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Original article

A morphological comparison of the cavity dwelling honeybees of Borneo *Apis koschevnikovi* (Buttel-Reepen, 1906)* and *Apis cerana* (Fabricius, 1793)

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Summary — Complete morphological descriptions using measurements common to honeybee taxonomy are provided for *Apis koschevnikovi* (Buttel-Reepen 1906) and *Apis cerana* (Fabricius 1793) from North East Borneo. Overall, *A. koschevnikovi* is larger than the sympatric *A. cerana*. *A. koschevnikovi* has a morphology which is very different from all other well-described forms of honey bees.

***Apis koschevnikovi* — *Apis cerana* — morphometrics**

* Two earlier reports on this bee, Tingek *et al.* (1988) and Koeniger *et al.* (1988), used the name *A. vechti* (Maa, 1953). Ruttner *et al.* (1989) reports Buttel-Reepen first named the species in 1906 as *Apis koschevnikovi*. Examinations of museum specimens confirm that *A. vechti* is a later synonym for *A. koschevnikovi*.

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INTRODUCTION

The cavity-nesting Saban honeybee, *Apis koschevnikovi* (Buttel-Reepen, 1906) has recently been re-evaluated and recognized as a valid biological species based on morphological evidence of a unique endophallus (Tingek *et al.*, 1988) and behavioral evidence that *A. koschevnikovi* drones have a different mating flight time from that of sympatric *A. cerana* drones (Koeniger *et al.*, 1988). In addition, 2 other characters were described as species specific. First, *A. koschevnikovi* drones have a secondary sex characteristic of a hairy fringe on the margin of the tibia of the hind leg. Secondly, worker bee forewing venation shows a cubital index which is both quite large and quite varied (Tingek *et al.*, 1988).

Recent descriptions of *A. koschevnikovi* (Tingek *et al.*, 1988; Koeniger *et al.*, 1988) and the description of Buttel-Reepen (1906) focus on characteristics which support the recognition of *A. koschevnikovi* as a species. In addition, some behavioral traits have been reported by Mathew & Mathew (1988). However, all these reports are incomplete descriptions because they do not describe the morphological measures which are commonly used in modern honeybee taxonomy (Ruttner, 1988). This paper provides these morphometric details for *A. koschevnikovi*. In addition, a description is provided of *A. cerana*, the Eastern honeybee, which is sympatric with *A. koschevnikovi* in northern Borneo. This form of *A. cerana* is among the smallest of that species size range.

MATERIALS AND METHODS

Colonies of cavity-nesting bees in northern Borneo were sampled; worker bees were taken from 9 colonies of *A. koschevnikovi* and 4 colonies of *A. cerana*. Ten workers from each colony were dissected and 36 morphometric measurements were made. These measurements and their alphabetical designations given in Table I follow the system of morphometric analysis described by Ruttner *et al.* (1978) and Ruttner (1988). Numerical designations for wing venation angles are presented in Fig. 1 and Table I and are a combination of the angles studied by Ruttner *et al.* (1978) and Daly & Balling (1978). For the most part, numbers represent lengths or widths of various structures and are reported in mm. Interior angles of vein intersections in wing venation patterns are reported in degrees. Pigmentation characteristics of the second, third and fourth tergites are scored according to the procedures of Ruttner *et al.* (1978) and Ruttner (1988). Scores represent the proportion of comparatively light areas to the total area of the tergite. For *A. koschevnikovi*, the comparatively dark areas are rufus; for the sympatric *A. cerana* of Borneo, the comparatively dark areas are black. Figure 2A shows characteristic patterns for all 3 tergites for bees of both species. Figure 2B identifies the scutellum (Sc) and the surrounding metatergal (R) and mesotergal (K) sclerites. Scores for the color intensity of Sc range from 0 to 9, with 0 being completely black (*A. cerana*) or red (*A. koschevnikovi*). A scale ranging from 0 to 5 was used for B and K; completely black (*A. cerana*) or red (*A. koschevnikovi*) being equal to 0, and completely yellow being equal to 5.

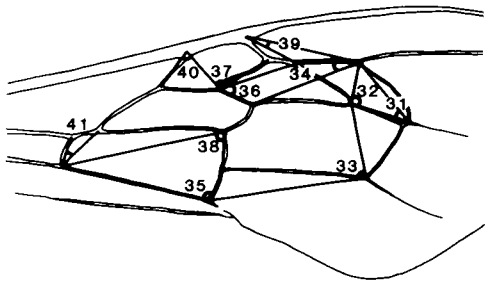

Fig. 1. Wing venation measured for *A. koschevnikovi* and *A. cerana*. The eleven angles are indicated on a representation of the wing of *A. koschevnikovi* and follow a unique numbering system combining the measures of Ruttner *et al.* (1978) and Daly and Balling (1978).

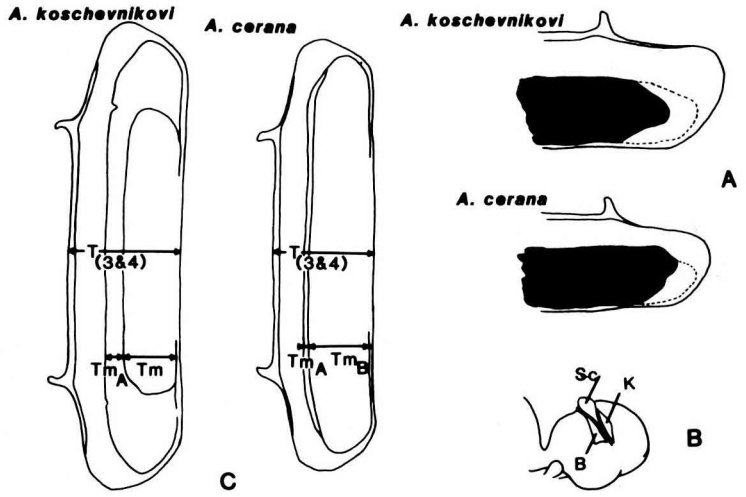

Fig. 2. A. Pigmentation on tergites 2, 3 and 4 follow the scheme of Ruttner *et al.* (1978), although neither species follows the exact patterns indicated for *A. mellifera.* **B.** Coloration scale used for the scutellum (Sc) metatergum (B) and mesotergum (K) follows that of Ruttner *et al.* (1978) as does the illustration. **C.** Linear measurement of tergites from *A. koschevnikovi* and *A. cerana.* The measurement T is made for tergites 3 and 4. The measurements Tm_A and Tm_B are from tergite 4. Tm_A is a distance on that portion of the tergites which is lightest and Tm_B is a distance on that portion of the tergite which is darkest.

After measurements were made on individual bees, colony averages for each characteristic were calculated. These averages were used to calculate means, variances and ranges for each measurement within each species. The colony averages were also used to calculate *t*-test evaluations of differences between the 2 species for each characteristic.

RESULTS

Apis koschevnikovi is larger than the sympatric *A. cerana.* Linear measurements of wings, legs and sclerites of *A. koschevnikovi* are consistently 10 to 15% larger than similar measurements of sympatric *A. cerana.* Of the linear measurements, 15 or 17 are larger for *A. koschevnikovi* (Table I). The width of the sternum (St) (W_D in Ruttner, 1988) of the third sternite is larger for the *A. cerana* we measured. This may be a general characteristic of smaller bees since Africanized *A. mellifera* which are smaller than European *A. mellifera*, also have a wider sternum as part of the third sternite.

The overall longitudinal length of *A. koschevnikovi* tergites is larger; however, the tomentum measures are such that a larger proportion of the tergites are covered by the darker tomentum (Tm_β) in *A. cerana.* In *A. koschevnikovi* the proportion of the tergites covered by Tm_β is much smaller (Fig. 2C). This trend is apparent in the tomentum patterns of the second, third and fourth tergites. These patterns contribute

Table I. Descriptive statistics and t-tests for equality of means of 36 morphometric characteristics of 10 bees each from 9 colonies of *Apis koschevnikovi* and 10 bees each for 4 colonies of *Apis cerana* from northern Borneo.

Character	*Apis koschevnikovi*					*Apis cerana*						
	X	*S. D.*	*Variance*	*Range*		*X*	*S. D.*	*Variance*	*Range*		*T*	*P*
Proboscis	5.34	0.11	0.01	5.15	5.45	4.06	0.02	0.00	4.04	4.08	22.60	0.0001
Femur (F)	2.38	0.04	0.00	2.32	2.46	2.13	0.02	0.00	2.09	2.14	10.85	0.0001
Tibia (T)	3.09	0.03	0.00	3.03	3.14	2.69	0.04	0.00	2.64	2.73	19.25	0.0001
Metatarsus length (M_L)	2.00	0.02	0.00	1.97	2.04	1.68	0.02	0.00	1.66	1.69	26.48	0.0001
Metatarsus width (M_w)	1.08	0.02	0.00	1.04	1.10	0.93	0.01	0.00	0.92	0.94	14.08	0.0001
Tergite 3 length (T_3)	2.00	0.04	0.00	1.92	2.07	1.71	0.02	0.00	1.69	1.73	12.57	0.0001
Tergite 4 length (T_4)	1.92	0.04	0.00	1.86	1.99	1.66	0.01	0.00	1.66	1.67	19.01	0.0001
Sternite 3 length (SL_3)	2.63	0.05	0.00	2.52	2.70	2.11	0.03	0.00	2.07	2.14	19.03	0.0001
Wax mirror length (W_L)	1.08	0.02	0.00	1.04	1.10	0.84	0.02	0.00	0.82	0.87	19.10	0.0001
Wax mirror width (W_w)	2.08	0.02	0.00	2.05	2.12	1.79	0.02	0.00	1.77	1.81	23.62	0.0001
Sternum (St)	0.29	0.03	0.00	0.25	0.33	0.33	0.02	0.00	0.31	0.36	2.34	0.04
Sternite 6 length (SL_6)	2.23	0.04	0.00	2.16	2.28	1.96	0.03	0.00	1.92	2.00	11.85	0.0001
Sternite 6 Width (SW_6)	2.57	0.05	0.00	2.51	2.65	2.44	0.02	0.00	2.42	2.46	5.09	0.0003
Forewing Length (F_l)	8.70	0.11	0.01	8.54	8.88	7.64	0.03	0.00	7.60	7.68	18.21	0.0001
Hamuli number	17.70	0.60	0.06	16.00	19.00	17.20	1.04	0.49	16.00	19.00	1.24	0.243
Forewing width (F_w)	3.02	0.06	0.00	2.90	3.08	2.67	0.04	0.00	2.61	2.70	10.66	0.0001
Cubital A (a)	0.57	0.03	0.00	0.53	0.63	0.47	0.02	0.00	0.46	0.49	6.11	0.0001

Cubital B (b)	0.09	0.01	0.00	0.07	0.11	0.13	0.02	0.00	0.12	0.15	5.25	0.0003
Cubital index A/B	7.23	1.27	1.62	5.65	9.54	3.67	0.46	0.21	3.08	4.21	5.34	0.0002
Angle 31	31.64	1.32	1.74	29.91	34.52	31.99	0.73	0.54	31.24	32.89	0.49	0.63
Angle 32	106.42	3.22	10.37	102.41	110.55	106.93	1.98	3.91	104.13	108.76	0.29	0.77
Angle 33	91.06	1.59	2.54	88.11	92.66	96.19	1.42	2.02	94.37	97.51	5.51	0.0002
Angle 34	20.85	0.49	0.24	20.13	21.65	20.09	0.87	0.76	19.17	21.26	2.06	0.06
Angle 35	93.85	2.85	8.11	89.40	98.45	89.72	2.39	5.70	86.64	92.37	2.52	0.03
Angle 36	44.21	0.99	0.99	42.63	45.59	48.76	1.79	3.21	46.18	50.15	5.99	0.0001
Angle 37	100.38	21.82	476.19	42.31	110.20	105.33	0.84	0.70	104.19	106.22	0.44	0.67
Angle 38	75.99	1.00	1.01	73.90	77.65	74.94	1.38	1.91	73.15	76.41	1.55	0.15
Angle 39	15.70	0.98	0.97	14.36	17.00	14.78	0.61	0.37	14.28	15.55	1.71	0.11
Angle 40	85.10	2.23	4.98	82.25	88.30	82.49	1.15	1.32	81.09	83.75	2.18	0.05
Angle 41	31.19	1.52	2.30	29.20	33.40	33.79	1.82	3.30	31.75	35.90	2.70	0.02
Tomentum A (Tm_A)	0.39	0.13	0.02	0.21	0.61	0.11	0.02	0.00	0.10	0.13	6.45	0.0002
Tomentum B (Tm_B)	0.85	0.09	0.01	0.72	0.98	0.96	0.02	0.00	0.95	0.98	3.54	0.006
Pigmentation Tergite 2	6.64	1.14	1.31	4.00	7.90	6.15	1.45	2.09	4.00	7.00	0.65	0.52
Pigmentation Tergite 3	6.51	1.01	1.01	4.00	7.30	6.30	1.54	2.36	4.00	7.20	0.29	0.78
Pigmentation Tergite 4	6.45	0.99	0.98	4.00	7.10	6.28	1.52	2.30	4.00	7.10	0.25	0.81
Scutellum (Sc)	8.59	0.56	0.31	7.50	9.00	6.75	0.87	0.76	5.80	7.90	4.65	0.0007
B	4.41	0.50	0.25	3.60	5.00	2.85	0.51	0.26	2.10	3.20	5.21	0.0003
K	4.41	0.50	0.25	3.60	5.00	2.72	0.52	0.27	2.10	3.20	5.59	0.0002

to the general impression of *A. koschevnikovi* of being a lightly colored rufus bee, while the sympatric *A. cerana* is intensely black.

The wing vein section, identified as cubital b, is generally longer in *A. cerana*. This, in combination with the opposite in measurements of the cubital a vein, leads to a much larger cubital index for *A. koschevnikovi*. This is the most exceptional of several differences in wing variation. Of the 11 venation angles, 5 of them are significantly different between the species (Table I; $P \leq 0.05$).

DISCUSSION

Overall, *A. koschevnikovi* has a very different morphology from the sympatric *A. cerana* and from all other well-described forms of honeybees. None of the differences presented here suggest additional species-specific characteristics for *A. koschevnikovi*. However, the entire constellation of measurements provides a picture of a remarkably different honeybee, unique in its morphological organization.

Much remains to be learnt about *A. koschevnikovi*. Its range and population size are among the most important of issues that require study. Answers to these questions will provide a better appreciation of the evolutionary origins of this species.

Résumé — Comparaison morphologique des abeilles de Bornéo qui nidifient dans les cavités : *Apis koschevnikovi* (Buttel-Reepen, 1906) et *Apis cerana* (Fabricius, 1793). Une description morphologique complète, utilisant les caractères habituels de la taxonomie de l'abeille, est donnée pour *Apis koschevnikovi* (Buttel-Reepen, 1906) et *A. cerana* (Fabricius, 1793) du nord-est de Bornéo. Dans l'ensemble *A. koschevnikovi* est plus grande que l'espèce *A. cerana* qui lui est sympatrique. Les mesures linéaires des ailes, des pattes et des sclérites d'*A. koschevnikovi* sont supérieures de 10 à 15% à celles de *A. cerana* (Tableau I).

Les diamètres longitudinaux des sclérites sont en général plus grands chez *A. koschevnikovi*. Les bandes tomenteuses laissent libre chez *A. cerana* une bande plus large du tergite sombre. La pilosité donne l'impression générale d'être plus claire et plus rougeâtre chez *A. koschevnikovi*, plus intensément noire chez l'abeille sympatrique *A. cerana*.

Pour la vénation alaire la différence la plus marquante est l'index cubital beaucoup plus élevé chez *A. koschevnikovi* (7,23) que chez *A. cerana* (3,67) (Tableau I). Sur les 11 angles intérieurs des intersections des veines, 5 sont significativement différents entre les deux espèces (Tableau I). L'ensemble des caractères donne d'*A. koschevnikovi* l'image d'une abeille nettement différente, unique dans sa structure morphologique.

Zusammenfassung — Ein morphologischer Vergleich der höhlebrütenden Honigbienen von Borneo : *Apis koschevnikovi* (Buttel-Reepen, 1906) und *Apis cerana* (Fabricius, 1793). Unter Benutzung der in der Taxonomie der Honigbienen üblichen Merkmale wird eine vollständige morphologische Beschreibung von *Apis koschevnikovi* (Buttel-Reepen, 1906) und von *A. cerana* von Nordborneo vorgelegt. Im ganzen ist *A. koschevnikovi* größer als die mit ihr sympatisch lebende *A. cerana*. Die linearen Maße von Flügeln, Beinen und Skleriten sind bei *A. koschev-*

nikovi durchgehend um 10-15% größer als bei *A. cerana* (Tab. I).

Die Längsdurchmesser der Sklerite sind bei *A. koschevnikovi* allgemein größer. Die Filzbinden lassen bei *A. cerana* einen breiteren Streifen der dunklen Rückenschuppen frei. Die Tomentbehaarung führt zu dem allgemeinen Eindruck von *A. koschevnikovi* als einer hellen, rötlichen Biene, und der sympatischen *A. cerana* als einer intensiv schwarzen.

Der deutlichste Unterschied bei der Flügeläderung ist der viel größere Cubitalindex von *A. koschevnikovi* (7,23) gegenüber *A. cerana* mit einem CI von 3,67 (Tab. I). Von 11 Winkeln zwischen den Flügeladern waren fünf zwischen den beiden Arten signifikant verschieden (Tab. I). Die ganze Zusammensetzug der Merkmale ergibt für *A. koschevnikovi* das Bild einer deutlich unterschiedlichen Honigbiene, einzigartig in ihrem morphologischen Aufbau.

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