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PHYLOGENY AND GEOGRAPHICAL DISTRIBUTION OF THE GENUS *BOETTCHERISCA* ROHDENDORF (DIPTERA: SARCOPHAGIDAE)

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SUMMARY: The phylogeny of the genus *Boettcherisca* Rohdendorf was investigated by numerical techniques. The phenetic and phyletic dendrograms were obtained by mean character difference (MCD) and Russell and Rao's coefficient (S_{RR}) proximity analyses and unweighted pair-group (UPGA) cluster analysis, and then related to the classification of the species group and the geographical distribution of the group. Two monophyletic and one paraphyletic groups were recognized: *peregrina*-group, *septrionalis*-group and *karmyi*-group, respectively. A biological evolution was postulated commencing with a hypothetical ancestor having occurred in Sundaland and involving two lines of specialization, the *peregrina*-group found in and around Sundaland and the *septrionalis*-group in Far East, Wallacea and Papualand. On the basis of the cladogram and the present geographical distribution, a Sundaland origin was postulated for the genus.

INTRODUCTION

Boettcherisca peregrina Robineau-Desvoidy is one of the synanthropic filth flies commonly found in Japanese privies throughout Japan. This species is known to be a mechanical vector of etiological agents of gastroenteric diseases and its larvae are also responsible for intestinal myiasis. Eleven related species are known to be distributed in and around the Indo-Australian Region. During the zoogeographical survey of dipterous insects of medical importance in South-East Asia in 1973, 1975 and 1978 (Tokyo Medical and Dental University Overseas Scientific Research Project), we accumulated enough materials to summarize their geographical distribution and consider their phylogenetic relationships. Examinations of the materials revealed four species new to science, which have been described by Kano and collaborators (1,2). Eleven species have typical appearance of flesh flies except two elegant species having yellowish-orange bases of the wings. A key to males of all species was given

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by Kano and Sugiyama (2). Females are very similar and can not easily be identified to species. As a rule, male genitalic characters are most useful in sarcophagid classification but only minor differences have been detected for application to the phylogenetic analysis of this genus. On the other hand, there is variation in characters among different populations of the same species. We dealt with this variation trying to find the phylogenetic relationships of each species including their forms.

MATERIALS AND METHODS

The original data comprised information on 11 species, four geographical forms and a hypothetical ancestor of *Boettcherisca*, as shown in Table II. Sixteen taxa or OTUs ($t=16$) were analyzed over 21 diagnostic characters ($n=21$) by two principal numerical taxonomic methods. Twelve species including the ancestor were coded in alphabetical order and their forms were distinguished by the numeral added. Twenty-one characters, A-U, were taxometrically treated, as shown in Table I. Each character was coded either in two states [plesiomorphous (-), and apomorphous (+)] according to presumed deviation from generalized features of the genus by means of comparative anatomy. The $n \times t$ matrix is prepared from the above list of character states and is put in mean character difference (MCD) and Russell and Rao's coefficient (S_{RR}) proximity analyses (3), and unweighted pair-group (UPGA) cluster analysis to obtain a dendrogram. The character U is used only for MCD proximity analysis. Each taxon is given the percent frequency of derived or apomorphous states (Derivedness D%) in the solid circle in the dendrogram. In calculating D%, ($\pm$) entries were counted twice, once as primitive (-) and once as derived (+) (4).

RESULTS

Phylogeny

Figure 1 shows a phenetic dendrogram calculated by MCD proximity analysis and UPGA cluster analysis. There are three clusters of similar species: (1) ancestor-*karnyi*-*koimani*; (2) *formosensis*-*septentrionalis*-*cabrerae*; and (3) *peregrina*-*javanica*-*nathani*. Three species, *B. nepalensis*, *invaria* and *timorensis*, are well differentiated and each represents a single branch. A phyletic dendrogram obtained with S_{RR} is shown in Fig. 2. Two clusters of species group branched from the stem can be found in the phyletic dendrogram. *B. timorensis* (D%=52) and *invaria* (D%=35-40) appear to be highly evolved. *B. karnyi* (D%=18) and *koimani* (D%=19) emerge as primitive. These two species represent the most obvious choices as the closest phyletic and phenetic approaches to the hypothetical ancestor. *B. nepalensis* (D%=23) is also related to both species. These three species seem to be paraphyletic but we would like to treat them as an ancestral group. We classified and named the species groups as follows; the *septentrionalis*-group consisting of *septentrionalis*-*formosensis*-*cabrerae*-*invaria*, the *peregrina*-group of *peregrina*-*javanica*-*nathani*-*timorensis*, the *karnyi*-group of ancestor-*karnyi*-*koimani*-*nepalensis*.

Table I. *Characters and character states*

Character states		
Characters	(+) Apomorphous	(-) Plesiomorphous
A: Parafacilia	golden-dusted	yellowish-gray dusted
B: Jowls	with yellow hairs posteroventrally	entirely with black hairs
C: Wings	orange at base	hyaline
D: Squamae	orange	milky white
E: Hind tibia	with posteroventral fringe	without fringe
F: Tergite 3	with strong median marginals	without median marginals
G: Tergites 3-4	with submetallic black disc	without black disc, chequered
H: Tergites 3-4	with golden lateral sides	without golden sides, chequered
I: Tergites 4-5	golden dusted	gray-dusted
J: Tergite 5	red	black
K: Epandrium	red	black
L: Cerci	strongly curved anteriorly	gently curved anteriorly
M: Cerci	with pointed apex, without incisura	apex with incisura
N: Cercal spines	extending apex to dorsal side	not extending to dorsal side
O: Aedeagus, Apical plate	with 3 projections	with 0-1 projection
P: Ventralia	reduced	well developed
Q: Ventralia	with straight anterior margin	with rounded anterior margin
R: Ventralia	with developed basal lobe	basal lobe not developed
S: Anterior paramere	larger than posterior one	as long as posterior one
T: Anterior paramere	with apical flap	without apical flap
U: Identity of male genitalia	a, b, c, d, e, f, g, h, i, j, k, l	

Geographical Distribution

The following data have been established from published records (2,5) and these of materials studied by authors. We would like to include a new record of *B. invaria* from Celebes, Indonesia: 500⁰⁰ Makassar, 50m, 11-12.XII.1973, Kano and Kurahashi.

Table II. *The species and forms of the genus Boettcherisca: n (characters) x t (taxa) matrix*

DATA MATRIX

Code	Species	Characters																						
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	D*	
a ₁	<u>peregrina</u> , (S)	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	+	-	-	a	19
a ₂	<u>peregrina</u> , (T)	-	+	-	-	+	-	-	-	-	-	+	-	-	-	+	-	-	+	+	-	-	a	29
b ₁	<u>javanica</u> , (T,M,S)	-	-	-	-	+	-	-	-	+	+	-	-	+	+	-	-	-	-	+	-	-	b	26
b ₂	<u>javanica</u> , (P)	-	-	-	-	+	-	-	-	-	+	-	-	+	+	-	-	-	-	+	-	-	b	24
c	<u>karnyi</u> , (P)	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	c	18
d ₁	<u>nathani</u> , (T)	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	+	+	-	-	d	25
d ₂	<u>nathani</u> , (M,I)	+	-	-	-	+	-	-	-	+	-	-	-	+	+	-	-	-	+	+	-	-	d	33
e	<u>formosensis</u>	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	e	19
f	<u>cabrerai</u>	-	-	-	-	+	-	-	-	-	-	-	+	-	-	+	-	+	+	-	-	-	f	24
g	<u>septentrionalis</u>	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	+	+	-	-	-	g	25
h ₁	<u>invaria</u> , (C,NB,NI)	-	-	-	-	+	-	-	-	-	+	+	+	-	+	+	+	+	+	-	-	-	h	40
h ₂	<u>invaria</u> , (NG)	-	-	-	-	+	-	-	-	-	+	+	+	-	+	+	+	+	+	-	-	-	h	35
i	<u>koimani</u>	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	i	19
j	<u>timorensis</u>	+	-	+	+	-	-	+	+	+	+	+	-	-	+	+	-	-	+	+	-	-	j	52
k	<u>nepalensis</u>	-	+	-	-	+	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	k	23
l	Ancestor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	l	0

(S): Singapore, (T): Thailand, (M): Malaysia, (P): Palawan,
 (I): Indonesia, (C): Celebes, (NB): New Britain, (NI): New Ireland,
 (NG): New Guinea

Fig. 1. Phenetic dendrogram of the genus *Boettcherisca*.

The *karnyi*-group.

B. karnyi: Burma, Andaman Is., Thailand, Malaysia, Indonesia (Sumatra, Java, Borneo, Celebes, Ambon, Ceram), Philippines, Cocos Is., Mariana Is., Caroline Is., Wake and Marshall Is.

B. koimani: Indonesia (Flores).

B. nepalensis: Nepal.

The *peregrina*-group.

B. peregrina: India, Sri Lanka, Nepal, Thailand, Indonesia, Malaysia, China, Formosa, Japan, Australia, New Guinea, New Britain, Fiji, Samoa, Volcano Is., Bonin Is., Gilbert Is., Hawaii and Mariana Is.

B. javanica: Thailand, Malaysia, Indonesia (Sumatra, Java, Borneo), and Philippines (Palawan).

B. nathani: India, Nepal, Thailand, Malaysia, Indonesia (Sumatra, Borneo), and Philippines (Palawan).

B. timorensis: Indonesia (Timor).

Fig. 2. Phyletic dendrogram of the genus *Boettcherisca*.

The *septentrionalis*-group.

B. septentrionalis: USSR (Sikhote-Alin) and Japan.

B. formosensis: Formosa and China (Chekiang, Liaoning).

B. cabrerai: Philippines (Luzon).

B. invaria: Indonesia (Celebes, Aru Is.), New Guinea, Solomon Is., Isabel Is.

Distributional maps are shown in Figs. 3-5. The primitive species, *B. koimani* and *karnyi*, which most nearly approach the hypothetical ancestor in morphological details, are found in forest in the tropical climate in South-East Asia. Records of *B. karnyi* from Micronesia are most probably due to introduction from the west. The origin also may be suggested by the fact that the distribution of *Boettcherisca* is concentrated in this area. *B. nepalensis* and *koimani* are indigenous to Nepal and Flores, respectively. The second group is restricted primarily to Sundaland and Wallacea (Lesser Sunda Is.). *B. peregrina*, however, has the widest distribution among the 11 species. *B. timorensis* is endemic to Timor. Three species of the third group are found in the Far East. *B. cabrerai* is indigenous to Luzon. *B. invaria* is distributed in Wallacea (Celebes)

Fig. 3. Geographical distribution of the *karnyi*-group.

Fig. 4. Geographical distribution of the *peregrina*-group.

and Papualand. *B. timorensis*, *nepalensis* and the members of the third group seem to be established in the periphery of the range of hypothetical ancestor.

Fig. 5. Geographical distribution of the *septentrionalis*-group.

DISCUSSION

The distribution of the ancestral stock may suggest that the genus *Boet-cherisca* arose in Sundaland. The original area may be close to the present day distribution of *B. javanica*. The *septentrionalis*-group has evolved along its eastern periphery. The *peregrina*-group seems to have evolved within Sundaland and Lesser Sunda Is. A synanthropic species, *B. peregrina*, has spread widely into the adjacent region. *B. karnyi* also seems to have invaded Wallacea and Micronesia. The wide distribution of synanthropic flies is often caused by introduction through human activities as well as natural dispersal.

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