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Original article

Apis florea in Jordan: source of the founder population*

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Abstract – A recent isolated population of *Apis florea* has been reported from Aqaba in Jordan at the Red Sea, consisting of numerous colonies within a still limited range which apparently is expanding. This region is about 1500 km apart from its next occurrences in Sudan where it had been introduced and first detected in 1985 and about 2000 km apart from its next natural occurrences in Iran and Oman. These bees apparently have been imported by human transport, most likely by ship. This new location thus represents a major jump in the progression of the species still to fill a wide area of possible locations offering adequate living conditions. Here we attempt to track the possible origin of this new population by morphometric methods. This analysis indicated closest relation to *A. florea* from Oman, thus being the most likely source of this population.

***Apis florea* / Jordan / spread**

1. INTRODUCTION

In recent years the dwarf honeybee *Apis florea* Fabricius has been steadily expanding westwards, both naturally and inadvertenetly via global transportation (Mogga and Ruttner, 1988; Hepburn et al., 2005). It is now well established in Iraq, Oman and Yemen (Wongsiri et al., 1996); and has recently been detected in Sudan, where it was first detected in 1985 (Mogga and Ruttner, 1988) and in central Saudi Arabia (Hepburn et al., 2005). Throughout this expansion along the Arabian peninsula and into Africa it has proven to be a highly successful colonizer, well adapted to hot arid conditions of both urban and rural landscapes and seemingly unaffected by competition from any local *A. mellifera* (El-Shafie et al., 2002). Most recently, *A. florea* has become established in the area around Aqaba, Jordan (Haddad et al., 2008). This region is about 1500 km apart from its next occurrences in Sudan, and about 2000 km apart from its next natural occurrences in Iran and Oman. We here report the results of morphometric analyses on the Jordanian and Sudanese samples in combination with others from the western half of the *A. florea* distribution to identify the probable source of origin of the founder population in Jordan.

The expansion of the range of *A. florea* is of more than academic interest given the expansions of the ranges of *A. cerana* Fabricius and *A. mellifera* L. and their possible effects on endemic biodiversity. In the last century the invasion of the Americas by the African *A. m. scutellata* Lepeletier has displaced the previously invasive European races of *A. mellifera* with yet uncharted consequences for local apifauna and other insect pollinators (Winston et al., 1981; Soares and De Jong, 1992). Similarly, since its introduction into

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Papua New Guinea, *A. cerana* has spread throughout this great island and is poised to enter Australia over the stepping stone small islands of the Torres Strait (D. Anderson, unpubl. data). Recommended policy of the Australian Honeybee Industry Council (2008, http://www.quarantinebiosecurityreview.gov.au/submissions_received) is to contain the introduction of another invasive honeybee species because of possible effects on biodiversity as well as commercial beekeeping on that continent. Against these concerns, it has been reported that while *A. florea* is indeed rapidly spreading through Sudan, that there are no real competitive interactions between the native *A. mellifera* and the former (El-Shafie et al., 2002). Possible effects on the local apifauna and other insect pollinators remain unexplored.

2. METHODS AND MATERIALS

2.1. Honeybees

The worker honeybees used for the analyses of *A. florea* in this study derive from: (1) new material collected from Jordan (9 colonies) and Sudan (8 colonies); (2) raw data from Southern India (1 colony), Sri Lanka (6 colonies), Iran (19 colonies), Pakistan (3 colonies), Saudi Arabia (1 colony) and Oman (3 colonies) from the Institut for Bienenkunde database at Oberursel. Morphometric analyses were performed on 870 individual worker bees from 50 colonies representing 28 localities (Fig. 1 and additional online material for the geographical co-ordinates).

2.2. Measurements

Morphological characters of worker bees were measured using the Ruttner (1988) parameters as follows: length of femur (5), tibia (6), metatarus (7), metatarsus width (8), length of tergite 3 (9), tergite 4 (10), forewing length (17), forewing width (18), cubital a (19), cubital b (20). Angles of venation were not available for most colonies from Iran and size related characters were not available for the colonies from Pakistan and Sri Lanka.

2.3. Data analysis

Colony sample means and standard deviations were computed for each morphometric character from 15-20 bees per colony. Multivariate statistical analysis of the data included principal components, discriminant and k-means cluster analyses (Johnson and Wichern, 2002). All tests were performed using Statistica© (StatSoft, 2007).

3. RESULTS

Principal components analyses were carried out using the colony means of ten morphometric characters of worker honeybees ((5), (6), (7), (8), (9), (10), (17), (18), CI = (19)/(20)). Two principal components with eigenvalues greater than one were isolated. PC 1: size-related characters (5) to (10), and (17) and (18) with component loadings between 0.86 and 0.96 accounted for 69.7% of the variation; PC 2: cubital index (CI) and size (8) with component loadings 0.90 and 0.53, respectively accounted for 14.1% of the variation. The two principal components accounted for a total of 83.8% of the variation in the data. The PC plot using the first and second PC scores, revealed two morphoclusters with a group of smaller bees from S. India and Sri Lanka forming one cluster, and an isolation of larger bees from Iran, bees from Sudan, Oman, Jordan and Pakistan forming the second cluster.

Canonical 1 and 2 scores plot from a discriminant analysis using the colony means of the same ten morphometric characters and the six countries with n >1 as the groups showed the colonies from Jordan and Sudan within the same 90% confidence ellipse as those from Pakistan and Oman (Fig. 2). The results of the squared Mahalanobis distances between the centroids of the groups showed that the colonies from Jordan were likely introduced via Oman ($d^2 = 4.6$, Tab. I).

A cluster analysis using the complete linkage procedure was carried out on colony mean character values combined for the 8 countries. The results showed a dendrogram of two main clusters. Cluster 1 first linked colonies from Pakistan and Sudan, then Oman and Jordan and then Saudi Arabia and finally Iran; cluster 2 linked colonies from S. India and Sri Lanka (Fig. 3).

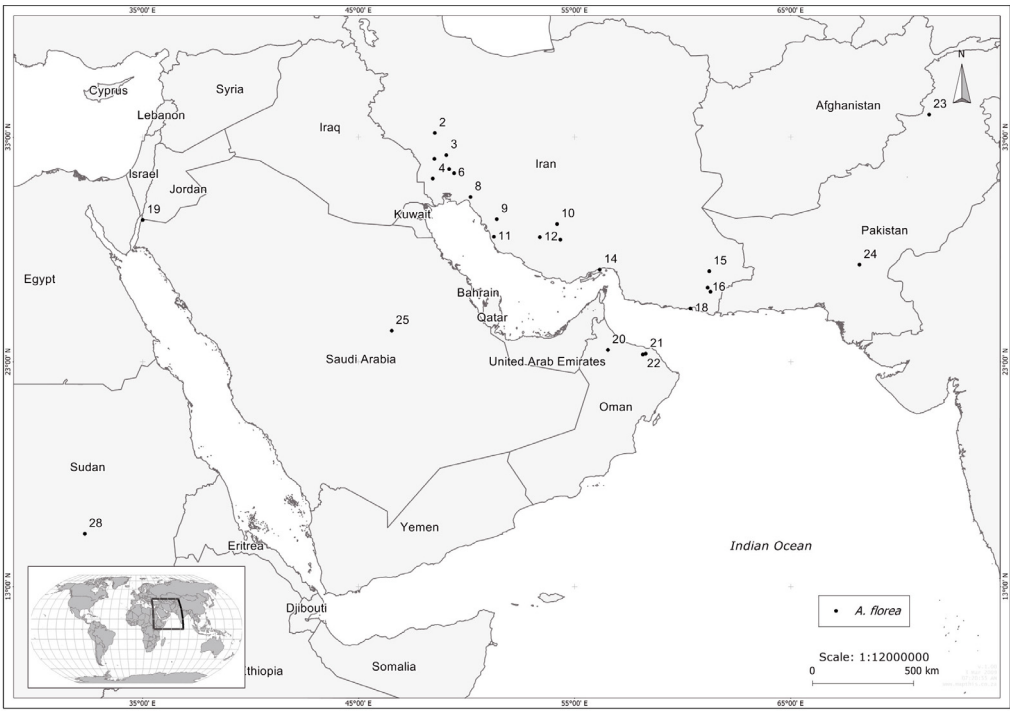

Figure 1. Geographical localities at which the *Apis florea* used in the study were collected. Names of the localities and their co-ordinates are given in additional online material.

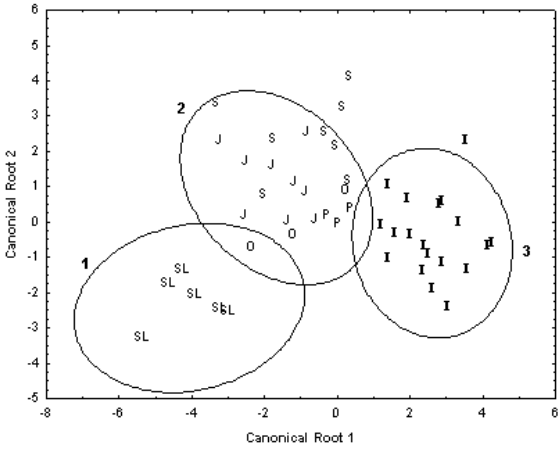

Figure 2. Discriminant analysis plot using the colony means of ten morphometric characters. Letters indicate colonies from countries: SL = colonies from Sri Lanka (cluster 1), J = colonies from Jordan, O = colonies from Oman, P = colonies from Pakistan, S = colonies from Sudan (cluster 2), I = colonies from Iran (cluster 3). Confidence ellipses are drawn at the 90% level.

Table I. Mahalanobis squared distances between centroids of *Apis florea* morphometric clusters by country.

	Squared Mahalanobis Distances					
Country	Sri Lanka	Iran	Pakistan	Oman	Jordan	Sudan
Sri Lanka	0.0					
Iran	48.6	0.0				
Pakistan	30.6	14.0	0.0			
Oman	17.9	16.5	6.3	0.0		
Jordan	24.4	24.2	15.2	4.6	0.0	
Sudan	32.8	22.6	14.9	13.5	13.6	0.0

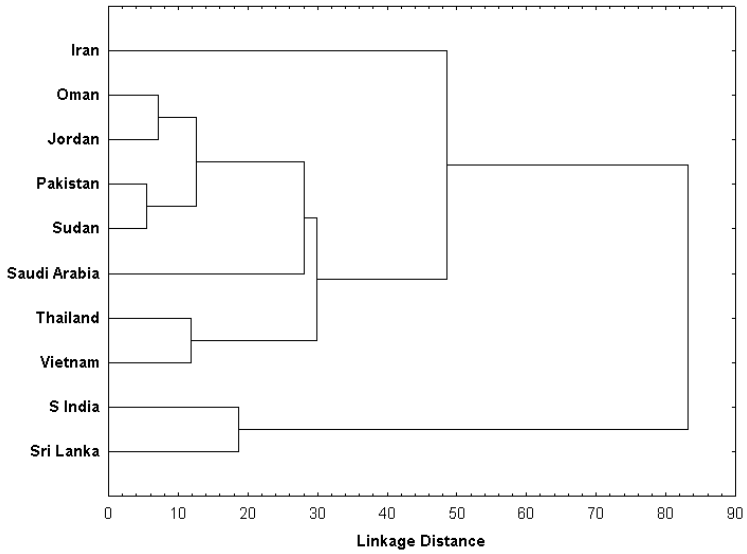

Figure 3. Hierarchical clustering dendrogram for *A. florea* in Jordan and adjacent countries, derived from complete linkage clustering procedure on ten morphometric characters averaged for countries.

4. DISCUSSION

The morphometric analyses clearly indicate that the *A. florea* in Jordan is derived from Oman. Though no sampling locations further to the east than Sri Lanka were included, the firm placement of the Aqaba samples within the Iran-Pakistan and Arabic Peninsula samples excludes any affiliation with *A. florea* from far eastern origins. The analyses also reconfirm that Pakistan was the origin of *A. florea* in Sudan (Mogga and Ruttner, 1988). It is almost certain that the *A. florea* in Jordan arrived through human transportation because the region is surrounded by vast expanses of barren wasteland that precludes gradual expansion of the natural geographic range. It is very probable that the route of entry was by sea into the port of Aqaba in the northeastern hook of the Red Sea. And, indeed, there is a very large shipping trade along the Red Sea and Arabian Sea between Oman and Jordan. The *A. florea* in Sudan were first discovered in Khartoum but have since spread along the Nile River (Mogga, unpubl. data). It seems highly probable that the Jordan and Sudanese populations will eventually converge in the Sinai Peninsula.

Recording the occurrence of a biogeographical event such as the introduction of *A. florea* to Jordan may appear insignificant. However, in an ecological and conservation context, such events could have considerable effects.

There is a nascent but growing corpus of literature documenting the effects of foreign introductions, many of which achieve major pest status (Samways, 1994; Kearns et al., 1998; Kato and Kawaki, 2004; Abe, 2006). Indeed, the history of applied entomology can be viewed as a chronicle of the behaviour of introduced species which have become invasive (Howard, 1930; Pedigo and Rice, 2008). We suggest that, short of eradication of such invasive honeybees, their careful scrutiny in a new environment is certainly warranted.

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***Apis florea* en Jordanie : origine de la population fondatrice.**

***Apis florea* / morphométrie / dispersion population**

Zusammenfassung – ***Apis florea* in Jordanien: Ursprung der Gründerpopulation.** Vor kurzer Zeit wurde ein aus zahlreichen Völkern in einem begrenzten Areal bestehendes Vorkommen von *Apis florae* in Aqaba, Jordanien aufgefunden, etwa 1500 km von seinen nächsten Nachbarn im Westen und 2000 km von denen im Osten entfernt.
Um die mögliche Herkunft dieser neuen Population zu bestimmen, führten wir eine Hauptfaktorenanalyse anhand von 10 an 870 einzelnen Arbeiterinnen aus 50 Völkern von 28 Herkunftsorten gewonnenen morphometrischen Merkmalen durch (Abb. 1 und zusätzliches Onlinematerial zu den Herkunftsorten). Das Hauptkomponentendiagramm zeigte zwei getrennte Morphokluster, von denen der erste von kleineren Bienen von Südindien und Sri Lanka, der zweite von größeren Bienen aus Iran in einer Abseitsposition und von den Bienen aus Sudan, Oman, Jordanien und Pakistan gebildet wurde. In den Diagrammen einer die Koloniemittelwerte aus den 6 Ländern mit mehr als einem Volk und die gleichen 10 morphometrischen Merkmale umfassenden Diskriminanzanalyse lagen die Völker aus Jordanien und Sudan innerhalb der gleichen 90 % Vertrauensellipse mit den Völkern von Pakistan und Oman (Abb. 2). Die quadrierten Mahalanobisabstände der Gruppenzentroide zeigten, das die Völker aus Jordanien höchstwahrscheinlich über Oman eingeführt wurden (Tab. I), dies erfolgte wahrscheinlich per Schiff.

***Apis florea* / Jordanien / Verbreitung**

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