A contribution on the biodiversity and conservation of the freshwater fauna of rocky outcrops in the central Wheatbelt of Western Australia

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Manuscript received January 2007; accepted June 2007

Abstract

Rock pools on top of inselbergs are probably the only freshwater biotopes in the Wheatbelt of southwest Western Australia not threatened by salinisation. Their invertebrate fauna is highly diverse, but variation on and between outcrops raises serious difficulties in setting minimum conservation goals to protect the rock pool fauna in the central Wheatbelt. We intensively sampled the invertebrate communities in a large number of pools on Wave Rock (57 pools) and King Rocks (35 pools) near Hyden. To help establish the conservation value of these habitats we present a comprehensive list of species. Overall 66 taxa were found. Sampling of 10 pools on an outcrop is enough to establish the most common species, but even after sampling 57 pools, new species were still being added to the list. We argue for the conservation of several rocky outcrops in different precipitation zones. Outcrops should be selected on the criteria of (a) degree of isolation from the other outcrops, (b) the presence of large and deep pools and (c) whether amphibians breed in the rock pools.

Keywords: conservation, rock pool, gnamma, granitic inselberg, freshwater fauna, biogeography.

Introduction

Freshwater habitats in the Wheatbelt of WA are scarce and disappearing through salinisation (Halse *et al.* 2003; Pinder *et al.* 2004). Probably the single habitat independent from this problem are rock pools on granitic inselbergs, locally known as "gnammas". These "freshwater havens", as Ian Bayly (1992) describes them, are completely rain dependent, support a diverse fauna and flora, and in many cases provide water for humans as well (Laing & Hauck 1997; Bayly 2002). The people of Hyden, a town in the central Wheatbelt in Western Australia, still use the water collected from Wave Rock for drinking and stock water. Two recent symposia (Hopper & Withers 1997; Withers & Hopper 2000) have drawn attention to rocky outcrops, but nonetheless the rock pools in Western Australia remain a poorly studied habitat. Some ecological, but mostly systematic studies, presenting the results of surveys at the community level have been completed (Bayly 1982 1997; Pinder *et al.* 2000). These studies found strong differences in species richness in pools on and between rocky outcrops. Differences in species richness between outcrops in WA are related to regional precipitation patterns, affecting the length of the inundation period (Jocqué *et al.* unpublished data). The length of the inundation period in temporary waters is probably the single most important factor determining the structure and richness of a community (Wellborn *et al.* 1996). The heterogeneous environment (*i.e.,* variation in depth, size, sediments, vegetation, in-pool boulders) of the pools further results in a diverse group of species occurring on a single outcrop (Pinder *et al.* 2000). The rich and diverse aquatic invertebrate fauna combined with the large proportions of endemic inhabitants in these rock pools (Frey 1998) and the vulnerability of temporary (freshwater) habitats in arid Australia (Roshier *et al.* 2001) urge the protection and conservation of these rock pool habitat systems. The high diversity on and between outcrops poses serious difficulties in setting minimum conservation goals to protect the rock pool fauna in this region and Pinder *et al.* (2000) made a plea for more intensive studies of Wheatbelt outcrops to obtain a better idea of the distribution of rock pool inhabitants. To help establish the conservation value of these habitats we present a species list from an intensive survey of 57 pools on Wave Rock and an extensive survey of 35 pools on King Rocks. A more detailed analysis of the data will be published elsewhere.

Material and Methods

Study site

The rock pools sampled were situated on Wave Rock (57 pools) near the town of Hyden and King Rocks (35 pools) approximately 50 km northeast of Wave Rock (Fig. 1) We sampled the pools in the winter of 2004 from 8th of July to 29th of August.

Sampling protocol

Two sampling methods were used to collect the

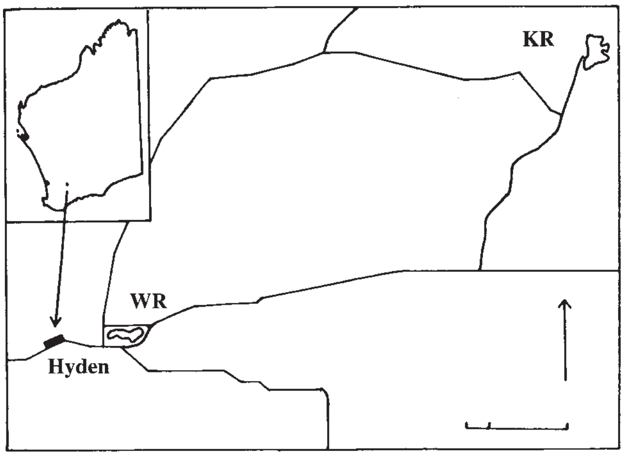

Figure 1. Map with the exact location of Hyden, the inselbergs Wave Rock (WR) and King Rocks (KR) in Western Australia. The lines indicate the major roads in the area. The scale indicates 5 km.

organisms, the first procedure aimed at the smaller benthic organisms and the second procedure was performed to collect the larger macro-invertebrates missed by the first sampling method. Benthos samples were taken by placing a plastic rectangular frame enclosing a surface of 0.5m^2 randomly in the pool. The water was stirred thoroughly to lift all the benthic organisms. The calculated volume of the enclosed water was subsequently removed with a plastic one litre measuring cup and poured through a 64μm filter. The filtered content was then preserved in 70% ethanol. This was done once for small pools, twice for medium sized pools and three times for large pools and aimed at sampling roughly 10% of the surface of the pools. On King Rocks there was time to sample only nine of the 35 pools by this method.

The second sampling method was done with a 500-μm kicksampler. Between 5 and 30 kicks were executed with the same speed and covering the same distance, aiming at covering the whole surface of the pool once. Macroinvertebrates were partly picked out in the field and the sample residuals were preserved in 70 % ethanol and double checked for presence of animals in the lab. Samples were screened in the lab for macroscopic organisms and identified as far as possible under an OLYMPUS SZ-X 12 stereo-microscope. All studied pools on both outcrops were sampled by this method.

In this study, the species list (Table 1) is compiled simply on a presence/absence basis and the cumulative richness curve (Fig. 2) is based on 999 permutations of the Wave Rock data. Due to identification uncertainties, Chironomidae (at least five taxa) as well as *Alona* (2), *Ephemeroporus* (2), *Paroster* (2), *Limnocythere* (3) and *Macrotrix* (2) are each treated as a single taxon in the graph.

Results

We found 58 and 43 taxa in the rock pools on Wave Rock and King Rocks, respectively, and 66 taxa overall (Table 1). The most speciose groups in our study were Coleoptera (15), Cladocera (13), Ostracoda (12) and Diptera (10). The most common organisms were the ostracod *Cypretta baylyi* and the endemic cladoceran *Neothrix armata*, both occurring in 51 of the sampled pools. Although not identified to species level, Chironomidae and Turbellaria were present in 55 and 48 of the sampled pools and are also a major component of the rock pool communities. The rare taxa in these systems occurring in only one, or two pools were all Insecta (*Necterosoma penicillatus*, Tipulidae, *Rhantus* sp., *Limnoxenus zelandicus*, *Micronecta gracilis*) as well as a gastropod (*Glyptophysa* sp.) and a cladoceran (*Planicirclus alticarinatus*).

On average we found 18.7 ± 5.0 taxa in the rock pools on Wave Rock. Most of the common species occurring on Wave Rock were found after the sampling of 10 rock pools. Although the slope of the Cumulative Species Richness curve (Fig. 2) decreased with increasing number of pools, the curve did not plateau.

Discussion

More species were found on Wave Rock than King Rocks (57 as against 43), probably because of the lower sampling effort on King Rocks. In fact King Rocks has more pools and bigger pools (see later) than Wave Rock, so it is likely it has more species. Our figures for species richness compare with the average 48.9 taxa in the study by Pinder *et al.* (2000). Their highest taxon richness (77 at Wanara Rock), was much higher than ours, but this rock was advantaged by having a deep (50cm) artificially dammed pool with macrophytes that is normally wet for much of the year (B. Turner pers. comm.). A long inundation cycle in temporary pools is one of the most important factors determining the composition and structure of communities (Wellborn *et al.* 1996). A longer inundation cycle, removes the developmental constraints which could prevent some organisms occurring in the most temporary pools (*e.g.,* Odonata), allows for a transition of taxa (succession) and also provides a refuge for actively dispersing insects with an adult aquatic phase such as several Hemiptera. The richness values for

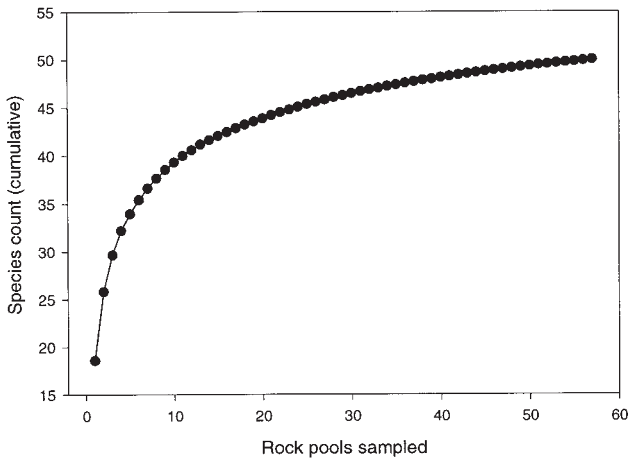

Figure 2. Cumulative species richness curve for 57 rock pools sampled on Wave Rock.

Table 1

Taxa collected from rock pools on Wave Rock and King Rocks. Identification of the underlined Cladocera was not confirmed N. Smirnov. * not caught in this study, but known to be present most years, ^ species restricted to granitic gnammas

Major group	Family	Species	WR	KR
Turbellaria			x	x
Spinicaudata	Limnadiidae	*Limnadia badia*^	x	x
	Cyzicidae	*Caenestheriella mariae*^		x
Anostraca	Branchinellidae	*Branchinella longirostris*^	x*	x
Copepoda	Centropagidae	*Boeckella opaqua*^	x	x
	Harpacticoida		x	x
Cladocera	Chydoridae	*Alona macrocopa*	x	x
		<u>*Alona rigidicaudis*</u>	x	
		Plurispina multituberculata^	x	x
		Leberis aenigmatosa	x	x
		<u>*Planicirclus alticarinatus*</u>	x	
		<u>*Ephemeroporus hybridus*</u>	x	
		Ephemeroporus barroisi	x	x
		Pseudomonospilus diporus	x	
	Macrotricidae	*Neothrix armata*	x	x
		Macrothrix breviseta	x	
		Macrothrix hardingii^		x
	Daphniidae	*Ceriodaphnia* sp.		x
	Moinidae	*Moina* sp.	x	
Ostracoda	Cyprididae	sp. A	x	x
		sp. B	x	
		Limnocythere sp. A	x	
		Limnocythere sp. B	x	x
		Limnocythere cf *porphyretica*	x	
		Limnocythere mowbrayensis	x	x
		Ilyodromus amplicolis	x	x
		Candonocypris incosta	x	x
		Candonocypris sp. A	x	
		Cypretta baylyi	x	x
		Bennelongia barangaroo	x	x
		Sarscypridopsis sp. A	x	
Odonata	Corduliidae	*Hemicordelia tau*	x	x
	Lestidae	*Austrolestes* sp.		x
Hemiptera	Corixidae	*Agraptocorica parvipunctata*	x	x
		Micronecta gracilis	x	x
	Notonectidae	*Anisops thienemanni*	x	x
Trichoptera	Leptoceridae	*Triplectides* sp.		x
Coleoptera	Dytiscidae	*Allodessus bistrigatus*	x	x
		Sternopriscus multimaculatus	x	x
		Paroster michaelseni	x	
		Paroster niger	x	
		Lancetes lanceolatus	x	
		Rhantus sp.	x	
		Antiporus gilberti	x	x
		Hyphydrus sp.		x
		Necterosoma penicillatus	x	
		Megaporus howitti		x
	Hydrophilidae	*Limnoxenus zelandicus*	x	
		Enochrus maculiceps	x	
		Berosus nutans	x	
		Berosus discolor	x	
		Berosus approximans	x	
Diptera	Chironomidae	*Orthoclad* sp.	x	x
		Paraborniella sp.	x	x
		Cryptochironomus sp.	x	x
		Dicrotendipes sp.	x	x
		Forcypomyninae sp.	x	x
	Culicidae	*Aedes alboannulatus*	x	x
	Ceratopogonidae		x	x
	Sciomyzidae		x	x
	Tabanidae		x	
	Tipulidae		x	x
Gastropoda	Planorbidae	*Glyptophysa* sp.	x	x
		Isidorella sp.		x
Acari	Caeculidae?		x	x
Anura		*Crinia* sp.	x	x

the outcrops presented from Pinder *et al.* (2000) are also not directly comparable to our figures as these authors included Protozoa, Rotifera and Oligochaetes in their list and most Diptera (generally the most speciose group) were identified to species, whereas we omitted these groups and incompletely identified dipterans. However the dominant taxonomic groups in both studies were comparable, but often slightly richer in our study — Coleoptera (15 taxa versus 12 taxa), Cladocera (13 versus 11) and Ostracoda (12 versus 12). The higher richness in our study most probably is a direct result from the sampling intensity: Pinder *et al.* (2000) sampled around 10 pools whereas we sampled 57 pools on Wave Rock.

The only species we added to the list of Pinder *et al.* (2000) were the beetle *Hyphydrus,* the small crustaceans *Ephemeroporus hybridus* and *Candonocypris incosta,* the listing of what was previously identified as *Cyzicus* as *Caenestheriella mariae* and the further identification of *Limnadia* as *L. badia* (see Timms, 2006). As Pinder *et al.* (2000) found, many species occurred in only a few pools, a phenomenon with implications for sampling intensity and conservation policies (see later).. The list will grow by increasing the search area and by more detailed identifications, particularly of the Turbellaria, Oligochaeta (*e.g.,* Pinder, 2003) Tardigrada, Nematoda and Mesostigmatid and Trombidoid mites. One particular difficulty in this is the large morphological variation between populations of passive dispersers on different outcrops. A studied example is the fairy shrimp *Branchinella longirostris* with large morphological variations between populations on a series of outcrops from the south to the north of WA (M. Zofkova & B. Timms, unpublished data).

Six species (10%) on our list are endemic to granitic gnammas (Table 1). For the Wheatbelt as a whole the figure is about 30 species (13%) (Pinder *et al.* 2000, 2004; A. Pinder pers.com.). The difference might be due to the much larger area covered by Pinder *et al.* (2000). Rock pool specialists such as the various branchiopods, ostracods and cladocerans are typically passive dispersers. These passive dispersers do not have the ability for active dispersal to another habitat patch and are dependent on other media such as wind (Brendonck & Riddoch 1999) and water (Brendonck *et al.* 1998). This results in strong dispersal limitation of populations between outcrops, so that the populations over time each evolve in their own direction and might differentiate to different species. Long-distance dispersal limitation in this habitat type in Botswana was found for *Branchipodopsis wolfi* (Anostracan) by Hulsmans *et al.* (2007) and probably applies also to the fairy shrimp and possibly other passive dispersers of local rock pools.

The active dispersers such as beetles and corixids are often generalist species of temporary waters with high dispersal capacities and easily spread over large areas, and also not particularly restricted to rock pools (Jocqué *et al.* 2006). In particularly wet winters as in our study period, pools have a relatively long inundation cycle and the longer exposure time results in more species and species from (more) permanent water bodies, which are absent in drier years (Jeffries 1994).

Despite the occurrence of the frequently encountered species discussed above, the most characteristic inhabitants of these gnammas are indeed the large branchiopods —Spinicaudata, together with Anostraca and Notostraca (Bayly, 1997; Timms, 2006). While the spincaudatan *Limnadia badia* was common and widespread, this study hardly encountered another clam shrimp (*Caenestheriella mariae*) and fairy shrimp *Branchinella longirostris,* yet in other years both were common (Timms 2006, and unpublished data). Anostraca are specialists of temporary pools and highly sensitive to predation, mostly from insects immigrating to the pools (Brendonck *et al.* 2002). Increasing predator pressure over time reduces Anostracan populations and could explain why *B. longirostris* completes its life cycle early in a pool's seasonal existence, so that after a few weeks individuals are no longer present. In 2004 the pools of Wave Rock filled early in the season (April–May), but in 2006 they filled late (July). In 2004, none were present on Wave Rock in August (Table 1), but in 2006 most pools had extant populations (Timms, unpublished data).

Pinder *et al.* (2000) did not mention any Anura. In several pools we found large densities of tadpoles of *Crinia* sp. Tadpoles may have an important role in rock pools as competitors or predators and they are also known to increase the nutrient availability in a rock pool by processing the sediment (Osborne & McLachlan 1985) and hence indirectly influence the primary productivity and richness of the community. Besides their ecological role, the presence of amphibians in rock pools also has serious implications for conservation. Amphibian diversity in Australia and on a global scale is declining dramatically (Pechmann & Wilbur 1994). When evaluating the conservation value of a rock pool system, attention should be devoted to the presence and diversity of amphibian populations.

The cumulative richness curve shows that the most common species are collected after sampling about 10 pools. This was the sampling intensity used by Pinder *et al.* (2000) and it provides information on the core species of the system and allows a good estimate of the total richness on these outcrops. If more complete information is needed on the diversity in a rock pool system, a large number of additional pools should be sampled. Most of the rare species collected on Wave Rock occurred in one of the deeper (and often also larger) pools with more permanent inundation, indicating that for an intensive sampling campaign aimed at finding the rare species in a rock pool system, it is best to focus on these deeper and larger pools, if present. However it should be noted that most of the rare species occurring in the pools with a longer inundation cycle are insects (*e.g.,* almost all were beetles and odonates) and appear to be generalist species of temporary habitats, also occurring in other types of freshwater wetlands. The later are declining in availability in the Wheatbelt of WA (Halse *et al.*, 2003), so that gnammas are becoming more important in their survival, but it is the crustaceans unique to gnammas for which this habitat should be evaluated to establish the primary conservation value.

As shown above, the rock pools and the entire rocky outcrops are unique habitats with a high diversity of specialist and endemic species. Protection of these habitats is essential but establishment of a conservation strategy will not be straightforward (Mawson 2000). The strong isolation of the communities on these outcrops potentially makes them sensitive for extinctions through human disturbance, climatic or stochastic events (Bussell & James 1997). If a species disappears on an outcrop it might take a while before it returns through a successful colonization and this most probably to a large extent explains a large part of the heterogeneity of communities on the different outcrops. The best approach would be to conserve a considerable number of outcrops scattered over a large area. At present relatively few granite outcrops lie in National Parks and/or Nature Reserves, though many like Wave Rock and King Rocks, enjoy a degree of protection as water catchments or for recreation. Terrestrial habitats on many granite rocks are compromised by human activities (Main 1997), though it seems to us that the pool environments are less affected and indeed are often pristine Even the intensive use of Wave Rock as a tourist destination seems largely not to have degraded the pools, though luckily most of the pools on Wave Rock are not on the main tourist routes across the rock. For a complete conservation of assemblages in gnammas, rocks should encompass a regional variation in climate-related variables, directly affecting the length of the hydroperiod, and related to this, the richness of the community. Based on the average length of the hydroperiod, it might be interesting to invest slightly more value to some of the outcrops in higher precipitation zones. Based on our experience at Wave Rock this will increase the more widely occurring species, often non-endemic active dispersers. To more adequately characterize the endemic passive dispersers, attention should be at the other end of the scale as most seem to be strongly adapted to temporary pools and not present in the higher rainfall zones. Examples include oligochaetes (Pinder 2003) and large branchipods (Timms, 2006). Two concerns should be mentioned; strongly isolated communities (far from other outcrops) most probably will hold some special rare species and if in the future climatic conditions shift, and especially precipitation zones and evaporation rates, then also the value of the established protected outcrops will change (with the changing length of the inundation period). A good strategy to follow now might be 1) an evaluation based on a thorough survey of the aquatic fauna present in the currently protected Nature Reserves such as Boyagen Rock, Yorkakrine Rock, Frog Rock, Cairn Rock, Dunn Rock and Yanneymooning Rock, 2) addition of other outcrops to the reserve system, aiming to include species not present on the already protected rocks and 3) appropriate management of rocks outside the reserve system by landholders and other interested parties.

Acknowledgments: Merlijn Jocqué is supported by an IWT (Institute for the Promotion of Innovation by Science and Technology in Flanders) PhD scholarship. This research is financially supported by project G.0118.03 of the FWO (Fund for scientific Research in Flanders). A travel scholarship was provided by the King Léopold III Fund for Nature Exploration and Conservation. We thank Nicolai Smirnov (Cladocera), Christopher Watts (Coleoptera), Koen Martens and David Horne (Ostracoda), Cameron Webb (Culicidae), Winston Ponder (Gastropoda) and Rosalind St Clair (Trichoptera) for help with identifications. We thank the residents from Hyden for their warm welcome and the science friendly environment. In particular we are grateful to the late Russell Mauritz and family for providing accommodation during our stay and ready access to Wave Rock. We are grateful to Ian Bayly and Adrian Pinder for helpful comments on the manuscript. Merlijn Jocqué is a founding member of BINCO (Biodiversity Inventory for Conservation).

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