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Desert Springs of the Australian Great Artesian Basin

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Abstract

The Great Artesian Basin (GAB) underlies about one fifth of mainland Australia. Much of this area is arid or semi-arid and often artesian water is the only reliable source of potable water, historically via springs. Prior to the 1870s, there were around 3,000 flowing springs ringing the GAB. The springs were a vital source of water for Aborigines as well as early explorers, workers and pastoralists. The drilling of thousands of bores led to the extinction of about a third of the springs and reduced flows for the remainder. Extant springs are clustered in 13 major spring "supergroups," mostly in South Australia and Queensland. Biological studies commenced late; fishes not being properly sampled in South Australian springs until the 1970s and in Queensland as late as the 1990s. The first report on aquatic invertebrates in South Australian springs was in the 1970s and the first report of an invertebrate group (hydrobiid snails) from Queensland springs was in 1990. The GAB springs are home to many indigenous aquatic invertebrates and fishes, most with restricted distributions and several rare or indigenous plants. Some higher taxa are unique to certain springs and each major group has a distinct fauna. While South Australian springs are relatively well studied, with some significant springs protected, these habitats in Queensland remain poorly known and mostly unprotected. The most immediate conservation issue is to reduce drawdown in the GAB. About 88 percent of current usage is by pastoralists and much is wasted through evaporation and soakage. Government-sponsored bore capping and control programs are reducing wastage, but major mining ventures increasingly use large amounts of GAB water, resulting in problems with local drawdown. Other significant threats include spring modification, trampling by stock and feral animals, and the introduction of exotic plants and animals. In the last decade, GAB water usage and spring conservation have become increasingly significant issues, providing hope for the future of at least some of these unique habitats.

Introduction

In some artesian systems in arid or semi-arid areas, or xeric basins[1], such as in the western United States, natural discharge forms significant springs that have high conservation value because they typically contain endemic biota (e.g., Cole 1968; Balik 1995; Abell *et al*. 2000). Some conservation problems encountered in many artesian systems are similar and include the over-extraction of water leading to drawdown, water contamination (mainly in smaller basins) and excessive modification of natural spring habitats (e.g., Ponder 1986; Contreras-Balderas 1978; Sada *et al*. 2001; Fairfax and Fensham 2002, 2003). This paper outlines the main features of the Australian Great Artesian Basin (GAB), the consequences of past poor management and over utilization, and the current responses to the need to sustainably manage this resource. The fate of the hundreds of artesian springs that occur around the perimeter of the GAB is dependent on the successful outcome of these management responses.

Brief description of the Great Artesian Basin: The GAB lies beneath about 1,711,000 km^2, or about one fifth, of the Australian Continent (Habermehl 2001), an area equivalent to about two and a half times

[1]http://www.panda.org/resources/programmes/global200/pages/habitat/habitat21.htm

the size of Texas. It underlies the northeastern part of the state of South Australia and much of Queensland, with smaller areas in northern New South Wales and the eastern Northern Territory. It is arguably the world's largest artesian system, holding around 8,700 million megalitres. Much of the land above the GAB is arid or semi-arid and in many areas it is the only reliable source of potable water.

Water enters the basin through recharge zones formed from outcropping aquifer mainly on the eastern margin of the basin, on the western slopes of the Great Dividing Range. Smaller recharge areas occur on the western margin in northern South Australia. Groundwater flows mainly westward towards the southwest and to the northwest and north in the northern part at around 1 to 5 m per year, with some of the GAB water shown to be about 1 million years old (Torgersen *et al*. 1991; Habermehl 2001).

The GAB, formed 100 to 250 million years ago and consists of alternating sandstone aquifers and impermeable siltstones and mudstones that vary from less than 100 m at the extremities to over 3,000 m thick in the deeper parts. Artesian bores range from about 500 m to up to 2,000 m in depth. Some of the sandstone sequences contain oil and gas in commercial quantities.

***Water usage and wastage*:** At present, around 570,000 megalitres are used annually, 88 percent by the pastoral industry, with as much as 90 percent of this wasted through evaporation and soakage (Cox and Barron 1998). Numerous free-flowing bores drain into nearly 40,000 km of bore drains, some in excess of 100 km long[2]. Government sponsored bore capping and control programs are slowly reducing the wastage and, overall, the GAB is now more or less in equilibrium (Habermehl 1980, 2001). In 1915, the total flow from the basin was up to 2,000 megalitres per day but has reduced to about 1,500 megalitres per day in 2000. Individual bore pressures have fallen up to 80 m in this period. Major mining ventures are increasingly using large amounts of GAB water resulting in problems with local drawdown.

***GAB artesian springs*:** Prior to the 1870s, there were around 3,000 flowing artesian springs ringing the basin clumped together in 13 major spring "supergroups" (Habermehl 1982; Ponder 1986; Fensham and Fairfax 2003), mostly in South Australia and Queensland (Figure 1). These springs flow via faults in the strata overlying the aquifer or from exposed parts of the aquifer (discharge springs), or as overflow from the aquifer in recharge areas (recharge springs). General accounts of the GAB springs are provided by Habermehl (1982), Ponder (1986), Boyd (1990), Knott and Jasinska (1998), Noble (1998) and Fensham and Fairfax (2003), although all but the last of these focus on the South Australian springs because of the scarcity of data for those in New South Wales and

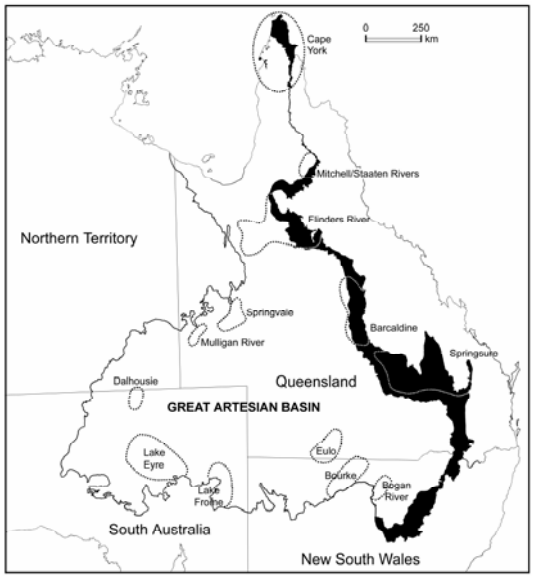

Figure 1. Map showing the Great Artesian Basin and the distribution of the spring supergroups (indicated by doted lines). Each supergroup is named. The eastern recharge area is shown in black. Modified from Fensham and Fairfax (2003).

Queensland. Most GAB discharge springs have small flows, the largest being at Dalhousie Springs in northern South Australia. The Dalhousie Springs collectively discharge around

[2]http://www.nrm.qld.gov.au/water/gab/wastage.html

19,300 megalitres per year (Smith 1989), about 41 percent of the estimated total GAB spring discharge. An inventory of the GAB springs is currently being undertaken (Habermehl 2000).

Extinct spring deposits can be significant land forms in South Australia. Some have been dated at up to 700,000 years, with some probably older (Habermehl 2001).

The springs in Queensland form a number of local clusters (groups) that in turn form eight larger supergroups (Fensham and Fairfax 2002, 2003). Most contain either recharge or discharge springs, but some contain both. Recharge springs are found along the western side of the Great Dividing Range where the GAB aquifer outcrops and is "recharged." Leakage or overflow from this area forms springs, some of which generate large flows (e.g., Major Mitchell Springs).

Artesian springs were originally the only access to the huge water resource associated with the Great Artesian Basin. Historically the springs provided a source of water for Aborigines, explorers, early railway and telegraph workers, and pastoralists (Harris 1981, 1992; Mudd 1999). The importance of the springs to human well-being diminished following the sinking of thousands of bores, mainly for pastoral purposes, since the late 1870s. This in turn has led to the extinction of about a third of the springs (e.g., Habermehl 1982; Ponder 1986; Mudd 1999; Fairfax and Fensham 2002, 2003) and reductions in flow for the remainder. In addition, where previously the spring heads had often been fenced to protect the water source, subsequent to the bores the fences fell into disrepair, allowing stock to trample and foul the springs.

Research on GAB Springs

Scientific appreciation of the springs was surprisingly slow, apart from hydrological investigations, which commenced relatively early in South Australia and New South Wales. Little work was carried out on the Queensland springs until the last decade and there is still little accessible information about flow rates and water chemistry of the great majority of these springs apart from some descriptive surveys in the decades following land settlement (Fairfax and Fensham 2002, 2003).

Biological investigation of the springs was late in happening. Even the fishes were not properly sampled in South Australia until the 1970s and in Queensland springs until the 1990s (Wager 1995). It is now known that the South Australian and Queensland springs are home to many indigenous aquatic invertebrates and fishes (Ponder 1986; Noble 1998; Noble *et al*. 1998), most with restricted distributions (see Unmack 1995 and Wager and Unmack 2000, for a summary of the fishes and Ponder 2004, for a summary of invertebrates) and several rare or indigenous plants (Fensham and Fairfax 2003). Some higher taxa are also unique to these habitats and each major spring group has a distinct fauna (Ponder 1986, 2004).

Although some biological studies had commenced in 1978 on some South Australian springs in the Lake Eyre Supergroup (Greenslade *et al*. 1985), the major incentive to work on the biota of these springs was the result of the Environmental Impact Statements for the Olympic Dam mine in the 1980s (Kinhill-Stearns Roger 1982; Kinhill-Stearns 1983, 1984; Roxby Management Services 1984). A general survey of the other major spring group in South Australia, Dalhousie Springs, was carried out in 1985 (Zeidler and Ponder 1989).

Overviews of the Queensland springs are provided by Wilson (1995) and Fairfax and Fensham (2003).The fishes in Queensland springs are reasonably well known (Wager 1995) and the associated plants have also been surveyed (Fensham and Fairfax 2003). To date, only one group of aquatic spring invertebrates (hydrobiid snails) has been reported on from Queensland (Ponder and Clark 1990), much of the available information on other groups being unpublished. Less than a half of the

over 400 known extant springs in Queensland remain unsampled for invertebrates. This situation is currently being rectified with surveys of the aquatic invertebrates being conducted by the author over the last three years (and ongoing). Some springs contain frogs, but these have not been well sampled and it is not known if any are endemics.

Nearly all of the survey work for invertebrates has focused on mollusks and malacostracan crustaceans. Until recently, other elements of this fauna have been collected in a somewhat *ad hoc* fashion and the microinvertebrates have generally been neglected. There are a few endemics known in the Ostracoda (but only one described) and one aquatic mite has been named. However, faunas in these size ranges are poorly collected and studied. The only published reports including microfauna are Mitchell (1985) for South Australian springs in the Lake Eyre Supergroup and Zeidler (1989) for Dalhousie Springs.

Conservation Status and Current Threats

The immediate conservation issue relating to the GAB springs is to reduce drawdown of the artesian water through extraction via bores (Ponder 1986; Dobrinski 1994; Jensen *et al*. 1998; Fairfax and Fensham 2002, 2003; Fensham and Fairfax 2003). The great majority of this water is used by the pastoral industry and more than 90 percent of that water is wasted. This fact has resulted in the formulation and partial implementation of water conservation strategies in recent years (see below for an outline of the main programs addressing this issue). Significant amongst these is the bore-capping program (Reyenga *et al*. 1998; Australia: State of the Environment Report 2001) which, although hampered due to inadequate funding, is slowly reducing wastage and enabling water pressure to be maintained approximately at equilibrium across the basin. Water conservation by the pastoral industry is essential because new developments, especially large mining ventures, are increasingly demanding a larger share of GAB water resources.

Some have argued strongly for retaining some of the artificial wetlands maintained by some bores because of their importance for birds and mammals and for tourism (see for example, Noble *et al*. 1998; James *et al*. 1999; Williams and Brake 2001). Such wetlands, with very few exceptions, are not suitable habitat for most spring endemics (Ponder 1986).

Other conservation issues relate to direct threats to individual springs. Most are on pastoral leases where they are subjected to impacts from trampling and fouling by stock and feral animals (Harris 1981, 1992; Ponder 1986; Lamb 1998a,b). Worse, landholders often modify springs to increase water flow and depth and consequently destroy the habitat of endemic biota.

Introduced animals and plants also threaten spring habitats. Mosquito fish (*Gambusia holbrooki*) are found in many springs and are no doubt impacting on the native fauna. Cane toads (*Bufo marinus*) are also found in many of the Queensland springs and are well known for their voracious and generalist appetites. Exotic plants can also dominate spring wetlands to the exclusion of native species (Fensham and Fairfax 2003).

Despite recent interest in conservation of the springs, much data are still needed to assist with their protection and management. The South Australian springs are now relatively well studied with several significant groups protected but, in contrast, the numerous springs in western Queensland remain poorly known and mostly unprotected. The New South Wales springs are, with the exception of one small group, very badly degraded or extinct (Pickard 1992), though some are now the subject of rehabilitation. While regenerating spring habitat is laudable, it will not bring back extinct endemic taxa and scarce resources should probably be focused on those springs where endemics are still surviving.

Criteria such as geomorphological, social and indigenous values are important in assessing the conservation values of a spring or spring group but an essential key

to successful conservation is the recognition of endemism. Current survey work in Queensland should provide sufficient data to rank springs on their endemics, providing a means of ensuring the best use of scarce conservation resources. While spring management should ideally focus on the whole ecosystem, it should not ignore the special needs of individual springs that contain unique endemic taxa.

In the last decade the sustainable use of GAB water has been an increasingly significant issue. However, major mining ventures (both current and projected) increasingly use large amounts of GAB water, resulting in problems with local drawdown. Such developments are generally encouraged by governments wanting to establish job-creating and export-earning industries in regional Australia, and environmental concerns in such circumstances can sometimes come a poor second.

Conservation concerns relating to the springs are now a national issue and culminated in the listing in April 2001 of the GAB discharge springs as an endangered ecological community under the Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act. Several springs are listed on the Commonwealth Register of the National Estate (Greenslade 2001) and springs in the vicinity of Lake Eyre were included in a World Heritage nomination (Reader 1985) that was unsuccessful. While several endemic snails have been listed as endangered by the IUCN (The World Conservation Union) (Ponder 1995; Hilton-Taylor 2000; Lydeard *et al*. 2004), none have been listed under commonwealth or state legislation, in part because some of the relevant legislation has, until recently, not enabled the listing of invertebrates (Hutchings and Ponder 1999). This is still the case in South Australia. Listing of at least some of the spring endemics under threatened species legislation may be a useful strategy. For example, in a report on "refugia for biological diversity in arid and semi-arid Australia" (Morton *et al*. 1995), few springs were considered and those rated poorly in conservation importance. This was largely because so few spring animals and plants were listed (or could be listed!) as threatened or endangered.

Several significant spring groups within the Lake Eyre Supergroup in South Australia are now within newly created national parks (Niejalke and Farrington 2000; Lewis 2001; Harris *et al*. 2002) and Dalhousie Springs have been included in Witjira National Park since 1985. In stark contrast, very few of the artesian springs in Queensland are protected. Many of the extant springs (probably well over 50 percent of those in Queensland) are already so highly degraded from reduced water flow, modification by land owners and stock and feral animal impacts, that any fauna they may have contained is now extinct. For Queensland springs, in particular, a serious and immediate issue is to determine the best strategies to ensure that springs known to contain endemic biota, or otherwise of high conservation significance, are prevented from undergoing further degradation.

Some Initiatives

Until recently, management of the GAB water resources was by state governments as well as state-based councils and local government, with the Commonwealth Government playing only a minor management role. In all of this, the springs hardly rated a mention, other than in South Australia from the 1980s. In the last decade there has been significant progress with a number of initiatives that have markedly enhanced the management of the GAB resource and the springs. These include:

***Mound Spring Researchers Forum*:** There have been five meetings to date, the proceedings of all but the first available on line[3]. The first four of these fora were held in South Australia and hosted by the South Australian Department for Environment and Heritage and Western Mining Corporation.

***The Great Artesian Basin Sustainability Initiative (GABSI)*:** The aim

[3]http://www.gab.org.au/srforum/srforums.html

of this initiative is to preserve the pressure of the Great Artesian Basin through rehabilitating bores and piping bore drains pipes. It is jointly funded by federal and state governments and pastoralists.

***The GAB Consultative Council* (GABCC):** The GABCC comprises representatives from government, industry and the community. It was established in 1997 and its objective is *"To manage the Great Artesian Basin, as a natural resource of national importance, in a coordinated way to optimize values of a sustainable and productive artesian groundwater resource for present and future generations."* [4] The council's website contains useful information on the GAB and it organized GAB FEST (see below). In addition to the GABCC, each of the relevant states has a GAB Advisory Committee or equivalent.

***GAB FEST*:** The inaugural symposium, *GAB FEST 2002: A resource under pressure,* was held in March 2002 in Toowoomba, Queensland, with over 180 delegates. Themes were based on the core outcomes of the Great Artesian Basin Strategic Management Plan (SMP) (water reform; environment and cultural heritage; changing attitudes; socio-economics; infrastructure renewal; and information and technology). A facilitated 'Landholder Perspectives Session' was also included to encourage discussion between landholders and other users of artesian water such as the mining industry.

This meeting provided an important forum to discuss issues relating to more economic and sustainable ways of utilizing GAB resources, to share experiences and information, to learn about new technologies for water management and to gain a better understanding of the social and economic benefits of this water resource.

The Fifth Spring Researchers Forum, hosted by Environment Australia, was held immediately prior to the meeting and issues relating to spring conservation were included in GAB FEST.

[4]http://www.gab.org.au/about/about.html

***Federal listing of the discharge springs*:** The listing in April 2001of the GAB discharge springs as an endangered ecological community[5] under the EPBC Act[6] has brought with it a potential degree of protection from the actions of landowners that has, unfortunately, yet to be realized. This is partly because the state-based conservation agencies are operating under their own state's threatened species legislation. Neither of the relevant state acts have been adjusted to comply with the provisions of the EPBC Act. In most circumstances, it is the state legislation that must be used because the commonwealth does not have jurisdiction other than in a few specific cases. There are also separate federal and state lists of threatened species (or communities) requiring separate nomination procedures with few existing reciprocal listing provisions.

***Catchment and regional authorities*:** There has been a move in recent years to move towards management at a catchment or regional basis. This has been in part driven by the recognition that catchment-based management is a better model than management based on political boundaries, such as counties or states. The current Commonwealth Government has recognized this and the significant funding for environmental projects, through the National Heritage Trust (NHT), is largely assigned through regional (mainly based on catchments) councils. Unfortunately, a result of this change is that funding for any overall work on the GAB springs will be more difficult to obtain as, especially on the eastern edge of the basin, they lie within a number of different catchment authorities.

Discussion

The recognition of the exceptional natural value of springs in xeric basins has been slow in coming. They are of great cultural value to indigenous people and very significant in the early history of European colonization and settlement. From the

[5]http://www.ea.gov.au/biodiversity/threatened/communities/gabsprings.html
[6]http://www.ea.gov.au/epbc/about/index.html

biological point of view they not only contain unique animals and plants, many of which are relictual, but their ecological communities are also unique. They are wonderful natural laboratories for evolutionary (e.g., Colgan and Ponder 2000) and ecological (e.g., Tyre *et al*. 2001a) studies. They are of great interest to hydrologists and are unusual and sometimes unique land forms. Their values are now slowly being appreciated by the wider community and, in those cases where they have been salvaged in conservation areas, the springs attract considerable interest from tourists.

State-based management of a multistate resource was the situation in Australia until a few years ago, largely parallelling the current situation in western USA. It was only when the GAB could be managed as a whole that basin-wide initiatives were considered seriously and implemented. The same mistakes have been made in Australia as in the USA, even to holding nuclear tests in an area adjacent to the basin. In both countries, over-usage of water and the lack of appreciation of spring values, until recently, have caused the extinction or degradation of many springs, resulting in the extinction of endemic taxa.

In Australia, there is, nonetheless, some welcome progress. Recognition of the value of conserving springs and their endemic biota is now an issue at both the state and federal levels, culminating in the listing of the GAB discharge springs by the Commonwealth. However, other than in South Australia, significant conservation action has yet to occur, and even there, a number of important springs remain unprotected. Data from surveys of fishes and vascular plants, together with information from the current aquatic invertebrate survey, can be used to prioritize springs on their levels of endemism. However, the overall conservation value of each spring must also take into account cultural, historical, tourism and geological values.

There is an imminent threat of the flooding of a substantial number of recharge springs (bogomosses) in the Dawson River Valley (Ingram and Stanisic 1997; Fensham 1998) by the proposed construction of a dam. Associated with these springs are two terrestrial snail endemics and rare plants. They have not yet been surveyed for aquatic invertebrates.

Public education has improved, with information in the public domain in print, on the web and museum exhibits. The Australian Museum, for example, has a working model of a mound spring in its biodiversity gallery.

Are there lessons from the Australian experience for the USA? The principal one is that there is a need to manage these systems as complete entities. Fragmented decision making by isolated bodies, whether they be state and/or agency-based, is clearly detrimental to successful long-term management outcomes. The Australian model also includes representatives from significant stakeholder groups in management so there is general ownership of the outcomes. Sustainable use of artesian water is in everyone's interest, being good for the springs and for the users of the water.

The springs can be sold nationally as systems of great importance through raising the awareness of the public, politicians, as well as the scientific community. Such education can use icons such as endemic fishes, as has already been done in the USA, but should also focus heavily on the overall levels of endemism and the unique nature of the spring ecosystems.

From what appears to be known about artesian spring ecosystems in the western USA, there is an urgent need for broad-scale research, especially given the unsustainable utilization of the ground water that feeds them. For example, to date, there is no overview of spring systems associated with the Great Basin. Nor is there a broad-scale attempt to provide an inventory of the spring biota that might enable a more effective prioritization of springs that can be used in directing management efforts (Sada and Pohlmann 2004, this volume).

Conservation can be pushed by different sectors of the community for different

reasons. In Australia, the first serious cry for GAB spring conservation was from South Australia and in large part because of their importance in Aboriginal and European history (Harris 1981). These actions were mainly precipitated by concern over the development of the Olympic Dam copper and uranium mine in the early 1980s. This mine requires major water extraction from the GAB with identified drawdown impacting on nearby GAB springs. The antinuclear lobby adopted spring conservation as an issue as part of their protest and gave it a profile that it may not have otherwise achieved so quickly. At the same time the mining company (Western Mining Corporation), with a little pressure from the South Australian Government, recognized the need for more information on the springs so that it could come up with a better management strategy. This resulted in financial support for spring studies that enabled a great deal of work to be done. Some experimental and ecological studies have led to the development of management strategies (e.g., Fatchen 1998, 2000a,b; Graham 1998; Lamb 1998a; Lamb *et al*. 2001; Niejalke and Richards 1998; Tyre *et al*. 2001a-c) and the development of monitoring techniques involving remote sensing (Niejalke *et al*. 2001). All of these studies were carried out in the Lake Eyre Supergroup springs and while probably relevant, at least in general terms, to those in the rest of the GAB (or elsewhere), this has yet to be tested.

Land-rights issues relating to the springs have mainly surfaced in South Australia, in large part centered on the drawdown resulting from the Olympic Dam mine and were strongly encouraged by the antinuclear lobby. Springs are typically very important to indigenous peoples and their support can greatly assist in their conservation.

By the early 1990s, the GAB springs were starting to appear on the national conservation agenda with, for example, mound springs being mentioned in a Commonwealth Government publication as one of the selected significant components of Australia's biodiversity (Biodiversity Unit 1994) and this has culminated in their listing under the EPBC Act (see above). However, the recognition of the urgent need to protect these highly significant ecosystems has come far too late for many of the springs but just in time to enable the conservation of some of the most significant. Of the remaining springs, as far as we know, only a small proportion of the surviving springs have endemic biota. These must be managed and conserved as a matter of urgency if they are to survive at all.

While the scenario of "too little and too late" is unfortunately true for many of the GAB springs, the situation with spring conservation in xeric basins in some other parts of the world is even worse, with little or no hope of sustainable water use in sight, no plans for regional spring studies and nothing but *ad hoc* strategies for their conservation. Where conservation actions are not backed by appropriate legislation, international agreements such as RAMSAR[7] (Convention on Wetlands) enable these wetlands to be listed, but few actually are. Whatever the mechanisms used to facilitate the protection and conservation of these remarkable habitats, it is clear that action must occur now if even a small subset is to be saved for future generations.

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[7] http://www.ramsar.org/

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