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**Research article**

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# Rare freshwater sponges of Australasia: new record of *Umborotula bogorensis* (Porifera: Spongillida: Spongillidae) from the Sakaerat Biosphere Reserve in Northeast Thailand

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**Abstract.** *Umborotula bogorensis* (Weber, 1890) is a freshwater sponge species that is recorded occasionally, mainly on islands and peninsulas of Australasia. Less than 10 records with morphological descriptions and illustrations have been published so far, and the most recent record is dated 1978. A list of the few voucher specimens from museum collections is provided here together with the rich unpublished Sasaki collection from Japan, Korea, and Taiwan, recently deposited in a Japanese museum. The present new record from Northeast Thailand enlarges the geographic range of *U. bogorensis* to the Indochina mainland. A comparison of historical data vs present Thai records is performed by morpho-analysis (SEM) as well as biogeographic, ecological and climatic data. Results show low variability in shape and size of the diagnostic morphotraits in populations scattered over the wide geographic range. Here we also formally accept the new taxonomic status (rank elevation) of the previous suborder Spongillina as a new order Spongillida. The presence of this potentially threatened species in the Sakaerat Biosphere Reserve, together with its possible long-term persistence in the Bogor Botanical Garden, may support its conservation. Only a census of the known, extremely scattered populations will define the status of this species.

**Keywords.** Biodiversity, taxonomy, biogeography, conservation, museum collections.

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## Introduction

Southeast Asia harbours nearly one-fourth of the planet's plant and animal species (Myers *et al*. 2000; Mittermeier *et al*. 2005). This biodiversity hot spot needs conservation measures (Sodhi *et al*. 2010; Woodruff 2010), particularly for the extremely vulnerable freshwater ecosystems and their biota (Lévêque *et al*. 2005; Balian *et al.* 2008; Manconi & Pronzato 2008; Manconi *et al*. 2013; Van Damme *et al*. 2013).

As for Porifera from Southeast Asian inland waters, data are scarce and based mostly on a few old records and scattered papers; the last synopsis highlighted that 26 species inhabit this area, with most species (18) reported only once, and a few reaching a maximum of 5 records (Manconi *et al*. 2013). Knowledge of taxonomic richness, endemicity level, and biogeographic patterns of freshwater sponges is scarce, and biodiversity seems to be highly underestimated in the entire Oriental Region (Manconi *et al*. 2013; Van Soest *et al.* 2015) as indicated also by recent new records, e.g., from Pune and Singapore (Jakhalekar & Ghate 2013; Lim & Tan 2013; Kulkarni *et al*. 2015). Extensive field campaigns in Thailand and SEM investigations have also yielded the discovery of a notably rich sponge fauna (Ruengsawang *et al*. 2012; Manconi *et al*. 2013; Ruengsawang 2013).

We report the discovery of *Umborotula bogorensis* (Weber, 1890) from Northeast Thailand in the Southeast Asian tropics, more than 80 years after one was last recorded. We provide a comparison of historical data and material vs present findings, together with synonymies and a detailed morphological analysis by SEM of the genus *Umborotula*. We further comment on the affinities of the genus, following a suggestion by Manconi *et al*. (2013) recommending its revision. In addition, we formally accept the rank elevation of the previous suborder Spongillina to the new order Spongillida.

### Study area

The Sakaerat Biosphere Reserve (14°26′ to 14°32′ N, 101°50′ to 101°57′ E; UNESCO-MAB Biosphere Reserve) is situated on the edge of Thailand's Khorat Plateau (Northeastern Thailand) ca 300 km northeast of Bangkok (Figs 1–2). It was created in 1977 around the Sakaerat Environmental Research Station (SERS), which was established in 1967 primarily as a site for research on dry evergreen and dry dipterocarp tropical forests. The SERS is one of five biosphere reserves in Thailand created to promote long-term ecological research and to demonstrate sustainable forest management and biodiversity conservation according to the Man and Biosphere Reserve (MAB) concept. It is also listed as one of two international long-term ecological research (ILTER) sites in Thailand (Trisurat 2010). The Sakaerat Biosphere Reserve has an area of 82 100 hectares at an elevation of 250 to 762 m a.s.l. The major ecosystem type is tropical dry or deciduous forest (including monsoon forests). Other vegetation types include bamboo forest, forest plantations and grassland. The average annual temperature at the Sakaerat Biosphere Reserve is 26°C and average annual rainfall is 1 260 mm. In the past three decades, natural forest cover, both inside and surrounding the SERS, has decreased because of deforestation

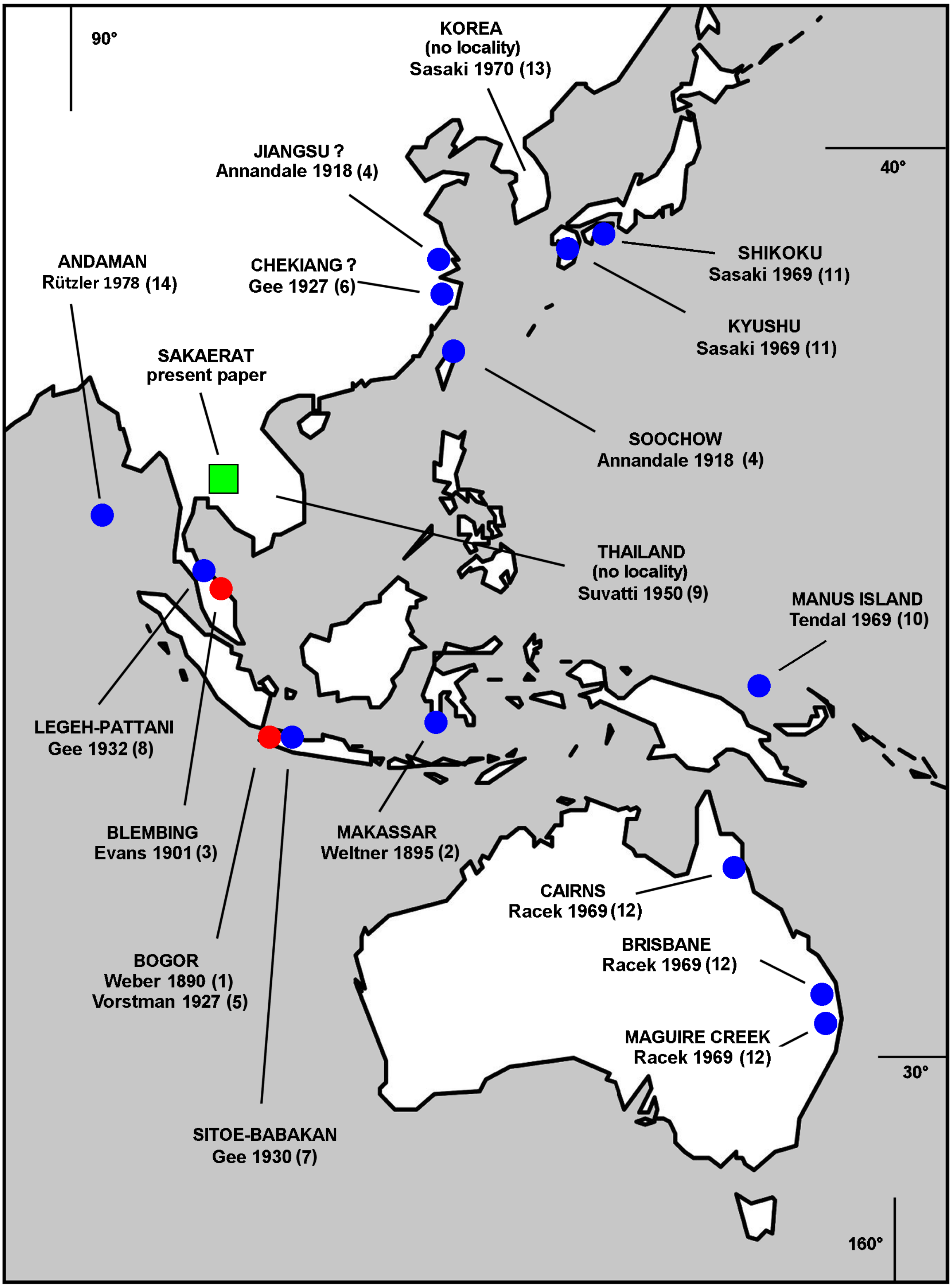


**Fig. 1.** Biogeographic pattern of the monotypic genus *Umborotula* with published records. The new record from the Sakaerat Biosphere Reserve in NE Thailand (14°30′15.83″ N, 101°55′03.64″ E) is indicated by the green square. For question marks, see text in the historical accounts section. The unpublished records are not reported (see Appendix). Red dots indicate the type localities of *Ephydatia bogorensis* Weber, 1890 and *E. blembingia* Evans, 1901.

for agriculture and human settlements. The forest cover inside SERS increased after the Royal Forest Department started to rehabilitate degraded forest in 1982 (Trisurat 2010).

The stream is a tributary of the Mun River belonging to the western Mekong hydrographic basin (Figs 1–3). This stream is a first order stream which usually flows for two months in September and October. Water quality parameters at the sampling site at a depth of 5 cm were as follows in December 2014: water temperature 16.7±0.1°C, pH 6.36±0.06, dissolved oxygen 1.12±0.47 mg/L, conductivity 203.33±1.15 µs/cm, total dissolved solids 98.33±3.79 ppm.

## Material and methods

Collection of sponges (21 December 2014; 17 January 2015) was carried out during a visual census by wading through a temporary small stream with pools at ca 400 m a.s.l. near the King Cobra Cave (14°30′15.83″ N, 101°55′03.64″ E) in a dry evergreen forest (Figs 1–2). This stream was classified as an intermittent stream, with water remaining in some places until December. The sponge was found in the water remains of a residual pool.

Growth form, consistency, architecture of ectosomal and choanosomal skeleton, traits of skeletal megascleres and microscleres, gemmular architecture and gemmulosclere morphology were all taken into account for the diagnosis at the genus and species levels (Manconi & Pronzato 2002, 2016). Representative fragments of sponges were dissected for light microscopy (LM) or scanning electron microscopy (SEM) investigations. Spicules were processed by dissolution of organic matter in boiling 65% nitric acid, suspended in ethanol and dropped onto slides or stubs (see Manconi & Pronzato 2000). Dry body fragments, dissociated spicules, entire gemmules and their cross sections were sputter-coated with gold and observed under TESCAN Vega3 (LMU) and LEO 1450VP scanning electron microscopes. Measurements were performed by LM on ca 50 spicules of each diagnostic spicular type. Measurements on gemmular diagnostic traits were performed by SEM. Museum acronyms are reported in the Appendix.

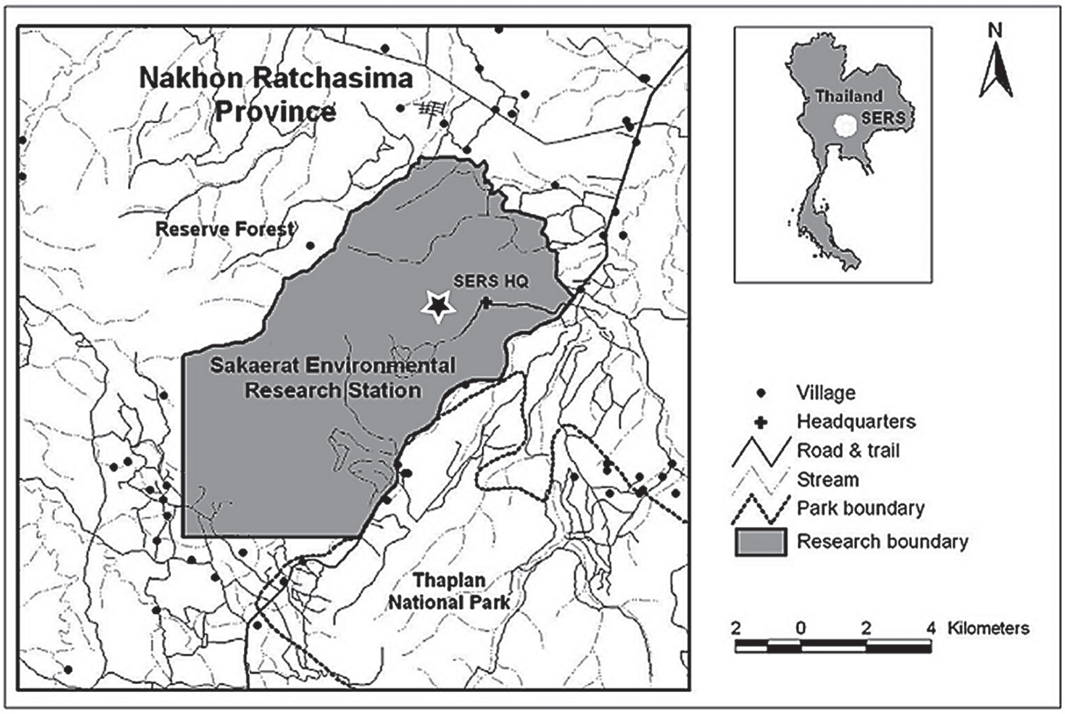


**Fig. 2.** Map of Sakaerat Biosphere Reserve in Thailand (modified from Trisurat 2010). The new record of *Umborotula bogorensis* (Weber, 1890) is indicated by a star.

## Results

Class Demospongiae Sollas, 1888
Subclass Heteroscleromorpha Càrdenas, Perez & Boury-Esnault, 2012

Order Spongillida Manconi & Pronzato, 2002

We formally accept the new taxonomic status (rank elevation) of the previous suborder Spongillina as the new order Spongillida. The definition and diagnosis (emended after Manconi & Pronzato 2002: 921–922 and Manconi & Pronzato 2011: 348) are here confirmed in part; we simply erase "Haplosclerida with" from the beginning of the diagnosis; we add strongyles among megascleres, and we anticipate the presence of the earliest fossil of the taxon at the Upper Carboniferous. We also add a final sentence which states: "The order Spongillida is cosmopolitan in freshwater and brackish water and it is absent only from Antarctica."

The rank elevation of the suborder Spongillina to the order Spongillida was proposed by Cárdenas *et al*. (2012) and Morrow & Cárdenas (2015), confirming the monophyly of freshwater sponges on the basis of both morphological (Manconi & Pronzato 2002, 2011) and molecular analyses (Itskovich *et al*. 1999, 2007, 2008; Addis & Peterson 2005; Meixner *et al*. 2007; Redmond *et al*. 2007; Morrow *et al*. 2012; Morrow & Cárdenas 2015).

Summarizing, from a morphological point of view, Spongillida are characterised by a skeletal architecture of monaxonid spicules (oxeas, styles, and strongyles) organized in isotropic/anisotropic networks of mono- to multi-spicular fibres, with scanty to abundant spongin. Microscleres are often present. Megascleres present as smooth, tubercled to variably spiny monaxons. The presence of resting bodies named gemmules is a trait shared by most families, genera, and species (ca 89%). Gemmules are a key diagnostic trait at genus and species levels. The closest taxon is the marine order Haplosclerida.

Family Spongillidae Gray, 1867

Genus ***Umborotula*** Penney & Racek, 1968

*Umborotula* Penney & Racek, 1968: 121.

*Ephydatia* sensu Weber 1890: 33 (pars).
*Meyenia* sensu Penney 1960: 46 (pars).

*Umborotula* – Manconi & Pronzato 2002: 965.

***Umborotula bogorensis*** (Weber, 1890)
Figs 1–8; Table 1; Appendix

*Ephydatia bogorensis* Weber, 1890: 33.
*Ephydatia blembingia* Evans, 1901: 71.

*Ephydatia bogorensis* – Weltner 1895: 114. — Annandale 1911: 54; 1918: 201. — Gee & Wu 1925: 393. — Gee 1926: 110; 1927a: 1; 1927b: 61; 1928: 225; 1929a: 13; 1929b: 297; 1930a: 84; 1930b: 170; 1930c: 28; 1930d: 90; 1931: 34; 1932a: 449; 1932b: 28. — Vorstman 1927: 184. — Arndt 1932: 564. — Sasaki 1970: 44. — Cheng 1991: 2.
*Ephydatia blembingia* – Annandale 1907: 269; 1911: 54, 109; 1918: 207. — Gee 1930a: 90; 1930d: 90; 1932a: 450; 1932c: 295.

*Ephydatia bogorensis* var. *blembingia* – Gee 1931: 34; 1932a: 449; 1932b: 28; 1932c: 308. — Suvatti 1950: 3.
*Meyenia bogorensis* – Penney 1960: 46.
*Meyenia bogorensis* var. *blembingia* – Penney 1960: 46.
*Umborotula bogorensis* – Penney & Racek 1968: 122. — Racek 1969: 300. — Rützler 1978: 143. — Tendal 1969: 47 (emended *in litteris*). — Masuda 1998: 296. — Wang 1998: 280. — Manconi & Pronzato 2002: 964; 2007: 65, 71–72. — Masuda 2006: 19. — Manconi *et al*. 2013: 315–316, 319.

### Note

Two specimens of *Umborotula bogorensis* were discovered and their morphotraits and habitat are reported. These specimens were registered in the Nisit Ruengsawang Collection as CNR-POR-FW100, on stick**,** Sakaerat Biosphere Reserve (Northeastern Thailand), N. Sangpradub leg., 21 Dec. 2014; CNR-POR-FW101, on rocky substrate**,** Sakaerat Biosphere Reserve (Northeastern Thailand), N. Sangpradub leg., 17 Jan. 2015. Both Thai specimens are also registered as slides (DTRG FW 770A, DTRG FW 770B) at the DISTAV, Genoa University.

### Description

Growth form thin, encrusting (ca 4 cm), on stick and rocky substrata. Colour yellowish in vivo, light brown in dry condition. Consistency soft, fragile. Texture loose. Oscules inconspicuous. Surface slightly hispid for spicules. Ectosomal skeleton as emerging fibre tips supporting the dermal membrane. Choanosomal skeleton as loose reticulate network, anisotropic, paucispicular, with ascending fibres evident only towards the surface; ill-defined, irregular network towards the basal portion. Spongin scanty except for gemmular theca and basal plate. Megascleres oxeas (265.1–348.8 × 9.3–14 µm) from abruptly pointed to acerate, from straight (dominant) to bent; abruptly pointed acanthoxeas (dominant), with small microspines scattered along the shaft and more dense towards the smooth apical tips; spine apices oriented towards the tips; spines from smooth to ornate by microspines. Smooth oxeas also present. Rare malformations. Microscleres absent; free gemmuloscleres abundantly scattered in the skeletal network. Gemmules not abundant and scattered singly from surface to basal portion within meshes of the fibrous network. Gemmules subspherical (413–546 µm in diameter), slightly flattened at the foramen side. Foramen single short foraminal tube with a short simple collar in a depression surrounded by a thickening of the gemmular wall. Gemmular theca trilayered. Outer layer thin,

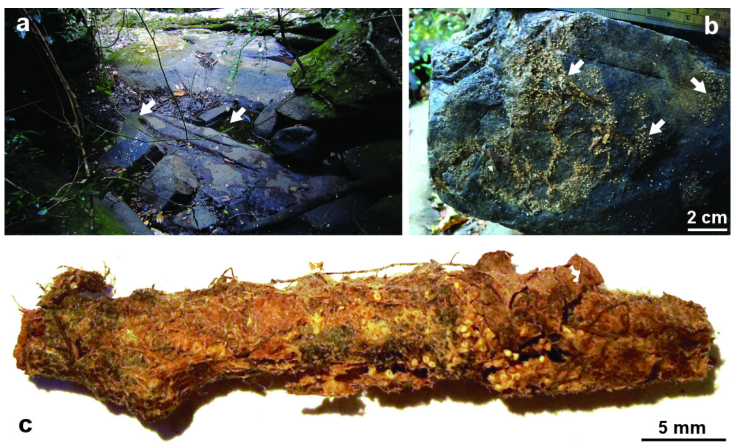


**Fig. 3.** *Umborotula bogorensis* (Weber, 1890) from the Sakaerat Biosphere Reserve, NE Thailand. **a.** sampling site along a temporary streamlet and pool; arrows indicate the microhabitat of the two recorded specimens. **b**. Gemmule carpets (arrows) during low water level (dry season). **c**. Encrusting sponge with gemmules on a stick from the pool.

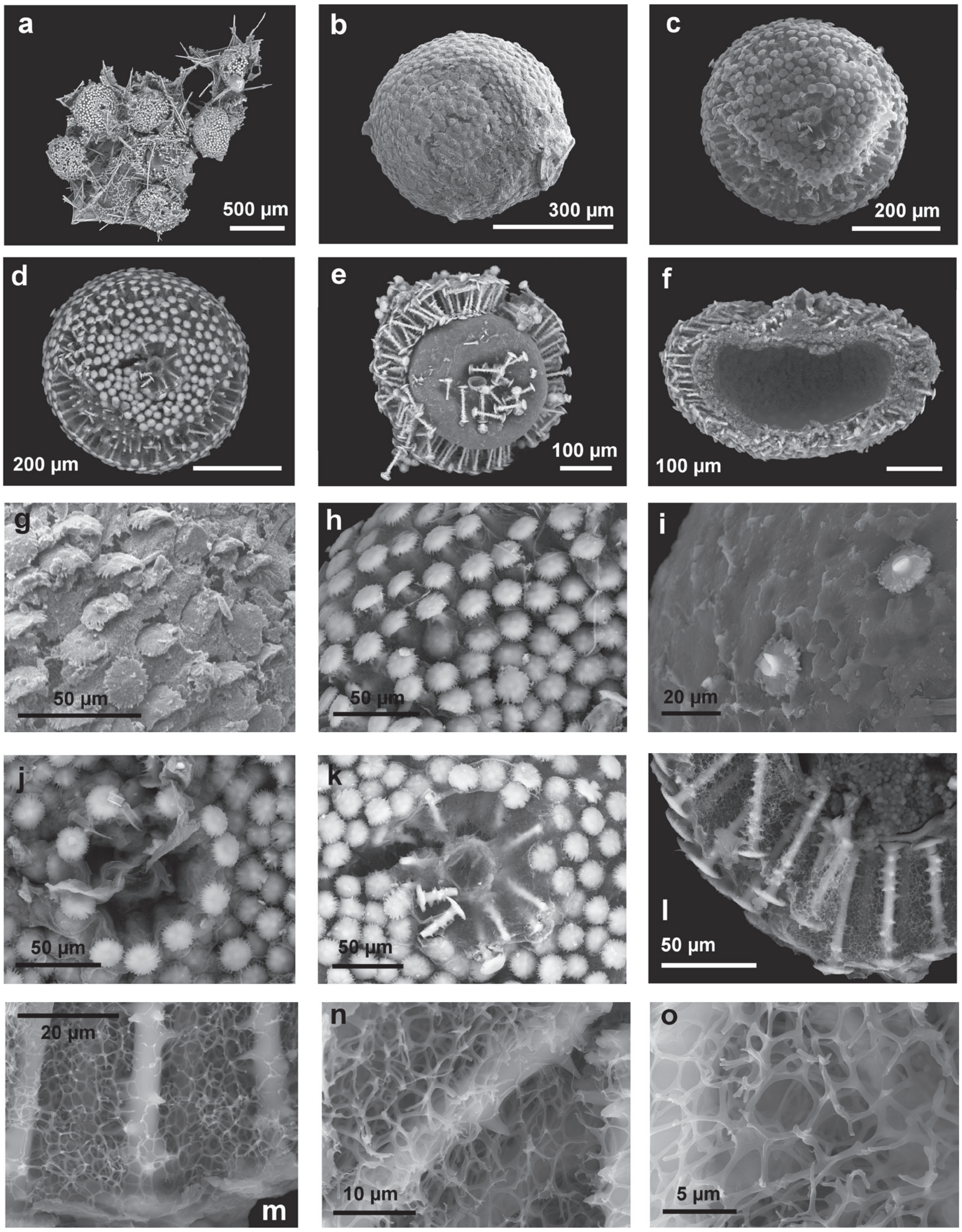


**Fig. 4.** *Umborotula bogorensis* (Weber, 1890) from the Sakaerat Biosphere Reserve, NE Thailand. SEM micrographs. **a**. Gemmules in a group within skeletal meshes. Gemmular theca with almost flat foraminal area. Several free gemmuloscleres also scattered in the skeletal network. **b**. Gemmule (basal area, top view) with developed outer layer covering the distal rotules of radial gemmuloscleres. **c–d**. Gemmules showing foraminal area (central); outer layer is lacking (top view). **e**. Gemmule without outer layer showing partially dissociated gemmuloscleres in the pneumatic layer and the smooth inner layer of compact spongin. Foramen simple, with short collar. **f**. Gemmule (cross section) with foraminal tubule and radial gemmuloscleres in the trilayered theca. **g**. Outer layer at the theca surface with distal rotules of gemmuloscleres. **h**. Distal rotules of gemmuloscleres without outer layer. **i**. Proximal rotules of gemmuloscleres adhering to the inner layer of the theca. **j–k**. Foraminal area supported by a network of spongin fibres and a rosette of radial gemmuloscleres. **l**. Architecture of trilayered gemmular theca with radial gemmuloscleres and spiny shafts (cross section). **m–o**. Fibrous network of thin spongin fibres in the pneumatic layer (detail, cross section).

armed with a robust continuous layer (mosaic-like) of distal rotules; frequently with distal rotules of gemmuloscleres notably emerging from outer layer. Pneumatic layer (60–80 µm in thickness) fibrous, without chambers, as a network of anastomosing very thin spongin fibres. Inner layer multilayered of compact spongin. Gemmuloscleres umbonate birotules of a single size class, radially and densely embedded in pneumatic layer, with overlapping umbrella-shaped rotules in contact with both inner and outer layer. Rotules of equal diameter (20–25 µm), distally convex and proximally concave, sometimes irregular. Margins incised, serrate, recurved bearing dense, short hooks. Hooks here and there in a double layer with simple, smooth tips (recurve spines) of variable length. Birotule shaft (55.1–76.9 × 4.4–5.8 µm) entirely spiny, with large, perpendicular conical spines. Spines straight in middle axis bending towards rotules, notably variable in length and density, with tips acute and sometimes bent, from smooth to ornate by microspines, rare tubercles also present. Young gemmuloscleres as birotules with scarcely developed rotules. Rare birotules (not young) with very short shaft (ca half length) and well developed rotules also present.

### Remarks

Morphotraits of the presently described Thai material match previous descriptions and the type material (Table 1), except for the absence of strongyles in the present material. For terminology we refer to Manconi & Pronzato (2002, 2016).

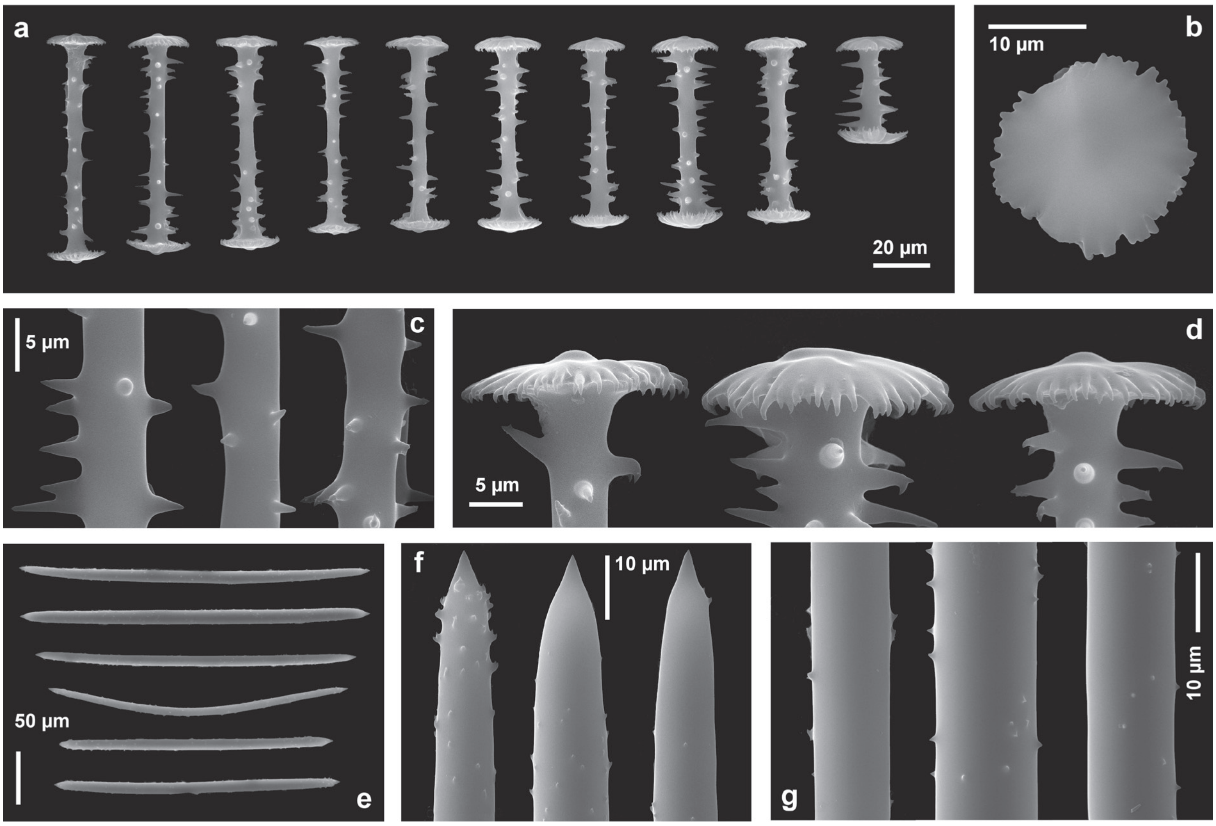


**Fig. 5.** *Umborotula bogorensis* (Weber, 1890) from the Sakaerat Biosphere Reserve, NE Thailand. Spicular complement (SEM) of gemmules and skeleton. **a**. Gemmulosclere birotules armed by large spines. **b**. Rotule of a gemmulosclere (top view). **c**. Shafts of gemmuloscleres with large scattered spines. **d**. Rotules of gemmulosclere (lateral view). **e**. Megascleres (oxeas) of the skeleton. **f**. Megascleres, tips. **g**. Megascleres, shafts.

## Discussion

### Historical sequence of records

*Umborotula bogorensis* was described, between the end of the 19th and the beginning of the 20th centuries, by Weber (1890) under the genus *Ephydatia* Lamoroux (1816) as *E. bogorensis* from the Java Botanical Garden of Bogor (Buitenzorg) and subsequently by Evans (1901) as *E. blembingia* from the Blembing River in the southernmost peninsular area of Thailand (now Malaysia).

Another record of *U. bogorensis* (as *E. bogorensis*) was reported by Weltner (1895) from southern Sulawesi (Makassar, Celebes). All these three records are from the tropical-equatorial areas. The first record from temperate regions was reported by Annandale (1918) on a specimen from Taiwan (as Formosa) apparently collected by Gee. In the same paper, Annandale (1918) also indicated the presence of this species in the Chinese Province of Jiangsu; the record was, however, located by Gee (1927a–b) in the Chekiang Province. These two continental records must be considered with caution (see related question marks in Fig. 1) because of a possible confusion about Formosa Island and its belonging to

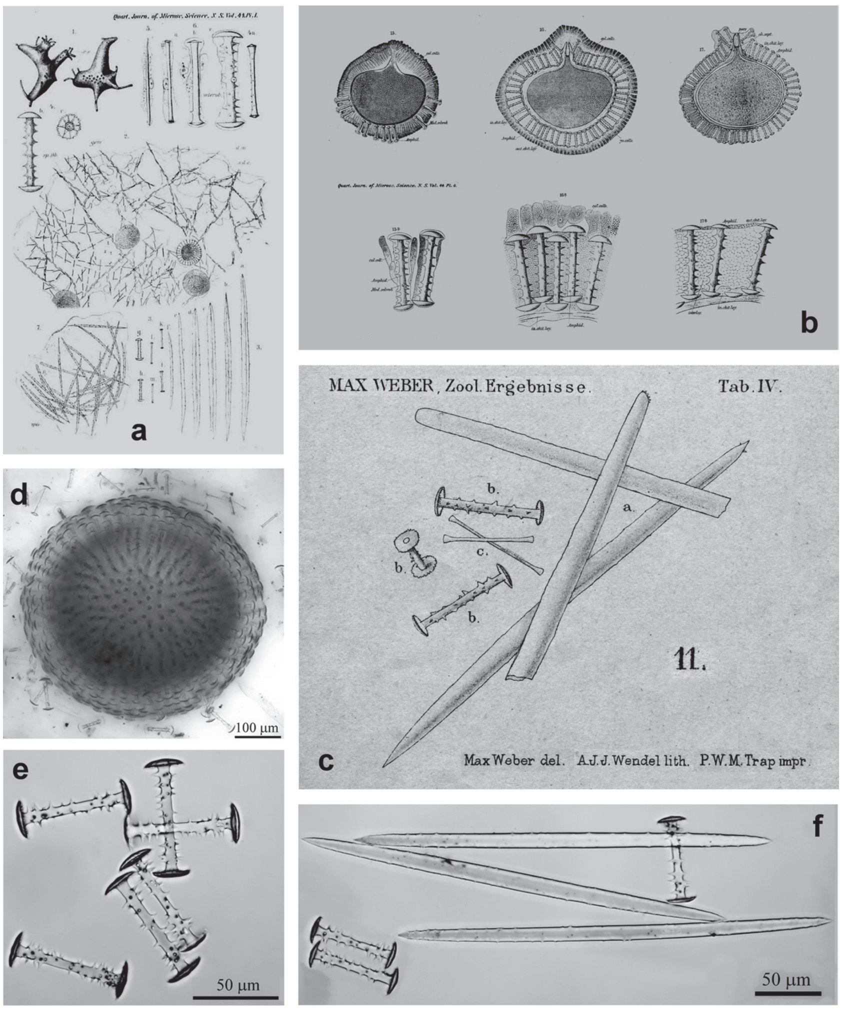


**Fig. 6.** *Umborotula bogorensis* (Weber, 1890) (as *Ephydatia bogorensis* Weber, 1890 and *E. blembingia* Evans, 1901). **a–c**. Diagnostic morphotraits from plates in original descriptions. **d–f**. Gemmule and spicules (LM) of *E. blembingia* from the type, BMNH 1901:10:22:1−2. a–b. Modified from Evans (1901). c. Modified from Weber (1890).

a Chinese Province. Vorstman (1927) described *E. bogorensis* from a sampling site in Bogor, and Gee (1930a) also collected this species in the Pond of Babakar, near Bogor, and from Legeh-Pattani, near Blembing (Gee 1932c). Only at the end of the 20th century were new records reported from outside Asia. Three Australian sites were indicated by Racek (1969) with records dated 1943 and 1958 (see below). Sasaki (1967, 1969, 1970) did not clarify the exact site for new records in South Japan and Taiwan. As for Sasaki's material, Y. Masuda and J. Nemoto (pers. comm.) informed us about several samples from Japan, South Korea, and Taiwan in Sasaki's freshwater sponge collection recently registered in the TUM museum (see Appendix).

Two other records without precise localities are from Thailand (Suvatti 1950) and Korea (Sasaki 1970). Moreover, Tendal (1969) discovered in the Bismarck Archipelago a freshwater sponge very close to *U. bogorensis*, although he reported it as "indeterminable sample". A.A. Racek identified it as *U. bogorensis* after the paper publication (Ole Tendal pers. comm.) and a reprint with Tendal's handwritten species name is in our bibliographic collection.

The most recent record in the literature is from the Andaman Archipelago by Rützler (1978).

In more than 125 years, from 40 papers reporting *U. bogorensis*, less than 20 indicate its precise locality (Figs 1, 7); less than ten provide the ranges of spicule and gemmule measurements (Table 1) and produce comparable figures (Fig. 6). Arndt (1932) reported a picture of the possible type locality of *U. bogorensis* (Fig. 8) in the botanical garden of Bogor (Buitenzorg). The preserved material is not abundant (see

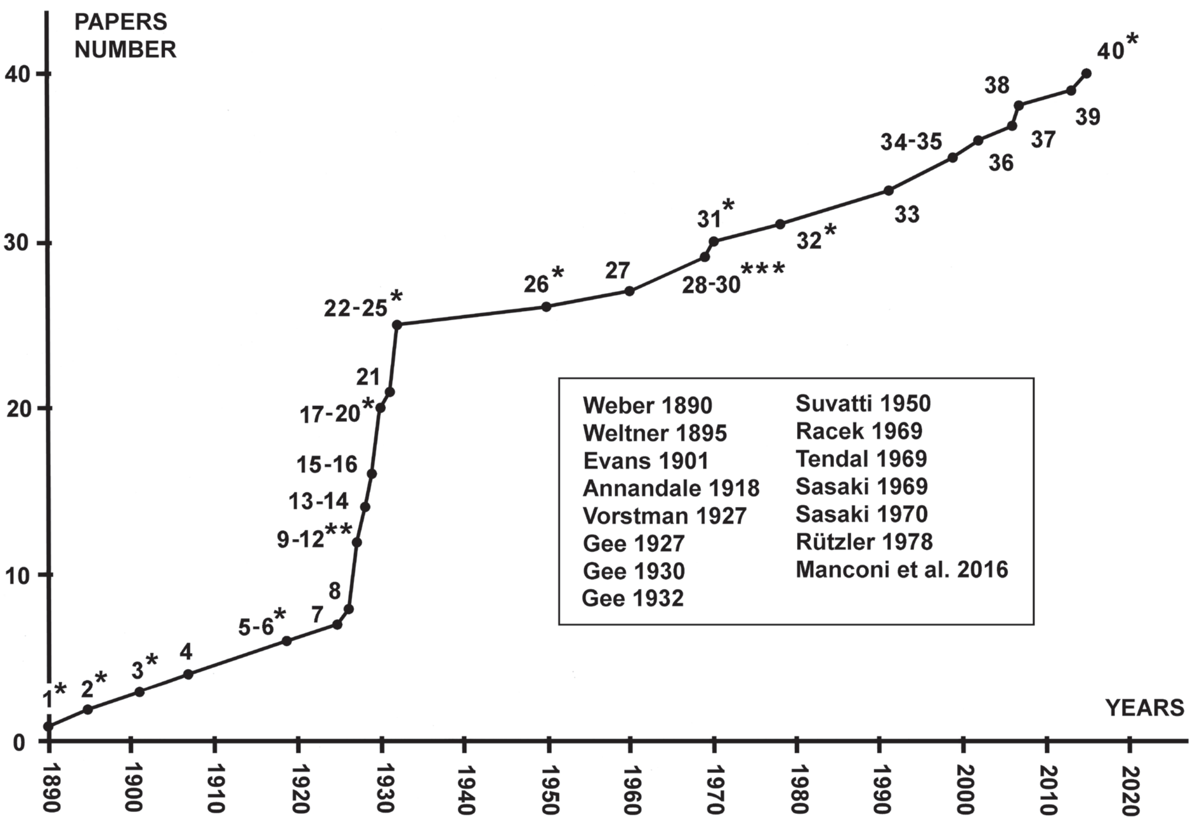


**Fig. 7.** Historical trend of faunistic and taxonomic investigations focusing on *Umborotula bogorensis* (Weber, 1890). The papers mentioning this species are 40. The 15 papers (box) reporting new records are indicated by asterisks. See also Fig. 1 (map) and Appendix.

Appendix for details on museum material). The present new record of the species is ca 40 years after the last record (Rützler 1978) and more than 60 years after the last record in the Indo-Chinese area (Suvatti 1950) (Figs 1, 7). The two Thai specimens are precious for comparative analysis.

**Taxonomy**

The monotypic genus *Umborotula* was erected by Penney & Racek (1968) with *U. bogorensis* (Weber, 1890) as type species after a deep study and discussion of the available material. The most recent study of the type material was performed by SEM (Manconi & Pronzato 2002).

All descriptions and illustrations of *U. bogorensis* highlighted a low intraspecific variability of diagnostic morphotraits (Fig. 6). However, as previously noted, the morphological descriptions of *U. bogorensis* reporting measurements are few (less than 10), the figures representing spicules are less (6) and they report both smooth oxeas and strongyles (Table 1). In particular, the figures of Gee & Wu (1925) are in contrast with those of Gee & Wu (1927).

Some taxa now ascribed to the genus *Umborotula* were previously placed in the genus *Ephydatia* (*E. bogorensis* and *E. blembingia*) on the basis of the trait 'birotules radially embedded in the gemmular theca', shared by the species previously ascribed to the subfamily Meyeninae Vejdovsky, 1887. Penney &

**Fig. 8.** *Umborotula bogorensis* (Weber, 1890). Possible type locality in a pond of the Bogor Botanical Garden (Java). Picture after Arndt (1932).

**Table 1** (continued on next page)**.** *Umborotula bogorensis* (Weber, 1890). Comparison of spicular and resting body morphotraits of the new specimens from Thailand against all other described specimens.

| Reference | Locality | Megascleres (µm) | Gemmuloscleres (µm) | Birotules (µm) | Gemmules (µm) |
|---|---|---|---|---|---|
| Weber 1890 | Java (Indonesia) | 200–280 × 8 smooth oxeas strongyles with spiny tips | 54–60 × 4 | 18 | 400 |
| Evans 1901 | Blembing (Malaysia) | microspiny oxeas | – | – | – |
| Gee & Wu 1925 | Soochow (Taiwan) | 276–343 × 10–14 microspiny oxeas with monstruosities | 70–76 | 20–26 | – |
| Gee 1930a | Java (Indonesia) | 230–282 × 14–15 smooth strongyles | 54–60 | 18 | 400 |
| | Java (Indonesia) | 289–357 × 14–16 microspiny oxeas | 68–76 | 23–27 | 600 |
| | Soochow (Taiwan) | 247–332 × 14–16 microspiny oxeas | 66–76 | 20–26 | 530 |
| Gee 1930b | Java (Indonesia) | 250–341 spiny oxeas | 68–76 | – | – |
| | Blembing (Malaysia) | 260–322 spiny oxeas | 64–70 | – | – |
| Gee 1932a | Java (Indonesia) | 231–297 × 12–15 strongyles, few oxeas | – | – | – |
| | Java (Indonesia) | 259–323 × 10–15 spiny oxeas | – | – | – |
| | Java (Indonesia) | 270–332 × 9–14 spiny oxeas | 70 × 6–7 | 24 | – |
| | Java (Indonesia) | 264–321 × 10–15 spiny oxeas | 62–72 × 5–6 | 22–26 | – |
| | Soochow (Taiwan) | 282–323 × 8–14 spiny oxeas | 70–76 × 6–8 | 24 | – |
| | Soochow (Taiwan) | 255–321 × 10–15 spiny oxeas | 70–82 × 5–8 | 23–26 | – |
| | Blembing (Malaysia) | 264–322 × 11–15 spiny oxeas | 64–68 × 5–7 | 23–26 | – |
| | Blembing (Malaysia) | 299–341 × 8–16 spiny oxeas | 64–69 × 6–8 | 22–26 | – |
| Penney & Racek 1968 | Blembing (Malaysia), Java (Indonesia), Soochow (Taiwan) | 240–370 × 13–16 microspiny oxeas | 60–78 × 3–4 | 22–27 | 450–600 |
| Rützler 1978 | Andaman Islands (India) | 240–320 × 11–12.5 microspiny oxeas | 75–83 × 5.0–6.3 | 21–23 | 490–600 |
| Soota 1991 | after Penney & Racek 1968; Rützler 1978 | 240–370 × 11–16 microspiny oxeas rare smooth oxeas rare spiny strongyles | 60–83 × 3–6 | 21–27 | 450–600 |

| Reference | Locality | Megascleres (μm) | Gemmuloscleres (μm) | Birotules (μm) | Gemmules (μm) |
|---|---|---|---|---|---|
| Manconi & Pronzato 2002 | Java (Indonesia) Blembing (Malaysia) | 200–330 × 8–16 microspiny oxeas | 62–82 × 5–8 | 22–27 | 450–600 |
| This study | Sakaerat (Thailand) | 265–349 × 9–14 microspiny oxeas spines irregularly scattered towards the tips | 55–77 × 4–6 | 20–25 | 413–546 |

Racek (1968) rejected the two subfamilies because the majority of spongillid species do not match exactly the definition of Meyeninae vs Spongillinae Vejdovsky, 1887.

As for affinities of the genus, *Umborotula* shares birotule gemmuloscleres radially arranged in the gemmular theca with *Ephydatia*, but the diagnostic trait 'architecture of the pneumatic layer' deeply diverges in the two genera, being chambered in the latter genus and clearly fibrous in the former. Gemmuloscleres as 'birotules radially arranged in the theca with fibrous pneumatic layer', together with 'hooks at the rotule margin' are traits also shared by *Umborotula* with the genera *Dosilia* defined by Gray (1867) and *Corvoheteromeyenia* defined by Ezcurra de Drago (1979), although the former genus lacks microscleres, which are typically present in the latter two genera. *Umborotula* also shows, as suggested by Penney & Racek (1968: 123), some affinities and differences from two other genera, i.e., *Heteromeyenia* defined by Potts (1881) and *Anheteromeyenia* defined by Schröder (1927); however, their gemmuloscleres belong to two categories, i.e., pseudobirotules and birotules in the former and exclusively pseudobirotules in the latter.

Results of the present morphoanalysis are in agreement with the majority of available morphological data on *U. bogorensis* in the literature, confirming 'spiny oxeas' as the dominant megascleres (Table 1). The presence of 'rare spiny strongyles' (Table 1) is not confirmed here for Thai material. Smooth strongyles (Table 1) are reported only by Gee (1930a).

**Habitat**

*Umborotula bogorensis* was found in both lotic and lentic freshwater bodies in shaded habitats. Japanese and Korean populations (Sasaki collection) are all from ponds. The sponges are encrusting and creeping on aquatic plants, the underside of leaves (Fig. 8), and blades of grass, branching weeds and woody debris (sticks and timbers). The discovery of *U. bogorensis* on the Thai mainland indicates that the rarity of records for this species could apparently be related to its cryptic habit, e.g., the small size and the encrusting growth form of specimens, which until now were mostly reported as creeping on vegetation, such as undersides of floating leaves, grass and sticks. The present record indicates that this species is also able to colonize both sticks and rocks in small streams and temporary pools. However, the population of this species at the collection sites apparently disappeared after a high flood in the rainy season (Sep. 2015).

**Biogeography**

*Umborotula* Penney & Racek (1968) is a monotypic Australasian genus of freshwater sponges, with several records in the Wallacea, Australia, China, Korea and Japan. *Umborotula bogorensis* is apparently very rare and known exclusively from the Palaearctic, with a geographic range from SE Asia to E Australia, with scattered records from Malaysia, Java, Makassar, Sulawesi, Thailand, China, Taiwan, South Korea, and Eastern Australia (Figs 1–2).

The approximate geographic range of *U. bogorensis* is from 90° to 160° E and from 40° N to 30° S. This wide distributional area, notwithstanding the clear eastern Australasian location, involves three zoogeographic regions, i.e., the eastern Oriental Region (Southeast Asia and South China), the eastern Palaearctic Region (Korea and Japan) and the eastern Australian Region. Many records are reported from coastal areas, i.e., islands and peninsulas (Fig. 1).

*Umborotula bogorensis* inhabits freshwater bodies in a wide climatic range, according to the Köppen-Geiger climate classification (Peel *et al*. 2007), from tropical monsoon to rain forest climates (Java, Sulawesi, peninsular Malaysia, inland Thailand, and Taiwan) to wet sub-tropical and tropical rain forest (East Australia) up to humid temperate (Japan) and boreal climates (South Korea).

### Conclusion

Although *U. bogorensis* has been considered an 'underestimated' species, it could be less rare than previously thought (Penney & Racek 1968; Racek 1969). In addition, there is a problem with disclosure of data. Accordingly, the present report of the unpublished Sasaki collection doubles the number of known species records (see Appendix and Figs 1, 7).

The rarity of this species could be related to its microhabitat, cryptic behaviour (cryptobiosis in the life cycle), and mimetic habitus (colour, encrusting growth form, and small body size). This sciophilous species seems also, however, to be able to adapt its life style to harsh conditions, i.e., temporary freshwater bodies as in the present case.

Taking into account the present scenario, *U. bogorensis* needs precise monitoring of the sites from where it was recorded. The rapidly growing environmental pressure from the human population and the high rate of habitat destruction (Woodruff 2010) predicts a severe biodiversity crisis in Southeast Asia (Sodhi *et al*. 2010). It seems urgent to insert freshwater sponge species on red lists of threatened freshwater fauna (see Fontaine *et al*. 2007).

The present study suggests that *U. bogorensis* could be an excellent species model to promote protection and conservation of rare freshwater sponge species, particularly in the tropical-subtropical and temperate (Japan, Taiwan) latitudes of Asia. Summarizing, only 30 specimens have been collected during more than 125 years. Sometimes the time lapse between two records is over 30 years. There are less than 20 taxonomic studies on this species and less than 10 papers giving illustrations. Unfortunately, almost all records are single; only from Bogor have two successive findings been reported (1890 and 1927). The new record of this species in the Sakaerat Biosphere Reserve, together with its potential (not confirmed) long-term persistence in the Bogor Botanical Garden, are consistent with a proposal for its conservation. The present scenario of the known populations, which are extremely scattered in time and space, suggests defining the status of *U. bogorensis* as extremely rare, vulnerable, if not endangered, following the IUCN "red list" criteria.

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# Appendix

## Collections

Voucher specimens of *Umborotula bogorensis* (Weber, 1890) are registered in the following places:

| | | |
|---|---|---|
| AUS MUS | = | Australian Museum of Marine Invertebrates, Sydney, Australia |
| BMNH | = | Natural History Museum, London, United Kingdom |
| ZMA POR | = | Naturalis Biodiversity Center, Leiden, the Netherlands |
| USNM | = | Smithsonian Institution, Museum of Natural History, Washington D.C., U.S.A. |
| DISTAV POR-FW | = | Genova University, Italy |
| CNR | = | Nisit Ruengsawang Collection, Thailand |
| TUM | = | Tôhoku University Museum, Sendai, Japan (Sasaki's collection) |

To date only 30 specimens of *U. bogorensis* are deposited in museum collections. Several of them are fragments of specimens preserved in other museums. Two new recently collected specimens from Thailand are focused on in the present paper.

### Australian Museum of Marine Invertebrates

AUS MUS Z.2832.001, Maguire Creek, Richmond River hydrographic basin, near Teven (28°49′ S, 153°30′ E), Ballina, New South Wales; Mr Lane leg., Fisheries Inspector, Jan. 1958, wet sub-tropical climate, no dry season (several specimens from the same locality and date).

AUS MUS Z.2945.001, Mulgrave-Russel River hydrographic basin, Peninsular Uplands Province, Cairns Ranges, Cairns (16°55′ S, 145°46′ E), Queensland; E.F. Riek leg., May 1943, Dr A.A. Racek det., Queensland Tropical Rain Forests (monsoonal).

AUS MUS Z.2959, Reservoir, Brisbane; E.F. Riek leg., May 1943, cited by Racek (1969).

AUS MUS Z.3381.001, Indonesia, no further locality data.

AUS MUS fragment ZMA POR_01551, Buitenzorg (Bogor), Indonesia; Zoological Museum Amsterdam, Porifera; M. Weber, leg. 1 Jan. 1889

AUS MUS fragment ZMA POR_11512, Buitenzorg (Bogor), Indonesia; Zoological Museum Amsterdam, Porifera; A.G. Vorstman leg.

Remarks

The specimen fragment (ZMA POR_01551) is apparently the holotype.

### Natural History Museum, London

BMNH 1901.10.22.1–2, *Ephydatia blembingia* Evans, 1900: 17 (BMNH 1901:10:22:1); "Part of Type", small pool of water in dense jungle a few yards from bank of River Blembing, Siamese Malay States. Evans collected and preserved 23 Jul. 1899 (see Evans 1900: 72).

**Naturalis Biodiversity Centre of Leiden** (ZMA code of previous Zoological Museum Amsterdam)

ZMA POR_01551, South East Asia, Indonesia, Buitenzorg; latitude supplied as: "-6,5897", longitude supplied as: "106,7914", Weber M. leg., 1 Jan. 1889.

ZMA POR_11512, Buitenzorg, collector A.G. Vorstman, latitude supplied as: "-6,5897", longitude supplied as: "106,7914".

Remarks

Unfortunately, in this collection only 6 slides of ZMA POR_01551 remain of Weber's type material (see Manconi & Pronzato 2002: 966). The related label reports: "*Meyenia blembingia* M. Weber.

Type - Buitenzorg - 1889 - leg. et det. M. Weber. Beschrijvingen in: Ergebnisse einer Reise n. NOJ. 5 prep. gemerkt. b of n. *Meyenia*? (zonder gemmulae). Buitenzorg - 1889 - leg. et det. praep., waarvan 2 gemerkt. A" (Fig. 9, see also Manconi & Pronzato 2002: fig. 80).

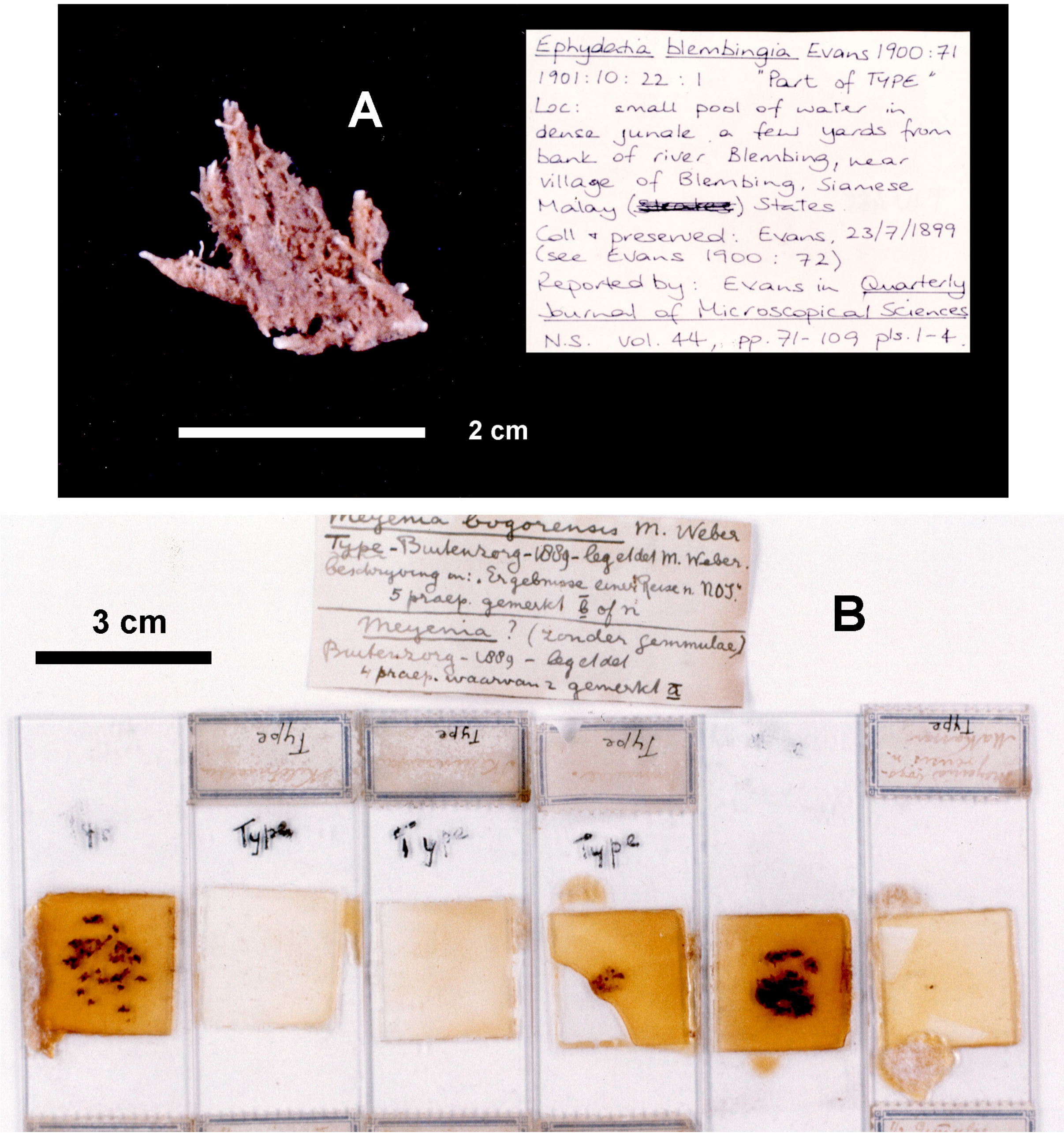


**Fig. 9. A**. Part of the type encrusting on a plant, 1901:10:22:1 of *Ephydatia blembingia* = *Umborotula bogorensis*, the Natural History Museum of London. **B**. Six slides ZMA POR 01551 representing the remains of the type material of *Umborotula bogorensis* preserved in the Institute for Systematics and Population Biology of the University of Amsterdam.

**Smithsonian Institution - Museum of Natural History**

USNM, 34489, *Ephydatia bogorensis* Weber, 1890, Indonesia, Java. 1 slide.

USNM, 24518, *Umborotula bogorensis* (Weber), India, Andaman Island. 1 specimen.

USNM, 31697, *Umborotula bogorensis* (Weber), Australia, New South Wales. 1 slide.

Remarks

The catalogue numbers for *E. bogorensis* in the USNM database presently reports a few data. Penney & Racek (1968) material is reported as 'slides of types of *E. bogorensis* (AmstM) and *E. blembingia* (BM), and specimens of *U. bogorensis* from Soochow, China, and Java'. The latter material is probably from Gee's collection. Here is also deposited the specimen from Andamans recorded by Rützler (1978).

**Tôhoku University Museum, TUM, Japan, Sasaki's collection** (J. Nemoto, *in litteris*)

Pori 60-8 (106), *E. bogorensis*. A pond in the 228 Peace Memorial Park, Taipei City, Taiwan, 2 Aug. 1933.

Pori 45-31(?), *E. bogorensis*. A pond in the 228 Peace Memorial Park, Taipei City, Taiwan, 2 Aug. 1933.

Pori 60-9 (351), *E. bogorensis*. Bentianchi Pond, Tianshulin, Taoyuan County, Taiwan, 4 May 1936.

Pori 60-12 (351), *E. bogorensis*. Bentianchi Pond, Tianshulin, Taoyuan County, Taiwan, 4 May 1936.

Pori 60-14 (351), *E. bogorensis*. Bentianchi Pond, Tianshulin, Taoyuan County, Taiwan, 4 May 1936.

Pori 60-15 (398), *E. bogorensis*. A pond in Ureshino City, Saga Prefecture, Japan (dried), 31 Oct. 1937.

Pori 60-11 (515), *E. bogorensis*. A drain to the south of Yakabe Primary School, Yanagawa City, Fukuoka Prefecture, Japan, 12 Nov. 1936.

Pori 60-13 (663), *E. bogorensis*. A pond in Sazare, Usa City, Oita Prefecture, Japan, 22 Dec. 1936.

Pori 60-34 (701), *E. bogorensis* and *E. crateriformis*. A moat in Jojima, Kurume City, Fukuoka Prefecture, Japan, 1 Sep. 1936.

Pori 60-10 (703), *E. bogorensis*. A streamlet in Tamamitsu, Mizuma, Kurume City, Fukuoka Prefecture, Japan, 30 Aug. 1937.

Pori 66-26 (1197), *E. bogorensis*, *E. crateriformis* and *H. baileyi* var. *petri*. Goeje Reservoir, Buan County, Jeollabuk Province, South Korea, 29 Nov. 1938.

Pori 61-31 (1198), broken specimens of *S. semispongilla*, *E. bogorensis*, *E. crateriformis* and *H. baileyi* var. *petri.* Deokje Reservoir, Buan County, Jeollabuk Province, South Korea, 29 Nov. 1938.

Pori 66-18 (1201), *S. semispongilla*, *E. bogorensis*, *E. crateriformis* and *H. baileyi* var. *petri.* Jeongjije Reservoir, Haengan, Jeollabuk Province, South Korea, 29 Nov. 1938.

Pori 52-30 (1211), broken specimens of *S. semispongilla*, *E. bogorensis*, *E. crateriformis*, *E. muelleri* and *H. baileyi* var. *petri.* Polaje Reservoir, Yeonggwang County, Jeollanam Province, South Korea, 3 Dec. 1938.

Pori 61-10 (1219), broken specimens of *S. semispongilla*, *E. bogorensis*, *E. crateriformis* and *H. baileyi* var. *petri.* Daxingje Reservoir, Pohang City, Gyeongsangbuk Province, South Korea, 7 Dec. 1938.

Remarks

The Tôhoku University Museum collection was almost unknown until now, but it contains the majority of the presently known material of *U. bogorensis*. Indeed, Sasaki never reported these specimens in his papers.

A further list (see below) is kindly provided by Masuda (pers. comm.) from the unpublished notes of Sasaki.

**Sasaki's collection, Japan** (Y. Masuda, *in litteris*)

*Ephydatia bogorensis* WEBER.

**Japan - Sampling Points**

1) 4 ponds, Fukuoka Prefecture.

2) 1 pond, Oita Prefecture.

3) 1 pond, Okayama Prefecture.

**South Korea - Sampling Points**

1) Daxingje Reservoir, Pohang-si, Gyeongsangbuk Province.

2) Jeongjije Reservoir, Haenganmyeon, Buan-gun, Jeollabuk Province.

3) Deokje Reservoir, Buan-gun, Jeollabuk Province.

4) Goeje Reservoir, Buan-gun, Jeollabuk Province.

5) Polaje Reservoir, Yeonggwang-gun, Jeollanam Province.

**Taiwan - Sampling Points**

1) 1 pond in the 228 Peace Memorial Park, Taipei City.

2) Neihu 1$^{st}$ Pond, Neihu District, Taipei City.

3) Songshan 3$^{rd}$ Pond, Songshan District, Taipei City.

4) Songshan 4$^{th}$ Pond, Songshan District, Taipei City.

5) Tianshulin Bentianchi, Taoyuan County.

6) Jungli 4$^{th}$ Pond, Taoyuan County.

7) Jungli 7$^{th}$ Pond, Taoyuan County.

8) 1 pond in the Jungli Shrine, Taoyuan County.

9) Longtian, Tainan City.

10) Fanzai Bridge Monument, Guantian District, Tainan City.

11) Liujia 1$^{st}$ Pond, Liujia District, Tainan City.

12) Linfengying, Liujia District, Tainan City.

Remarks

This list is different from the TUM museum catalogue reported above and refers to private notes by Sasaki.

**Nisit Ruengsawang Private Collection, CNR, Thailand**

*Umborotula bogorensis* (Weber), CNR-POR-FW 100.

*Umborotula bogorensis* (Weber), CNR-POR-FW 101.

**DISTAV, Genova University, Italy, POR-FW freshwater sponge collection**

DTRG FW 488, *Ephydatia blembingia* Evans, fragment of specimen BMNH 1901:10:22:1-2.

DTRG FW 492, *Meyenia bogorensis*, photograph of type material, 6 slides of the Naturalis Biodiversity Center, Leiden.

DTRG FW 770A, *Umborotula bogorensis* (Weber), slides and SEM stubs, fragments of POR-FW 100 of the CNR collection.

DTRG FW 770B, *Umborotula bogorensis* (Weber), slides and SEM stubs, fragments of POR-FW 101 of the CNR collection.