

First Record of Thermosbaenacea (Crustacea) from the Southern Hemisphere: a New Species from a Cave in Tropical Western Australia

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Abstract

The crustacean order Thermosbaenacea is reported for the first time from the Southern Hemisphere, from almost fresh water in a cave habitat in tropical Western Australia. *Halosbaena tulki*, sp. nov. belongs to a genus previously known only from saline waters in the West Indies, Columbia and Canary Is. The discovery is consistent with a very ancient origin of the order and distribution of the genus by plate movements following the breakup of Pangaea.

Introduction

Thermosbaenacea are a rare order of about 16 species of considerable biogeographic interest because their known distribution is so scattered. Six genera are known, all occurring in underground waters, variously hot springs, hypersaline, marine or fresh water. *Thermosbaena* Monod is restricted to thermal waters of Tunisia, *Limnosbaena* Stock to inland Yugoslavia, *Theosbaena* Cals & Boutin to Cambodia, and *Tulumella* Bowman & Iliffe to the Caribbean area. Two remaining genera are widespread, with *Monodella* Ruffo being known from Somalia to Texas and *Halosbaena* Stock from Colombia to the Canary Is. Unidentified species, of *Halosbaena* and presumably of *Monodella*, have been recorded widely from the Mediterranean and Caribbean (Stock 1986). This paper is the first record of the order from the Southern Hemisphere.

Knowledge of the biology of thermosbaenaceans is limited to detailed studies of functional morphology and feeding in *Monodella argentarii* (Fryer 1965) and morphology, reproduction and behaviour of *Thermosbaena mirabilis* (Barker 1962).

Study Area

General Area

The thermosbaenaceans were collected from almost fresh water in a cave on the semi-arid North West Cape peninsula of Western Australia (22°01'S., 113°56'E.).

Cape Range, which forms the spine of the peninsula, is an anticline of Lower Miocene marine limestones. The highly cavernous Tulki Limestone (more than 350 known caves) contains a rich troglobitic (obligatory cave-dwelling) fauna which represents, in part, a relictual tropical rainforest litter fauna with affinities in north-eastern Queensland (Humphreys 1991). Standing water is found at four locations within Cape Range, probably on three isolated perched water tables (Humphreys *et al.* 1989; Humphreys 1990; Humphreys and Adams 1991). This water contains a single species of melitid amphipod similar to members of the genus *Psammogammarus* Karaman.

The western side of the range is cut by four marine erosion terraces emerged to about 50 m. The Tantabiddi Terrace forms the coastal plain bordering Cape Range and is up to 3 km wide.

The Quaternary deposits of this lowest terrace are thought to be similar to those offshore (Hocking *et al.* 1987) so that during periods of lower sea level the habitat would have been much more extensive, especially to the north and east of Cape Range.

The coastal plain is inhabited by a subterranean aquatic fauna containing five other troglobitic species: an amphipod, two species of shrimps, *Stygiocaris lancifera* Holthuis and *S. stylifera* Holthuis (Caridea: Atyidae), and two fishes, the blind gudgeon, *Milyeringa veritas* Whitley (Perciformes: Eleotridae), and the blind cave eel, *Ophisternon candidum* (Mees) (Synbranchiformes: Synbranchidae). The four named species known from the coastal limestone are sympatric and endemic to the peninsula (Humphreys and Adams 1991). The fish are the only troglobitic vertebrates known in Australasia.

This coastal aquatic ecosystem seems to be continuous around the peninsula but not to extend beneath Cape Range itself (Humphreys and Adams 1991); hence, the system is linear and prone to fragmentation. Allozyme data for *Stygiocaris* spp. and *M. veritas* show lack of panmixia around the coast (Humphreys and Adams 1991). Some parts of the coastal system are clearly influenced by the tides and, even if the waters in cave C-215 are not anchialine, they probably connect with the anchialine system.

The Cave

Cave C-215 opens from the Milyering Terrace adjacent to the Jurabi scarp and descends through Tulki Limestone, reaching the coastal water table at a depth of about 24 m and level with the Tantabiddi Terrace. Plant roots hang from the roof of the 40-m-long canal (illustrated in Humphreys 1991) and into water up to 2 m deep.

In July 1991 the cave had recently flooded and the surface water had a salinity of 1.4 ppt (estimated from conductivity). By October 1991 the water level had fallen by about 0.6 m resulting in a discontinuous canal system and a surface salinity of 1.6 ppt and bottom salinity (at 1 m depth) of 1.7 ppt. At this time the relative humidity of the air in the canal section was 88% and the cave air temperature was 22.9°C, presumably close to the water temperature.

Thermosbaenaceans were collected from the open canals but not from among the tree roots. Troglobitic meenoplids (Hemiptera) inhabit the aerial part of the roots, *Stygiocaris* spp. and gudgeons occur in the water while *Draculoides vinei* (Harvey) (Chelicerata: Schizomida) and millipedes (Diplopoda: Paradoxosomatidae) occur on the mud banks (Humphreys 1991; Humphreys and Adams 1991). It is the only location known where elements of the troglobitic fauna of the range and the subterranean coastal fauna co-occur.

Because of the complexity of both the geology and the fauna associated with C-215 it is unclear whether the thermosbaenaceans are part of the subterranean aquatic fauna of the coastal plain or more rightly belong with the Cape Range fauna proper.

Systematics

Halosbaena Stock

Halosbaena Stock, 1976: 56–8.

Remarks

The genus was clearly defined by Stock (1976) for the type species, *H. acanthura* Stock, from marine coral rubble at Curaçao. Only one other species had been described, *H. fortunata* Bowman & Iliffe, 1986, from a marine lava cave in the Canary Is. Perhaps as many as four undescribed species from Curaçao, Columbia, Bonaire, Venezuela and San Andros I. have been reported by Stock (1986) and Wagner (1990). Members of the genus can be reliably identified by using the keys of either Bowman and Iliffe (1988) or Monod and Cals (1988).

The family placement of *Halosbaena* is uncertain. Bowman and Iliffe (1988) placed the genus in Monodellidae Taramelli, 1954 while Monod and Cals (1988) placed it in Halosbaenidae, a new family erected by them. These two conflicting arrangements (which incidentally involve the placement of all genera) can only be resolved by a more rigorous methodology than has been applied so far, perhaps phylogenetic methods using parsimony. We will not enter into this debate and the new species described here contributes no new information.

Because the two described species of *Halosbaena* and the new one described here are morphologically very close, only a brief diagnosis highlighting differences is presented.

Mouthparts of the new species have been dissected but present no significant differences from those figured by earlier authors.

Halosbaena tulki, sp. nov.

(Fig. 1)

Material Examined

Western Australia: North West Cape, western slope of Cape Range (22°02'S., 113°56'E.), standing water in cave C-215 in Tulki Limestone, W. F. Humphreys, 16.x.1991: holotype female, 2.1 mm (Western Australian Museum 74-92); 59 paratypes (WAM 75-92 to 89-92 with slides from 5 individuals); 5 paratypes (Museum of Victoria J23975); 5 paratypes (Australian Museum, Sydney P40998); 5 paratypes (Zoological Museum, Amsterdam).

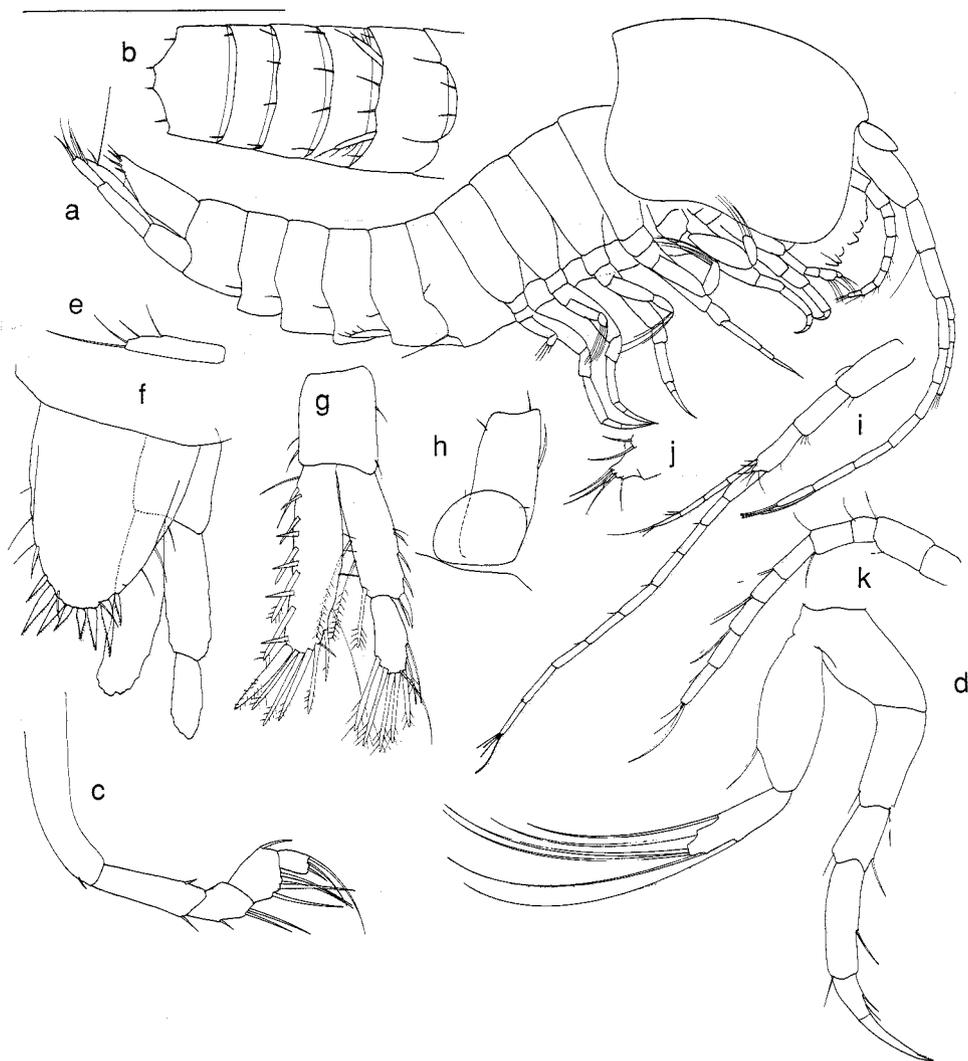


Fig. 1. *Halosbaena tulki*, sp. nov. Paratype female, WAM 75-92: a, habitus (scale bar, 0.5 mm); b, ventral view of pleonites 1-6; c, pereopod 1; d, pereopod 6; e, pleopod 2; f, telson; g, right uropod. Paratype female, WAM 76-92: h, left eye and first article of antenna 1; i, antenna 1; j, distal lobe of antenna 1 peduncle; k, antenna 2.

Diagnosis

Eye distally evenly rounded, wider than long.

Antenna 1 with distal lobe of peduncle bearing 4 setae; outer flagellum of 7-9 articles; inner flagellum of 4 articles. Antenna 2 with peduncle and flagellum weakly differentiated, totalling 9 articles.

Pereopod 1 with basis and ischium apparently fused, bearing short posterodistal seta; merus with 1 anterodistal and 1 posterodistal seta; carpus with 1 midposterior and 2 posterodistal setae; propodus almost as wide as long, with 1 anterodistal and 4 posterior setae; dactylus with 3 distal simple setae. Pereopods 2-7 typical of genus: pereopod 6 endopod basis almost twice as long as wide; fused ischium-merus and carpus each with 1 anterodistal and 1 posterodistal seta; propodus $3.7\times$ as long as wide, with 1 midposterior and 1 anterodistal seta; dactylus with 2 setae on posterior margin, unguis with distal serration, whole as long as propodus; pereopod 6 exopod with first article $3\times$ as long as wide, with 1 seta $\frac{2}{3}$ along, second article with 6 distal plumose setae.

Pleonites without dorsal spination; pleonites 1-6 with 1, 1, 2, 2, 1 and 2 pairs of short ventral setae, respectively. Pleopod 1 obscure, with 1 long seta. Pleopod 2 with 4 setae, fourth the longest.

Uropod peduncle $1.5\times$ as long as wide; endopod reaching $\frac{2}{3}$ along second article of exopod, lateral margin sparsely setose, distomesial corner defined by strong plumose seta, 5 more slender and shorter plumose setae laterally on apex, mesial margin with 5 oblique plumose setae and 5 shorter simple perpendicular setae; first article of exopod with 4 strong setae laterally plus finer setae, 3 plumose setae mesially; second article of exopod with 6 apical plumose setae plus 2 finer setae, none along most of mesial margin.

Telson width: length 0.9; without dorsal setae; apically with 5 pairs of serrated setae of which third is longest; 2 subapical fine setae; laterally with 3 fine setae in middle $\frac{1}{3}$.

Etymology

From the name of the geological formation in which the type locality occurs; a noun in apposition.

Remarks

The three described species of *Halosbaena* are very similar but *H. tulki* differs from both the Northern Hemisphere species in at least three characters. The possession of rounded eyestalks is unique; the others have an acute mediodistal angle. The uropodal endopod is longer, reaching beyond the midpoint of the second article of the exopod (not doing so in the other species). Mesial marginal setae on the second article of the uropodal exopod are absent (2-3 present in the other species).

Otherwise, *H. tulki* shares more features with *H. acanthura* than with *H. fortunata*. For example, the shape of the telson is similar to that of *H. acanthura*, both wider than in *H. fortunata*. The numbers of equivalent setae on the uropod are similar in *H. tulki* and *H. acanthura*, and generally fewer than in *H. fortunata*. *H. tulki* has a similar number of antennal flagellar articles to that reported for *H. acanthura*, more than in the other species. A significant difference between these two species is seen in pleopod 1, which is much less developed in *H. tulki* (1 seta) than in *H. acanthura* (more produced and with 3 setae).

Of the specimens collected in October, one female was carrying three young in her brood pouch and many post-embryos separated from females were presumably displaced during sampling. These data are consistent with what is known for other species which have a small number of eggs (2-10) incubated in the dorsal thoracic brood pouch.

Samples from plant roots did not contain thermosbaenaceans. During sorting the animals swam rapidly but remained on the substrate when undisturbed; nearly all had completely full guts. These observations suggest that thermosbaenaceans are essentially benthic animals that do not filter feed but live on the bottom detritus (*Thermosbaena mirabilis* feeds on algae in hot springs).

This is the first occurrence of the genus *Halosbaena* in almost fresh water; it was previously known only from sea water (*H. fortunata*) and euryhaline hypersaline waters

(*H. acanthura*). This range of conditions is also occupied by the other speciose genus, *Monodella*, which additionally is found in thermomineral springs (*M. relicta*).

Special searches were made for *Halosbaena tulki* at four locations (C-23, C-105, C-413 and C-440) on the eastern side of the North West Cape peninsula, three of which contained other elements of the stygofauna, but none was found. Thermosbaenaceans tend to be absent from groundwater when gammaridean amphipods are abundant (Stock 1985) and may serve as food for larger predators (Yager 1987).

Biogeography

When thermosbaenaceans were known only from the edges of the Mediterranean they were thought to have been stranded inland by a combination of sea-level changes during the Miocene and the associated salinity crisis. Maguire's (1965) discovery of the first thermosbaenacean outside the Mediterranean area (Texas) was a matter of considerable interest and has led to much biogeographic speculation; each subsequent jump in their distribution has required reappraisal of the evidence. However, no species has yet been found outside the tropics.

The common thread has been to consider thermosbaenaceans as having originated in the Tethys Sea (Barker 1959; Fryer 1965; Stock 1976; Abele 1982; Wagner 1990) and directly colonised phreatic water in the Miocene–Pliocene or even earlier (Bowman and Iliffe 1986). The discovery of a possible Pleistocene immigrant of the interstitium (*Halosbaena acanthura*) made it likely that marine thermosbaenaceans would be found (Stock 1976); *H. fortunata* from marine lava caves (Bowman and Iliffe 1986) and *Halosbaena* sp. from shallow marine sands (Stock 1986) were reported soon after.

Monodella and *Halosbaena* occur on both sides of the Atlantic and on the shores of the Indian Ocean, a distribution explained by cave colonisation and subsequent dispersal through sea-floor spreading and continental drift as the Atlantic opened up (Stock and Longley 1981; Iliffe *et al.* 1984; Hart *et al.* 1985; Wägele 1985; Wilkens *et al.* 1986). Thus, the thermosbaenacean genera of the Greater Tethys invaded the proto-Mediterranean and proto-Caribbean during the Triassic and Jurassic (225–160 million years ago: Cals and Boutin 1985) and became separated by the breakup of Pangaea in the Mesozoic (Wilkens *et al.* 1986). At that time (Early Cretaceous) the plate that is now Western Australia formed the eastern shore of Greater Tethys (Howarth 1981). The finding of *Halosbaena* in Australia is consistent with this hypothesis but presupposes a remarkable degree of morphological conservation over 200 million years; *Halosbaena tulki* is very close morphologically to both its Caribbean and Canary Is congeners.

While the Cape Range system (Lower Miocene) did not exist in the Mesozoic, pre-Mesozoic rocks lie to the north-east across the North West Shelf. This shallow shelf would have been widely emerged during periods of lowered sea level (Chappell and Thom 1977), even as recently as the Late Pleistocene, and could have provided a route for the colonisation of the North West Cape peninsula.

On both sides of the Atlantic Ocean Thermosbaenacea co-occur with other relictual Crustacea (remipedes, cephalocarids and spelaeogriphaceans: Newman 1991), as well as cyclopoid copepods, mysids (*Stygiomysis*), isopods (microparasellids and stenasellines) and amphipods (*Hadzia* and *Psammogammarus* also found in the Indo-Pacific part of Tethys: Schram 1986). Hence the finding of Thermosbaenacea and Mystacocarida (Newman 1991) in Western Australia indicates poor sampling of stygofauna in Australia and suggests that further work may reveal some of these other orders.

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