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A revision of the octocoral genus *Ovabunda* Alderslade, 2001 (Anthozoa, Octocorallia, Xeniidae)

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Abstract

The family Xeniidae (Octocorallia) constitutes an abundant benthic component on many Indo-West Pacific coral reefs and is ecologically important in the Red Sea. The genus *Ovabunda* Alderslade, 2001 was recently established to accommodate previous *Xenia* species with sclerites comprised of a mass of minute corpuscle-shaped microscleres. The aim of the present study was to examine type material of *Xenia* species in order to verify their generic affiliation. We present here a comprehensive account of the genus *Ovabunda*, using scanning electron microscopy to depict sclerite microstructure. We assign three *Xenia* species to the genus: *O. ainex* **comb. n.**, *O. gohari* **comb. n.**, and *O. crenata* **comb. n.**; and synonymize several other species of *Ovabunda*. We provide a key to *Ovabunda* species and conclude that they are mainly confined to the Red Sea, with some occurrence in the West Indian Ocean.

Keywords

Red Sea, sclerite microstructure, taxonomy, *Xenia*

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Introduction

Members of the octocoral family Xeniidae form a major component of shallow coral-reef communities in the tropical Indo-West-Pacific region, and in the Red Sea in particular (e.g., Gohar 1940; Benayahu 1990; Reinicke 1997). In the Red Sea, a remarkably high number of 34 species have been recorded from the family prior to this revision, 24 of which were originally described from the region (Reinicke 1995, 1997). Some of these species have not been reported in any other region, thus emphasizing their high diversity and importance in the Red Sea.

The xeniids comprise for the most part small and soft colonies, which are often slippery due to the secretion of large amounts of mucus (Fabricius and Alderslade 2001). A morphological feature unique to most of them is that the pinnules along the margins of the polyp tentacles are arranged in more than one longitudinal row. The number of pinnule-rows and the number of pinnules in the outermost row have been considered diagnostic features used for species identification (e.g., Hickson 1931a; Verseveldt and Cohen 1971; Benayahu 1990; Reinicke 1997). Several additional characteristics have been considered of taxonomic value, such as the size, shape, and coloration of the colonies, as well as polyp retractability and pulsation in live colonies (e.g., Gohar 1940; Verseveldt 1960; Reinicke 1995, 1997; Fabricius and Alderslade 2001).

Most xeniids feature a high density of sclerites in all parts of the colony, such as members of the genera *Asterospicularia* Utinomi, 1951; *Sansibia* Alderslade, 2000 (see Fabricius and Alderslade 2001) and *Xenia* including *X. blumi* Schenk, 1896; *X. garciae* Bourne, 1894 (see Gohar 1940) and *X. benayahui* Reinicke, 1995 (see Reinicke 1997); while other species have no sclerites or only a few (e.g., *X. hicksoni* Ashworth, 1899 and *Heteroxenia ghardaqensis* Gohar, 1940).

Over the years studies have revealed that a number of taxa have relatively simple sclerites in the form of round platelets, including those of the genera *Cespitularia* Milne-Edwards & Haime, 1850; *Heteroxenia* Kölliker, 1874; *Funginus* Tixier-Durivault, 1970; *Sansibia* Alderslade, 2000; *Sarcothelia* Verrill, 1928; *Sympodium* Ehrenberg, 1834 and *Xenia* Lamarck, 1816 (see also Fabricius and Alderslade 2001). This finding led to coining of the terms "general xeniid structure" (Gohar 1940: 95, 99, 104, 107) and "xeniid type of sclerites" (Verseveldt 1970: 227; Verseveldt 1974: 35). The majority of species descriptions of those genera thus did not depict sclerites, but rather presented the size range of their maximal diameter (e.g., *X. crassa* Schenk, 1896 in Hickson 1931a; *X. blumi* and *X. garciae* in Gohar 1940; *X. biseriata* Verseveldt & Cohen, 1971 and *X. faraunensis* Verseveldt & Cohen, 1971). Similarly, in his original description of *X. macrospiculata*, Gohar (1940) provided the size range of the sclerites and their morphological features, referring to them as "generally spherical, rarely ovoid or of irregular roughly spherical shape but always with smooth surface"; and also noted for *X. blumi* sclerites: "They are mostly ovoid, rarely circular or ellipsoidal". Later, Fabricius and Alderslade (2001: 53) argued that xeniid sclerites are "nearly always minute platelets or corpuscle-like forms, with a surface that generally appears almost smooth at the magnification of a light microscope". Only a few studies

presented drawings of xeniid sclerites, such as those of *Cespitularia mantoni* Hickson, 1931a and *C. multipinnata* Quoy & Gaimard, 1833 (Hickson 1931a: 168, fig. 5); *C. taeniata* May, 1899 (Utinomi 1950: 15, fig. 3f); *X. kusimotoensis* Utinomi, 1955: 264, fig. 1d; *Fungulus heimi* Tixier-Durivault, 1970: 324; *Xenia macrospiculata* (see Verseveldt 1971: 64, fig. 39c), and *Sympodium caeruleum* Ehrenberg, 1834 (see Klunzinger 1877: 42, pl. III, fig. 5 from Ehrenberg's unpublished drawings).

Over the last two decades the use of scanning electron microscopy (SEM) has revealed microstructural features of xeniid sclerites, which were not visible under a light microscope. Benayahu (1990) presented sclerite images of the type of *X. verseveldti* Benayahu, 1990; and of his collected *X. nana* Hickson, 1931b whose surface microstructure revealed corpuscular aggregations of microscleres, recorded for the first time among octocorals. Subsequently, SEM images with similar features were presented for *X. obscuronata* Verseveldt & Cohen, 1971 (Reinicke 1995: 18, fig. 6h, i), *X. benayahui* Reinicke, 1995: 18, fig. 6g and *X. faraunensis* Verseveldt & Cohen, 1971 (Reinicke 1997: 19, fig. 9a, b). A contrasting form, made of latticework matrix of calcite rods (*sensu* Alderslade, 2001) was demonstrated for the first time by Reinicke (1997: 19, figs 7, 8, 10) for *H. fuscescens* Ehrenberg, 1834; *Sympodium caeruleum* Ehrenberg, 1834 and *X. umbellata* Lamarck, 1816. It should be noted that the sclerites of *H. fuscescens* and *Sympodium caeruleum* were initially depicted by Reinicke 1995 (page 18, fig. 6e, f), but unfortunately the micrographs were of low quality. Reinicke (1997) assigned the two types of sclerites, featuring both corpuscular and dendritic structure, to *Xenia*, and concluded that their taxonomic significance remained to be studied. These findings prompted the use of SEM for studying sclerites of the genera *Anthelia* Lamarck, 1816 (see Reinicke 1997) and *Asterospicularia* Utinomi, 1951 (see Alderslade 2001). The latter study further used SEM to describe the genera *Bayerxenia* Alderslade, 2001; *Ingotia* Alderslade, 2001; *Ixion* Alderslade, 2001 and *Orangaslia* Alderslade, 2001.

The discovery of a corpuscular sclerite-type among previously described *Xenia* species led Alderslade (2001) to establish the genus *Ovabunda* while retaining those with the dendritic surface in the original genus. Consequently, he assigned seven of the originally described *Xenia* species to the new genus. Those assignments were made based on examination of type colonies of *X. benayahui* and *X. verseveldti* by L.P. van Ofwegen and the last author of the current study. For the remaining species, the assignment was not based on examination of types, but rather on sclerite descriptions in Reinicke (1997) for *X. biseriata* Verseveldt & Cohen, 1971 (p. 18) and *X. faraunensis* (Fig. 9a, b), and in Reinicke (1995) for *X. obscuronata* (p. 18, fig. 6h, i). The assignment of *X. macrospiculata* was based on examination of Red Sea material by the last author of the current study (Alderslade 2001: fig. 30), and that of *X. arabica* Reinicke, 1995 was not justified by Alderslade.

In a later study, Janes (2008) depicted sclerites of *Ovabunda benayahui*, *O. hamsina* Reinicke, 1997 and *O. impulsatilla* Verseveldt & Cohen, 1971, as well as of his new species, *O. aldersladei*, all collected in the Seychelles and featuring *Ovabunda*-type sclerites with corpuscular microstructure. Aharonovich and Benayahu (2011) employed high-resolution environmental SEM (ESEM) for a study of sclerites of type

Table 1. List of *Xenia* type material examined during the current study along with corresponding museum numbers.

Species name	Type	Museum and museum number
Xenia actuosa Verseveldt & Tursch, 1979	Holotype	RMNH Coel. 12866
Xenia antarctica Kükenthal, 1902	Syntype	MNHHWU 63
Xenia bauiana May, 1899	Syntype	ZMB 3673
Xenia blumi Schenk, 1896	Holotype	SMF 44
Xenia crassa Schenk, 1896	Holotype	SMF 39
Xenia delicata Roxas, 1933	Syntype	ZMB 6908
Xenia fusca Schenk, 1896	Syntype	SMF 40
Xenia garciae Bourne, 1894	Type	BML 1921.11.18.1
Xenia grasshoffi Verseveldt, 1974	Holotype	SMF 2616
Xenia kükenthali Roxas, 1933	Holotype	ZMB 6917
Xenia lepida Verseveldt, 1971	Holotype	RMNH Coel. 6703
	Paratype	RMNH Coel. 6704
Xenia membranacea Schenk, 1896	Holotype	SMF 41
Xenia mucosa Verseveldt & Tursch, 1979	Holotype	RMNH Coel. 12867
Xenia multispiculata Kükenthal, 1909	Syntype	ZMB 6920
Xenia novaebritanniae Ashworth, 1900	Type	BML 1962.7.20.148
	Syntype	BML 1962.7.20.149
Xenia plicata Schenk, 1896	Holotype	SMF 45
Xenia rubens Schenk, 1896	Holotype	SMF 46
Xenia sansibariana May, 1899	Syntype	ZMB 3828
Xenia ternatana Schenk, 1896	Holotype	SMF 43
Xenia viridis Schenk, 1896	Holotype	SMF 42

material of *O. biseriata*, *O. faraunensis* and *O. impulsatilla*, which revealed how the microscleres adhere.

Establishment of the genus *Ovabunda* by Alderslade led us to examine type material that was originally described as *Xenia*, in order to verify its generic affiliation. Not only were the types of the species assigned to *Ovabunda* by Alderslade examined, and their sclerites studied using SEM, but the types of a number of other nominal species of *Xenia* were also studied (see Table 1). Consequently, the current study has assigned three *Xenia* species to *Ovabunda* and retained 20 in the former genus; it also synonymizes several other species and designates a neotype for *Ovabunda macrospiculata*. The findings of the study emphasize the importance of re-examination of type material and the use of SEM to study xeniid sclerite microstructure for taxonomic purposes.

Methods

The study examined ethanol-preserved type specimens obtained on loan from the British Museum of Natural History (BML); National History collections of the Hebrew University of Jerusalem (HUJ); Museum of Natural History, Wroclaw University, Poland (MNHHWU); The Naturhistorisches Museum Wien (NHMW); the Naturalis Bio-

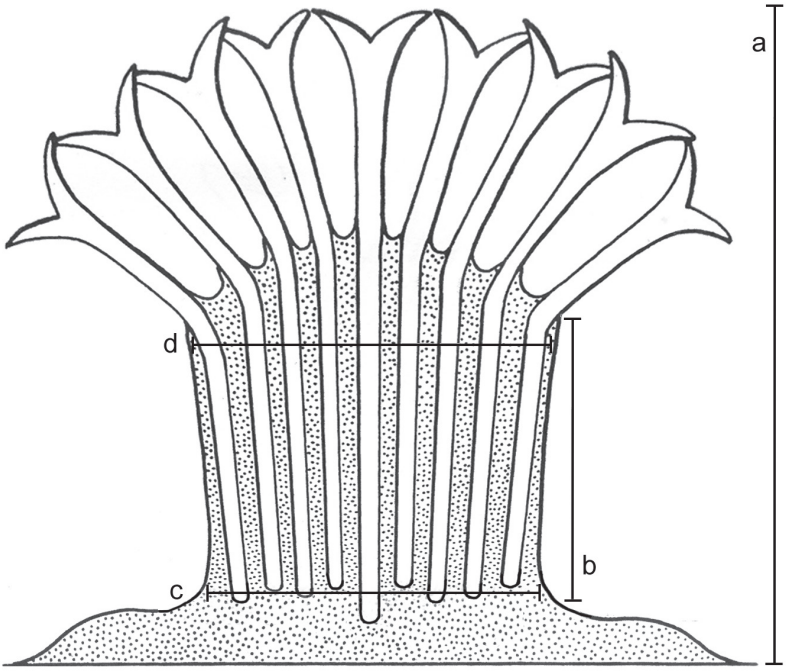

Figure 1. Illustration of colony dimensions. **a** Colony height **b** Stalk length **c** Stalk width at base **d** Stalk width at uppermost part. Illustration adopted from Hickson (1931a).

diversity Centre, formerly Rijksmuseum van Natuurlijke Historie, Leiden (RMNH); Senckenberg Naturmuseum Frankfurt (SMF); Zoologisches Museum Berlin (ZMB); and the Zoological Museum of Tel Aviv University (ZMTAU). Neotype material of *O. macrospiculata* was collected by the last author from the northern Red Sea, Gulf of Suez, Shag Rock from ~5 meters, 11 July 1986 and preserved in 70% ethanol.

Morphological features of the preserved colonies were recorded: colony height, numbers of branches, stalk length, width at colony-base, and width at the uppermost part below the capitulum where the polyps arise (Fig. 1). The number of rows of pinnules and number of pinnules in the outermost row were counted under a compound microscope from five to ten tentacles, as much as possible from different polyps. The polyps examined were the biggest within the colony and preferably from the mid-part of the capitulum, and not from the outer part which contains the newly grown and smaller polyps. In addition, the length of the anthocodiae – consisting of the polyp body and extended tentacles – the dimensions of the pinnules (length and width at base), and the distance between adjacent pinnules were recorded (Fig. 2).

To examine the sclerites, the tissue was treated with 10% sodium hypochlorite followed by repeated rinses in distilled water. Wet preparations of the clean sclerites from polyps, colony stalk, the coenenchyme and canal walls within were examined and photographed under an Optishot Nikon light microscope at × 400 magnification. After comparison of these sclerites we concluded that there are no differences in appearance and

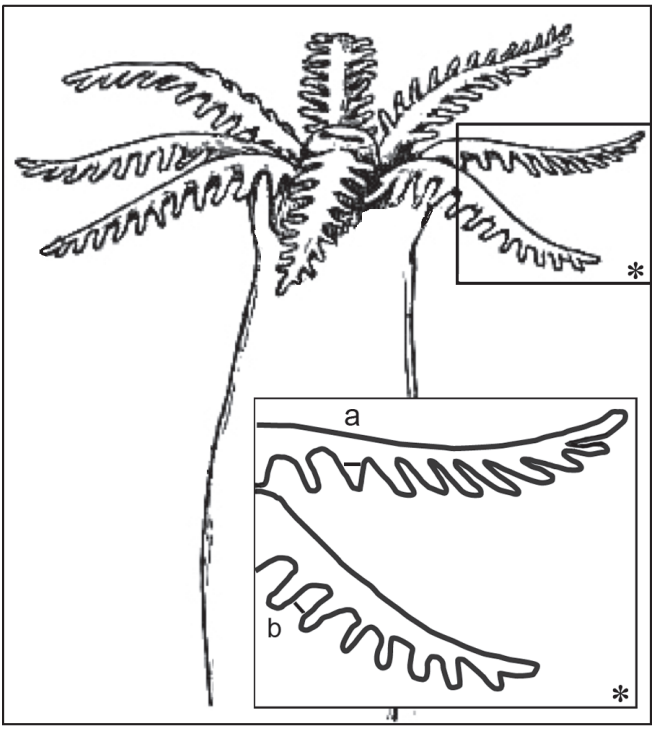

Figure 2. Illustration of polyp dimensions. **a** Pinnule width at its base **b** Gap between adjacent pinnules; asterisk indicates magnified area. Illustration adopted from Encyclopedia Britannica, 11th Edition, Volume 3 (http://www.digilibraries.com/html_ebooks/105312/34018/www.digilibraries.com@34018@34018-h@34018-h-7.htm).

dimensions between sclerites in different colony parts. Therefore, only polyp sclerites were examined under SEM and presented in this paper. SEM stubs for polyp sclerites were prepared following Aharonovich and Benayahu (2011), and examined with a Jeol 840Å electron microscope. Measurements of sclerite images, taken by both light microscopy (images not presented) and SEM, were carried out using ImageJ 1.440 (National Institute of Health, USA). At least 20 randomly selected sclerites were measured for each colony in order to determine sclerite size variation. Number of sclerites measured is indicated in the text for each species. Since the sclerites are mostly spheroids, their dimensions are presented as the range of their minimal-to-maximal smallest diameters × range of their minimal-to-maximal largest diameters. The current study undertakes to clarify some confusion that resulted from differences between Reinicke (1995) and Reinicke (1997) which can be found in some descriptions in the Remarks section (e.g. *O. crenata*, *O. hamsina*).

The zoogeographical species distribution is based on the examination of types and other material, unless specified otherwise in the text. Table 1 lists *Xenia* types that were examined by us and maintained their original generic affiliation.

Results

Systematic section

Order Alcyonacea Lamouroux, 1812

Family Xeniidae Ehrenberg, 1828
http://species-id.net/wiki/Xeniidae

Genus *Ovabunda* Alderslade, 2001: 49–52.

Diagnosis. Colonies are small and soft with cylindrical stalks, undivided or branched, terminating in one or more domed polyp-bearing regions. Polyps are not retractile and are always monomorphic. Sclerites are oval spheroids, usually abundant in all parts of the colony, mostly up to 0.035 mm in maximal diameter, and comprised of a mass of minute corpuscle-shaped microscleres.

Key to species

1 **Non-pulsating polyps in live colonies**
1.1 **One row of pinnules on each side of the tentacles**
6–7 pinnules in each row ..... ***O. benayahui***
12–18 pinnules in each row ..... ***O. verseveldti*** (No data on pulsation present in the literature)
1.2 **Mostly one row, but sometimes two rows of pinnules on each side of the tentacles**
18–22 pinnules in the outermost row ..... ***O. gohari***
1.3 **Two rows of pinnules on each side of the tentacles**
8–11 pinnules in the outermost row ..... ***O. impulsatilla***
13–16 pinnules in the outermost row ..... ***O. biseriata***
17–24 pinnules in the outermost row ..... ***O. faraunensis***
24–29 pinnules in the outermost row ..... ***O. arabica***
1.4 **Mostly two, but sometimes three rows of pinnules in the outermost row**
12–16 pinnules in the outermost row ..... ***O. crenata***
1.5 **Three rows of pinnules on each side of the tentacles**
15–20 pinnules in the outermost row ..... ***O. ainex***
1.6 Mostly three but sometimes four rows of pinnules in the outermost row
17–22 pinnules in the outermost row ..... ***O. hamsina***
2 **Pulsating polyps in live colonies**
2.1 **Three rows of pinnules on each side of the tentacles**
14–18 pinnules in the outermost row ..... ***O. macrospiculata***

Ovabunda ainex **(Reinicke, 1997), comb. n.**
http://species-id.net/wiki/Ovabunda_ainex
Fig. 3

Xenia ainex Reinicke, 1997: 45–48, figs 19a–b, plates 6, 26.

Material. Holotype: RMNH Coel. 23539, Sudanese Red Sea, Sanganeb Atoll, 20 km off Port Sudan, southern-slope near jetty (19°21'33.81"N, 37°19'37.66"E), 6 m, April 1991, coll. G. B. Reinicke; **paratype:** RMNH Coel. 23540, same location, 5 m S- jetty, October 1992, coll. G. B. Reinicke; **additional material:** RMNH Coel. 23535, Red Sea, Gulf of Aqaba, Aqaba, Saudi Arabian border Bay (29°21'37.31"N, 34°57'39.48"E), October 1989, coll. G. B. Reinicke; NHMW 2250, Saudi Arabia; **holotype of *X. crassa*** SMF 39, Indonesia, Ternate island, 1894, coll. Kükenthal; **holotype of *X. ternatana*** SMF 43, Indonesia, Ternate island, 1894, coll. Kükenthal.

Description. The holotype is 45 mm high; its stalk is 15 mm long and splits at the base into three branches, two of which split again into two, 22 and 18 mm above the colony base; the latter branches are 35 and 30 mm long, 8 and 10 mm wide at their base, 4 and 6 mm wide at their uppermost part, respectively. The third branch splits 20 mm above the base into three branches, and is 40 mm long and 7 mm wide at its base and 5-7 mm wide at the uppermost part. The polyp's body is up to 10 mm long, and the tentacles are up to 5 mm long, featuring three rows of pinnules on each side. The pinnules are relatively slender, up to 1 mm long and 0.08 mm wide, 17-20 in the outermost row with a space of one to two pinnule widths between adjacent pinnules. The spheroidal sclerites, typical regular *Ovabunda* sclerites, are scarce in all parts of the colony, measuring 0.011–0.030 × 0.018–0.042 mm in diameter (n=25), composed of a mass of corpuscle-shaped microscleres. The original description indicated non-pulsating polyps for the live colonies. The ethanol-preserved holotype is light yellowish-beige, almost transparent.

The paratype is 20 mm long; its stalk is 15 mm wide at its base, splitting into two branches, each 5 mm long and 10 and 8 mm wide at the base. The polyp's body is up to 5 mm long, and the tentacles up to 5 mm long, bearing three rows of pinnules and 15–17 pinnules in the outermost row. The pinnules are 1.6 mm long and 0.16 mm wide, with a gap between adjacent pinnules ranging from one to three pinnule widths. The sclerites are O*vabunda*-type, regular or irregular in shape (Fig. 3a, c), 0.012–0.026 × 0.02–0.04 mm in diameter (n=21 sclerites). When two sclerites fuse they reach 0.039 mm in maximum diameter (Fig. 3b). The original description indicated non-pulsating polyps for live colonies. The ethanol-preserved colony is light beige.

Remarks. RMNH Coel. 23535 features polyps with three rows of pinnules on each side of the tentacles and 16–19 pinnules in the outermost row. The sclerites are *Ovabunda*-type, measuring 0.016–0.026 × 0.022–0.030 mm in diameter (n =13).

Reinicke (1997) noted under the species *X. ainex* n.sp. (p. 44): "nec *Xenia ternatana*; Kükenthal 1913: 8 (partim. NHMW 2250)" and "*Xenia crassa*; Reinicke 1995:

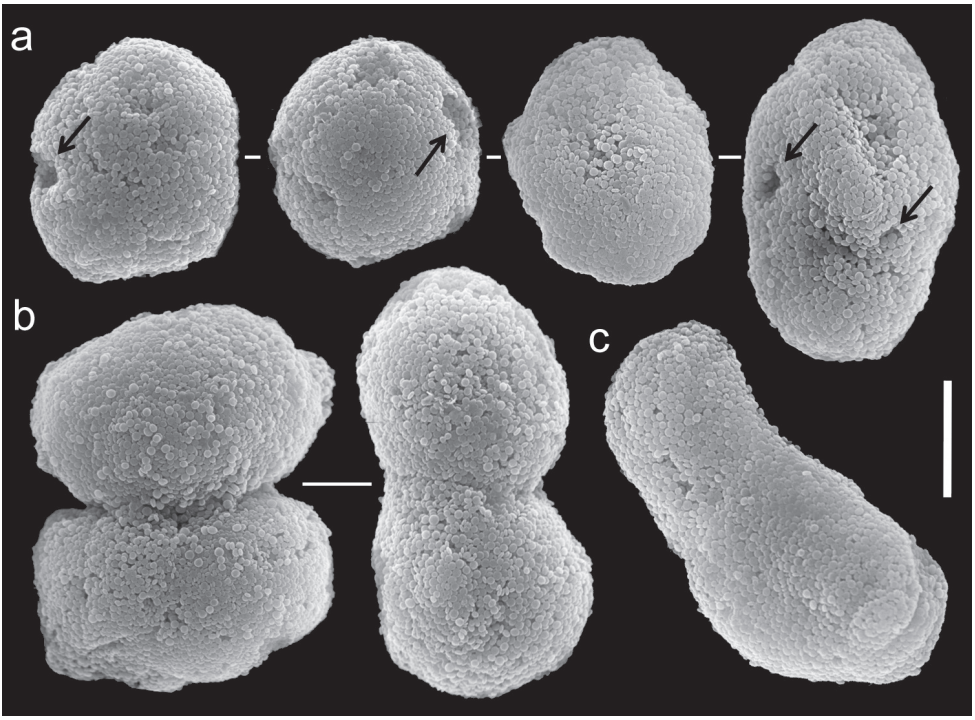

Figure 3. Scanning electron micrographs of polyp sclerites of *Ovabunda ainex* (Reinicke, 1997) paratype (RMNH Coel. 23540). **a** Regular sclerites **b** Fused sclerites **c** Irregular sclerite. Arrows indicate surface dents. Scale bar: 10 μm.

43, Fig. 32". The description of *X. ternatana* given by Kükenthal (1913) indicated two rows of pinnules, with 18 pinnules on average, and sclerites measuring 0.017 mm in diameter, thus differing from the features of *O. ainex* (see above). The NHMW 2250 specimen of *X. ternatana* was examined and found to match *O. ainex*, as stated by Reinicke (1997). *X. crassa* was suggested to be a synonym of *O. ainex* (Reinicke 1997). The current examination of the types of *X. crassa* and *X. ternatana* indicates that their sclerites distinctly differ from those of *O. ainex*, and thus those species' original generic assignment should be retained.

Conclusions. Our findings confirm the original description of Reinicke (1997) of *O. ainex*, but the structure of its sclerites justifies the generic re-assignment of the species to *Ovabunda*.

Similar species. *O. ainex* is most similar to *O. macrospiculata*. Although they both have three rows of pinnules, the number of pinnules in the outermost row ranges from 15–20 in *O. ainex* compared to 14–18 in *O. macrospiculata*. The major difference between them, however, is that *O. macrospiculata* has pulsating polyps in live colonies and *O. ainex* does not.

Distribution. Red Sea: Gulf of Aqaba, Sudan.

Ovabunda arabica **(Reinicke, 1995)**
http://species-id.net/wiki/Ovabunda_arabica
Figs 4, 5

Xenia arabica Reinicke, 1995: 37, figs 47–49; 1997: 36, fig. 14
Ovabunda arabica; Alderslade 2001: 51
Xenia crista Reinicke, 1997: 38, figs 16a–b, plate 23, **syn. n.**

Material. Holotype: RMNH Coel. 18673, northern Red Sea, Gulf of Aqaba, Saudi Arabian border bay, 20 km South of Aqaba (29°21'37.31"N, 34°57'39.48"E), 15 m, 12 November 1991, coll. G. B. Reinicke. **Paratypes:** RMNH Coel. 18675, northern Red Sea, Gulf of Aqaba, Nature Reserve (Aqaba), Marine science station (MSS), 10 km South of Aqaba (29°27'27.33"N, 34°58'24.19"E), 15 m, 4 November 1991, coll. G. B. Reinicke; RMNH Coel. 18676, location as above, 12 m, 5 November 1991, coll. G. B. Reinicke; **additional material: holotype of *X. crista*** RMNH Coel. 18677, northern Red Sea, Gulf of Aqaba, Nature Reserve (Aqaba), Marine science station (MSS), 10 km South of Aqaba (29°27'27.33"N, 34°58'24.19"E), 12 m, October 1989, coll. G. B. Reinicke; **paratype of *X. crista*** RMNH Coel. 18678, location as above, 15 m, October 1990, coll. G. B. Reinicke.

Description. The holotype is 45 mm high; its stalk is 15 mm long, 7 mm wide at its base and 7 mm wide at its upper part. The polyp's body is 12 mm long, and tentacles up to 11 mm long. The pinnules are 2 mm long and 0.2 mm wide at the base; the gap between adjacent pinnules is one pinnule wide. There are two rows of pinnules on each side and 24-25 pinnules in the outermost row. The sclerites are spheroids of the *Ovabunda*-type, measuring 0.028–0.036 mm at largest diameter.

One paratype (RMNH Coel. 18675) has a total height of 20 mm; its stalk is 16 mm long, 10 mm wide at the base, and 18 mm wide at its uppermost part. The polyp's body is 9 mm long; the tentacles are 6 mm long, featuring two rows of pinnules 2.2 mm long and 0.2 mm wide on each side, and 24–29 pinnules in the outermost row. The pinnules mostly feature a one pinnule width gap. Sclerites are *Ovabunda*-type, regular and pear- shaped (Fig. 4a, c), measuring 0.016–0.030 × 0.022–0.038 mm in diameter (n=27 sclerites). Occasionally, two sclerites are fused (Fig. 4b), measuring up to 0.048 mm in diameter. The sclerites are more abundant on the aboral side of the tentacles than the oral one. The second paratype (RMNH Coel. 18676) has 2 rows of pinnules on each side of the tentacles, 24–27 in the outermost row. The sclerites are *Ovabunda*-type, measuring 0.026–0.036 mm at maximal diameter. The original description indicated non-pulsating polyps for live colonies. Colour of the ethanol-preserved holotype is light brown.

Remarks. The number of rows of pinnules and pinnules in the outermost row correspond to the original description of the holotype and paratypes of *X. arabica*. Their sclerites are *Ovabunda*-type (Fig. 4) and, therefore, the species should be reassigned to that genus. Sclerite sizes given for the holotype and paratype in the original description exceed those obtained by us, as follows: holotype 0.043–0.053 mm *vs.* 0.028–0.036 mm at the larger diameter, and paratypes (RMNH Coel. 18675) 0.039 × 0.043 *vs.* 0.016–0.030 × 0.022–0.038 mm and (RMNH Coel. 18676) 0.043 × 0.051

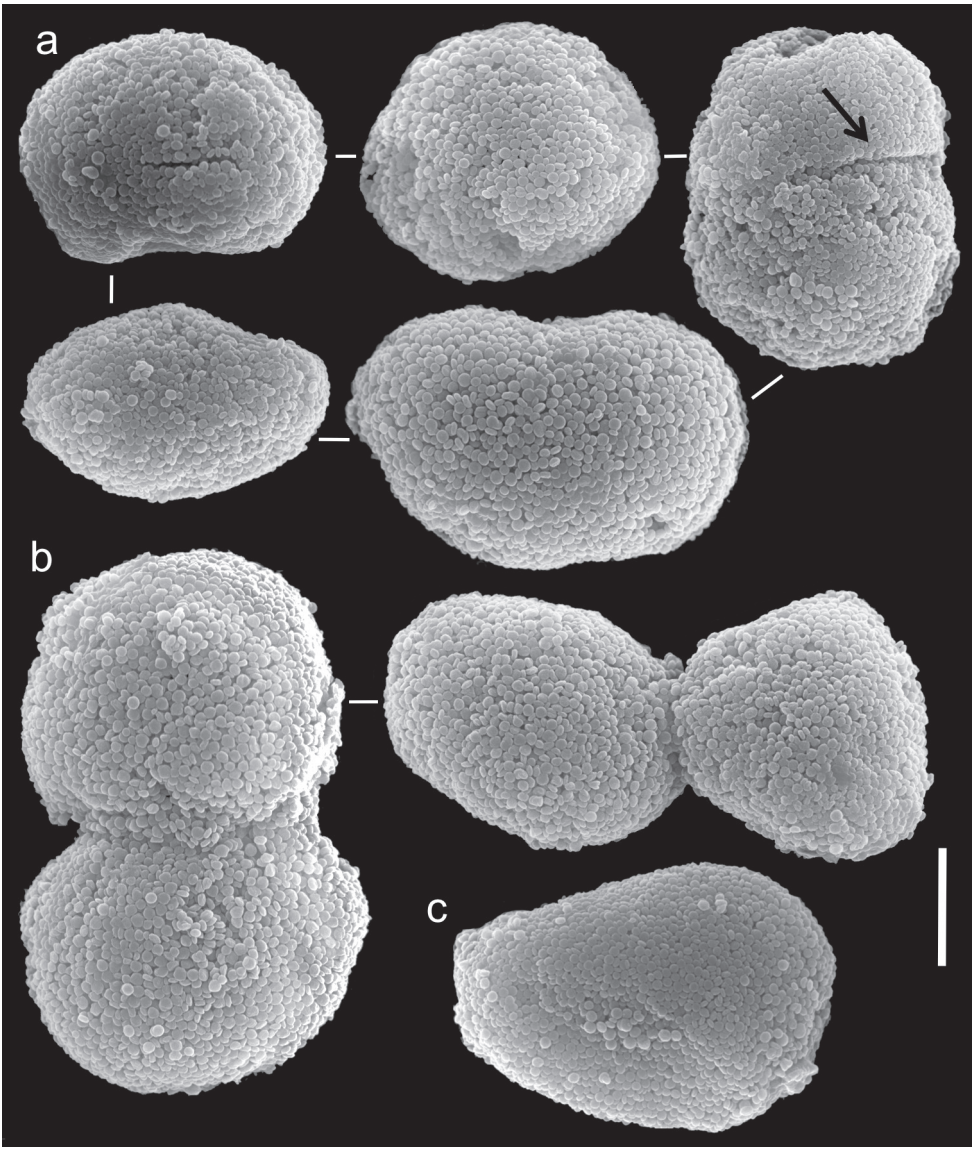

Figure 4. Scanning electron micrographs of polyp sclerites of *Ovabunda arabica* (Reinicke, 1995) paratype (RMNH Coel. 18675). **a** Regular sclerites **b** Fused sclerites **c** Pear-shaped sclerite. Arrow indicates surface irregularity, might represent the fusion area of two individual sclerites. Scale bar 10 μm.

vs. 0.026–0.036 mm, respectively. The larger size of 0.053 and 0.051 mm indicated by Reinicke (1997) falls within that of other *Ovabunda* species, such as *O. crenata* for the fused sclerites and *O. gohari* for larger and rare individual sclerites.

The holotype of *X. crista* (RMNH Coel. 18677) is 50 mm high and its stalk is 27 mm long, split into two branches 17 mm above its base. The branches are 10 mm long and 8 mm wide at their base and uppermost part. The polyp's body is up to 10 mm long. The

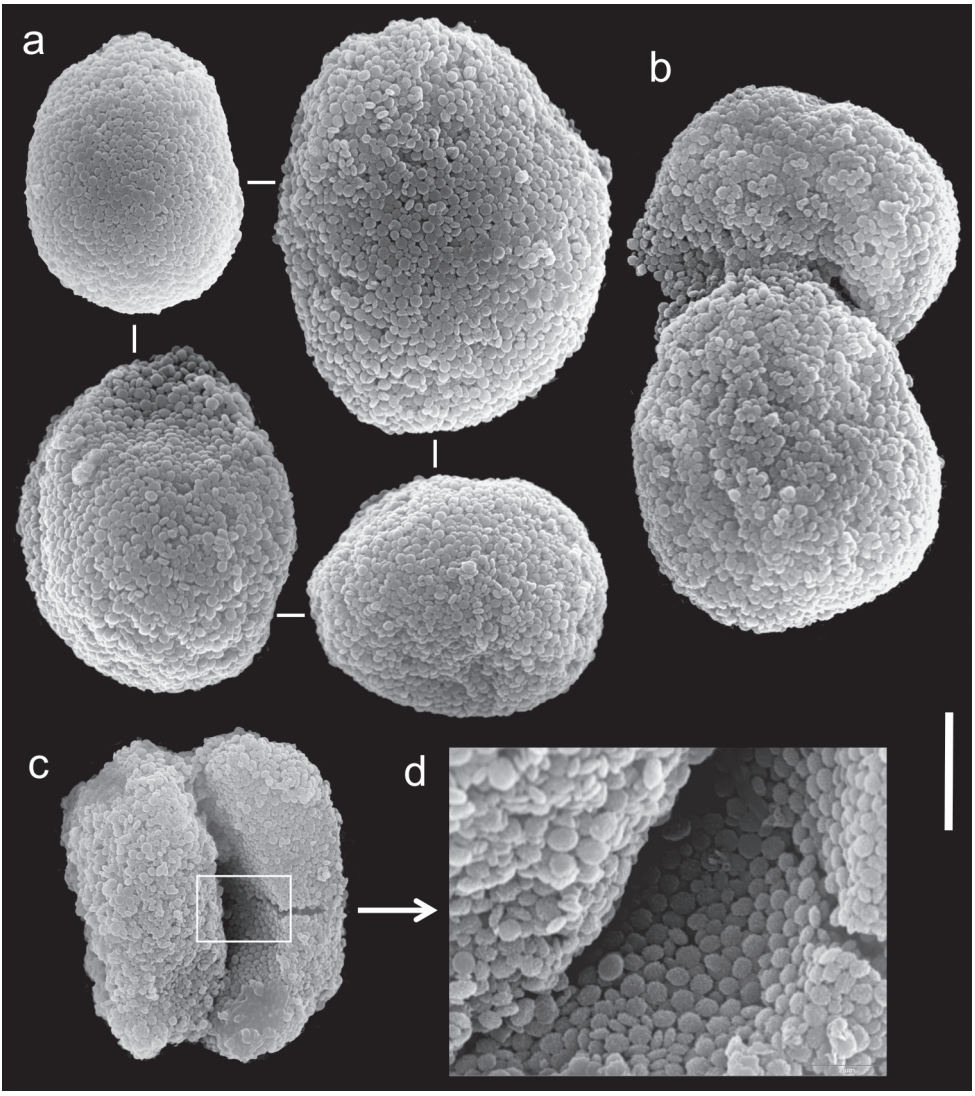

Figure 5. Scanning electron micrographs of polyp sclerites of *Xenia crista* Reinicke, 1997 holotype (RMNH 18677). **a** Regular sclerites **b–c** Fused sclerites **d** White rectangle in c indicates magnified area. Scale bar 10 µm.

tentacles are up to 10 mm long; pinnules up to 1.5–2 mm long and 0.2 mm wide, featuring one pinnule-width gap between adjacent pinnules. The tentacles have two rows of pinnules on each side, with 22–30 pinnules in the outermost row. Sclerites are *Ovabunda*-type (Fig. 5a), measuring 0.014–0.030 × 0.017–0.037 mm in diameter (n=48 sclerites). Occasionally, two sclerites are fused, reaching a maximal diameter of 0.042 mm (Fig. 5b, c).

The paratype of *X. crista* (RMNH Coel. 18678) features tentacles with two rows of pinnules and 26–29 pinnules in the outermost row. The sclerites are *Ovabunda*-type, 0.025–0.036 mm in maximal diameter. The original description of the species indicated non-pulsating polyps in live colonies.

Conclusions. Both the original description of *X. crista* and the current examination revealed two rows of pinnules; however, we found 22–30 pinnules in the holotype and 26–29 in the paratypes, compared to 29–33 and 28–32, respectively, in the original description. The taxonomic features of *X. crista* overlap those of *O. arabica* and, therefore, they should be considered as synonyms, giving an alphabetical priority to *O. arabica*.

Similar species. *O. arabica* is most similar to *O. faraunensis*. Although they both have two rows of pinnules and both have non-pulsating polyps in living colonies, the number of pinnules in the outermost row ranges from 24–29 in *O. arabica* compared to 17–24 in *O. faraunensis*.

Distribution. Red Sea: Gulf of Aqaba.

***Ovabunda benayahui* (Reinicke, 1995)**
http://species-id.net/wiki/Ovabunda_benayahui
Figs 6, 7

Xenia nana; Benayahu 1990: 117–118, fig. 3, table 1
Xenia benayahui Reinicke, 1995: 26–27, figs 1c, 15; 1997: 29, fig. 12, plate 16
Ovabunda benayahui; Alderslade 2001: 51; Janes 2008: 609–610, fig. 7

Material. Holotype and two paratypes (the holotype is the largest colony): RMNH Coel. 19664, northern Red Sea, Gulf of Aqaba, Saudi Arabian border bay, 20 km south to Aqaba (29°21'37.31"N, 34°57'39.48"E), 21 m, 3 October 1989, coll. G. B. Reinicke; **additional material:** ZMTAU Co 26043, northern Red Sea, Gulf of Suez, Shag Rock (27°47'13.59"N, 34° 0'22.61"E), 14 July 1987, coll. Y. Benayahu; ZMTAU Co 26044, northern Red Sea, Gulf of Suez, Southern tip of Sinai, Shaab el Utaf (27°45'9.00"N, 34°10'18.00"E), 10 m, 8 July 1986, coll. Y. Benayahu.

Description. The holotype is 25 mm high; stalk is 10 mm long, 6 mm wide at colony-base, and 15 mm wide at the uppermost part. The polyp's body is up to 4 mm long, and the tentacles up to 4 mm long, featuring a single row of 6–7 pinnules along each edge. The pinnules are short, up to 0.7 mm long and 0.4 mm wide with a 0.2–0.3 mm gap between adjacent pinnules. The sclerites are *Ovabunda*-type spheroids (Fig. 6a) and measure 0.019–0.035 × 0.027–0.041 mm in diameter (n=22 sclerites). When two sclerites are fused they measure up to 0.043 mm in maximal diameter (Fig. 6b). The original description indicated non-pulsating polyps in live colonies. The ethanol-preserved colony is light brown-beige.

Remarks. ZMTAU Co 26043, originally identified by Benayahu (1990) as *X. nana*, comprises 13 colonies up to 17 mm in height. Their stalks are not divided, and are up to 8 mm long, 8 mm wide at the base, and 10 mm wide at the uppermost part. Polyp's body reaches up to 1.4 mm in length, tentacles up to 1.6 mm, featuring a row of 5–6 closely set pinnules, 0.4 mm long and 0.16 mm wide. Sclerites are *Ovabunda*-type spheroids (Fig. 7a), 0.016–0.029 × 0.020–0.039 mm in diameter (n= 34 sclerites); some are egg-shaped (Fig. 7c) and sometimes two spheroids are fused (Fig. 7b). ZMTAU Co 26044 comprises several disintegrated small colonies, similar in size to those of ZMTAU Co 26043. There are 5–7 pinnules in a single row on each side of the tentacles. The sclerites are *Ovabunda*-

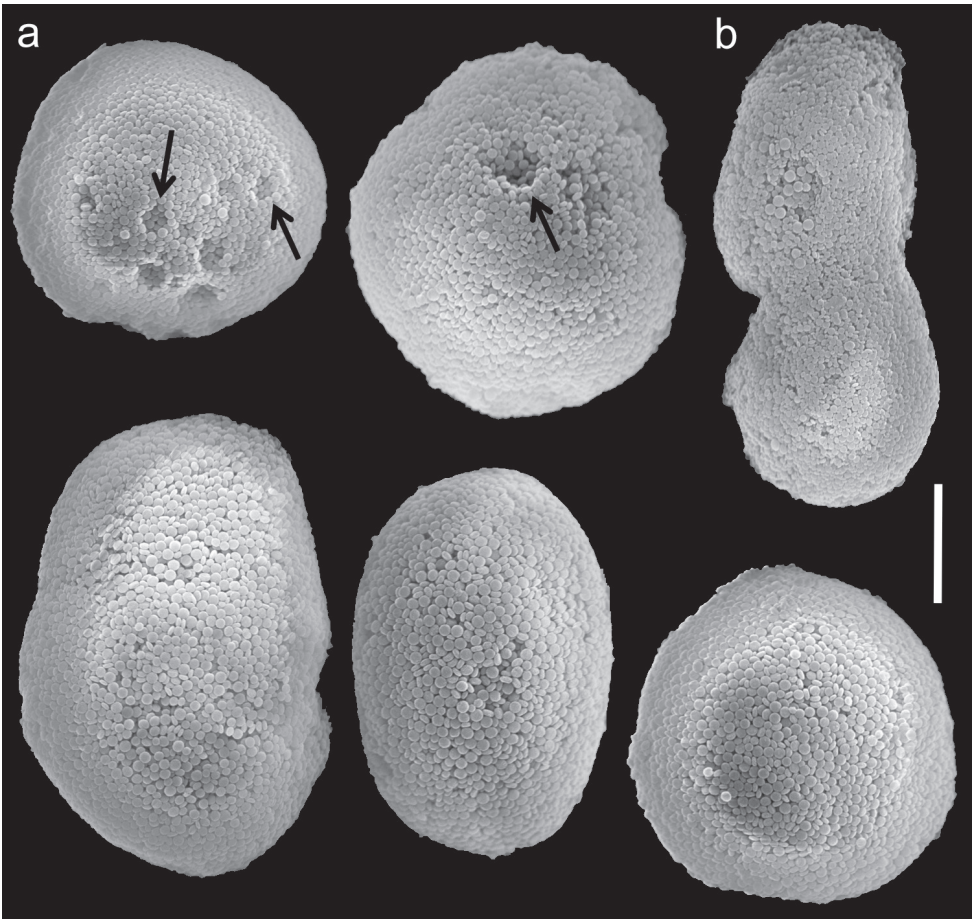

Figure 6. Scanning electron micrographs of polyp sclerites of *Ovabunda benayahui* (Reinicke, 1995) holotype (RMNH Coel. 19664). **a** Regular sclerites **b** Fused sclerite. Arrows indicate surface dents. Scale bar 10 μm.

type, 0.015–0.031 × 0.022–0.039 mm in diameter (n=34 sclerites). Polyp pulsation was not noted by Benayahu (1990). The colonies (ZMTAU Co 26043–26044) were misidentified as *X. nana* by Benayahu (1990) and should be reassigned to *O. benayahui*. The type of *X. nana* (BML 1939.6.12.9) was examined by the last author of the current paper and found to be of the genus *Aldersladum* Benayahu & McFadden, 2011.

Conclusions. The features of the holotype and paratypes of *O. benayahui* agree with the original description of the species, and the assignment to *Ovabunda* by Alderslade (2001) was confirmed in the current study.

Similar species. *O. benayahui* is most similar to *O. verseveldti*. Although they both have one row of pinnules, the numbers of pinnules in the outermost row ranges from 6–7 in *O. benayahui* compared to 12–18 in *O. verseveldti*.

Distribution. Red Sea: Gulf of Aqaba, Southern tip of Sinai Peninsula; Seychelles (see Janes 2008).

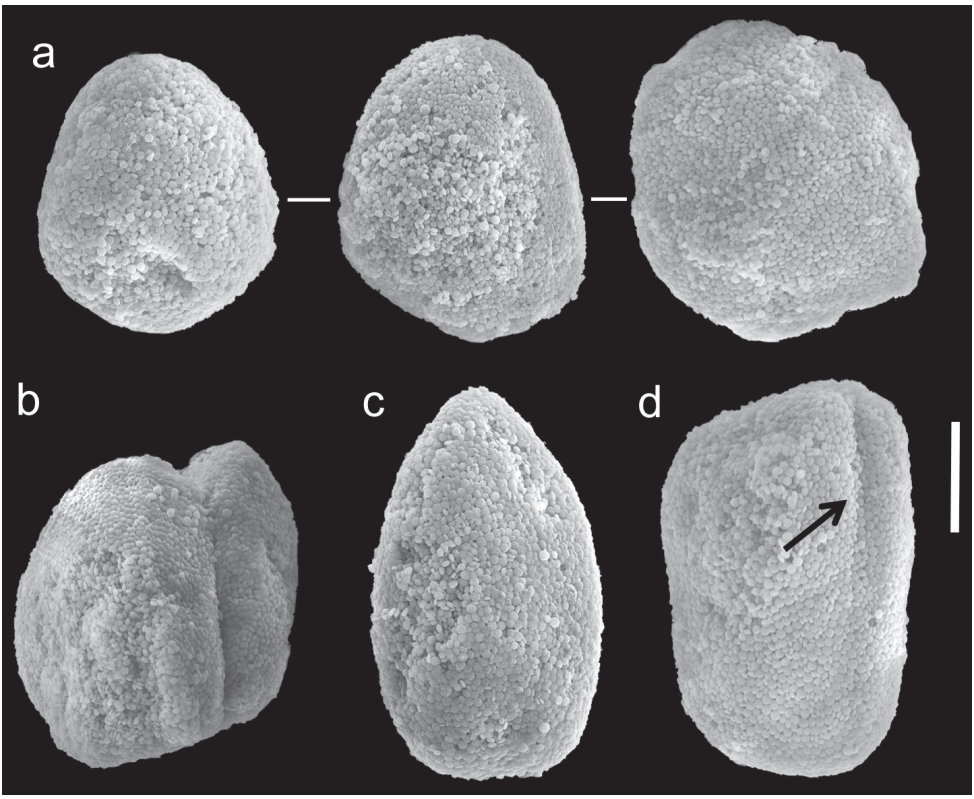

Figure 7. Scanning electron micrographs of polyp sclerites of *Ovabunda benayahui* Reinicke, 1995 (ZM-TAU Co 26043). **a** Regular sclerites **b** Fused sclerites **c** Egg-shaped sclerite **d** Rectangular sclerite. Arrow indicates surface crest. Scale bar 10 μm.

Ovabunda biseriata **(Verseveldt & Cohen, 1971)**
http://species-id.net/wiki/Ovabunda_biseriata
Figs 8, 9

Xenia biseriata Verseveldt & Cohen, 1971: 60, table 1; Benayahu 1990 table 1 listed only; Reinicke 1997: 33, plate 20
Xenia obscuronata Verseveldt & Cohen, 1971: 60, table 1, fig 10; Benayahu 1990 table 1 listed only; Reinicke 1997: 33, 35, plates 2, 4, 7, 21
Ovabunda biseriata; Alderslade 2001: 51; Aharonovich and Benayahu 2011
Ovabunda obscuronata; Alderslade 2001: 5, **syn. n.**

Material. Holotype and five paratypes: HUJ I Co. 72, northern Red Sea, Gulf of Aqaba, Marsa Murach (29°25'34.44"N, 34°50'10.46"E), 1–4 m, 15 September 1969, coll. Y. Cohen; **holotype of *O. obscuronata*** HUJ I Co. 120, northern Red Sea, Gulf of Aqaba, Ras el Muqebla (29°24'1.20"N, 34°48'41.99"E), 12 m, 16 August 1971, coll. Y. Cohen; **holotype of *X. ternatana*** SMF 43, Indonesia, Ternate island, 1894, coll. Kükenthal.

Figure 8. Scanning electron micrographs of polyp sclerites of *Ovabunda biseriata* (Verseveldt & Cohen, 1971) holotype (HUJ I Co. 72). Arrow indicates surface dents. Scale bar 10 μm.

Description. The holotype is 28 mm high, stalk is 15 mm long, 11 mm wide at its base and 10 mm wide at the uppermost part; it is attached to the skeleton of a stony coral. Polyp's body reaches up to 8–10 mm, and the tentacles 6–7 mm, bearing pinnules up to 1 mm long and 0.24 mm wide, separated by less than a pinnule-width. Two rows of pinnules are aligned along each of the tentacles margins, with 13–15 pinnules in the outermost row. There are numerous sclerites, abundant in all parts of the colony except for the mid-line of the oral side of the tentacles, where they are scarce. The sclerites are *Ovabunda*-type (Fig. 8), measuring 0.013–0.029 × 0.018–0.039 mm in diameter (n=100 sclerites). Rarely, two sclerites are fused, reaching a maximum diameter of 0.048 mm and occasionally 0.060 mm. The paratypes are of similar size to the holotype, featuring tentacles with two rows of pinnules and 13–16 pinnules in the outermost row. The stalk of the smallest paratype is divided into two branches; the paratype tentacles bear two rows of pinnules with 10–12 pinnules in the outermost row. The sclerites of all paratype colonies are *Ovabunda*-type, ranging 0.018–0.025 × 0.023–0.039 mm in diameter. The original description of the species indicated non-pulsating polyps in live colonies. The preserved colonies are yellowish-light beige in colour.

Remarks. In general the original description of the species corresponds to the current findings. SEM micrographs of the holotype sclerites (Fig. 8) indicate that they are indeed

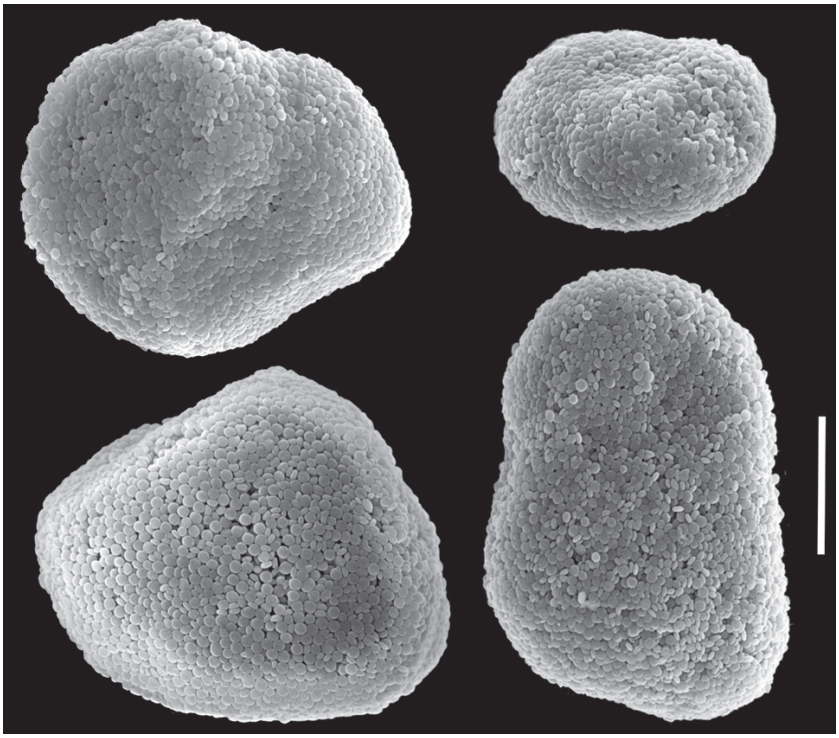

Figure 9. Scanning electron micrographs of polyp sclerites of *Ovabunda obscuronata* (Verseveldt & Cohen, 1971) holotype (HUJ I Co. 120). Scale bar 10 μm.

Ovabunda-type, and therefore further confirm the previous assignment to that genus (Alderslade 2001; Aharonovich and Benayahu 2011). The number of rows of pinnules, the number of pinnules in the outermost row, and the dimensions of the holotype colony of *O. obscuronata* (HUJ I Co. 120) correspond to the original description by Verseveldt and Cohen (1971). The sclerites are oval spheroids, *Ovabunda*-type, ranging 0.012–0.026 × 0.018–0.041 mm in diameter (Fig. 9, n=61 sclerites). Rarely, two sclerites are fused, reaching a maximal diameter of 0.060 mm. The original description indicated a maximum diameter of 0.045 mm for the stalk sclerites, 0.060 mm for those of the anthocodiae and "irregular spicules" in the tentacles (Verseveldt and Cohen 1971: 60). The latter probably referred to fused sclerites, which were not identifiable under light microscopy. The original description of *O. obscuronata* indicated non-pulsating polyps in live colonies, similar to *O. biseriata*. The ethanol-preserved holotype is light brown in colour.

Reinicke (1997) noted under the description of *X. obscuronata* (p. 33): "nec *Xenia ternatana*; Kükenthal 1913: 8 (in part)". The type of *X. ternatana* was examined during the present study and its features do not agree with those of *O. obscuronata*. *X. ternatana* features platelets composed of dendritic rods, measuring up to 0.022 mm in maximal diameter. It should be noted that the description of *X. ternatana* by Kükenthal also does not correspond to the features of *O. obscuronata*.

Conclusions. Examination of the holotype of *O. biseriata* and *O. obscuronata* revealed certain similarities, as already noted in the original description (Verseveldt and Cohen 1971): two rows of pinnules, with 12–15 *vs.* 14–16 pinnules, respectively, in the outermost row. The original description noted differences in the size of sclerites; 0.018–0.035 mm in *O. biseriata vs.* 0.045 mm in the stalk and anthocodiae and 0.060 mm in the tentacles of *O. obscuronata*. The current examination revealed a similar size range in the two species (0.013–0.029 × 0.018–0.039 *vs*. 0.012–0.026 × 0.018–0.041, respectively). Therefore, it is concluded that *O. biseriata* and *O. obscuronata* are in fact synonyms, giving alphabetical priority to the former.

Similar species. *O. biseriata* is most similar to *O. impulsatilla* and *O. faraunensis*. Although they all have two rows of pinnules and non-pulsating polyps in living colonies, the number of pinnules in the outermost row ranges from 13–16 in *O. biseriata* compared to 8–11 in *O. impulsatilla* and 17–24 in *O. faraunensis*.

Distribution. Red Sea: Gulf of Aqaba, Gulf of Suez, Sudan.

***Ovabunda crenata* (Reinicke, 1997), comb. n.**
http://species-id.net/wiki/Ovabunda_crenata
Fig. 10

Xenia crenata Reinicke, 1997: 41–42, figs 3c, 15; plates 5, 25

Material. Holotype: RMNH Coel. 23538, Sudanese Red Sea, Sanganeb Atoll, 20 km off Port Sudan, S-slope near jetty (19°21'33.81"N, 37°19'37.66"E), 10 m, April 1991, coll. G.B. Reinicke. **additional material:** RMNH Coel. 23517, Sudanese Red Sea, Sanganeb Atoll, lagoon slope, TQ II station, 8 m, March 1991, coll. G.B. Reinicke; **type of *X. viridis*** SMF 42, Indonesia, Ternate island, 1894, coll. Kükenthal; **type of *X. blumi*** SMF 44, Indonesia, Ternate island, 1894, coll. Kükenthal.

Description. The holotype is 30 mm high and 10 mm wide at its base. The stalk splits into two branches. The first is 15 mm long, 6 mm wide at its base and 10 mm wide at its uppermost part; the second splits further into two branches, 15 and 7 mm long, each 5 mm wide at the base, and 10 and 7 mm wide at the upper part, respectively. Polyp's body is up to 5 mm long and the tentacles up to 5 mm long. The pinnules are mostly arranged in two rows, with an occasional third row. There are 12–16 pinnules in the outermost row, 1 mm long and 0.14 mm wide, with a 0.2 mm space between adjacent pinnules. Sclerites are very scarce in all parts of the holotype; they are *Ovabunda*-type spheroids, measuring 0.012–0.028 × 0.018–0.036 mm in diameter (n=35 sclerites). Occasionally, two sclerites are fused, reaching 0.050 mm in maximal diameter. SEM micrographs of sclerites were obtained only from the additional material due to low density of sclerites in the holotype. Reinicke (1997) recorded non-pulsating polyps for the species. The ethanol preserved holotype is light beige.

Remarks. RMNH Coel. 23517 is similar in size to the holotype. Polyp's body is up to 2 mm long, with 2 mm long tentacles, mostly bearing two rows of 1 mm long

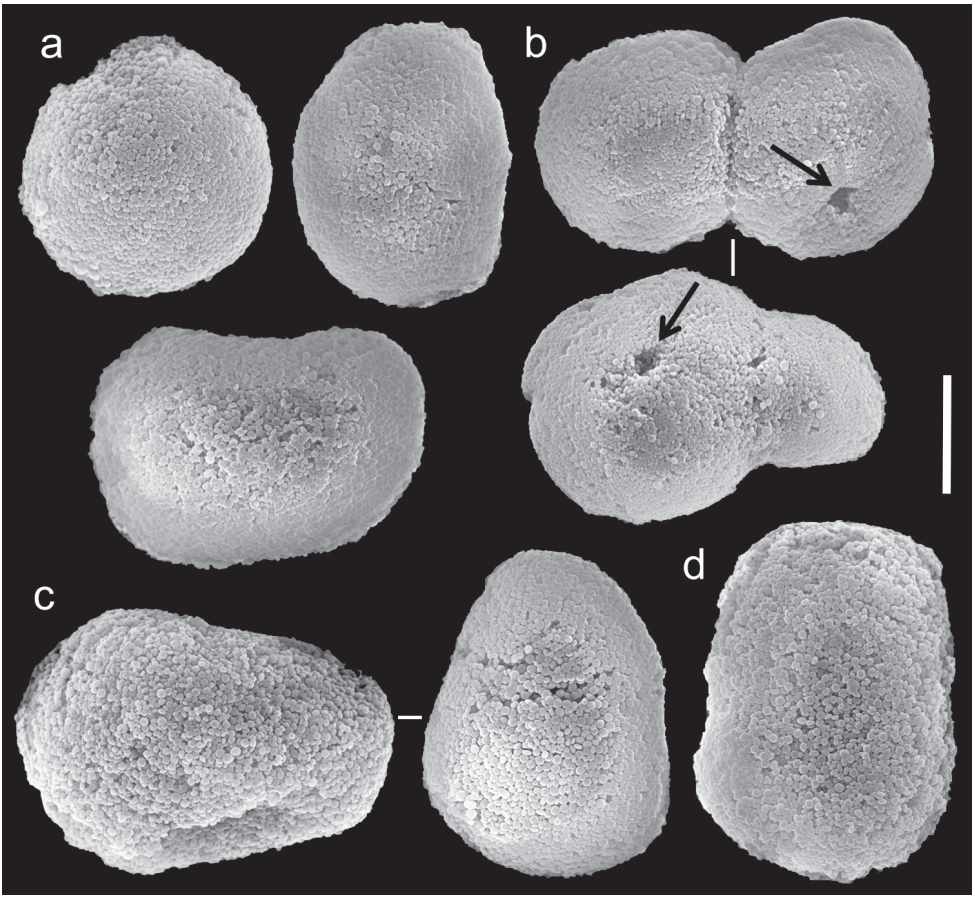

Figure 10. Scanning electron micrographs of polyp sclerites of *Ovabunda crenata* (Reinicke, 1997) (RMNH Coel. 23517). **a** Regular sclerites **b** Fused sclerites **c** Egg-shaped sclerites **d** Rectangular sclerite. Arrows indicate surface dents. Scale bar 10 μm.

and 0.1 mm wide slender pinnules on each of the tentacle sides, and, rarely, a third row. The outermost row features 12–15 pinnules, up to one pinnule-width apart. Sclerites are of the *Ovabunda*-type, varying in shape from regular (Fig. 10a), egg-shaped (Fig. 10c) and more rectangular (Fig. 10d), ranging 0.016–0.026 × 0.028–0.040 mm (n=25 sclerites) in diameter. Occasionally, two sclerites are fused, reaching 0.047 mm in maximal diameter (Fig. 10b).

Reinicke (1997) noted under the description of *X. crenata* sp. n. (p. 41): "*?Xenia blumi* Schenk 1896; Gohar 1940: 98, Plate 5" and "*Xenia blumi* Schenk 1896 sensu Gohar –Reinicke 1995: 42, Fig. 31". Reinicke (1997) also noted: "*?Xenia viridis* Schenk 1896; Benayahu 1990: 115 (listed)". The description of *X. blumi* according to Gohar (1940) does not match *O. crenata* features. Examination of the types of *X. blumi* and *X. viridis* during the current study (see Table 1) revealed them to have platelet-shaped sclerites composed of dendritic rods, and to differ from *O. crenata*.

Conclusions. The original description of the holotype indicated three rows of pinnules, whereas the present examination revealed mostly two rows, with an indication of a third one. There is agreement between our findings and the original description regarding the number of pinnules in the outermost row of the tentacles (12–16 *vs*. 12–15, respectively). Sclerites correspond to the original description in size but are *Ovabunda*-type spheroids; therefore, it is concluded that the species should be assigned to *Ovabunda.*

Similar species. *O. crenata* is most similar to *O. biseriata*. Although they both have overlapping number of pinnules in the outermost row, 12–16 and 13–16, respectively, *O. biseriata* has two rows of pinnules and *O. crenata* occasionally presents a third row. They both have non-pulsating polyps in live colonies.

Distribution. Red Sea: Gulf of Aqaba, Sudan.

***Ovabunda faraunensis* (Verseveldt & Cohen, 1971)**
http://species-id.net/wiki/Ovabunda_faraunensis
Fig. 11

Xenia faraunensis Verseveldt & Cohen, 1971: 62, table 1; Benayahu 1990 table 1 listed only; Reinicke 1997: 35, figs 3b, 9a-b, plates 2-4, 7, 22
Ovabunda faraunensis; Alderslade 2001: 51; Aharonovich and Benayahu 2011

Material. Holotype: HUJ I. Co. 140, northern Red Sea, Gulf of Aqaba, opposite Gezirat Fara'un (Coral Island) (29°27'46.95"N, 34°51'27.38"E), 18 m, 15 October 1969, coll. Y. Cohen.

Description. The holotype is 16 mm high; its stalk is 6-10 mm long, 4 mm wide at the base and 7 mm wide at its uppermost part. Polyp's body is up to 2-4 mm long and the tentacles 3-5 mm long, featuring two rows of pinnules on each side with 17-24 pinnules in the outermost row. The sclerites are *Ovabunda*-type spheroids (Fig. 11a), measuring 0.013–0.028 × 0.019–0.033 mm in diameter (n=46 sclerites). Occasionally, two sclerites are fused, reaching up to 0.044 mm in maximal diameter (Fig. 11b). Verseveldt and Cohen (1971) recorded non-pulsating polyps for this species. Colour of the ethanol-preserved holotype is beige.

Remarks. At the time of examination the holotype was dry, and therefore precise dimensions of the pinnules could not be obtained. The original description (Verseveldt and Cohen 1971: 62) indicated that: "The colony is 25 mm high. The stem is 15 mm high and 5–6 mm wide at the base, then narrows to 3–4 mm and widens again to 7 mm or more at the beginning of the polyparium. The anthocodiae are up to 10 mm long... the tentacles are 5–6.5 mm long". It is evident that the dimensions of the dried holotype are smaller than those of the original. The other features of the holotype recorded correspond to the original description, including two rows of pinnules, 17–24 pinnules in the outermost row, and sclerite diameter up to 0.044 mm (*vs*. 17–23 and 0.042 mm, in the original description). Reinicke (1997) presented a SEM micrograph of a single sclerite of *O. faraunensis* which later led Alderslade (2001) to assign it to the genus *Ovabunda*.

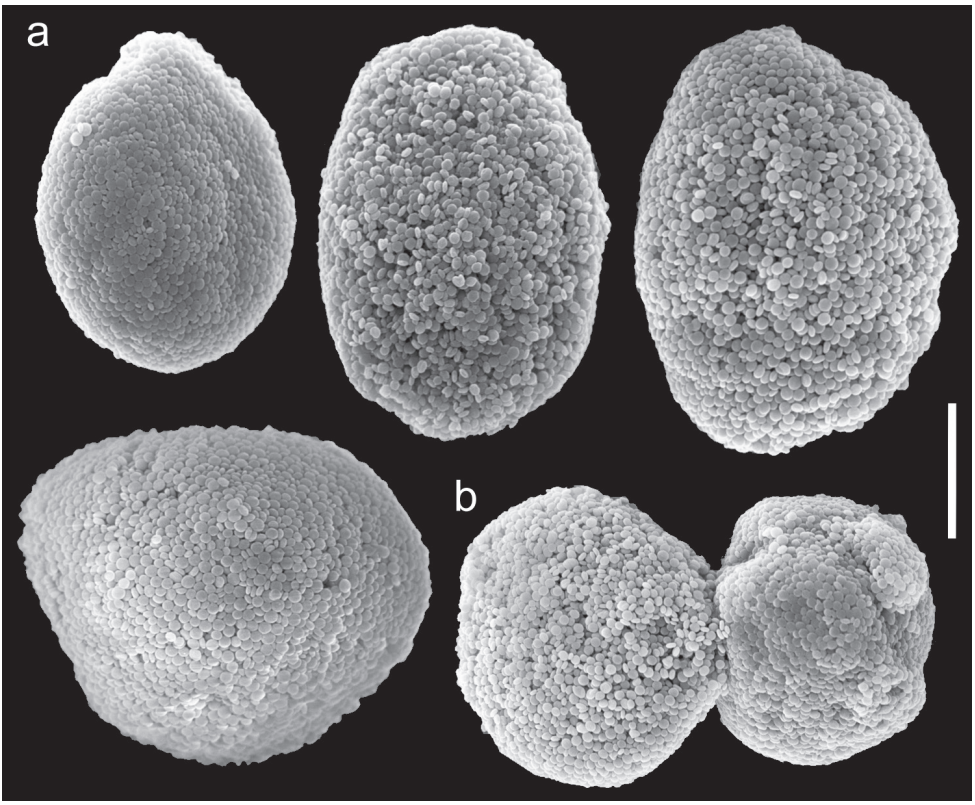

Figure 11. Scanning electron micrographs of polyp sclerites of *Ovabunda faraunensis* (Verseveldt & Cohen, 1971) holotype (HUJ I. Co. 140). **a** Regular sclerites **b** Fused sclerite. Scale bar 10 μm.

Conclusions. The current examination of the holotype (Fig. 11) along with the examination of the holotype by Aharonovich and Benayahu (2011), further confirmed the previous assignment.

Similar species. *O. faraunensis* is most similar to *O. arabica*. Although they both have two rows of pinnules and both have non-pulsating polyps in living colonies, the number of pinnules in the outermost row ranges from 17–24 in *O. faraunensis* compared to 24–29 in *O. arabica*.

Distribution. Red Sea: Gulf of Aqaba, Sudan (see Reinicke 1997).

***Ovabunda gohari* (Reinicke, 1997), comb. n.**
http://species-id.net/wiki/Ovabunda_gohari
Fig. 12

Xenia gohari Reinicke, 1997: 30–31, plate 18

Material. Holotype: RMNH Coel. 23435 and a **paratype:** RMNH Coel. 23436 northern Red Sea, Gulf of Aqaba, 10 km south to Aqaba, Nature Reserve (Agaba)

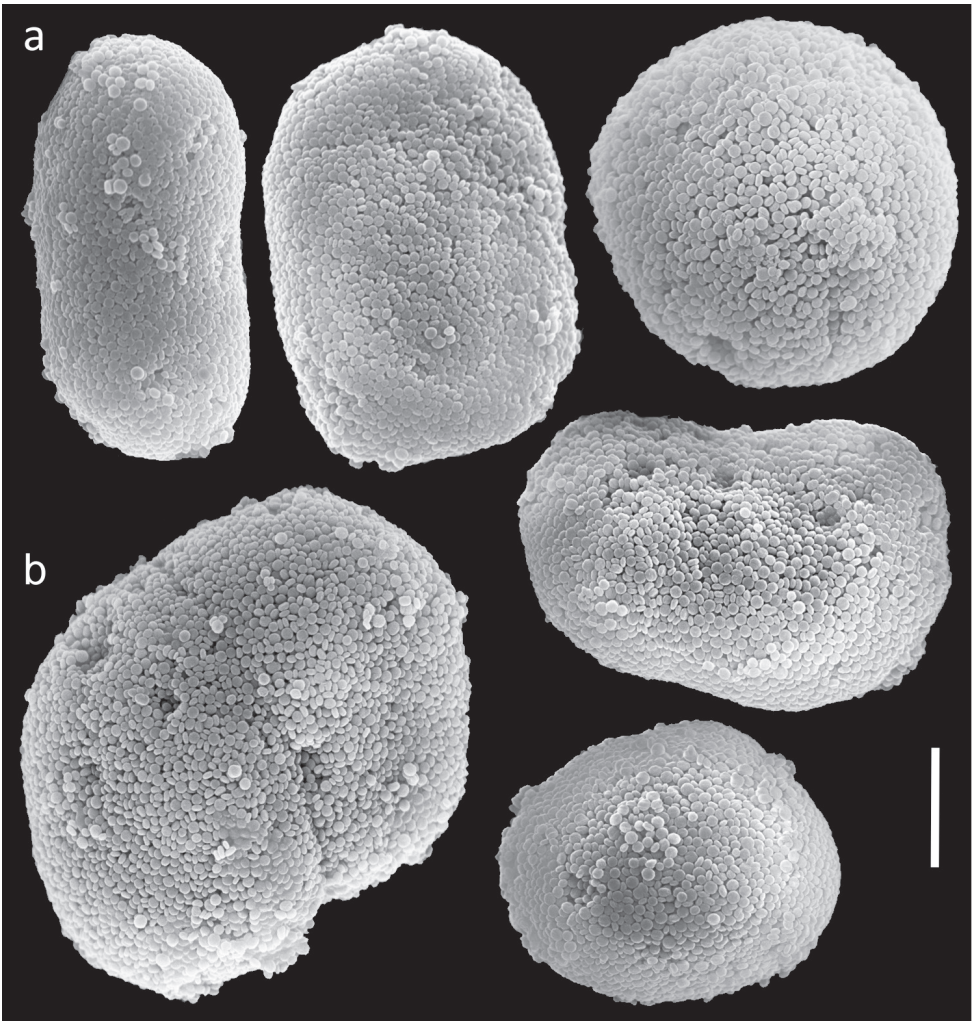

Figure 12. Scanning electron micrographs of polyp sclerites of *Ovabunda gohari* (Reinicke, 1997) paratype (RMNH Coel. 23436). **a** Regular sclerites **b** Fused sclerite. Scale bar 10 μm.

(29°26'29.03"N, 34°58'0.50"E), 10 m, November 1991 and 3 December 1991, respectively; coll. G. B. Reinicke.

Description. The holotype is 25 mm high; the stalk is 15 mm long, 10 mm wide at its base and 20 mm wide at its uppermost part and is divided into two. Polyp's body reaches 5 mm and the 11 mm long tentacles mostly feature a single row bearing 19–22, 3 mm long and 0.2 mm wide pinnules. The gap between the pinnules is up to twice their width; occasionally a second row exists and then the outermost row bears 19–22 pinnules. The gap between adjacent pinnules in the outmost row is almost twice their width, as in the case of a single row. The sclerites are *Ovabunda*-type spheroids, measuring 0.028–0.045 mm in diameter (Fig. 12).

The paratype is 18 mm long. Its stalk is divided into two branches, 8 mm and 4 mm long; each branch is 3 mm wide at its base, and 5 and 4 mm wide at the uppermost part, respectively. Polyp's body is up to 3 mm long, and tentacles 5–8 mm long, each have one row of 18–21 pinnules on each side; some small polyps have only 11–13 pinnules. The pinnules are up to 3 mm long and 0.24 mm wide at the base and the gap between the pinnules is up to twice their width. The sclerites (Fig. 12a) measure 0.015–0.035 × 0.028–0.055 mm in diameter (n=30 sclerites). Occasionally, two sclerites are fused, measuring up to 0.060 mm in maximal diameter; the fusion of sclerites can be partial or almost complete (Fig. 12b). The sclerites are more abundant at the base of the pinnules along the tentacle midline compared to their distal part, and similarly at the aboral side of the tentacles compared to their oral side. The original description indicated non-pulsating polyps in live colonies. The ethanol-preserved colony is light yellowish, beige.

Remarks. The current study confirmed the number of rows of pinnules and number of pinnules of the original description. Sclerite dimensions of the latter are larger than our findings, probably due to measurements that included fused sclerites.

Conclusions. The sclerites are *Ovabunda*-type spheroids and justify assignment to that genus.

Similar species. *O. gohari* is most similar to *O. faraunensis*. Although they both have overlapping number of pinnules in the outermost row, 18–22 and 17–24, respectively, *O. gohari* has mostly one row of pinnules and *O. faraunensis* presents two rows of pinnules. They both have non-pulsating polyps in live colonies.

Distribution. Red Sea: Gulf of Aqaba, Sudan (see Reinicke 1997).

***Ovabunda hamsina* (Reinicke, 1997)**
http://species-id.net/wiki/Ovabunda_hamsina
Fig. 13

Xenia hamsina Reinicke, 1997: 49-50; figs 20a–b, plate 30
Ovabunda hamsina; Janes 2008: 610–611

Material. Holotype: RMNH Coel. 23904, Sudanese Red Sea, Sanganeb Atoll, off Port Sudan, reef flat (19°21'33.81"N, 37°19'37.66"E), 6 April 1991, coll. G. B. Reinicke; **paratypes:** RMNH Coel. 23902, same data as above, April 1991; RMNH Coel. 25906, same locality SW corner, 15 m; RMNH Coel. 23553, Sudanese Red Sea, Sanganeb Atoll, lagoon slope near TQ II, 12 m, October 1992, coll. G. B. Reinicke; **additional material:** RMNH Coel. 23552, same locality, W-slope, TQ IV, 12 m, April 1991, coll. G. B. Reinicke; RMNH Coel. 25903, same locality, SE corner, reef flat; RMNH Coel. 25905 SW corner, 15 m; RMNH Coel. 23907, near southern jetty, 10 m; all April 1991, all coll. G. B. Reinicke; RMNH Coel. 23908, Indian Ocean, Madagascar, 1960, coll. M. Cherbounier, MNHN Oct.A.1993.16; **holotype of *X. grasshoffi*** SMF 2616, northern Red Sea, Gulf of Aqaba, Elat, 1 January 1968, coll. Grasshoff M.

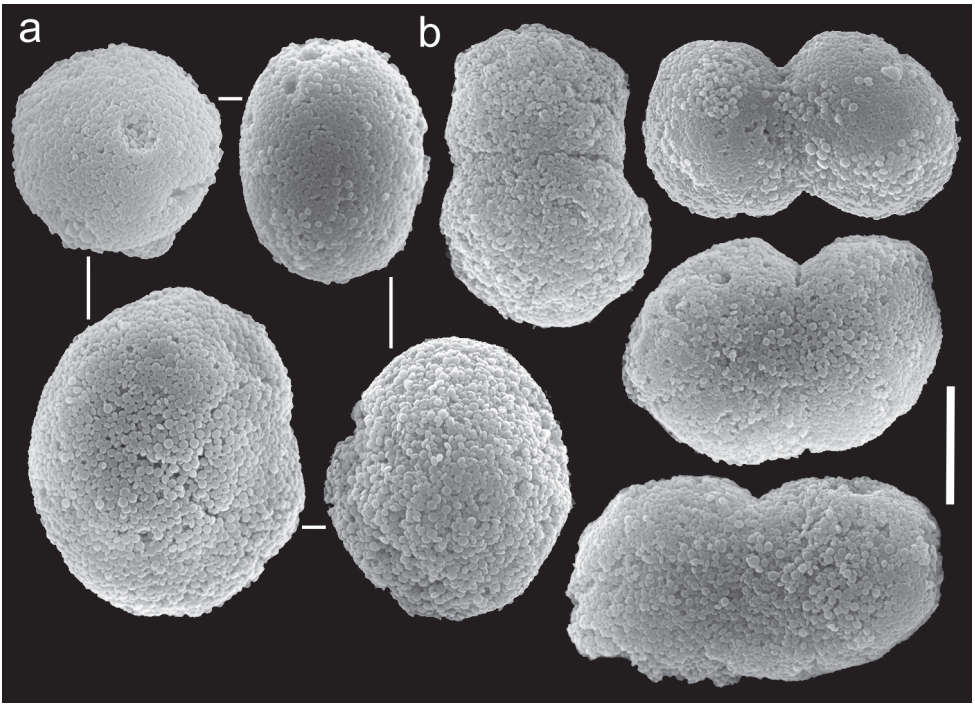

Figure 13. Scanning electron micrographs of polyp sclerites of *Ovabunda hamsina* (Reinicke, 1997) holotype (RMNH Coel. 23904). **a** Regular sclerites **b** Fused sclerites. Scale bar 10 μm.

Description. The holotype is 25 mm high and its stalk is 18 mm long, 15 mm wide at its base and 12 mm wide at its uppermost part. Polyp's body reaches up to 2 mm long; tentacles 5 mm long featuring three rows of 1 mm long and 0.16 mm wide pinnules, 19-21 in the outermost row. An incomplete fourth row is occasionally present. The pinnules are separated by a two-pinnule width space. The sclerites are *Ovabunda*-type (Fig. 13a), 0.015–0.025 × 0.016–0.035 mm in diameter (n=25). Occasionally, two sclerites are partially fused, reaching 0.034 mm in maximal diameter (Fig. 13b). The tentacles of the paratypes (RMNH Coel. 25902, 23533, 25906) bear three rows of pinnules on each side, with 19–22, 19–21 and 17–22 pinnules in the outermost row, respectively, and all feature *Ovabunda*-type sclerites. The original description indicated non-pulsating polyps in live colonies. The ethanol-preserved colony is light beige.

Remarks. The colonies RMNH Coel. 25905, 23907, 23908 feature three rows of pinnules with 17–22 pinnules in the outermost row. The tentacles of RMNH Coel. 23552 have four rows of pinnules and 18–21 pinnules in the outermost row; RMNH Coel. 25903 has three rows of pinnules with an indication of a fourth row, and 19–22 pinnules in the outermost row. All colonies feature *Ovabunda*-type sclerites.

Janes (2008) described *O. hamsina* from the Seychelles and the current findings confirm the assignment of *O. hamsina* to the genus *Ovabunda* based on sclerite microstructure.

Reinicke (1997) noted under the description of *X. hamsina* sp. n. (p. 49): "*Xenia* aff *grasshoffi* Reinicke, 1995: 59, Fig. 33". The type of *X. grasshoffi* was examined by us (see Table 1), and found to have the type of sclerites found in *Xenia* and clearly different from *O. hamsina*.

Similar species. *O. hamsina* is most similar to *O. ainex.* Although they both have overlapping number of pinnules in the outermost row, 17–22 and 15–20, respectively, *O. ainex* has three rows of pinnules and *O. hamsina* presents three and sometimes four rows of pinnules. They both have non-pulsating polyps in live colonies.

Distribution. Sudanese Red Sea, Madagascar, Seychelles (see Janes 2008).

***Ovabunda impulsatilla* (Verseveldt & Cohen, 1971)**
http://species-id.net/wiki/Ovabunda_impulsatilla
Figs 14, 15, 16

Xenia impulsatilla Verseveldt & Cohen, 1971: 59–60, table 1; Verseveldt 1974: 2 listed only; Benayahu 1990, listed only; Reinicke 1997: 32, plate 19
Xenia miniata Reinicke, 1997: 39–40 figs 17a-b, plate 24, **syn. n.**
Ovabunda aldersladei Janes, 2008: 613–614, figs 9–10, **syn.n.**
Ovabunda impulsatilla; Janes 2008: 611–613, fig. 8; Aharonovich and Benayahu 2011

Material. Holotype: HUJ I Co. 84 northern Red Sea, Gulf of Aqaba, near Solar Pond (Sinai), (29°25'44.43"N, 34°49'50.31"E), 2 m, 15 August 1969, Coll. Y. Cohen. Eight colonies on a sponge, one of them is the holotype. **Additional material: the holotype of *X. miniata*:** RMNH Coel. 23514, Sudanese Red Sea, Sanganeb Atoll, 20 km off Port Sudan, W-slope, TQ IV, (19°21'33.81"N, 37°19'37.66"E), 12 m, March 1991; **paratypes of *X. miniata*:** RMNH Coel 25412, RMNH Coel 25413, details as above, RMNH Coel. 25411, same location, SW-corner slope, TQ I, 12 m, March 1991, coll. G. B. Reinicke; RMNH Coel. 6848, northern Red Sea, gulf of Suez, El Tur (28°14'10.99"N, 33°36'51.06"E), 6 July 1969, coll. L. Fishelson; RMNH Coel. 6847, same details; RMNH Coel. 8938, same details, Abu Durbah (28°28'27.56"N, 33°19'30.13"E); **the holotype of *O. aldersladei*** RMNH Coel. 38681, Indian Ocean, Seychelles, northern coast of Bird Island (03°42'S; 55°12'E), <30 m, 21 December 1992, Tyro expedition; type of ***X. ternatana*** SMF 43, Indonesia, Ternate island, 1894, coll. Kükenthal; **type of *X. garciae*** BML 1921.11.18.1, Indian Ocean, Chagos Archipelago, coll. Diego Garcia; **RMNH Coel. 8938** Red Sea, Gulf of Suez, Abu Zanima; **RMNH Coel. 6847**, Red Sea, Gulf of Suez, El Tur, 6 July 1969, coll. L. Fishelson; **RMNH Coel. 6848**, same location, misidentified as *X. miniata*

Description. The now dry holotype is 18 mm high. The stalk is divided into two branches, 10 and 8 mm long, 6 and 4 mm wide at the base, and 8 and 4 mm wide at the uppermost part, respectively. Polyp's body is up to 2–2.5 mm long, and tentacles up to 1.5–2 mm, featuring two rows of pinnules on each side, with 8–11 pinnules in the outermost row. The sclerites are *Ovabunda*-type (Fig. 14a) and are almost evenly

Figure 14. Scanning electron micrographs of polyp sclerites of *Ovabunda impulsatilla* (Verseveldt & Cohen, 1971) holotype (HUJ I Co. 84). **a** Regular sclerites **b** Fused sclerites. Scale bar 10 μm.

distributed in all parts of the colony, measuring 0.013–0.028 × 0.019–0.039 mm in diameter (n=36 sclerites). Occasionally, two sclerites are fused, measuring up to 0.045 mm in maximal diameter (Fig. 14b). The original description stated that polyp pulsation in this species occurs in live colonies. The ethanol-preserved colony is light brown.

Remarks. At the time of examination the type was dry and, therefore, the dimensions of the pinnules are lacking and the current measurements do not reflect the original ones given by Verseveldt and Cohen (1971), who stated that "The colonies are 8–15 mm high and 10–15 mm wide. Three to four branches arise from a short stem 1–2 mm high. These branches, 2–3 mm high and 3–4 mm wide... The anthocodiae are 2 mm high and 1.2 mm wide, and tentacles are up to 2 mm long". We encountered three colonies, one with a branched stalk and two with undivided stalks. It is possible that they originally belonged to a colony that disintegrated. The current findings in general agree with the original description, although the maximal diameter of sclerites noted in the original description is larger than our findings (0.030 *vs.* 0.044 mm, respectively). A colony from the Seychelles was also assigned to *O. impulsatilla* by Janes (2008). The SEM micrographs of the holotype sclerites given by Aharonovich and Benayahu (2011), along with the current ones (Fig. 14), confirm that the species should be assigned to the genus *Ovabunda*.

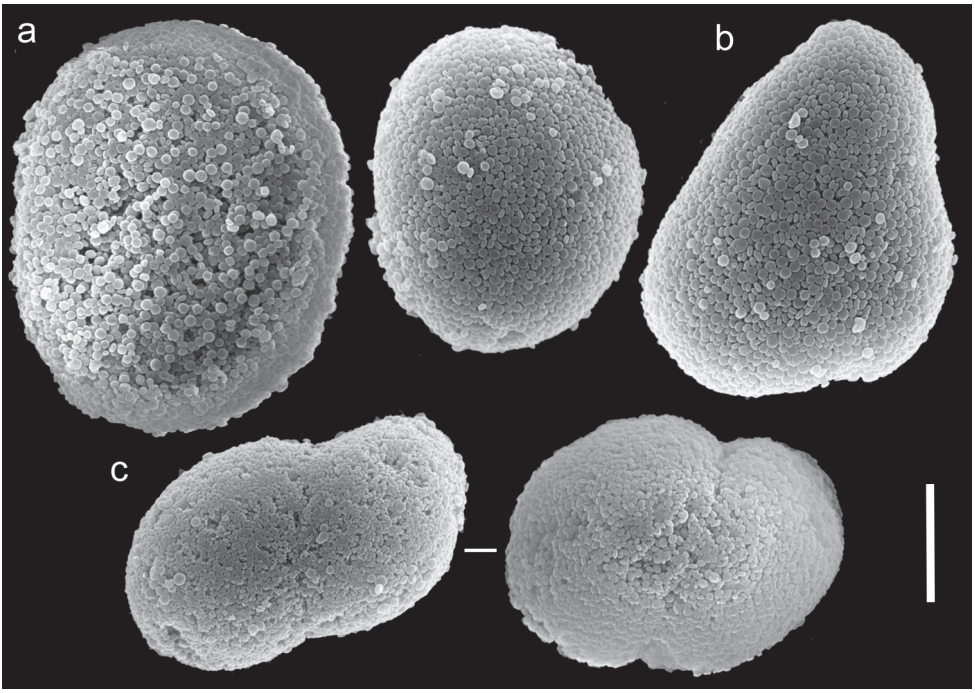

Figure 15. Scanning electron micrographs of polyp sclerites of *Xenia miniata* Reinicke, 1997 holotype (RMNH Coel. 23514). **a** Regular sclerites **b** Pear-shaped sclerite **c** Fused sclerites. Scale bar 10 μm.

The holotype of *X. miniata* (RMNH Coel. 23514) features two rows of pinnules on each side of the tentacles, with 8–13 pinnules in the outermost row. The sclerites are *Ovabunda*-type, some regular (Fig. 15a), some pear-shaped (Fig. 15b) measuring 0.017–0.034 × 0.022–0.053 mm in diameter (n=30 sclerites). Occasionally, two sclerites are fused, reaching 0.059 mm in maximal diameter (Fig. 15c). The paratypes of that species (RMNH 25411, 25412, 25413) feature tentacles with two rows, 11–13 pinnules in the outermost row and *Ovabunda*-type of sclerites, measuring 0.018–0.030 × 0.024–0.034 mm in diameter (n=24 sclerites). Although the original description of *X. miniata* indicated three rows of pinnules in the holotype and paratypes, we found only two rows. The original description of the species indicated non-pulsating polyps in live colonies. Colour of the ethanol preserved colony is beige. Consequently, we conclude that *X. miniata* should be synonymised with *O. impulsatilla*.

We also examined additional colonies that were identified by Reinicke (1997) as *X. miniata.* Specimen RMNH Coel. 6848 has two rows of pinnules, with 12–14 pinnules in the outermost row; its sclerites are *Ovabunda*-type, reaching up to 0.051 mm in maximal diameter. Based on sclerite size, number of pinnule rows and number of pinnules in the outermost row, this specimen should be reassigned to *O. biseriata*. Specimen RMNH Coel. 6847 has two rows of pinnules, with 10–11 pinnules in the outermost row; and its sclerites are also of the *Ovabunda*-type, reaching up to 0.045

Figure 16. Scanning electron micrographs of polyp sclerites of *Ovabunda aldersladei* Janes, 2008 holotype (RMNH Coel. 38681). Arrow indicates surface crest. Scale bar 10 μm.

mm in maximal diameter. RMNH Coel. 8938 has two rows of pinnules, but with only 8–9 in the outermost row; its sclerites are *Ovabunda*-type, reaching up to 0.047 mm in maximal diameter. Based on the number of rows of pinnules on the tentacles, the number of pinnules in the outermost row, and the size and microstructure of sclerites, the latter two colonies also belong to *O. impulsatilla*.

Our measurements of the dimensions of the holotype of *O. aldersladei* (RMNH Coel. 38681) agree with those of the original description. It features 3 mm long polyp's body, 2 mm long tentacles, with two rows of pinnules on each side, and 8–12 pinnules in the outermost row. The densely set pinnules are up to 0.6 mm long and 0.2–0.3 mm wide and with almost no gap between adjacent pinnules. The sclerites are *Ovabunda*-type spheroids (Fig. 16), measuring 0.012–0.030 × 0.018–0.042 mm in diameter (n=46 sclerites). Janes (2008) did not mention polyp pulsation for that species. The ethanol-preserved colony is light beige. The features of the holotype match the original description of *O. aldersladei*, except for sclerite size, which was found to be larger in our examination (up to 0.042 mm *vs*. up to 0.026 mm). The sclerites are indeed *Ovabunda*-type (Fig. 16), similar to those depicted by Janes (2008: fig. 10). Based on similarity between *O. aldersladei* and *O. impulsatilla* in number of rows (two in both), number of pinnules in the outermost row (8–12 and 8–11, respectively), and the size and microstructure of the sclerites it is concluded that the junior species *O. aldersladei* should be synonymized with *O. impulsatilla*, giving priority to the latter.

Reinicke (1997) noted under the description of *X. miniata* n.sp. (p. 39): "*Xenia ternatana* Schenk, 1896; Cohn 1908: 238 (ZMB 4991)" as well as: "nec *Xenia ternatana*; Kükenthal 1913: 8 (partim, NHMW C.16618)". These two colonies were not examined in the current study. However, the type of *X. ternatana* was examined (see Table 1) and found to have *Xenia* type sclerites. Moreover, Reinicke 1997 noted: "*Xenia garciae*; Verseveldt 1970: 210 (RMNH Coel. 6846–6848); Verseveldt 1974:2 (RMNH Coel. 8934, 8935, 8938); Reinicke 1995: 37, Fig 30". Several of the above mentioned colonies were found to be *O. impulsatilla* (see above), whereas the type of *X. garciae* presents *Xenia* type sclerites and thus is not a synonym of *O. impulsatilla*.

Similar species. *O. impulsatilla* is most similar to *O. biseriata*. Although they both have two rows of pinnules and non-pulsating polyps in living colonies, the numbers of pinnules in the outermost row ranges from 8–11 in *O. impulsatilla* and 13–16 in *O. biseriata*.

Distribution. Red Sea: Egypt, Sudan; Seychelles.

***Ovabunda macrospiculata* (Gohar, 1940)**
http://species-id.net/wiki/Ovabunda_macrospiculata
Figs 17, 18, 19

Xenia macrospiculata Gohar, 1940: 96–98; Benayahu 1990 table 1 listed only; Reinicke 1997: 42, plates 1–3, 29
Ovabunda macrospiculata; Alderslade 2001: 51, figs 29–30
Not *Xenia macrospiculata*; Verseveldt 1971: 64–65, fig. 39

Material. Neotype: ZMTAU Co 25635, northern Red Sea, Gulf of Suez, Shag Rock (27°47'1.48"N, 33°59'23.17"E), <5m, 11 July 1986, coll. Y. Benayahu. **Paratypes: ZMTAU** Co 35789 (field number A69) northern Red Sea, Gulf of Aqaba, Underwa-

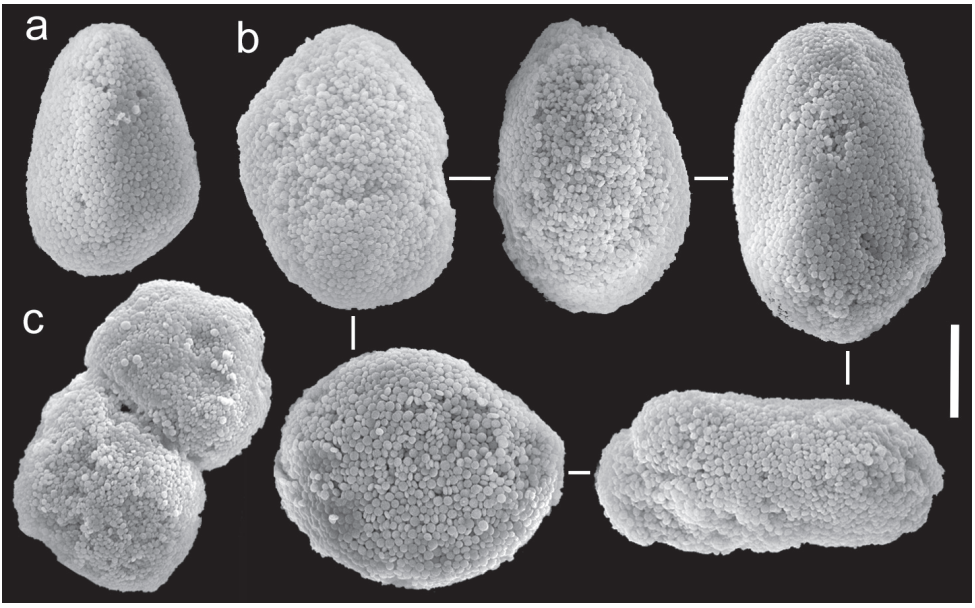

Figure 17. Scanning electron micrographs of polyp sclerites of *Ovabunda macrospiculata* (Gohar, 1940) neotype (ZMTAU Co 25635). **a** Pear-shape sclerite **b** Regular sclerites **c** Fused sclerite. Scale bar 10 μm.

ter Restaurant (29°32'49.43N; 34°57'14.51"E), 5 m, 3 May 2010, coll. A. Halász; ZMTAU Co 35790 (field number A70) northern Red Sea, Gulf of Aqaba, The Interuniversity Institute of Marine Sciences in Eilat (IUI) (29°30'6.54"N; 34°55'4.44"E), 22 m, 4 May 2010, coll. A. Halász; ZMTAU Co 35791 (field number A72), collection details as above, 9 m.

Description. The neotype is 20 mm high. Its stalk is 10 mm wide at its base, splitting into three branches, 7, 5 and 5 mm long; 5, 4 and 4 mm wide at the base and 10, 6 and 7 mm wide at the uppermost part, respectively. Polyp's body reaches up to 2 mm and tentacles up to 5 mm, bearing three, occasionally two, rows of pinnules. The pinnules are 1 mm long and 0.2 mm wide, with less than a pinnule-width space between them, and there are 15–17 pinnules in the outermost row on each side of the tentacle. The sclerites are *Ovabunda*-type, both regular and pear-shaped, measuring 0.015–0.025 × 0.023–0.041 mm (n=34, Fig. 17a, b). Occasionally two sclerites are fused, reaching 0.041 mm in maximal diameter (Fig. 17c).

The other specimens (ZMTAU Co 35789, 35790, 35791) are of similar size to the neotype; all with three rows of pinnules aligned on both sides of the tentacles, and 14–18, 14–17 and 14–17 pinnules in the outermost row, respectively. Their sclerites are of the *Ovabunda*-type and vary in shapes from regular to irregular, pear-shaped or fused. Their size ranges through 0.016–0.025 × 0.023–0.043 mm; 0.014–0.03 × 0.019–0.043 mm (Fig. 18) and 0.015–0.027 × 0.022–0.046 mm (Fig. 19) in diameter, respectively (n=21 for each colony).

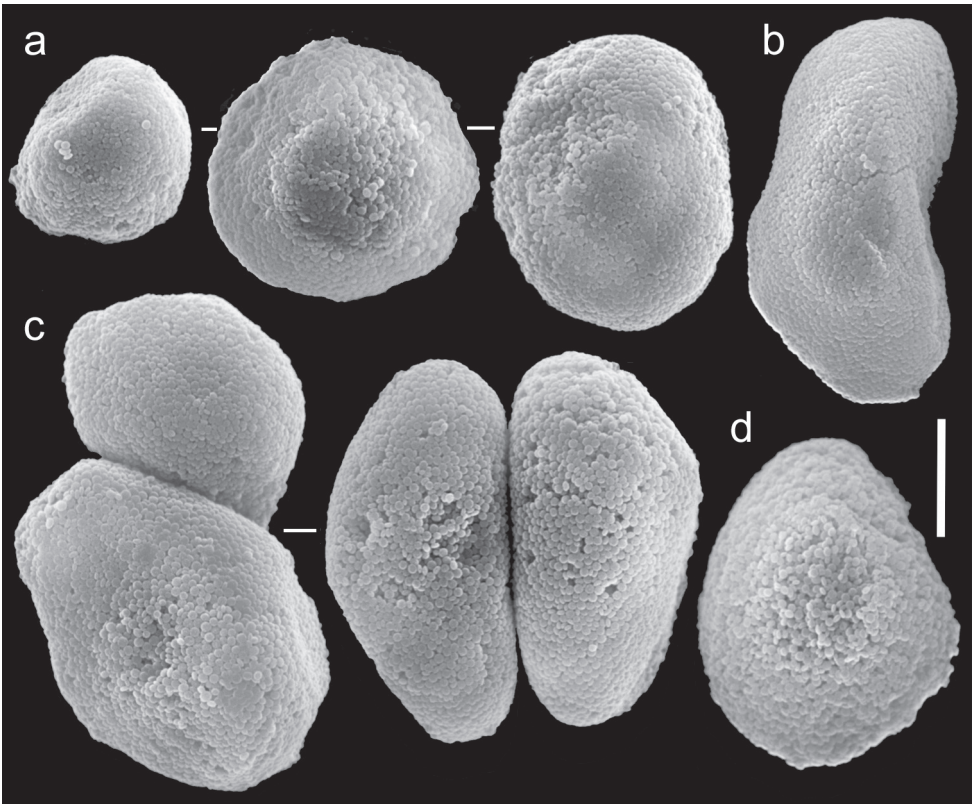

Figure 18. Scanning electron micrographs of polyp sclerites of *Ovabunda macrospiculata* (Gohar, 1940) paratype (ZMTAU Co 35790). **a** Regular sclerites **b** Irregular sclerite **c** Fused sclerites **d** Pear-shaped sclerite. Scale bar 10 μm.

Remarks. *X. macrospiculata* was originally described by Gohar (1940) from Ghardaqa, Egyptian Red Sea, as having pulsating tentacles, bearing three, occasionally two, rows of pinnules, with 12–16 pinnules in the outermost row (and 10–14 pinnules on the middle row, 0–10 on the oral one). That study did not indicate the museum in which the type was deposited. The last author of the current study searched in the museums listed in the Methods and found no trace of it; over time this type was probably lost. The designation of a neotype in this revision is thus necessary. The purpose of the designation is to clarify the species' taxonomic status and its assignment to *Ovabunda*. Although the sclerites were described quite accurately in the original description (0.024–0.036 mm in diameter, and "spicules fused in pairs"), SEM micrographs of the sclerites are essential as in the other species of the revision.

The neotype was collected in proximity to the collection site of the original specimen collected by Gohar. The neotype is located at ZMTAU, and available upon request for future examination.

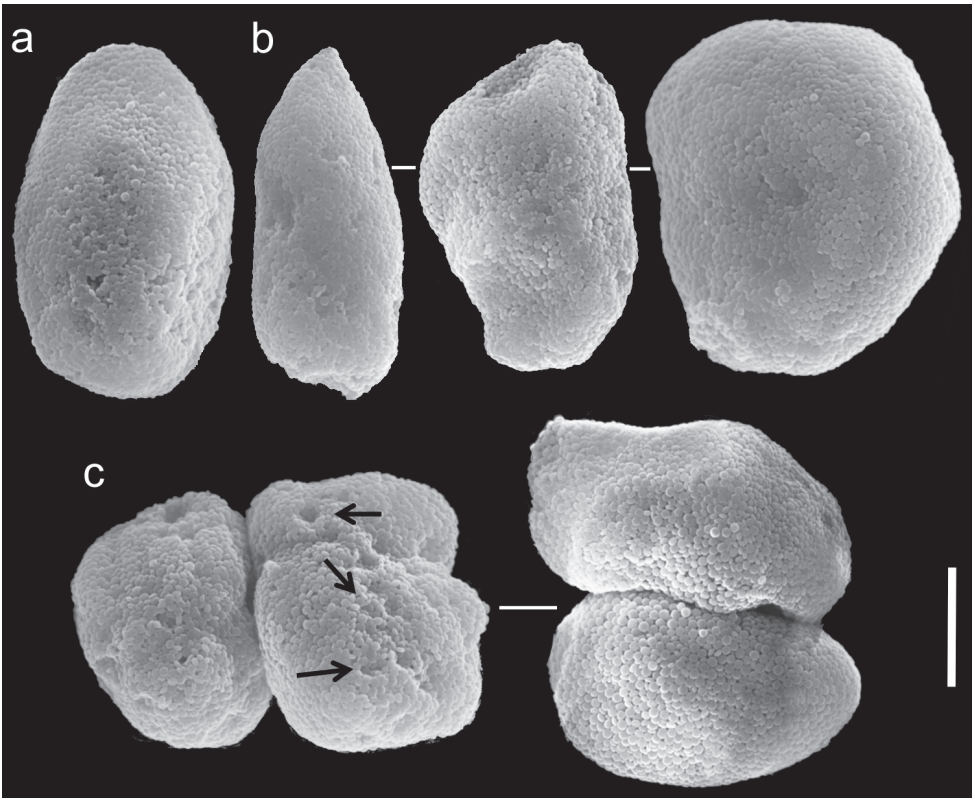

Figure 19. Scanning electron micrographs of polyp sclerites of *Ovabunda macrospiculata* (Gohar, 1940) paratype (ZMTAU Co 35791). **a** Regular sclerite **b** Irregular sclerites **c** Fused sclerites. Arrows indicate surface dents. Scale bar 10 μm.

O. macrospiculata was also described by Verseveldt (1971: 64–65, fig. 39) from Nosy Be, Madagascar, referring to three and sometimes four rows of pinnules with 12–16 pinnules in the outermost row, and sclerites 0.020–0.042 mm in maximal diameter. Examination of RMNH Coel. 6702 from that study revealed that its tentacles have mostly four, rarely three rows of pinnules, and 14–16 pinnules in the outermost row (Reinicke 2013, pers. comm.). During our study the sclerites were examined and they are indeed *Ovabunda*-type, measuring up to 0.043 mm in maximum diameter, while fused sclerites are 0.055 mm in diameter. Based on the number of rows of pinnules and the number of pinnules at the outermost row, we conclude that it does not agree with *O. macrospiculata*.

Similar species. *O. macrospiculata* is most similar to *O. ainex*. Although they both have three rows of pinnules, the numbers of pinnules in the outermost row ranges from 14–18 in *O. macrospiculata* compared to 15–20 in *O. ainex*. The major difference between them is that *O. macrospiculata* presents pulsating polyps in live colonies and *O. ainex* does not.

Distribution. Red Sea: Gulf of Aqaba, southern tip of Sinai Peninsula.

***Ovabunda verseveldti* (Benayahu, 1990)**
http://species-id.net/wiki/Ovabunda_verseveldti
Fig. 20

Xenia verseveldti Benayahu, 1990: 115–116, fig. 2, table 1; Reinicke 1997: 29–30, plate 16
Ovabunda verseveldti; Alderslade 2001: 49

Material. Holotype: ZMTAU Co 26048 and four paratypes: ZMTAU Co 31625 northern Red Sea, Gulf of Aqaba, Dahab (28°30'34.21"N, 34°31'18.26"E), 1 m, 9 November 1979, coll. Y. Benayahu.

Description. The holotype is 18 mm high; its stalk is 9 mm long, 5 mm wide at its base and 13 mm wide at its uppermost part. Polyp's body is 1–4 mm long, and the tentacles 6 mm long, bearing 1.8 mm long and 0.2 mm wide pinnules separated from each other by a small gap, less than one pinnule width. A single row of 14–18 pinnules is aligned on each side of the tentacles. There are numerous sclerites in all parts of the colony, densely packed in the pinnules and scarce in the mid-line of the tentacles' oral side. The sclerites are *Ovabunda*-type, varying in shape from regular spheroids (Fig. 20b) to egg-shaped (Fig. 20a) and more rectangular forms (Fig. 20c), measuring 0.014–0.033 × 0.022–0.046 mm in diameter (n=45). Rarely, two sclerites are fused, reaching a diameter of up to 0.051 mm (Fig. 20d).

The four paratypes (ZMTAU Co 31625) are smaller than the holotype, 12–17 mm high; the stalk is 10–15 mm long, 4–6 mm wide at the stalk base and 6–8 mm wide at the upper part. Polyp's body is up to 5 mm long, and tentacles up to 3 mm long, featuring one row of 12–17 pinnules on each side. The pinnules are 1.2 mm long and 0.2 mm wide at their base, densely set in each row, almost touching each other. The sclerites are *Ovabunda*-type, measuring 0.018–0.030 × 0.022–0.049 mm in diameter (n=38). Occasionally, two sclerites are fused, reaching a maximum size of 0.049 mm. The original description did not mention polyp pulsation. The ethanol-preserved colonies are light brown.

Conclusions. The features of the holotype and paratypes agree with the original description of the species. The species was assigned by Alderslade (2001) to *Ovabunda* (see Introduction) and this is confirmed in the current study.

Similar species. *O. verseveldti* is most similar to *O. benayahui*. Although they both have one row of pinnules the numbers of pinnules in the outermost row ranges from 12–18 in *O. verseveldti* compared to 6–7 in *O. benayahui*.

Distribution. Red Sea: Gulf of Aqaba, southern tip of Sinai Peninsula.

Discussion

The current study revises the genus *Ovabunda* Alderslade, 2001, following examination of relevant type material. Examination of the types has confirmed the previous

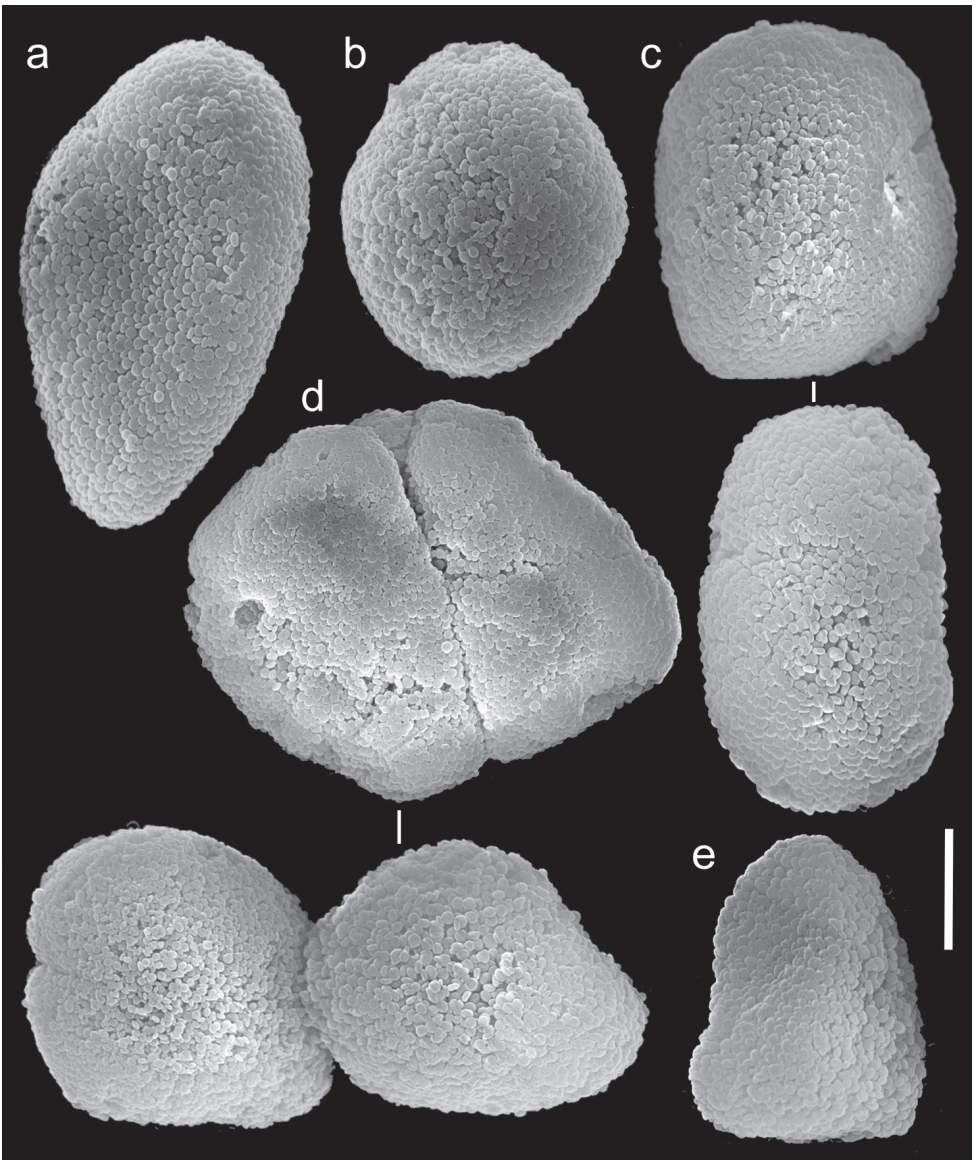

Figure 20. Scanning electron micrographs of polyp sclerites of *Ovabunda verseveldti* (Benayahu, 1990) holotype (ZMTAU Co 26048). **a** Egg-shaped sclerite **b** Regular sclerite **c** Rectangular sclerites **d** Fused sclerites **e** Irregular sclerite. Scale bar 10 μm.

assignment of the following four species to this genus: *O. benayahui*, *O. faraunensis*, *O. hamsina*, *O. verseveldti* (see Alderslade 2001; Janes 2008; Aharonovich and Benayahu 2011). It synonymizes another three species: *X. crista* with *O. arabica*; *O. obscuronata* with *O. biseriata*; and *X. miniata* and *O. aldersladei* with *O. impulsatilla.* In addition, three *Xenia* species are assigned for the first time to this genus: *X. ainex*, *X. crenata*

and *X. gohari,* and a neotype is designated for the lost type of *O. macrospiculata*, thus bringing the total number of *Ovabunda* species to 11. Moreover, examination of an additional 22 *Xenia* types (see Table 1) out of the 58 species listed in WoRMS (http://www.marinespecies.org/aphia.php?p=taxlist), including SEM of their sclerites, has furnished the required data for revision of that genus (Halász et al. in prep.).

The first taxonomic revision of the family Xeniidae was that by Kükenthal in 1902, who presented 26 *Xenia* species and five *Cespitularia*. That revision used various morphological features for the species description, such as colony dimensions, pinnule form, number of rows of pinnules and number of pinnules in the outermost row, and also specified the geographic distribution of each species. No details were given for the dimensions of the sclerites or their shape but occasionally their density or absence was noted. The subsequent revision by Hickson (1931a) listed 13 valid *Xenia* species, five *Cespitularia*, one *Heteroxenia*, and included a discussion of *Sympodium*. In that revision the number of rows of pinnules and the number of pinnules in the outermost row were presented for each species. Hickson pointed out the difficulty in counting the somewhat irregular rows along each edge of the tentacles, and referred to it as a general problem of the Xeniidae. In the current study we also encountered this difficulty (see Results: e.g., *O. crenata* and *O. hamsina*). Since Hickson's study (1931a), no revision has been published on any genus of the family Xeniidae. The above-mentioned two revisions failed to establish a standardized template for species descriptions within the family, which most probably hindered further attempts to carry out such a revision.

Here we discuss the reliability of each of the characteristics used to diagnose species, according to the order they appear in the species descriptions for each species. Colony dimensions as presented in the current study might in part be determined by age (Verseveldt 1960: 242) and environmental factors (Meestert et al. 2001) and also change according to collection and preservation conditions. Such dimensions might also exhibit a wide variation within a given species (Gohar 1940), therefore we doubt their value in species-specific taxonomic descriptions. However, pinnule length and width and the gap between adjacent pinnules are suggested here as a diagnostic trait: e.g. in *O. arabica* and its synonym *X. crista*, which had 1.8–2.2 mm long, 0.2 mm wide pinnules, with one pinnule-wide gap between adjacent ones. Similar to other studies (e.g., Gohar 1940, Verseveldt and Cohen 1971, Benayahu 1990, and Reinicke 1997), the number of pinnule rows and the number of pinnules in the outermost row are suggested to be of major taxonomic importance for species distinction, and the key (see above) is mainly based on these features.

The application of SEM for octocoral taxonomic studies, and Xeniidae in particular, has significantly increased the resolution of sclerite imaging and led to the establishment of new taxa based on their microstructural features (e.g. *Ovabunda* Alderslade, 2001; *Fasciclia* Janes, 2008; *Yamazatum* Benayahu, 2010). In the current study, SEM revealed for *Ovabunda* species the full shape and size range of the spheroidal sclerites including fused ones. The latter type of sclerite is found in all species, although sometimes rare (as in the case of *O. verseveldti*). For each species the dimensions of the individual sclerites and the fused ones are presented, which together are necessary for

future species description. The range of the smallest diameter of the single *Ovabunda* spheroids was found to be similar in all the types, ranging 0.026–0.035 mm (e.g., *O. ainex*: Fig. 3, *O. biseriata*: Fig. 8). Their maximal diameter is mostly 0.035–0.040 mm (e.g., *O. benayahui*: Figs 6–7; *O. macrospiculata*: Figs 17–19; *O. gohari* Fig. 12); and in some species, such as *O. gohari* (Fig. 12) and *O. verseveldti* (Fig. 20), they occasionally reach a larger size, up to 0.046–0.055 mm. It is important to emphasize that these larger sclerites are rare in the above-mentioned types, which mainly have sclerites within a range of 0.035–0.040 mm. In order to present the actual range of sclerite sizes we measured at least 20 sclerites from each colony, a standard that we recommend for future studies. The lack of such a detailed account in past studies has led to taxonomic errors, as in the establishment of *O. aldersladei* (Janes 2008: sclerite maximal diameter range 0.018–0.026 mm), which is in fact a synonym of *O. impulsatilla* (sclerite maximal diameter range 0.018–0.042, Fig. 16). It should also be noted that only high-quality and sharp SEM images of *Ovabunda* sclerites reveal the morphological features of the sclerites, composed of corpuscular microscleres that are diagnostic for that genus. The current findings reveal that *Ovabunda* species feature spheroids of various sizes (e.g., *O. benayahui*: Fig. 6, *O. gohari*: Fig. 12), and shapes, some of which are regular, spherical (e.g. *O. ainex*: Fig. 3a, *O. faraunensis*: Fig. 11a) and others less so (e.g., *O. macrospiculata*: Fig. 18b; *O. verseveldti*: Fig. 20e; *O. ainex*: Fig. 3c). The sclerites in the latter species can be pear-shaped, or egg-shaped, or more rectangular (e.g. *X. miniata*: Fig. 15b, *O. faraunensis*: Fig. 20a; *O. benayahui*: Fig. 7d, respectively). Occasionally the sclerites feature surface dents or crests (e.g., *O. crenata*: Fig. 10; *O. macrospiculata*: Fig. 19c; *O. ainex*: Fig. 3; *O. benayahui*: Fig. 7). There is no apparent correlation between these different shapes and the different species and therefore sclerite shape has not been included in the key (see above). Prior to the current study, SEM micrographs and detailed sizes of fused sclerites were never recorded in *Ovabunda* species, and were recognized by light microscopy only in the original descriptions of *O. macrospiculata* (Gohar 1940) and *O. obscuronata* (Verseveldt and Cohen 1971). In most studies the fused sclerites were erroneously considered to be large individual sclerites, giving them a size of up to 0.060 mm in maximal diameter (e.g. *O. benayahui*, *O. crenata*: Reinicke, 1997). In the case of the fused sclerites, the use of SEM has enabled the full range of shapes to be captured, including some that were almost fully fused and could not be detected using light microscopy (e.g., *O. benayahui*: Figs 6b and 7b; *O. gohari*: Fig. 12b), partially fused figure-eight shapes (*X. crista*: Fig. 5b; *O. impulsatilla*: Fig. 14b), or spheroids with only a medial narrowing (*O. hamsina*: Fig. 13b). Undoubtedly, when measuring sclerites under a light microscope, the existence of both individual spheroids and fused ones should be taken into account. The occurrence of fused sclerites and their significance to the taxonomy of the genus and other xeniid genera should be further examined.

Polyp pulsation of living xeniid colonies was first noted by Lamarck (1816) (in: Kremien et al. 2013) and later by Hickson (1931a: 154) and Gohar (1940: 82–83). This feature was considered indicative for species identification. Recently, Kremien et al. (2013) found that such pulsation increases photosynthesis, which in absolute en-

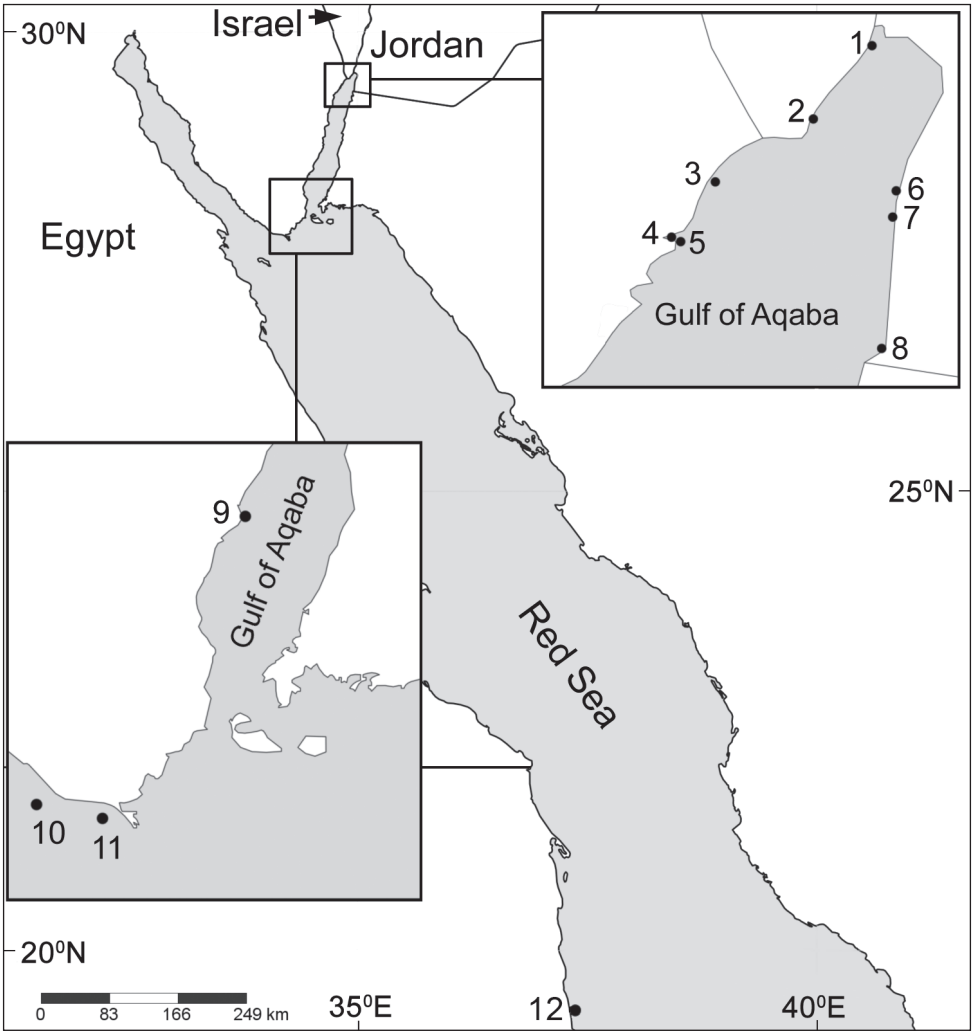

Figure 21. Distribution map of type localities of *Ovabunda* species. Areas of small rectangles are represented in respective large ones: **1** Underwater Restaurant, Eilat **2** The Interuniversity Institute of Marine Sciences (IUI), Eilat **3** opposite Gezirat Fara'un **4** Solar pond **5** Marsa Murach **6** Marine Science Station, Jordan **7** Nature reserve, Jordan **8** Saudi Arabia border bay **9** Dahab **10** Shag Rock **11** Shaab el Utaf **12** Sanganeb Atoll.

ergy gain greatly surpasses the added metabolic cost. Since 1940 it has been noted in most descriptions of *Xenia* and *Heteroxenia* species (e.g. Gohar 1940, Verseveldt and Cohen 1971; Reinicke 1995, 1997). Among *Ovabunda* species the state of pulsation (absence/presence) in living colonies has been noted for all species (Gohar 1940, Verseveldt and Cohen 1971; Reinicke 1995, 1997), except *O. verseveldti*. As in previous studies, we consider the pulsation state of living colonies an important characteristic and we recommend recording it when collecting colonies. Hickson's revision (1931a) and several later publications (e.g., Benayahu 1990; Reinicke 1997; Janes 2008) noted

the color of the colonies. We doubt color is of taxonomic value, however, since it can change with preservation, and also depends on the type and density of the symbiotic zooxanthellae (Berner et al. 1987, Siebeck et al. 2006). We have also noted that sclerite density and distribution affect tissue coloration (Reinicke 1997: 18).

The current study indicates that the Red Sea is the type locality of most *Ovabunda* species (Fig. 21). Some species, such as *O. hamsina*, *O. impulsatilla*, and *O. macrospiculata*, were also recorded in the West Indian Ocean (e.g., Madagascar and the Seychelles). The possibility that the genus has a wider distributional range is not excluded, and remains to be confirmed by re-examination of already collected material deposited in various collections, or of freshly collected material from throughout the Indo-Pacific basin.

Re-examination and appropriate re-descriptions of octocoral type material, as conducted in the current study, is highly important in an era of molecular phylogeny and increasing phylogeographic studies, despite the difficulty or inability to extract DNA from the types themselves. This kind of comprehensive study based mainly on type material is a critical first step in the process of understanding phylogenetic relationships among species and genera, and their ecology. Due to similar morphologies in the case of *Xenia* and *Ovabunda*, further analysis is needed in order to reveal their radiation, especially in regions where they have a sympatric distribution. There is also a need to validate the current *Ovabunda* species, through an integrated taxonomic effort, combining molecular genetic evidence of species boundaries, ecological, and reproductive differences.

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References

Aharonovich D, Benayahu Y (2011) Microstructure of octocoral sclerites for diagnosis of taxonomic features. Marine Biodiversity 42(2): 173–177. doi: 10.1007/s12526-011-0102-3

Alderslade P (2000) Four new genera of soft corals (Coelenterata: Octocorallia), with notes on the classification of some established taxa. Zoologische Mededelingen, Leiden 74(16): 237–249.

Alderslade P (2001) Six new genera and six new species of soft corals, and some proposed familial and subfamilial changes within the Alcyonacea (Coelenterata: Octocorallia). Bulletin of the biological Society of Washington 10: 15–65.

Ashworth JH (1899) The structure of *Xenia hicksoni* nov. sp. with some observations on *Heteroxenia elizabethae* Kölliker. Quarterly Journal of Microscopical Sciences (N.S.) 42 (3): 245–304.

Ashworth JH (1900) Report on the Xeniidae collected by Dr. Willey. Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere, collected by Dr. A. Willey during the years 1895–1897: 509–530.

Benayahu Y (1990) Xeniidae (Cnidaria: Octocorallia) from the Red Sea with description of a new species. Zoologische Mededelingen, Leiden 64: 113–120.

Benayahu Y (2010) A new genus of a soft coral of the family Xeniidae (Cnidaria: Octocorallia) from Japan. Galaxea 12: 53–64. doi: 10.3755/galaxea.12.53

Benayahu Y, McFadden CS (2011) A new genus of soft coral of the family Alcyoniidae (Cnidaria, Octocorallia) with re-description of a new combination and description of a new species. ZooKeys 84: 1–11. doi: 10.3897/zookeys.84.781

Berner T, Achituv Y, Dubinsky Z, Benayahu Y (1987) Pattern of distribution and adaptation to different irradiance levels of zooxanthellae in the soft coral *Litophyton arboreum* (Octocorallia: Alcyonacea). Symbiosis 3: 23–40.

Bourne GC (1894) On the structure and affinities of *Heliopora coerulea*, Pallas. With some observations on the structure of *Xenia* and *Heteroxenia*. Philosophical Transactions of Royal Society (B) 186: 455–483. doi: 10.1098/rstb.1895.0009

Cohn M (1908) Alcyonacea von Madagaskar und Ostafrika. E. Schweizerbartsche Verlagsbuchhandlung, 206–244.

Ehrenberg C (1828) In: Hemprich F, Ehrenberg C (Eds) Symbolae physicae, seu icones et descriptiones corporum naturalium novorum aut minus cognitorum quae ex itineribus per Libyam, Aegyptium, Nubiam, Dongalam, Syriam, Arabiam et Habessiniam, pars zoologica II, animalia evertebrata exclusis insectis. Officina Academica, Berolina.

Ehrenberg CG (1834) Beitrage zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des rothen Meeres, Nebst einem Versuche zur physiologischen Systematik derselben. Abhandlungen der Koniglichen Akademie der Wissenschaften zu Berlin, 225–287.

Fabricius K, Alderslade P (2001) Soft Corals and Sea Fans: A Comprehensive Guide to the Tropical Shallow-Water Genera of the Central-West Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Townsville.

Gohar HAF (1940) Studies on the Xeniidae of the Red Sea. Their ecology, physiology, taxonomy and phylogeny. Publications of the Marine Biological station, Ghardaqa, (Red Sea) 2: 27–118.

Hickson SJ (1931a) The alcyonarian family Xeniidae, with a revision of the genera and species. Great Barrier Reef Expedition, 137–179.

Hickson SJ (1931b) Three species of Alcyonaria from the Gulf of Manaar. Bulletin of the Madras Government Museum. Natural History 1(2): 79–89.

Janes MP (2008) A study of the Xeniidae (Octocorallia, Alcyonacea) collected on the "Tyro" expedition to the Seychelles with a description of a new genus and species. Zoologische Mededelingen, Leiden 82(49): 599–626.

Kölliker A (1874) Die Pennatulide *Umbellula* und zwei neue Typen der Alcyonarien. Festschrift zur Feier des 25-Jährigen Bestehens der Physikalisch-Medicinischen Gesellschaft, 5–23.

Kremien M, Shavit U, Mass T, Genin A (2013) Benefit of pulsation in soft corals. Proceedings of the National Academy of Sciences (PNAS) 110(22): 8978–8983. doi: 10.1073/pnas.1301826110

Kükenthal W (1902) Versuch einer Revision der Alcyonarien: I. Die Familie der Xeniiden. Zoologisches Jahrbüch, Abteilung für systematic, Geographie und Biologie der Tiere 15: 635–662.

Kükenthal W (1909) Diagnosen neuer Alcyonarien. Zoologischen Anzeiger, Bd XXXV. 1/2

Kükenthal W (1913) Alcyonaria des Roten Meeres. In: Expeditionen S.M. Schiff "pola" in das Rote Meer. Zoologische Ergebnisse 29: 1–33.

Lamarck MC (1816) Les Caracteres Generauxet Particuliers de ces Animaux, leur Distribution, leur Classes, leurs Familles, leurs Genres, et la Citation des Principales Especes qui s'y Rapportent." Histoire Naturelle des Animaux sans Vertebres (2): 388–421.

Lamouroux JVF (1812) Memoires sur la montee et sur une nouvelle classification des polypiers coralligenes non entierement pierreux. Nouveau Bulletin Society Philomath. Paris, 181–188.

May W (1899) Beiträge zur Systematik und Chorologie der Alcyonaceen. Jenaische Zeitsch. Naturwiss 33 (Neue Folge 26): 1–180.

Meestert EH, Hilterman M, Kardinaal E, Keetman M, de Vries M, Bak RPM (2001) Colony size-frequency distributions of scleractinian coral populations: spatial and interspecific variation 209: 43–54.

Milne-Edwards H, Haime J (1850) A monograph of the British fossil corals. Pat I: Introduction, corals from the Tertiary and Cretaceous formation. Palaeontographical Society, London, LXXXV + 71 pp.

Quoy JRC, Gaimard P (1833) Zoophytes. In: Voyage de découvertes de l'Astrolabe executé par ordre du Roi, pendant les années 1826–1827–1828–1829, sous le commandement de M.J. Dumont d'Urville. Zoologie 4: 1–390.

Reinicke GB (1995) Xeniidae des Roten Meeres (Octocorallia, Alcyonacea). Beiträge zur Systematik und Ökologie. Essener Ökologische Schriften 6: 1–168.

Reinicke GB (1997) Xeniidae (Coelenterata: Octocorallia) of the Red Sea with descriptions of six new species of *Xenia.* Fauna of Saudi Arabia 16: 5–62.

Roxas HA (1933) Philippine Alcyonaria, the Families Cornulariidae and Xeniidae. The Philippine Journal of Science 50(1): 49–108.

Schenk A (1896) Clavulariiden, Xeniiden und Alcyoniiden von Ternate. Abhandlungen der Senkenbergischen naturforschenden Gesellschaft 23(1): 40–80.

Siebeck UE, Marshall NJ, Klüter A, Hoegh-Guldberg O (2006) Monitoring coral bleaching using a colour reference card. Coral Reefs 25: 453–460. doi: 10.1007/s00338-006-0123-8

Tixier-Durivault A (1970) Les octocoralliaires de Nouvelle-Calédonie.— L'Expédition française sur les récifs coralliens de la Nouvelle-Calédonie 4: 171–350. doi: 10.1007/s13127-012-0119-x

Utinomi H (1950) Some Xeniid Alcyonarians from Japan and Adjacent Localities. Publications of the Seto Marine Biological Laboratory 1(3): 7–17.

Utinomi H (1951) *Asterospicularia laurae*, n. gen. et n. sp., the type of a new family of Alcyonarians with stellate spicules. Pacific Science 5(2): 190–196.

Utinomi H (1955) Two new species of *Xenia* from Kusimoto (Coelenterata, Alcyonaria). Publications of the Seto Marine Biological Laboratory 4(2-3): 263–267.

Verrill AE (1928) Hawaiian shallow water Anthozoa. Bernice P. Bishop Museum Bulletin 49: 1–30.

Verseveldt J (1960) Biological results of the Snellius-Expedition XX. Octocorallia from the Malay Archipelago (Part 1). Temminckia 10: 209–251.

Verseveldt J (1970) Reports of some Octocorallia (Alcyonacea) from the northern Red Sea. Israel Journal of Zoology 19(4): 209–229.

Verseveldt J (1971) Octocorallia from North-Western Madagascar (Part II). Zoologische Verhandelingen (117): 1–73.

Verseveldt J (1974) Alcyonacea (Octocorallia) from Red Sea, with a discussion of a new *Sinularia* species from Ceylon. Israel Journal of Zoology 23(1): 1–37.

Verseveldt J, Cohen J (1971) Some new species of Octocorallia from the Gulf of Elat (Red Sea). Israel Journal of Zoology 20: 53–67.

Verseveldt J, Tursch A (1979) Octocorallia from the Bismarck Sea, Part 1. Zoologische Mededelingen, Leiden 11: 1–25.

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RESEARCH ARTICLE

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Contributions to the knowledge of the Chinese *Primeuchroeus* Linsenmaier, 1968 (Hymenoptera, Chrysididae), with a key to species

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Abstract

The genus *Primeuchroeus* Linsenmaier, 1968 from China is revised and an illustrated identification key is produced for the first time. Three species are recorded from China, with one species, *Primeuchroeus yongdaerianus* Kim, new to China.

Keywords

Chrysididae, *Primeuchroeus*, revision, new record, Oriental, China

Introduction

Primeuchroeus Linsenmaier belongs to the tribe Chrysidini of the subfamily Chrysidinae (Kimsey & Bohart, 1991). Bohart (1988) revised the genus and divided it into five species-groups, with a key to all known species at that time. More detailed diagnosis and discussion of each species-group was published later by Kimsey and Bohart (1991). Linsenmaier (1997) considered three species, *alces* Linsenmaier, 1968, *paradoxa* Linsenmaier, 1968 and *tenuimediata* Linsenmaier, 1968 belonged to the genus *Chrysis*. However, we follow the systematics proposed by Kimsey and Bohart (1991).

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Presently 33 species of *Primeuchroeus* are known worldwide (Kimsey and Bohart 1991; Kim 2013), of which 26 are from the Australian region, four are from the Oriental region, one is from the Palaearctic region, one is from both the Oriental and the Palaearctic regions, and one is from the Afrotropical region (Kimsey and Bohart 1991; Madl and Rosa 2012; Kim 2013).

In China, before this study, only two species have been recorded from Taiwan by Tsuneki: *Primeuchroeus crassiceps* (Tsuneki, 1970) and *Primeuchroeus kansitakuanus* (Tsuneki, 1970). In this study, three species are recognized, with one new to China.

Materials and methods

All specimens were examined and described under stereomicroscope (Olympus SZ61). All photos were taken with a digital camera (CoolSNAP) attached to a Zeiss Stemi 2000-CS stereomicroscope. Images were processed using Image-Pro Plus software.

Morphological terminology mainly follows Kimsey and Bohart (1991).

Abbreviations used in the descriptions as follows: F-I, F-II, F-III, etc. = flagellum I, flagellum II, flagellum III and so on; MOD = midocellar diameter; MS = malar space, the shortest distance between the base of mandible and the margin of compound eye; S-II spots = two oval dark spots on metasomal sternum II; TFC = transverse frontal carina; T-I, T-II, T-III, etc. = metasomal tergum I, tergum II, tergum III and so on.

All specimens are kept in the Hymenopteran Collection, South China Agricultural University, Guangzhou, China (SCAU) and the Shanghai Entomological Museum, Chinese Academy of Science, Shanghai, China (SEM).

Taxonomy

Genus *Primeuchroeus* Linsenmaier, 1968
http://species-id.net/wiki/Primeuchroeus

Primeuchroeus Linsenmaier 1968: 38. Type species: *Chrysis papuana* Mocsáry 1899. Linsenmaier 1982: 325; Bohart 1988: 21; Kimsey and Bohart 1991: 535; Kim 2013: 95.

Papuachrysis Linsenmaier 1968: 52. Type species: *Chrysis alces* Linsenmaier 1968. Synonymized by Kimsey and Bohart 1991.

Diagnosis. Scapal basin usually with fine transverse striae (Figs 3, 12, 21, 30). TFC often down-curved crescent, sometimes apparently double (Figs 21, 30), rarely flat or absent (Figs 3, 12). Subgenal area defined by carina. Mesopleuron without scrobal sulcus (Figs 6, 15, 24, 33). Forewing with Rs short and ending abruptly (Figs 5, 14, 32), or Rs long and

nearly complete (Fig. 23). Lateral margin of T-III edentate (Figs 9, 18, 36), dentate, or convex basally (Fig. 27). Apex of T-III usually round (Figs 7, 16, 34) or obtusely angled medially (Fig. 25), rarely tridentate. Female T-IV with coarse transverse ridges.

Key to the Chinese species of *Primeuchroeus* Linsenmaier

1 Forewing with Rs long, about two times as long as stigma, and bent sharply in the middle (Fig. 23); lateral margin of T-III convex, with a small tooth basally (Fig. 27) ..... ***P. kansitakuanus* (Tsuneki)**

– Forewing with Rs short, about half as long as stigma, and ending obtusely (Figs 5, 14, 32); lateral margin of T-III nearly straight, without tooth basally (Figs 9, 18, 36) **2**

2 TFC absent (Figs 3, 12); pronotum with an obtuse angle on each lateral margin (Figs 4, 13) ..... ***P. crassiceps* (Tsuneki)**

– TFC distinct and double (Fig. 30); pronotum with an indistinct angle on each lateral margin (Fig. 31) ..... ***P. yongdaerianus* Kim**

***Primeuchroeus crassiceps* (Tsuneki, 1970)**
http://species-id.net/wiki/Primeuchroeus_crassiceps
Figs 1–18

Chrysis crassiceps Tsuneki 1970: 8.
Primeuchroeus crassiceps (Tsuneki, 1970): Bohart 1988: 23; Kimsey and Bohart 1991: 541.

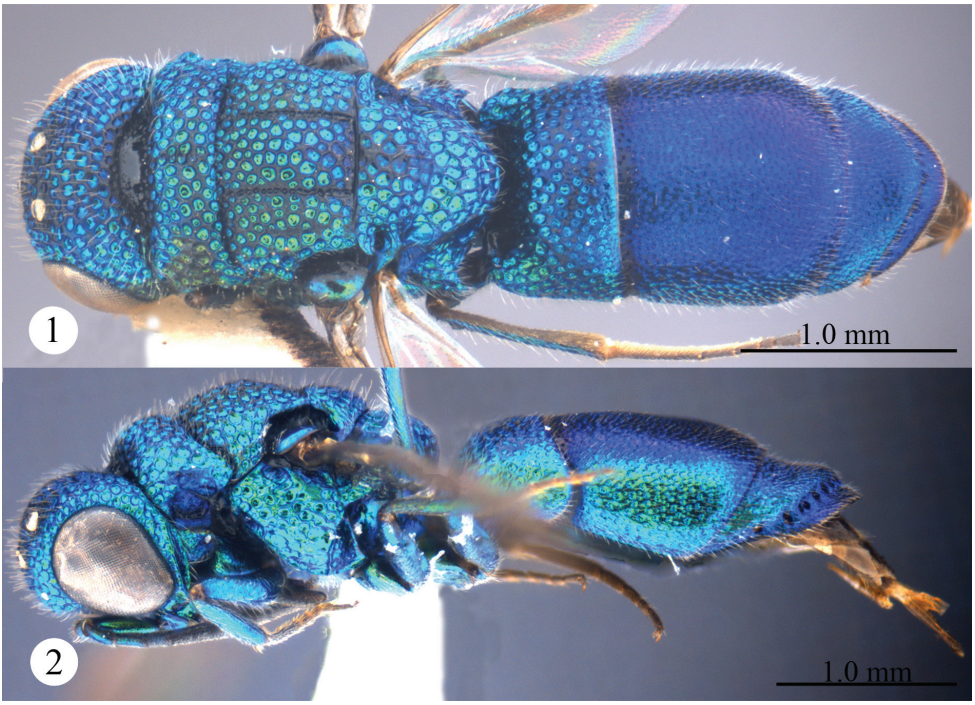
Materials. 1♀ (SCAU), Yunnan, Gaoligongshan National Nature Reserve (24°49'N, 98°46'E), 20–21.VII.2006, Jie Zeng, Juan-juan Ma & Bin Xiao leg., No. CP0038; 4♀♀+2♂♂ (SCAU), Yunnan, Gaoligongshan National Nature Reserve, Mailongxia (25°50'23"N, 98°51'23"E), 17.VIII.2005, Kai Wu leg., No. CP0039–0044.

Description. Described after a female from Yunnan. Body length 4.3 mm (Figs 1, 2). Forewing length 3.1 mm. MS = 0.7 MOD. F-I 2.0× as long as wide.

Head. Scapal basin deep and impunctate, with transverse striae and a round pit anteromedially (Fig. 3). F-I slightly longer than F-II (Fig. 3). TFC absent (Fig. 3).

Mesosoma. Pronotum with anterior declivity polished and impunctate between the two pits (Fig. 4); with an obtuse angle on each lateral margin (Fig. 4), with sublateral carina complete and lateral depression shallow (Fig. 6). Mesonotum with areolate punctures (Fig. 4). Mesopleuron without enlarged foveae along episternal sulcus (Fig. 6), without carina and projection (Fig. 6). Forewing with discoidal cell faint outwardly (Fig. 5); Rs short, 0.6 times as long as stigma, and ending obtusely (Fig. 5). Propodeal angle sharp and pointing backwards (Fig. 4).

Metasoma. T-I with sparser and considerably larger punctures than those on T-II and T-III (Fig. 7). S-II spots separated by 1.7 MOD (Fig. 8). T-III slightly bulging



Figures 1, 2. *Primeuchroeus crassiceps* (Tsuneki, 1970), female from Yunnan. **1** Habitus, dorsal view **2** habitus, lateral view.

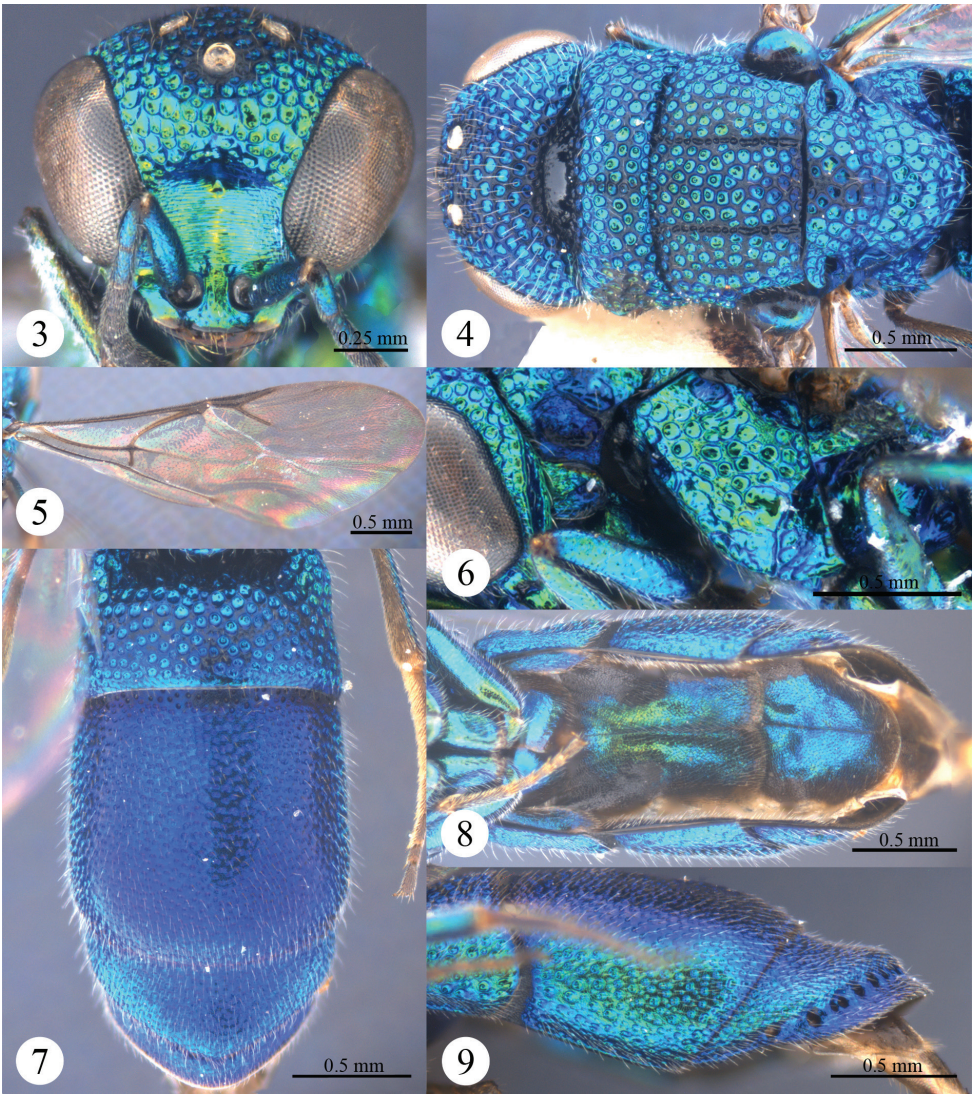
before pit row (Fig. 9); apex of T-III round, without transparent rim (Fig. 7); lateral margin of T-III nearly straight, without tooth (Fig. 9).

Colouration. Head and mesosoma metallic green, blackish along notauli. Mandible brown, with metallic green basally. Antenna black, with scape, pedicel and basal F-I metallic bluish-green. Tegula metallic bluish-green. Leg metallic bluish-green, with inner surface of tibia and tarsus brown. Metasoma metallic blue, with T-I metallic greenish-blue.

Male. Body length 4.3 mm (Figs 10, 11). Forewing length 3.1 mm. MS = 0.7 MOD. F-I 2.0× as long as wide. Subantennal space = 0.8 MOD. Differing from female as follows: vertex, mesosoma, T-I and T-II darker than those of female; forewing with discoidal cell more distinct than that of female (Fig. 14); apex of T-III rounder than that of female, without angle medially (Fig. 16).

Variation. Females (n = 5). Body length 3.5–4.4 mm. Forewing length 3.0–3.4 mm. Rs 0.5–0.6 times as long as stigma. Metasoma with purple tints; F-I subequal to F-II. Males (n = 2). Body length 3.5–4.3 mm. Forewing length 3.0–3.1 mm.

Diagnosis. F-I slightly longer than F-II. TFC absent. Pronotum with an obtuse angle on each lateral margin. Forewing with Rs short, 0.6 times as long as stigma, ending obtusely. Lateral margin of T-III nearly straight, without tooth.



Figures 3–9. *Primeuchroeus crassiceps* (Tsuneki, 1970), female from Yunnan. **3** Head, anterior view **4** head, pronotum, mesonotum, metanotum, and propodeum, dorsal view **5** forewing **6** pronotum, mesopleuron and metapleuron, lateral view **7** metasoma, dorsal view **8** metasoma, ventral view **9** T-II and T-III, lateral view.

Distribution. China (Taiwan, Yunnan).

Biology. Unknown. Collected in July and August.

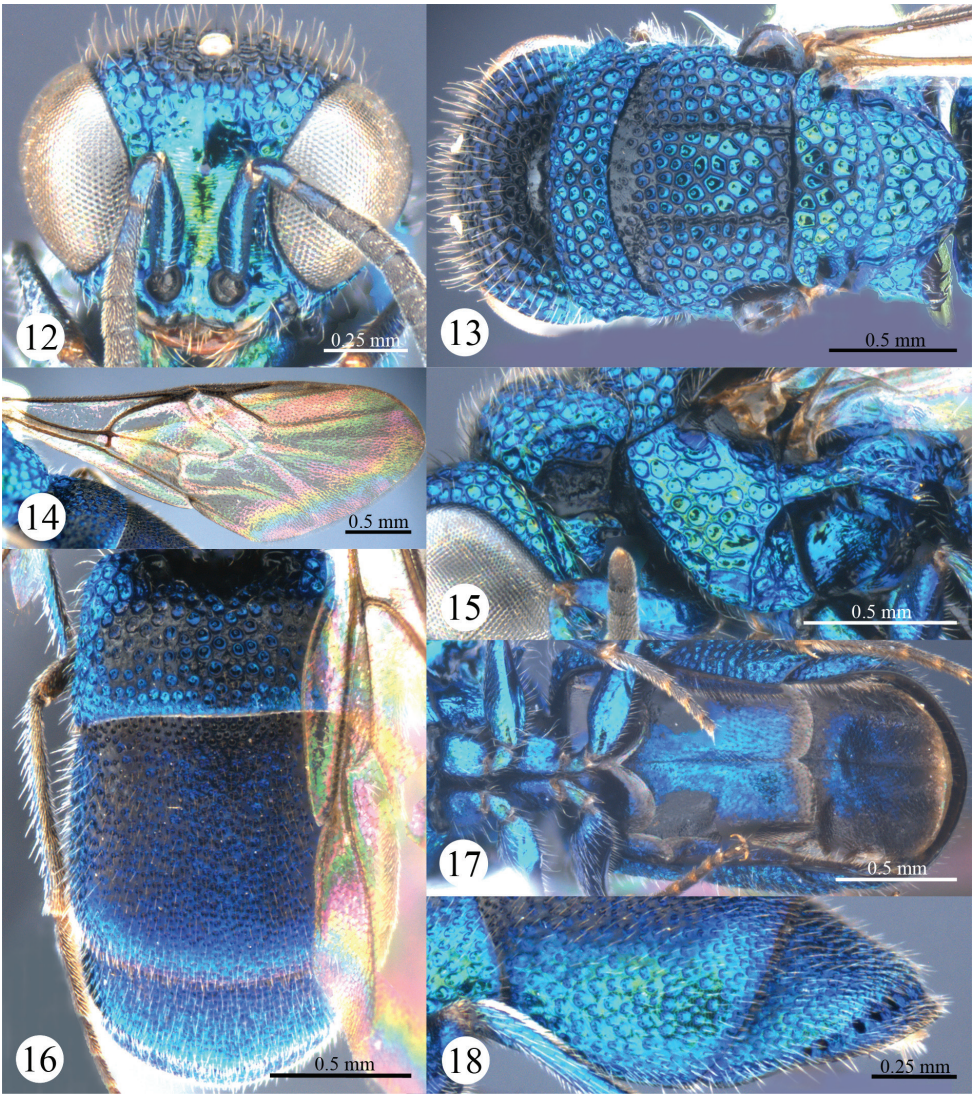
Remark. According to Bohart (1988), *P. crassiceps* belongs to the *siamensis* species-group.

Figures 10, 11. *Primeuchroeus crassiceps* (Tsuneki, 1970), male from Yunnan. **10** Habitus, dorsal view **11** habitus, lateral view.

***Primeuchroeus kansitakuanus* (Tsuneki, 1970)**
http://species-id.net/wiki/Primeuchroeus_kansitakuanus
Figs 19–27

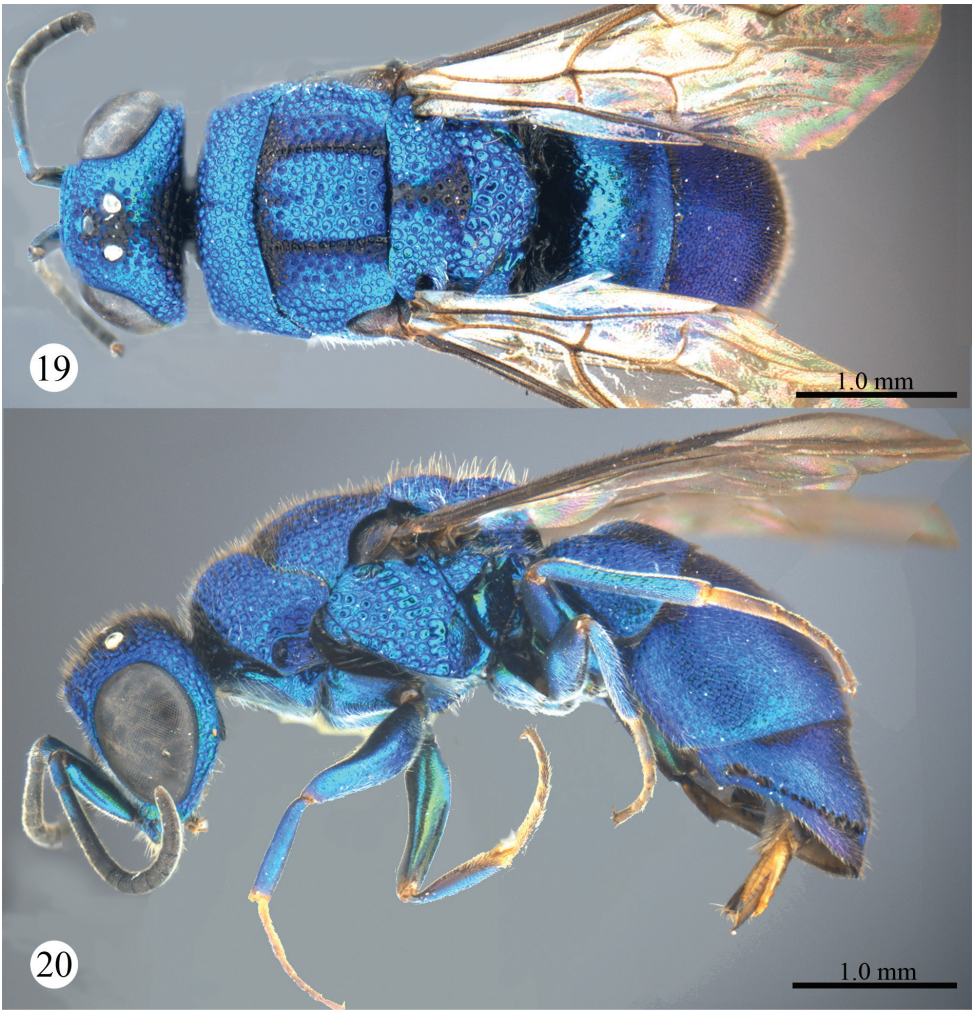
Chrysis kansitakuanus Tsuneki 1970: 9.
Primeuchroeus kansitakuanus (Tsuneki, 1970): Bohart 1988: 23; Kimsey and Bohart 1991: 542.

Materials. 1♀ (SCAU), Zhejiang, Lin'an, Mt. Qingliangfeng (30°04'N, 118°52'E), 9.VIII.2005, Hong-ying Zhang leg., No. 200603255; 1♀ (SEM) Fujian, Da'an (27°51'12.80"N, 117°54'24.42"E), 1.VII.1959, Gen-tao Jin & Yang-ming Lin leg., No. 34022850; 1♀ (SCAU), Hubei, Jingmen, Jingshan (31°1'1'N, 113°78'10"E), 15.VII.2009, Yuan Ye leg., No. CP0029; 13♀♀ (SCAU), Hunan, Mt. Huping, Shinianzigou (29°55'38"N, 118°48'48"E), 9.VII.2009, Ya-li Tang leg., No. CP0002–0014; 4♀♀ (SCAU), Hunan, Mt. Huping, Shinianzigou, 9.VII.2009, Shi-hong Wang leg., No. CP0015–0018; 1♀ (SCAU), Hunan, Mt. Huping, Zongfeng (29°55'N, 118°48'E), 9.VII.2009, Shi-hong Wang leg., No. CP0019; 1♀ (SCAU), Hunan, Mt.



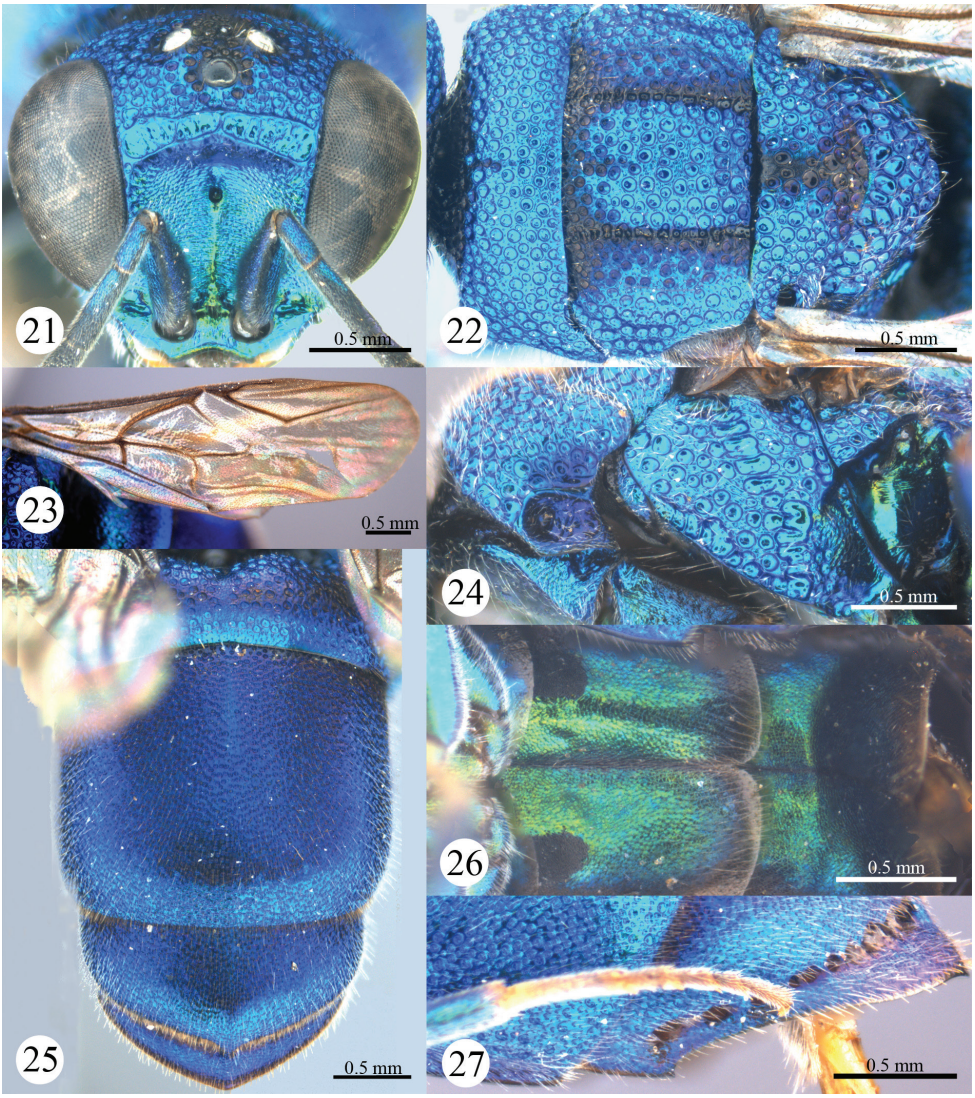
Figures 12–18. *Primeuchroeus crassiceps* (Tsuneki, 1970), male from Yunnan. **12** Head, anterior view **13** head, pronotum, mesonotum, metanotum, and propodeum, dorsal view **14** forewing **15** pronotum, mesopleuron and metapleuron, lateral view **16** metasoma, dorsal view **17** metasoma, ventral view **18** T-II and T-III, lateral view.

Huping, Shuawu village (29°55'N, 118°48'E), 10.VII.2009, Li Ma leg., No. CP0020; 1♀ (SCAU), Hunan, Huaihua (27°33'17"N, 109°59'53"E), VIII.2004, Jian-hua Zhou leg., No. CP0021; 2♀♀ (SCAU), Guangzhou, Wangzishan Forest Park (23°34'49"N, 113°13'21"E), 20.V.2006, Ju-jian Chen & Zai-fu Xu leg., No. CP0030, 0031; 4♀♀ (SCAU), Guangzhou, Liuxihe Forest Park (23°44'31"N, 113°47'0"E), 20.VI.2004, Zai-fu Xu leg., No. CP0032–0035; 2♀♀ (SCAU), Guangdong, Chebaling National



Figures 19, 20. *Primeuchroeus kansitakuanus* (Tsuneki, 1970), female from Guizhou. **19** Habitus, dorsal view **20** habitus, lateral view.

Nature Reserve (24°43'N, 114°14'E), 22–28.VII.2008, Zai-fu Xu leg., No. CP0036, 0037; 1♀ (SCAU), Hainan, Mt. Wuzhi (18°51'N, 109°39'E), 15–16.V.2008, Jing-xian Liu leg., No. 200800155; 1♀ (SCAU), Guizhou, Tianzhu (26°54'32"N, 109°12'22"E), VIII.2009, Yang-wen Wang leg., No. CP0001; 2♀♀ (SCAU), Guizhou, Mayang River, Dahe Dam (28°38'12"N, 108°17'13"E), 27.IX–2.X.2007, Jie-min Yao leg., No. CP0027, 0028; 3♀♀ (SCAU), Yunnan, Jinggu, Yunhai Reserve (23°29'37"N, 100°42'39"E), 3.X.2004, Jing-xian Liu leg., No. CP0022–0024; 1♀ (SCAU), Yunnan, Yingjiang, Taiping village (24°39'29"N, 97°51'9"E), 15.VIII.2005, Qiang Li leg., No. CP0025; 1♀ (SCAU), Yunnan, Chenggong, Luoyang (24°55'35'N, 102°48'37"E), 8–19.VIII.2006, Qiang Li leg., No. CP0026.



Figures 21–27. *Primeuchroeus kansitakuanus* (Tsuneki, 1970), female from Guizhou. **21** Head, anterior view **22** pronotum, mesonotum, metanotum, and propodeum, dorsal view **23** forewing **24** pronotum, mesopleuron and metapleuron, lateral view **25** metasoma, dorsal view **26** metasoma, ventral view **27** T-II and T-III, lateral view.

Description. Described after a female from Guizhou. Body length 7.0 mm (Figs 19, 20). Forewing length 4.6 mm. MS = 0.6 MOD. F-I 3.0× as long as wide.

Head. Scapal basin deep, with transverse striae and punctures, with a round pit anteromedially (Fig. 21). F-I dinstinctly longer than F-II (Fig. 21). TFC distinct and double (Fig. 21).

Mesosoma. Pronotum with anterior declivity polished and impunctate between the two pits (Fig. 22); without angle on each lateral margin (Fig. 22), without sublateral carina, but with lateral depression deep (Fig. 24). Mesonotum with round punctures (Fig. 22). Mesopleuron with enlarged foveae along episternal sulcus (Fig. 24), with scrobal carina and a very small projection near scrobe (Fig. 24). Forewing with discoidal cell distinct (Fig. 23); Rs long, 2.4 times as long as stigma, sharply bent in the middle and nearly complete (Fig. 23). Propodeal angle sharp and pointing backwards.

Metasoma. T-I with sparser and considerably larger punctures than those on T-II and T-III (Fig. 25). S-II spots separated by 3.0 MOD (Fig. 26). T-III not bulging before pit row (Fig. 27); apex of T-III obtusely angled medially, without transparent rim (Fig. 25); lateral margin of T-III convex, with a small tooth basally (Fig. 27).

Colouration. Face metallic green. Mandible brown, with metallic green basally. Antenna black, with scape, pedicel and basal F-I metallic bluish-green. Vertex and mesosoma metallic bluish-green, with ocellar triangle, anterior part of pronotum, notauli, and metanotum black. Tegula blackish-brown. Leg metallic bluish-green, with tarsus testaceous. Metasoma metallic bluish-green.

Variation. Females (n = 40). Body length 5.0–7.0 mm. Forewing length 3.4–4.6 mm. Rs 2.0–2.4 times as long as stigma.

Male. Unknown.

Diagnosis. F-I distinctly longer than F-II. TFC distinct and double. Forewing with Rs long, 2.0–2.4 times as long as stigma, and bent sharply in the middle. Lateral margin of T-III convex, with a small tooth basally.

Distribution. China (Zhejiang, Hubei, Hunan, Taiwan, Fujian, Guangdong, Hainan, Guizhou, Yunnan); Vietnam; Malaysia.

Biology. Unknown. Collected from May to October.

Remarks. According to Bohart (1988), *P. kansitakuanus* belongs to the *ghilianii* species-group.

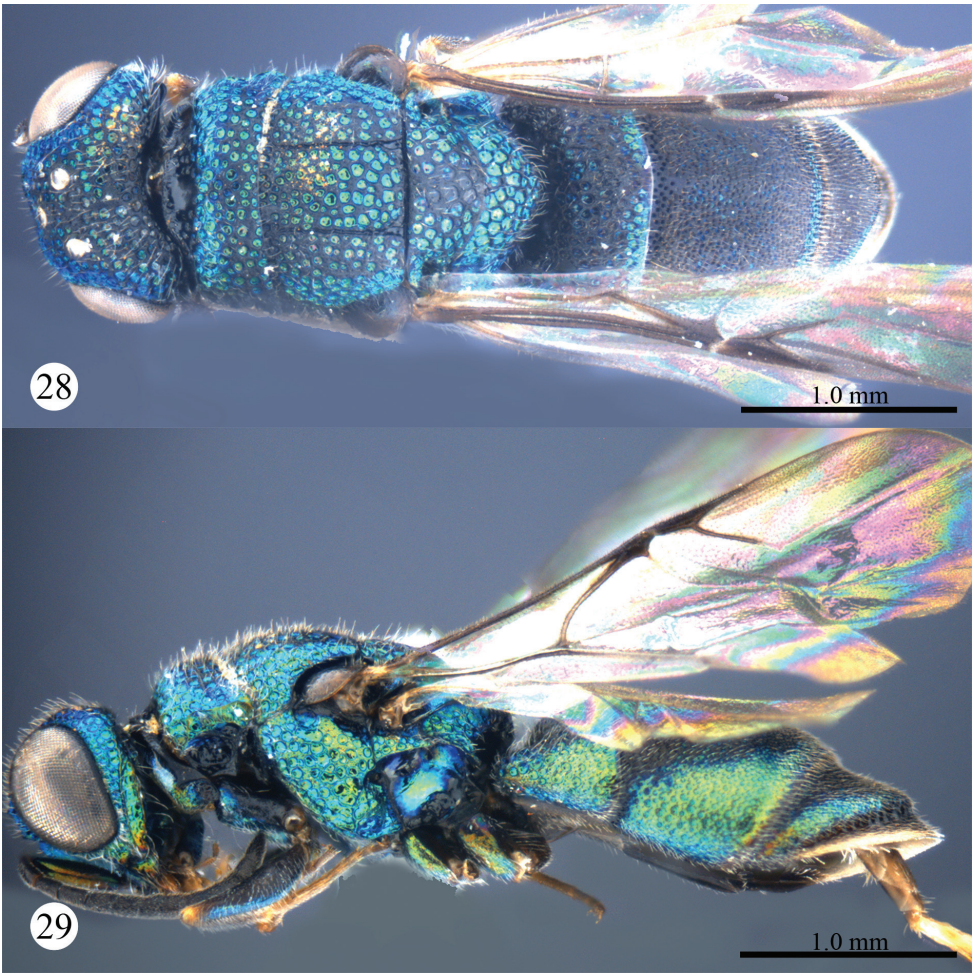
Primeuchroeus yongdaerianus **Kim, 2013, new to China**

http://species-id.net/wiki/Primeuchroeus_yongdaerianus
Figs 28–36

Primeuchroeus yongdaerianus Kim 2013: 95.

Materials. 4♀♀ (SCAU), Yunnan, Gaoligongshan National Nature Reserve (24°49'N, 98°46'E), 20–21.VII.2006, Jie Zeng, Juan-juan Ma & Bin Xiao leg., No. CP0045–0048; 8♀♀ (SCAU), Yunnan, Gaoligongshan National Nature Reserve, Mailongxia (25°50'23"N, 98°51'23"E), 17.VIII.2005, Kai Wu leg., No. CP0049–0056.

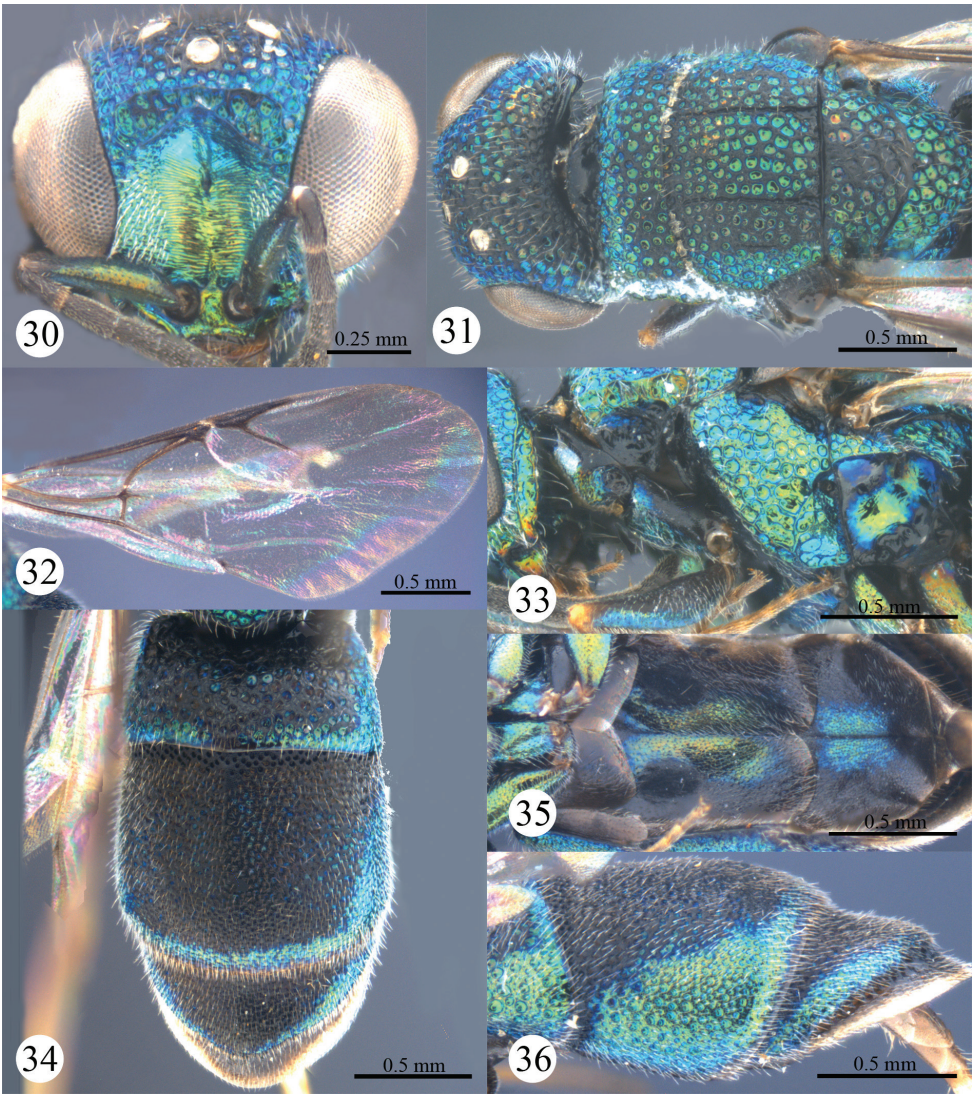
Description. Described after a female from Yunnan. Body length 3.1 mm (Figs 28, 29). Forewing length 2.5 mm. MS =1.2 MOD. F-I 2.5× as long as wide.



Figures 28, 29. *Primeuchroeus yongdaerianus* Kim, 2013, female from Yunnan. **28** Habitus, dorsal view **29** habitus, lateral view.

Head. Scapal basin deep and impunctate, with transverse striae and an elongate pit anteromedially (Fig. 30). F-I slightly longer than F-II (Fig. 30). TFC distinct and double (Fig. 30).

Mesosoma. Pronotum with anterior declivity polished and impunctate between two pits (Fig. 31); with an indistinct angle on each lateral margin (Fig. 31), with sublateral carina incomplete, and with lateral depression shallow (Fig. 33). Mesonotum with areolate punctures (Fig. 31). Mesopleuron without enlarged foveae along episternal sulcus (Fig. 33), without scrobal carina and projection (Fig. 33). Forewing with discoidal cell faint outwardly (Fig. 32); Rs short, 0.6 times as long as stigma, and ending obtusely (Fig. 32). Propodeal angle sharp and pointing backwards (Fig. 31).



Figures 30–36. *Primeuchroeus yongdaerianus* Kim, 2013, female from Yunnan. **30** Head, anterior view **31** head, pronotum, mesonotum, metanotum, and propodeum, dorsal view **32** forewing **33** pronotum, mesopleuron and metapleuron, lateral view **34** metasoma, dorsal view **35** metasoma, ventral view **36** T-II and T-III, lateral view.

Metasoma. T-I with sparser and considerably larger punctures than those on T-II and T-III (Fig. 34). S-II spots separated by 2.3 MOD (Fig. 35). T-III slightly bulging before pit row (Fig. 36); apex of T-III round, with broad testaceous transparent rim (Fig. 34); lateral margin of T-III nearly straight, without tooth (Fig. 36).

Colouration. Face metallic green, with yellow reflections. Mandible brown, with metallic green basally. Antenna black, with scape metallic green. Vertex, pronotum,

mesonotum, and metanotum metallic bluish-green. with black colour. Tegula blackish-brown, with metallic blue hints. Leg with coxa and femur metallic green; tibia mostly brown, with slight metallic reflections; tarsus brown. Metasoma mostly black, with metallic green reflections posteriorly and laterally on each segment.

Variation. Females (n = 12). Body length 2.6–4.1 mm. Forewing length 2.4–3.1 mm. F-I subequal to F-II. Rs 0.6–0.7 times as long as stigma.

Male. No available specimens for this study.

Diagnosis. TFC distinct and double. Forewing with Rs short, 0.6 times as long as stigma, and ending obtusely. Lateral margin of T-III nearly straight, without tooth.

Distribution. China (Yunnan); Korea.

Biology. Unknown. Collected in July and August.

Remarks. According to Kim (2013), *P. yongdaerianus* belongs to the siamensis species-group. It is the first record to the Oriental region and to China. The specimens from Yunnan vary from those from Korea by tibia and tarsus brown, and with metallic blue on S-III.

Acknowledgements

Many thanks to Assoc. Prof. Hai-sheng Yin and Ms Li Dai of Shanghai Entomological Museum (Shanghai, China) and Dr. Frank Koch of Museum für Naturkunde (Berlin, Germany) for their kind help during the first author's visit. We appreciate the kind help of Assoc. Prof. Geoff Allen of University of Tasmania (Hobart, Australia) and Mr. David Baldock (Milford Surrey, England) in improving the manuscript English. This study was supported by the National Basic Research Program of China (No. 2013CB127600) and the National Natural Science Foundation of China (30770265).

References

Bischoff H (1910) Die Chrysididen des Königlichen Zoologischen Museums zu Berlin. Mitteilungen aus dem Zoologischen Museum in Berlin 4(3): 427–493, pl. 7.

Bohart RM (1988) A key to species of the genus *Primeuchroeus* and descriptions of new species (Hymenoptera: Chrysididae). Insecta Mundi 2(1): 21–27.

Kim JK (2013) Description of a new species of the genus *Primeuchroeus* Linsenmaier, 1968 (Hymenoptera, Chrysididae) from Korea and redescription of *P. malayensis* (Linsenmaier, 1982). Zootaxa 3686(1): 95–98. doi: 10.11646/zootaxa.3686.1.7

Kimsey LS, Bohart RM (1991) The Chrysidid Wasps of the World. Oxford University Press, New York, 652 pp.

Linsenmaier W (1968) Revision der familie Chrysididae (Hymenoptera). Zweiter Nachtrag Mitteilungen der Schweizerischen Entomologischen Gesellschaft 41: 1–144.

Linsenmaier W (1982) Neue Chrysididae aus Indo-Australien (Hymenoptera). Entomofauna 3(21): 323–347.

Linsenmaier W (1997) Altes und Neues von den Chrysididen (Hymenoptera Chrysididae). Entomofauna 18: 245–300.

Madl M, Rosa P (2012) A catalogue of the Chrysididae (Hymenoptera: Chrysidoidea) of the Ethiopian Region excluding Malagasy Subregion. Linzer biologische Beiträge 44 (1): 5–169.

Mocsáry A (1899) Species chrysididarum novae in collectione musaei nationalis Hungarici. Természetrajzi Fúzetek 22: 483–494.

Tsuneki K (1970) Ein beitrag zur goldwespen-fauna Formosas. Etizenia 49: 1–21.

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RESEARCH ARTICLE

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Morphogenia: a new genus of the Neotropical tribe Jubini (Coleoptera, Staphylinidae, Pselaphinae) from the Brazilian Amazon

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http://zoobank.org/ADD598C9-C7D1-45A4-B79C-0ED9FC401A22

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Abstract

A new genus and species of the large Neotropical pselaphine tribe Jubini is described from Manaus, Brazil, based on material preserved in the Natural History Museum, London. *Morphogenia struhli* **gen.** et **sp. n.** represents the possible sister taxon of the abundant and speciose genus *Barrojuba* Park, sharing with it the putatively derived condition of anterolaterally shifted vertexal foveae, producing a smoothly convex vertex devoid of fovea or sulci. However, unlike *Barrojuba*, *Morphogenia* retains a plesiomorphic antebasal sulcus on the pronotum in both sexes, and additionally lacks elaborate abdominal fovea-like pockets and teeth on the lateral margins of the pronotum that are typical of *Barrojuba*. The genus is also unusual among jubine genera in lacking the characteristic V- or Y-shaped gular carina. In contrast to the commonly-collected *Barrojuba*, specimens of *Morphogenia* are absent in extensive jubine collections housed in museums in the United States, indicating that the new taxon may be relatively scarce or localised.

Keywords

Pselaphinae, Jubini, Neotropical, Brazil, new genus, new species

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Introduction

The pselaphine tribe Jubini is an entirely Neotropical radiation and a major component of the South American rove beetle fauna (Park 1942, 1952). The tribe is highly distinctive, with a wide mentum and maxillary cardos that project anteriorly, to the point that they are sometimes visible in dorsal view. A conspicuous V- or Y-shaped gular carina commonly adorns the underside of the triangular head, and the pronotum is also of a characteristic form, often abruptly constricted at the base.

Thirteen genera of Jubini have been described (Newton and Chandler 1989, Chandler 1999), with several, including *Jubus* Schaufuss, *Sebaga* Raffray and *Barrojuba* Park being abundant and potentially very species rich elements of the Neotropical forest floor. Despite their ubiquity, and the accumulation of a mass of new material from collecting efforts over the past several decades, little work has been conducted on Jubini since the creation of the majority of genera over a century ago. One exception is the genus *Barrojuba*, erected by Park (1942) and subsequently revised by (Chandler 1983, 1988), and now including fourteen species. *Barrojuba* is distinctive in possessing an overtly simplified and smoothly convex vertex, resulting from an evolutionary loss of sulci and an anterolateral repositioning of the vertexal foveae (the dorsal tentorial pits) to the vicinity of the postantennal notches.

Investigation of the pselaphine collection at the Natural History Museum, London (NHM), revealed undescribed jubine material collected during the 1990s from the Smithsonian Tropical Research Institute/INPA Biological Dynamics of Forest Fragments Project in Manaus, Brazil. Among this material were specimens with apparent affinities to *Barrojuba*, but differing in crucial aspects that warrant their placement in a new genus. Here, the new genus is described and illustrated, its sexual dimorphism documented, and putative phylogenetic relationships discussed.

Methods

For morphological description, specimens were removed from mounts and relaxed in a Sodium Dodecyl Sulphate-based buffer with Proteinase K, and then transferred into ethanol for observation with stereo microscopy, or into 1:1 ethanol: glycerol for imaging with a Zeiss compound microscope. Genitalia and terminal segments were dissected and mounted in temporary glycerol slide mounts, and are stored in glycerol microvials pinned with their respective specimens. Photographs of specimens were taken by using a Visionary Digital photomicrographic apparatus with Infinity optics and a Canon 60D camera, installed at the American Museum of Natural History, New York. Montage images were constructed from stacks using Helicon Focus. DNA from two paratype females was extracted according to a non-destructive protocol outlined previously (Parker and Maruyama 2013). The symbol "//" is used to separate different data labels attached to the specimens. The terminology used to describe the foveal system follows Park (1942), as modified by Chandler (2001), except that the terms "mesoventral" and "metaventral" are used in place of "mesosternal" and "metasternal", following the discussion of Herman (2013).

Taxonomy

***Morphogenia* gen. n.**
http://zoobank.org/4368E5BC-73B0-443D-AE2C-020F58EFD36C
http://species-id.net/wiki/Morphogenia

Type species. *Morphogenia struhli*, here designated.

Diagnosis. *Morphogenia*, and its only species, *M. struhli*, can be distinguished from all other known jubine genera by the following combination of characters: (1) smoothly convex vertex lacking sulci, and afoveate due to anterolateral shift of vertexal foveae into vicinity of postantennal notches anterior to eyes; (2) absence of V- or Y-shaped gular carina; (3) pronotum with margins smooth, lacking lateral spines, and with a simple, well-defined transverse antebasal sulcus in both sexes; (4) abdomen lacking fovea-like cuticular pockets at bases of tergites V–VII and sternites V–VII (but tergite IV and sternite IV with true mediobasal foveae present).

Description. Body length ~3 mm (Fig. 1). Form relatively flattened and broadened posteriorly, with compact abdomen and elongate legs.

Head: Approximately triangular (Figs 1, 18), 1.3× wider than long; without distinct frontal rostrum and lacking prominent, raised antennal tubercles. Vertex smoothly convex, devoid of foveae or sulci, lateral margins incised behind antennal sockets by postantennal notches (region enclosed by dashed line in Fig. 2). Antennae separated by 1/3 maximum head width. Foveae of apparent homology to the vertexal foveae of other Pselaphinae shifted from vertex, situated instead on frontolateral margins, recessed into the top of postantennal notches (Figs 2, 5). Apodemes of tentorium extending from these foveae (Fig. 5) and converging on gular foveae with single opening (Fig. 3). Lateral margins of head smoothly rounded dorsoventrally, lacking ocular mandibular carina. Venter lacking any trace of gular carina (Fig. 3; a medial sutural line can be weakly detected). Antennae (Fig. 4) with 11 antennomeres, with club formed by enlarged antennomeres VIII–XI. Maxillary palpi comprised of five palpomeres, with small triangular palpomeres III and fusiform palpomeres IV (Fig. 3). Maxillary cardos projecting anteriorly, reaching slightly beyond sides of mandibles, with single long setae positioned at apex.

Thorax: Pronotum (Fig. 6) moderately transverse, 1.4× wider than head and similar in length, obcordate in shape, approximately semicircular before abrupt constriction in basal quarter. Lateral margins before constriction smoothly rounded, without spines or teeth. Pronotal disc simple and convex, lacking foveae or sulci. Typical, deep and well-impressed antebasal sulcus present, demarcating point of pronotal constriction. Lateral antebasal foveae present, median antebasal fovea absent. Prosternum with lateral procoxal foveae. Mesoventrite with single unpaired median mesoventral fovea, lateral mesoventral foveae and lateral mesocoxal foveae. Metaventrite with lateral metaventral foveae, with median carina from 1/3 segment length to posterior margin.

Abdomen: Abdomen 2/3 length of elytra (measured along suture). Five tergites (IV–VIII) evident. Tergites with broad, angularly-projecting paratergites on segments III–VI and smaller paratergites on VII (Fig. 7). Tergite IV longest, 2.7× tergite V

length, with posterior tergites becoming shorter and narrower. Tergite IV with mediobasal foveae present in basal sulcus. Six sternites (III–VIII) evident; penial plate apparently internalized, not externally visible, with genital aperture formed by contiguous apical margins of tergite and sternite VIII (Figs 11, 12). Apical margin of sternite III entire, uninterrupted by metacoxae. Sternite IV longest, mediobasal foveae present. All tergites and sternites lacking fovea-like cuticular pockets at their bases (Fig. 7 shows bases of tergites V–VII revealed in cleared specimen).

Elytra: 1.3× longer than pronotum, broadening gradually until narrowing just before apices. With sinuate transverse basal carina; sutural foveae and single median basal foveae present but largely obscured by arcing of basal carina. Humeri indented by impressed bases of humeral sulci; humeral sulci extending length of elytra, with humeral foveae at base. Sutural striae entire.

Legs: All pairs of coxae contiguous. Coxae all carinate along length of external face. Procoxal length greater than half femoral length, procoxae strongly conically projecting ventrally. Mesocoxae shorter than procoxae, moderately conically projecting, orientated somewhat posteriorly. Metacoxae transverse-conical, spanning from ventral midline to metaventral margin, and projecting posteriorly. All trochanters short, with negligible separation of coxal apex and femoral base ("brachysceline" type). Femora and tibiae simple, lacking modifications. Profemora somewhat thickened. Tarsi (Figs 8, 9) 3-segmented with short tarsomeres I; tarsomeres II longest. Metatarsi especially elongate. Tarsi with two claws of equal size.

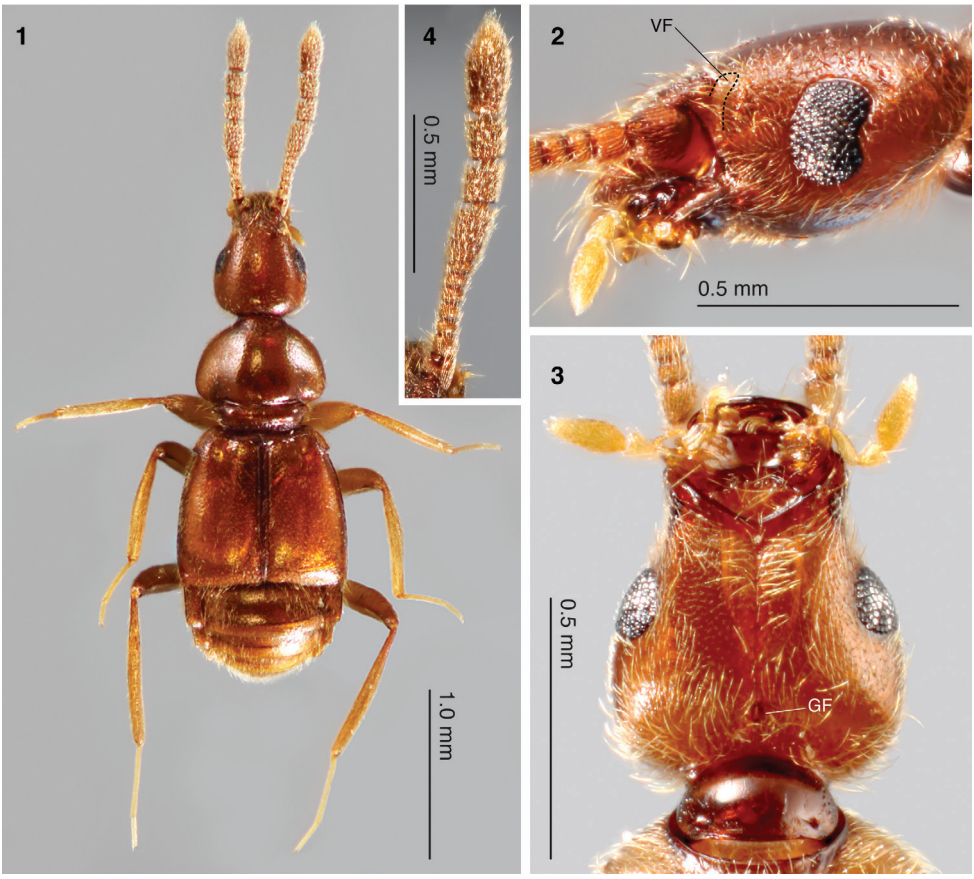
Etymology. Morphogens are gradient-forming molecules that specify positional information and govern tissue growth during animal development. The generic name acknowledges the pervasive role of morphogens in sculpting organismal morphology. The gender is feminine.

Morphogenia struhli sp. n.

http://zoobank.org/21B35D69-23FB-42AE-8601-80AEFEB986CE
http://species-id.net/wiki/Morphogenia_struhli

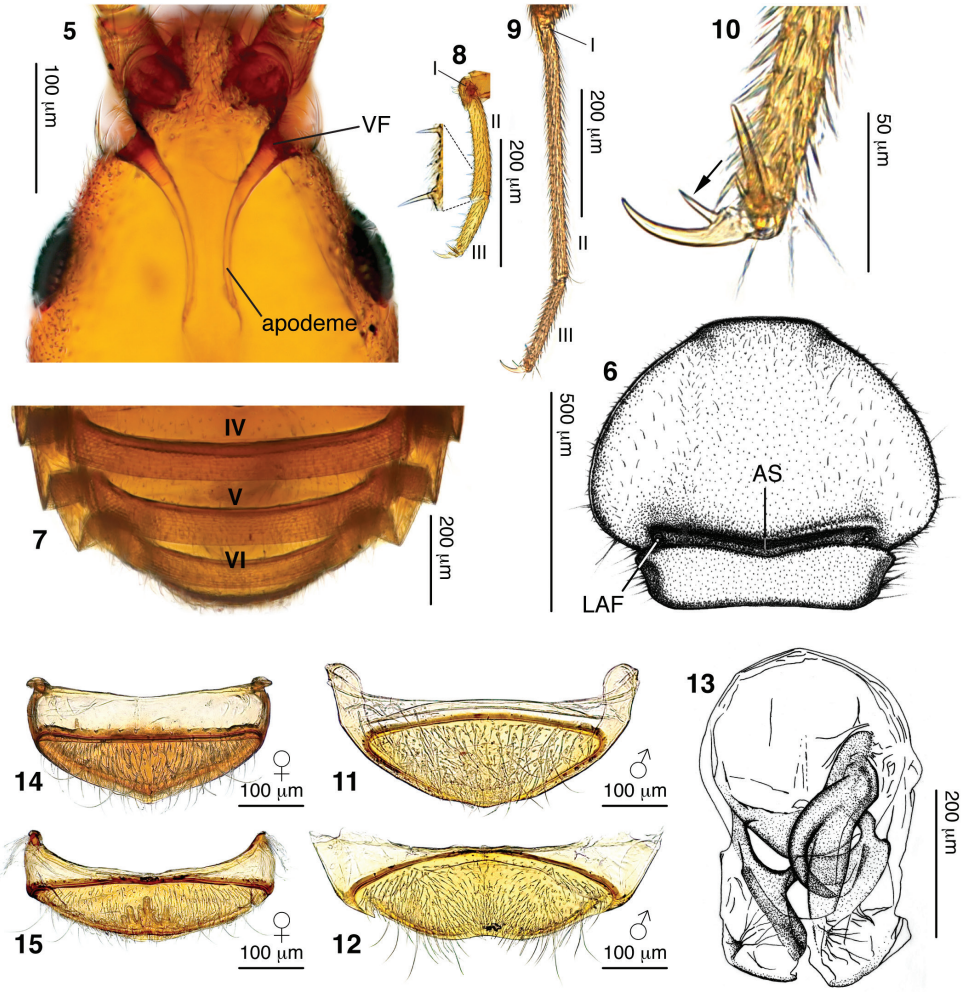
Type material. Holotype ♂: "88 1 // Leaf litter, Winkler method. Terra firmé fst. // **BRAZIL:** Manaus, A.M. INPA/Smithsonian Res. 2°25'S, 59°50'W, R. Didham, i. 1994 // BMNH{E} 2003-84.". Paratypes (2 ♀♀): "89 7 // Leaf litter, Winkler method. Terra firmé fst. // **BRAZIL:** Manaus, A.M. INPA/Smithsonian Res. 2°25'S, 59°50'W, R. Didham, i. 1994//BMNH{E} 2003-84 // (pink label) 0749". "68 12 // Leaf litter, Winkler method. Terra firmé fst. // **BRAZIL:** Manaus, A.M. INPA/Smithsonian Res. 2°25'S, 59°50'W, R. Didham, i. 1994 // BMNH{E} 2003-84". All material is deposited in the Coleoptera collection of the Department of Entomology, Natural History Museum, London.

Description. Body length 2.9 mm (Fig. 1). Holotype male somewhat teneral; body colour of female paratypes dark reddish-purple (e.g. Figs 17, 19) with appendages lighter in colour. Dorsal regions shiny, with shallow punctures and sparse setae in most areas.



Figures 1–4. *Morphogenia struhli* sp. n. holotype male. **1** dorsal habitus **2** head, lateral view, with position of vertexal fovea (VF) indicated at dorsal extreme of postantennal notch (region enclosed by dashed line) **3** head venter showing gular fovea (GF). Note the absence of a gular carina **4** right antenna, dorsal view.

Head: Length 0.71 mm from occipital constriction to clypeus; width across widest point (posterior to eyes) 0.55 mm. Margins broadly and smoothly rounded from eyes to base (Figs 1, 18). Margins narrowing anterior to eyes before broadening slightly to clypeus. Setae sparse on vertex and becoming longer and denser towards clypeus. Anterolaterally-shifted vertexal fovea concealed in postantennal notches (region indicated in Fig. 2) by several long, apically-directed setae (Fig. 5). Eyes (Fig. 2) large with ~105 ommatidia, broadly crescent-shaped with shallow ocular canthi at posterior margin. Antennae received by triangular frontolateral excavations with carinate edges (Fig. 2). Antennal (Fig. 4) length 1.18 mm, with scape weakly transverse in dorsal view, pedicel slightly narrower and subquadrate. Antennomeres III–V subequal in width, slightly narrower and shorter than pedical, with segments becoming progressively longer apically; VI and VII transverse and subequal in length; VII wider than VI and approaching width of segment VIII. Antennomeres VIII–X with carinate apical



Figures 5–15. Diagnostic characters of *Morphogenia struhli* sp. n. **5** compound micrograph of male head showing anterolaterally shifted vertexal fovea (VF) and apodemes of the tentorium **6** male pronotum with antebasal sulcus (AS) and lateral antebasal fovea (LAF) indicated **7** male dorsal abdominal segments showing absence of fovea-like cuticular pockets at the bases of tergites V–VII **8** male left protarsus with tarsomeres indicated. A magnified portion of the ventral face of tarsomere II shows the large spines of possible raptorial function **9** male left metatarsus with tarsomeres indicated. Note that tarsi in **8** and **9** are to the same scale. **10** male left hind tarsal claw, with arrow indicating internal spike **11** male tergite VIII **12** male sternite VIII **13** dorsal view of aedeagus **14** female tergite VIII **15** female sternite VIII. In **11–15** all structures are orientated with anterior to the top.

and basal margins, roughly obconical and equal in width. Antennomere VIII slightly longer than preceding three segments, 2/3 longer than wide; antennomeres IX and X 0.7× length of VIII; XI longest, 1.8× length of VIII, with carinate basal margin, widest in apical half before tapering to apex. Antennomeres densely covered with apically-

directed setae. Apical pseudosegment of maxillary palpus continuous with external face of palpomere IV and pointing slightly mesially.

Thorax: Pronotum (Fig. 6) length 0.68 mm, width 0.77 mm at widest point. Disc region sparsely setiferous. Lateral margins behind antebasal sulcus with several long, laterally-projecting setae. Prosternum with medial region in front of procoxae with long setae covering setiferous lateral procoxal fovea. Episternal areas with moderately dense, shorter setae orientated somewhat dorsally. Short lateral prosternal carinae extending briefly from sides of procoxal cavities. Mesoventral plate moderately setiferous, meso-epiventral regions largely glabrous. Metasternum with sparse, dorsoapically-pointing aciculate setae.

Abdomen: Dorsal abdominal length (with segments contracted) 0.57 mm. Tergite lengths: IV= 0.32 mm, V = 0.12 mm, VI = 0.10 mm. Apical margin of sternite IV with male-specific medially positioned small, round tubercle covered in small setae. Male tergite VIII (Fig. 11) with basal margin of sclerite weakly convex; with uniform moderately dense distribution of long setae. Sternite VIII (Fig. 12) with basal margin of sclerite strongly convex; mediobasal region with sparse, short setae becoming much denser towards apical margin; lateral areas of sternite with much longer setae of moderate density. Apical margin of sternite VIII medially depressed to receive corresponding apex of tergite VIII.

Elytra and flight wings: Elytra with scattered, short setae. Elytral length along suture 0.87 mm; width at widest point 0.5 mm. Full flight wings present.

Legs: Femora brownish-red, slightly lighter than body; tibiae and tarsi lighter than femora, yellowish (Fig. 1). Tarsi of increasing relative length: protarsi 0.5× protibial length; mesotarsi 0.6× protibial length; metatarsi 0.7× metatibial length. Protarsomeres II 1.7× tarsomere III length (Fig. 8). Mesotarsomeres II 1.8× tarsomere III length. Metatarsomeres II especially long (Fig. 9), 2.3× tarsomere III length. All tarsal claws with inner spine present on ventral face (Fig. 10). Pro- and mesotarsi with additional spines on ventral side of tarsomeres II and III (Fig. 8).

Aedeagus: Length 0.43 mm, width 0.27 mm at widest point (Fig. 13). Asymmetric, dorsoventrally relatively flattened, with large spherical and very weakly sclerotized basal bulb. Lacking obvious remnants of parameres. Complex, more heavily sclerotized medioapical piece with "hooked" apophysis extending apically from right side of basal bulb.

Sexual dimorphism. Female dimensions similar to male. Males with large crescent shaped eyes (Fig. 16); female eyes very small and approximately oval, consisting of ~12 ommatidia (Fig. 17). Vertex of female head (Fig. 19) broader at base than that of male (Fig. 18). Antennal club (VIII–XI) twice as long as preceding segments combined in male (Fig. 18), only 1/3 as long as preceding segments combined in female (Fig. 19). Medial sexual patch on sternite IV absent in female, and flight wings lacking. Female tergite VIII (Fig. 14) with basal margin of sclerites shallowly concave; with moderate density of long setae and two pairs of much longer setae. Female sternite VIII (Fig. 15) with basal margin of sclerite weakly convex; covered in moderate density of short setae and several pairs of much longer setae. Apex with internally-projecting cuticular protuberance.

Figures 16–19. Sexual dimorphism in head morphology **16** male head, lateral view **17** female head, lateral view **18** male head dorsal view **19** female head dorsal view. Arrows in **18** and **19** indicate extent of the antennal club.

Etymology. The type species of *Morphogenia* is named in honour of Dr. Gary Struhl, developmental biologist, whose *Drosophila* studies have yielded great insights into the genetic control of animal development.

Biology. *Morphogenia* was collected from rainforest litter—the typical habitat of jubines. Like other pselaphines, jubines are most likely predators of soil microarthropods. The spines on the ventral face of the pro- and mesotarsi of *M. struhli* (Fig. 8) may serve a raptorial function. Prior to photography, a filament protruding from the mouthparts of one female paratype was removed. A subsequent survey of jubine specimens in a range of genera have revealed similar filaments, which appear to be dried, threadlike residues of glutinous secretions from the enlarged maxillary cardos that are characteristic of the tribe. Such structures suggest the evolution of a novel mode of feeding or prey capture in Jubini (J. Parker & C. Carlton unpublished observations).

Discussion

Phylogenetic relationships of *Morphogenia*

Creation of a new genus, *Morphogenia*, is supported by cladistic interpretation of the suit of adult character states presented by the NHM material. Among jubines, *Morphogenia* appears to be allied to *Barrojuba* based on its putatively derived dorsal head morphology: the lack of sulci, and the proposed synapomorphy of anterolaterally shifted vertexal foveae that sit in the post-antennal regions anterior to the eyes. A smoothly convex vertex is present in *Arctophysis* Reitter, another jubine genus, but here the vertexal foveae have been evolutionarily lost rather than repositioned, and vestiges of the apodemes of the tentorium remain connected to the medial vertex (visible in cleared

specimens). The dorsal head morphology of *Barrojuba* and *Morphogenia* is perhaps most closely approached by *Endytocera* Sharp, where the vertexal foveae sit somewhat anterolaterally on the head vertex, but are recessed into deep S-shaped sulci that extend from the gular region dorsally between postantennal notch and eye, merging apically at the interantennal area of the frons.

Despite their similar vertexal morphologies, *Morphogenia* and *Barrojuba* differ markedly in several important characters. *Barrojuba* lacks a typical (straight and simple) antebasal sulcus on the pronotum in the male sex. Instead, this part of the pronotum is variously modified and impressed (females of a few species have what approaches a typical sulcus; D.S. Chandler pers. comm.). In contrast, *Morphogenia* retains the plesiomorphic condition of a conventional antebasal sulcus in both sexes. A further autapomorphy of *Barrojuba* is the presence of large, fovea-like cuticular invaginations at the bases of tergites V–VII and sternites V–VIII. Such invaginations are absent in *Morphogenia*. Hence, *Morphogenia* possesses only one of three putatively derived character states of *Barrojuba*, arguing for its distinctiveness and proposed sister taxon status.

A large number of other characters of systematic utility separate *Barrojuba* and *Morphogenia*, in combination supporting the reciprocal monophyly of the two genera. However, for several such characters, whether these differences represent gains or losses in the respective genus is presently unclear. *Barrojuba* has tooth-like acuminations at the lateral edges of the pronotum that are absent in *Morphogenia*, but seemingly homologous structures are present in many jubine genera, implying a possible loss in *Morphogenia*. Most strikingly, *Morphogenia* lacks any trace of a V- or Y-shaped gular carina—a character found in all jubine genera except *Balega* Reitter, *Pselaphomorphus* Motschulsky, and *Phamisus* Aubé. Such an absence may again be consistent with a loss occurring in *Morphogenia*. The tarsal claws of *Morphogenia* are equal in size, while in *Barrojuba* they are unequal. Equally-sized claws are plesiomorphic in pselaphines, but instances of evolutionary reversal from inequality may have occurred (Parker and Maruyama 2013), and this character state varies among jubine genera, and even within them in the case of *Jubus* Schaufuss, the largest genus of the tribe (Park 1942). A further discrepancy between the two genera exists in the pattern of sexual dimorphism. In *Barrojuba*, the male antennal club is comprised of elongate antennomeres VII–XI or VIII–XI, depending on the species. The antennomeres of the female club are relatively less elongate than those of the respective male, and the club contains one fewer antennomere. In *Morphogenia*, the female antennomeres are again relatively less elongate than those of the male, but the number of antennomeres forming the club is equal in both sexes (four).

Interpreting transitions in these more broadly distributed or sexually dimorphic characters will require a thorough phylogenetic analysis of the entire tribe. Extensive collections of Neotropical pselaphines, accumulated from expeditions spanning decades, are housed in the Field Museum of Natural History, American Museum of Natural History, Louisiana State Arthropod Museum and University of Kansas Biodiversity Institute. Screening these collections for *Morphogenia* yielded no further specimens, implying that the genus may be relatively scarce or geographically localised. Fortunately, despite the age of the three known specimens, which were collected almost twenty

years ago, DNA extraction from the two female paratypes of *M. struhli* was successful. Partial gene sequences have been obtained that may help resolve the placement of the new genus in a future molecular phylogenetic analysis of Jubini.

Acknowledgements

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References

Chandler DS (1983) A revision of *Barrojuba* (Coleoptera: Pselaphidae). Entomologische Arbeiten - Museum G. Frey 31: 97–108.

Chandler DS (1988) New *Barrojuba* with a revised key to species (Coleoptera: Pselaphidae). Pan-Pacific Entomologist 64: 371–380.

Chandler DS (1999) New synonymies and combinations for New World Pselaphinae (Coleoptera : Staphylinidae). Transactions of the American Entomological Society 125: 163–183. http://www.jstor.org/stable/25078677

Herman LH (2013) Revision of the New World Species of Oedichirus (Coleoptera: Staphylinidae: Paederinae: Pinophilini: PROCIRRINA). Bulletin of the American Museum of Natural History 375: 1–137. doi: 10.1206/816.1

Newton AF, Chandler DS (1989) World catalog of the genera of Pselaphidae (Coleoptera). Fieldiana Zoology 53: 1–110. doi: 10.5962/bhl.title.3209

Park O (1942) A Study in Neotropical Pselaphidae. Northwestern University Studies in the Biological Sciences and Medicine 1: 1–468. doi: 10.5962/bhl.title.6838

Park O (1952) A revisional study of Neotropical pselaphid beetles. Part One. Tribes Faronini, Pyxidicerini and Jubinini. Chicago Academy of Sciences Special Publication No. 9: 1–49.

Parker J, Maruyama M (2013) *Jubogaster towai*, a new Neotropical genus and species of Trogastrini (Coleoptera: Staphylinidae: Pselaphinae) exhibiting myrmecophily and extreme body enlargement. Zootaxa 3630: 369–378. doi: 10.11646/zootaxa.3630.2.11

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RESEARCH ARTICLE

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A preliminary report on the distribution of lizards in Qatar

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Abstract

We have updated the list of the lizard species present in Qatar and produced the first distribution maps based on two field surveys in 2012 and 2013. We used the QND95/Qatar National Grid with a grid of 10 × 10 km squares for mapping. Our results show the occurrence of 21 lizard species in Qatar, from the 15 species indicated in the last biodiversity report conducted in 2004. The most abundant family found in Qatar is Gekkonidae with nine species (*Bunopus tuberculatus, Cyrtopodion scabrum, Hemidactylus robustus, H. flaviviridis, H. persicus, Stenodactylus arabicus, S. slevini, S. doriae, Pseudoceramodactylus khobarensis*), followed by Lacertidae with four species (*Acanthodactylus schmidti, A. opheodurus, Mesalina brevirostris, M. adramitana*), Agamidae with three species (*Trapelus flavimaculatus, Uromastyx aegyptia, Phrynocephalus arabicus*), Scincidae with two species (*Scincus mitranus, Trachylepis septemtaeniata*), and Varanidae (*Varanus griseus*), Sphaerodactylidae

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(*Pristurus rupestris*) and Trogonophiidae (*Diplometopon zarudnyi*) with one species each. The species richness fluctuated largely across Qatar between one and eleven species per grid square. We believe that the lizard fauna records in Qatar are still incomplete and that additional studies are required. However, our study here fills a gap concerning lizard biodiversity knowledge in the Gulf Region.

Keywords

Reptilia, geographic distribution, species richness, inventory, maps, biodiversity, atlas

Introduction

The rapid worldwide decline of reptiles has raised concerns about their conservation and the urgent need for action (Gibbons et al. 2000). A recent survey of the status of reptiles has shown that nearly one of five reptilian species are threatened with extinction and one of five classified as Data Deficient (Böhm et al. 2013). The decline of reptiles has been influenced by a variety of threats such as habitat loss, degradation and fragmentation, pet trade, invasive species, pollution, diseases and climate change (Böhm et al. 2013, Cox and Temple 2009, Gibbons et al. 2000). For the management and conservation of reptiles, quality species and population data is required to understand and predict the potential impacts caused by human activities. Because the lack of occurrence data is limiting both our understanding of the species needs and the management options (Primack 2010), several global scale initiatives were initiated to compile the vast biodiversity datasets (e.g. Global Biodiversity Information Facility – GBIF, Encyclopedia Of Life – EOL). Such databases accompanied by the advances in computation and advanced analysis allow for the proper management of data based on scientific knowledge (Matin et al. 2012, Reese et al. 2005). Unfortunately, the data available in these global databases is spatially biased, mainly because only few countries are contributing the majority of data.

The state of Qatar is a peninsula with an area of 11,571 km^2 that lies between 24–27°N and 50–52°E (Figure 1). The peninsula projects 186 km north from Saudi Arabia and varies in width between 55 and 90 km. Much of the country is flat with a highest elevation of 103m. Global Land Cover v2.3 identifies 10 coverage categories in Qatar (Figure 1, ESA 2010). The soil consists of a low barren plain covered with rocks, sand or small dunes, arable land representing only 1.6% (Hutchinson Encyclopedia 2011). Qatar's climate is hot and arid with an average annual mean temperature of 27 °C and 75 mm rainfall/year. There are no forests in Qatar and vegetation coverage is scarce with bushes and grasses of sporadic species and some *Acacia* trees (Batanouny 1981). Date palms and exotic vegetation is concentrated in farms across the country. Qatar has the highest density of camels in the Middle East (Richer 2008), however conservation measurements related to livestock management have been only recently implemented by the Ministry of the Environment (MOE) in Qatar. Qatar's population has been increasing rapidly throughout the last decades, reaching currently 1.8 million inhabitants mainly concentrated (80%) in

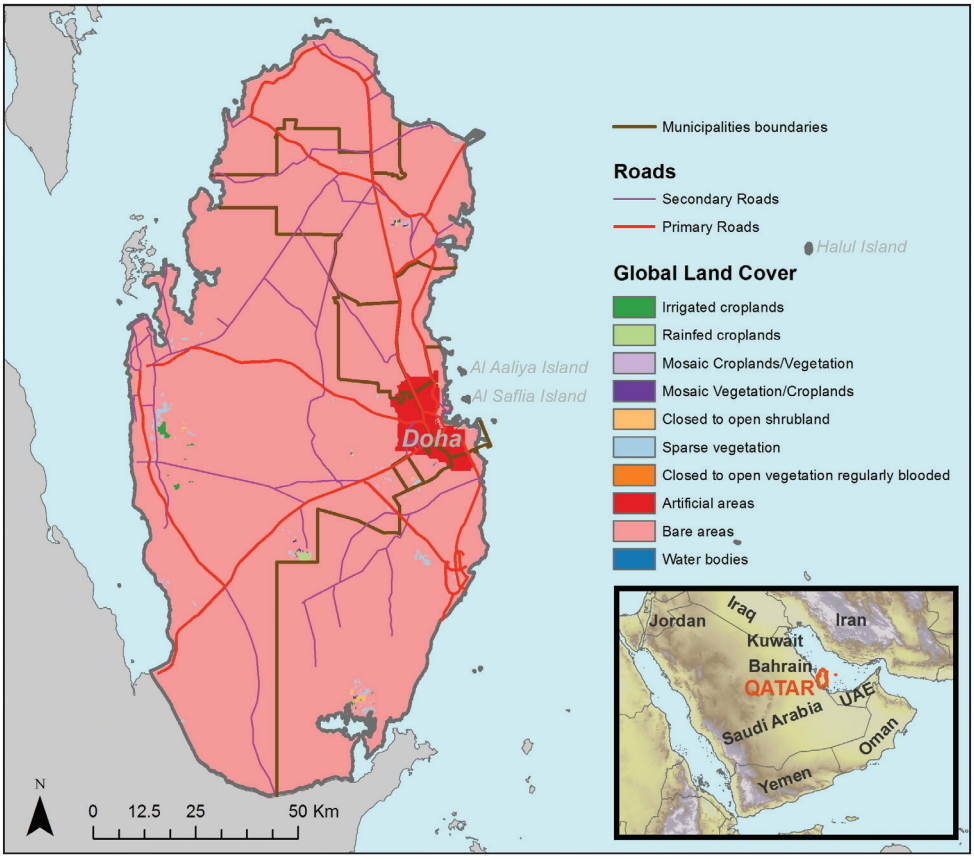

Figure 1. Location of Qatar within the Arabian Peninsula, and general map of Qatar. Global Land Cover was obtained from GlobCover 2.3 (ESA 2010)

the capital of the country (Doha) (Qatar Statistics Authority 2013). The economic growth of Qatar is closely related to ongoing increases of hydrocarbon extraction, since Qatar lies in a strategic location with major petroleum and gas deposits (Qatar Statistics Authority 2013). Human impact, including oil and gas extraction, population growth and infrastructure development represent major threats for the survival of the sparsely and locally disseminated lizard populations, usually with low densities. As a Party of the Convention of Biological Diversity (CBD), Qatar has prepared a National Biodiversity Strategy and Action Plan clearly indicating the commitment to give priority to environmental issues towards sustainable development and preservation of biodiversity (MOE 2004).

The lizard fauna of Qatar is poorly known. Apart from the study of Mohammed (1988) who reports the presence of 16 lizard species in Qatar, there is no comprehensive study available for the country. Additional information reporting the presence of lizards in the country is dispersed in several scientific publications (e.g., Arnold 1980a, 1980b, Leviton et al. 1992, Castilla et al. 2011a, Metallinou et al. 2012) or the data

is scattered in grey literature (Anonymous 2010, Nasher et al. 2009). To date there is not a single distribution map for any lizard species in Qatar, and very little is known about the biology and ecology of any of the Qatar lizard species except for some recent studies (Castilla et al. 2011a, b, Castilla et al. 2013, Martín et al. 2012, Herrel et al. 2013, Valdeón et al. 2013a). The aim of the present study is (i) to provide an inventory of the lizard species present in Qatar, (ii) to map their distribution, and (iii) to conduct a preliminary analysis of spatial lizard richness.

Methods

Mapping species occurrences

The inventory of lizard species present in Qatar was conducted during 45 days of field work in October 2012 (15 days) and in March-May 2013 (30 days), with an average time of 6 hours per day spent searching for lizards (range 3–10 hours/day). The surveys were conducted in the mainland and in three islands. Halul Island (25.67N, 52.40E) is in the E of Qatar at 81.5 km from the nearest coast in Al-Khor. Al Aaliya Island (25.41N, 51.56E) is situated at 2.5 km from the Eastern coast near Doha city. Al Saflia Island (25.34N, 51.58E) is also in the Eastern coast at a distance of 3.1 km from Doha. Al Aaliya and Al Saflia islands are separated by 5.5 km. The methods used for the inventory varied according to the habitat and time of the day, and are consistent with McDiarmid et al. (2012). The most used methods were active search during the day and night-torch surveys along transects. Most types of habitats were inventoried and special focus was given to searching under natural cover (rock-flipping) and artificial (i.e. litter) cover that often provided shelter to reptiles. On low traffic roads we conducted road surveys, both during the day and night. We occasionally also used pitfall traps and artificial cover (i.e. cardboard) for short periods of time of less than 48 hrs. The geographic location of each individual was taken on a Global Positioning System (GPS). When several individuals of the same species occurred within a short distance of one another, only one spatial data point for that given species was considered. This explains the difference between the number of species sightings and the higher number of lizards observed.

The majority of the data included in the final distribution maps come from our own surveys. However, we have also added three records from publications of Qatar University (Anonymous 2010, Nasher et al. 2009), and 41 records from local volunteers and photographers that accompanied their observations with clear photographs, GPS coordinates or grid square locations. The lizard species were identified based on morphological traits described in Arnold (1986) and Leviton et al. (1992). The most current changes in the nomenclature of the species were according to Fujita and Papenfuss (2011), Moravec et al. (2006), Pyron et al. (2013) and Bauer et al. (2013). Lizard voucher specimens are deposited in the scientific collections of the Ministry of Environment in Qatar. The distribution data belongs to the Ministry of Environment of the State of Qatar and will be uploaded to GBIF in the future.

Data management and analysis

To make the distribution maps we proceeded as follows. The GPS geocoordinates were exported to ArcGIS 10 (ESRI) to create a shapefile, which was projected to the official reference system in the country, QND95/Qatar National Grid (UPDA 2009). A regular grid with squares of 10 × 10 km was made following the Qatar National Grid, while adapting the traditional nomenclature of UTM (Universal Transversal Mercator) or MGRS (Military Grid Reference System) squares (NGA 2013) to the Qatar National Grid (Valdeón et al. 2013b). A similar spatial resolution of 100 km^2 was previously used in several national and regional herpetological atlases (e.g. Arnold 1995; Godinho et al. 1999; Gosá and Bergerandi 1994; Oldham and Weller 2000; Pickard and Towns 1988; Pleguezuelos et al. 2002).

Species richness per square was calculated as the number of species detected in each 10 × 10 km square. We used two relative measures as estimators of species abundance: (i) The percentage of daily sightings, measured as the number of days a certain species was observed from the total number of fieldwork days (n = 45), so we did not consider multiple sightings of the same species. (ii) The percentage of overall sightings. This was calculated as the number of times a species was observed from the total number of sightings (n = 617). We used presence-absence data for computing a species accumulation curve (SAC) and five non-parametric estimators of species richness (ICE, Chao 2, Jackknife 1, Bootstrap and Michaelis-Menten) using EstimateS 9 (Colwell 2013).

Results

During the 45 days of field surveys we observed a total of 865 individual lizards ranging from 5 to 35 per day (average of 19 individuals/day). The total number of species sightings is lower (617), since for some species several individuals were located close together, usually under the same shelter.

We inventoried 21 species of lizards belonging to seven families: Gekkonidae with nine species, Lacertidae with four species, Agamidae with three, Scincidae with two and Varanidae, Trogonophiidae and Sphaerodactylidae with one species each (Table 1). The number of lizard species observed per day ranged between 1 to 10 (average of 4.1 ± 2.1). In the island Al Saflia we only found two species (*Pseudoceramodactylus khobarensis* and *Mesalina brevirostris*), in Al Aaliya island we found three species (*Pseudoceramodactylus khobarensis, Mesalina brevirostris* and *Hemidactylus robustus*), and in Halul island we found five species (*Hemidactylus persicus, H. flaviviridis, Cyrtopodion scabrum, Pristurus rupestris* and *Trachylepis septemtaeniata*). Based on our measurements of relative abundance, we found that four species of lizards appear to be the most abundant: *Bunopus tuberculatus, Cyrtopodion scabrum, Uromastyx aegyptia* and *Mesalina brevirostris* (Figure 2). The species accumulation curve approaches a plateau, suggesting that the majority of species present has been inventoried (Figure 3). The

Table 1. Lizard species inventoried in Qatar during the surveys conducted in 2012–2013, and publications where the species (or other species probably mistaken with correct species) are recorded for the first time in Qatar.

Species	Family	First record in Qatar
Pristurus rupestris Blanford, 1874 (a)	Sphaerodactylidae	Ministry of Environment 2004
Pseudoceramodactylus khobarensis Haas, 1957	Gekkonidae	Valdeón et al. 2013a
Stenodactylus arabicus (Haas, 1957)	Gekkonidae	Metallinou et al. 2012
Stenodactylus doriae (Blanford, 1874) (a)	Gekkonidae	Metallinou et al. 2012
Stenodactylus slevini Haas, 1957	Gekkonidae	Arnold 1980b
Bunopus tuberculatus Blanford, 1874 (a)	Gekkonidae	Mohammed 1988
Cyrtopodion scabrum (Heyden, 1827)	Gekkonidae	Mohammed 1988 (cited as *Gymnodactylus scaber*)
Hemidactylus flaviviridis Rüppell, 1835	Gekkonidae	Mohammed 1988
Hemidactylus persicus Anderson, 1872	Gekkonidae	Castilla et al. 2013
Hemidactylus robustus Heyden, 1827	Gekkonidae	Mohammed 1988 (cited as *H. turcicus*)
Scincus mitranus Anderson, 1871	Scincidae	Mohammed 1988 (cited *S. scincus*, probably mistaken with *S. mitranus*)
Trachylepis septemtaeniata (Reuss, 1834)	Scincidae	Mohammed 1988 (cited as *Mabuya aurata*)
Diplometopon zarudnyi Nikolsky, 1907	Trogonophiidae	Mohammed 1988
Mesalina adramitana (Boulenger, 1917)	Lacertidae	Arnold 1980a
Mesalina brevirostris Blanford, 1874 (b)	Lacertidae	Mohammed 1988 (cited as *Eremias brevirostris*)
Acanthodactylus schmidti Haas, 1957	Lacertidae	Mohammed 1988 (cited *A. scutellatus*, probably mistaken with *A. schmidti*)
Acanthodactylus opheodurus Arnold, 1980	Lacertidae	Mohammed 1988 (cited *A. boskianus*, probably mistaken with *A. opheodurus*)
Varanus griseus (Daudin, 1803)	Varanidae	Mohammed 1988
Uromastyx aegyptia (Forskål, 1775)	Agamidae	Mohammed 1988 (cited as *U. microlepis*)
Phrynocephalus arabicus Anderson, 1894	Agamidae	Mohammed 1988 (cited as *P. nejdensis*)
Trapelus flavimaculatus Rüppell, 1835	Agamidae	Mohammed 1988 (cited as *Agama flavimaculata*)

use of non-parametric estimators of species richness supports this statement indicating that only 2–4 species of lizards remain to be discovered (estimator, mean value ± standard deviation): ICE 23.61 ± 0.01, Chao 2 25.83 ± 5.86, Jackknife 1 25.83 ± 2.01, Bootstrap 23.11, and Michaelis-Menten 24.63. The preliminary lizard species richness varied largely across Qatar between 1–11 species per grid square (Figure 4). The distribution maps for the 21 lizard species in Qatar are presented in Figures 5–13, and Figure 14 shows the photos of the lizards.

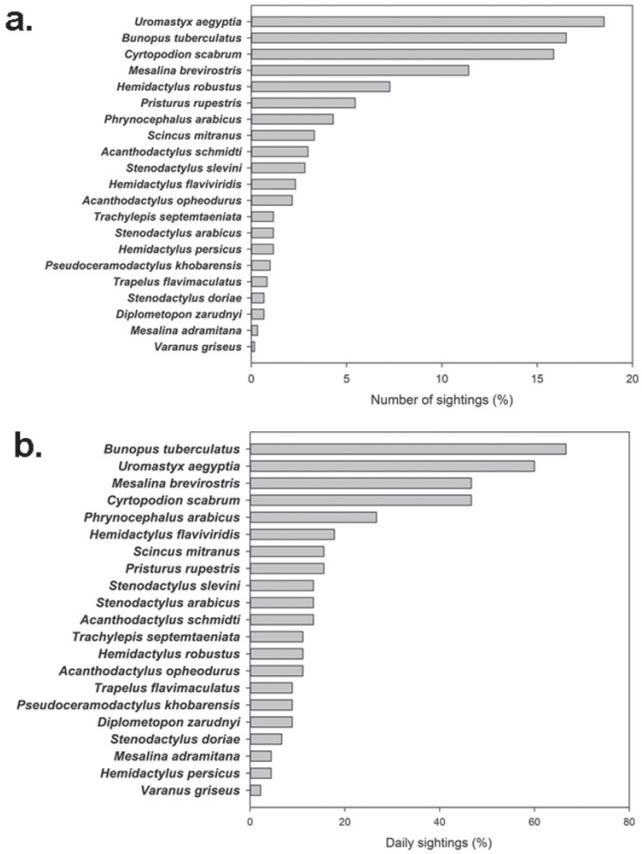

Figure 2. Estimates of lizard species abundance based on **a** the proportion of sightings of a certain species from the total number of sightings (n = 617), and **b** the presence of a species per day from the total number of fieldwork days (n = 45) (see methods for details).

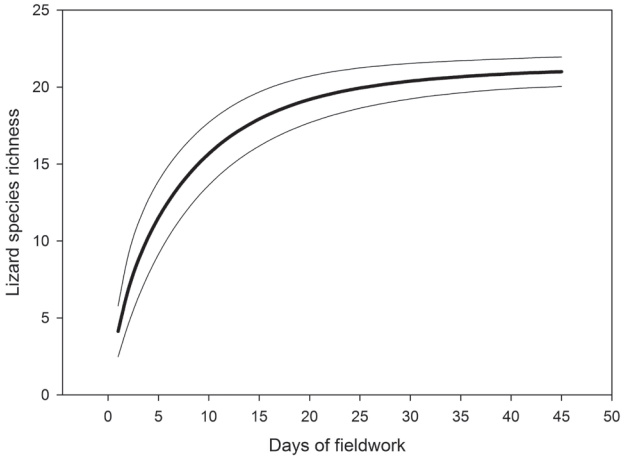

Figure 3. Species accumulation curve (bold line) reflecting lizard species richness based on presence-absence data for the whole country. The thin lines indicate the estimated error margins (95%).

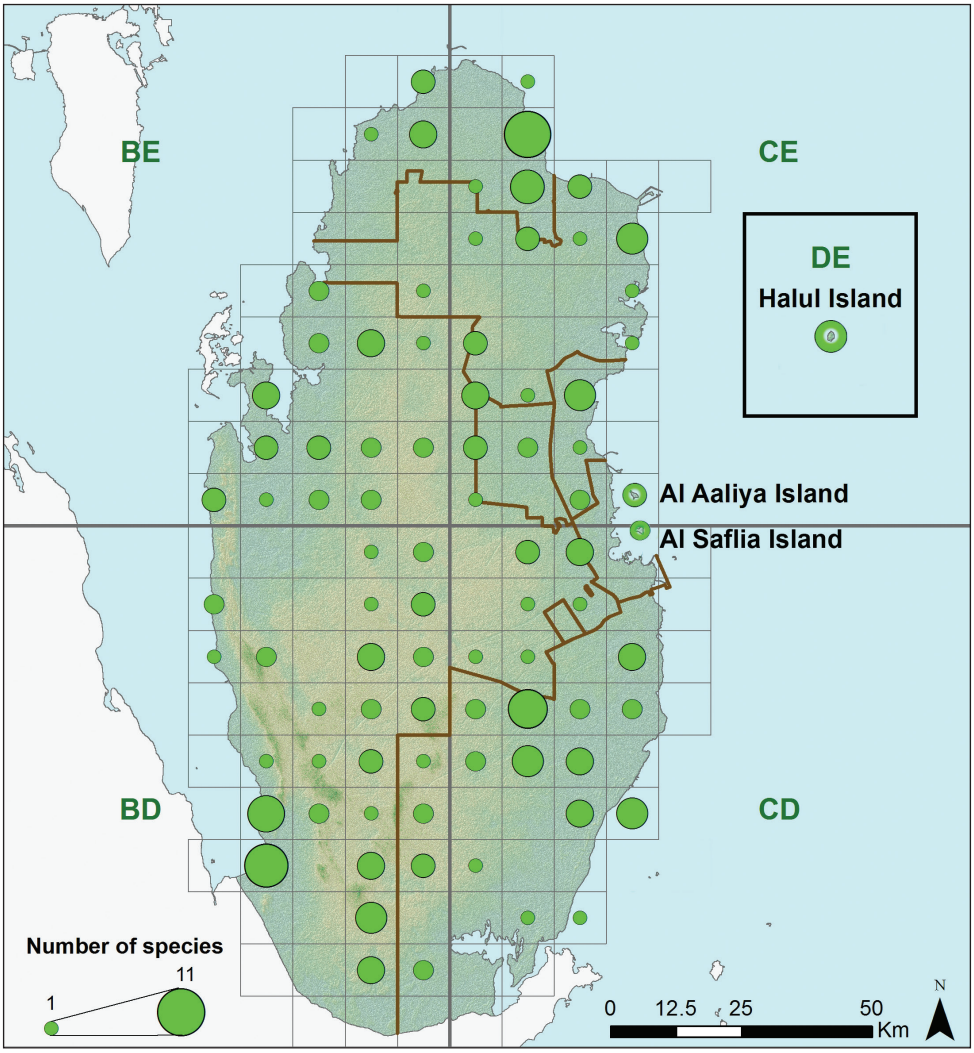

Figure 4. Lizard species richness at a resolution of 100 km^2.

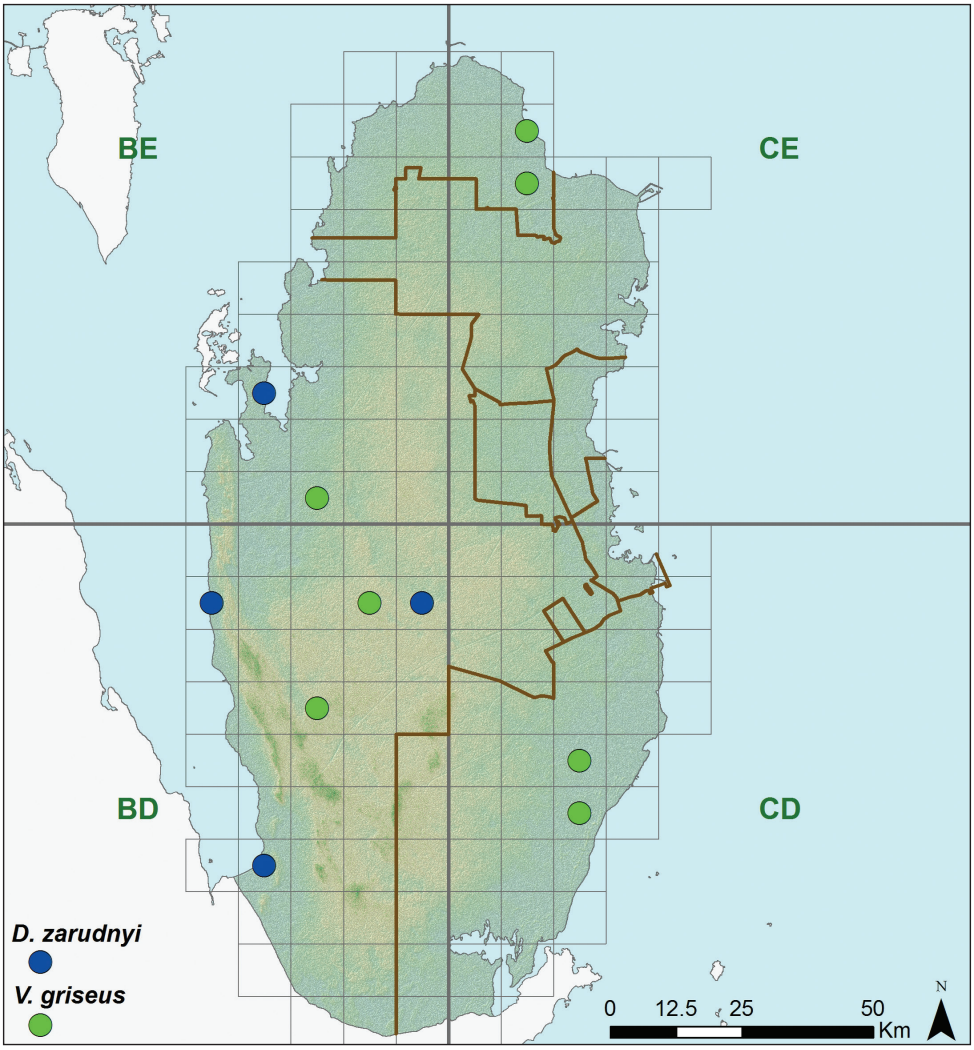

Figure 5. Distribution of *Diplometopon zarudnyi* and *Varanus griseus*.

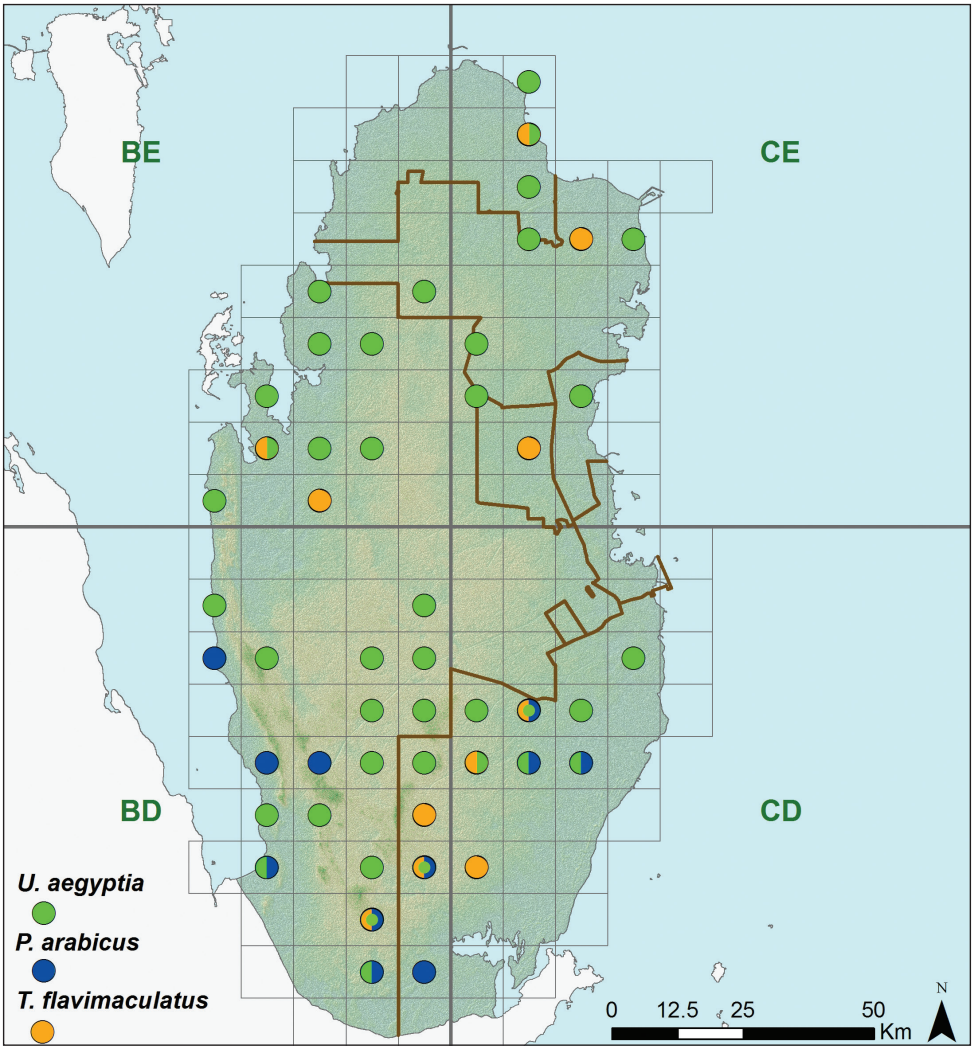

Figure 6. Distribution of three agamid species (*Phrynocephalus arabicus, Trapelus flavimaculatus, Uromastyx aegyptia*).

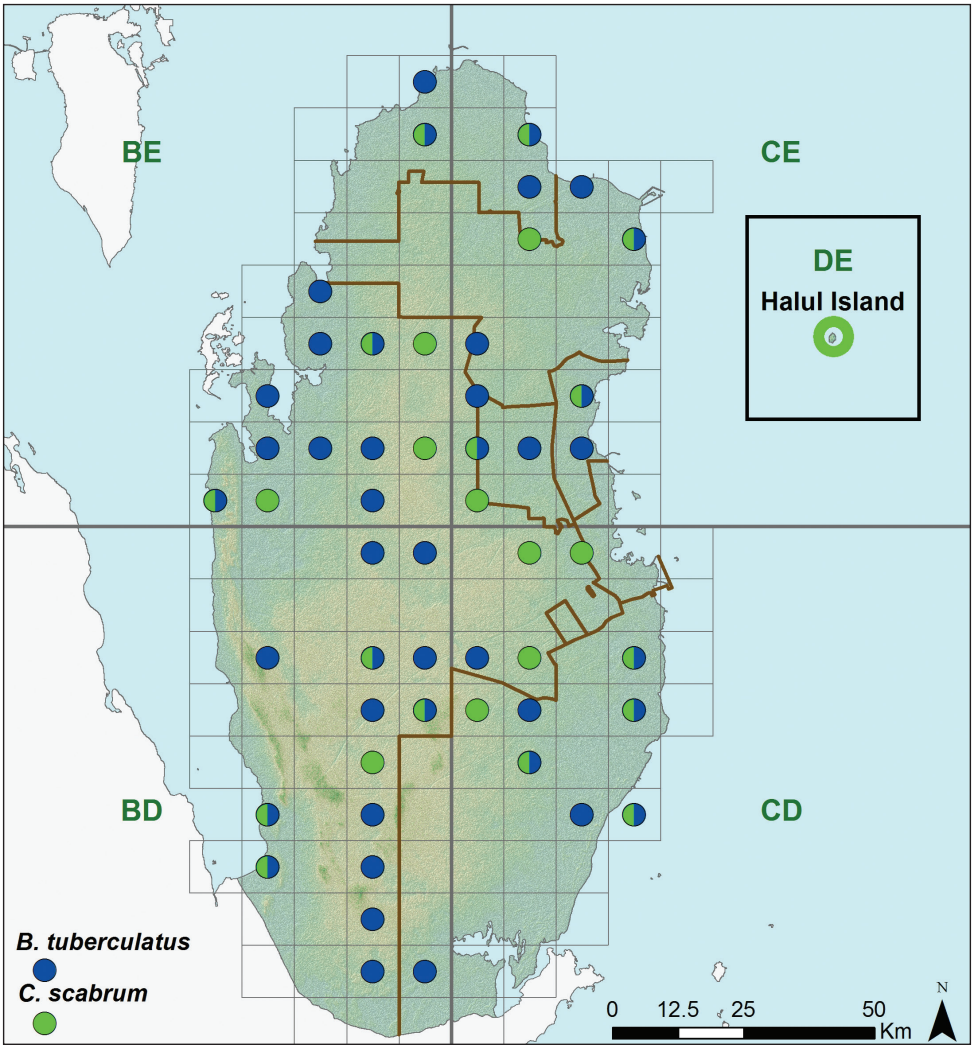

Figure 7. Distribution of *Bunopus tuberculatus* and *Cyrtopodion scabrum*.

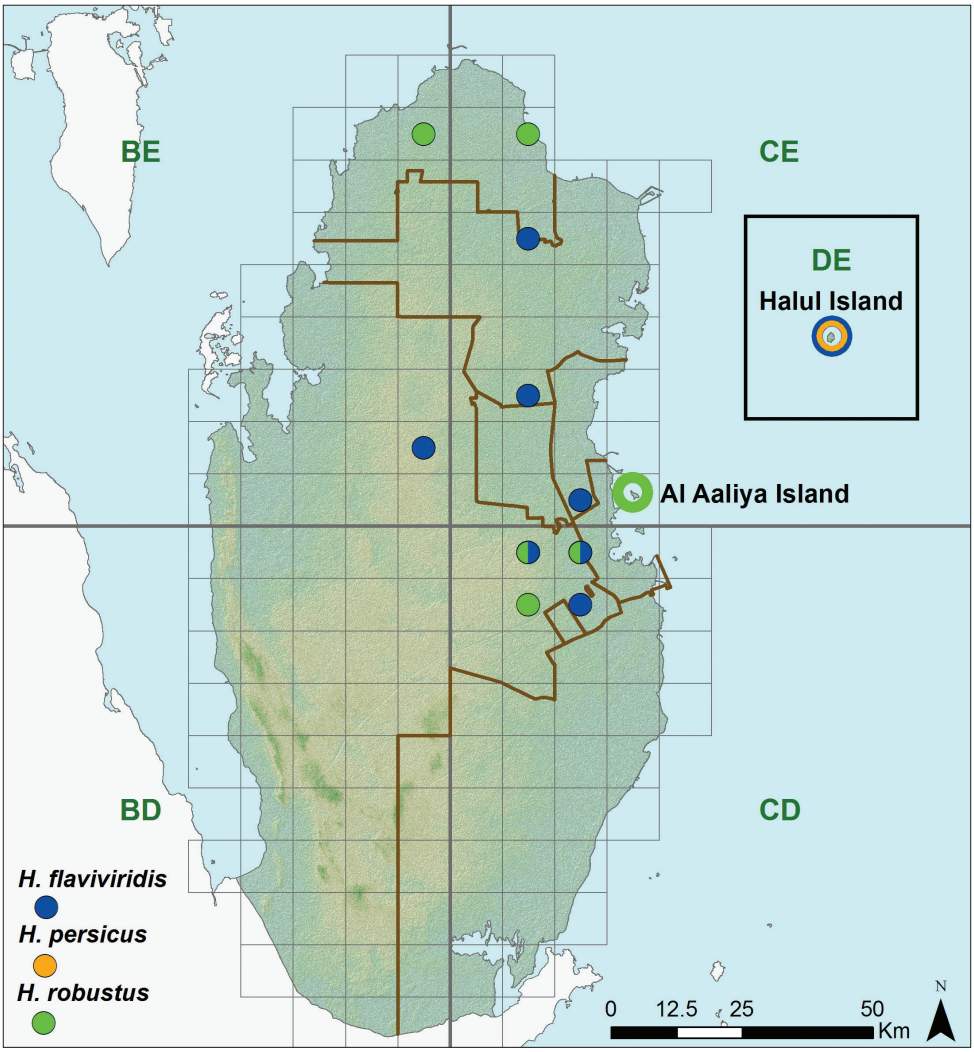

Figure 8. Distribution of the species of the genus *Hemidactylus*.

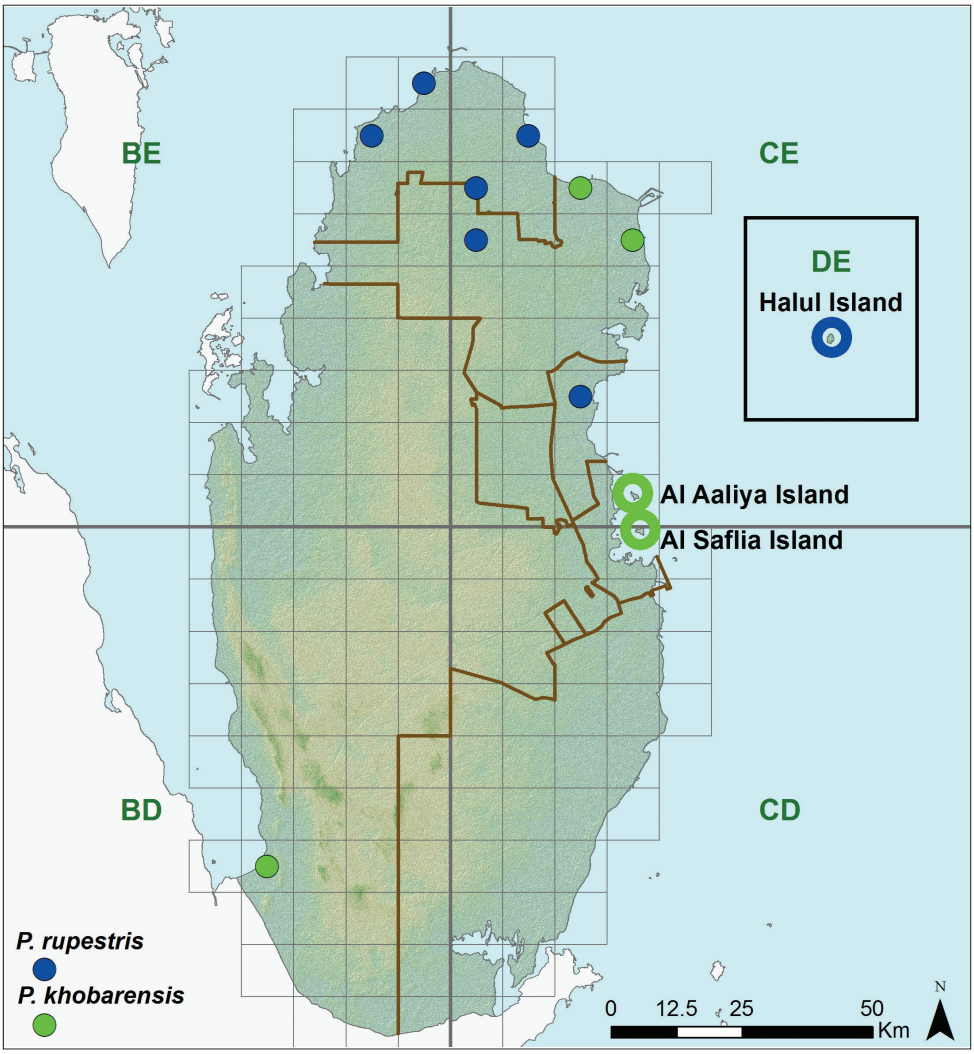

Figure 9. Distribution of *Pseudoceramodactylus khobarensis* and *Pristurus rupestris*.

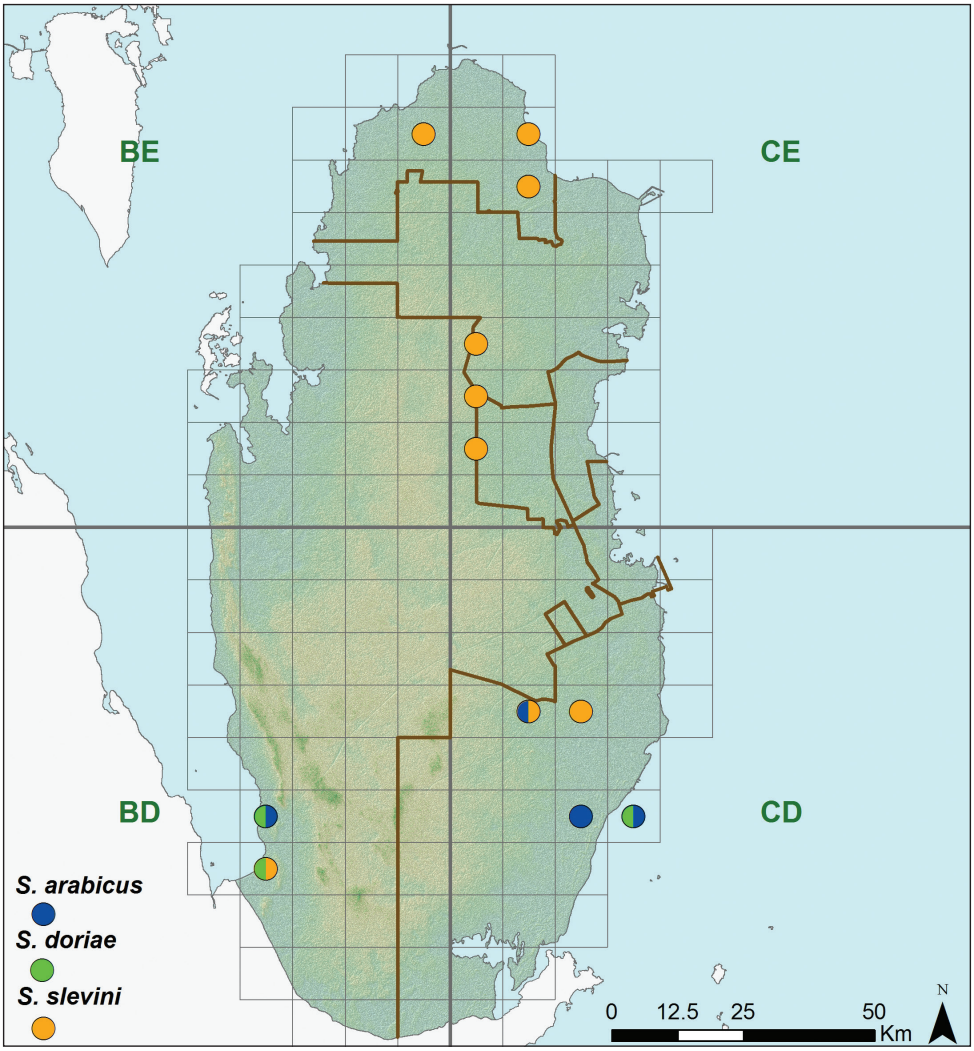

Figure 10. Distribution of the species of the genus *Stenodactylus*.

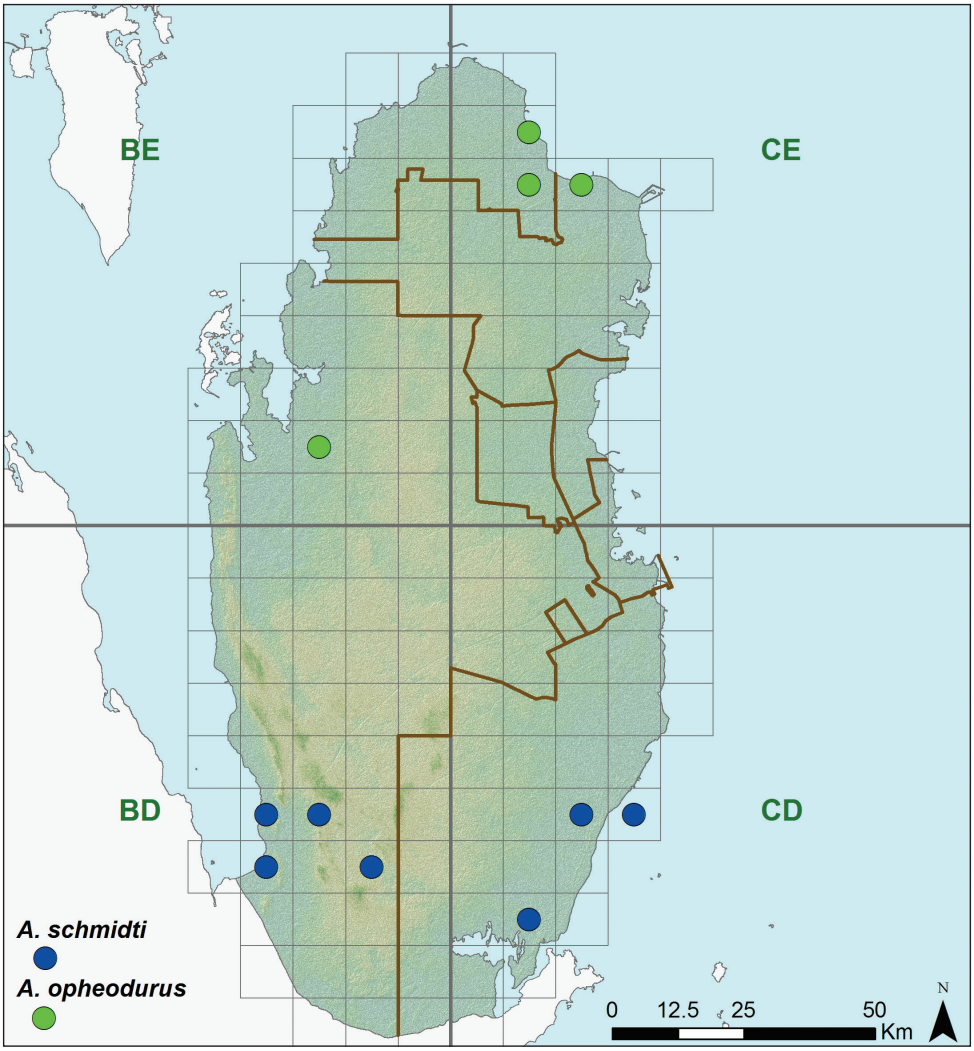

Figure 11. Distribution of the species of the genus *Acanthodactylus*.

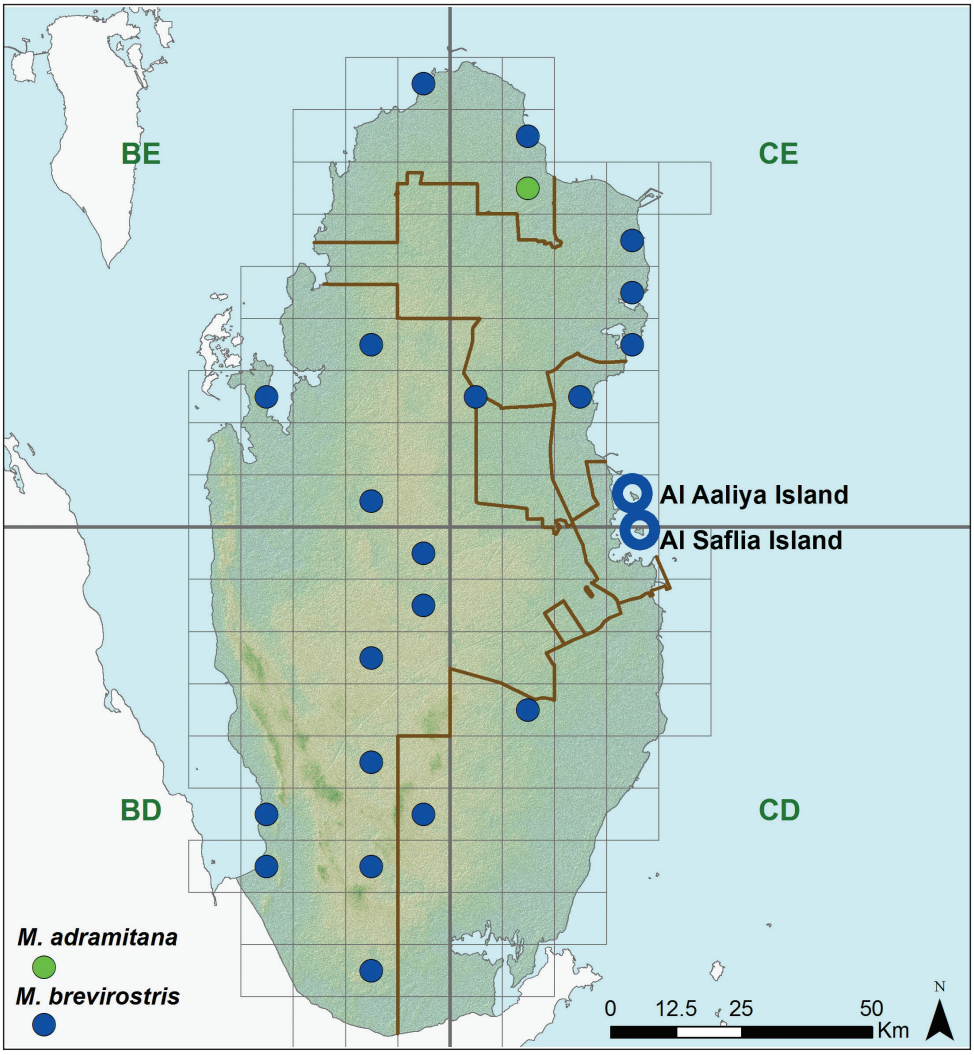

Figure 12. Distribution of the species of the genus *Mesalina*.

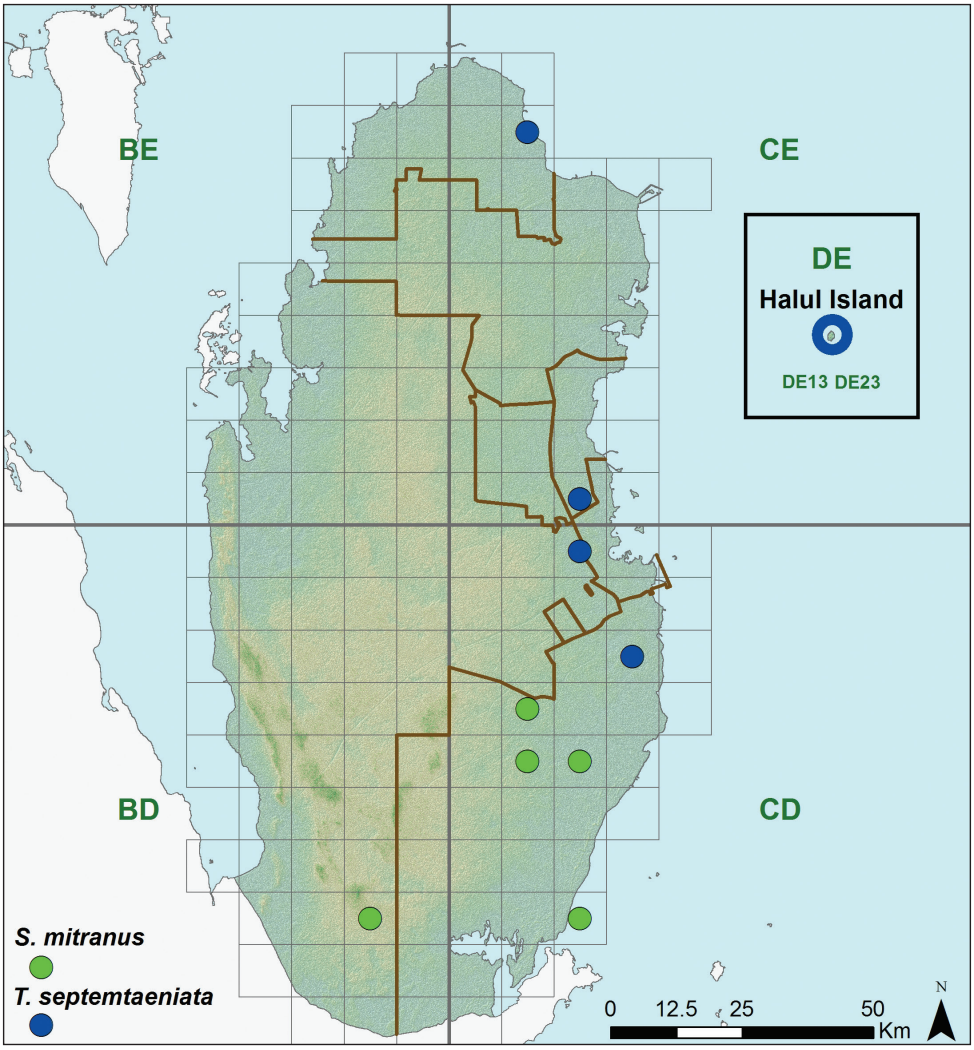

Figure 13. Distribution of Scincidae species (*Scincus mitranus* and *Trachylepis septemtaeniata*).

Figure 14. Photos of lizard species inventoried in Qatar (Author: Valdeón A, except for *Diplometopon zarudnyi* (Yamaguchi N)).

Discussion

In this study we provide the first consistent list of lizard species for Qatar, and the first distribution maps based on field surveys. Our study fills a gap in the knowledge of lizard distributions in the Arabian Peninsula and in Qatar specifically. Except for the study of Mohammed (1988), previous data has not been systematic and only included anecdotal references (Arnold 1980b, Leviton et al. 1992, Metallinou et al. 2012, Sindaco and Jeremčenko 2008).

During our surveys we attempted to collect data throughout the entire country; however this was not possible due to difficulties of accessing certain areas (e.g. industrial and private properties). The SE part of Qatar is difficult to access due to sandy soils and that was not fully sampled either. There are also differences in lizard species detectability due to differences in body size (e.g. maximum snout-vent length in *Uromastyx aegyptia* of 375 mm and only 32 mm in *Pristurus rupestris* (Meiri 2008)), behavior and period of activity (night or day). The lack of past information on the lizard species present in Qatar does not allow identifying allochtonous from native species. We consider species strictly associated with urban areas (e.g., *Hemidactylus flaviviridis*) as probably introduced, but further phylogeographic studies are required to elucidate their status. However, despite such difficulties, our lizard species inventory seems to be nearly completed as indicated by the estimators of species richness and the SAC (Fig. 3). Nevertheless, it could be not surprising to find in Qatar additional lizard species that occur in the vicinity of Qatar. The maps provided in Sindaco and Jeremčenko (2008) show that 13 lizard species are present near Qatar, including *Ptyodactylus hasselquistii*, *Teratoscincus* (*scincus*) *keyserlingii*, *Phrynocephalus maculatus*, *Pseudotrapelus* sp., *Trapelus ruderatus*, *T. pallidus*, *Chalcides ocellatus*, *Scincus scincus*, *Acanthodactylus boskianus*, *A. haasi*, *A. gongrorhynchatus*, *A. scutellatus*, and *Mesalina guttulata.*

The preliminary species distribution maps provided in this study allow, nevertheless, for further analysis on distribution patterns of abundance, rarity, richness and assemblage composition at larger spatial scales (Elith et al. 2010, Baselga et al. 2012). The distribution data are also valuable for conservation planning and modeling species distribution at regional and global level (Sillero et al. 2005).

The reptiles of Qatar are threatened by the rapid human population growth that increased from several tens of thousand inhabitants to almost two million in the last century, habitat destruction caused by construction development, gas and oil extraction and transport facilities, and the introduction of alien species (especially cats). The human impact is unevenly distributed, with high human impact in and around Doha, moderate along the coast and low in the interior (WCS 2005). Qatar produces around 2 million tons of solid municipal waste annually, corresponding to a daily generation rate of about 2.5 kg per capita that are disposed mainly through landfill and composting. This increase in solid waste generation not only results in the environmental pollution but also habitat destruction (Al-Maaded et al. 2012). There are 7790 km of roads (0.67 km road/km^2), of which 90% are paved, and 571 cars per 1,000 people (2002

est) (Hutchinson Encyclopedia 2011). High traffic on roads, particularly in rural areas, can result in high mortality in reptile populations (e.g. Shepard et al. 2008). Road-kills are frequent and while it is difficult to document it in small lizards, carcasses of larger lizards like *Uromastyx* are often found along roads. The response of lizards to the relatively recent human impact in Qatar provides an excellent example of the winner-loser concept (McKinney and Lockwood 1999), with several species benefiting from man-made artificial habitats (e.g. *Cyrtopodion scabrum, Hemidactylus flaviviridis, H. robustus*). We estimate that human activities will result in changes in the ranges of the lizards of Qatar and stress the urgent need for a complete species inventory and mapping, as a background study for a future monitoring program.

Conclusion

The distribution maps presented in this paper as visualized occurrence records fill a gap in the knowledge of biodiversity in Qatar, and will help the prioritization of conservation efforts and the identification of important conservation areas for lizards. This study is a first step in updating the Qatar databases of lizards and wildlife, with the goal to make scientific biodiversity data available and useful for the international community.

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References

Al-Maaded M, Madi NK, Kahraman R, Hodzic A, Ozerkan NG (2012) An Overview of Solid Waste Management and Plastic Recycling in Qatar. J Polym Environ 20: 186–194. doi: 10.1007/s10924-011-0332-2

Anonymous (2010) Amphisbaenid record – another first for Qatar? Qatar Natural History Group 3: 16.

Anderson J (1871) Description of a new species of *Scincus*. P. Asiat. Soc. Bengal 1871: 115–116.

Anderson J (1872) On some Persian, Himalayan and other Reptiles. Proc. Zool. Soc. London 1872: 371–404.

Anderson J (1894) On two new species of agamoid lizards from the Hardramut, South-Eastern Arabia. Ann. Mag. Nat. Hist. 6th Series 14: 376–378.

Arnold EN (1980a) The reptiles and amphibians of Dhofar, southern Arabia. Journal of Oman Studies Special Report (No. 2) 1980: 273–332.

Arnold EN (1980b) Reptiles of Saudi Arabia. A review of the lizard genus *Stenodactylus* (Reptilia: Gekkonidae). Fauna of Saudi Arabia 2: 368–404.

Arnold EN (1986) A Key and Annotated Check List to the Lizards and Amphisbaenians of Arabia. Fauna of Saudi Arabia 8: 385–435.

Arnold EN (1995) Atlas of Amphibians and Reptiles in Britain. ITE research publication no. 10. Centre for Ecology and Hydrology. Natural Environment Research Council. HMSO, London, 42 pp.

Baselga A, Lobo JM, Svenning JC, Araújo MB (2012) Global patterns in the shape of species geographical ranges reveal range determinants. Journal of Biogeography 39: 760–771. doi: 10.1111/j.1365-2699.2011.02612.x

Batanouny KH (1981) Ecology and flora of Qatar. Environmental Studies Center, University of Qatar, 245 pp.

Bauer A, Masroor R, Titus-McQuillan J, Heinicke MP, Heinicke MP, Daza JD, Jackman, TR (2013) A preliminary phylogeny of the Palearctic naked-toed geckos (Reptilia: Squamata: Gekkonidae) with taxonomic implications. Zootaxa 3599: 301–324. doi: 10.11646/zootaxa.3599.4.1

Blanford WT (1874a) Descriptions of new lizards from Persia and Baluchistan. Ann. Mag. Nat. Hist. 4th Series 13: 453–455.

Blanford WT (1874b) Descriptions of new Reptilia and Amphibia from Persia and Baluchistan. Ann. Mag. Nat. Hist. 4th Series 14: 31–35.

Böhm M, Collen B, Baillie JEM, Bowles P, Chanson J, Cox N, Hammerson G, Hoffmann M, Livingstone SR, Ram M, Rhodin AGJ, Stuart SN, van Dijk PP, Young BE, Afuang LE, Aghasyan A, García A, Aguilar C, Ajtic R, Akarsu F, Alencar LRV, Allison A, Ananjeva N, Anderson S, Andrén C, Ariano-Sánchez D, Arredondo JC, Auliya M, Austin CC, Avci A, Baker PJ, Barreto-Lima AF, Barrio-Amorós CL, Basu D, Bates MF, Batistella A, Bauer A, Bennett D, Böhme W, Broadley D, Brown R, Burgess J, Captain A, Carreira S, Castañeda MDR, Castro F, Catenazzi A, Cedeño-Vázquez JR, Chapple DG, Cheylan M, Cisneros-Heredia DF, Cogălniceanu D, Cogger H, Corti C, Costa GC, Couper PJ, Courtney T, Crnobrnja-Isailovic J, Crochet PA, Crother B, Cruz F, Daltry JC, Daniels RJR, Das I, de

Silva A, Diesmos AC, Dirksen L, Doan TM, Dodd CK, Doody JS, Dorcas ME, Duarte de Barros Filho J, Egan VT, El Mouden EH, Embert D, Espinoza RE, Fallabrino A, Feng X, Feng ZJ, Fitzgerald L, Flores-Villela O, França FGR, Frost D, Gadsden H, Gamble T, Ganesh SR, Garcia MA, García-Pérez JE, Gatus J, Gaulke M, Geniez P, Georges A, Gerlach J, Goldberg S, Gonzalez JCT, Gower DJ, Grant T, Greenbaum E, Grieco C, Guo P, Hamilton AM, Hare K, Hedges SB, Heideman N, Hilton-Taylor C, Hitchmough R, Hollingsworth B, Hutchinson M, Ineich I, Iverson J, Jaksic FM, Jenkins R, Joger U, Jose R, Kaska Y, Kaya U, Keogh JS, Köhler G, Kuchling G, Kumlutaş Y, Kwet A, La Marca E, Lamar W, Lane A, Lardner B, Latta C, Latta G, Lau M, Lavin P, Lawson D, LeBreton M, Lehr E, Limpus D, Lipczynski N, Lobo AS, López-Luna MA, Luiselli L, Lukoschek V, Lundberg M, Lymberakis P, Macey R, Magnusson WE, Mahler DL, Malhotra A, Mariaux J, Maritz B, Marques OAV, Márquez R, Martins M, Masterson G, Mateo JA, Mathew R, Mathews N, Mayer G, McCranie JR, Measey GJ, Mendoza-Quijano F, Menegon M, Métrailler S, Milton DA, Montgomery C, Morato SAA, Mott T, Muñoz-Alonso A, Murphy J, Nguyen TQ, Nilson G, Nogueira C, Núñez H, Orlov N, Ota H, Ottenwalder J, Papenfuss T, Pasachnik S, Passos P, Pauwels OSG, Pérez-Buitrago N, Pérez-Mellado V, Pianka ER, Pleguezuelos J, Pollock C, Ponce-Campos P, Powell R, Pupin F, Quintero Díaz GE, Radder R, Ramer J, Rasmussen AR, Raxworthy C, Reynolds R, Richman N, Rico EL, Riservato E, Rivas G, da Rocha PLB, Rödel MO, Rodríguez Schettino L, Roosenburg WM, Ross JP, Sadek R, Sanders K, Santos-Barrera G, Schleich HH, Schmidt BR, Schmitz A, Sharifi M, Shea G, Shi HT, Shine R, Sindaco R, Slimani T, Somaweera R, Spawls S, Stafford P, Stuebing R, Sweet S, Sy E, Temple HJ, Tognelli MF, Tolley K, Tolson PJ, Tuniyev B, Tuniyev S, üzüm N, van Buurt G, Van Sluys M, Velasco A, Vences M, Veselý M, Vinke S, Vinke T, Vogel G, Vogrin M, Vogt RC, Wearn OR, Werner YL, Whiting MJ, Wiewandt T, Wilkinson J, Wilson B, Wren S, Zamin T, Zhou K, Zug G (2013) The conservation status of the world's reptiles. Biological Conservation 157: 372–385. doi: 10.1016/j.biocon.2012.07.015

Boulenger GA (1917) Descriptions of new lizards of the family Lacertidae. Ann. Mag. Nat. Hist. 8th Series 19: 277–279.

Castilla AM, Richer R, Herrel A, Conkey AAT, Tribuna J, Al-Thani M (2011a) First evidence of scavenging behaviour in the herbivorous lizard *Uromastyx aegyptia microlepis*. Journal of Arid Environments 75: 671–673. doi: 10.1016/j.jaridenv.2011.02.005

Castilla AM, Richer R, Herrel A, Conkey AAT, Tribuna J, Chan R, Martínez de Aragón J, Böer B, Mohtar R (2011b) Plant diversity in the diet of the lizard *Uromastyx aegyptia microlepis* in Qatar: The effect of zone, sampling date and faeces size. Proceedings of the Qatar Foundation Annual Research Forum 2011a (QF-ARF). doi: 10.5339/qfarf.2011.evp7

Castilla AM, Valdeón A, Cogălniceanu D, Gosá A, Alkuwary A, Saifelnasr EH, Al Naimi S, Al-Hemaidi AA (2013) First record of a gecko species to the fauna of Qatar: *Hemidactylus persicus* Anderson, 1872 (Gekkonidae). QScience Connect 2013.28. doi: 10.5339/connect.2013.28

Colwell RK (2013) EstimateS: Statistical estimation of species richness and shared species from samples. Version 9. User's Guide and application published at: http://purl.oclc.org/estimates

Cox NA, Temple HJ (2009) European red list of reptiles. Office for Official Publications of the European Communities, Luxembourg, 32 pp.

Daudin FM (1803) Histoire Naturelle, Générale et Particulière des Reptiles. Vol. 8. F. Dufart, Paris, 442 pp.

Elith J, Kearney M, Phillips S (2010) The art of modelling range-shifting species. Methods in Ecology and Evolution 1: 330–342. doi: 10.1111/j.2041-210X.2010.00036.x

ESA, European Space Agency (2010) GlobCover 2009 v.2.3. http://due.esrin.esa.int/globcover/

Forskål P (1775) Descriptiones animalium, avium, amphibiorum, piscium, insectorum, vermium; quae in itinere Orientali observavit Petrus Forskål. Mölleri, Hauniae, xxxiv + 164 pp.

Fujita MK, Papenfuss TJ (2011) Molecular systematics of *Stenodactylus* (Gekkonidae), an Afro-Arabian gecko species complex. Molecular Phylogenetics and Evolution 58: 71–75. doi: 10.1016/j.ympev.2010.10.014

Gamble T, Bauer AM, Greenbaum E, Jackman TR (2008) Evidence for Gondwanan vicariance in an ancient clade of gecko lizards. Journal of Biogeography 35: 88–104. doi: 10.1111/j.1365-2699.2007.01770.x

Gibbons J, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy S, Wiine C (2000) The Global Decline of Reptiles, *Déjà Vu* Amphibians. BioScience 50: 653–666. doi: 10.1641/0006-3568(2000)050[0653:TGDORD]2.0.CO;2

Godinho R, Teixeira J, Rebelo R, Segurado P, Loureiro A, Álvares F, Gomes N, Cardoso P, Camilo-Alves C, Brito JC (1999) Atlas of the continental Portuguese herpetofauna: an assemblage of published data. Revista Española de Herpetología 13: 61–82.

Gosá A, Bergerandi A (1994) Atlas de distribución de los Anfibios y Reptiles de Navarra. Munibe (Ciencias Naturales) 46: 109–189.

Haas G (1957) Some amphibians and reptiles from Arabia. Proc. Cal. Acad. Sci. 29(3): 47–86.

Herrel A, Castilla AM, Al-Sulaiti M, Wessels J (2013) Does large body size relax constraints on bite force generation in lizards of the genus *Uromastyx*. Journal of Zoology. doi: 10.1111/jzo.12089

Heyden CHG von (1827) Reptilien. In: Rüppell E. Atlas zu Reise im nördlichen Afrika. l. Zoologie. HL Brönner, Frankfurt a.M., 1–24.

Hutchinson Encyclopedia (2011) Qatar. eLibrary. Web. 06 Nov. 2013.

Leviton AE, Anderson SC, Adler K, Minton SA (1992) Handbook to Middle East Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles. Oxford, USA, 252 pp.

Martín J, Castilla AM, López P, Al Jaidah M, Mohtar R (2012) Lipophilic compounds in femoral gland secretions of spiny-tailed lizard, dhub, *Uromastyx aegyptia microlepis* (Reptilia, Agamidae) from the Qatar desert. Proceedings of the Qatar Foundation Annual Research Forum 2012 (QF-ARF). doi: 10.5339/qfarf.2012.EEP53

Matin S, Chitale VS, Behera MD, Mishra B, Roy PS (2012) Fauna data integration and species distribution modelling as two major advantages of geoinformatics-based phytobiodiversity study in today's fast changing climate. Biodiversity and Conservation 21: 1229–1250. doi: 10.1007/s10531-012-0233-2

McDiarmid RW, Foster MS, Guyer C, Gibbons WJ, Chernoff N (2012) Reptile Biodiversity. Standard methods for inventory and monitoring. University of California Press.

McKinney ML, Lockwood JL (1999) Biotic homogenization: a few winners replacing many losers in the next mass extinction. Trends in Ecology and Evolution 14: 450–453. doi: 10.1016/S0169-5347(99)01679-1

Meiri S (2008) Evolution and ecology of lizard body sizes. Global Ecology and Biogeography 17: 724–734. doi: 10.1111/j.1466-8238.2008.00414.x

Metallinou M, Arnold EN, Crochet P, Geniez P, Brito JC, Lymberakis P, Baha El Din S, Sindaco R, Robinson M, Carranza S (2012) Conquering the Sahara and Arabian deserts: Systematics and biogeography of *Stenodactylus* geckos (Reptilia: Gekkonidae). BMC Evolutionary Biology 12: 258. doi: 10.1186/1471-2148-12-258

Mohammed MBH (1988) Survey of the reptiles of Qatar. Proceedings of the Zoological Society of the Arab Republic Egypt 15: 17–26.

Moravec J, Franzen M, Böhme W (2006) Taxonomy, nomenclature and distribution of the *Trachylepis* (formerly *Mabuya*) *aurata* (Linnaeus, 1758) complex. Herpetologia Bonnensis II. Proceedings of the 13th Congress of the Societas Europaea Herpetologica, 89–93.

MOE, Ministry of the Environment (2004) Qatar National Biodiversity Strategy and Action Plan Assessment. Biodiversity Inventory, Final Report. Ministry of the Environment, Doha, Qatar.

Nasher AK, Al Thani RF, Altaeb AA (2009) The University Farm, a potential field station for scientific research. Qatar Biodiversity Newsletter 13: 2–11.

NGA (2013) DMA Technical Manual 8358.1. http://earth-info.nga.mil/GandG/publications/tm8358.1/toc.html

Nikolsky AM (1907) Reptiles et amphibiens recueillis (part.) M. N. A. Zarudny en Perse en 1903–1904. Ann. Mus. Zool. Acad. Imp. Sci., St. Petersburg 10 [1905]: 260–301. [in Russian and Latin]

Qatar Statistics Authority (2013) Qatar Atlas, Doha, Qatar, 1–303.

Oldham MJ, Weller WF (2000) Ontario Herpetofaunal Atlas. Natural Heritage Information Centre, Ontario Ministry of Natural Resources.

Pickard CR, Towns DR (1988) Atlas of the amphibians and reptiles of New Zealand. Conservation Sciences Publication Number 1. Science and Research Directorate. Department of Conservation, Wellington, 59 pp.

Pleguezuelos JM, Márquez R, Lizana M (2002) Atlas y Libro Rojo de los Anfibios y Reptiles de España. Dirección General de Conservación de la Naturaleza – Asociación Herpetológica Española (2ª impresión), Madrid, 587 pp.

Primack R (2010) Essentials of Conservation Biology, 5th edition. Sinauer Associates, Sunderland, MA, 601 pp.

Pyron RA, Burbrink FT, Wiens JJ (2013) A phylogeny and revised classification of Squamata, including 4161 species of lizards and snakes. BMC Evolutionary Biology 13: 93. doi: 10.1186/1471-2148-13-93

Reese GC, Wilson KR, Hoeting JA, Flather CH (2005) Factors affecting species distribution predictions: a simulation modeling experiment. Ecological Applications 15: 554–564. doi: 10.1890/03-5374

Reuss A (1834) Zoologische Miscellen, Reptilien. Abhandlungen aus dem Gebiete der beschreibenden Naturgeschichte. Museum Senckenbergianum, Frankfurt am Main 1(6): 27–62.

Richer R (2008) Conservation in Qatar. Impacts of increasing industrialization. CIRS. Centre for International and Regional Studies. Georgetown University School of Foreign Service in Qatar, 27 pp.

Rüppell E (1835) Neue Wirbelthiere zu der Fauna von Abyssinien gehörig, entdeckt und beschrieben. Amphibien. S. Schmerber, Frankfurt a.M., 437 pp.

Supreme Council for Environment and Natural Reserves (SCENR) (2007) Protected Area Action Plan 2008–2013 for Qatar. Department of Wildlife Conservation, 25pp.

Sillero N, Celaya L, Martin-Alfageme S (2005) Using Geographical Information System (GIS) to make an atlas: a proposal to collect, store, map and analyse chorological data for herpetofauna. Revista Española de Herpetología 19: 87–101.

Sindaco R, Jeremčenko VK (2008) The Reptiles of the Western Palearctic. 1. Annotated checklist and distributional atlas of the turtles, crocodiles, amphisbaenians and lizards of Europe, North Africa, Middle East and Central Asia. Edizione Belvedere, Latina.

Shepard DB, Dreslik MJ, Jellen BC, Phillips CA (2008) Reptile Road Mortality around an Oasis in the Illinois Corn Desert with Emphasis on the Endangered Eastern Massasauga. Copeia 2008: 350–359. doi: 10.1643/CE-06-276

Underwood G (1954) On the classification and evolution of geckos. Proceedings of the Zoological Society of London 124: 469–492. doi: 10.1111/j.1469-7998.1954.tb07789.x

UPDA, Urban Planning & Development Authority (2009) Qatar Survey Manual. Urban Planning & Development Authority, Doha, Qatar.

Valdeón A, Castilla AM, Cogălniceanu D, Gosá A, Alkuwary A, Saifelnasr E, Naumann E, Mas-Peinado P, Richer R, Al-Hemaidi A (2013a) On the presence and distribution of the Gulf sand gecko, *Pseudoceramodactylus khobarensis* Haas, 1957 (Reptilia: Squamata: Gekkonidae) in Qatar. QScience Connect 2013.34. doi: 10.5339/connect.2013.34

Valdeón A, Castilla AM, Laso B, Longares LA, Bukhari S, Mohielden Y, Mohd Al-Hemaidi AA (2013b) Development of a Qatar National Biodiversity Grid (QNBG) to create Biodiversity Atlas in Qatar. Proceedings of the Qatar Foundation Annual Research Conference 2013 (QF-ARC). doi: 10.5339/qfarf.2013.EESP-040

WCS, Wildlife Conservation Society - WCS, and Center for International Earth Science Information Network - CIESIN - Columbia University (2005) Last of the Wild Project, Version 2, 2005 (LWP-2): Global Human Footprint Dataset (Geographic). NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY. http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-footprint-geographic [accessed 11 November 2013]