSENULUS) IWATAI GUSSAKOVSKIJ

This species is not abundant in Japan. Its beautifully yellow maculated legs obviously indicate that the species originates in the southern tropical region, because the occurrence of such maculated species of *Psenulus* is in East Asia confined to the tropical regions only. The northward progress of this species in Japan is performed along the direction of the warm current, as is generally the rule in the insects of the southern derivation. Therefore, the wasps of this species occur only in the districts lying not far from the sea. This is also the case in Fukui Prefecture.

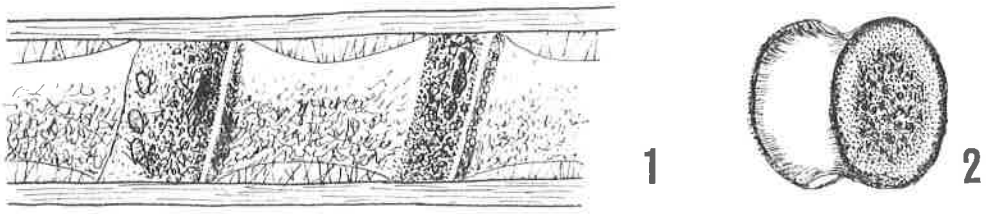
In the sandy shore of Sanrihama, near Fukui, several rows of fences made of marsh reeds were stood to a height of about one meter to protect the pine plantation from the sand storm. The reeds were well dried, stood vertical and provided various tube-nesting wasps and bees with a favourable nesting site.

On June 16, 1963, I happened to know that among the inhabitants of the reed canes of the fences were included the wasps of this species and on the 21st of the same month I could collect 10 of their nests made in the pith cavity of the reed. The internodal space is utilised by the wasp by perforating the entrance on the lateral wall. The entrance is rounded, 1.2–1.5 mm in diameter and is made either at the upper portion, towards the middle, or at the lower portion of the space. Therefore, the cells are constructed sometimes from upper to lower and sometimes from lower to upper. When the cells are made from upper to lower the wasp keeps the collected prey in the tube by tying them together and hanging them from the cell wall, using the silk threads secreted probably from her mouth. This is not the particularity of this species, but appears to be one of the common characters of the genus. The partitioning wall between the cells is also woven with the same kind of the silk threads.

Nest 1. Internodal length was 23.5 cm, average diameter of the tube was 4.2 mm, the entrance was located 9.5 cm from the upper end. The upper portion of the tube above the entrance was occupied by the old cells and the perforated cocoons, while the lower portion included the new cells constructed by the wasp. The upper part included 5 cells and 1 empty cell. The cells were from the upper end downward 10, 7, 6, 6, 22 and 8 mm in length respectively. The large cell of 22 mm in length was the empty cell. The partitions between the cells were thin white membranes, made of silk threads possibly secreted by the mother wasp, and were broken by her offsprings emerged. The cocoon was pale yellow in colour, somewhat brownish, semitransparent (Fig. 1). Its orbiculate outer lid was detached and three such lids were scattered in the tube. The lower part: New nest. At the bottom there was a broad empty space, the outer wall of which (the bottom wall of the next cell) was particularly thick, made of mud and dust scraped off the inner wall of the tube and outside which a thin white membrane was stretched. Other walls were all made of the silk threads, the white membranes. The bottom

* *Contribution No. 131 from the Biological Laboratory, Fukui University, Japan.*

space was 50 mm in length, including a prey before the inner node, without the wasp's egg. Possibly the owner of this space was killed soon after beginning to make her first cell and the



Figs. 1 and 2. Cocoons of *Pseudulus iwatai* Guss.
1, lateral view. 2, seen obliquely in front.

second wasp occupied the abandoned tube to make her own there. It seems worthy of notice that she made a particular wall at the bottom of her series of cells to separate them from the abandoned nest. She had already completed 3 cells and was engaging in provisioning the fourth cell. Cell 1 was 8 mm in length, empty. Cell 2 was 9 mm in length and was stuffed with 14 prey, all being a species of the leaf-hopper, *Sogata furcifera* Horvath, including 1 imago and 13 nypmhs, on one of which located 4th or 5th from the outer side was a larva of the wasp, about 4.7 mm in length. It had a particularly large head and must have been soon after the 2nd or the 3rd ecdysis and was eating the near-by leaf-hopper. Cell 3 was 7 mm in length, included 17 nymphal prey of the same species as above, tightly packed and to one of which located near the outer side, possibly the 4th or the 5th prey from the outermost one, was attached a younger larva of the wasp (Fig. 3). Cell 4 was still empty.

Nest 2. Internodal length 20 cm. The entrance was made toward the middle. At the lowermost portion the first cell was just completed, 20 mm in length and 4 mm in diameter, which contained 20 nymphal leaf-hoppers, all belonging to *Sogata furcifera* Horvath. On the 5th prey from the bottom an already dried-up egg of the wasps was attached at the same position as in the case of the young larva in nest 1. The outer cell wall, a thin whitish membrane, was concavely stretched (the examination was made the next day).

Nest 3. This nest contained 2 cells, both provisioned with the *Sogata*. It was examined at the habitat of the wasps and when splitted in two the nodes were cracked and the contents of the cells were scattered.

Others were all old nests.

Larval growth. The larvae in nest 1 were returned to each own chamber in the reed-cane with each prey. The larger larva finished its diet in about 2 days and a half and began to weave its cocoon. During the course, however, it fell out of the cell, attached the silk thread irregularly over the floor and failed to build the cocoon. The smaller larva spent about 3 days to eat, but died before attempting the cocoon spinning.

Observation on the second generation

On July 19, the same year, I visited again the habitat of the species and found that the offsprings of the first generation were at work. Among the wasps collected the males were obviously more abundant than the females, showing that it was soon after the emergence of the second generation. I searched for the reed canes of the fences that had a small hole on the side wall and obtained 5 nests. However, these were the nests made by the wasps of the first generation and mostly empty, because it was after the emergence of the adult wasps. In one of them, however, the last 3 imagoes were about to emerge.

Of the nests collected 2 had the cells made from upper to lower, 12 and 4 in number respectively, while in the remaining 3 they were made from lower to upper, including 6, 9 and 5 cells. In both cases the opposite part of the nest tube was closed with the silk membrane a short distance from the entrance.

The cocoon was flattened on both ends and broadly constricted in the middle as shown in Fig. 2. The outer flattened end was somewhat crust-like, considerably hardened, the central and the periferal areas being brownish and thick, while the intermediate zone being whitish and thinner. This is because that the central area is smeared with a larger amount of the secretion of the silk gland, usually brownish in colour, but sometimes ivory white and glossy. This lid was not perforated by the emerging wasp, but was cut off as a whole from the cocoon body. The wasp who thus came out of its own cocoon broke through the partition in front of it, then either irregularly cut through the bottom face of the cocoon of the next cell, or pressed it aside without cutting and went to the opening of the nest. In some cases the cocoon of the preceding cell was pressed forward to cover the cocoon of the next cell, as if to be duplicated and then pressed aside. In the old nest, therefore, several intact disc-like outer ends of the cocoons and the crumpled rests of the cocoons are scattered.

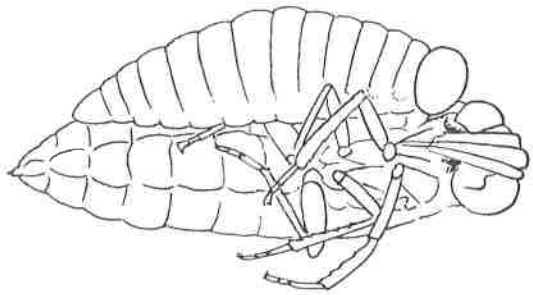


Fig. 3. Young larva of *Psenulus iwatai* on the prey.

The brownish or the thicker part of the cocoon, the cocoon lid, is always directed outwards, that is to say, the larva directed always its head toward the entrance, irrespective of whether the series of cocoons was made from upper to lower, or from lower to upper. The excrement of the larva was found attached to the inside layer of the cell, in a black and elongated mass, sometimes in two sticks. In some cases, however, it was found outside the cocoon. The fact tells us that the larva excretes either after or before the cocoon spinning. This is quite strange. A larva that failed in spinning the cocoon under my rearing excreted before beginning the cocoon building. Usually the larva of the fossorial wasp excretes after the cocoon is completed and utilizes the discarded substance to prevent the expansion of moisture by accumulating it at the inner end of the cocoon where the cocoon is in touch with the cell wall. Whether the time of excretion is really uncertain in this species or not, or whether the excretion before the cocoon spinning is exceptional or not I can not say at the present state of my knowledge. Further investigation is required.

Iwata's observation. As to this species Iwata in his young days (1938) published his observation on the two nests made in the stems of *Sophora angustifolia* which was withered and blown down by the wind. He supposed that the nests were made while the plants were alive and standing. He presumed also from the remains of food that the prey were the insects belonging to Fulgoroidea, Hemiptera, and certainly he found among the remains an intact dried-up prey which was identified with *Tropidocephala brunneipennis* Signoret. According to him the partition between the cells is a tampon of pith chips, 6–26 mm in thickness which is covered beneath with a semitransparent film probably made of buccal secretion of the mother wasp. The cocoon is cylindric, shorter than that of *Trypoxylon (obsonator?)* and on its cephalic end a brown-coloured tray-like membrane is attached and the cocoon as a whole looks like a mushroom.

These nests collected in Kyoto Prefecture comprise a considerable difference from those of mine above described, especially in regard to the separating wall between the cells and the structure of the cocoon. But the first point may be due to that the wasps of his observation dug the tunnel by themselves in the pith.

PSENULUS PALLIPES YAMATONIS TSUNEKI

This species is very common in the montanic regions of Central and North Japan. The wasps live from the mountain foot to a considerable height. They make their nests mainly in the wheat straws or the miscanthus used for thatching, but as well in the abandoned beetle burrows found in the pillars and railings. Hence they always accompany the human dwellings or some architectures such as shrines and temples. In Fukui Prefecture in the eastern montanic region everywhere they are common and abundant and scores of wasps can be seen in their colony founded in the thatched roof. They carry in their nests various species of aphides as food for the larvae. In carrying the prey they hold them between the mandibles and never use their legs as was described by some authors. This mode of prey carriage may be common to all the species of Pemphredoninae.

As to the biology of this subspecies Yasumatsu (1934) simply touched on the nest structure and the number of the prey per cell in connection with his descrpition of the larva (under the name of *Psenulus lubicus* Pérez). It seems to be a note-worthy fact that the wasp observed by him in Kyushu used some resinous substance to make the final closure of the nest. Iwata (1938) also recorded the nesting habits and the nest structure of the species. According to him the cell partition consists of a thin semitransparent film like spider's gossamer and a bit of debris crudely pressed over it, about 0.5 mm in thickness. The prey were the aphides of the genera, *Aphis*, *Macrosiphoniella*, *Agrioaphis* etc. and 24–53 in number per cell. During transportation the wasp holds the prey with her middle pair of legs (?) and the egg is laid on one of the prey in the middle of the provisioning work. He also used the name, *Psenulus lubricus*, following Yasumatsu. According to the description of the latter author, however, his *lubricus* is in reality the subspecies of *pallipes* dealt with here, not *lubricus* Pérez.

As regards the typical race in Europe numerous references have been published and these were reviewed and summarized by G. M. Spooner (1948) under the name, *atratus* Fabricius, together with his own observations. Three points regarding the breeding habits of this species that seem to me questionable from my knowledge based on the East Asiatic race will be extracted:

(1) The partitions between cells are "very thin membranous wall" (Harttig, 1932, under the specific name, *P. rubicola* Harttig), or "very thin and formed from particles of straw" (Freeman, 1938) or "of pith, 0.5 mm thick" (Richards in Spooner's paper, 1948), or "resinous consistency, composed of macerated pith mixed with a varying amount of glutinous secretion" (Spooner). (2) When the prey is carried "it is held close to the wasp's body, belly uppermost, clasped by the wasp's mid legs (a habit, incidentally, which it shares with *Mimesa*, but not *Mimumesa*) (Chevalier, 1925). In the appendix in regard to habits related to taxonomy Spooner himself describes that prey is carried ventrally, held by middle legs. (3) The egg was "attached to the abdomen of an aphis at the bottom of the cell (Kennedy, 1834, quoted by Westwood, 1840), or "attached flat on the side of one of the last few aphides stored (Chevalier, 1925), or "found in various positions in the cell, from the inner to the outer end, and so may sometimes be laid at the start of provisioning" (Freeman, 1938).

Stress was placed by Spooner upon the "Cocoon cap" which the full-fed larva makes across the anterior end of the cell, against the original partition made by tde mother wasp (which may already be collapsing at this moment). It was a complete and firm membrane, though the cocoon is very incomplete and the larva spins very sparingly and irregularly only against the anterior part of the side walls of its cell.

* * *

Of the three items mentioned above, regarding the first (cell partition), Harttig's observation is consistent with mine and Spooner's seems unique. Of the observations made in Japan Iwata's is similar to mine, but a thin layer of pith particles are added in his case. Yasumatsu says that the wasp observed by him smeared resin at the outer face of the final partition. Whether such variety really exists or not must be confirmed in future. (2) Chevalier, Spooner and Iwata agree in observing that the wasp carries the prey with the middle pair of legs. But it seems to me doubtful. I have never observed as yet any of the aphis-hunters use legs to hold the prey. They always catch the prey with the mandibles only. (3) In the nests of the Psenine wasps the egg is usually found on the prey stored towards the broad middle part of the prey collection. But I have never found it attached to the bottommost prey. The presence of the egg towards middle of the prey mass, however, does not always indicate that it was laid in the course of provisioning. Because it has been brought to light that a considerable number of species having similar habits in placing the egg in the middle part or at the bottom of the prey collection lay their eggs, in reality, after full or almost full provisioning to the cell is finished. Certainly there are some observations that seem to suggest the possibility of similar habits in this species also.

As to the structure of the cocoon the observation of Spooner is certainly confirmed also in our subspecies. But it seems strange that no investigator including those of Europe and Japan has ever paid attention to the curious threads that bind the collected prey together in the cell. It seems quite unique habits which can not be met with in any of the wasp groups hitherto investigated.

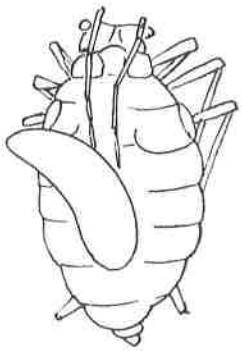
I have had innumerable chances to investigate the nests of this species. But in my note books only two instances are described.

Under the permission of the dweller I pulled out a wheat straw from a thatched roof which was lived by a flourishing colony of this species. The place was a village in the eastern montanic region of Fukui Prefecture and it was toward the evening of June 18, 1954. I examined it in the morning of the 21st.

The straw was without node from the entrance for 24 cm. It was 2.5–3.0 mm in diameter and 3.0 mm or so at the portion of the cells of the wasp. The straw was, of course, obliquely arranged in the roof, with the inner portion up. The space of the tube was at the inner end partitioned with a mud stopper, 4 cm apart from the bottom node, which was made concave at the outer surface. The first cell was made on the basis of this mud wall. It was 10.5 mm in length, its outer wall was a thin membrane, made of whitish silk and it was stuffed with 25 apterous aphides of green colour which were common on the leaves of the chestnut tree. The body orientation of the prey was without rule, but mostly laid transverse against the length axis of the cell. They were loosely combined together with silk threads into a mass and kept in the cell that was open downward. I could find among them the egg of the wasp which was attached to the prey located at the 13th from the bottom.

The egg was about 1.0 mm in length, somewhat thickened toward the posterior end, fairly strongly bent as given in Figure 4. When I examined it was about to hatch, dimly showing the

development of the segmentation, both of its ends being yellowish, while the middle portion broadly milky white. It was laid on the 18th, possibly in the forenoon. Therefore, its egg period is about 2.5 days and seemed unusually long. Its attachment to the prey was as given in Figure 4, but its cephalic end as well as the egg body seemed to be not tightly stuck to the body of the prey, but merely mounted on it.



Fgi. 4 Egg of *Psenulus pallipes yamatonis* Tsuneki.

The second cell was soon after the commencement of the provisioning, including only 3 aphides that were bound together with silk.

The straw used by this wasp was considered to be used by some other wasp or wasps. The inside of the tube showed the marks of the partitioning walls. At the entrance was a mark of the mud wall and thereafter the marks of the white membraneous walls were at the following intervals: 4.5, 1.7, 1.7, 2.0, 10.0, 9.7, 9.8, 9.7, 16.0, 17.0, 10.0 and 10.0 mm. At the marks of 16 mm and 17 mm the mark of the cocoon and the larval excrement were also perceived and the innermost mark was accompanied with the mark of the mud wall. Whether these marks were those of a nest of a single individual, or of some wasps of the different generations, I can not say.

The second nest was obtained from a thatched roof of a barn built by the side of the mountain pass. It was made in the pith cavity of the miscanthus stem, the burrow being about 2 mm in diameter. I took it on September 7, 1965 and examined the next day. The nest contained 7 larval cells, but the 7th was in the course of provisioning. The remaining cells were from inner 10.5, 11.0, 10.5, 10.0, 9.8 and 8.0 mm in length respectively and partitioned with the same whitish memdrane of silk as observed in the first nest. The prey were the apterous aphides of dark coloration, the number to the cells being from inner 28, 27, 30, 23, 25 and 17 and the outermost incompletad cell contained 8 prey which were distinctly bound together with silk threads. In the inner two cells 3 and 2 already sucked up and dried prey were found respectively near each larva. The offsprings of the wasp were in the inner 4 cells the larva, the outer 2 cells the egg and the incomplete cell contained as yet no egg. They were found towards middle, somewhat near the outer end of the mass of the prey, but in cells 4 and 6 very close to the outer end.

The rearing trial ended in failure.

PSENULUS ANOMONEURAE (YASUMATSU)

(=*Nipponopsen anomoneurae Yasumatsu*,=*Psenulus mandidularis* Tsuneki)

This species is also not rare in the montanic region of Central Japan. Except for the fact that it makes its nest in the cavity of the reed canes or miscanthus used for thatching the conditions of its habitat are similar to those of the preceding species. It differs, however, from the preceding species in some important points in biology. First, the prey collected by the wasps of this species is not the aphis, but the wood-louse, especially of *Anomoneura mori* Schwarz which is parasitic on the leaf of the mulberry tree. Second, the partitioning wall between the larval cells is not made of the secretion of the wasp only, but mainly of the thin layer of saw dust gnawn off by the wasp from the inner wall of the cavity the bottom of whick is supported by a rough membrane of silk. Third, the larval cells are broadened than the natural cavity of the reed or the miscanthus by taking the material from there to make the partitioning wall (Fig. 5). Probably on this account I have had no experience to see that the wasp of this species

makes its nest in the abandoned beetle burrow in wood. But it is similar to the foregoing species in the habit that the prey are loosely bound together with the threads of silk during the course of provisioning work, lest they should fall down from the inverted larval cell.

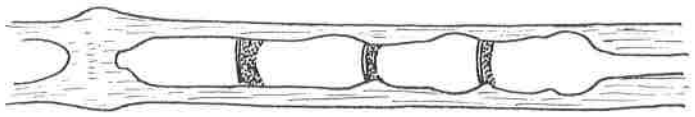


Fig. 5. Nest of *Psenulus anomoneurae* (Yasum.).

The reed canes or miscanthus selected by the wasps as their nests have their outer diameter 8–10 mm and the inner diameter 3–3.5 mm. The following nests were obtained from a thatched roof of a barn in an eastern montanic village of Fukui Prefecture, together with the nest of the preceding species.

Nest 1. The reed cane used by the wasp was 8–9 mm in outer diameter, having 85 mm space outside the outermost node where the wasp had completed 3 cells and was provisioniog the 4th one.

Cell 1. The cell occupied the innermost part of the space. It was 9.5 mm in length and 4–4.5 mm in diameter, except for the mammiform impression before the node. The lateral wall of the cell was evenly enlarged. In the cell was a full-grown larva, thrusting its caudal end into the mammiform impression. It had just finished its work of smearing the brownish secretion of the silk gland to the inner surface of the partition, but the lateral wall was received as yet no smearing nor lining. The caudal end of the larva had distinctly a hiatus, but the larva had not excreted. The prey were broken to pieces.

Cell 2. 9.3 mm in length and 4 mm in width, at the outer portion markedly broadened to about 6 mm in diameter. In the cell 27 prey of *Anomoneura mori* were compactly stuffed. But the egg or the larva of the wasp could not be discovered. As two plump mites were present in the cell the egg might have been sucked by them. All the prey had turned into brownish, some of the smaller ones even into black. The partitioning walls were distinctly concave at the outer surface. It was made of the gnawn particles of the lateral wall and was pressed hard, about 1–1.5 mm in thickness at the peripheral, wall-attaching part, but apparently much thinner at the central area and at the bottom of which a whidish silk membrane was roughly spun by the wasp.

Cell 3. 9.5 mm long and 4 (–6) mm wide. Prey 24 in number, of the same species as above and the one found at the 6th from the outermost carried the first instar larva of the wasp. It attached its mouth to the underside of the thorax of the prey between the front pair of legs and laid along the median line. All the prey had begun to change its colour. Most of them were almost green-brown and some ones alreaby completely brownish. It appeared, therefore, to be a rule in this species that the larva ate the partly or completaly rotten prey.

Cell 4. Without the outer wall, but its lateral wall was irregularly grawn off and the space was markedly enlarged. The cell was in the course of provisioning, including 5 green *Anomoneura mori*, but some had already lost its vivid green coloration.

All the prey found in this nest belonged to a single species of the wood-louse, all being in the nymphal instars.

Nest 2. The outer diameter of the reed cane was 7.5 mm and the utilized length was 11 cm in length. In the nest 4 cells had already been completed and the wasp was obeying the provisioning work for the 5th cell. The inner wall of each cell was rather evenly bit off and

the cell was enlarged to about 4.5–4.8 mm in diameter. The length of the cells was from inner to outer 9.0, 10.0, 9.0 and 8.5 mm respectivelly, that is to say, all were of almost equal size. The partitions were about 0.5 mm in thickness, made of chips from the cell wall, compactly pressed on the silk membrane and concave at the outer surface.

Cell 1. The larva was making the whitish, flattened, cap-like outer lid of the cocoon. It was similar in appearance to the partition of the cell found in the nest of *Psenulus pallipes yamatonis*. The prey were broken to pieces and could not be counted.

Cell 2. The prey were 17 in number, one of which was soon after the final moult, but its wings had not as yet the blackish marking, all others being in the nymphal stages. The egg of the wasp was attached to one of the prey that was located slightly more inner than the middle which was, strange enough, had been dead and partly covered with mould. All the other prey had turned into brownish, including some that had completely blackened and dried up.

Cell 3. The prey 13, the same species as above, all nymphs, the egg or the larva could not be discovered, probably destroyed by the mite that was present in the cell.

Cell 4. The prey 15, on the one lying in the middle of the mass (the 7th from the outside) the egg of the wasp was laid. Strange to say, it had been half crashed, possibly by the pressure with which the wasp compactly stuffed the prey later collected.

Cell 5. The prey 7, all fresh, showing the vivid green abdomen, but some one had the thorax already turning somewhat to brownish. No egg nor larva. The outer cell-wall was not made as yet and the cell was in the course of provisioning. The prey were roughly bound together with silk threads.

Nest 3. The reed cane was 7 mm in outer diameter, the utilized space being 12 cm in length within which were included 7 completed cells and 1 provisioning cell. The inside diameter of the cells was 3.7–4.0 mm, though the natural space of the pith cavity was about 3.0 mm in diameter.

Cell 1. 10 mm in length, including the completely dried up prey of the wood-louse, 24 in numder, with a few mites and their numberless eggs. The prey as well as the egg of the wasp must have been suck up by the parasites.

Cell 2. 10 mm in length, with a full-grown larval wasp which had already spun the brownish flattened cap close to the inner surface of the outer wall. The prey were 24 in number, completely dried up, but not broken to pieces.

Cell 3. 9.5 mm long, with 25 completely dried up wood-lice, with a few mites, the remains of the egg or the larva of the wasp could not be discovered.

Cell 4. In length 10.2 mm, involving 22 dark brown wood-lice, with a shrunk egg on the 9th prey from the outside. The manner of attachment was as uaual.

Cell 5. 12 mm in length, with 20 prey having the abdomens turned browhish and the thorces blackish. The larval wasp, about doubled length of the prey, was on the 7th wood-louse and was sucking it. It was a second prey and the first one, that was, the pedestal of the egg, was dried up and discarded by its side. It detached its mouth from time to time from the prey and moved its mandibles as if to gnaw it.

Cell 6. 10.0 mm in length, with 17 prey of which 1 was blackened and the remaining ones green and brown, still completely soft. On the prey at the 7th from the outside was a dried egg-shell which a mite was sucking.

Cell 7. 8.7 mm in length, with 17 prey, including 2 completely blackened and 15 green and brown ones. On the prey at the 7th from the interior was attached a half crashed egg of the wasp.

Cell 8. In the course of provisioning, with 6 fresh wood-lice, no egg of the wasp.

In this nest it seemed strange that in cell 2 there was a full-grown larva and yet the prey were merely sucked and not broken to pieces as observed in the preceding nests. Was it due to that the larva left the skins of the prey when the food was ample enough? The egg was always attached to the underside of the thorax of the prey between the front pair of legs and laid along the median line of the mesosternum.

As to the partitions of this nest, I particularly confirmed that the inside of each wall was supported with a thin layer of silk threads possibly spun by the mother wasp. The fact was presumed from that the wall was not easily crumbled down even when it was manipulated with the pincette. Certainly, under the microscope the threads were distinctly observable. In this nest it seemed worthy of notice that the partitions were comparatively thin toward the inner portion and thicker toward the outer portion. The outer cell wall was about 1.0 mm in thickness at cells 1 and 2, while it was 2.5–3.0 mm at cells 6 and 7.

The number of the prey stored in each cell informs us that in this species also the female is laid in the inner cells and the male in the outer cells as is the rule in the tube-nesting wasps and bees.

Nest 4. Obtained on June 28 of the same year as above, from a thatched roof of a barn in another village. It included 7 larval cells, from the inside 11, 10, 10, 11, 10, 11 and 11.5 mm in length respectively, each except the 4th including a full-grown larva, mostly already spun the cocoon. In the 4th cell the larva was dead. The outermost wall was made of mud in addition to the usual wall of pith particles.

The cocoon was of the thin membraneous consitution, covering whole the surface of the cell. The outer side was truncate, somewhat brownish and to this truncate surface a particularly made cap (Fig. 6) was attached. It was incrassated at the margin and coloured dark brownish there, but at the broad central area it was pale brown and thickly woven with silk. Inside the cocoon a large black mass of the excrement was pressed hard at the inner end and outside it a small amount of the remains of the prey was scatteringly attached which were very scanty as compared with the prey stored in the cell.

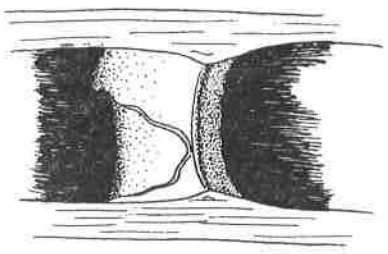


Fig. 6. Cocoon of *Psenulus anomoneurae.*

Emergence of the adult wasp. On March 11 the next year I examined the nests that were preserved in my laboratory which was artificially heated during the winter.

In nest 1 the larva in cell 1 still remained in the prepupal stage and occupied whole the length of the cell, but it was very slender, leaving a broad space around it. The larva in cell 3 was soon after pupation, still completely whitish in colour.

In nest 2 the larva in cell 1 had turned into a deeply blackened pupa.

In nest 3 the 2 larvae had turned into the papae, somewhat browhish in colour. The cocoon was not fully spun over the inner surface of the cell, but the curious outer cap of the cocoon was completed in both the cells. The excrement was voided at the inner end.

On April 4, the adult wasp in cell 3 of nest 1 had emerged, biting the wall of the cell, but the offspring in cell 1 was still in the pupal stage, only the eyes being coloured brownish. The wasp in cell 1 of nest 2 was just in the course of emergence (♀). The pupae in nest 3 were accidentally died.

As for the 4th nest I examined it on May 10 of the next year. The two outermost wasps

had already emerged, both being the males. On June 21, the next outer wasp had emerged and been deed and the 3 inner pupae were markedly darkened and supposed to be a short time before emergence. They were all females.

* * *

In the taxonomical affinity this spedies is close to the European representative, *Psenulus concolor* (Dahlbom), the biology of which has been studied mainly by Giraud (1866), Borries (1897), Grandi (1937) and especially by Spooner (1948). The wasp of this species makes its nest in hollow stems in the main and hunts the insects of Psyllidae just as in our *anomoneurae*. According to Spooner the cell partitions in the nest of *concolor* are firmer and more specialized than in *pallipes* (his *atratus*); though usually quite thin, they may be more than 1 mm thick; as Borries first observed, the matter of which they are composed is finely macerated pith moistened into a coarse pulp with saliva and closely resembles parchment. He confirmed the fact by viewing them from the inner side. The interior surface was distinctly convex, smooth and parchment-like, because it consisted of a finely-spun agglutinated meshwork (reminiscent of the material of a burnet moth cocoon). He says that it is clear that the wasp first constructs, with its own secretion a thin diaphragm which is first pure white and later discoloured, on which the rest of the partition of macerated pith is laid down. Borries observed that the pith for the partitions was taken from the adjacent wall, so that the cells were appreciably enlarged towards the inner end. Spooner noticed this same effect in a minor degree and considered it not general, depending on the availability of suitable pith. No mention was made as to the threads that bind the prey together.

According to the observations above quoted it is very clear that *Psenulus anomoneurae* of Japan is very close in biology also to *P. concolor* of Europe.

(*P. concolor* once reported to occur in Japan, but its occurrence in this country is doudtful.)

GENERAL SUMMARY ON THREE SPECIES OF *PSENULUS*

Apparently the species are the utilizers of the pre-existing hollow tubes to make their nests. Sometimes, however, the wasps of the subgenus *Psenulus* dig their nests in the pith of the slender stems of the plants. It is not an unusual event that the wasps of *P. pallipes yamatonis* or *P. p. puncticeps* throw away the debris from the end of the reed-canes or miscanthus used for thatching. But this species appears to prefer to use the ready-made hollow such as the abandoned beetle burrow or the reed-canes, miscanthus and hemp-plant in which the pith was collapsed and lost. On the other hand, the wasps of *P. anomoneurae* seem to prefer to dig the pith of the plant. The nests observed by Iwata were certainly dug into the pithy tissue of the young branches of the mulberry tree that were cut off and horizontally piled up. As to the subgenus *Eopsenulus* the wasp that made the nests which were observed by Iwata apparently dug the pithy tissue of the herbaceous plant, because the saw dust were used as the cell-partitioning material. While, the wasps observed by me always utilized the pith cavity already existed and sectioned the space into cells with the membranes of the silk gland secretion. However, in my case also the wasp dug the entrance on the lateral wall of the miscanthus to reach the empty cavity. Therefore, in some cases when the condition of the nesting base demands the wasp of our district also may dig the tunnel in the soft tissue of the dead plant.

The habits common to all the three species are to use the silk thread to bind the collected prey together during the course of provisioning activity. This seems certainly an instinctive

adaptation when the cells are arranged from upper to lower. But when they are made from lower to upper the same habits come to show the blindness of the instinct. Nature will have given the insect a superfluous working order in preparation for the time of necessity. At any rate, this seems to be a very interesting and characteristic habit of the species dealt with here (or genus?). Strange to say, however, no mention has been given as to the habit by any observers in Japan as well as in Europe. On the other hand, the same substance is also used to make the partition between the cells, though in *anomoneurae* only playing a supporting rôle. As to the origin of this substance Iwata considered it to be the spider's gossamar in regard to the partition wall of the nests of *P. pallipes yamatonis* (his *lubricus*). In regard to the nests of *P. anomoneurae* in which the substance is only used to form the bottom of the partition to support the saw dust he says that it is the gossamar-like buccal secretion of the mother wasp. Possibly he could not have confidence as to the derivation of the threads. I believe that the threads are derived from the silk gland of the mother wasp, although the presence of such a gland is not anatomically confirmed. The reasons for my belief are that the thread that binds the prey together has no such a structure under the microscope, as observed in the sticky thread of the spider's web and that it seems very improbable for the wasp to collect such a large amount of the spider's web to form the partitioning membranes and to have technique to transform the collected material into the film.

The prey are all Homopterous insects, mostly aphides, but in *anomoneurae* the Psyllid of the genus *anomoneura*. The egg of the wasp is laid on one of the prey stuffed which is not the first nor the last one collected, but on some one between them. This is apparently due to that the wasp makes oviposition in the course of provisioning. But the possibility seems still to remain that the wasp lays her egg after the full provisioning on one of the prey located more or less apart form the last during the course of rearrangement of the collected prey, because such instances are not less among the tube-nesting fossorial wasps. Iwata observed in the nests of *pallipes yamatonis* the cells that were stored wish 25, 17, 34 and 17 prey respectively and yet without the egg of the wasp. Further studies are needed to confirm the time of oviposition. In carrying the prey the wasp of the genus always catches it with the mandibles only and goes on the wing. The larva at first sucks the prey one by one, but later devours them. The prey are probably killed, at least soon dead and become rotten and it seems that the larva eats usually the dead prey. As to the cocoon it is common to all of the species observed here that the outer end is truncate and is made particularly thick and rigid as if to be a lid.

All the species observed appear twice a year, early and late in summer.

STIGMUS (CARINOSTIGMUS) FILIPPOVI GUSSAKOVSKIJ

This species is a tube-renter or a pith borer in regard to its nesting base. I have observed that it makes its linearly arranged cell group in the pith cavity of the dried stem of *Diervilla* in Nikko and in Koike. But it lives more usually in the hollow of the reed canes or miscanthus used for thatching. Regarding the biology of this species Iwata (1938) observed several nests made in the pith of *Kerris* and *Rubus* which included 3, 3, 3, 3, 5, 6 and 8 larval cells, some of the three-celled nests of which were in the course of provisioning. According to him the partitions are made of pith chips bit off from the adjoining wall, with no thin film at the inner surface of the tampons and the prey (aphides of *Myzus*, *Agrioaphis* and *Amphorophora*) stored in one cell ranges from 19 to 49, and the egg is laid on one of the last prey brought in. In Koike, a village among the mountain ranges in the eastern district of Fukui Prefecture, 800–

900 m above the level of the sea, this species abundantly lived in the thatched roof. The following material was obtained from such a roof of the village on June 3, 1956, and examined at my laboratory two days later.

Nest 1. The space of 19 cm from the cut end up to the first node was utilized by the wasp for her nest tube. The averaged outside diameter of the miscanthus was about 5 mm and the diameter of the inside hollow was about 1.5 mm which was dug by the wasp herself. This nest included 7 cells.

Cell 7. (The outermost cell). The inner partition that was made of the saw dust of the pith pressed hard was 2 mm in thickness and concave at the outer surface. Cell space was 7 mm in length and contained 13 aphides, but the egg of the wasp was not laid as yet, showing that the provisioning was going on. The outer wall was made of saw dust very loosely collected. Probably the wasp of this species uses this loose tampon as a temporary closure during her food collecting work and when the cell is accomplished presses it compactly to make it the cell partitioning wall. An ample space remained still outside this tampon to make further cells.

Cell 6. 8.5 mm in length, the inner wall somewhat thicker than the outer, about 2.5 mm, the prey the green aphides having transverse lines of small tubercles on the dorsum of the abdomen, 29 in number, to the 6th one from the inside a 1–2 day old larval wasp was attached.

Cell 5. 11.7 mm in length, 18 aphides of the same species; a young larval wasp on the 8th prey from the interior that began already to blacken, but the larva was healthy and vigorous. The manner of attachment was as given in Figure 7.

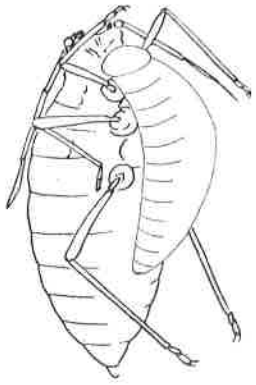


Fig. 7. Young larva of *Stigmus filippovi* Guss. on the prey.

Cell 4. Cell length 9.0 mm. Prey somewhat larger, 14 in number, the same species as above; on the 8th prey from the inside was found the larva of the wasp. Packing mode of the prey was rather loose, 4 of them had already somewhat blackened.

Cell 3. 9 mm in length, prey 16, large aphides, the 6th one carried the egg of the wasp which was lusterless and probably dead. Six of the prey already turned blackish.

Cell 2. 8 mm in length, prey 15, large aphides, the inner 5 had already been sucked up and covered partly with mould. The larval wasp was eating the prey which together with all others had already turned brownish.

Cell 1. Cell length 9.5 mm. Prey 12, large aphides, all turned brownish. The sucked prey were only 2 in number, the larva fairly grown, about 7 mm in length, possibly there had been some further prey devoured up by the larva.

Partitions between cells about 2 mm in thickness except for the outer one of cell 5.

Nest 2. The outer diameter of the miscanthus used by the wasp was about 5 mm in diameter and the space dug in the pith was 22 mm in length. The wasp had completed 2 cells and was collecting food to cell 3.

The bottommost cell. This was not used for the larval cell and remained empty. The innermost and the outermost parts were loosely stuffed with saw dust, 5 and 8 mm in length respectively and the space left between was about 10 mm in length. Just in front of the outer loose tampon of saw dust a compactly pressed hard partition, 3 mm in length, was built as the bottom of cell 1.

Cell. 1. Length about 10 mm, including 12 aphides, the 5th one from the interior carried a young larva of the wasp. The outer partition was a compact layer of saw dust, 2 mm in

length.

Cell 2. Length 17 mm, exceptionally long; the prey included were 15 in number, all turned brownish, one of them rather blackish. A young larval wasp was on the 5th prey from the interior, attaching its head between the first pair of legs of the prey, as given in Fig. 7. The outer cell wall was exceptionally thick, 10 mm in length, and tightly pressed.

Cell 3. Four small aphides were collected without the egg of the wasp. There was no loose tampon was observed as in nest 1. An ample space to make further cells remained outside the cell.

Nest 3. The outer diameter of the miscanthus was about 5 mm and the space to the first node was 9.5 mm in length. But the tunnel burrowed by the wasp, 2–3 mm in diameter, pierced through the first node and reached 30 cm from the cut end, including 11 completed cells and 1 provisioning cell, occupying inner 16.5 cm of the burrow, leaving still the space of 13.5 cm unused. If the wasp was allowed to build further cells in the cavity she might arrange at least 20 cells in the burrow. In this nest the partitioning walls between the cells were comparatively thick, 3.5–5.5 mm in length, showing distinctly an inclination to becoming thicker outwards.

Cell 11 (the outermost cell). It was in the course of provisioning, without the outer wall of the temporary nature, with only 1 aphis stored, of course without the egg of the wasp.

Cell 10. 14.5 mm in length, with 33 small aphides, all turned brownish. The larva of the wasp was soon after hatching and found on the 18th prey from the innermost one, the attaching manner was the same as given in Figure 7.

Cell 9. 11 mm in length, with 35 small aphides, all turned brownish. The larva of the wasp was found on the prey located toward the middle of the prey mass.

Cell 8. 12.5 mm, 13 large aphides, the 7th carried the larval wasp. All the prey but one had turned brownish.

Cell 7. 11.5 mm, 12 large aphides, the waspling on the 2nd prey from the bottom, one of the prey covered with mould.

Cell 6. 11 mm, 17 aphides, on the 16th from the inside (the 2nd from the outside) the larval wasp was present and eating, the next inner prey had been sucked up. All the remaining prey had been turned dark brownish.

Cell 5. 10 mm. 12 aphides, the 4th from the innermost with the waspling eating, the next inner prey had been sucked up.

Cell 4. 10.5 mm, 15 aphides, the larva on the 6th prey from the interior, 2 of the prey were already sucked up.

Cell 3. 13.0 mm, 10 prey, the larva was eating the innermost prey, no sucked-up and dried prey, possidly some of the aphides had been devoured.

Cell 2. 11.0 mm, 18 aphides, the larva was eating the 5th prey counted from the bottom, from the 2nd to the 4th the prey had been sucked up and discarded. As to the 5th the head only remained and the larva was eating it.

Cell 1. 14.5 mm, 13 aphides. The larva was eating the 7th prey, the 2 next inner aphides had been sucked up. Possibly several other aphides had completely been eaten up.

Nest 4. The miscanthus used was 4.7 mm in thickness, the inside hollow dug by the wasp was 1.8 mm in diameter. The wasp pierced the first node and went in 20 cm further up to the second node where the first cell was made. It was 12 mm in length, with the outer wall 2.5 mm in thickness, including 28 small aphides, to one of them placed toward the middle a just hatched larva was attached. No prey had been stored in the 2nd cell.

Nest 5. The miscanthus used was 5 mm in thickness, the tunnel pierced the first node

that was 8 cm from the cut end of the stem and went in deep through the second segment. Just 15 cm from the stem end the outermost partition was present inside which 6 cells had been completed and outside the outermost wall the 7th cell was in the course of provisioning: Table 1.

Table 1. Nest 5 of *Stigmus filippovi*.

Cell No.	Cell length	Prey	Waspling
1	18.5 mm	18	On the 15th prey
2	10.5	12	On the 3rd prey
3	12.5	15	On the 5th prey
4	8.5	8	On the outermost
5	7.0	9	On the 4th prey
6	12.5	22	On the 15th prey
7	—	17	None

The innermost part of the tunnel was compactly stuffed with saw dust for 8 mm. Each wall was 2.0–2.5 mm in thickness, made of saw dust compactly pressed, only the outermost being 5 mm. The prey stored were more or less turned brownish or partly blackish. In the tunnel outside cell 6, about 4 cm apart from the outermost wall a ball of saw dust was accumulated in a loose mass as if to be a temporary closure.

Nest 6. The miscanthus was 3.7–4.5 mm in outer diameter. The tunnel dug by the wasp up to the first node was 13 cm in length, with the averaged width amply 2 mm. Two cells were completed at the interior of the tunnel.

Cell 1. 9.5 mm, with 14 aphides, on the 9th from the bottom was the waspling. All the prey turned brownish.

Cell 2. 14.0 mm, with 14 prey, on the 8th was the waspling. The prey turned dark brownish and the larva was eating one of such prey, with its own body colour also blackish brown. Some of the prey placed in the inner part of the cell were covered with mould. The tunnel was twice closed with a loose mass of saw dust, 2.6 and 4.2 cm from the entrance and outside the 2nd wall where cell 3 was to be made a similar loose mass of saw dust was present. These loose masses of saw dust were brown in colour and not originated from the wall of the tunnel. Possibly the material was brought in from outside the tunnel, or collected at the end of the stem.

Nest 7. The miscanthus used was 5.5 mm thick. The tunnel dug by the wasp was 16 cm in length and 1.5–2.0 mm in width, including 4 completed cells and 1 provisioning cell: Table 2.

Table 7. Nest 7 of *St. filippovi*.

Cell No.	Cell length	Prey	Waspling
1	10.2 mm	22	On the 9th
2	10.5	21	On the 15th
3	9.0	22	On the 9th
4	10.7	26	On the 16th
5	—	5	None

The innermost attenuate part of the tunnel was filled compactly with saw dust. The partitions were from inside 4.5, 1.8, 2.0 and 4.0 mm in thickness, made of saw dust as in others. The prey in cells 1 and 2 were all turned dark-brownish. Those in cell 3 were blackened except the innermost one and 5 outermost ones. The prey that was being eaten by the larva at the moment of examination was blackened. But the larva was vivid and apparently quite indifferently eating it. The larva in cell 4 was soon after hatching and the prey stored were, except 3, all vivid green in colour. The prey in cell 5 were all fresh and green, mixed with the brown saw dust.

Nest 8. The halm of the same species of the plant, 4.5 mm in thickness, with the tunnel made by the wasp 21.4 cm in length, including 1 completed and 1 provisioning cells.

Cell 1. 14 mm in length, with 53 aphides, the 40th from the inside carried the waspling that was soon after hatching. The partition wall was 5 mm in thickness.

Cell 2. prey 5, in the course of provisioning, no egg.

Summary on the biology of *Stigmus filippovi*

The nest is made in the pith cavity of the dried stem of *Diervilla* or allied shrubs, or of the reed cane or miscanthus used for thatching. In most of the cases the pith is bored by the wasp itself. In the cavity the larval cells are linearly arranged, separated by the walls of the saw dust gotten from the inner wall of the cavity, more than 15 in number under the favourable condition. The prey collected by the wasp was always the aphis, the number stored per cell markedly varies according to the size of the prey, 8–55 under my observation. The egg of the wasp is apparently laid during the course of provisioning, since it was always found attached to some one between the first and the last, mostly toward the middle of the prey mass. The prey is carried on the wing. It is held under the head of the wasp and is captured with the mandibles only. The prey are apparently not paralyzed but killed. Hence they become soon rotten, turning from green to brown and finally to black. But the larva of the wasp eats the rotten prey, apparently without receiving any harm. It may be one of the natural saprophagous insects. Certainly the prey becomes rotten soon after stored in the larval cell, but not dried up—the dried up prey can not be eaten by the larva—, this is probably due to that the nesting site is always selected by the wasp at the shaded place. During the course of provisioning the wasp sometimes places a loose mass or two of saw dust in the tunnel, possibly for the instinctive purpose of the temporary closure.

As for the cell size in the tunnel any decided difference can be observed between those made inside and outside. The same is also true as regards the quantity of the prey. Whether there is a rule in this species also or not wth respect to the arrangement of the sexes of the offsprings in a nest, therefore, still remains unknown. However, this may be due to that the nests observed by me were not the completed ones, leaving a considerable space to be filled with further cells.

NOTES ON THE BIOLOGY OF THREE SPECIES OF *STIGMUS* (*STIGMUS*)

***Stigmus* (*Stigmus*) *munakatai* Tsuneki** occurs rarely in Japan. The record of capture of this species has been confined to three localities of Central and North Japan, namely Hakodate, Utsunomiya and Fukui. Apparently this species is a lowland inhabitant. No specimen has been collected in montanic region or high altitude. The species is certainly rare, but at the place where it occurs the wasps form a crowded colony. In a temple that is situated in the suburbs of Fukui I found a very flourishing settlement of this species. Scores of the pigmy wasps live in the small hollows of the abandoned beetle burrows, about one mm or so in diameter, opening on the pillars and railings of the old temples. During May and June we can observe the wasps very actively provision their nests. The wasp comes flying back, capturing the prey between the mandibles, flying very slowly from about 30 cm in front of her nest and alights on the wood. Thence she walks to the entrance and goes in it with the prey. The prey is a species of the soft green aphides, 1–2 mm in length, but the specific identification has not been made as yet.

***Stigmus* (*Stigmus*) *convergens* Tsuneki** is comparatively common in the montanic region of the northern half of Japan. The wasp of this species lives also in the old burrow of the small wood-boring beetle, not of the standing dead tree, but of timbers used for building the human houses, barns, temples and shrines. In one place of Fukui Prefecture I found a small colony of this species settled in the thatched roof of a barn. The mode of life of this species

is much the same as in the previous species. The wasp also hunts the small, soft, green or yellow aphides, captures the prey between the mandibles and carries them on the wing.

***Stigmus* (*Stigmus*) *quadriceps* Tsuneki**. Except for that the wasps are more rarely met with even in their habitat the life of this species is also much the same as in the preceding species. At present the species of the aphides can not easily be identified and it is very regret that the species of the prey can not be listed here.

NOTES ON TWO SPECIES OF *SPILOMENA*

***Spilomena japonica* Tsuneki**. On July 9, 1955, I found a wasp of this species enter a small hole opening on the trunk of a standing dead tree near Shobugahama of Lake Chuzendzi, Nikko. After her departure I closed the entrance loosely with a bit of leaf and when the wasp came back with a prey and alighted at the entrance it was caught in a small tube bottle. The wasp was walking about on the inside wall of the bottle without letting off the prey. So I observed by the aid of the magnifying glass and could confirm that the prey was a nymph of a species of the thrips and it was held by the head with the wasp's mandibles, laid under her body along the median line of the sterna and reached with the other end near the metacoxa. None of the legs of the wasp cooperated in holding the prey with the mandibles. The nest could not be cut open.

***Spilomena laeviceps* Tsuneki**. In the east montanic region of Fukui Prefecture this species is rarely found to live in the minute beetle-burrows opening on the railings of barns and cottages. As in other aphis-hunters this species also prefers to nest in the shaded and moist place. Hence the nest of this species is usually found in wood of the northern side of the old house. In one of such places in the village of Koike, about 800 meters high, I found a colony of this species which consisted of about 60 female wasps settled in one of the joists of a barn. It was on July 18, 1959. The wasps came back each with a prey between the mandibles. They flew very slowly, but as they were so tiny that it was very difficult to follow them with the eyes to their nests. At the joist they landed near the entrance of each nest, walked to it and penetrated with the prey. The entrance was always left open. The prey robbed of the wasps were a species of the thrips, but their identification was not as yet performed. The nest could not be examined.

NOTES ON THE BIOLOGY OF THE SUBGENERA OF *PSEN* S. LAT.

Spooner (1948) in his excellent paper on the British species of Psenine wasps summarized in relation to habits related to taxonomy that the members of *Mimesa* are the ground diggers, those of *Mimumesa* are the utilizers of cavities in wood, dry plant stem (?) or crevices near ground and those of *Psen* (s. str.) are either the utilizers of ready-made cavities in wood or sandstones (*ater*) or in plant stems (some species in N. America).

In my previous paper (1959) on the taxonomy and the biology of the Japanese and Korean species of the genus *Psen* s. lat. I recorded that at least two species of *Mimumesa*, namely *atratinus longulus* Gussakovskij and *littoralis* Bondroit, were the ground diggers and showed some of the instances of their nests. Since the appearance of this paper I have received a question from some persons who apparently misunderstood the Spooner's summarization to be the universal conclusion, as to whether there was not an error either in the identification of the species or in my observation. This is, of course, out of question. I only added some correct

records to the knowledge hitherto accumulated. Basing upon these data Spooner's knowledge, then ample and correct, in regard to the nesting base of *Mimumesa* should be enlarged as "nests either in ready-made cavities in wood (*dahlbomi* including ssp. *pacificus*, *spooneri*) or in ground (*littoralis*, *atratinus longulus* and ?*vanlithi*)".

It must further be added here that the Spooner's summarization in regard to *Mimumesa* "prey carried in mandibles" is not a rule, if not incorrect, in this subgenus. At least in *atratinus longulus* and *littoralis* occurring in Japan the prey is held with one or both of the middle pair of legs.

As regards the nesting base of *Psen* s. str. found in Japan some species such as *aurifrons* Tsuneki and *affinis* Gussakovskij nest in the ground, while *richardsi* Tsuneki and *ater* Fabricius make their nests in wood.

PSEN (MIMESA) BIDENTATUS GUSSAKOVSKIJ

Psen (Aporina) bidentatus Gussakovskij, Trav. Inst. Zool. Acad. Sci. URSS, IV: 643 (key), 673, 1937 (S. W. Siberia—Pavlodar, Bayan-Aud, Minusinsk).
Psen (Mimesa) bicolor: Yasumatsu, Mushi, 14 (2): 113, 1942 (Inner Mongolia—Apaka, nec Peking).
Psen (Mimesa) bicolor: Tsuneki, A Naturalist at the Front (Osaka), 332-335, 1942,

During my stay in Inner Mongolia in 1939 I could observe some nests of this species. In my book listed above I gave simply one of the nests that I observed. On this occasion I will put on record the breeding habits of this species in more detail.

In the village of wasps and bees, so I called the place in my previous papers dealing with the nesting biology of the Inner Mongolian digger wasps, I found a flourishing colony of this species. Of course, the wasps of this species did not form a pure single species settlement, but they lived side by side with the members of the colonies of other genera or families. At the upper edge of the slope that formed a dried rain ditch between the hills, about 4-5 m in depth and 10 m or so in width, where the ground was not covered with grass and sunny, the wasps and bees of various species were found gregariously nesting, the breeding activities of some of which were already separately described in some of my previous papers. Among the inhabitants the wasps of this species having the red-banded and long-petiolated abdomen occupied one of the top rank in the number of the colony members.

In choicing the nesting site the *Mimesa* preferred the perpendicular wall of small hollows, 5-15 cm in width, or some steep inclination that was resulted from the showering rain of the rainy season to the flat or gently sloped area. This is probably due to that they did not like to make a mound of soil at the entrance of their nests. Certainly it was usually observed that the wasps threw down the debris taken out of the tunnel of their nests from the entrance-openings located on such a place. During the wasp was away the entrance to her nest was always left open.

On September 18, 1939, when the time was rather late in the wasps' season, I found, together with other species, the *Mimesa* still actively work to provision their nests. I tried to examine the inner aspects with several nests, but I succeeded in only one of them (nest 1) to follow the tunnel up to the larval cells.

Nest 1 (Fig. 8). The tunnel, after proceeding horizontally for 1 cm, inclined to form a parabolic curve and then penetrated perpendicularly for 15 cm. There it became gentle in inclination without any obstacle and went for further 8 cm to reach the end. At the end the tunnel was compactly filled with soil for about 7 mm and when the filling was removed a larval

cell (cell 1) was exposed. It was half filled with the prey, a species of Jassidae (Fig. 9), 12 in number, but I failed to discover the egg of the wasp. The cell was, as usually the case, ellipsoidal in form, comparatively large, about 12 mm in length and 7 mm in width. By the side of this cell I found the other cell which contained 11 prey of the same species as in cell 1 and in this cell the owner of the nest was found hiding. Whether the wasp that might have been in the tunnel was driven by my excavation and fled into the larval cell or she was habitually rested there I can not say. But it was certain that the branch gallery leading to the cell was not closed with soil. In this cell also I could not discover the egg of the wasp.

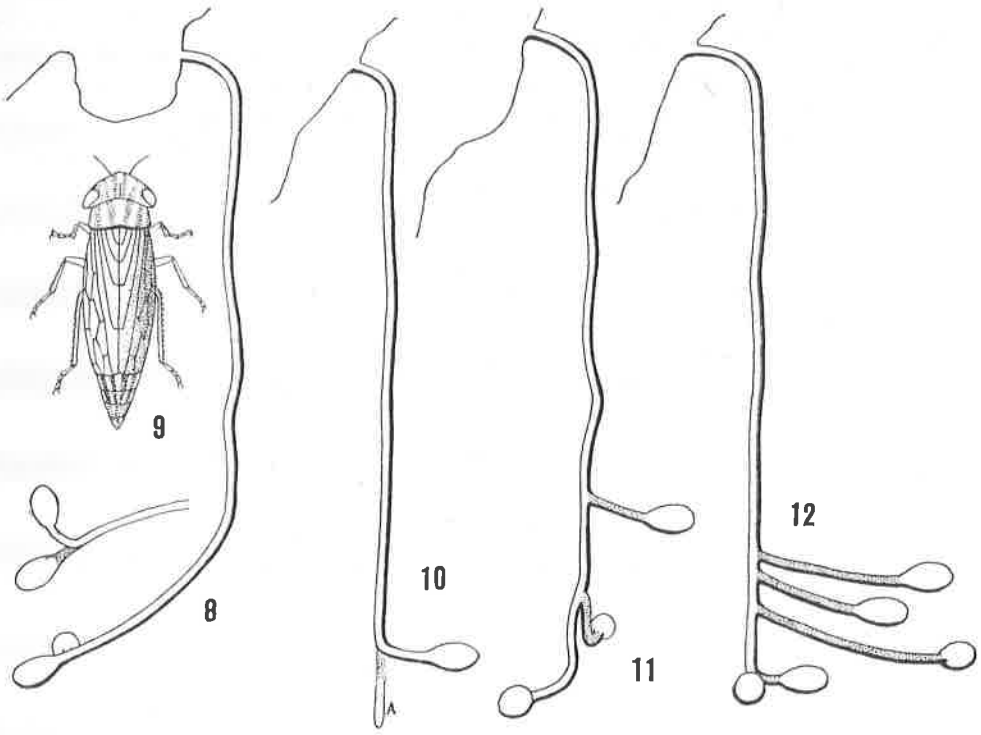
The prey (Fig. 9) was 2–4 mm in length, mostly the nymphs, only 5 out of 23 being the adult insects, mixing the ones of various instars, yellow green in colour, with increasing black as development proceeded (in the adult insect the underside of the body wholly black). They were all placed with their head inwards and ventral surface uppermost.

Nest 2. On the 24th, the same month, I visited the place again. The day was exceptionally warm and various species of butterflies of Pieridae and Nymphalidae were seen flying about in the sunshine. Over the wasps' village many bees of *Colletes* that had a habit of making a curious cellophane sac in their underground nests and *Andrena*, *Halictus* etc., together with their parasites, various species of *Nomada*, were also very actively flying and walking. Of the digger wasps, two species of *Bembix*, *Palarus*, *Ammophila*, *Gorytes*, *Oxybelus*, *Cerceris* etc. were observed to work for provisioning their nests. But of such bees and wasps the most abundant and most actively working were the wasps of the *Mimesa* dealt with here. A large number of openings of their nests were discovered and I tried to dig several of them. But, this day, too, I succeeded only in one of them to examine the larval cell. It was as given in Figure 10.

The nest was very deep, reaching 18 cm below the level of the entrance, but it included only a single cell. The fact told me that the time was the most active period of the species, though for the other species it seemed to be near the off season. Possibly they were the wasps of the second generation. The cell was laid horizontal, 12×6 mm in dimensions and was stored with only 4 prey of the Jassidae as found in nest 1. It was surely an unaccomplished cell and the egg of the wasp was not laid as yet. The mother wasp was at A, 2 cm below the turning point of the branch galley to the cell and was digging the tunnel. It was also uncertain whether the wasp was digging the tunnel to flee from the intruding metallic matter (in reality a knife) or she was doing so in preparing for the next cell, though she was in the course of provisioning her first cell. The main tunnel and the side one leading to cell 1 were thoroughly left open.

Nest 3. Three days later, September 27, I revisited the place and excavated a nest of *Agnosicrabro mongolicus* m. The tunnel of the nest penetrated deep into the ground and I missed the tunnel on the way. In order to rediscover the continuation of the tunnel I dug a large hole. During the time I discovered quite unexpectedly several nests of other wasps and one of which was the nest of the *Mimesa* having the two lateral projections at the anterior margin of the clypeus.

The structure of the nest was given in Figure 11. The length of the branch tunnels leading horizontally to the larval cells was short, 1–1.5 cm and the cells were as large as those of the previous nests. The first cell which was 18 cm below the entance included 11 prey of Jassidae, the second cell 16 prey and the third 10 prey. They were mostly the nymphs of various instars, consisting of 2 species, including the same one as found in other nests. In cell 1 I found the wasp's egg which was laid on the uppermost prey, attached to the right side of the neck, laid along the outside of the fore and middle legs of the same side and reached near the hind coxa. It was slightly curved, semitransparent white in colour. The branch tunnels were all



Figs. 8–12. *Psen* (*Mimesa*) *bidentatus* Guss. 8, 10–12: Nests. 9: Prey.

compactly closed with soil and so the cells were the accomplished ones. But I failed to discover the offspring of the wasp in other cells. The failure that was repeatedly experienced was utterly due to the lacking of the favourable digging tool, because I went to Mongolia not to study the life of the wasps and bees.

Nest 4. On September 29. The structure of this nest was shown in Figure 12, the depth to cell 1 being 16 cm. This nest included 5 cells, as far as discovered by me. Cell 1 included 16 prey, of which only 2 were imagoes, the upper- and outermost prey carrying the egg of the wasp. It was laid as in the previous instance except that the side was opposite. Cell 2 was empty. Cell 3 contained 8 prey including 3 imagoes, but the larva was crushed together with the pedestal prey. In cell 4 I found 6 prey and a small maggot of the parasitic fly, about 2 mm in length. The egg of the wasp might have been eaten by it. Cell 5 included numerous prey, but they were all rotten. The tunnel to each cell except cell 2 was closed with soil.

Judging from the contents of each cell it was considered that they were constructed from upper to lower and the possible order of construction was 5 – 4 – 3 – 1 – 2.

Summary. Seemingly this species appears twice a year in Inner Mongolia and the second generation works early in autumn, when the climate rapidly shifts to show the winter aspect at night which is quite unfavourable to the activity of the digger wasps in general. In Inner Mongolia also this species nests gregarously as in other relatives in other parts of the world. The site chosen by this species is a small perpendicular or steeply inclined wall at the upper part of the bank of a dried rain ditch, facing the south, where the ground is not covered with grass and the soil is of firm sand admixed with more or less clay. The burrow is at first dug in horizontally, but after going 1 cm or so turned downward parabolically and penetrates 16–20 cm below the entrance level. The cells made from the bottom of this main tunnel are

connected with it with the horizontal branch tunnel, 1–5 cm (mostly 1–2 cm) in length. They are apparently constructed from upper to lower, that is to say, in a endless type, but the interval between the adjacent branch burrows is usually not large. The larval cell is 11–13 mm in length and 6–7 mm in width, always horizontally laid. The wasp hunts the small Jassid hoppers (undetermined, consisted at least of two species), mostly the nymphs, and stores in each cell from 6 to 16 prey (usually 12 or so in number). In carrying the prey the wasp holds it head to head and venter to venter with her middle pair of legs. In the cell the prey is placed all head in and venter up and to the one carried in last the egg of the wasp is laid. The place and the manner of oviposition are the same as in other hopper-hunters that lay the egg directly on the prey, namely, the cephalic end of the egg is attached to one side of the neck and the egg body is laid along the outside of the fore and middle coxae of the same side and the caudal end reaches near the hind coxa. When the egg is laid the branch tunnel leading to the cell is compactly closed with soil. As far as observed by me the cells made in one nest are at the maximum 5 in number. But in this nest the mother wasp was still working and the climate might allow the wasp to work for at least several further days it seemed possible that 2 or 3 cells might be added to the nest. On the other hand, judging from the depth of the nest and its compound structure it seemed improbable that the wasp made more than one nest during her life time.

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