THE BUMBLE BEES (HYMENOPTERA: APIDAE) OF TAIWAN

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ABSTRACT—The bumble bees of Taiwan are taxonomically reviewed and keyed. Eight social species and one social-parasitic species are recorded. Distribution ranges within Taiwan are plotted, based on examination of about 4500 specimens. Taiwan ranges of the honey bee *Apis cerana,* and the stingless bee *Trigona ventralis* are estimated, with discussion of possible competitive displacement by honey bees of other social bees.

Some notes are given on the incidence of uropodid mites on queens, workers and males of *Bombus wilemani.*

A key to the large carpenter bees (Anthophoridae: *Xylocopa*) of Taiwan is appended.

KEY WORDS: *Bombus,* Apidae, Taiwan

INTRODUCTION

Bumble bees are a distinctive group of social and social-parasitic insects. Their large size, day-active habits loud, droning flight and frequent abundance in the late summer and early fall make them a conspicuous part of the insect fauna in many parts of Taiwan. About 240 species are known (Williams, 1990), with the true worldwide total unlikely to exceed 300 (P.H. Williams, pers. comm.). This is primarily a temperate and arctic group, with only slight representation in tropical Asia and America and none in Australia or subsaharan Africa.

Bumble bees are commonly ranked as a subfamily Bombinae within the Apidae, the family of corbiculate bees. The other three groups of corbiculate bees are the highly social honey bees (Apinae: *Apis*) and stingless bees (Meliponinae, including the genus *Trigona*) and the solitary orchid bees (Euglossinae). Among the shared derived characters which set the Apidae apart from other bees is the distinctive pollen basket, or corbicula, on the outer side of the hind tibia. While the naturalness of the Apidae is unquestioned, relationships among its four component groups remain controversial. The most favored hypothesis in recent years places the bumble bees as the sister-group of the Euglossinae (Kimsey, 1984; Winston and Michener, 1977). However, Michener (1990) considers the hypothesis of the bumble bees as the sister-group of the Apinae + Meliponinae to be about equally well supported by present evidence.

Traditionally, the social bumble bees have been grouped into the genus *Bombus* and the social-parasitic species, or cuckoo bumble bees, into the genus *Psithyrus*. Various proposals to divide the social species into several genera (e.g. Milliron, 1961; Tkalcu, 1972) have not been widely accepted, apparently because of the remarkable degree of physical uniformity across this large group. It has generally been presumed that *Bombus* (in the traditional sense) and *Psithyrus* are each other's sister-groups (e.g. Plowright and Stephen, 1973). Recent phylogenetic studies uphold the monophyly of *Psithyrus,* but indicate that the social species together form a paraphyletic group (Williams 1985, 1991). In keeping with this finding and in order to avoid use of paraphyletic taxa, I will treat *Psithyrus*

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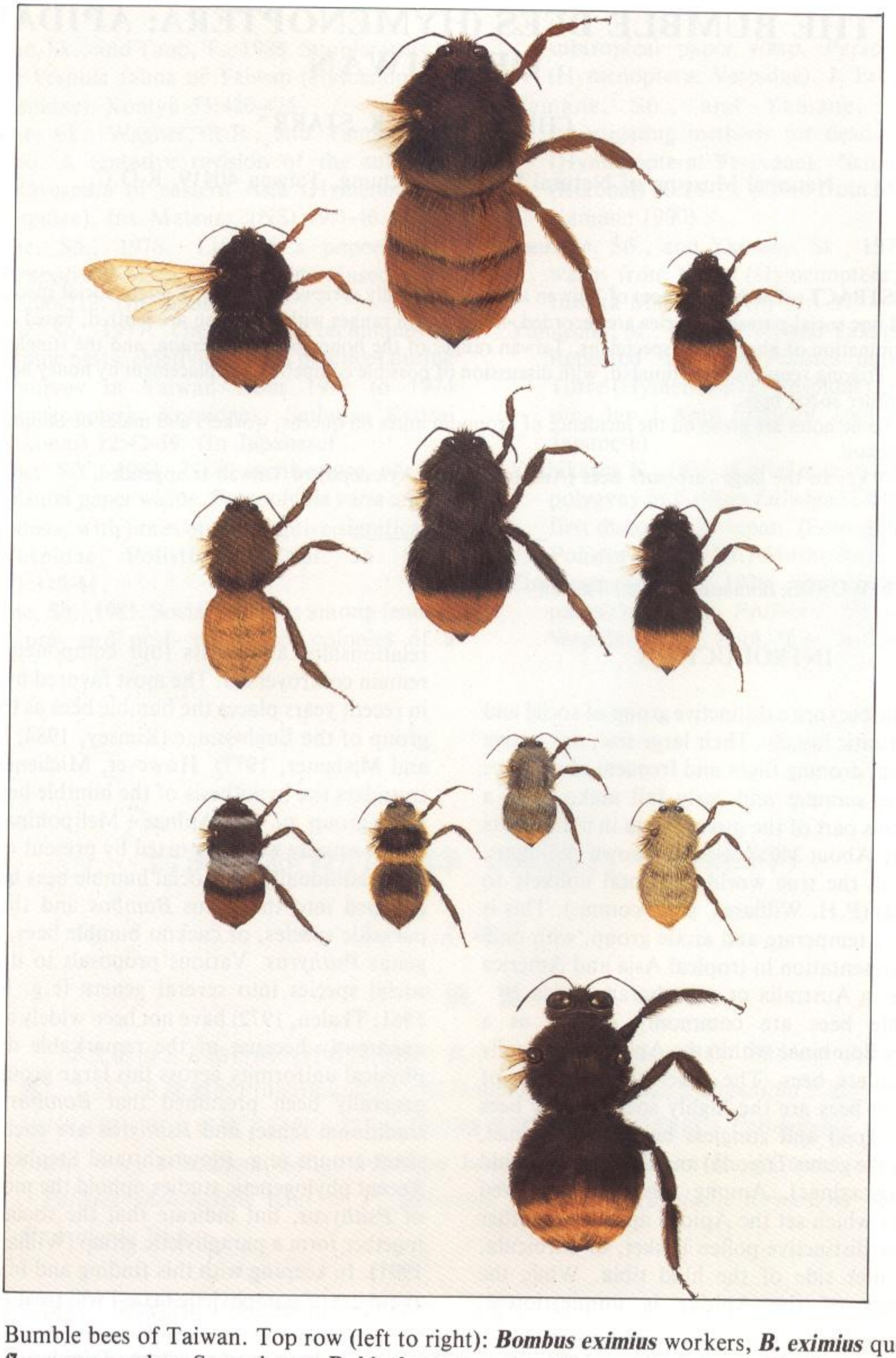

Figure 1. Bumble bees of Taiwan. Top row (left to right): ***Bombus eximius*** workers, ***B. eximius*** queen, ***B. flavescens*** worker. Second row: ***B. bicoloratus*** worker, ***B. angulatus*** queen, ***B. wilemani*** worker. Third row: ***B. formosellus*** worker, ***B. formosellus*** male, ***B. sonani*** worker, ***B. sonani*** male. Bottom right: ***Xylcopa bomboides*** female. Painting by H.C. Yu.

as a subgenus of *Bombus*.

In this paper I follow Richards's (1968) subgeneric classification of the social bumble bees. It has yet to be superceded by any widely accepted scheme, and placement of the Taiwanese species is unaffected by more recent phylogenetic findings. The ecology and nesting biology of bumble bees has been reviewd by Alford (1975), Heinrich (1979), Michener (1974), Morse (1982) and Ploweright and Laverty (1984), among others. In the main features of their social organization, social bumble bees are more primitive than honey bees and stingless bees, the other social corbiculate bees. Queens are usually clearly larger than workers but otherwise show very little external physical difference. In addition, sexual dimorphism tends to be slight or moderate. The typical colony cycle begins with independent founding (i.e. without the participation of workers) by a single queen and ends in a single period of production of new reproductives.

Cuckoo bumble bees are workerless social parasites of other bumble bees. The females are equipped to physically overcome host queens in their nests and usurp their reproductive monopoly. Although all cuckoo bumble bees are obligately parasitic, the evolutionary precedent for this habit is seen in frequent usurpation attempts among *Bombus* queens. Not only do *Psithyrus* females produce no workers but their pollen baskets are undeveloped, so that they are physically incapable of effective foraging.

This paper is a faunistic review of the species present in Taiwan, based on examination of material in all of the substantial collections here. Due to the limited scope of this study, I have largely deferred judgement on primary taxonomic questions, although possible synonymies are mentioned.

HISTORICAL BACKGROUND

In an unillustrated two-page review of the bumble bees of Taiwan, Cockerell (1911) recognized three species, all putatively endemic: *B. bicoloratus* F. Smith, *B. latissimus* Friese and *B. wilemani* Cockerell. The male of *B. wilemani* was unknown at that time, and as a general rule descriptions of females have continued to precede those of males.

Skorikov (1933) presented an annotated list of 64 species from the east coast of temperate Asia, including six from Taiwan (his area XI): *B. diversus* F. Smith, *B. formosanus* Skorikov, *B. flavescens* F. Smith, and the three mentioned by Cockerell. I comment on his *B. diversus* record below. Skorikov evidently saw no specimens labeled as *B. wilemani* and based his treatment of it on Cockerell's brief, confusing description. His description of *B. formosanus* was based on both females and males, and as Chiu (1984) later noted, it is clearly a junior synonym of *B. wilemani*.

Taiwan's only known cuckoo bumble bee, *B. monozonus*, was described by Friese (1931), who hypothesized *B. eximius* F. Smith (=*latissimus*) as its host. Maa (1948) gave a fuller redescription of the species.

Skorikov was the first to attempt a faunistic characterization of the bumble bees of Taiwan. He reached no definite conclusions, but toward the end of his paper we find the following interesting remark (my translation): "Analysis of the Formosan fauna is made more difficult by the island's complex zoogeographic character. On the one hand, it shows considerable endemism, while on the other hand we find substantial affinity with the Japanese fauna."

Modern treatment of the bumble bees of Taiwan begins with Frison (1934). He presented a real taxonomic revision of the group, including extensive description and good keys. It was his standpoint that a proper revision of the Taiwan fauna required examination of mainland forms as well, so that the scope of his paper went well beyond Taiwan. He also gave considerable attention to microtaxonomy within Taiwan, a topic which I will largely disregard. Frison treated the genus of social bumble bees as *Bremus*, a synonym of *Bombus*, and recognized six species in Taiwan: *B. bicoloratus, B. eximius, B. formosellus* Frison, *B. mearnsi* (Ashmead), *B. sonani* Frison and *B. wilemani*. He seems to have been unaware of Skorikov's paper -- not surprising in the 1930s, as Frison was an American and Skorikov a Russian -- and made no mention of *B. formosanus* or the Taiwan records of *B. diversus and B. flavescens*.

Frison tentatively divided the social bumble bees into two habitat groups, placing *B. bicoloratus, eximius* and *mearnsi* in the medium-altitude group and *B. formosellus, sonani* and *wilemani* in the high-altitude group. However, he cautioned that more material was required for corroboration of this distinction. He also made comparisons between the known bumble bee fauna of Taiwan and those of the Philippines and the Chinese mainland and predicted that when more material became available some putative Taiwan endemics would be shown to conspecific with mainland forms.

Chiu (1948) explicitly regarded her review as a supplement to Frison's (1934) revision. The treatment was less fundamentally revisionary than was Frison's, but Chiu took advantage of access to a greater mass of material; she examined about 500 Taiwan specimens, versus fewer than 60 for Frison. In addition, she took Skorikov's (1933) paper into account. With regards to the latter, Chiu doubted the Taiwan records of *B. diversus* and *B. flavescens* and synonymized *B. formosanus* under *B. wilemani.* Her list of Taiwan species differs from that of Frison in just two points: a) the addition of *B. angustus* Chiu, and b) the genus of social bumble bees treated as *Bombus* rather than *Bremus.* She likewise devoted considerable attention to microtaxonomy and described several new forms.

Chiu (1948) discussed the same two faunistic questions considered by Frison (1934): a) altitudinal separation of species within Taiwan, and b) geographic affinities of the Taiwan fauna. Her Table 1 is an altitudinal frequency distribution of most of the specimens seen, divided into four 1000-m altitude groups. However, there is a puzzling inconsistency in the data as presented, in that all but five specimens are placed in the lowest (below 1000 m) and highest (above 3000 m) groups. In fact, it is indicated in the text that Chiu saw significant numbers of bees from Musha (=Wushe, Nantou, about 1050 m), Arisan (=Alishan, Chiayi, about 2200-2500 m) and Gokan (=Mt. Hohuan, Nantou, somewhat below 3000 m). In addition, her conclusion that the putative endemics (*B. angustus, bicoloratus, formosellus* and *wilemani*) are restricted to high altitudes, while the widespread species (*B. eximius, mearnsi* [=*flavescens*] and possibly *sonani*) are frequent in the lowlands is not corroborated by the data as presented. The table shows no such separation, with the greater part of each well-collected species in the lowlands. Inasmuch as the paper ends with a list of 21 errata on other pages, I suspect the table was scrambled in the editing process.

Chiu (1948) explicitly characterized the bumble bee fauna of Taiwan as "very simple", in contrast to Skorikov's (1933) remark quoted above. Chiu's Table 2 is a listing of bumble bee species known from Taiwan and several other parts of Asia. She confidently concluded that the Taiwan fauna is "mainly derived from the mainland, even as far as the E. Himalayas, and [that] the Japanese, Malaysian and Philippine elements are very weak."

The present paper takes the trend from Frison (1934) to Chiu (1948) yet a step further, by at once narrowing the scope and expanding the data base. This review contributes virtually nothing to revision of the genus, and microtaxonomy is disregarded. On the other hand, I base my results on an eight-fold increase in the number of specimens examined, compared with what Chiu had on hand.

MATERIALS AND METHODS

This study is based on about 4500 specimens (Table 1) in seven institutional and private collections. Collections are listed here, each preceded by the acronym used in the text. Where I borrowed material, the person arranging the loan is identified in brackets.

BMNH	British Museum (Natural History), London
NCAI	National Chiayi Agricultural Institute, Chiayi (Kuo Muh-chwan)
NCHU	National Chunghsing University, Taichung (Yang Jeng-tze)
NMNS	National Museum of Natural Science, Taichung
NTU	National Taiwan University, Taipei (Hsu Tung-ching)

Table 1. Checklist of bumble bee *(Bombus)* species of Taiwan and numbers of specimens examined.

Species	Females	Males	Total
B. angustus Chiu	19	2	21
B. bicoloratus F. Smith	233	17	250
B. eximius F. Smith	447	84	531
B. flavescens F. Smith	870	47	917
B. formosellus (Frison)	548	47	595
B. nr. *hypnorum* (Linnaeus)	3	2	5
B. monozonus Friese	3	8	11
B. sonani (Frison)	723	147	870
B. wilemani Cockereli	1256	99	1355
Total	4102	453	4555

Table 2. Provenance by county of material examined for this study, proportional to land area. Changhua County is taken as the point of reference. For example, there were three times as many specimens from Hsinchu County as from Changhua County, which is 0.77 times as large; the resulting figure of 2.31 times as many specimens per unit area from Hsinchu County is rounded off to 2. The Taipei, Keelung, Taichung, Tainan and Kaohsiung city administrative districts and the smaller islands are not considered here.

County	Relative number of specimens
Tainan	0
Changhua	1
Yunlin	1
Taitung	2
Hsinchu	2
Miaoli	3
Taoyuan	7
Kaohsiung	9
Taichung	15
Taipei	18
Yilan	20
Pintung	20
Hualien	53
Chiayi	115
Nantou	177

TARI	Taiwan Agricultural Research Institute, Wufeng, Taichung (Chou Liangyih)
TPM	Taiwan Provincial Museum, Taipei (An Kwei).

Taiwan place names are romanized according to the simplified form of the Wade-Giles system used in Taiwan. Place names in mainland China follow the Pinyi system. Japanese names of Taiwan localities (on specimens collected during the colonial period, 1896-1945) are interpreted according to Chiu (1948), Chu and Yamanaka (1973-1975) and Price (1982).

Table 2 shows the proportional provenance by county of material from different parts of Taiwan. Taking into account the greater abundance of bumble bees at higher altitudes, these figures suggest that collecting attention has been reasonably evenly distributed, in contrast to the situation with social wasps (Starr, 1992). However, the paucity of material from mountainous Taitung County (see Figure 2) is striking, and future collecting in that area should be especially fruitful.

Figure 2 shows the positions of 13 especially well collected localities. Except for the relatively rare *Bombus angustus* and *B.* nr. *hypnorum*, lack of a collecting record from any of these localities is good evidence that the species does not occur there. This is taken into account in estimating distribution limits.

Distribution ranges outside of Taiwan are taken from an unpublished database compiled by Paul H. Williams.

KEY TO BUMBLE BEES (*BOMBUS* SPP.) OF TAIWAN

Bumble bees and carpenter bees (Anthophoridae: *Xylocopa* spp.; see Appendix A) are the only large, very robust hairy hymenoptera in Taiwan. Unlike bumble bees, carpenter bees have the head broader than long, the malar space (see Figure 4) extremely short, and the abdomen dorsoventrally flattened with little hair above. Most carpenter bees encountered in Taiwan are either all black or have the abdomen all black above and the thorax densely covered in reddish hair, color patterns not found in any of our bumble bees.

In bumble bees females can be distinguished from males by their shorter, 12-segmented antennae (vs. 13 segments in males), the presence of a corbiculum, or pollen basket on the hind tibia (except in the parasitic *B. monozonus*) and the more conical tip of the abdomen, from which the stinger sometimes protrudes.

Unless otherwise noted, color characters refer to the pubescence, Size characterizations are relative to bumble bees only.

I. Females

1. Hind tibia rounded posteriorly, outer surface (corbicular area) densely covered with orange-red hairs, as with fore and mid tibiae. Antennal segment 4 shorter than wide (Figure 4m)······ ······································*monozonus* Friese

Figure 2. Map of Taiwan, showing counties and city administrative district and the positions of 13 fairly thoroughly collected localities. A species not recorded from any one of these localities is presumed not to occur there.

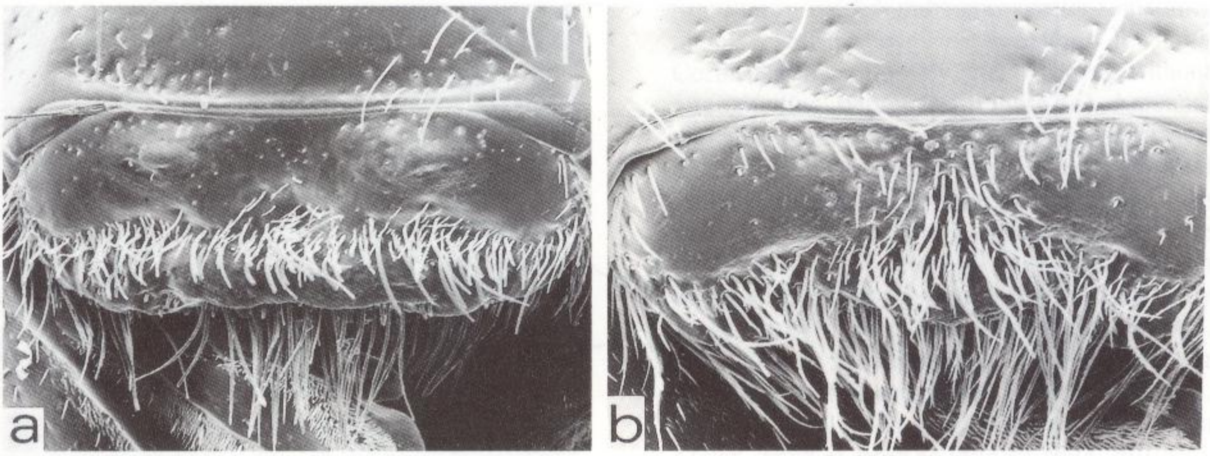

Figure 3. Labrum and lower part of clypeus in female. a. ***Bombus eximius*** b. ***B. flavescens.***

- Hind tibia unlike fore and mid tibiae, with a distinct posterior edge, corbicular area bare and shiny ···································· 2

2. Head and thorax dark brown to black above. Gaster above dark brown to black at base and orange to red apically, or entirely reddish ···· 3

- Without this color pattern. Thorax and gaster above with abundant whitish or yellow hairs. Corbicular hairs black ···························· 8

3. Cuticle of tibiae and tarsi uniformly reddish. Corbicular hairs orangered ······················ 4

- Cuticle of tibiae and tarsi brown. Corbicular hairs black ·· 5

4. Lower margin of labrum more or less straight, without a distinct curved lamella (Figure 3a). Antennal segment 4 longer than wide, usually distinctly so, segment 3 distinctly longer than segment 5 (Figure 4e). Corbicular hairs exceptionally dense (Figure 5a). Workers medium-sized to large, queens very large ······· ···································· *eximius* F. Smith

- Lower part of labrum with a distinct, curved lamella (Figure 3b). Antennal segment 4 as long as wide or slightly longer, segment 3 little longer than segment 5 (Figure 4g). Corbicular hairs less dense (Figure 5b). Medium-sized species ······· ································ *flavescens* F. Smith

5. Malar space distinctly shorter than wide, about as long as antennal segment 3 (Figure 4a). Entirely dark brown to black above, except for last three gastral segments, which are reddish. Medium-sized to large species···*angustus* Chiu

- Malar space at least as long as wide, distinctly longer than antennal segment 3·················6

6. Malar space distinctly longer than wide, about as long as antennal segments 3 + 4 + 5 (figure 4q). Antennal segment 4 shorter than wide. First three gastral terga entirely black, last three or four contrastingly reddish ········ *wilemani* Cockerell

- Malar space about long as wide (Figure 4c, k). Antennal segment 4 at least as long as wide··7

7. Gaster almost entirely reddish above. Antennal segment 4 about as long as wide (Figure 4c)··· ································ *bicoloratus* F. Smith

- Gaster mainly dark brown above, except segments 4-6 mainly yellowish orange. Antennal segment 4 distinctly longer than wide (Figure 4k)········ ························· nr. *hypnorum* (Linnaeus)

8. Thorax above with a wide black band between wings, a whitish band in front and behind this black band. Pubescence of head black. Last four segments of gaster above contrastingly red ····· ································ *formosellus* (Frison)

- Thorax and gaster above and face with dominant yellow pubescence, some black hairs mixed in, but no contrasting patch of reddish hairs ··········· ···································· *sonani* (Frison)

II. Males

1. Hind tibia rounded posteriorly, outer surface densely covered with yellow hairs, as with fore and mid tibiae. Antennal segment 4 about as long as segment 3 (Figure 4n)····· *monozonus* Friese

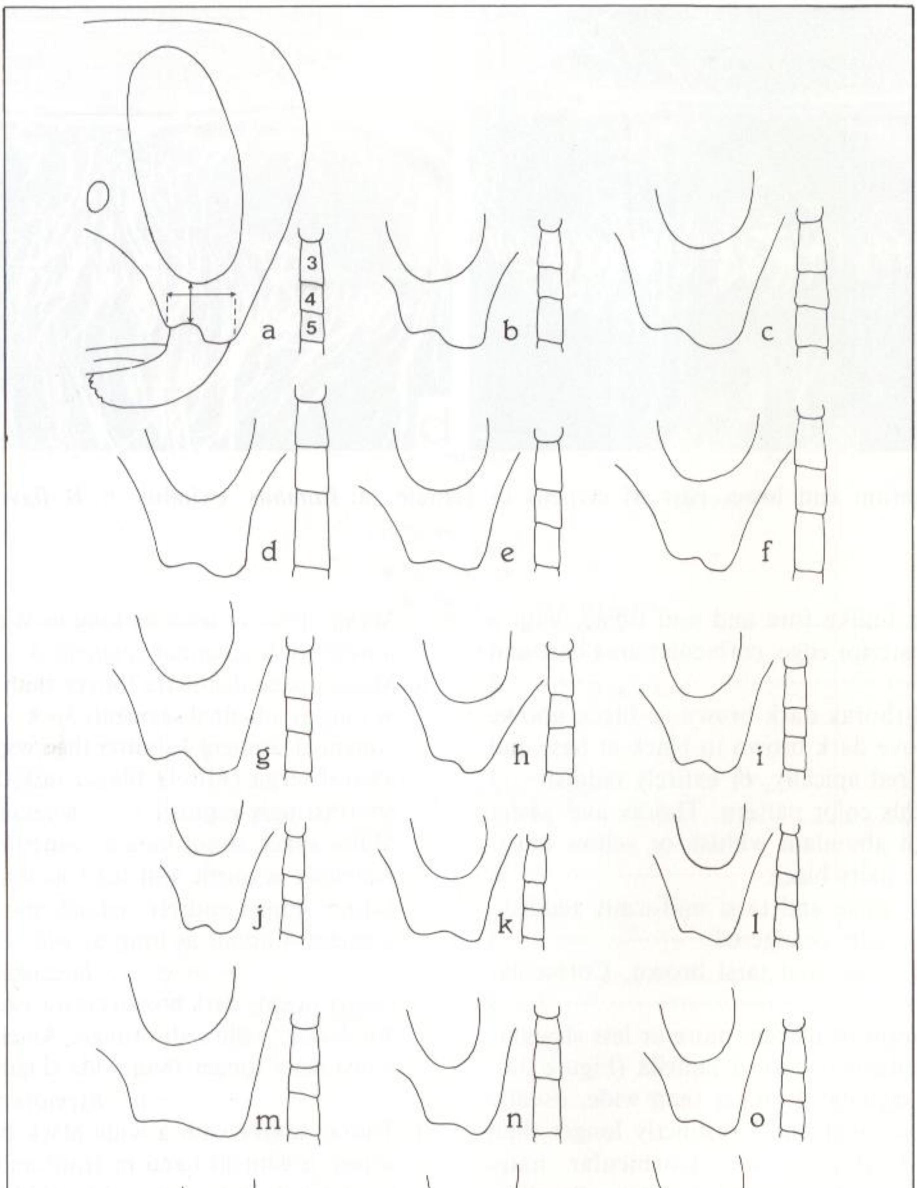

Figure 4. Malar space and basal segments of antennal flagellum. In each pair of drawings, the malar space is illustrated on the left, antennal segments 3-5 in top view on the right. All are to the same scale. Figure 4a gives the orientation of all malar space drawings. a. ***Bombus angustus*** female. b. ***B. angustus*** male. c. ***B. bicoloratus*** female. d. ***B. bicoloratus*** male. e. ***B. eximius*** female. f. ***B. eximius*** male. g. ***B. flavescens*** female. h. ***B. flavescens*** male. i. ***B. formosellus*** female. j. ***B. formosellus*** male. k. ***B.*** nr. ***hypnorum*** female. l. ***B.*** nr. ***hypnorum*** male. m. ***B. monozonus*** female. n. ***B. monozonus*** male. o. ***B. sonani*** female. p. ***B. sonani*** male. q. ***B. wilemani*** female. r. ***B. wilemani*** male.

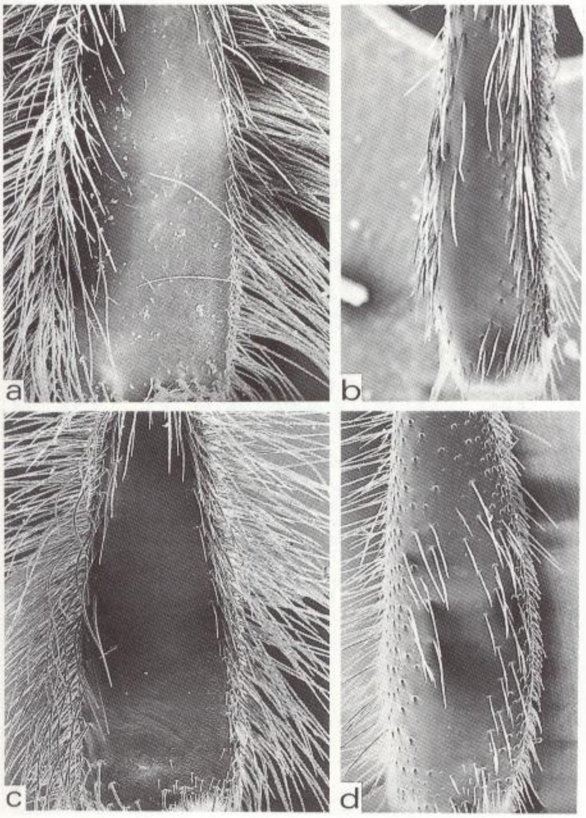

Figure 5. Hind tibia, to show corbicular area. a. ***Bombus eximius*** female. b. ***B. eximius*** male. c. ***B. flavescens*** female. d. ***B. flavescens*** male.

- Hind tibia unlike fore and mid tibiae, with a distinct posterior edge, not rounded, outer surface with a distinct bare area ························· 2

2. Head and thorax dark brown to black above. Gaster above dark brown to black at base and orange to red apically, or entirely reddish ····· 3

- Without this color pattern. Thorax (and often gaster) above with abundant whitish or yellow hairs ·· 7

3. Cuticle of tibiae and tarsi uniformly reddish. Corbicular hairs orange-red ····················· 4

- Cuticle of tibiae and tarsi brown. Corbicular hairs black ··· 5

4. Corbicular area roughened by upraised bases of many hairs, with a longitudinal depression near hind edge (Figure 5c). Antennal segment 3 about as long as segment 4, segment 5 a little longer than either (Figure 4f). Gastral terga with a gradual transition around the middle from anterior black to posterior reddish pubscence; gaster sometimes mainly reddish above ··········· *eximius* F. Smith

- Corbicular area smoothly, evenly convex, without a longitudinal depression (Figure 5d). Antennal segments 3 and 5 about equally long, segment 4 distinctly shorter than either (Figure 4h). Gastral terga with a relatively abrupt transition from anterior black to posterior reddish pubescence ································· *flavescens* F. Smith

5. Malar space distinctly shorter than wide, slightly longer than antennal segment 3 (Figure 4b). Entirely dark brown to black above, except for last three gastral segments, which are reddish. Medium-sized to large species ···· *angustus* Chiu

- Malar space at least as long as wide, distinctly longer than antennal segment 3 ················· 6

6. Malar space almost twice as long as wide (Figure 4r). Antennal segment 4 shorter than wide, distinctly shorter than segment 3. First three gastral terga entirely black, last three or four contrastingly reddish ········· *wilemani* Cockerell

- Malar space about long as wide (Figure 4d). Antennal segment 4 distinctly longer than wide, about as long as segment 3. Gaster almost entirely reddish above ··············· *bicoloratus* F. Smith

7. Thorax above with a wide dark brown to black band between wing bases, a tawny to yellow band in front and behind this dark band. Last four segments of gaster above contrastingly reddish ·· 8

- Thorax and gaster above and face with dominant yellow pubescence, thorax without contrasting dark band between wing bases, last segments of gaster not contrastingly reddish ··················· ···································· *sonani*(Frison)

8. Dark band on thorax only about as broad each pale band in front and behind. Gastral terga 1 and 2 mainly yellow, tergum 3 mainly orange ······· ································· *formosellus* (Frison)

- Dark band on thorax about twice as broad as each pale band in front and behind. Gastral tergum 1 mainly yellowish brown, terga 2 and 3 mainly black ··················· nr. *hypnorum* (Linnaeus)

Bombus (Alpigenobombus) angustus Chiu

Bombus angustus Chiu 1948:59-61

This species is easily recognized by its very short malar space (Figure 4a, b) and 6-toothed mandibles (Figure 6a).

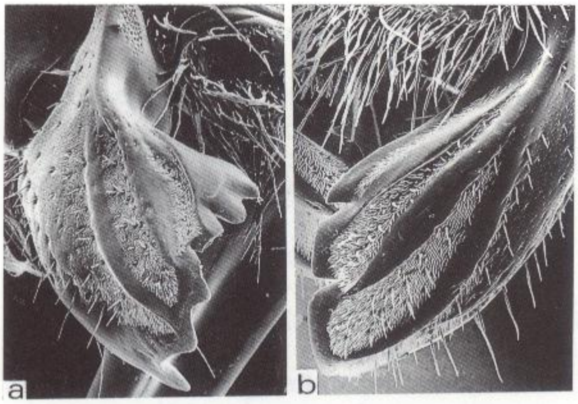

Figure 6. Female mandible. a. ***Bombus angustus*** b. ***B. wilemani.***

Figure 7. Known localities of ***Bombus angustus*** (solid dots) and ***B.*** nr. ***hypnorum*** (stippled dots). Contour lines are at 100, 1000, 2000 and 3000 m.

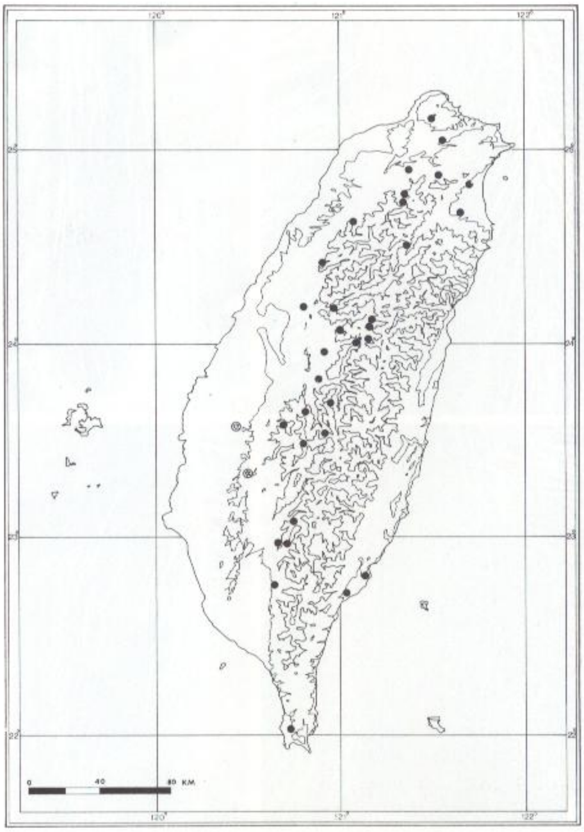

Figure 8. Distribution of ***Bombus bicoloratus.*** Stippled dots represent records from Frison (1934). Contour lines are at 100, 1000, 2000 and 3000 m.

Distribution: Taiwan endemic (Figure 7). The present sparse data suggest that this is mainly a medium-elevation species, present only on the western side of the island.

Bombus (Senexibombus) bicoloratus F. Smith

Bombus bicoloratus Smith 1879:132 -- Cockerell 1911:101 -- Skorikov 1933:61 -- Yasumatsu 1934 (first description of male) -- Chiu 1948:71-73
Bremus bicoloratus (Smith) -- Frison 1934:181-183

The red pubescence covering most or all of the gaster above is usually a quick and accurate way to recognize this species in the field.

Distribution: Taiwan endemic (Figure 8). This seems to be a relatively commmon species with a broad altitudinal range throughout the length of Taiwan.

Figure 9. Distribution of ***Bombus eximius*** in Taiwan. Stippled dots represent records from Frison (1934). Contour lines are at 100, 1000, 2000 and 3000 m. Dashed line delimits estimated range.

Its apparent virtual absence on the eastern side of the Central Mountain Range requires confirmation.

Bombus (Rufipedibombus) eximius F. Smith

Bombus latissimus Friese -- Cockerell 1911:101 -- Friese 1916:109 -- Skorikov 1933:61
Bremus eximius (Smith) -- Frison 1934:152-163
Bombus eximius F. Fm. -- Chiu 1938:63-66

The queens of this species are the largest bumble bees in Taiwan (Figure 1)

Distribution: Malay Peninsula to eastern and central China, west to the Himalaya (P.H. Williams, unpubl.). In Taiwan the species is relatively common, occurring over a broad altitudinal range on the western side of the Central Mountain Range (Figure 9).

Early in the study I or an assistant recorded this species from Orchid Island, evidently without realizing the significance of the record. To my considerable annoyance, I have failed to relocate the specimen(s) and must therefore regard this record with suspicion. If there are in fact bumble bees on Orchid Island it would be interesting to know their identity, on account of the posited Taiwan route for the immigration of bumble bees in the Philippines (Starr, 1989).

Bombus (Pyrobombus) flavescens F. Smith

Pratobombus flavescens (Smith) -- Skorikov 1933:60
Bremus mearnsi (Ashmead) -- Frison 1934:167-175
Bombus mearnsi Ashmead -- Chiu 1948:67-70

Similar to *B. eximius* in overall form and color, but usually easily distinguishable by the key characters.

Distribution: Malay Peninsula to the Philippines and eastern China, west to the Himalaya (P.H. Williams, unpubl.). Broadly distributed in Taiwan on both sides of the island (Figure 10).

Bombus (Melanobombus) formosellus (Frison)

Bremus formosellus Frison 1934:163-167
Bombus formosellus (Frison) -- Chiu 1948:61-62

The distinctive color pattern of this species makes both sexes very easy to recognize (Figure 1). Williams (1991) provisionally treats this as a local form of *B. pyrosoma* Morawitz.

Distribution: Taiwan endemic. It is found on both sides of the Central Mountain Range but is unknown from almost the southern half of the island (Figure 11). Distribution of *B. pyrosoma:* Eastern and central China west to the Himalaya (Williams, 1991: Map 59).

Bombus (Pyrobombus) nr. ***hypnorum*** (Linnaeus)

? *Bombus* sp. non descripta -- Chiu 1948:71

This form clearly does not match any species heretofore recorded from Taiwan. The females show the black-and-red color pattern common to the majority of Taiwan bumble bees. Three females are known to me, labeled with the following locality information: a) "C. TAIWAN: Tsuifeng 2300m, Nantou Hsien, 23-25.VI.1983, K.S. Lin & S.C. Lin" (TARI), b) same as a (BMNH), and c) "C.

Figure 10. Distribution of **Bombus flavescens** in Taiwan. Contour lines are at 100, 1000, 2000 and 3000 m.

Figure 11. Distribution of **Bombus formosellus.** Stippled dots represent records from Frison (1934). Contour lines are at 100, 1000, 2000 and 3000 m. Dashed line delimits estimated range.

TAIWAN: Tayuling 2560m, Hualien Hsien, 9-16.VI.1980, K.S. Lin & B.H. Chen" (TARI). All are presumably workers.

The males are less obviously distinctive. I in fact failed to recognize them until P.H. Williams pointed out that two specimens which I had hastily identified as *B. formosellus* must in fact be conspecific with females of the present form. These two males (TARI, BMNH) bear the same locality information as female c above. It is possible that among TARI specimens from Nantou county are additional males of this species misidentified as *B. formosellus*.

Chiu (1948) designated as *Bombus* sp. non descripta a single worker in TARI. She placed the specimen in the subgenus *Agrobombus (= Thoracobombus)* and gave the label information only as "Horisha (Acces. No. 3182)". I have not found the specimen, but if Chiu mistook the subgenus, then it may well be the same as the present species. Horisha is the Japanese name for the large town of Puli in Nantou county. It is at a much lower elevation than Tsuifeng and Tayuling, but on a presumably old specimen the locality "Horisha" really only tells us that the specimen came from somewhere in the Puli area.

The present form is very similar to *B. hypnorum*, and there is at present no evidence it is a distinct species (P.H. Williams, pers. comm.). If it is not, it represents a significant range extension and a novel color pattern for *B. hypnorum*. Given the very little material available, it seems best to leave its specific status undecided. The following descriptions, based on examination of three females and one male, are intended as an aid to future investigation of its taxonomic status.

Description of female: Forewing length 9-11 mm. Labral tubercles low, rounded, furrow shallow, lamella short and relatively strongly curved. Central area of clypeus sparsely, punctured, sides densely, punctured. Malar space about 80% as long as broad, about as long as antennal segments 2 + 3 (Figure 4k). Lengths of antennal segments 3, 4 and 5 in ratio of 1.4:1:1.1 (Figure 4k); segment 3 a little less than twice as long as apical width; segment 4 distinctly longer than broad. Ocellar-ocular area with a band of large punctures but very few small punctures. Dorsal furrow of gena faintly present. Ocelli separated by 2.5 diameters from eye, hind edges slightly behind postocular line. Mid basitarsus with posterior apical angle variable, from rounded to approximately forming a right angle, without a spurlike process. Surface of pollen basket bare, smooth, hairs not especially dense. Hind basitarsus apically symmetrical; fore and hind margins with the same low, even curve. Surface of gastral tergum 6 granular, with no macro sculpturing. Cuticle of legs red-brown to dark brown. Pollen basket hairs brownish black. Pubescence long; dark brown over most of the body, with much admixture of tawny hairs; yellow-orange on gastral terga 4-6.

Description of male: Forewing length 12-13 mm. Malar space as long as broad, a little shorter than antennal segments 2 + 3 (Figure 4l). Antennal segments 3 and 5 about equally long, distinctly longer than segment 4 (Figure 4l); segment 3 a little less than twice as long as apical width; segment 4 distinctly longer than broad. Ocelli separated by 2.5 diameters from eye, hind edges slightly behind postocular line. Mid basitarsus with posterior apical angle obtuse, without a spurlike process. Surface of corbicular area smooth, with sparse hairs throughout. Hind basitarsus apically symmetrical; fore and hind margins with the same low, even curve. Cuticle of legs redbrown. Hairs of corbicular area reddish orange. Pubescence long; mainly tawny on head, with interspersed longer, chocolate brown hairs; mainly tawny on thorax, except for a broad brownish black between the wing bases; black on gastral terga 1-3, orange on remaining terga.

Distribution: *B. hypnorum* is known from across the northern Palearctic and from scattered localities in the Himalaya and central China (Williams, 1991: Map 33, 34). The present form is known in Taiwan only from Nantou county (Figure 7).

Figure 12. Known localities of ***Bombus monozonus.*** Stippled dot respresents a record from Frison (1934). Contour lines are at 100, 1000, 2000 and 3000 m.

Bombus (Psithyrus) monozonus Friese

Psithyrus monozonus Friese 1931, Konowia 10:304 (Cited from Frison, 1934) -- Frison 1934:183-185 -- Maa 1948:23-26 -- Chiu 1948:75-76

This superficially resembles the other red-rumped species but is readily distinguished by the hairy outer surface and rounded hind edge of the hind tibiae with. P.H. Williams (pers. comm.) provisionally regards it as a local form of *B. turneri* Richards.

Distribution Taiwan endemic (Figure 12). The range of this species is compatible with that of several *Bombus* spp. and thus gives little clue to its likely host(s). Distribution of *B. turneri:* China to the Himalaya (P.H. Williams, unpubl.).

Figure 13. Distribution of ***Bombus sonani.*** Contour lines are at 100, 1000, 2000 and 3000 m.

Bombus (Pyrobombus) sonani (Frison)

Bremus sonani Frison 1934:175-178
Bombus sonani (Frison) -- Chiu 1948:70-71

Like *B. formosellus,* this species is readily recognized on the basis of color (Figure 1). The workers are the smallest bumble bees in Taiwan, sometimes little larger than the native honey bee, *Apis cerana*. Williams (1991) suggests that *B. sonani* is a local form of *B. parthenius* Richards.

Distribution: Taiwan endemic, widely distributed within the island (Figure 13). Distribution of *B. parthenius:* Mountains of central China, Himalaya (P.H. Williams, unpubl.). The two appear to form a clade (whether of one species or two) with a disjunct Himalayan-Taiwan distribution.

Bombus (Diversobombus) wilemani Cockerell

Bombus wilemani Cockerell 1911:100-101 -- Skorikov 1933:61-62 -- Chiu 1948:73-75
Diversobombus formosanus Skorikov 1933:59
Bremus wilemani (Cockerell) -- Frison 1934:178-181

Figure 14. Distribution of ***Bombus wilemani.*** Contour lines are at 100, 1000, 2000 and 3000 m.

In my experience, this is the commonest bumble bee in Taiwan. Any redrumped bee with blackish legs encountered anywhere in the island is likely to be this species. It is readily recognizable by the long malar space (Figure 4q, r). Williams (1991) *B. wilemani* provisionally treats it as a local form of the widespread *B. trifasciatus* F. Smith. However, the color pattern in *B. wilemani* is strikingly different from that of *B. trifasciatus* in mainland areas adjacent to Taiwan, an abrupt transition that does not appear elsewhere in the range of the *B. trifasciatus* group (Williams, 1991: Figure 11).

Distribution: Taiwan endemic, widely distributed on both sides of the island (Figure 14). Distribution of *B. trifasciatus* (s.lat.): Eastern Asia from the Malay

Peninsula to eastern China (Jiangsu, Anhui), central China, the Himalaya (Williams, 1991: Figure 11, Map 23).

One striking feature of museum specimens of this species is the appearance of deutonymphs of an unidentified uropodid mite (M. Delfinado-Baker, pers. comm.) clustered in the pollen baskets of some individuals. The mites are evidently phoretic, utilizing the bees as a ready means of transport into new habitat (Houck and OConnor, 1991), and they presumably spend their lives mainly in bumble bee nests as scavengers or/and kleptoparasites (Eickwort, 1990). As seen in Table 3, this phenomenon is frequent in queens collected outside the nest, while it occurs only occasionally in males and apparently never in workers. A few males in the sample had many mites on other parts of the body but none in the corbicular area. Among other Taiwan bumble bees, I have noticed apparently similar mites only in pollen baskets of a single *B. eximius* queen. A similar mite has very recently been found in pollen baskets of workers in swarms of the honey bee *Apis mellifera* (Rubink et al., 1991).

Table 3. Incidence of mites on the hindlegs in different phena of *Bombus wilemani*. The named localities are all in Nantou county, as are the majority of unnamed localities. All specimens sampled are in TARI, collected with Malaise traps or net by K.S. Lin and co-workers during the 1980s. Fractions are proportions of bees with mites. Whole number below them are mean numbers of mites on each left hindleg in the sample.

Locality	Queens	Workers	Males
Tsuifeng	4/5	0/320	1/27
	24.6	0	0.3
Sungkang	4/5	0/23	2/31
	8.6	0	0.3
Meifeng	2/2	0/58	1/6
	34.5	0	1.8
Tungpu		0/16	1/9
		0	0.1
other localities	0/2	0/83	
	0	0	
Total	10/14	0/500	5/75
	16.8	0	0.4

The data in Table 3 are consistent with the hypothesis that phoresy on *B. wilemani* functions to move the mites into nests at the start of the colony cycle. By seeking the smooth, relatively flat surface of a pollen basket, a mite is assured of attachment to a female. The mite presumably remains undisturbed until the bee begins pollen foraging, and is then scraped off into the nest with one of the first pollen loads. If the carrying bee is a worker, the mite will simply have landed back in the old nest and would have to try again. If, on the other hand, the bee is a young queen, the mite might remain in place until deposited in a newly initiated nest. This hypothetical scenario accounts for the high incidence of mites on founding-stage queens, their small incidence on males, and their absence on workers old enough to have been collected outside the nest. It predicts that they will be abundant on young (pre-foraging) workers but may be scarce or absent on mother queens.

EXCLUDED SPECIES

1. *Bombus (Diversobombus) diversus*

Skorikov (1933) recorded this species from several localities in Japan and from "Ko-tan-kgan", Taiwan, without further comment. I have been unable to identify the Taiwan record and doubt that it is based on material seen by Skorikov himself.

2. *Bombus (Pyrobombus) festivus* F. Smith

Wang (1988) includes Taiwan in the range of this species, without further comment. No reference is given in support of this record, and I know of none. The color pattern of *B. festivus* (P. H. Williams, pers. comm.) does not approach that of any Taiwan specimens I have seen.

DISCUSSION

The eight known *Bombus* species in Taiwan represent six of the 12 subgenera found in East Asia (Richards, 1968). Regardless of whether the various putative Taiwan endemics continue to be regarded as such, the Taiwan fauna is thus taxonomically diverse and of composite origin.

I have elsewhere (Starr, 1992) draw three conclusions regarding the general pattern of social wasp species distributions within Taiwan:

1. The evidence does not favor a key role for historical factors. The Central Mountain Range and its radiating watersheds seem to have little to do with why a given species is at one locality but not at another.
2. Among ecological factors, there is little indication of latitudinal effects.
3. Altitudinal effects seem to be of primary importance. The data are consistent with the idea that most species occupy particular altitudinal zones around the entire island.

The different bumble bee species, in contrast, seem less unitary in this respect. Leaving aside the parasitic *B. monozonus* (which cannot disperse independently of its hosts) and the poorly known *Bombus* nr. *hypnorum,* they seem to show three different distribution patterns:

1. Present on both sides of the Central Mountain Range from north to south: *B. bicoloratus, B. flavescens, B. sonani* and *B. wilemani.*
2. Present on both sides of the range but absent from almost the southern half of the island: *B. formosellus.*
3. Present on the western side of the range only, from north to south: *B. angustus* and *B. eximius.*

Within this variety of patterns, it is hard to discern strong altitudinal effects. It is not surprising that such predominantly cool-temperate insects should have little presence in the lowlands of Taiwan, but this may be due less to climate or original vegetation than to recent habitat alteration by humans. In addition, all bumble bees are strong fliers, and in mountain areas they may forage over a substantial range in elevation. Nesting habitat is probably more species-characteristic than foraging habitat, yet most specimens in collections were evidently taken foraging. In fact, I am not aware of having seen a single nest series from Taiwan.

I suggest that progress in understanding the causes of species distributions in bumble bees will come from careful altitudinal transects. If artificial nest-boxes can be integrated into the effort, so that samples are based on colonies as well as foragers, they will yield additional valuable information about nesting biology.

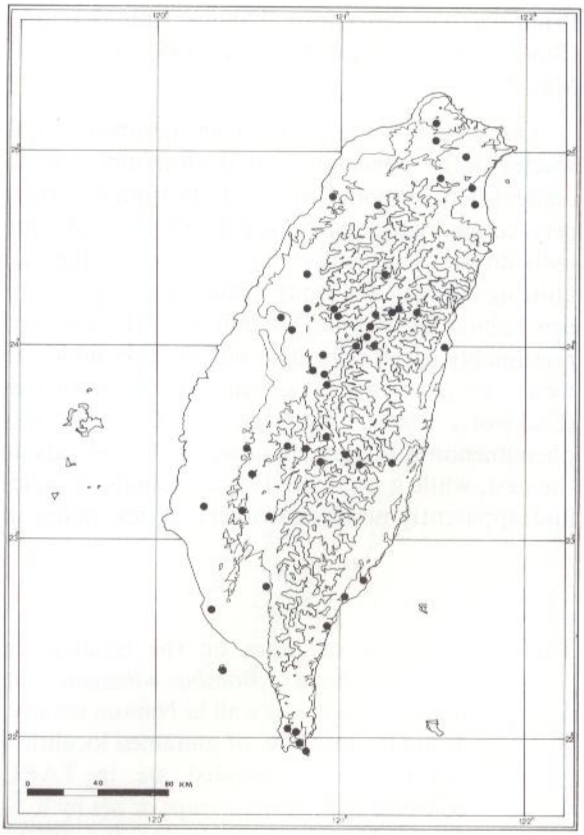

Figure 15. Distribution of ***Apis cerana*** in Taiwan. Based on review of about 1200 workers. Contour lines are at 100, 1000, 2000 and 3000 m.

The ecological relations between bumble bees and other corbiculate bees in Taiwan have yet to be investigated. Michener (1979) has suggested the presence of honey bees as a major factor in depressing the diversity of other bees in east Asia. He sees honey bees as such efficient, voracious foragers that they take a large share of the pollen and nectar that would otherwise support a great many less abundant species. Yet the rapid invasion of much of South America by African honey bees, *Apis mellifera,* seems to have surprisingly little effect on native stingless bees (Roubik, 1991). Taiwan's native honey bee, *Apis cerana,* is abundant at low and medium elevations throughout the island (Figure 15), yet I see no indication that it competitively displaces bumble bees. The latter are taxonomically diverse, and some species are abundant and broadly sympatric with honey bees.

Figure 16. Known localities of ***Trigona ventralis*** in Taiwan. Stippled dot represents a record from Sakagami & Yamane (1987). Contour lines are at 100, 1000, 2000 and 3000 m.

On the other hand, the distributional data seem consistent with the hypothesis that the presence of honey bees depresses the stingless bee fauna in Taiwan. This primarily tropical group is represented here only by *Trigona ventralis,* known from a very few localities (Figure 16) and apparently not common anywhere. I myself have not seen even a single forager in the field in Taiwan. One might suppose that stingless bees are scarce simply because the group is at the northern limit of its range here, except that *T. ventralis* is only known from medium- to high-elevation localities, never in the warmer lowlands. In other words, it appears to occur only where honey bees are less abundant.

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APPENDIX

KEY TO *XYLOCOPA* (HYMENOPTERA: ANTHOPHORIDAE) OF TAIWAN

The large carpenter bees of Taiwan are easily distinguished and taxonomically well worked out (Maa, 1939-1940, 1946; Sonan, 1932; Yu , 1954), but no key has been available based on up-to-date nomenclature. The following key is intended to fill this need. *X. dejeanii* is the *X. collaris* Lepeletier

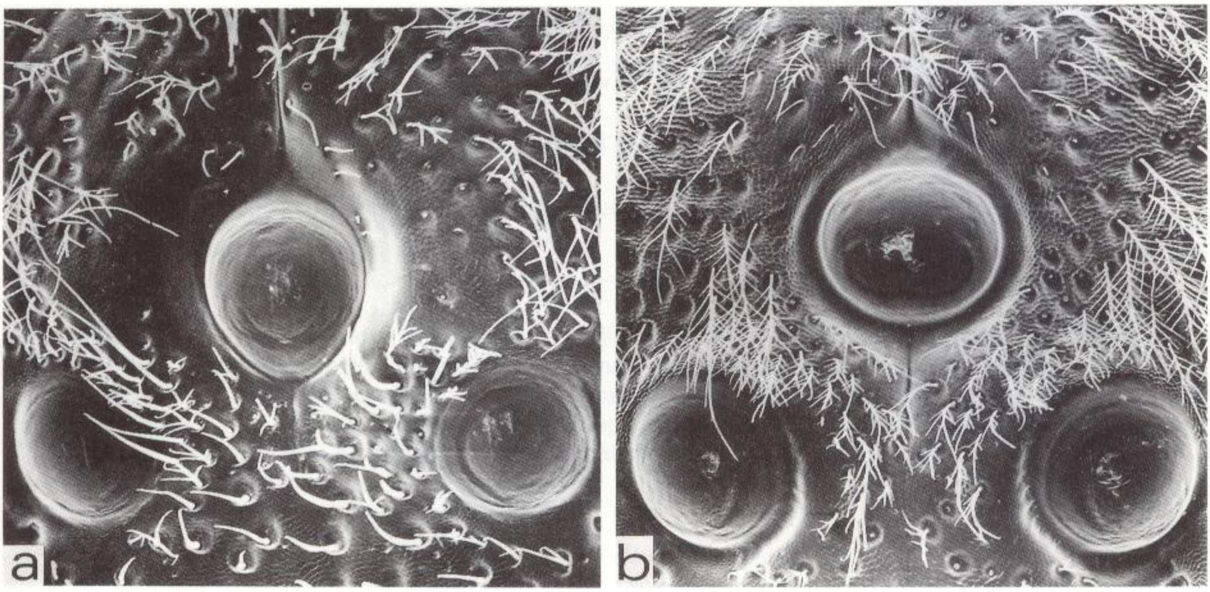

Figure 17. Ocellar area in ***Xylocopa tranquebarorum*** (a) and ***X. dejeanii*** (b).

of earlier authors (R.W. Brooks, pers, comm.). In all Taiwan species the sexes are readily distinguished by the color of the face: mainly yellow in males, all black in females.

1\. Gaster with many red hairs above ·············· 2

– Gaster entirely black above or with black and yellowish hairs ······································ 3

2\. Red hairs of gaster restricted to first segment. Thorax and tibiae abundantly clothed in red hairs ·· *ruficeps* Friese

– Tip of gaster clothed in red hairs (so that the overall color pattern mimics that of several bumble bees). Hairs of thorax, tibiae and base of gaster dark brown to black ·· *bomboides* Smith

3\. Anterior ocellus bordered on each side by a distinct smooth, raised area (Figure 17a), which is yellow in males···*tranquebarorum* Swederus

– Area on each side of anterior ocellus punctured, not distinctly raised (Figure 17b), black in both sexes ······························ *dejeanii* Lepeletier

台灣的熊蜂（膜翅目：蜜蜂科）

石達愷

摘　要

本文綜述及檢索台灣的8種社會性及1種社會寄生性熊蜂，並標出其在台灣的分布範圍。文中嘗試探討中國蜂*Apis cerana*及無螫蜂*Trigona ventralis*爲其他社會性蜜蜂競爭取代之現象及推測其在台灣的分布範圍。文末也附記一些在*Bombus wilemani*的蜂后、工蜂及雄蜂身上發現的寄生蟎類，及台灣大型花蜂（花蜂科：木蜂屬）的檢索表。

關鍵詞：*Bombus*，蜜蜂科，臺灣。