The Distribution of the Endangered Fish Edgbaston Goby, *Chlamydogobius squamigenus*, and Recommendations for Management

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Abstract

Surveys conducted in bore drains in the Aramac district of central-western Queensland found that species of both plants and animals endemic to Great Artesian Basin springs are capable of colonising and surviving in these artificial environments. In particular, the discovery of an endangered fish, Edgbaston goby (*Chlamydogobius squamigenus*) in bore drains approximately 20 km from its native natural spring habitat suggests that spring-dependent species are likely to seek new habitats when migration pathways are open during flooding. Managing the declining populations of spring endemics, such as Edgbaston goby, could occur through maintaining populations in artificial springs or wetlands where the invasive eastern gambusia (*Gambusia holbrooki*), which is thought to competitively exclude small native fishes, can either be excluded or removed.

Keywords: Edgbaston goby, bore drains, endangered species, Edgbaston springs, Great Artesian Basin springs

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Introduction

Great Artesian Basin (GAB) springs are considered the most ecologically important inland waters in Australia and provide habitat for a number of endemic species from diverse plant and animal groups (Fensham et al., 2011). Great Artesian Basin springs are generally concentrated around the margins of the Basin, and examples include the Mulligan supergroup on the eastern edge of the Simpson Desert in Queensland, and the Dalhousie supergroup in northern South Australia. Although many GAB spring complexes can be considered compromised due to extended exploitation and concomitant destruction due to their use as water points for grazing, the springs at Edgbaston, located in the Barcaldine supergroup in central-western Queensland, are an exception. Comprising approximately 100 individual spring vents, Edgbaston is the most diverse spring complex in the GAB and was purchased in 2008 by the conservation not-for-profit Bush Heritage Australia.

Since 2009, the endangered fish species red-finned blue-eye (*Scaturiginichthys vermelipinnis*) has commanded the majority of attention at Edgbaston due to its heightened extinction risk (Kerezsy & Fensham, 2013; Radford et al., 2018). Although this has resulted in a better survival outlook for this species, work on the other endemic fish, Edgbaston goby (*Chlamydogobius squamigenus*) has generally not occurred – and certainly not to the same degree – until recently. Similarly, general work on the presence/absence of invertebrates, though ongoing for some time (Ponder et al., 2010), has only recently considered ecological themes (Rossini et al., 2017).

Gobies are a widespread and speciose fish family worldwide, but comparatively few species are native to Australia, and even fewer live in the arid and semi-arid interior of the country. Indeed, the only gobies known from the Lake Eyre Basin are the Edgbaston goby and its related species at the Elizabeth springs complex (Springvale supergroup) in the Diamantina catchment in western Queensland (*Chlamydogobius micropterus*), at Dalhousie springs in northern South Australia (*Chlamydogobius dalhousiensis*), in the Finke River in the Northern Territory (*Chlamydogobius japalpa*),

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and in the southern Lake Eyre Basin (*Chlamydogobius eremius*), as well as the larger species golden goby (*Glossogobius aureus*), which is known from riverine sites in the Mulligan, Georgina and Diamantina catchments in far-western Queensland (Wager & Unmack, 2000; Kerezsy et al., 2013; Kerezsy, 2017).

Speciation within the *Chlamydogobius* genus is likely to be a result of isolation due to Australia's drying climate over a long time period: as permanent water in the arid zone became scarcer, the gobies were probably forced to retreat to spring complexes (at Edgbaston, Elizabeth springs and Dalhousie) and isolated water sources in the Finke and southern Lake Eyre regions. These small 'desert' gobies possess adaptations that enable them to live in oxygen-poor and shallow water, such as a pharyngeal organ that extracts oxygen from the air (Thompson & Withers, 2002). They also exhibit parental care of their young, as the male guards and fans (or aerates) clutches of fertilised eggs until they hatch (Allen et al., 2002).

Edgbaston goby is a benthic species that grows to a maximum length of 5–6 cm (Allen et al., 2002). The species is listed as endangered under the *Nature Conservation Act 1992* (Parliament of Queensland, 1992), vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Parliament of Australia, 1999) and critically endangered by the IUCN (Kerezsy et al., 2019). Populations of Edgbaston goby were found in eight springs at Edgbaston in 1994 (Wager, 1994), and at nine in 2009 (Kerezsy, 2009). A population previously recorded from a bore drain at Crossmoor Station can be considered extinct, as this bore has been capped (Russell Fairfax, pers. comm.). Populations of Edgbaston goby have also been recorded in a spring environment at Myross (which adjoins Edgbaston; Rod Fensham, pers. comm.). It is important to note that as Edgbaston goby is a bottom-dwelling species, the term 'population' may only refer to a small number of individuals (<50) that live in small colonies in isolated springs.

This paper presents the results from biological surveys of bore drains and springs in the Aramac district conducted in mid-2014. The objectives were to more accurately establish the current distribution of Edgbaston goby, to audit extant aquatic fauna and flora, and to inform future management of this endangered species and other spring endemics. Bore drains were included in the surveys as they are similar to springs and represent areas of permanent water in an otherwise arid environment. In many cases they have been present within the GAB landscape for over 100 years, and it was considered possible that spring endemics (such as the Edgbaston goby) may have colonised such habitats during periods of flooding (for example 1974–1975 and 2010–2011). The paper concludes with discussions of the future management of Edgbaston goby and other spring endemics, and the role that bore drains could possibly play in sustaining populations of range-limited threatened species and communities.

Materials and Methods

Study Area

Bore drains were identified and a list of properties and landowners was provided by the natural resource management group Desert Channels Queensland. Landowners were contacted in order to arrange a convenient time for the surveys to be conducted. Surveys were undertaken on a total of 10 properties in the Aramac district including Glenaras, Acacia Downs, Merino Downs, Stainburn Downs, Ravenswood, Stagmount, Myross, Pendine, Hathaway and Edgbaston. Multiple sites were chosen on properties where more than one drain or spring was present (such as Stagmount, Ravenswood, Myross and Edgbaston).

During an earlier fish survey at Edgbaston, over 90 springs were sampled (Kerezsy, 2009), and more springs have been found in the interim (A. Kerezsy, R. Rossini, R. Fensham, P. Kern, pers. ob.). However, approximately half of the known spring vents at Edgbaston do not discharge enough water to provide habitat for fish, and these were omitted from the current survey. Springs/sites used during the Edgbaston survey included all springs where fish (of any species) have been recorded previously (Wager, 1994; Fairfax et al., 2007; Kerezsy, 2009), as well as shallow springs (<2 cm deep) that could be considered potential habitat for Edgbaston goby. Fifty-four springs were sampled at Edgbaston during the survey. Surveys took place from 14–24 August 2014.

Physical Characteristics and Water Quality

At each site, a snapshot of environmental conditions was made by recording physical characteristics such as the depth, width and length of each drain and spring (where possible), as well as the soil type and surrounding terrestrial vegetation. Similarly, a singular recording of water quality parameters such as pH, electrical conductivity (a surrogate for salinity), dissolved oxygen and temperature was made using a Eutech multimeter at each site, and turbidity was measured using a Secchi disc. Although all bores were sampled along their drains – the section that meanders through the landscape – additional water quality readings were taken in some instances (Glenaras, Acacia Downs and Ravenswood) at or close to the bore 'heads' (i.e. the location of the bores, and where the water first enters the above-ground landscape).

Biological Sampling

A combination of methods was used in order to maximise the chances of sampling the greatest diversity of biota; however, in the shallow spring environments active searching was the only viable method, as the depth of each spring rarely exceeded 5 cm. Active searching – slowly walking through the spring and recording observations – was undertaken at each site for a minimum period of 30 minutes in order to identify plants and any animals that were easily observed (such as red-finned blue-eye, Edgbaston goby, the alien fish eastern gambusia (*Gambusia holbrooki*), yabbies (*Cherax destructor*), and cane toads (*Rhinella marina*)). Fish and invertebrates were sampled by random dip-netting for the same time period using a 250 μm mesh net, and included both longitudinal and transverse netting of each bore-drain channel. Where depth allowed, cylindrical plastic bait traps (30 cm long and 10 cm in diameter with a 2 cm entry hole) were baited with dog food and set for 2 hours. In deeper water, mesh bait traps (40 cm × 20 cm with a 3 cm entry hole made from 2 mm mesh) were also used. At Ravenswood and Edgbaston, spotlighting was used as a follow-up method to confirm the presence of Edgbaston goby. At Edgbaston, plant and invertebrate sampling was omitted due to the number of sites (54), the diversity of species, and the existing literature pertaining to the diversity of these groups (Ponder et al., 2010; Fensham et al., 2011; Rossini et al., 2017).

All invertebrate and fish sampling was carried out under General Fisheries Permits issued by the Queensland Department of Primary Industries (89212 and 166743) and an animal ethics agreement (CA2010/02/415). Any sampled native fish were returned to the water at the point of capture, and any alien fish that were collected (as opposed to observed) were euthanised using approved techniques.

Results

Physical Characteristics and Water Quality

The majority of the sampled bore drains (those on Glenaras, Acacia Downs, Merino Downs, Stainburn Downs, Pendine, Hathaway and Myross 1) were very similar: long, meandering channels in black, cracking clays that were generally between 10 and 100 cm wide and less than 15 cm deep. As an example, the drain at Merino Downs was 8 km long but less than 1 m wide (Figure 1). In general, the drains have been configured with a view to watering more than one paddock: at Glenaras, four drains flow in different directions from the bore head, whereas at Stainburn Downs 'tributary' channels run at right angles to the main channel. The dominant terrestrial vegetation at the sites mentioned above was Mitchell grass (*Astrebla* spp.) with an overstorey of mimosa (*Acacia farnesiana*).

Figure 1. The drain at Merino Downs north of Aramac is a typical example of the majority of bore drains in the district.

The bore drains at Ravenswood differed from the main group, as they occurred in sandy country and, rather than running for many kilometres, they terminate in wetlands. Similarly, at Stagmount 1 (Figure 2), the head of the bore drained straight to an extensive wetland (approximately 2 km long and up to 100 m wide) before reverting to the more typical drains discussed above. At Stagmount 2, the drain ran through a canopy of black gidgee (*Acacia argyrodendron*). At Myross 2, the spring drain (which was generally wider than 1 m) originated in a large spring (approximately 100 × 30 m and up to 1.5 m deep), where the surrounding vegetation is comprised of spinifex and *Melaleuca*: this vegetation is typical of springs in the area, as is the surrounding rock (travertine).

Water quality parameters at all sites fell within expected ranges for water from the GAB in central western Queensland, with neutral to alkaline pH values (7.09–8.80) and slightly salty conductivity readings (381–1085 μS/cm; Table 1). Dissolved oxygen (0.91–8.09 mg/L) and temperature (10.5–58.1°C) were far more variable (as expected) depending on proximity to the bore head and time of day. In general, drains reverted to ambient temperatures after a distance of approximately two kilometres from the bore head. The bore with the highest temperature was at Acacia Downs, and the bore with the lowest temperature was at Ravenswood (Table 1).

At Edgbaston, water quality parameters fell within expected ranges at all sites (Appendix 1). Temperature varied according to the time of day each spring was sampled: water temperatures higher than 30°C were recorded between 11 am and 4 pm, whereas lower water temperatures were recorded at sites sampled in the mornings and afternoons (Appendix 1). Dissolved oxygen varied according to distance from the spring vent: low dissolved oxygen (<1 mg/L) was recorded close to spring vents, whereas high dissolved oxygen was recorded in the larger pooled areas (Appendix 1).

Figure 2. The bore drain at Stagmount, showing a much larger diversity of aquatic vegetation (which included spring endemics). Drains at both Stagmount and Ravenswood were notable for this increased diversity.

Table 1. Water quality at bore drains in the Aramac district in August 2014. G = Glenaras, AD = Acacia Downs, MD = Merino Downs, SB = Stainburn Downs, R = Ravenswood, S = Stagmount, P = Pendine, H = Hathaway, and M = Myross. All readings (and samples) were taken from the tails of bore drains unless stipulated.

Site	pH	Conductivity (μS/cm)	DO (mg/L)	DO (% saturation)	Temperature (°C)	Turbidity (cm)
G	8.28	1075	3.04	41.9	34	Clear
G head	7.79	804	0.91	12.8	47.7	Clear
AD	7.82	1085	8.09	75.4	10.5	3
AD 100 m from head	8.6	1034	5.65	73	45.1	Clear
AD head	7.75	1064	1.43	26.2	58.1	Clear
MD	8.09	710	6.04	68.7	16.7	5
SB 1	6.91	451	7.65	71.4	10.5	5
SB 2	7.2	701	1.8	18	12.3	3
SB 3	7.16	941	7.38	77.3	15.6	4
R	8.8	398	6.03	80.5	29.2	Clear
R head pool	7.39	381	3.3	47.3	32.8	Clear
R head	7.44	382	1.49	20.1	32.7	Clear
S1	7.38	609	2.8	34.2	30.3	Clear
S2 head	7.09	687	2.37	32.6	43.1	Clear
P	7.95	542	5.2	57.3	16.8	6
H	7.39	543	2.48	33.1	26.3	5
M	7.42	483	7.73	96	25.7	4

Biological Survey Results

Across all 17 sites (excluding Edgbaston), biota sampled in mid-2014 included five species of fish, two crustaceans (yabbies and shrimp), various insects and both generic aquatic plants (i.e. species that could be expected to occur in inland Australian waters), and endemic plant species only known from Great Artesian Basin springs (Table 2).

Gambusia was the most commonly collected fish species and was found at all sites (Table 2).

Outside Edgbaston, the endangered Edgbaston goby was found at Myross 2 (which was expected, given this is a spring drain very close to Edgbaston, where the species is widespread) and, unexpectedly, in a bore drain at Ravenswood (Table 2; Figure 3). This represents a significant range extension for this species. The site at Ravenswood is approximately 20 km south of the closest Edgbaston/Myross population, and it is speculated that gobies from Edgbaston/Myross likely migrated to Ravenswood during overland flooding (Figure 3). Spangled perch, *Leiopotherapon unicolor*, is a colonising species and has been found in remote desert environments following sporadic rainfall (Kerezsy et al., 2013), so the presence of this species at two sites, Myross 2 and Ravenswood, during this survey is unremarkable. Other landholders also mentioned seeing this species in their drains at various times (C. Dyer, Stainburn Downs and P. McAuliffe, Stagmount, pers. comms). Finally, two riverine species, desert rainbowfish (*Melanotaenia splendida tatei*) and glassfish (*Ambassis* sp.), were also recorded at Myross 2. It seems most likely that these species colonised Myross 2 from the nearby (and ephemeral) Pelican Creek during a flood or wet period (Table 2). Although a species of hardyhead (*Craterocephalus* sp.) has previously been recorded at Myross 2, none were collected on this occasion.

The survey results suggest that a variety of native crustaceans and insects utilise the bore drains in the Aramac district (Table 2); however, it is notable that the vast majority (for example yabbies, shrimp, dragonfly nymphs and corixids) are either capable aquatic colonisers or flying insects that utilise available water for breeding and when immature. Undoubtedly, the low detection rate for cane toads during the survey was a function of the time of year (14–24 August 2014), as most landholders commented that during warmer months cane toads were common in their bore drains.

Common aquatic plants such as *Azolla* and/or *Cyperus*, *Nardoo*, *Monochoria*, *Typha* and *Phragmites* were present throughout the sites, and the terrestrial weed Noogoora Burr (*Xanthium occidentale*) was present on both Stainburn and Merino Downs (Table 2). Stands of *Typha* and *Phragmites* were most common (and densest) at Stagmount 1 and Ravenswood (Figure 3). Spring vegetation, such as *Myriophyllum artesium* and *Eriocaulon carsonii*, was found (as expected) at Myross 2. However, both species were also found at Stagmount 1, and *M. artesium* was also found at Ravenswood (Table 2). These populations are significant, as they demonstrate that plant species endemic to springs may also colonise artificial waters.

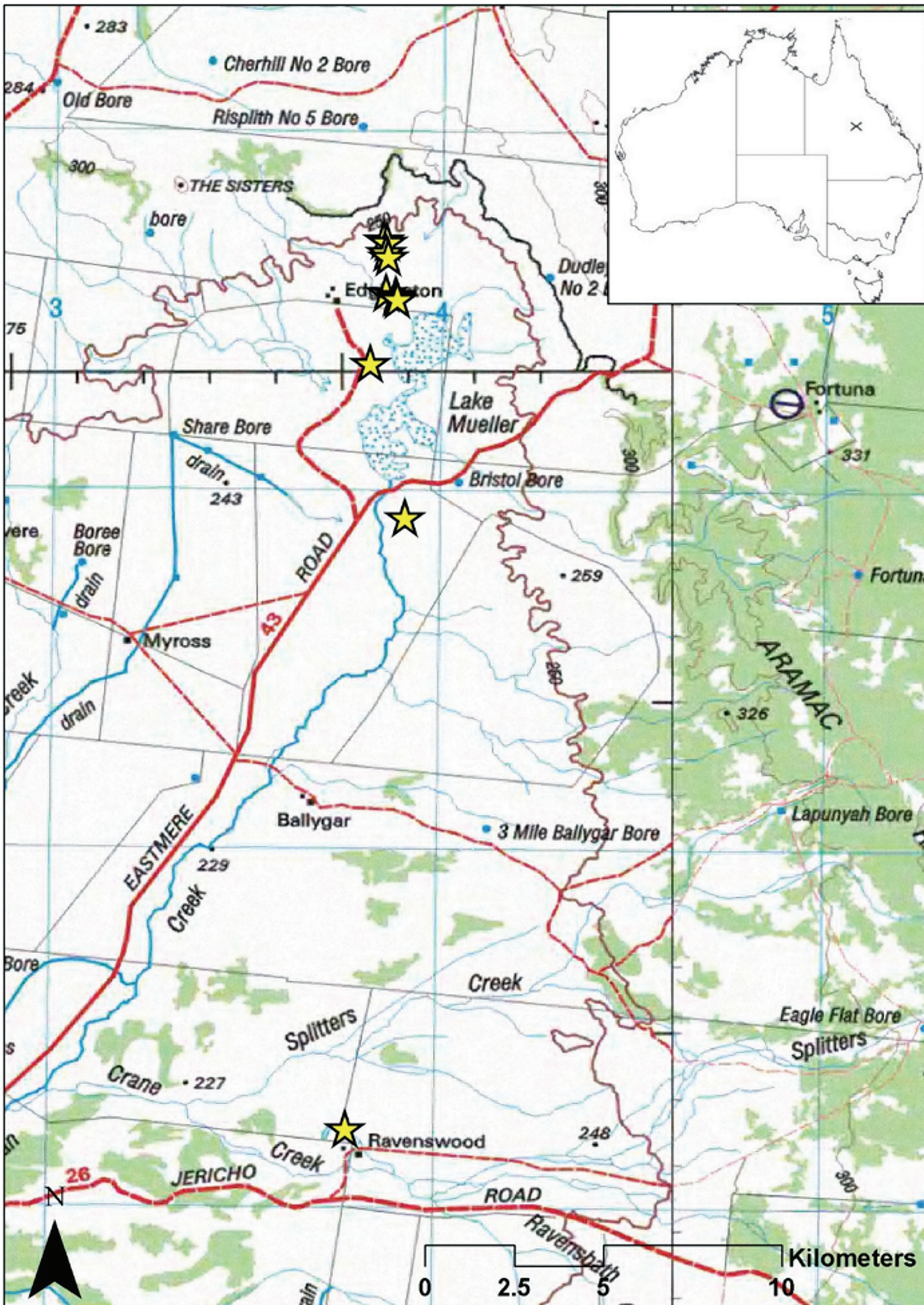
At Edgbaston, fish were found in 39 of the 54 sampled springs in mid-2014. Gambusia was the most widespread fish and occurred in all spring groups (NW, E, SE, SWN, SW, NE; see Kerezsy & Fensham, 2013 for further explanation) and in a total of 28 springs (Appendix 2). Red-finned blue-eye was recorded from nine springs in the NW and E spring groups, comprising natural and relocated populations (Appendix 2; Kerezsy & Fensham, 2013). Edgbaston goby was recorded from nine springs in the NW and E spring groups (Appendix 2). At three springs Edgbaston goby was the only fish present, and at a further three springs Edgbaston goby co-occurred with red-finned blue-eye (Appendix 2). Edgbaston goby co-occurred with both red-finned blue-eye and gambusia at two springs (Appendix 2).

Table 2. Aquatic biota sampled in bore drains and one spring drain in the Aramac district in August 2014. G = Glenaras, AD = Acacia Downs, MD = Merino Downs, SB = Stainburn Downs, R = Ravenswood, S = Stagmount, P = Pendine, H = Hathaway and M = Myross.

	G	AD	MD	SD1	SD2	SD3	R1	R2	S1	S2	P	H	M1	M2
Fish														
Gambusia*														
Edgbaston goby**														
Spangled perch														
Glassfish														
Rainbowfish														
Crustaceans														
Shrimp (Atyidae)														
Yabby														
Insects														
Dragonfly larvae														
Damselfly larvae														
Beetles														
Corixids														
Other fauna														
Cane toad*														
Plants														
General aquatic														
Spring endemic**														

Note that the Myross 2 site is a spring drain (as opposed to a bore drain), *alien species, **endangered species/ecological community.

Figure 3. The current distribution of Edgbaston goby (indicated by yellow stars) includes the cluster of populations in and around springs at Edgbaston, and the newly discovered Ravenswood population approximately 20 km south (map courtesy of J. Silcock).



Discussion

The 'rediscovery' of populations of endangered species is not a common occurrence. Undoubtedly the most high-profile and controversial instance of this occurring in recent Australian history pertains to the night parrot (*Pezoporus occidentalis*) in Australia's arid inland (Ohlsen et al., 2016). Although the range extension for the endangered Edgbaston goby revealed by this study is easily explained by the geographic proximity of the 'new' population at Ravenswood to the likely source populations at Edgbaston and Myross, the result is important for two reasons. First, the Ravenswood population does not occur in a GAB spring, but in a bore drain; and second, the existence of the Ravenswood population demonstrates that this species can – at least under certain circumstances – survive (as a viable population) despite the presence of gambusia. These observations suggest that Edgbaston goby may be a hardy species (especially compared with red-finned blue-eye) and that management of such an endangered species could involve a suite of unconventional methods, such as retaining populations in artificial environments that utilise GAB water but otherwise are physically different from GAB springs.

All artificial water points in central-western Queensland are the result of Anglo-European colonisation. As bore drains often provide permanent water in an otherwise arid environment, they have undoubtedly altered the local and regional ecosystems in which they occur (Fensham & Fairfax, 2008). Although the bores and their drains have provided water to support stock grazing and to sustain isolated communities and homesteads, their presence – in essence the fact that they provide a reliable water supply – has also facilitated an expansion in native macropod numbers as well as similar increases in introduced herbivores (such as goats and camels), omnivores (pigs), and both native and introduced carnivores (dingoes, dogs, cats and foxes; James et al., 1999). The Great Artesian Basin Sustainability Initiative (GABSI) has been effective in reversing some of these negative impacts, and through capping and piping bores has conserved water, restored groundwater pressure and reduced the number of artificial water points. Nevertheless, the current survey provides evidence that these artificial environments also have the potential to support aquatic biota previously thought to be endemic spring specialists. Additional surveys of bore drains throughout the GAB could reveal further sites of significance for the conservation of spring biota.

At local scales (within individual bores and their drains), it is also possible to discern successional trends, and these patterns of colonisation are obviously related to the proximity of bore drains to source populations of aquatic biota. In 'basic' bore drains that were somewhat isolated from springs, such as those on Merino Downs and Stainburn Downs, the colonising biota could be described as 'generalist' or 'ubiquitous'. For example, the insects were all corixids, there were shrimp and yabbies, the fish were (all) gambusia, and there had been colonisation by general aquatic vegetation. However, bore drains closer to springs, such as Ravenswood and Stagmount, also included endemic spring vegetation, a greater diversity of invertebrates and – at Ravenswood – Edgbaston goby. These results suggest that maintaining populations of spring endemics is certainly possible in artificial/created wetlands that utilise water from the GAB, and given the endangered status of these communities (and many of the species within them) this may be a sensible management option.

Conserving endangered species in managed habitats – particularly in arid areas – is developing into a viable conservation tool. In South Australia, the populations of at least two genera of native rodents increased following the completion of a predator-proof fence at the Arid Recovery site near Roxby Downs (Moseby et al., 2009). In North America, translocation has been advocated and practised for far longer, and this has included Cyprinodontid spring fishes (i.e. pupfishes) that face similar challenges to Australia's spring endemics (Minckley, 1995; Keepers et al., 2018). There is certainly a precedent for actively managing the population of Edgbaston goby in 'safe' habitats (such as predator/competition-free springs), as the relocation of red-finned blue-eye has been mostly successful in the same area (Kerezsy & Fensham, 2013; Appendix 2). Creating artificial spring environments appears to be slightly more difficult, or at least subject to more challenges (Karam et al., 2012); however, the creation of 'artificial' springs on-site at Edgbaston in order to conserve the red-finned blue-eye is a local example that appears to be achieving early success (P. Kern, pers. comm.).

Unfortunately, the great majority of bore drains in central-western Queensland (and all of the drains sampled during this study) have been colonised by gambusia, thus rendering them unsuitable for the recovery of endangered native fish. The impacts of gambusia on other small-bodied fish include egg predation, direct competition for resources, and territorial behaviour (Howe et al., 1997; Ivantsoff & Aarn, 1999), while their life history advantages include giving birth to live young, as well as tolerance of high temperatures and poor water quality (Pyke, 2008). Springs and bore drains in central Australia – again unfortunately – provide perfect habitat for this adaptable invasive species, so creating areas that are (and can be kept) free from gambusia should be a priority for the conservation of endemic fishes from GAB springs (Kerezsy & Fensham, 2013). Ongoing monitoring of the Ravenswood population of Edgbaston goby, as well as the populations at Edgbaston that currently co-habit with gambusia, is also necessary in order to better ascertain the linkage (if there is one) between gambusia presence/abundance and Edgbaston goby decline. Additionally, given that there is already low genetic diversity within extant populations of Edgbaston goby (Faulks et al., 2016) and that the Ravenswood population is not genetically distinct from those at Edgbaston (P. Unmack, pers. comm.), preservation of the species could be well served by the establishment of 'insurance' populations in artificial springs and wetlands that are inaccessible to gambusia.

The discovery of a previously unknown population of an endangered species such as Edgbaston goby should provide valuable lessons to those charged with managing Australia's endangered species. It demonstrates, firstly, that effort must be directed towards accurately establishing the distribution of such species, and that this can only be achieved through surveys of likely habitats. Similarly, effort must be directed towards identifying and mapping habitat areas that may be suitable for maintaining populations of endangered species, even if these areas have artificial origins, such as bore drains. Last, this survey demonstrates that endangered species, despite being disadvantaged by small populations, limited suitable habitats and the imposition of invasive species, are sometimes capable of persisting in less-than-perfect circumstances. To enable such species to endure, and to improve these circumstances as much as possible, should therefore be the aim of all endangered species programs and recovery plans.

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Author Profile

Adam Kerezsy is an aquatic ecologist who works in the rivers and springs of inland and central Australia. He is the author of many scientific publications and the natural history book *Desert Fishing Lessons: Adventures in Australia's Rivers* (UWA Publishing, 2011).

Appendix 1

Water quality parameters recorded from all springs sampled at Edgbaston in October 2014

Spring	pH	Conductivity (μS/cm)	Dissolved oxygen (% saturation)	Dissolved oxygen (mg/L)	Temperature (°C)
NW30	8.22	457.4	43.2	2.95	27.5
NW70	7.70	801.7	14	1.23	27.2
NW80	7.90	878.1	17.8	1.48	26.9
NW90n	7.66	911.2	48.9	3.5	29.5
NW90s	8.01	856.1	75.5	4.64	28.7
NW72	7.93	982.8	56.7	4.28	24.1
E502	7.93	845.8	60.1	4.54	29.9
NW40	8.07	785.8	24.8	1.31	27.3
NW50	8.85	826.6	70.6	5.27	27.1
NW60	8.11	1024	87.5	6.69	27.5
NW20	7.95	927.2	45.2	3.70	27.9
NW10	8.59	925.4	74.7	5.29	28.5
NW100	8.49	904.7	66.1	4.41	33
E501	8.6	700	90.9	6.23	32.6
E524	9.2	698.5	88.2	6.89	32.2
E505	8.17	1164	72.3	6.13	34.2
Smithy's	8.95	1060	82.3	5.42	34.7
E504	8.48	846.2	47.5	3.41	31.6
New Big	7.84	860.7	65.8	4.48	29.5
E518	9.08	966.6	102.4	7.34	33.2
E515	9.44	1107	78.3	5.31	35
E508	8.14	655.3	43.6	3.22	32.7
E509	9.5	827.2	83.9	5.61	30.4
E1	8.68	896.4	71.4	4.58	32.5
Fence	8.49	655.4	54.5	3.39	30.5
2011#1	8.4	884.8	73.3	5.05	31.9
2011#2	9.89	1172	120.4	9.05	32.2
NE95	7.53	795.7	13.4	1.29	22.1
NE75	8.07	804.3	27.2	1.3	21.6
NE72	8.05	875.4	13	1.12	22.5
NE08	8.32	646.9	28.7	1.05	28.9
NE07	8.45	1538	10.1	0.9	22.5
NE10	8.82	957.6	41.8	2.6	22.1
NE01	8.19	1373	29.8	2.45	22.5
NE03	8.19	1218	26.3	1.91	25.1
NE20	7.79	795.5	7.4	0.74	27.3
NE30	7.85	881.2	68	4.95	31.9
NE40	7.76	769.6	11.5	0.96	26.8
NE50	8.19	958.1	78.2	5.93	31.3
NE60	8.29	887.8	59.7	4.67	30.7
SWN10	9.4	941.5	81.3	5.99	32.3
SWN20	10.10	1225	149.2	10.73	34.4
SWN30	8.08	880.9	97	6.74	32.8
SW40	8.65	1686	18.7	0.51	36.1
SW42	9.34	742.1	81.1	5.67	32
SW50	9.52	977.6	72.5	5.00	30.3
SW65	8.94	640.3	85.6	5.94	33.9
SW60	8.57	552.4	76.5	4.09	31.9
SW70	9.6	579.6	68.2	4.81	30.2
E523	8.09	699	41.8	3.28	27.8

Appendix 2

Fish presence/absence at 54 springs at Edgbaston in October 2014. Filled areas indicate the species was present at the site. Relocation establishment dates are given for relocated red-finned blue-eye populations and are explained in more detail in Kerezsy & Fensham (2013).

Spring	Edgbaston goby	Red-finned blue-eye	Gambusia
NW30			
NW70			
NW80		Relocated 2014	
NW90n			
NW90s			
NW72		Relocated 2009	
NW40			
NW50			
NW60			
NW10			
NW20			
NW100			
E502			
E501		Relocated 2009 and 2011	
E524		Relocated 2011	
E505			
Smithy's			
E504		Relocated 2012	
New Big			
E518		Relocated 2011	
E515			
E508			
E509		Relocated 2012	
E1			
Fence			
2011#1			
2011#2			
E523			
SWN10			
SWN20			
SWN30			
SW40			
SW42			
SW50			
SW60			
SW65			
SW70			
SE40			
SE50			
SE60			
SE10			
NE95			
NE75			
NE72			
NE08			
NE07			
NE10			
NE01			
NE03			
NE20			
NE30			
NE40			
NE50			
NE60			