

# THE ACULEATE FAUNA OF THE KRAKATAU ISLANDS (INSECTA, HYMENOPTERA)

|                                 |   |
|---------------------------------|---|
| 著者                              | YAMANE Seiki  |
| journal or<br>publication title | 鹿児島大学理学部紀要．地学・生物学   |
| volume                          | 16  |
| page range                      | 75-107  |
| 別言語のタイトル                        | クラカタウ諸島の有剣膜翅類相  |
| URL                             | <a href="http://hdl.handle.net/10232/00009972">http://hdl.handle.net/10232/00009972</a> |

## THE ACULEATE FAUNA OF THE KRAKATAU ISLANDS (INSECTA, HYMENOPTERA)

By

Seiki YAMANE\*

(Received Sept. 9, 1983)

### Abstract

A list of the Aculeata collected on the Krakatau Islands in 1982 is presented. The area-species relation, colonisation process, derivation of the Krakatau's fauna and faunal disharmony are discussed using DAMMERMAN's and my own data. A summary of the species so far found on the Krakataus is given. Aculeata collected on Peucang I. and Panaitan I., and in Carita, West Java are also listed.

### I. Introduction

The Krakatau Islands have received considerable attention from biologists since the world famous great eruption in 1883 by which the entire flora and fauna are said to have been destroyed (DAMMERMAN, 1948). The processes of recolonisation by plants and animals were described by DOCTERS VAN LEEUWEN (1936) and DAMMERMAN (1922, 1929, 1948). Although the recolonisation of the Krakataus occurred without a pre-eruption census and involved few and differentially exhaustive monitorings (SIMBERLOFF, 1974), the results of these earlier authors have been used to support the modern equilibrium theory by MACARTHUR and WILSON (1967), DIAMOND and MAY (1976), GORMAN (1979) and others. Unfortunately, since the 1930's only few surveys have been made on these islands, and the results of the expedition by the Zoological Museum, Bogor, in 1955 have not yet been systematically arranged.

In 1982 I and Dr. J. YUKAWA collected invertebrates, mainly insects, on the Krakataus as members of the Kagoshima University expedition team to assess the present state of the recolonisation process. Special attention was paid to the aculeate Hymenoptera (excluding ants) which occupy higher positions in trophic level (pollen collectors and predators on other insects and spiders). In total 86 species belonging to 11 families were obtained. In this paper a list of the collected species and some biogeographical discussions are given together with a summary of the species so far recorded from the Krakataus and lists of species collected on Peucang and Panaitan, and in Carita, West Java (Appendices 1-4).

---

\* Department of Biology, Faculty of Science, Kagoshima University, Kagoshima, 890 Japan.

## II. Survey Areas

The Krakatau Islands are located in the Sunda Strait between Java and Sumatra (Fig. 1A). They consist of four islets close to one another, i.e., Rakata Besar (1,152 ha), Sertung (784 ha), Rakata Kecil (272 ha), and Anak Krakatau (280 ha) (Fig. 1B).

Rakata Besar is the largest islet and has the richest flora and fauna; its topography is most diversified, with the highest point (813 m alt.\*) in this island group. It is covered with dense forests and has sands which are in area relatively restricted. Sertung and Rakata Kecil are similar in topography and flora to each other; both are covered with

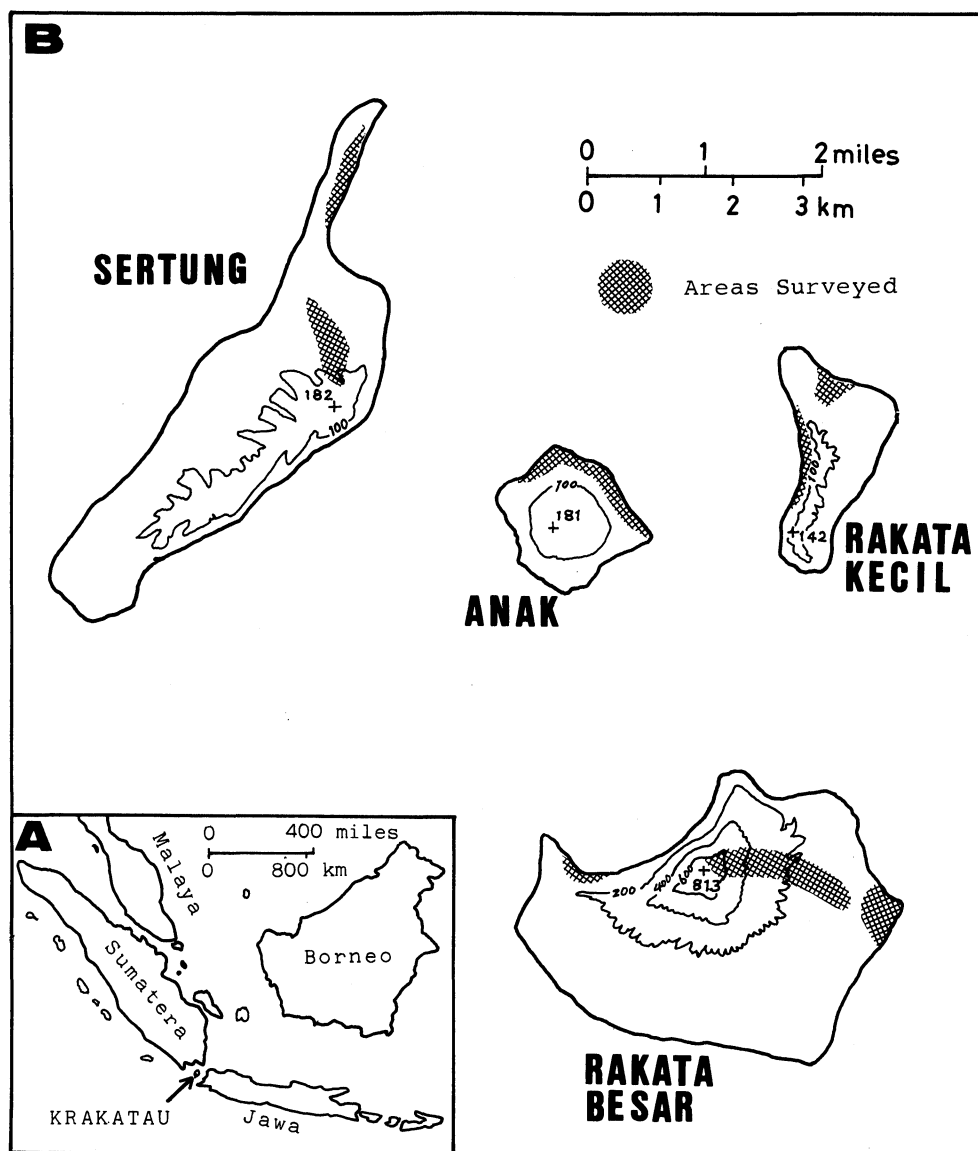


Fig. 1. Map showing the survey area, partly based upon Richards (1982).

\* Our clinometer indicated 730 m when the top was reached.

dense forests but Sertung has a longer sand beach and a larger *Casuarina* forest in the northern part. Anak Krakatau first appeared in 1927 but soon submerged by wave action. The present islet (Anak Krakatau IV) appeared in August of 1930 and thereafter grew gradually. Now it is still active and has a simple beach flora and relatively developed *Casuarina* forests along the coast (Fig. 2). More than 90% of its area may be barren due to continual volcanic activity (Fig. 3). The volcanic history of these islands has been well documented by ESCHER (1919), DAMMERMAN (1948) and others.

Aculeate Hymenoptera were mainly netted on flowers of such plant species as *Ipomoea pescaprae*, *Canavalia marotima*, *Eupatorium odoratum* and *Premna corymbosa* growing near coastal line. Collections were made also in the open sites in forests and at the water spots (Rakata Besar and Sertung). A few species were found only at the top of Rakata Besar. The collection sites are shown in Fig. 1B.

### Synonyms

**The Krakatau Islands** : The Krakataus, Krakatau group, Krakatau, Krakatoa.

**Rakata Besar** : Pulau Rakata Besar, P. Rakata, Rakata, Krakatau Besar, Krakatau Island, Krakatoa Island.

**Sertung** : Pulau Sertung, Verlaten Island.

**Rakata Kecil** : Pulau Rakata Kecil, Lang Island, Panjang.

**Anak Krakatau** : Pulau Anak Krakatau, Anak Krakatau IV, Anak.

### III. List of the Aculeata collected on the Krakataus

All the specimens listed below were collected by the Kagoshima University Expedition to the Krakataus in 1982 (July : Sk. YAMANE ; October/November : J. YUKAWA). Many species could be determined only to generic level, and for such species brief descriptions of specimens are given. The names of the islets are abbreviated as follows : RB (Rakata Besar), S (Sertung), RK (Rakata Kecil), and AK (Anak Krakatau).

#### Family Pompilidae

All the species except for *Auplopus blandus* were identified by Dr. R. ISHIKAWA.

1. ? *Hemipepsis velutina* VECHT

1 ♀, RB, 16 vii ; 1 ♀, S, 12 xi.

2. *Hemipepsis* spec. 1

1 ♂, RK, 28 vii.

A medium-sized species measuring 11 mm. Body black ; head and thorax marked with yellowish brown ; gaster brownish with the first segment darker. Legs yellowish brown ; coxae and trochanters blackish. Wings blackish.

3. *Leptodialepis bipartitus* LEPELETIER

*Leptodialepis praestabilis* Bingh. : Dammerman, 1948, p. 360.

1 ♀, S, 9 vii.

4. *Leptodialepis* (?) spec.

1 ♂, RB, 1 viii.

A medium-sized species measuring 11.5 mm. Body black ; thorax with yellowish markings ; gaster entirely black. Similar in coloration to the preceding species, but smaller and the wings paler.



Figs. 2 and 3. Anak Krakatau (July, 1982).

5. *Auplopus* spec. 1

1 ♀, S, 30 vii; 1 ♂ 1 ♀, AK, 29 vii.

A black wasp measuring 6-7.5 mm. This species belongs to the subgenus *Conagenia*.

6. *Auplopus blandus* GUÉRIN

*Pseudagenia blanda* Guér.: Dammerman, 1929, p. 101; 1948, p. 361.

3 ♀, RB, 28-31 x; 1 ♀, S, 30 vii; 2 ♀, S, 7 xi; 3 ♀, RK, 17 x-10 xi.

7. *Aporinellus* spec.

1 ♀, AK, 6 xi.

A small species measuring 8 mm. Body black, with grayish scale piles, especially on gastral tergites apically.

8. *Episyron* spec.

*Episyron* spec.: Dammerman, 1948, p. 361.

1 ♂ 2 ♀, RK, 27-28 vii.

9. *Tachypompilus analis* FABRICIUS

*Balanoderes analis* F.: Dammerman, 1948, p. 361.

1 ♀, RB, 28 x; 1 ♀, S, 6 xi; 1 ♂, RK, 28 vii.

10. *Paraferreola* spec.

1 ♀, RB, 16 vii; 1 ♂, AK, 6 xi.

A small wasp conspicuous by its red thorax; other parts of body black. Apical third of forewing infusate.

### Family Mutillidae

11. *Mutilla dimidiata* LEPELETIER

1 ♂, S, 12 xi; 1 ♂ 1 ♀, RK, 28 vii (in copula).

12. *Mutilla* spec. 1

1 ♂, RB, 16 vii; 8 ♂ 2 ♀, S, 6-30 vii; 2 ♂ 2 ♀, S, 7-11 xi; 1 ♂, RK, 10 xi; 4 ♂ 1 ♀, 29 vii; 1 ♂, AK, 6 xi.

A smaller species measuring 8-13 mm in ♂, 5-6.5 mm in ♀.

### Family Scoliidae

The identifications of the species were mainly based upon BETREM (1928).

13. *Triscolia azurea azurea* CHRIST

*Scolia rubiginosa* F.: Jacobson, 1909 (in list).

*Scolia azurea* Chr.: Dammerman, 1948, p. 364-365.

1 ♂, AK, 30 vii.

BETREM (1928) distinguished the subspecies *rubiginosa* Fabricius from the nominate subspecies by the possession of a pair of red spots on the 3rd gastral tergite. DAMMERMAN (1948) recorded both the forms from Krakatau, but there are individuals with intermediate colour patterns. The present specimens has a pair of small red spots on the 3rd segment, but not regarded as belonging to the subspecies *rubiginosa*.

**14. *Microscolia cephalotes* BURMEISTER**

*Scolia cephalotes* Burm. : Dammerman, 1948, p. 365.

1 ♀, RB, 16 vii ; 1 ♀, S, 6 vii ; 6 ♂ 1 ♀, RK, 27-31 vii.

Not rare in the forest of Rakata Kecil.

**15. *Liacos dimidiata* GUÉRIN subsp.**

2 ♂, RB, 29 x.

**16. *Campsomeris leefmansi* BETREM**

*Campsomeris leefmansi* Betr. : Dammerman, 1948, p. 366.

1 ♂, RB, 29 x ; 17 ♂ 1 ♀, S, 6-9 vii ; 13 ♂ 3 ♀, S, 7-12 xi ; 2 ♂, RK, 28 vii ; 1 ♀, AK, 5 xi.

Common in both the forest and coast.

**17. *Campsomeris quadrifasciata* FABRICIUS**

*Campsomeris aureicollis* Lep. : Dammerman, 1929, p. 101.

*Campsomeris quadrifasciata* F. : Dammerman, 1948, p. 366.

2 ♂, RB, 29-30 x.

**18. *Campsomeris* spec.**

3 ♂, RB, 29-30 x ; 4 ♂, RK, 27 vii.

Similar to the two preceding species in ♂, but smaller (11-14 mm in length) and the gastral bands much narrower. Scutellum and metanotum with yellow spots.

**19. *Campsomeris phalerata bankaensis* BETREM**

*Campsomeris phalerata* Sauss. var. *bankaensis* Betr. : Dammerman, 1948, p. 366.

1 ♀, AK, 5 xi.

**20. *Campsomeris marginella terminata* SMITH**

3 ♂ 1 ♀, RB, 16 vii ; 1 ♂, RB, 31 x ; 11 ♂ 4 ♀, S, 6-7 vii ; 15 ♂, S, 7-14 xi ; 10 ♂ 3 ♀, RK, 27-31 vii ; 19 ♂, RK, 9-10 xi ; 1 ♀, AK, 29 vii.

This small species was most commonly found on all the islets, but had not been previously collected on any islet of the Krakataus.

## Family Eumenidae

21. *Rhynchium haemorrhoidale* FABRICIUS

*Rhynchium haemorrhoidale* F.: Dammerman, 1948, p. 363.

2 ♀, RB, 16 vii; 1 ♀, RB, 27 x; 4 ♀, S, 7-30 vii; 3 ♀, S, 7 xi; 2 ♂ 1 ♀, RK, 27-28 vii; 1 ♀, AK, 29 vii.

22. *Allorhynchium argentatum* FABRICIUS

*Rhynchium argentatum* F.: Dammerman, 1948, p. 363.

3 ♂ 3 ♀, RB, 15-31 vii; 1 ♀, RB, 31 x; 2 ♂ 1 ♀, S, 6-7 vii; 10 ♂ 2 ♀, RK, 27-28 vii; 1 ♂, RK, 10 xi; 1 ♂ 3 ♀, AK, 29-30 vii; 1 ♀, AK, 6 xi.

23. *Pachymenes fragilis* SMITH

*Odynerus Drescheri*: Jacobson, 1909 (in list).

*Pachymenes fragilis* Sm.: Dammerman, 1948, p. 363.

6 ♂ 1 ♀, RK, 27 vii; 1 ♂, AK, 10 vii; 2 ♂, AK, 6-8 xi.

According to Dr. J. VAN DER VECHT (personal communication), this species should be placed in another genus and the species name altered.

24. *Eumenes conspicuus* SMITH

? *Eumenes architectus* Sm.: Dammerman, 1948, p. 364.

1 ♂, RB, 10 vii; 1 ♀, RB, 31 x; 1 ♀, S, 7 xi; 7 ♂ 3 ♀, RK, 27-28 vii; 7 ♂ 1 ♀, AK, 29-30 vii; 1 ♂ 3 ♀, AK, 6-8 xi.

25. *Delta campaniforme* FABRICIUS

1 ♂, RB, 16 vii; 5 ♀, RB, 31 x; 1 ♂ 1 ♀, S, 8-9 vii; 1 ♂ 3 ♀, S, 7-14 xi; 3 ♂, RK, 27 vii; 3 ♂, AK, 29-30 vii; 1 ♂ 1 ♀, AK, 6-8 xi.

A very common species, but had not been previously recorded from the Krakataus.

26. *Phi flavopictus continentalis* ZIMMERMAN

*Eumenes arcuatus continentalis* Zim.: Dammerman, 1948, p. 364.

1 ♂ 1 ♀, S, 6-9 vii; 2 ♀, S, 7 xi.

DAMMERMAN (1948) stated that the race *continentalis* was found in Sumatra but on Krakatau once a form had been collected intermediate between *continentalis* and the subspecies *blanchardi* (melanic form), occurring in Java. The present material comprises four specimens of which two (1 ♂ 1 ♀) are intermediate between these subspecies in colour pattern as follows:

♂ (S, 6 vii): Head as in *continentalis*. The yellow markings on thorax and propodeum much reduced, only the following parts yellow: anterior margin of pronotum very narrowly, narrow, medially interrupted line on mesopleuron, a pair of very faint lines on mesoscutum, a pair of very small spots on scutellum, a very small median spot near the



posterior margin of metanotum, apices of propodeum, outer margins of tegulae. Legs coloured as in *continentalis*, but much darker. Gastral colour pattern as in *continentalis*.

♀ (S, 7 xi): Clypeus yellow but distinctly margined with black. Yellow marking on ocular sinus narrower than in *continentalis*. Colour pattern of thorax and propodeum much as in the preceding male specimen, but mesopleural yellow marking much more reduced, yellow spots on metanotum slightly developed, and hind legs almost wholly black as in *branchardi*.

The other two female specimens are typical *continentalis*.

### Family Vespidae

#### 27. *Eustenogaster* spec. 1

2 ♂ 3 ♀, RB, 15 vii-1 viii.

A large species measuring about 20 mm in ♂, and 23-25 mm in ♀. The sixth gastral tergite of the female has a distinct tooth near the posterior margin. Female clypeus is entirely yellow. Mandibles are ferruginous in both sexes. This species was seen only in the forest of Rakata Besar.

#### 28. *Eustenogaster* spec. 2

? *Stenogaster micans* Sauss.: Dammerman, 1948, p. 363.

14 ♂, RB, 16 vii; 4 ♂ 6 ♀, RK, 27-28 vii; 7 ♂, RK, 9 xi.

A smaller species measuring 16-17 mm in ♂, and about 18 mm in ♀. The sixth gastral tergite of the female has no tooth. Female clypeus has a wide black bar in its upper half. Male mandibles are largely yellow. This species was found only near the coast. Males were often seen flying around large trees.

#### 29. *Parischnogaster mellyi* SAUSSURE

*Ischnogaster Mellyi*: Jacobson, 1909 (in list).

*Parischnogaster mellyi* Sauss.: Dammerman, 1948, p. 362.

2 ♀, RB, 14-18 vii; 2 ♀, RB, 27-29 x; 11 ♂ 6 ♀, RK, 27-28 vii; 1 ♂ 2 ♀, AK, 29-30 vii; 1 ♀, AK, 6 xi.

This species was quite common near the coast on Rakata Kecil.

#### 30. *Parischnogaster* spec. near *costulatus* SCHULTHESS

? *Ischnogaster Serrei*: Jacobson, 1909 (in list).

? *Parischnogaster nigricans* Cameron: Dammerman, 1948, p. 363.

3 ♀, RB, 29 x.

The female clypeus is yellow except for central black bar not reaching its ventral margin (in the preceding species clypeus is wholly blackish).

#### 31. *Ropalidia fasciata* FABRICIUS

1 ♀, AK, 29 vii.

This is the only specimen of the genus *Ropalidia* found on the Krakataus in the course of the present survey. It was determined by Mr. J. KOJIMA.

**32. *Polistes stigma* FABRICIUS**

*Polistes stigma* F.: Dammerman, 1948, p. 362.

1 ♀, RB, 16 vii; 2 ♀, RB, 29-30 x; 6 ♀, S, 7-9 vii; 3 ♀, S, 7 xi; 9 ♀, RK, 27-28 vii; 1 ♀, RK, 9 xi; 6 ♀, AK, 29 vii.

This is the most common species of *Polistes* on the Krakatau. On Rakata Besar an initial nest with two queens was found on a climbing vine in a coastal forest (Fig. 4). On Anak Krakatau some dissolved nests were found in the *Casuarina* forest, and an initial nest in a cavity of lava.

**33. *Polistes tenebricosus tenebricosus* LEPELETIER**

1 ♂, RB, 16 vii; 2 ♀, S, 8-9 vii; 1 ♀, S, 7 xi; 5 ♀, RK, 27 vii; 2 ♀, RK, 8-10 xi.

A large wasp of entirely brown. This species had not been recorded by JACOBSON or DAMMERMAN. The present subspecies has been known from Java and Bali (BEQUAERT, 1934). On July 27, I found several nests of this species in cavities of a cliff along the west coast, and collected one of them. All the wasps were missed. The nest consisted of 35 cells; the contents of the cells are as follows: 20 eggs, 2 1st instars, 2 2nd instars, 1 3rd instar, 2 5th instars, 3 cocoons; 3 cells with no immature. On all of the cocoons an egg was observed so that the total number of eggs amounted to 23. The behaviour of laying eggs on cocoon caps is typical of the subgenus *Megapolistes* to which this species belongs.



Fig. 4. Initial nest of *Polistes stigma* (Rakata Besar, 16 July, 1982). One female was absent from the nest.

**34. *Polistes sagittarius indonesicus* BEQUAERT**

*Polistes sagittarius* Sauss. : Dammerman, 1948, p. 362.

5 ♀, RB, 14 vii-1 viii; 1 ♀, RB, 29 x; 1 ♂ 2 ♀, S, 7 vii; 1 ♀, RK, 27 vii.

All the specimens examined belong to the subspecies *indonesicus* known from Java, Bali and Palawan (BEQUAERT, 1940) as stated by DAMMERMAN (1948) for the specimens collected earlier.

**35. *Vespa analis analis* FABRICIUS**

*Vespa analis analis* F. : Vecht, 1957, p. 14.

1 ♂, RB, 30 x; 1 ♂ 7 ♀, RK, 27-28 vii; 3 ♀, AK, 29 vii.

For the distribution of this form, see IV-3.

**36. *Vespa affinis indosinensis* PÉREZ**

*Vespa affinis* L. : Dammerman, 1948, p. 362.

1 ♀, RB, 16 vii; 1 ♀, S, 8 vii; 43 ♀, S, 10 vii from a nest; 1 ♀, AK, 30 vii.

An orphan nest of this species was collected in a *Casuarina* forest along the east coast of Sertung. It was suspended from a twig at 50 cm above the ground, was 12 cm in diameter with envelope. The brood composition is shown in Table 1. For the distribution of this form, see IV-3.

Table 1. Brood composition of the *Vespa affinis* colony

|          | Eggs | Larvae<br>1st-4th inst. | 5th inst. | Cocoons | Empty | Total |
|----------|------|-------------------------|-----------|---------|-------|-------|
| 1st comb | 23   | 33                      | 38        | 43      | 2     | 139   |
| 2nd comb | 19   | 22                      | 24        | 4       | 1     | 70    |
| Total    | 42   | 55                      | 62        | 47      | 3     | 209   |

**Family Sphecidae**

Species with an asterisk were identified by Dr. W.J. PULAWSKI. The determinations of the *Trypoxylon* specimens were based upon TSUNEKI (1978, 1979).

**37. *Ampulex compressa* FABRICIUS**

*Ampulex compressa* F. : Dammerman, 1948, p. 358.

1 ♀, S, 12 xi.

**38. *Dolichrus* spec. 1**

2 ♀, AK, 29 vii.

**39. *Dolichrus* spec. 2**

2 ♂, AK, 29 vii.

**40. *Sphex sericeus sericeus* FABRICIUS**

*Sphex aurulentus* F. var. *sericeus* F.: Dammerman, 1948, p. 359.

*Sphex sericeus sericeus* F.: Vecht & Krombein, 1955, p. 41.

1 ♂, S, 8 vii; 4 ♂, RK, 27-28 vii; 3 ♂, AK, 10-29 vii.

VECHT and KROMBEIN (1955) wrote that it was of interest to note that on this island (RB) both the subspecies *lineolus* and *sericeus* had been collected, and that apparently the species had reached Krakatau from Sumatra as well as from Java. In the present survey only the Javan subspecies was collected.

**41. *Polemistus* spec.\***

1 ♀, S, 30 vii.

**42. *Carinostigmus* spec.**

1 ♀, S, 6 vii; 3 ♀, AK, 29 vii.

A small black wasp, measuring 5-6 mm.

**43. *Liris subtessellata* SMITH**

4 ♂ 1 ♀, RB, 15-18 vii; 2 ♂, RB, 27-30 x; 3 ♂ 3 ♀, S, 7-9 vii; 5 ♂ 1 ♀, RK, 27-28 vii; 2 ♀, RK, 9-10 xi; 3 ♂ 1 ♀, AK, 29-30 vii.

The most common species of the genus *Liris* in the Krakataus. Nestings were mainly observed in the sands.

**44. *Liris* spec. 1**

3 ♂, RB, 16-18 vii; 1 ♀, S, 9 vii.

This species is of the same size as the preceding species, but the legs are wholly black.

**45. *Liris* spec. 2**

1 ♂, RB, 16 vii; 2 ♂ 3 ♀, S, 6-9 vii; 3 ♂, RK, 31 vii; 2 ♂ 1 ♀, RK, 8 xi; 2 ♂, AK, 29 vii.

A smaller species, measuring 5-8 mm. Body is almost entirely black.

**46. *Liris* spec. 3**

1 ♀, RB, 16 vii.

An entirely black species measuring 10 mm.

**47. *Tachytex* spec. 1**

? *Tachytes vicina* Cam.: Dammerman, 1948, p. 360.

3 ♀, RB, 16-18 vii; 2 ♀, S, 7-8 vii; 2 ♀, RK, 27 vii.

Collected only near the coast.

48. *Tachysphex* spec.

1 ♂ 5 ♀, RB, 14-16 vii; 1 ♀, RB, 31 xi; 3 ♂ 3 ♀, RK, 28 vii; 10 ♂, RK, 9 xi; 1 ♂ 1 ♀, AK, 29 vii.

A black wasp measuring 6-11 mm.

49. *Trypoxylon thaianum thaianum* TSUNEKI

4 ♀, RB, 16 vii; 2 ♀, RB, 31 x.

The *Trypoxylon* species were mainly collected at the water spots on Rakata Besar and Sertung.

50. *Trypoxylon schmiedeknehti schmiedeknehti* KOHL

2 ♀, RB, 16 vii-5 viii.

51. *Trypoxylon vicinum* TSUNEKI

1 ♀, RK, 31 vii.

This species has been known only from Java (TSUNEKI, 1979). The specimen was collected in a forest.

52. *Trypoxylon bicolor* SMITH

*Trypoxylon bicolor* Sm.: Jacobson, 1909 (in list); Dammerman, 1948, p. 356.

3 ♀, RB, 16 vii; 1 ♀, RB, 29 x; 8 ♀, S, 27 vii; 2 ♀, S, 7 xi.

53. *Trypoxylon khasiae* CAMERON

1 ♀, RB, 29 x.

54. *Trypoxylon nesianum* TSUNEKI

3 ♀, RB, 16 vii; 2 ♀, RB, 31 x; 1 ♀, S, 27 vii.

55. *Trypoxylon petiolatum* SMITH

*Trypoxylon petiolatum* Sm.: Dammerman, 1948, p. 359.

6 ♀, RB, 16 vii; 6 ♀, RB, 29-31 x; 1 ♀, S, 6 xi.

56. *Trypoxylon maculiventre* TSUNEKI

1 ♀, RB, 15 vii.

This specimen well agrees with the Javan form (TSUNEKI, 1979, pp. 29-30).

57. *Trypoxylon ornatigaster* TSUNEKI

2 ♀, RB, 16-18 vii.

This species has been known from Malaya and Sumatra.

58. *Podagritus* (?) spec.\*

1 ♀, S, 7 xi.

59. *Piyuma* (?) spec.\*

2 ♂, S, 26 vii.

60. *Bembix borrei* HANDLIRSCH*Bembix borrei* Handl.: Jacobson, 1909 (in list); Dammerman, 1948, p. 358.

2 ♂ 2 ♀, AK, 10-29 vii.

61. *Bembecinus littoralis* VECHT

2 ♂ 1 ♀, RB, 16 vii; 3 ♂ 2 ♀, RK, 27-28 vii; 3 ♂ 1 ♀, AK, 29 vii; 1 ♂, AK, 6 xi.

As stated by VECHT (1949) this species was common on sandy beaches.

62. *Cerceris pictiventris pictiventris* DAHLBOM

9 ♂ 1 ♀, RB, 14-16 vii; 13 ♂ 3 ♀, RK, 27-28 vii; 1 ♂ 1 ♀, RK, 9 xi; 2 ♂ 1 ♀, AK, 29 vii; 1 ♂, AK, 8 xi.

This form is distributed in Java, Sumatra and Borneo, and is said to be common in cultivated areas in the plains and on mountain slopes (VECHT, 1964). On the Krakataus we found it most common near the coast.

## Family Halictidae

Species with an asterisk were identified by Dr. Y. HIRASHIMA.

63. *Homalictus* spec. 1\*? *Halictus revidivus* Blüthgen: Dammerman, 1948, p. 355.

2 ♀, RB, 16 vii-1 viii; 5 ♀, RB, 28-31 x; 12 ♀, S, 6-9 vii; 1 ♂ 2 ♀, RK, 27-28 vii.

A metallic green species measuring 6-7 mm.

64. *Homalictus* spec. 2\*

2 ♀, S, 6-9 vii; 4 ♀, RK, 27-31 vii; 1 ♂, AK, 6 xi.

Similar to the preceding species, but smaller and more slender; body colour more strongly tinged with golden.

65. *Homalictus* spec. 3\*

1 ♀, RB, 31 x.

An entirely black species, but head, thorax and propodeum tinged with metallic green. 4.5 mm in body length.

66. *Homalictus* spec. 4\*

1 ♂, RB, 18 vii.

Similar to the preceding species, but more robust and without distinct metallic green luster.

67. *Nomioides* spec.\*

1 ♀, RK, 27 vii.

A black species with the clypeus and legs extensively marked with yellow ; thorax and propodeum with bluish luster. Body slender, measuring 4 mm.

68. *Lasioglossum* spec. 1\*

1 ♀, RB, 16 vii.

A small species measuring 6.5 mm. Tibiae and tarsi of all legs light brown.

69. *Lasioglossum* spec. 2\*

1 ♀, RB, 16 vii ; 1 ♂, S, 5-6 vii ; 1 ♂, RK, 28 vii ; 4 ♀, AK, 29 vii.

A slightly larger species (8 mm in body length). Legs are blackish brown. Gastral tergites basally with whitish scale piles.

70. *Nomia strigata* FABRICIUS

*Nomia strigata* F. : Dammerman, 1948, p. 355.

1 ♀, S, 9 vii ; 1 ♂, RK, 28 vii ; 1 ♂, AK, 29 vii.

71. *Nomia* spec. 1

1 ♀, RK, 9 xi.

Similar to the preceding species, but the 1st gastral tergite without green apical band and the apical bands on 2nd to 4th tergites wider.

72. ? *Nomia fuscipennis* SMITH

2 ♀, RB, 1 viii.

Gaster without apical bands. Forewing apically infusate. This species was found only at the top of Rakata Besar.

### Family Megachilidae

73. *Megachile umbripennis* SMITH

*Megachile umbripennis* Sm. : Dammerman, 1948, p. 357.

4 ♀, RB, 14-16 vii ; 2 ♂ 1 ♀, RB, 28 x ; 1 ♀, S, 7 vii ; 1 ♀, S, 13 xi ; 7 ♂, RK, 27-28 vii ; 1 ♀, RK, 9 xi ; 4 ♀, AK, 29-30 vii.

74. *Lithurgus atratus* SMITH

*Lithurgus atratus* Sm. : Dammerman, 1948, p. 357.

3 ♀, RB, 16 vii ; 1 ♀, RB, 29 x ; 1 ♀, RK, 27 vii.

### Family Anthophoridae

Species with an asterisk were identified by Dr. Y. HIRASHIMA. The *Pithitis* and *Ceratina* specimens were determined based upon VECHT (1952).

#### 75. *Amegilla zonata* LINNAEUS

*Anthophora zonata* L.: Dammerman, 1948, p. 355.

7 ♀, RB, 14-16 vii; 1 ♀, RB, 28 x; 1 ♀, S, 6 vii; 1 ♀, S, 14 xi; 10 ♀, RK, 28-31 vii; 1 ♂, AK, 30 vii.

Table 2. Numbers of species of aculeate groups collected on the Krakataus in 1982

|            | Rakata B.<br>(1152 ha) | Sertung<br>(784 ha) | Rakata K.<br>(272 ha) | Anak<br>(280 ha) | Total |
|------------|------------------------|---------------------|-----------------------|------------------|-------|
| Pompilidae | 5                      | 5                   | 4                     | 3                | 10    |
| Mutillidae | 1                      | 2                   | 2                     | 1                | 2     |
| Scoliidae  | 6                      | 4                   | 4                     | 4                | 8     |
| Eumenidae  | 4                      | 5                   | 5                     | 5                | 6     |
| Vespidae   | 9                      | 4                   | 6                     | 5                | 10    |
| Sphecidae  | 16                     | 13                  | 8                     | 11               | 26    |
| Apoidea    | 14                     | 14                  | 16                    | 14               | 24    |
| Total      | 55                     | 47                  | 45                    | 43               | 86    |

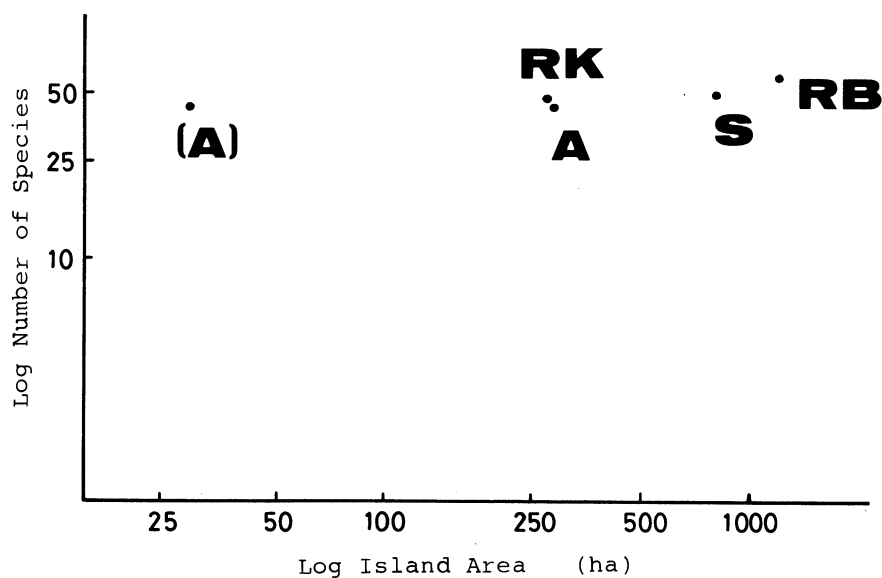


Fig. 5. Relation between aculeate species number and island area in the Krakataus. A: Anak Krakatau; [A]: Habitable area of Anak Krakatau; RB: Rakata Besar; RK: Rakata Kecil; S: Sertung.



**76. *Thyreus nitidulus* FABRICIUS**

*Crocisa nitidula* F.: Dammerman, 1948, p. 357.

3 ♂ 9 ♀, S, 6-26 vii; 1 ♀, S, 7 xi; 2 ♂ 3 ♀, RK, 27-28 vii; 1 ♀, AK, 29 vii.

This species may be parasitic on the preceding species; both the species were often collected exactly at the same sites.

**77. *Pithitis smaragdula* FABRICIUS**

*Ceratina sexmaculata* Sm.: Jacobson, 1909 (in list); Dammerman, 1948, p. 356.

1 ♀, S, 8 vii; 1 ♂ 3 ♀, AK, 29-30; 1 ♀, AK, 8 xi.

**78. *Ceratina collusor* COCKERELL**

1 ♀, RK, 28 vii.

**79. *Ceratina punctigena* VECHT**

? *Ceratina lepida* Sm.: Dammerman, 1948, p. 356.

3 ♂, RB, 31 x; 1 ♂ 4 ♀, AK, 10-30 vii.

**80. *Ceratina accusator* COCKERELL**

1 ♀, RB, 16 vii; 1 ♀, RB, 31 x; 1 ♀, AK, 8 xi.

**81. *Ceratina litoraria* VECHT**

? *Ceratina hieroglyphica* Sm.: Jacobson, 1909 (in list); Dammerman, 1948, p. 355.

*Ceratina litoraria* Vecht, 1952, pp. 59-61.

1 ♀, RB, 21 vii; 5 ♂ 1 ♀, RB, 29-31 vii; 14 ♀, RK, 27-28 vii; 1 ♀, AK, 29 vii.

**82. *Xylocopa confusa* PÉREZ**

*Xylocopa confusa* Pér.: Dammerman, 1948, p. 356.

4 ♀, RB, 15 vii-1 viii; 5 ♀, RB, 29-31 x; 2 ♀, S, 9-10 vii; 4 ♂, S, 7-16 xi; 3 ♀, RK, 27-28 vii; 3 ♀, RK, 9-10 xi; 1 ♀, AK, 30 vii.

**83. *Xylocopa latipes* DRURY**

*Xylocopa latipes* Drury: Jacobson, 1909 (in list); Dammerman, 1948, p. 356.

1 ♂, RB, 16 vii, 1 ♀, RB, 30 x; 2 ♀, S, 9 vii; 1 ♂ 1 ♀, AK, 30 vii.

**84. *Allodapula* spec 1.\***

1 ♀, S, 14 xi; 6 ♂ 7 ♀, RK, 27 vii; 2 ♀, AK, 29 vii.

**85. *Allodapula* spec. 2\***

4 ♀, RB, 14-16 vii; 2 ♀, S, 6-9 vii; 1 ♀, RK, 27 vii; 3 ♀, AK, 29-30 vii.

Table 3. Length of visit to each island (in days)

|             | Collector(s)     | Season                | Rakata Besar | Sertung |
|-------------|------------------|-----------------------|--------------|---------|
| 1908        | Jacobson         | May                   | 3            | 1       |
| 1919 - 1921 | Dammerman et al. | Apr. Sept. Dec.       | 16           | 12      |
| 1932 - 1934 | Dammerman et al. | Apr. May Oct.<br>Dec. | 14           | 10      |
| 1982        | Yamane & Yukawa  | Jul. Oct. Nov.        | 12           | 12      |

The figures for the first three periods are rough estimates based upon Dammerman (1948).

### Family Apidae

#### 86. *Apis dorsata* FABRICIUS

*Apis dorsata* F.: Dammerman, 1948, p. 357.

1 ♀, RK, 9 xi.

### IV. Biogeographical considerations

#### 1. Area-species relation

A total of 86 aculeate species excluding ants were collected on the Krakataus (Table 2). The species number did not vary greatly among the four islets (55 on Rakata Besar, 47 on Sertung, 45 on Rakata Kecil and 43 on Anak Krakatau) despite the differences in area, topography and flora (Fig. 5). The largest species number for Rakata Besar may be explained by its large size and rather diversified topography and flora. Several species were found only in the forests, especially of Rakata Besar (*Eustenogaster* spec. 1, *Trypoxylon* spp., ? *Nomia fuscipennis*, etc.). These species, however, may constitute a minor portion of the present aculeate fauna of the Krakataus. The relatively large species number on Anak Krakatau is worthy of special mention, for this islet probably could receive insects only after 1932, and the 1952 eruptions of Anak Krakatau destroyed most of its own flora and fauna (WHITTAKER & FLENLEY, 1982). Further, although Anak Krakatau is the second smallest (280 ha; SUWARDI, 1982) among the Krakataus, the actual habitable area may be less than 10% (28 ha) because this islet is still largely sterile owing to the continual volcanic activity. Sertung and Rakata Kecil, smaller than Rakata Besar, are also said to have been ravaged by the eruptions of Anak Krakatau in 1930 and 1952 (DAMMERMAN, 1948; WHITTAKER & FLENLEY, 1982). So the faunas of these two islets may be younger than usually supposed. Although it is not certain whether equilibrium in species number has been reached, the slight difference in species number among the four islets means that these islets located close to one another have served as mutual source areas of colonists. Thus, the ravaged areas of Sertung and Rakata Kecil and newly formed areas of Anak Krakatau permitting insect life may have been quickly colonised. The mutual-source-area effect and the aculeates' preference for open sites rather than dense forests may explain the relative richness of the fauna of Anak Krakatau. As mentioned by WHITTAKER and FLENLEY (1982) for vascular plants, it may be predicted that

Table 4. Numbers of species of aculeate groups recorded from Rakata Besar and Sertung

|                | 1908 | 1921 | 1933 | 1982 |
|----------------|------|------|------|------|
| Pompilidae     | 1    | 5    | 4    | 7    |
| Mutillidae     | 0    | 3    | 3    | 2    |
| Scoliidae      | 1    | 3    | 6    | 6    |
| Eumenidae      | 3    | 3    | 4    | 5    |
| Vespidae       | 2    | 5    | 7    | 9    |
| Sphecidae      | 7    | 6    | 6    | 22   |
| Apoidea        | 4    | 11   | 13   | 20   |
| Total          | 18   | 36   | 43   | 71   |
| (Social spec.) | 2    | 6    | 8    | 9    |

1908, 1921, 1933 and 1982 correspond to A, B, C and D in Appendix 1, respectively.

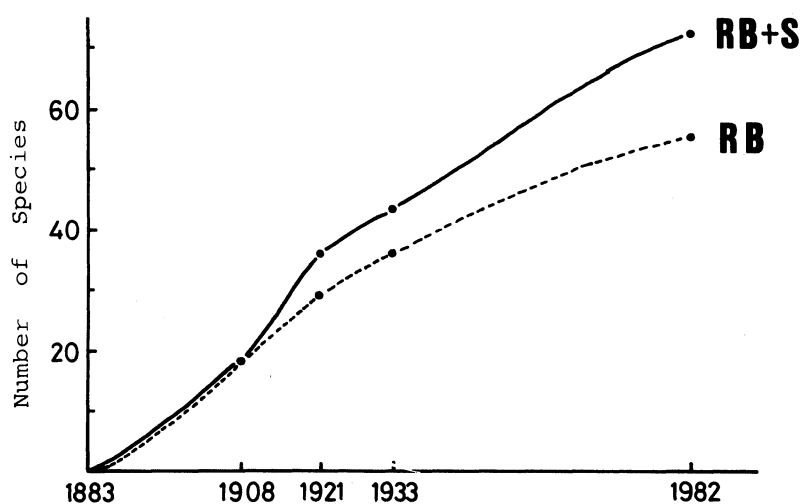
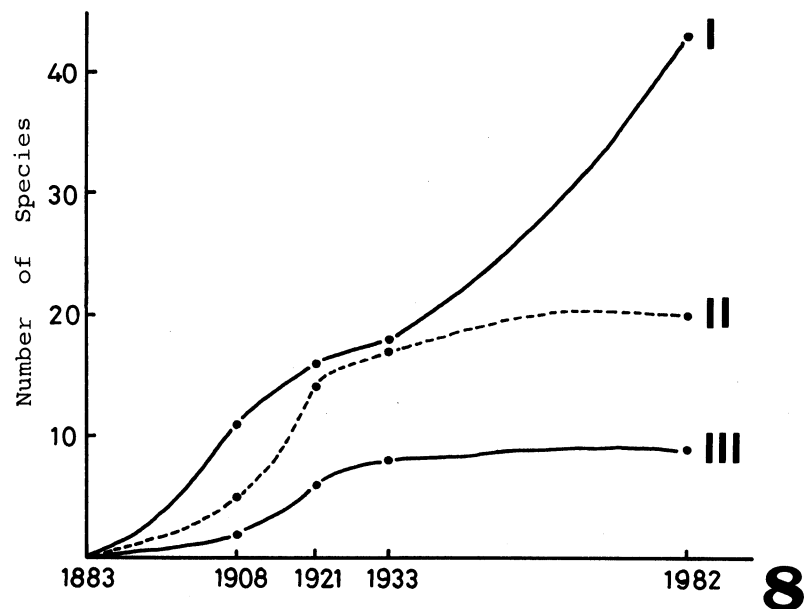
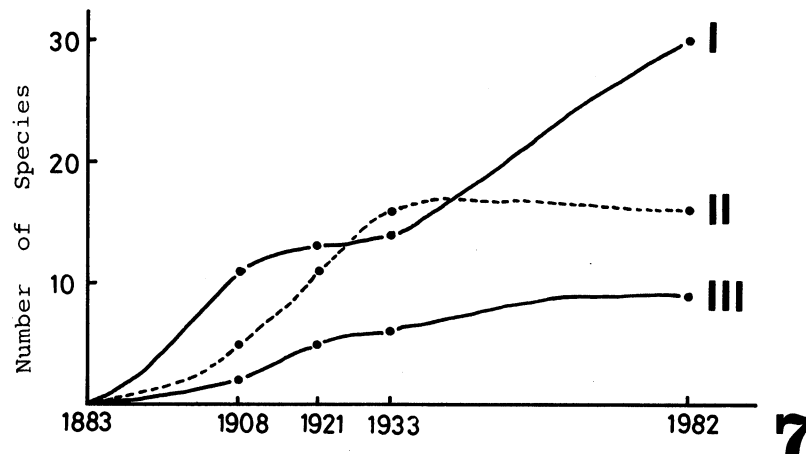


Fig. 6. Recolonisation of Rakata Besar and Sertung by aculeate Hymenoptera excluding ants. RB: Rakata Besar; RB+S: Rakata Besar and Sertung combined. 1908, 1921, 1933 and 1982 correspond to A, B, C and D in Appendix 1, respectively.

in some groups of Aculeata the species number will continue to increase rather slowly, by the addition of *K*-species (primary forest species), with the gradual loss of some *r*-species.

## 2. "Colonisation curves"

DAMMERMAN (1948) compiled a table listing all the animal species collected on Rakata Besar and Sertung through three survey periods (1908, 1919-1922, 1932-1934). Major difficulty in using these data for comparison is caused by the difference among the surveys in collection efforts (number of collectors, their collection skill, duration of time devoted to collection, etc.). The estimated net durations of visits indicate the difference among the surveys to be relatively trivial (Table 3). At any rate it should be kept in mind that all the



Figs. 7 and 8. Recolonisation of Rakata Besar and Sertung by aculeate Hymenoptera excluding ants. I: Apoidea (excluding *Apis*) and Sphecidae; II: Pompilidae, Mutillidae, Scoliidae and Eumenidae; III: Social species (*Apis* and Vespidae). 1908, 1921, 1933 and 1982 correspond to A, B, C and D in Appendix 1, respectively. Fig. 7, Rakata Besar; Fig. 8, Rakata Besar and Sertung combined.

data (including mine) are likely to be incomplete tallies of the fauna at any time.

The number of species for each family or superfamily in the four periods are shown in Table 4. Since Rakata Besar and Sertung were most intensively surveyed by earlier workers, "colonisation curve" should be drawn for one of them (Fig. 6, RB, for Rakata Besar) or for both combined (Fig. 6, RB+S). These two curves are similar to each other. At a glance the number of species seems to be still constantly increasing at the same rate as that before 1933. However, if different groups are separately examined it turns out that in some groups (Scoliidae, Eumenidae, Vespidae, etc.) flattenings of species/time curves have occurred, while in others (Apoidea and Sphecidae) they have not (Figs. 7, 8). We must remember that the latter groups contain many small and inconspicuous species which

easily escape detection so that the "colonisation curves" for the former groups (especially of social species) are more reliable than those for the latter.

It is uncertain that equilibrium has been reached for the aculeates on the Krakataus because the data brought about by different teams are not directly comparable as mentioned above. The levelling-off of species number in some groups, however, suggests the possibility of approaching equilibrium. Equilibrium is reached when immigration and extinction balance each other so that the number of species remains constant (MACARTHUR and WILSON, 1967). The faunal components naturally change through the process, that is, turnover is continually occurring. It is difficult to find evidence for turnover on the Krakataus between 1933 and 1982 because of the incompleteness of the data. One of the most notable turnover events confirmed in 1982 was the disappearance of *Polistes diabolicus* (seen from 1919 to 1933 on Rakata Besar and Sertung) and the occurrence of the previously unencountered species *Polistes tenebricosus* on all the islets except for Anak Krakatau. These two species are quite conspicuous, and may not have escaped detection even by nonspecialists. To determine the present state of colonisation process, intensive surveys must be done every ten years from now on.

### 3. Derivation of the fauna

In most cases the distribution of a given species is too insufficiently known to draw out any reliable conclusion about the origin of the Krakatau population. DAMMERMAN (1948) considered that the majority of the Krakatau species were of Sumatran origin. His tentative conclusion was mainly based upon the avifauna, and supported by the fact that there were species that had not been found on Rakata Besar but found on Sertung or Rakata Kecil. The present data suggest that regarding the aculeates the Javanese elements have the slight preponderance over the Sumatran ones. There are 4 wasp species which were represented by races (subspecies) from Java (*Polistes tenebricosus tenebricosus*, *P. sagittarius indonesicus*, *Vespa analis analis*, *Sphex sericeus sericeus*), while there is only one species represented by Sumatran race (*Phi flavopictus continentalis*) (but see below). A similar tendency was observed also for the butterflies (YUKAWA, unpub.).

Table 5. Distribution of *Vespa analis* and *V. affinis* on the Krakataus, P. Sebesi and P. Sebuku

|                | 1921           | 1933           | 1955                            | 1982                            |
|----------------|----------------|----------------|---------------------------------|---------------------------------|
| Sertung        | <i>affinis</i> | <i>affinis</i> | <i>analis</i>                   | <i>affinis</i>                  |
| Rakata Besar   | -              | -              | <i>analis</i>                   | <i>analis</i><br><i>affinis</i> |
| Rakata Kecil   |                | -              | -                               | <i>analis</i>                   |
| Anak Krakatau  |                | -              | -                               | <i>analis</i><br><i>Affinis</i> |
| Sebesi, Sebuku | <i>analis</i>  |                | <i>analis</i><br><i>affinis</i> |                                 |

The distributions of the two *Vespa* forms (*analisis analis* and *affinis indosinensis*) are of special interest because VECHT (1957) considered that competitive exclusion occurred among them in the Sunda regions. The Javanese population of *V. analis* is adapted to the tropical lowlands, common along the coast of West Java, and has been found on Sebesi, Sebuk, Legundi and South Sumatra. On the other hand, though commonly distributed in Sumatra, *V. affinis indosinensis* is rare or absent in Java (VECHT, 1957, 1959). VECHT (1957) thought that the spread of *V. affinis* had been halted by the presence of the West Javan lowland race of *V. analis*, a previously established competitor occupying the same ecological niche. The most recent investigations suggest that *V. analis analis* has invaded central and northern Sumatra where no record of this form was known in the 1930's (MATSUURA, personal communication). On the Krakataus both the species was found to be common in 1982, and on two islets they were collected at the same sites (but this does not mean their coexistence because the four islets are so closely situated to one another that worker wasps can easily travel between them) (Table 5). The vacant niche there may have permitted the colonisation by *V. affinis*. However, it is necessary to follow up the future distribution pattern in order to test VECHT's hypothesis.

Interactions between the Javan and Sumatran races of the same species were indirectly observed. *Sphex sericeus* was represented by both the Javan and Sumatran races in 1928 (VECHT & KROMBEIN, 1955), but only the Javan form was collected in 1982. Probably the Sumatran form has been driven off, or its gene contribution was so small that the Sumatran genes have been diluted with the Javan genes. Another interesting case is that of *Phi flavopictus* for which individuals of the Sumatran type and supposed hybrids between Javan and Sumatran races (*branchardi* and *continentalis*) were collected. One such intermediate individual was found also in November, 1932 (Dammerman, 1948). Curiously no individual of typical *branchardi* has been met on the Krakataus.

#### 4. Disharmony

The oceanic island faunas are frequently disharmonious (CARLQUIST, 1974; KIMOTO, 1982). For the Krakatau Aculeata the most remarkable aspect of faunal disharmony is the lack of species of swarm-performing social groups such as *Polybioides*, *Ropalidia* subgenus *Icarielia*, and *Trigona*. The swarming is usually a complex and delicate event so that a swarm is not expected to endure a long trip over the sea. Only exception is *Apis dorsata* which was already found in April, 1919 on Rakata Besar and again confirmed between 1920 and 1933 on Rakata Besar and Sertung, and in 1982 on Rakata Kecil. This species is known to make a long trip (150-200 km) in a swarm frequently when the nest site is deteriorated (KOENIGER & KOENIGER, 1980; SEELEY et al, 1982). Other widely distributed honeybees, *Apis cerana* and *A. florea*, which are known relatively residentary, have not been found from the Krakataus. The lack of species of certain sphecid genera (*Sceliphron*, *Chalybion* and *Ammophila*) which are very common in the open sites of Java and Sumatra is another aspect of disharmony. Other groups of wasps and bees are variously represented on the Krakataus (Table 6).

Table 6. Numbers of species in certain groups of Aculeata known from Sumatera, Jawa and the Krakatau

|                        | Jawa | Sumatera | J + S | Krakatau | K/J+S | K/J |
|------------------------|------|----------|-------|----------|-------|-----|
| Vespidae               | 28   | 39       | 44    | 10       | 23%   | 36% |
| <i>Trypoxylon</i>      | 32   | 17       | 39    | 9        | 23    | 28  |
| <i>Bembecius</i>       | 7    |          |       | 1        |       | 14  |
| <i>Cerceris</i>        | 19   |          |       | 1        |       | 5   |
| <i>Campsomeris</i>     | 23   | 16       | 26    | 5        | 19    | 22  |
| <i>Ceratina</i> (s.l.) | 18   | 12       | 18    | 6        | 33    | 33  |

### Acknowledgements

This study was aided by grants from the Toyota Foundation (no. 81-1-242) and from the Ministry of Education, Science and Culture (no. 57041044).

I also thank the following persons for their kind help in various ways. Prof. Hideo TAGAWA (Kagoshima Univ.), the leader of our expedition team to the Krakatau in 1982, gave me the opportunity to survey the insect fauna of these interesting islands. Dr. Junichi YUKAWA (Kagoshima Univ.) collected many aculeate Hymenoptera, and read through an earlier draft of the manuscript. The staff of LIPI (Indonesian Institute of Science), especially Dr. Soenartono ADISOEMARTO (Museum Zoologicum Bogorensis), gave us great facilities in Indonesia. All the members of our expedition team much helped me in collecting material. Dr. J.C. ROSKAM (Univ. Leiden) sent me a copy of DAMMERMAN's paper. Some of the specimens were determined by authorities: some Apoidea by Prof. Yoshihiro HIRASHIMA (Kyushu Univ.), Pompilidae by Prof. Ryôsuke ISHIKAWA (Tokyo Metropolitan Univ.), *Ropalidia* by Mr. Jun-ichi KOJIMA (Tokyo Metropolitan Univ.), some Sphecidae by Dr. W.J. PULAWSKI (California Academy of Science), and Meliponini by Prof. Shôichi F. SAKAGAMI (Hokkaido Univ.). Dr. Tamiji INOUE (Kyoto Univ.) gave me useful suggestions about the migration of *Apis dorsata*.

### References

(\*not directly accessible)

- BEQUAERT, J. 1934. Les races de coloration de *Vespa luctuosa* de Saussure et de *Polistes tenebricosus* Lepeletier. *Bull. Mus. Roy. d'Hist. Nat. Belgique.*, **10** (1): 1-11.
- BEQUAERT, J. 1940. Notes on Oriental *Polistes* wasps (Hymenoptera: Vespidae). *Trans. Amer. Ent. Soc.*, **66**: 265-272.
- BETREM, J.G. 1928. Monographie der Indo-Australischen Scoliiden mit Zoogeographischen Betrachtungen. *Treubia*, **9**, Suppl., 338 pp.
- CARLQUIST, S. 1974. *Island Biology*. Columbia Univ. Press, 660 pp.
- DAMMERMAN, K.W. 1922. The fauna of Krakatau, Verlaten Island and Sebesy. *Treubia*, **3**: 61-112.
- DAMMERMAN, K.W. 1929. Krakatau's new fauna. *Krakatau* (4th Pacific Sci. Congr.). Pp. 83-118.
- DAMMERMAN, K.W. 1948. The fauna of Krakatau 1883-1933. *Kon. Ned. Akad. Wet. Verh. Wetenschap. Afdel. Natuurk.*, (2) **44**: 1-594.

- DIAMOND, J.M. & R.M. MAY, 1976. Island biogeography and the design of natural reserves. In: R. M. MAY (Ed.) *Theoretical Ecology*. Pp. 163-186.
- DOCTERS VAN LEEUWEN, W.M. 1936. Krakatau 1883-1933. *Annls Jard. Bot. Buitenz.*, **46/47**: 1-506.
- \*ESCHER, B.G. 1919. De Krakatau-groep als vulkaan; Verhandelingen in de Krakatau-Groep na 1908. *Hand. 1ste Ned. Ind. Natuurw. Congress.* Pp. 28-35, 198-219.
- GORMAN, M. 1979. *Island Ecology*. Chapman & Hall, 79 pp.
- \*JACOBSON, E.R. 1909. Die nieuwe fauna van Krakatau. *Jaar. Top. Dienst. Ned. Ind.*, **1908**: 192.
- KIMOTO, S. 1982. Zoogeography and ecology of the Ryūkyū Archipelago with special reference to leaf beetles (Coleoptera: Chrysomelidae). *Ent. General.*, **8**: 51-58.
- KOENIGER, N. & G. KOENIGER, 1980. Observations and experiments on migration and dance communication of *Apis dorsata* in Sri Lanka. *J. Apicult. Res.*, **19**: 21-34.
- MACARTHUR, R.H. & E.O. WILSON, 1967. *The Theory of Island Biogeography*. Princeton Univ. Press, 203 pp.
- RICHARDS, K. 1982. Introduction. In: J.R. FLENLEY & K. RICHARDS (Eds.) The Krakatoa Centenary Expedition. *Dept. Geogr. Univ. Hull Misc. Ser.*, **25**: 1-7.
- SEELEY, T.D., R.H. SEELEY and P. AKRATANAKUL, 1982. Colony defence strategies of the honeybees in Thailand. *Ecol. Monogr.*, **52**: 43-63.
- SIMBERLOFF, D.S. 1974. Equilibrium theory of island biogeography and ecology. *Ann. Rev. Ecol. Syst.*, **5**: 161-182.
- SUWARDI, A. 1982. Geomorphology of the Krakatau Islands with special reference to the coastline changes and coastal processes on Anak Krakatau and Sertung. In: *Seminar on Coastal Resources Management in the Krakatau and the Sunda Strait Region*. Pp. 1-39.
- TSUNEKI, K. 1978. Studies on the genus *Trypoxylon* Latreille of the Oriental and Australian Regions (Hymenoptera, Sphecidae). I. Group of *Trypoxylon scutatum* Chevrier, with some species from Madagascar and the adjacent islands. *Spec. Publ. Jap. Hymen. Assoc.*, **7**: 1-87.
- TSUNEKI, K. 1979. Studies on the genus *Trypoxylon* Latreille of the Oriental and Australian Regions (Hymenoptera, Sphecidae). V. Species from Sumatra, Java and the Lesser Sunda Islands. *Spec. Publ. Jap. Hymen. Assoc.*, **11**: 1-68.
- VECHT, J. VAN DER, 1949. On Indo-Australian *Bembecinus*, with special reference to the species occurring in Java (Hym., Sphec.). *Treubia*, **20**: 289-307.
- VECHT, J. VAN DER, 1952. A preliminary revision of the Oriental species of the genus *Ceratina* (Hymenoptera, Apidae). *Zool. Verh. Leiden*, **16**: 1-85.
- VECHT, J. VAN DER, 1957. The Vespinae of the Indo-Malayan and Papuan Areas (Hymenoptera, Vespidae). *Zool. Verh. Leiden*, **34**: 1-83, 6 pls.
- VECHT, J. VAN DER, 1959. Notes on Oriental Vespinae, including some species from China and Japan (Hymenoptera, Vespidae). *Zool. Meded. Leiden*, **36**: 205-232.
- VECHT, J. VAN DER, 1964. The *Cerceris* species of Java (Hymenoptera, Sphecoidea). *Zool. Meded. Leiden*, **39**: 346-368.
- VECHT, J. VAN DER and K.V. KROMBEIN, 1955. The subspecies of *Sphex sericeus* (Fabr.) (= *S. aurulentus* auct., nec. Fabr. 1787) (Hymenoptera, Sphecidae). *Idea*, **10**: 33-43.
- WHITTAKER, R. and J. FLENLEY, 1982. The flora of Krakatau. In: J.R. FLENLEY & K. RICHARDS (Eds.) The Krakatoa Centenary Expedition. *Dept. Geogr. Univ. Hull Misc. Ser.*, **25**. Pp. 9-54.
- YUKAWA, J., T. ABE, T. IWAMOTO and Sk. YAMANE, 1983. The fauna of the Krakatau, Peucang and Panaitan Islands. Paper presented to the Symposium on 100th Year Development of Krakatau and Its Surroundings, Aug. 1983, Jakarta, Indonesia.



## Appendix 1. Summary of the aculeate species found on the Krakataus

[illegible]

[illegible]

| Family           | Species                                | Rakata Besar |   |   |   | Sertung |   |   |   | Rakata Kecil |   |   |   | Anak Krakatau |   |   |   |
|------------------|--|--------------|---|---|---|---------|---|---|---|--------------|---|---|---|---------------|---|---|---|
|                  |  | A            | B | C | D | A       | B | C | D | A            | B | C | D | A             | B | C | D |
| Vespidae (cont.) | <i>Vespa analis analis</i> Fab.        |              |   |   | + |         |   |   |   |              |   |   | + |               |   |   | + |
|                  | <i>Vespa affinis indosinensis</i> Pér. |              |   |   | + |         |   |   | + |              |   |   | + |               |   |   | + |
|                  | <i>Vespa tropica tropica</i> L.        |              |   |   | * |         |   |   | + |              |   |   |   |               |   |   |   |
| Sphecidae        | <i>Ampulex compressa</i> Fab.          |              |   |   | + |         |   |   | + |              |   |   |   |               |   |   |   |
|                  | <i>Dolichrus</i> spec. 1               |              |   |   |   |         |   |   |   |              |   |   |   |               |   |   | + |
|                  | <i>Dolichrus</i> spec. 2               |              |   |   |   |         |   |   |   |              |   |   |   |               |   |   | + |
|                  | <i>Sphex sericeus sericeus</i> Fab.    |              |   |   | + |         |   |   | + |              |   |   | + |               |   |   | + |
|                  | <i>Polemistus</i> spec.                |              |   |   |   |         |   |   | + |              |   |   |   |               |   |   |   |
|                  | <i>Diodontus</i> spec.                 |              |   |   | + |         |   |   |   |              |   |   |   |               |   |   |   |
|                  | <i>Carinostigmus</i> spec.             |              |   |   |   |         |   |   | + |              |   |   |   |               |   |   | + |
|                  | <i>Larra maura</i> Fab.                |              |   |   | + |         |   |   |   |              |   |   |   |               |   |   |   |
|                  | <i>Larra</i> spec.                     |              |   |   | + |         |   |   |   |              |   |   |   |               |   |   |   |
|                  | <i>Liris subtessellata</i> Sm.         |              |   |   | + |         |   |   | + |              |   |   | + |               |   |   | + |
|                  | <i>Liris</i> spec. 1                   |              |   |   | + |         |   |   | + |              |   |   |   |               |   |   | + |
|                  | <i>Liris</i> spec. 2                   |              |   |   | + |         |   |   | + |              |   |   | + |               |   |   | + |
|                  | <i>Liris</i> spec. 3                   |              |   |   | + |         |   |   |   |              |   |   |   |               |   |   |   |
|                  | <i>Tachytes</i> spec. (=vicina?)       |              |   |   | ? |         |   |   | + |              |   |   | + |               |   |   |   |
|                  | <i>Tachysphex</i> spec.                |              |   |   |   |         |   |   |   |              |   |   |   |               |   |   | + |
|                  | <i>Trypoxylon thaianum</i> Tsuneki     |              |   |   | ? |         |   |   |   |              |   |   |   |               |   |   | ? |
|                  | <i>Trypoxylon schmidecknehti</i> Kohl  |              |   |   |   |         |   |   | + |              |   |   |   |               |   |   | + |

[illegible]



In compiling this table I have encountered several taxonomic problems. For example, when material was determined only to generic level it was difficult to compare such records with each other. Although it may be desirable to compare all the specimens of different sources, the studies of the previously collected specimens were in most cases impossible. (See also Whittaker & Flenley, 1982 for plant records.)

A: collecting records by Jacobson in 1908 (Jacobson, 1909).

B: collecting records by Dammerman and others from 1919 to 1922 (Dammerman, 1922, 1929).

C: collecting records by Dammerman and others from 1932 to 1934 (Dammerman, 1948).

D: collecting records by Yamane and Yukawa in 1982 (present paper). (See also Yukawa et al., 1983.)

\*: sight record.

## Appendix 2. List of the Aculeata collected on Peucang Island near Ujung Kulon

All the specimens were collected on 5-6 August, 1982 by Sk. Yamane.

### I. Pompilidae

1. *Leptodialepis* (?) spec. (Det. by R. Ishikawa.) 1 ♂.
2. *Auplopus* spec. 2 (Det. by R. Ishikawa.) 2 ♂ 2 ♀.
3. *Auplopus* spec. 3 (Det. by R. Ishikawa.) 1 ♂.
4. *Orientaloplius* spec. (Det. by R. Ishikawa.) 1 ♂.

### II. Mutillidae

5. *Mutilla dimidiata* Lep. 3 ♂♂.
6. *Mutilla* spec. 1 3 ♂♂.

### III. Scoliidae

7. *Austroscolia ruficeps* Sm. 1 ♂ 1 ♀.
8. *Scolia vollenhoveni* Sauss. 1 ♂.
9. *Liacos erythrosoma* Burm. 1 ♀.
10. *Campsomeris leefmansii* Betr. 3 ♂♂.
11. *Campsomeris quadrifasciata* Fab. 2 ♂♂.
12. *Campsomeris* spec. 7 ♂♂.
13. *Campsomeris bicolor* Sauss. 4 ♂♂.

### IV. Eumenidae

14. *Rhynchium haemorrhoidale* Fab. 2 ♂ 1 ♀.
15. *Allorhynchium snelleni imitator* Vecht 3 ♂ 1 ♀\*.
16. *Allorhynchium argentatum* Fab. 1 ♂ 1 ♀.
17. *Anterhynchium flavomarginatum flavonigrans* Vecht 1 ♂.
18. "Odynerus" spec. 5 ♀.
19. *Delta campaniforme* Fab. 2 ♂ 1 ♀.
20. *Phi flavopictus blanchardi* Sauss. 2 ♀.

### V. Vespidae

21. *Eustenogaster* spec. 2 1 ♀.
22. *Ropalidia stigma stigma* Sm. (Det. by J. Kojima) 1 ♀.
23. *Ropalidia artifex* Sauss. (Det. by J. Kojima.) 1 ♀.
24. *Polistes stigma* Fab. 3 ♀.
25. *Polistes tenebricosus tenebricosus* Lep. 3 ♀.
26. *Polistes sagittarius indonesicus* Beq. 2 ♂ 4 ♀.
27. *Vespa analis analis* Fab. 1 ♀.
28. *Vespa tropica tropica* L. 2 ♀.

### VI. Sphecidae

29. *Sphex sericeus sericeus* Fab. 1 ♂.
30. *Sphex argentatus argentatus* Fab. 1 ♂ 1 ♀.
31. *Isodontia diodon severini* Kohl 1 ♂ 1 ♀.
32. *Sceliphron javanum javanum* Lep. 1 ♀.

---

\* In the female specimen apical margin of clypeus has a blunt median projection in addition to two sharp lateral teeth. This suggests that this specimen belongs to another species.

33. *Chalybion bengalense* Dahlb. 1 ♂ 1 ♀.
34. *Psenulus* spec. (Det. by W.J. Pulawski.) 1 ♀.
35. *Carinostigmus* spec. 1 ♀.
36. *Liris subtessellata* Sm. 1 ♀.
37. *Liris* spec. 2 1 ♂.
38. *Liris* spec. 3 1 ♀.
39. *Trypoxylon nesianum* Tsuneki 1 ♀.
40. *Bembecinus boreanus* Cam. 3 ♂ 1 ♀.
41. *Bembecinus littoralis* Vecht 1 ♀.
42. *Bembecinus alternatus* Vecht 1 ♂.
43. *Bembecinus insularis* Handl. 2 ♂ 1 ♀.
44. *Cerceris pictiventris pictiventris* Dahlb. 3 ♂.

## VII. Halictidae

45. *Homalictus* spec. 1 (Det. by Y. Hirashima.) 1 ♂.
46. *Nomia* spec. 2 2 ♂.

## VIII. Megachilidae

47. *Megachile* spec. 1 1 ♀.

## IX. Anthophoridae

48. *Thyreus nitidulus* Fab. 2 ♂ 1 ♀.
49. *Ceratina flavopicta* Sm. 1 ♂ 4 ♀.
50. *Xylocopa confusa* Pér. 4 ♀.
51. *Xylocopa* spec. 3 ♂ 1 ♀.

## X. Apidae

52. *Trigona laeviceps* Sm. (Det. by S.F. Sakagami.) 14 ♀.
53. *Trigona terminata* Sm. (Det. by S.F. Sakagami.) 15 ♀.

**Appendix 3. List of the Aculeata collected on Panaitan Island near  
Ujung Kulon**

All the specimens were collected on 20-22 October, 1982 by J. Yukawa.

## I. Pompilidae

1. *Hemipepsis* spec. 2 (Det. by R. Ishikawa.) 2 ♂.
2. *Tachypompilus analis* Fab. (Det. by R. Ishikawa) 1 ♂.

## II. Mutillidae

3. *Mutilla* spec. 1 1 ♂.

## III. Scoliidae

4. *Triscolia azurea azurea* Chr. 3 ♂.
5. *Microscolia cephalotes* Burm. 2 ♂.
6. *Liacos dimidiata* Guér. subsp. 2 ♂.

## IV. Eumenidae

7. *Rhynchium haemorrhoidale* Fab. 1 ♀.
8. "*Odynerus*" *guttulatus nigradorsus* Vecht 1 ♂.



## V. Sphecidae

9. *Liris subtessellata* Sm. 2 ♂.
10. *Tachysphex* spec. 1 ♂.

## VI. Megachilidae

11. *Chalicodoma* spec. (Det. by Y. Hirashima.) 2 ♀.

## VII. Apidae

12. *Apis dorsata* Fab. 6 ♀.
13. *Apis cerana* Fab. 1 ♀
14. *Trigona* spec. 15 ♀

**Appendix 4.** List of the Aculeata collected in Carita, West Jawa

The specimens were collected on 2 July-7 August, 1982 by Sk. Yamane, and on 15 October-18 November, 1982 by J. Yukawa.

## I. Pompilidae

1. *Auplopus (Conagenia)* spec. 1 (Det. by R. Ishikawa.) 2 ♂.
2. *Batozonellus annulatus* Fab. (Det. by R. Ishikawa.) 1 ♀.

## II. Mutillidae

3. *Mutilla* spec. 2 1 ♂.

## III. Scolidae

4. *Triscolia azurea azurea* Chr. 1 ♂.
5. *Campsomeris quadrifasciata* Fab. 2 ♂ 1 ♀.
6. *Campsomeris javana* Lep. 2 ♀.

## IV. Eumenidae

7. *Rhynchium haemorrhoidale* Fab. 5 ♂.
8. *Allorhynchium argentatum* Fab. 4 ♂ 1 ♀.
9. ? *Antepipona brunnipes* Fab. 1 ♂.
10. *Antepipona* spec. 1 ♀.
11. *Pachymenes fragilis* Sm. 4 ♂ 1 ♀.
12. *Subancistrocerus* spec. 1 ♂.
13. *Ancistrocerus* spec. 1 ♂.
14. *Delta campaniforme* Fab. 7 ♂ 5 ♀.

## V. Vespidae

15. *Parischnogaster mellyi* Sauss. 3 ♀.
16. *Ropalidia (Icariola)* spec. 1 ♀.
17. *Polistes tenebrosus tenebrosus* Lep. 3 ♂ 9 ♀.
18. *Polistes sagittarius indonesicus* Beq. 3 ♂ 2 ♀.
19. *Vespa analis analis* Fab. 5 ♀.

## VI. Sphecidae

20. *Sphex sericeus sericeus* Fab. 3 ♀.
21. *Ammophila* spec. (= *clavus* Fab.) 8 ♂ 4 ♀.
22. *Sceliphron javanum javanum* Lep. 2 ♀.
23. *Sceliphron madraspatanum madraspatanum* Fab. 7 ♂.

24. *Chalybion bengalense* Dahlb. 1 ♂.
25. *Liris aurulenta* Fab. 2 ♂.
26. *Liris subtessellata* Sm. 1 ♂.
27. *Liris* spec. 1. 1 ♂.
28. *Liris* spec. 2 1 ♀.
29. *Tachytes* spec. 1 1 ♂.
30. *Tachytes* spec. 2 1 ♂.
31. *Pison* spec. (Det. by W.J. Pulawski.) 1 ♀.
32. *Trypoxylon schmiedeknechti schmiedeknechti* Kohl. 1 ♀.
33. *Dasyproctus* spec. (Det. by W.J. Pulawski.) 1 ♂.
34. *Bembix borrei* Handl. 1 ♂ 8 ♀.
35. *Cerceris varia* Maidl 1 ♀.

## VII. Halictidae

36. *Rhopalomelissa* spec. (Det. by Y. Hirashima.) 1 ♂.
37. *Nomia* spec. 2 1 ♂.
38. *Nomia* spec. 3 (Det. by Y. Hirashima.) 1 ♂.

## VIII. Megachilidae

39. *Megachile umbripennis* Sm. 1 ♂.
40. ? *Megachile disjuncta* Fab. 1 ♀.

## IX. Anthophoridae

41. *Amegilla zonata* L. 1 ♀.
42. *Amegilla* spec. 1 ♀.
43. *Pithitis smaragdula* Fab. 1 ♂.
44. *Ceratina punctigena* Vecht 1 ♀.
45. *Xylocopa confusa* Sm. 7 ♂ 8 ♀.
46. *Xylocopa latipes* Drury 1 ♂.
47. *Xylocopa* spec. 1 ♂.

## X. Apidae

48. *Apis cerana* Fab. 3 ♀.

## Corrigenda in proofing

I thank Dr. J. van der Vecht (the Netherlands) who has found some errors in my manuscript, identified some species, and informed them to me just prior to proofing.

## Family Eumenidae

*Eumenes conspicuus* Smith should read *E. inconspicuus* Smith (p. 81, no. 24 ; Appendix 1)

"*Odynerus*" spec. should read *Euodynerus* (*Knemodynerus*) spec. (Appendix 2, no. 18)

? *Antepipona brunnipes* Fab.: Delete ? (Appendix 4, no. 9)

*Antepipona* spec. should read *A. bipustulatus* Saussure (Appendix 4, no. 10)

*Subancistrocerus* spec. should read *S. sichelii* Saussure (Appendix 4, no. 12)

*Ancistrocerus* spec. should read *Parancistrocerus exiguus* Saussure (Appendix 4, no. 13)

## Family Vespidae

*Eustenogaster* spec. 2 should read *E. hauxwellii* Bingham (p. 82, no. 28 ; Appendix 1 ; Appendix 2, no. 21)

*Parischnogaster* spec. nr *costulatus* Schulthess should read *P. foveata* Buysson (p. 82, no. 30 ; Appendix 1)

## Family Sphecidae

*Ammophila* spec. (= *clavus* Fab.) should read *A. atripes taschenbergi* Cameron (Appendix 4, no. 21)