Delineation of the fauna of the Millstream aquifer

W.F. Humphreys
Western Australian Museum, Francis Street, Perth
Western Australia 6000

January 1998

Delineation of the fauna of the Millstream aquifer

W.F. Humphreys
Western Australian Museum, Francis Street, Perth
Western Australia 6000

SUMMARY

In 1996 it was shown that the aquifer of the Western Fortescue Plain (the Millstream aquifer) contains a stygofauna distinct from that known elsewhere and apparently comprising an ancient gondwanan relict fauna. Additional sampling in 1997 has not extended the range of the typical Millstream stygofauna. However, the sampling showed that the stygal community varies both along the length of the Fortescue River, from its headwaters to the coast, and from that in the adjacent catchments of the Robe and Hardey Rivers, the latter being a tributary of the Ashburton River. These faunas were mainly found in groundwater calcretes but also in river gravels, especially those deposited below water gaps downstream of Millstream.

INTRODUCTION

In October 1996 a brief reconnaissance survey of the Millstream groundwater monitoring borefield (Water and Rivers Commission) and one augmentation bore (Water Corporation) showed a significant fauna specialised for the subterranean environment—stygofauna—to be present in the groundwater.

The fauna includes an order and a number of genera new to Australasia, as well as a number of undescribed genera and species. The fauna has close gondwanan affinities and is probably an ancient relict fauna.

The initial findings suggested that the fauna may be much richer and that, given the hydrogeological context, it may be confined to the aquifer on the western Fortescue plain—there is no continuity of phreatic groundwater with the coastal region because drainage is via water gaps cut through Proterozoic rocks, while to the east the groundwater drains inland towards the "Swamp", a region of closed groundwater drainage.

Information is required by a number of agencies on the distribution and vulnerability of the fauna. Consequently a joint proposal for funding was put to the National

Heritage Trust (CALM, Water Corporation, W.A. Museum of Natural History and the Water and Rivers Commission). In anticipation of this funding some preliminary survey work was conducted by WAMNH to progress the taxonomic work—which has a long lead time involving numerous specialists — in order to facilitate the NHT funded work, funding which eventually was not forthcoming.

Background

Arid northwestern Australia is proving to contain a diverse subterranean fauna in both terrestrial (Humphreys 1993b) and aquatic systems (Humphreys 1993c; papers in Humphreys, 1993a). The stygofauna in particular contains many remarkable disjunct lineages in both anchialine (e.g. Yager and Humphreys, 1996) and freshwater aquifers (Poore and Humphreys, in press), the existence, extent and affinities of which are only just being explored (Table 1: Humphreys, in press a, submitted).

Table 1: Some stygofauna genera of northwestern Australia —mostly found in the last seven years— with their probable affinities and the authority for the genera or for their affinities. CRP, Cape Range peninsula; BI, Barrow Island; T, Tethys; P, Pangea; G, Gondwana.

Major taxon	Genus	Locality	Affinities	Authority
Tethyan genera with North Atlantic affinities				
Ostracoda: Halocyprida	*Danielopolina*	CRP	T	Baltanas & Danielopol , 1995
Remipedia: Nectiopoda	*Lasionectes*	CRP	T	Yager & Humphreys, 1996
Isopoda: Cirolanidae	*Haptolana*	CRP/BI	T	Bruce & Humphreys, 1993
Amphipoda: Hadziidae	*Liagoceradocus* [2 spp.]	CRP/BI	T	Bradbury & Williams, 1996b
Thermosbaenacea	*Halosbaena*	CRP/BI	T	Poore & Humphreys, 1992
Probable freshwater lineages				
Syncarida: Bathynellacea: Parabathynellidae	*Atopobathynella*	CRP/BI Kimberley	G/P	H.K. Sminke, pers. comm. ,1994
Syncarida: Bathynellacea: Bathynellidae	gen. indet.	CRP/BI Kimberley	P	H.K. Sminke, pers. comm. ,1994
Isopoda: Flabellifera: n. fam.	**Tainisopus* [2+ spp.]	Kimberley	•	Wilson & Ponder, 1992
Isopoda: Flabellifera: n. fam.	*gen. nov. [2+ spp.]	Pilbara	•	G.F. Wilson, pers. comm., 1997
Isopoda: Phreatoicidea: Amphisopidae	*n. gen.	Kimberley	G	Wilson & Keable, in press
Isopoda: Phreatoicidea: Amphisopidae	*Hyperoedesipus*	Pilbara	G	G.F. Wilson, pers. comm. 1997
Oligochaeta: Phreodrilidae	gen. indet.	Pilbara	G	A. Pinder, pers. comm. 1997
Chelicerata: Acarina: Hydracarina	*Tiramideopsis*	Pilbara	India	M.S. Harvey, 1998.
Spelaeogriphacea	*n. gen.*	Pilbara	G/P	Poore & Humphreys, in press
Amphipoda: Bogidiellidae	**Bogidomma*	BI	T	Bradbury & Williams, 1996a
Decapoda: Atyidae	**Stygiocaris* [2 spp.]	CRP/BI	Madagascar	Holthuis, 1960
? lineages				
Pisces: Eleotridae	**Milyeringa*	CRP	•	Whitley, 1945
Pisces: Synbranchiformes	*Ophisternon*	CRP	T	Mees, 1962
Ostracoda: Cypridacea: Candoninae	*?Caribecandona*	Pilbara	Haiti	K. Wouters, pers. comm. 1997
Amphipoda: Melitidae	**Nedsia* [8+ spp.]	CRP/BI	T	Barnard & Williams, 1995 Bradbury & Williams, 1996a
Amphipoda: Melitidae	*n. gen.	CRP/BI	T	J. Bradbury, pers. comm., 1997.

The area is arid with the annual evaporation exceeding the low annual rainfall (c. 350 mm) by about an order of magnitude and is characterised by very high summer temperatures. The detailed environment of the faunas is unknown but water chemistry data are available for a number of sites.

Sampling in 1996-7

A number of sites has been visited over the two sampling periods (Table 2) to determine the distribution of the typical "Millstream stygofauna" within the Western Fortescue Plain and the limits to its distribution beyond the plain both within the drainage basin and in adjacent drainage basins. Furthermore, should the fauna be limited to the Western Fortescue Plain, then to determine its relationships with neighbouring faunal assemblages. Sampling was conducted variously using 250 µm mesh haul nets, trapping using micro-cray pots, Bou-Rouch pumps and by the Karaman-Chappuis method.

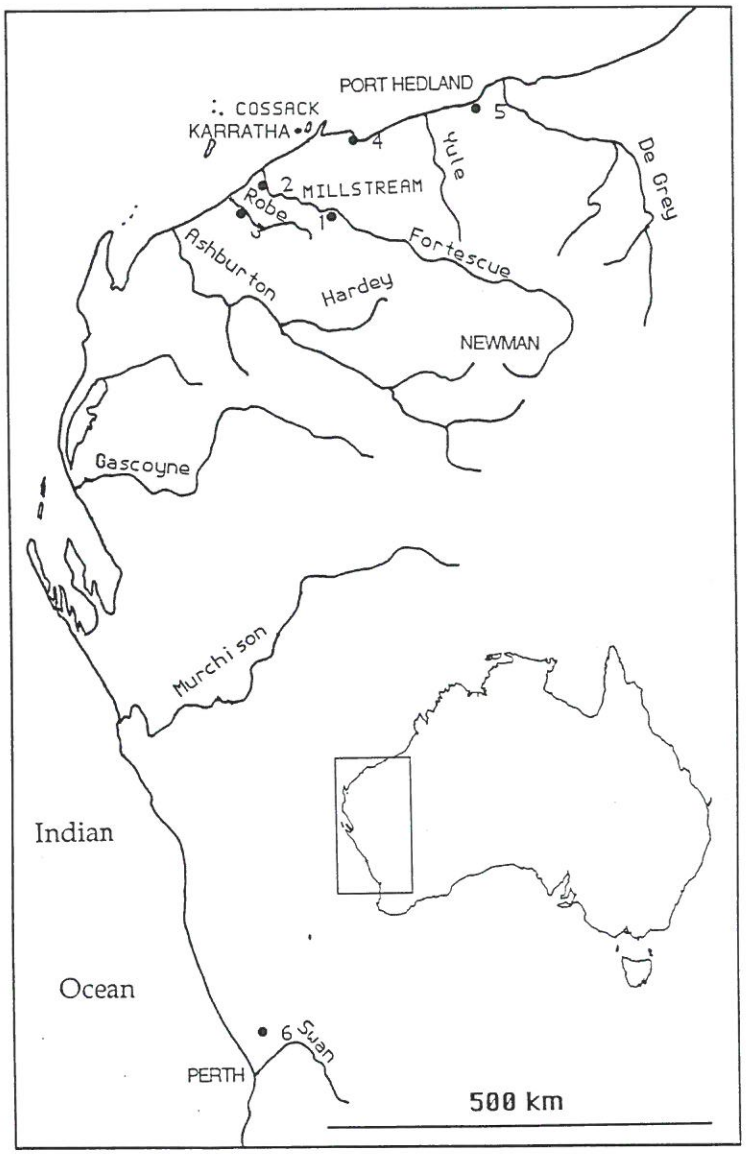
Table 2: Sampling intensity of groundwater habitats: number of sites sampled by location.

	1996	1997
Ashburton basin: Hardey River	•	19
Canning Basin	5	•
Cossack	1	•
De Grey River	5	•
Lower Fortescue: Mardie Station	18	10
Lower Robe: Yarraloola Station	15	•
Millstream aquifer	46	44
Mt Lionel	•	5
Port Hedland	1	•
South Fortescue: Tom Price	•	12
Upper Fortescue: Newman	•	21
Upper Robe	•	7
Yule River	15	•
Total	106	118

Nature of the habitats

Millstream: the Millstream aquifer (Figure 1) is in a karstic groundwater calcrete and freshwater (TDS 864 mg L^{-1} [s.e. 128.8, n= 6]— raw data from pump tests in Barnett and Commander, 1985) with a pH of 7.4 ±0.09. The characteristics of the Millstream aquifer and its geological context have been discussed at length by Poore and Humphreys (in press) together with the potential great age of the associated fauna (see also Humphreys 1993d, in press b, submitted).

Figure 1: Location map for sampling sites.



The associated fauna in the aquifer includes a new genus of Spelaeogriphacea, the first record of the order in Australasia (Poore and Humphreys, in press), as well as other elements of a clearly gondwanan fauna *inter alia* a genus of water mites previously known only from India (Harvey, 1998), syncarids (Bathynellacea), phreatoicid isopods, phreodrilid oligochaetes, hydrobioid gastropods, ostracods and crangonyctoid amphipods (W.F. Humphreys, unpublished).

Mardie and Yarraloola Stations: the aquifers are in gravel fans resulting from the discharges respectively of the Fortescue and Robe Rivers from the Pilbara craton onto the coastal plain (Commander, 1994a, 1994b). They lie unconformably on Precambrian banded iron formation (Proterozoic schist in the case of the Robe valley) and basalt, Cretaceous conglomerate and siltstone, and on Tertiary pisolite and limestone (ibid.). Groundwater salinity ranges from 345 mg L-1 (TDS) close to the river to 1200 mg L-1 near the tidal flats where there is a saltwater interface (ibid.). Samples were taken from 35 bores and pastoral wells in two groundwater assessment borefields. The fauna of these aquifers includes elements of the tethyan fauna found on the Cape Range peninsula and Barrow Island (Humphreys, 1993c, in press a) including atyid shrimp, cirolanid isopods and thermosbaenaceans, ostracods, bathynellid syncarids, halacarid mites, hydrobioid gastropods and microturbellaria (W.F. Humphreys, unpublished), as well as diverse amphipods (Paramelitidae, Bogidiellidae: J. Bradbury, pers. comm. 1997; Bradbury and Williams, 1997).

Yule and De Grey Rivers: samples were taken from unused bores in the current freshwater production borefield (Water Corporation) located in these sand aquifers. Samples were taken at 18 locations (13 in the Yule) and the associated fauna included ostracods, amphipods (Melitidae) and bathynellid syncarids (W.F. Humphreys, unpublished).

Port Hedland and Cossack: a single sample was taken at each site from early historical wells. Associated fauna includes ostracods (2+ species, W.F. Humphreys, unpublished) and cyclopoid copepods (De Laurentiis, Pesce and Humphreys, submitted).

Ashburton basin: Hardey River: borefield in calcrete aquifer for Tom Price. The fauna includes flabelliferan isopods, cyclopoid copepods, amphipods and ?phreodrilid oligochaetes.

Canning Basin: about 7 groundwater monitoring bores on Pardoo Station and Shay Gap borefield. No fauna was recovered.

South Fortescue Borefield for Tom Price: all available bores were sampled in this calcrete aquifer in which drawdown has been considerable. No fauna was recovered.

Mt Lionel Borefield for Tom Price: all available bores were sampled in this calcrete aquifer. No fauna was recovered.

Upper Fortescue: borefield in a calcrete aquifer supplies water for mining operations plus some groundwater monitoring bores associated with mining activities. Stygofauna was found in 13 bores including several amphipods, flabelliferan isopods (a new clade of an undescribed family), phreatoicid isopods and ostracods whose affinities a tentatively placed in Haiti.

Upper Robe: groundwater monitoring bores and riverine gravels in Western Fortescue Plain area. A number of bores, riverine gravels and pastoral wells were sampled. The fauna includes thermosbaenaceans, amphipods (3+ species), water mites, flabelliferan isopod, molluscs and cyclopoid copepods.

RESULTS

The field work in 1997 covered selectively the area from the Upper Fortescue (Newman), South Fortescue (Tom Price), Mt Lionel and Hardey River (Ashburton basin), as well as the Western Fortescue Plain—Millstream—aquifer (both the Robe and Fortescue sections), the upper Robe and the lower Fortescue (Mardie Station).

This work has suggested the limited extent of the Millstream stygofauna and shown that the faunal community differs both upstream and downstream of Millstream aquifer and from different drainage basins.

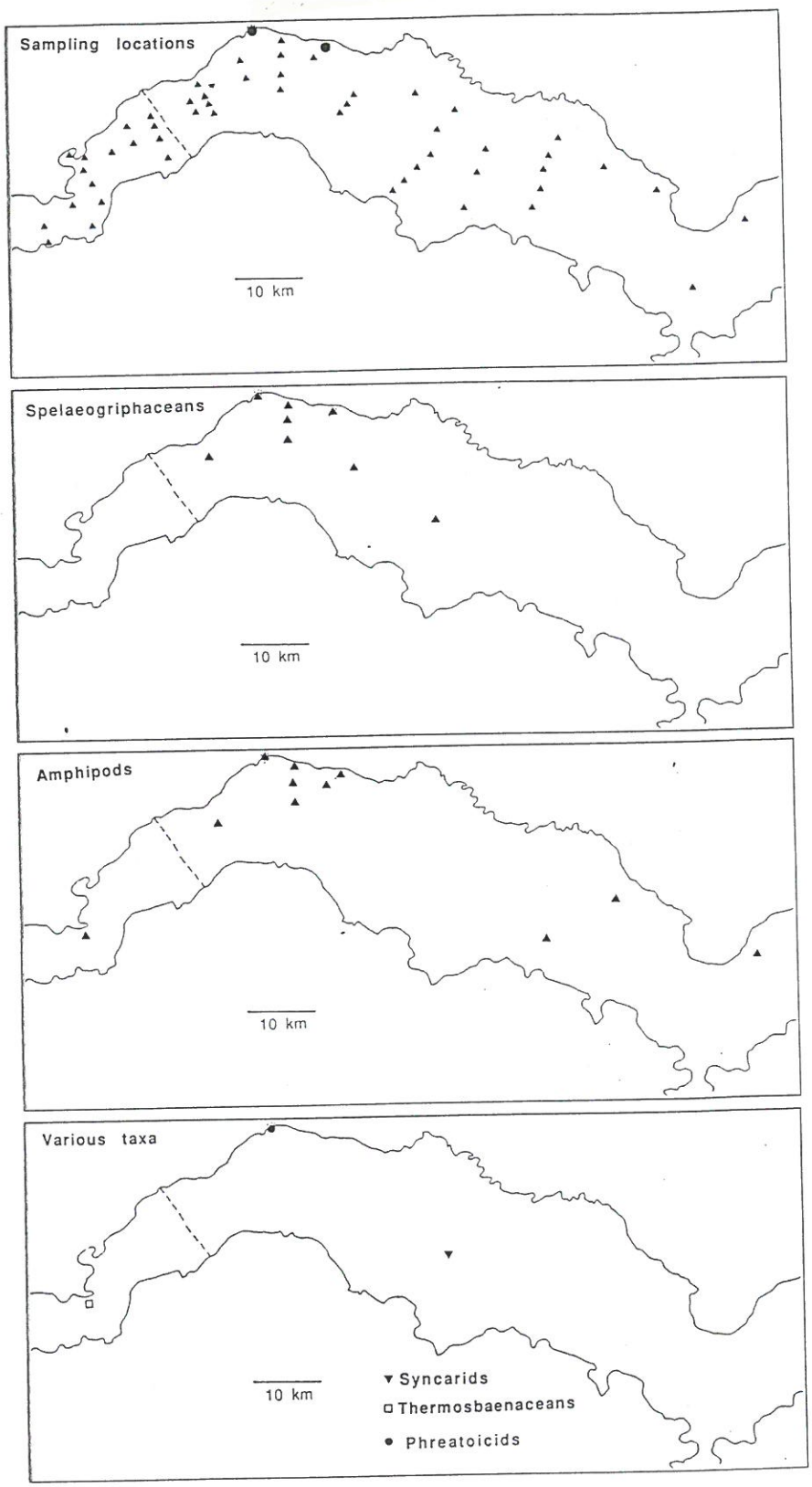
Nature of the fauna in the aquifer of the Western Fortescue Plain

No additional site for spelaeogriphaceans was found within the Millstream aquifer so that the extent of the fauna would appear to be rather limited (Figure 2). However, it is important to note that as the sampling was conducted solely to get specimens for taxonomic work. In consequence, only one-off haul netting was conducted but no trapping was conducted or measurement made of the water quality. Both are considered essential before confidence can be gained that the apparent limited range of the Millstream stygofauna is real.

Some taxa collected from the Millstream aquifer in 1996 were not collected again in 1997 either at the same sites or elsewhere, suggesting that the fauna may be sparse, even rare e.g. the Phreodrilidae.

While a detailed biogeographical assessment of the fauna is not yet possible, a high proportion of the species appear to have widely disjunct relatives from gondwanan fragments. It includes the order Spelaeogriphacea, populations of which were

Figure 2: Limits of Millstream aquifer (based on Barnett and Commander, 1985) showing sampling locations (triangles in upper map: circles denote multiple sampling points at Palm Springs and Millstream), and the distribution of selected stygofauna taxa in the aquifer of the Western Fortescue Plain. In the upper map the groundwater divide between the Fortescue and the Robe drainages is denoted by a broken line.



previously known only from two caves in South Africa and Brazil (Poore and Humphreys, in press). The associated fauna includes phreodrilid oligochaetes that generally have a cool climate Gondwanan distribution (Pinder and Brinkhurst, 1997), phreatoicid isopods (?closest to *Hyperoedesipus* , G.F. Wilson, pers. comm. 1996), a diverse amphipod fauna including crangonyctoid amphipods of the families Paramelitidae and Melitidae (J. Bradley, pers. comm. 1997), syncarids (Bathynellacea), the ostracod ?*Caribecandona* (K. Wouters, pers. comm. 1997), the water mite genus *Tiramideopsis* previously known only from India (Harvey, in press), plus at least another 10 species of ostracods, copepods and microturbellaria.

As predicted, the first elements of a terrestrial troglobitic fauna were sampled from the air filled voids above the aquifer.

There is a groundwater divide in the Western Fortescue Plain between the Robe and Fortescue drainages (Figure 2). Sampling in the Robe sections yielded no spelaeogriphaceans, but elements of the coastal plain fauna were found there.

Nature of the fauna in the Fortescue Valley

Upstream, in the upper Fortescue, calcrete aquifers contain a rich stygofauna. This includes a second clade of a new family of flabelliferan isopod being described from a species named in the Kimberley stygofauna (Wilson and Ponder, 1992), several taxa of amphipods, cyclopoid and harpacticoid copepods, turbellaria, both micro and macro, phreatoicid isopods and several species of ostracods. The fauna seemingly bears little resemblance to that of the Western Fortescue Plain.

Downstream, below the water gaps cut through Proterozoic rocks, the fauna is quite different and in parts has clear affinities with the tethyan fauna associated with the coastal karst of the Cape Range peninsula and Barrow Island, as predicted elsewhere (Humphreys, 1993c)

Nature of the fauna in adjacent drainages

In the adjacent drainage basin to the south, the Hardey River (Figure 2) is part of the upper reaches of the Ashburton basin. A borefield in calcrete there contains a stygofauna related to that of the upper Fortescue but, at this stage, is seemingly distinct from it.

The Yule and De Grey rivers drain the Pilbara craton from the north. The limited

fauna from the lower reaches of these rivers is not clearly allied to that of the Millstream aquifer, but the lower reaches of these river share very different aquifer facies.

Taxonomy and systematics

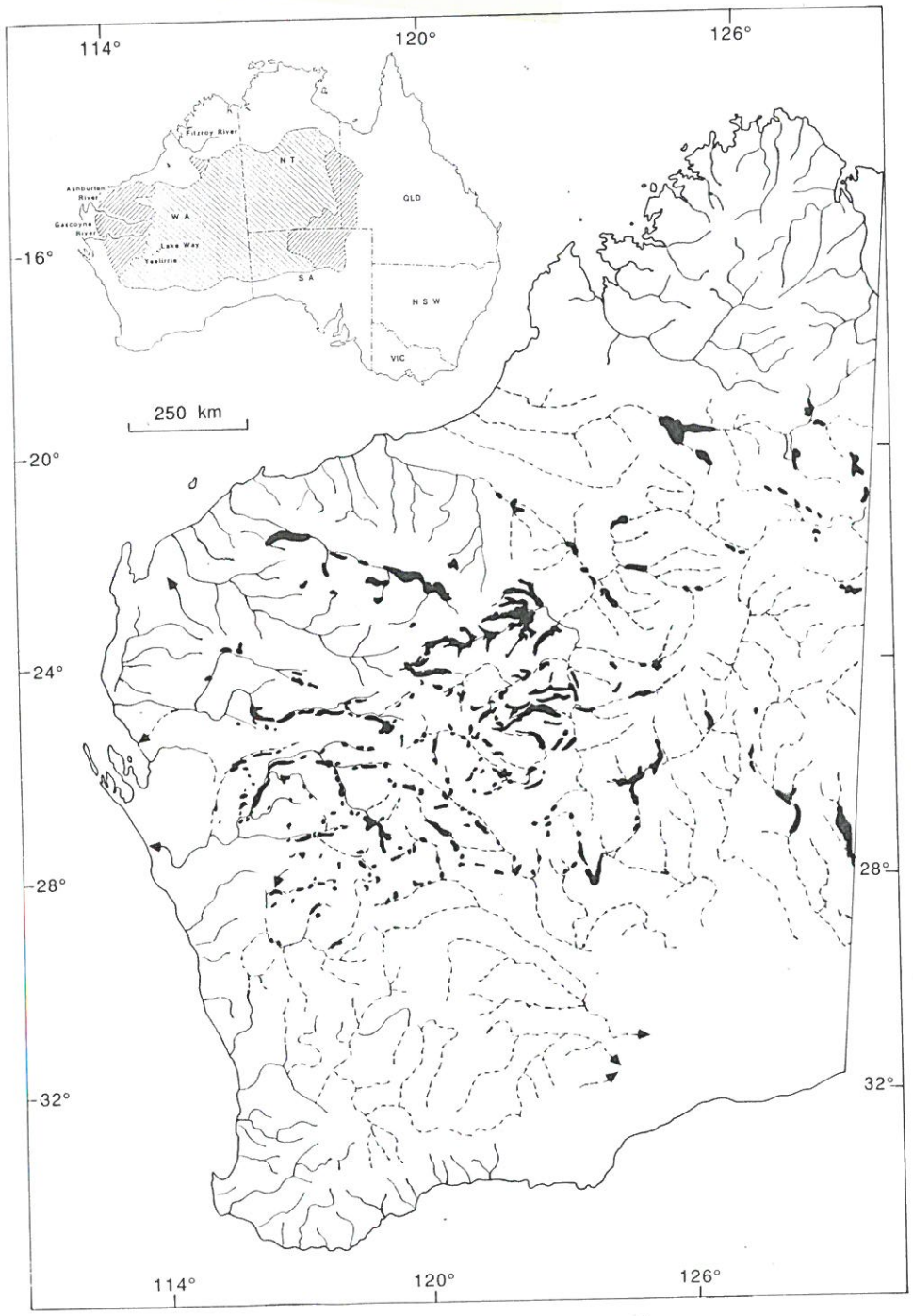
Systematic and taxonomic studies of these faunas are progressing well. The taxonomy of the following groups is progressing actively:- Gastropoda: new hydrobioid; Ostracoda (several species) ; Isopoda: Phreatoicidea; Amphipoda: Crangonyctoidea: Paramelitidae (several species) and Melitidae (several species; J. Bradley, pers. comm. 1998); Spelaeogriphacea (Poore and Humphreys, in press); Acari: Hydracarina (Harvey, 1998); Copepoda: Cyclopoidea (1 ms completed); Syncarida: Bathynellacea (probably be started in 1998); Oligochaeta: Phreodrilidae (more specimens required). In addition, DNA work on the three extant species of spelaeogriphaceans—from Australia, South Africa and Brazil— is being undertaken with colleagues in Rome.

Calcretes and karst

The fauna is principally found in karstic groundwater calcretes (Figure 3). Calcrete deposits are widespread throughout the arid zone both as soil (vadose) and groundwater (phreatic) calcretes (Arakel, 1996). They are especially important in the Australian context as they form in arid climates (annual rainfall <200 mm) with high potential evaporation (>3000 mm per year: Mann and Horwitz, 1979). Groundwater calcretes often develop typical karst features which are suitable stygofauna habitat, as shown in the Millstream aquifer in the western Fortescue Valley, Pilbara (Barnett and Commander, 1985).

Groundwater calcretes occur widely in Australia but in isolated, sometimes extensive, pockets often associated with palaeodrainage lines. Sampling to date suggests these pockets may contain distinct faunas, hence there is potential in these calcrete aquifers to contain substantial hidden biodiversity. In consequence, the stygal communities in the calcretes of Australia—and probably other arid regions— are of considerable interest both as regards the biogeographic of the faunas themselves, for their potential in the study of landscape evolution and, especially, as indicators of changing conditions in the water—stygofauna have not been recovered from areas where there has been substantial drawdown.

Figure 3 The distribution of calcretes aquifers in Western Australia. Derived from data in Geological Survey (1989, 1990). Inset: general distribution of groundwater calcretes in mainland Australia, adapted from Mann and Horwitz (1979).

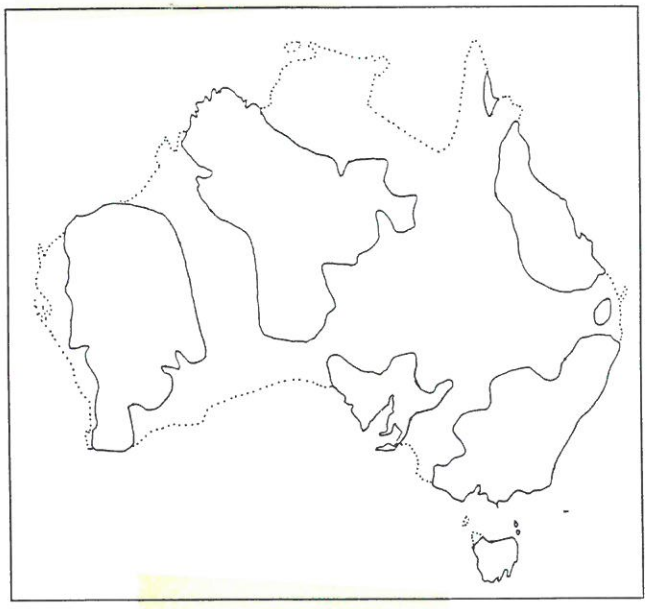


These relictual lineages are best conserved by protecting their habitat. In this arid area karst and calcretes often constitute the principle water supply for human activities. We need to recognise that excessive water abstraction resulting in a reduction of the water table below levels naturally occurring, and especially dewatering operations are likely to lower the water table below the karstic calcrete and so represents a potential hazard to these ancient relictual communities. Furthermore, this process may lead to upconing of hypersaline groundwaters and permanently damage the aquifer (Jacobson and Arakel, 1986).

Prospects

The biodiversity discussed here represents the barest glimpse of the stygofauna liable to be present in northwestern Australia. The Pilbara craton, like the Kimberley (Wilson and Keable, in press), having been emergent since the Precambrian (Figure 4), is liable to harbour freshwater lineages whose origins can be traced to Gondwana and Pangea. The fauna has potential to aid our understanding of the evolution of lineages both within Australia and Gondwana, as well as the evolution of tethyan stygofaunas and the colonisation of Tethys as its development separated the Old World from the New. In this arid area these groundwater calcretes constitute the principle water supply for many mining and pastoral activities. The presence of these newly discovered relictual stygofauna communities in calcrete deposits offers exciting possibilities as well as presenting real challenges to those concerned with resources and ecosystem managers.

Figure 4: The current outline of Australia superimposed on the areas continually emergent since the Proterozoic. 1. Cape Range; 2. Pilbara; 3. Kimberley. Derived from data in BMR Palaeogeographic Group (1990).



Many other areas remain to be examined to delineate properly the extent of the Millstream fauna, especially the upper reaches of those rivers draining northwards and eastwards from the Pilbara craton. An assessment is needed of the occurrence and nature of stygofauna in areas affected by pastoral and mining activities, water abstraction and dams so that their impact on these unique ecosystems can be mitigated.

Acknowledgements

Julianne Waldock provided excellent support in Perth and Stefan Eberhard provided much needed support in the field in 1997. I thank the many specialists referred to throughout the text and in Table 1 for examining material.

REFERENCES

Arakel, A.V., 1996. Quaternary vadose calcretes revisited. AGSO Journal of Australian Geology and Geophysics, 16: 223-229.

Barnett, J.C. and Commander, D.P., 1985. Hydrogeology of the western Fortescue Valley, Pilbara Region, Western Australia. Geological Survey Record 1986/8. Western Australia Geological Survey, Perth.

Bradbury, J.H. and Williams, W.D., 1997. The amphipod (Crustacea) stygofauna of Australia: description of new taxa (Melitidae, Neoniphargidae, Paramelitidae), and a synopsis of known species. *Records of the Australian Museum*, 49: 249-341.

Commander, D.P., 1994. Hydrogeology of the Robe River alluvium, Ashburton Plain, Carnarvon Basin. Geological Survey of Western Australia: Professional Papers, Report 37: 75-100.

Commander, D.P., 1994. Hydrogeology of the Fortescue River alluvium, Ashburton Plain, Carnarvon Basin. Geological Survey of Western Australia: Professional Papers, Report 37: 101-124.

De Laurentiis, P., Pesce, G.L. and Humphreys, W.F. in prep. Copepods from ground waters of Western Australia, IV. New species from the Pilbara (Crustacea: Copepoda: Cyclopidae). *Records of the Western Australian Museum*

Geological Survey, 1989. Hydrogeological map of Western Australia, 1: 2,500,000. Geological Survey of Western Australia, Perth.

Geological Survey, 1990. *Geology and mineral resources of Western Australia.* Geological Survey of Western Australia, Memoir No. 3.

Harvey, M.S., 1998. Unusual new water mites (Acari: Hydracarina) from Australia, Part 1. *Records of the Western Australian Museum* (in press).

Humphreys, W.F. (Editor), 1993a. *The Biogeography of Cape Range, Western Australia.* Western Australian Museum, Perth, 248 pp.

Humphreys, W.F., 1993b. Cave fauna in semi-arid tropical Western Australia: a diverse relict wet-forest litter fauna. *Mémoires de Biospéologie* **20**: 105-110.

Humphreys, W.F., 1993c. Stygofauna in semi-arid tropical Western Australia: a Tethyan connection? *Mémoires de Biospéologie,* 20: 111-116.

Humphreys, W.F., 1993d. The significance of the subterranean fauna in biogeographical reconstruction: examples from Cape Range peninsula, Western Australia. In: W.F. Humphreys (Editor), *The Biogeography of Cape Range, Western Australia.* Western Australian Museum, Perth, pp. 165-192.

Humphreys, W.F., in press a. The hypogean fauna of the Cape Range peninsula and Barrow Island, north-west Australia. Pp ...-... *in* H. Wilkens, D.C. Culver and W.F. Humphreys (eds). *Ecosystems of the World, vol. 30. Subterranean Biota.* Elsevier, Amsterdam.

Humphreys, W.F., in press b. Relict faunas and their derivation. Pp ...-... *in* H. Wilkens, D.C. Culver and W.F. Humphreys (eds). *Ecosystems of the World, vol. 30. Subterranean Biota.* Elsevier, Amsterdam.

Humphreys, W.F., submitted. Relict stygofauna diversity preserved in sea salt, karst and calcrete in arid northwestern Australia. *Australian Zoologist,*

Jacobson, G. and Arakel, A.V., 1986. Calcrete aquifers in the Australian arid zone. Pp 515-523 In *Proceedings of international conference on groundwater systems under stress, Brisbane.* Australian Water Resources Council.

Mann, A.W. and Horwitz, R.C., 1979. Groundwater calcrete deposits in Australia: some observations from Western Australia. *Journal of the Geological Society of Australia*, 26: 293-303.

Pinder, A.M. and Brinkhurst, R.O., 1997. Review of the Phreodrilidae (Annelida: Oligochaeta: Tubificida) of Australia. *Invertebrate Taxonomy*, 11: 443-523.

Poore, G.C.B. and Humphreys, W.F., in press. The first record of the Spelaeogriphacea (Crustacea) from Australasia: a new species from an aquifer in the arid Pilbara of Western Australia. *Crustaceana* ...:...-....

Wilson, G.D.F. and Keable, S.J., in press. A New Genus Of Phreatoicidean Isopod (Crustacea) from the North Kimberley Region, Western Australia. *Zoological Journal of the Linnean Society, London.*

Wilson, G.D.F. and Ponder, W.F. 1992. Extraordinary new subterranean Isopods (Peracarida: Crustacea) form the Kimberley Region, Western Australia. *Records of the Australian Museum* **44**:279-298.

Yager, J. and Humphreys, W.F., 1996. *Lasionectes exleyi*, sp. nov., the first remipede crustacean recorded from Australia and the Indian Ocean, with a key to the world species. *Invertebrate Taxonomy* 10: 171-187.