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ON THE TWO FORMS OF THE ANT *MYRMICA RUGINODIS* NYLANDER (HYMENOPTERA, FORMICIDAE) FROM SAPPORO AND ITS VICINITY, JAPAN

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札幌およびその近郊におけるシワクシケアリの2型について

北海道大学農学部昆虫学教室　水　谷　　章

Synopsis

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Based upon ecological aspects, *Myrmica ruginodis* Nylander from Sapporo and its vicinity is divided into two forms, one occurring in riverside areas and the other in woodland. The riverside form is polygynous and produces fewer new queens, which suggests colony reproduction by fission and the internest movement of workers. The woodland form is generally monogynous, produces many queens, and conducts colony reproduction by solitary queens.

Introduction

It is often difficult to classify ants by their morphological characteristics alone as exemplified by *Formica pallidefulva*-group (TALBOT, 1948) and *F. rufa*-group (GÖSWALD, 1942), etc. Ecological information is indispensable for a reliable classification. The present paper reports the two forms of *Myrmica ruginodis* Nyl., occurring in Sapporo and its vicinity, Japan, one which inhabits riverside areas and the other woodlands. The two forms are compared with *M. ruginodis* macrogyna and *M. ruginodis* microgyna from England, which were separated by BRIAN and BRIAN (1949, 1954). COLLINGWOOD (1958) suggested that microgyna may be an adaptive response of the species towards an oceanic type of climate, and that the two forms of European *M. ruginodis* are not subspecies but races. ELMES (1975) also pointed out that macrogyna is the normal form, microgyna being better called the microgyne variety. In this paper, the term race is applied to each form of European *M. ruginodis*.

Methods and Site Characteristics

Collection: A pit of about 50 cm depth was excavated about 20 cm to the side of the nest entrance. The profile of the pit was carefully leveled little by little toward the nest with a kitchen knife. All the inhabitants of the nest were collected and preserved in 70% alcohol for sorting in the laboratory. A total of eighty nests of *M. ruginodis*, 60 from riverside areas and 20 from woodlands, were excavated and collected during 1975–1977.

Internest movement: On June 21, 1976, 100 workers which left the entrance of the nest (NI) were mass-marked on the gastric dorsum with quick-drying ink (PENTEL WHITE), and then released where they had been caught. After three days, nest NI and three adjacent nests were collected. Both marked and unmarked ants were examined under a binocular microscope.

Site characteristics: From December to March, the riverside areas in Sapporo and its vicinity are covered with heavy snow which thaws and disappears in April. Plant growth is abundant from early to late June. The plant cover flourishes from July to early September, then decays in mid September to October, leaving a desolate winter scene in November until it is covered with snow.

Correspondingly, the annual cycle of riverside *M. ruginodis* is characterized by low level activity by post-hibernating workers beginning in late May after thawing. The full scale activity usually starts during late June when the honey dew secreted by

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aphids on weeds becomes available. In early August new sexuals emerge in most nests. New workers usually emerge slightly later than the sexuals, from mid August to late September. Extranidal activities drop abruptly from early to late October and cease in November.

In this paper the *M. ruginodis* collected from woodland and riverside areas is called woodland form and riverside form respectively.

Results

Comparison of body size

To give an index of size, the head width of 25 sample workers taken from each mature colony was measured immediately behind the eyes. The riverside form and the woodland form differed in body size, but they were similar morphologically. As shown in Fig. 1, the mean size of workers from mature colonies in the woodland group was significantly larger than that of the riverside group ($P<0.001$), 1.12 ± 0.051 mm and 0.99 ± 0.046 mm respectively (arithmetic mean and SD.). Fig. 2 gives the size distribution of the queens. The riverside queens appeared to consist of two groups which formed a bimodal distribution with modes of 1.00 and 1.15 mm. There were more smaller queens than larger ones. Of the colonies collected from the riverside areas, some (ca. 45%) contained only the smaller queens, the others (ca. 55%) both the smaller and larger ones. On the other hand, the queens of woodland *M. ruginodis* showed a unimodal size distribution. The mean head width (1.15 ± 0.052 mm) in the woodland form was significantly larger than that in the riverside form (1.05 ± 0.056 mm) ($P<0.05$). Fig. 3 shows the relation between colony size and body size in the two forms. In the woodland form, larger colonies tended to consist of larger workers. The small body size in the small colonies was probably caused by poor nourishment at the incipient stage of colonial development by the solitary queens. The woodland *M. ruginodis* colonies showed a curvilinear regression of average worker head width. A simple exponential curve was fitted by ordinary regression methods (Fig. 3). However, no such relation was found in the riverside form.

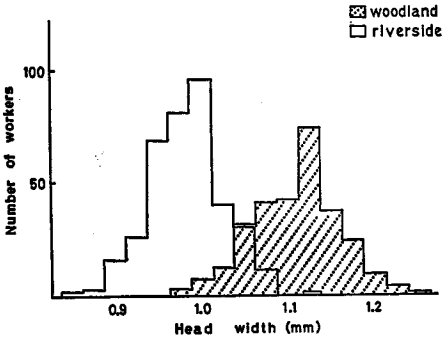

Fig. 1. Frequency distributions of head widths of workers from mature colonies. Woodland: 1.12 ± 0.054 mm, riverside: 0.98 ± 0.058 mm (mean and SD.).

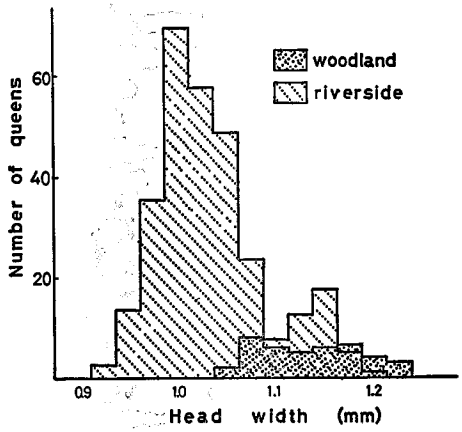

Fig. 2. Frequency distributions of head widths of dealated queens.

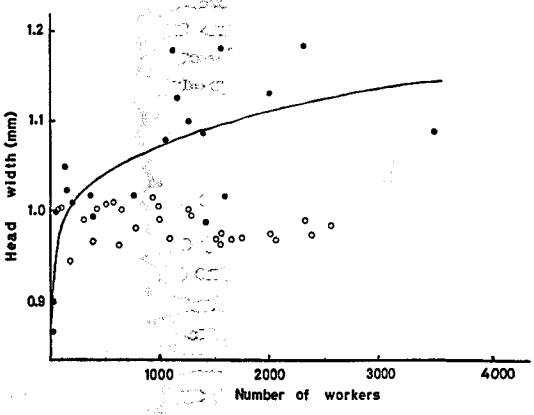

Fig. 3. Relation between the number of workers in a colony (x) and their average head width (y). Black circles: nests from woodland, the equation of the best fitting line is, $y = 0.095 \log x + 0.80$ (SD. of regression coefficient: 0.023); white circles: nests from riverside, curve fitting was not made.

Number of queens and workers in nests

Among the 20 colonies collected from the woodlands, 14 (70%) were monogynous and 5 (25%) were polygynous, the latter containing 2–7 queens

Table 1. Populations of woodland colonies of *Myrmica ruginodis*, grouped in five-hundreds for workers.

	Workers								
Queens	1 to 499	500 to 999	1000 to 1499	1500 to 1999	2000 to 2499	2500 to 2999	3000 to 3499	3500 to 3999	Total
0	1	.	.	.	.	.	.	.	1
1	5	1	4	1	2	.	.	.	13
2	1	.	1	.	.	.		.	2
3	.	.	.	.	.	.	.	1	1
4	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.
6	.	.	1	1	.	.	.	.	2
7	1	.	.	.	.	.	.	.	1
Total	8	1	6	2	2	.	.	1	20

Table 2. Populations of riverside colonies of *Myrmica ruginodis*, grouped in fives for queens and five-hundreds for workers.

	Queens											
Workers	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	Total
0– 499	8	2	2	.	.	.	.	.	.	.	.	12
500– 999	9	7	3	4	1	1	2	.	.	.	.	27
1000–1499	3	.	2	1	.	2	.	1	.	.	.	9
1500–1999	.	.	1	1	1	2	1	.	.	.	.	6
2000–2499	.	.	1	.	1	1	.	1	.	.	.	4
2500–2999	.	.	1	.	.	.	.	.	.	.	.	1
3000–3499	.	.	.	.	.	.	.	.	.	.	1	1
Total	20	9	10	6	3	6	3	2	.	.	1	60

(Table 1). Only one colony was orphan. The colonies from the riverside areas were all polygynous and contained 2–52 queens (Table 2). The number of queens per nest significantly differed between the two forms ($P<0.05$); the geometric means was 2.1 in the woodland form and 11.2 in the riverside form. On the other hand, the number of workers per nest did not differ statistically between the two forms; the geometric means were 783.1 with a range of 62–3437 in the riverside form and 466.5 with a range of 8–3526 in the woodland form. There was no difference in the mean number of workers between the two forms, although the number of queens differed remarkably, moreover, the number of dealated riverside form queens in each nest seemed to fluctuate seasonally. From May to mid August (before the nuptial flight) 21 nests were excavated, and among them, 15 nests (71%) contained 0–9 queens, 4 had 10–19 queens and 2 had 20–29. However, from late September to late No-

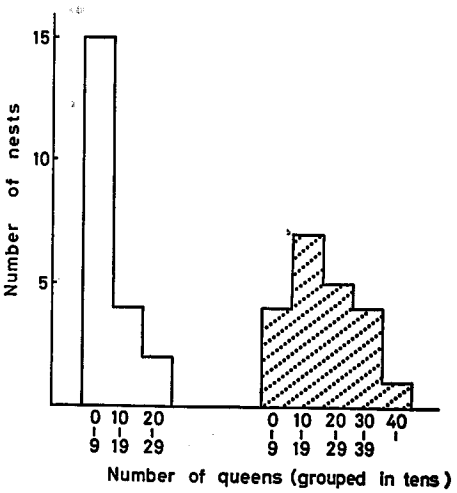

Fig. 4. Distribution of dealated queens of the riverside *M. ruginodis*. Unshaded: before nuptial flight (May to mid August), shaded: after nuptial flight (late September to late November).

vember after the nuptial flight, only 4 (19%) out of the 21 examined nests contained 0–9 queens, 7 nests had 10–19 queens, 5 nests had 20–29, 4 nests had 30–39, and 1 nest had more than 40 queens (Fig. 4). The geometric means of queens in each nest were significantly 8.0 before the nuptial flight and 17.9 after it ($P<0.05$). Thus the number of dealated queens in each nest increased after the nuptial flight, which suggests that newly mated queens were adopted by the nest. In the riverside colonies collected from May to mid August, there was no correlation between the worker and the dealated queen number in one colony ($r = 0.24$). On the other hand, in those collected from late September to late November, the worker number correlated, though weakly, with the queen one ($r = 0.60$). This suggests that more newly mated queens were adopted by the larger colonies.

Production of sexuals

The emergence of alates seemed to be limited to August and early September in both forms. In the ten nests examined, the number of alate queens found in the riverside nests (geometric mean 10.2) was lower than that in the woodland nests (g.m. 340.5) (Table 3). There was a statistically significant difference in the production of alate queens between the two forms ($P<0.05$). However, no statistical difference is found in the production of males between the two forms.

Soon after the nuptial flight, the *M. ruginodis* dealated queens were observed to have thread-like ovaries. On the other hand, all of the dealated

Table 3. Production of sexuals in colonies distributed in the different habitats.

1. Production of sexuals in riverside colonies.

Nest Codes	Alate queens	Males	Old queens	Workers
760811	1	73	2	634
750814	9	310	3	1298
760822	13	243	11	1267
750828	56	21	6	801
750905	6	42	3	290

2. Production of sexuals in woodland colonies.

Nest Codes	Alate queens	Males	Old queens	Workers
770810	205	243	1	1141
770813	332	175	1	2105
770818	474	311	1	1562
770822	262	87	2	1263
770907	536	72	1	1401

First two numerals in nest codes indicate the year, and the other four the date of excavation.

Table 4. Number of new and old queens in riverside colonies collected soon after the nuptial flight.

Nest Codes	New queens	Old queens	Total
760921-a	30	8	38
760921-b	28	6	34
760929	23	12	35
761001-a	2	2	4
761001-b	18	10	28
761001-c	5	2	7
761001-d	10	15	25
761006-a	15	13	28
761006-b	0	0	0
761009-a	8	10	18
761009-b	15	14	29
761009-c	8	2	10
Total	162	94	256

Table 5. Distribution of workers marked on nest NI. D: distance from nest NI.

Nest Code	D (m)	Queens	Workers	Marked workers
NI		1	175	4
NII	0.4	16	949	4
NIII	0.4	15	1068	8
NIV	0.9	29	1211	3

One hundred workers were mass-marked on June 21, 1976, and the four nests were collected after three days.

queens found in the nest before the nuptial flight had well developed ovaries. The ovaries of dealated queens from 12 riverside colonies were examined soon after the flight period. Queens having immature ovaries like the alate individuals were classified as new queens. Among the total of 256 queens, all of which were fertilized, 162 were classified as new ones (Table 4). Thus adoption of newly mated queens was quite frequent in the riverside form.

A field experiment on worker drifting

Nineteen workers were recaptured by the marking experiment (Table 5); of these, 15 were obtained from different nests adjacent to those where they had been first caught and marked. It is probable that the riverside colonies were united into a large living unit, or a polydomous colony, like those established by *Formica rufa*-group ants, e.g., *F. yessensis* (HIGASHI, 1978). However, the polydomous colonies of *M. ruginodis* were not as large as those of the *Formica* species. For precise analysis of the internest movement in the riverside *M. ruginodis*, more marking recapture experiments should be made. As the gaster of this ant is smooth, the color dots were rapidly eradicated.

Discussion

Some of the important differences between the two forms are summarized below. The riverside form colonies were polygynous whereas those of the woodland form were generally monogynous. The average body size of workers was correlated with the worker number in a woodland form colony. This tendency was not found in the riverside form, and the average body sizes varied little between the colonies. The production of alate queens was abundant in the woodland form but scarce in the riverside one. In the riverside colonies the number of dealated queens increased soon after the flight period.

On the contrary, this tendency was not observed in the woodland form colonies, although only a few colonies were examined. Although worker drifting was observed among the riverside colonies, the woodland form ants appeared to have little social contact, and fighting was observed among workers from different woodland colonies (unpublished).

The above-mentioned differences between the two forms suggest that woodland colonies are founded by solitary queens and riverside ones by fission. This conjecture is confirmed by the following finding: All the queens found in the monogynous woodland colonies had worn mandibles, and all the queens in the riverside colonies had mandibles like the alate queens (generally, foundress queens showed worn mandibles, while queens which returned to existing nests after nuptial flight showed mandibles like those of alate queens).

It was not necessary for the riverside colonies in which new fertilized queens were adopted to produce as many queens as the woodland form as they were less exposed to the danger of death than the woodland queens which established their colonies solitarily. Fission was more effective for establishing nests in the sunny riverside areas. Polygyny was maintained by the adoption of newly mated queens. In this way each reproductive strategy of the two forms differed markedly. Colony fission, polygyny, and production of fewer new queens (or monogyny and production of many queens) appeared to be linked. Thus, although there were many ecological differences between the forms, they may be linked by a common cause.

TALBOT (1948) studied two forms of genus *Formica*, *F. pallidefulva nitidiventris* and *F. P. incerta*. Comparing her results with those of the present study, *F. pallidefulva nitidiventris* and *F. P. incerta* have features respectively similar to woodland *M. ruginodis* and riverside *M. ruginodis*.

Among the colonies collected from the woodland, about one third (7/20) were polygynous, and all the queens examined had mandibles like those of

alate queens. The following considerations may be used to explain the polygyny observed in the woodland form. (1) Although colonies may be founded by the association of queens, this seems to impossible, in this case because all the queens found in the colonies had mandibles like alate queens. (2) The woodland form may be divided into two types: One which reproduces its colony by solitary queens, the other by fission. Because the monogynous and polygynous colonies were collected mainly from wood margins and from within the woods respectively, the two types may be connected with habitat types. If this assumption is true, it is necessary to study the two types in detail for clarifying the evolution of the polygyny in *M. ruginodis*. (3) Orphan colonies may accept newly fertilized queens. The relative importance of these explanations may need to be clarified in further investigations.

Comparing the two forms with the two England races of *M. ruginodis* (BRIAN & BRIAN, 1949), the woodland form is probably similar to *M. ruginodis* macrogyna in its monogynous character, although some woodland colonies appeard to be polygynous in Sapporo and its vicinity. BRIAN and BRIAN (1951) examined the colonies of *M. ruginodis* macrogyna and represented the relation between worker number and their body size.

The regression equations are:

$y = 0.113x + 0.766$ (open nests) and $y = 0.072x + 0.810$ (shaded nests) where x is the common logarithm of worker number in a colony and y is their average head width. Based upon these results, they indicated that for a given colony-size, the workers of *M. ruginodis* macrogyna from open nests were larger than those from shaded nests. In this study, the regression coefficient obtained for woodland *M. ruginodis*, 0.095, was approximately between that obtained from the open and shaded nests in *M. ruginodis* macrogyna. This intermediate value of the woodland *M. ruginodis* may have occurred because some of the 20 woodland colonies were collected from shaded areas in the woods, and others were collected from relatively open wood margins. The woodland queens showed a unimodal size distribution as in *M. ruginodis* macrogyna. On the other hand, two groups of queens were observed in the riverside nests, as reported in *M. ruginodis* microgyna by COLLINGWOOD (1958). However, the riverside form and the European *M. ruginodis* microgyna differ from each other in at least some points. First, *M. ruginodis* microgyna is known to produce sexuals only once every several years, but the riverside form of the Japanese *M. ruginodis* yielded sexuals every year during 1975–1977. Secondly, *M. ruginodis* microgyna colonies which are situated close to each other have no social contact, whereas the Japanese riverside colonies exchanged workers among neighboring nests, although the degree of exchange may have been low. These two differences may be caused environmentally or by the different climates.

ELMES (1978) pointed out that European *M. ruginodis* responds by evolving the microgyne type, which enables the species to make full use of the heterogenous areas into which it has been relegated. At present it is not clear whether the riverside and woodland forms of the Japanese *M. ruginodis* can be separated into two species or whether they are ecological races of the same species. It may be useful to transplant riverside colonies to woodland (or vice-versa) and observe their colony life continuously.

Summary

1. Two forms of Japanese *Myrmica ruginodis* Nyl. have been found to differ in their habitat preference, one inhabiting woodland and the other riverside areas.

2. The riverside form is polygynous, while the woodland form is generally monogynous. Also, the number of dealated queens in the riverside colonies abruptly increased after the nuptial flight. This was due to the adoption of newly fertilized queens by existing nests.

3. The woodland colonies produced many alate queens, while the riverside colonies produced only a few. This phenomenon may be due to the different colony reproductive methods in both forms. The former generally reproducing by dissemination and the latter fission.

4. The mean body sizes of the workers and queens from woodland colonies were significantly larger than those from the riverside. Also, the body size of the workers from woodland colonies increased as the colonies grew; however, there was little change in that of the riverside colonies.

5. This study suggested that the two forms show many features in common with the two races of European *M. ruginodis*. The woodland form resembles the European *M. ruginodis* macrogyna, and the riverside form resembles *M. ruginodis* microgyna.

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摘　　要

1．札幌およびその近郊の山地および河岸に棲息するシワクシケアリの生活型はそれぞれ異なっている．

2．河岸棲シワクシケアリは多雌性であるが，山地棲のそれは一般に単雌性であると考えられる．また前者の巣内に見い出される脱翅女王数は結婚飛行シーズン後に著しく増加する．これは交尾した新女王が既存の巣に入り込むことによっている．

3．山地棲シワクシケアリの巣において生産される新女王数は河岸棲のそれに比べかなり多い．それはコロニー繁殖法が前者では女王の巣独営巣，後者では巣分かれによることに起因すると考えられる．

4．河岸棲シワクシケアリの成熟コロニーにおける職蟻および女王の体長は，山地棲の成熟コロニーのそれらに比べより小さい．また山地棲の職蟻の体長はコロニーの成長に従い大きくなるが河岸棲のそれはコロニー間に殆んど相違がみられない．

5．札幌およびその近郊において観察された山地棲および河岸棲シワクシケアリはそれぞれヨーロッパに棲息する *M. ruginodis* macrogyna および *M. ruginodis* microgyna に相当すると思われる．