Government of South Australia
South Australian Arid Lands Natural Resources Management Board

October 2009

South Australian Arid Lands Natural Resources Management Board

Gambusia control in spring wetlands

Adam Kerezsy

GAMBUSIA CONTROL IN SPRING WETLANDS

Final report, October 2009

Adam Kerezsy

Aquatic Ecologist, Bush Heritage Australia

Table of Contents

Background

The property 'Edgbaston' in western Queensland was purchased in 2008 by Bush Heritage Australia. The property includes a system of artesian springs that provide habitat for two critically endangered (IUCN) fish species, the red-finned blue-eye, *Scaturiginichthys vermeilipinnis*, and the Edgbaston goby, *Chlamydogobius squamigenus* as well as a variety of endemic plants and invertebrates (Table 1). Management of the property in order to conserve endemic fish and other species within the springs is a primary goal of Bush Heritage Australia (Bush Heritage Australia 2008), and this goal is also supported by the regional natural resource management agency for the Queensland Lake Eyre Basin, Desert Channels Queensland (Steve Wilson, Desert Channels Queensland, pers. comm.) and by the Queensland Department of Environment and Resource Management (Rod Fensham, Russell Fairfax, pers. comms.). Currently, many of the springs are also inhabited by the noxious invasive fish species gambusia, *Gambusia holbrooki*. Vertebrate pests such as feral pigs, goats and domestic stock are also present at Edgbaston, as are introduced plants such as prickly acacia, *Acacia nilotica*, and parkinsonia, *Parkinsonia aculeata*.

Table 1. Endemic species from Edgbaston and their current conservation status (Source: Bush Heritage Australia 2008).

Species	Conservation Status
Red-finned blue-eye (*Scaturiginichthys vermeilipinnis*)	Critically Endangered (IUCN); Endangered (EPBC 1999); Endangered (NCA).
Edgbaston Goby (*Chlamydogobius squamigenus*)	Critically Endangered (IUCN); Vulnerable (EPBC 1999); Endangered (as *Chlamydogobius* sp.B) (NCA)
Nine species of hydrobiid snail known only from the Edgbaston springs (R.J. Fensham pers. comm.);	Unclassified/Not available
One Ostrocod known only from the Edgbaston springs (R.J. Fensham pers.	Unclassified/Not available

comm.);	
One Flatworm known only from the Edgbaston springs (R.J. Fensham pers. comm.);	Unclassified/Not available
one Spider known only from the Edgbaston springs (R.J. Fensham pers. comm.);	Unclassified/Not available
Eriocaulon aloefolium (Davies *et al.* 2007);	Critically endangered (IUCN)
Eriocaulon giganteum (Davies *et al.* 2007);	Critically endangered (IUCN)
Eriocaulon carsonii ssp. orientale (Davies *et al.* 2007);	Vulnerble (IUCN)
Peplidium sp. (Edgbaston R.J. Fensham 3341) (mentioned in Davies *et al.* 2007);	Critically (IUCN)
Sporobolus pamelae (R.J. Fensham pers. comm.);	Endangered under the Qld Nature Conservation Act 1992 (NCA).
Isotoma sp. (Myross R.J. Fensham 3883);	Unclassified/Not available
Myriophyllum artesium (R.J. Fensham pers. comm.);	Endangered under the Qld Nature Conservation Act 1992 (NCA).
Fimbristylis sp. (Elizabeth Springs R.J. Fensham 3743);	Unclassified/Not available

The current project aims to investigate and trial methods of gambusia removal and control at Edgbaston with a view to conserving the populations of endemic fish species.

The following report has been prepared in four sections, as follows:

1. The current distribution of alien and native fish species at Edgbaston.
2. Control of gambusia at Edgbaston.
3. Additional relevant work at Edgbaston
4. Recommendations for gambusia control in spring wetlands and the future management of fish populations and the spring environments at Edgbaston.

The current distribution of alien and native fish species at Edgbaston

Abstract

A fish audit of all springs at Edgbaston was undertaken between March 24 and March 30, 2009. A total of 93 springs were surveyed, including a number (approx. 15) not recorded in previous mapping. Fish were found in 29 springs, and also in ephemeral creeks fed by run-off from recent rainfall. Gambusia were the most widely distributed and abundant species and occurred in 23 springs. Edgbaston goby were found in 9 springs, red-finned blue-eye in 4 springs and spangled perch in 2 springs. Apparent range extensions of gambusia, Edgbaston goby and spangled perch throughout the spring complex at Edgbaston are notable, as is the static distribution of red-finned blue-eye.

Introduction

Alien fish species are present on every continent except Antarctica. Introductions of non-native fish species have occurred for many reasons ranging from the liberation of farmed stock to unauthorised introductions and the introduction of species for specific purposes such as angling or pest control.

In Australia, fish introductions began in the late 19th century with the importation of European fish such as trout, *Oncorynchus mykiss* and *Salmo trutta*, redfin perch, *Perca fluviatilis*, and carp, *Cyprinus carpio*, for angling purposes. Gambusia, *Gambusia holbrooki*, were introduced in 1925 to control mosquitos (hence the common name 'mosquitofish'). Gambusia are a live-bearing fish of the Poecilid family. In subsequent years, other Poecilids including guppies, *Poecilia reticulata*, platys, *Xiphophorus maculatus*, swordtails, *Xiphophorus helleri*, and mollies, *Poecilia latipinna*, have also been detected in Australian waterways, as have members of the Cobitid and Cichlid families. The most recent invasive fish species occurring in Australian freshwaters are generally thought to be the descendents of liberated aquarium fish. Consequently, the populations of these species are often concentrated close to large urban centres, but many appear to be capable of rapid geographic expansion (for example *Tilapia* species in north Queensland; Damien Burrows, James Cook University, pers. comm.). In inland Australia, populations of carp, goldfish, *Carassius auratus*, redfin perch, trout and gambusia are well-established in the Murray-Darling Basin and have been implicated in the decline of native fish populations (Roberts *et al.* 1995; Stuart and Jones 2006; Lintermans 2007).

Edgbaston is located in central western Queensland within the Lake Eyre Basin. Alien fish species known to occur in this endorheic drainage currently include only goldfish and gambusia. The distribution of both species within the Lake Eyre Basin appears to be patchy (Costelloe *et al.* 2004; Arthington *et al.* 2005; pers. obs.), however populations of gambusia are robust in certain areas including Nocundra on the Wilson River (pers. obs.), the Neales River in South Australia (Costelloe *et al.* 2004; Dale McNeil, SARDI, pers. comm.) and at Edgbaston (Fairfax *et al.* 2007; pers. obs.).

Current estimates recognise approximately 300 native freshwater fish species occurring in Australian systems (Allen *et al.* 2002). Although this number of species can be considered depauperate when compared with similar sized continents (eg: South America), Australia's dry climate and comparative lack of major freshwater river systems accounts for the comparative lack of species. Almost all freshwater fish families in Australian systems are derived from marine ancestors, and colonisation of freshwater systems most likely occurred as a result of changes in sea level and area of marine inundation of the Australian landmass over geological time.

In inland Australia, the Murray-Darling Basin contains approximately 46 native fish species (Lintermans 2007) and the Lake Eyre Basin considerably less (Wager and Unmack 2000). The comparative lack of species in the Lake Eyre Basin can again be attributed to aridity. Major watercourses within the Lake Eyre Basin include the Cooper, Diamantina and Georgina drainages. These rivers exist for the majority of the time as isolated waterholes but they occasionally flood and permit colonisation and migration opportunities for fish. Consequently, large-bodied species such as yellowbelly, *Macquaria* sp., bony bream, *Nematolosa erebi* and various Plotosid catfish and Terapontid fish are generally found only within these major systems. In contrast, several spring complexes occur throughout the Lake Eyre Basin, and these areas generally contain a locally endemic rather than a regionally endemic or widespread fish fauna. At the largest spring complex – Dalhousie in South Australia – a total of five species occur, including four local endemics, *Mogurnda thermophila, Craterocephalus dalhousiensis, Neosiluris gloveri and Chlamydogobius gloveri*, and one species with a widespread distribution, spangled perch, *Leiopotherapon unicolor*. At a far smaller spring complex, Elizabeth Springs in western Queensland, only one endemic fish species occurs, the Elizabeth Springs goby, *Chlamydogobius micropterus* (Allen *et al.* 2002).

The spring complex at Edgbaston comprises a series of soaks, mounds, pools and excavated areas that lie to the east of the homestead approximately 35 kilometres north-east of Aramac in western Queensland. The fish fauna at Edgbaston is unique due to the presence of an endemic Pseudomugilid fish, the red-finned blue-eye, and an endemic goby, the Edgbaston goby. Due to its limited range and current population estimates (approximately 3000; Fairfax *et al.* 2007), the red-finned blue-eye is considered one of the rarest fish in Australia (Allen *et al.* 2002). The presence of local varieties of Plotosid catfish, hardyheads and gobies at spring complexes such as Dalhousie can be explained by the evolution of range-limited species following a period of prolonged isolation and aridity, as all families are represented in other areas of the Lake Eyre Basin. The presence of red-finned blue-eyes at Edgbaston is more difficult to explain, as this is the only species and genus in the sub-family Scaturiginichthyinae (Wager 1994) and the only Pseudomugilid fish from the Lake Eyre Basin.

Surveys of the fish fauna within the springs at Edgbaston have been undertaken since November 1990 and indicate that populations of red-finned blue-eye are declining (Fairfax *et al.* 2007). As an example, red-finned blue-eye were found to naturally occur in 6 springs in 1994 and their total number was estimated at 5954 (Wager 1994), whereas this had declined to approximately 2700 in 4 springs by September 2006 (Fairfax *et al.* 2007). The impact of the alien live-bearing fish gambusia has been associated with the decline of red-finned blue-eye, as this species has increased in number and distribution at Edgbaston during the same period (Fairfax *et al.* 2007). Negative impacts of gambusia such as physical aggression on a related Pseudomugilid species, *Pseudomugil signifier*, have been detected in tank trials (Howe *et al.* 1997), and gambusia have been demonstrated to prey on endemic Australian fish species (Ivantsoff and Aarn 1999). Current population estimates and distribution of the Edgbaston goby can be considered incomplete, however this species was present in 8 springs in 1994 (Wager 1994).

The current study aimed to survey all springs at Edgbaston in order to create an up-to-date inventory of fish species and their distribution. In addition, standing surface waters were also sampled opportunistically.

Methods

Springs were located using GPS points provided by Rod Fensham and Russell Fairfax of the Queensland Herbarium. In instances where springs were located that were not mapped, co-ordinates were recorded. All springs were photographed and measured. For the purposes of this report, the coding of springs has been retained from earlier work (Wager 1994; Fairfax *et al.* 2007). Consequently, all springs have a letter and number code or a descriptive name in the case of new springs. However, for ease of results dissemination and discussion, it is recommended that the spring complex be considered as follows:

1. Springs in the southern section (prefixed by 'SW', 'SWn' or 'SE').
2. Springs in the northern section (prefixed by 'NW' or 'NE').
3. Springs in the central section (prefixed by 'E').

Fish sampling

Fish were sampled using a combination of methods depending upon the depth of water and amount of vegetation. Due to the variability of spring size, depth and within-spring architecture, the majority of springs were sampled using visual inspection for 10 minutes by two operators with identification of species confirmed by dip-netting (Table 2). In larger springs, a small seine net was hauled or un-baited bait traps were set overnight (Table 2). Where surface water pooled in ephemeral depressions along creek lines, these sites were sampled opportunistically in addition to the springs themselves using small fyke nets set overnight or a small seine net

(Table 2). The inventory of techniques used to audit the springs and surface water at Edgbaston included the following:

1. A 5 metre long seine net with 2mm mesh.
2. Fyke nets with a 2mm mesh and 3 metre wing set in opposite directions from a central post and set overnight.
3. Un-baited 40x20x20cm traps with a 5cm entry funnel set overnight.
4. Visual observation (10 minutes per spring x 2 operators) confirmed using dip nets.

Table 2. Techniques used in each spring at Edgbaston to sample fish in March 2009.

Spring code	Sampling method
SW40	2 x seine (5m x 2mm mesh) hauls through centre of spring
SW42	2 x seine (5m x 2mm mesh) hauls through centre of spring
SW50	Visual inspection confirmed using dip nets
SW70	2 x seine (5m x 2mm mesh) hauls through centre of spring
SWn30	Visual inspection confirmed using dip nets
SWn20	Visual inspection confirmed using dip nets
SWn10	Visual inspection confirmed using dip nets
SE10	Visual inspection confirmed using dip nets
SE30	Visual inspection confirmed using dip nets
SE40	Visual inspection confirmed using dip nets
SE50	Visual inspection confirmed using dip nets
NW90s	Visual inspection confirmed using dip nets
NW90n	Visual inspection confirmed using dip nets
NW100	Visual inspection confirmed using dip nets
NW80	Visual inspection confirmed using dip nets
NW30	Visual inspection confirmed using dip nets
NW70	Visual inspection confirmed using dip nets
NW10	Visual inspection confirmed using dip nets
NE01	Visual inspection confirmed using dip nets
NE20	Visual inspection confirmed using dip nets
NE40	Visual inspection confirmed using dip nets
NE50	Visual inspection confirmed using dip nets
NE60	2 x un-baited bait traps set overnight + visual inspection confirmed

	using dip nets
E503	Visual inspection confirmed using dip nets
E522	Visual inspection confirmed using dip nets
E509	Visual inspection confirmed using dip nets
E508	Visual inspection confirmed using dip nets
E523	Visual inspection confirmed using dip nets
E504	Visual inspection confirmed using dip nets
Sites sampled in standing surface waters	
Creek south-east of NE60	2 x small fyke nets (2mm mesh) set overnight
Creek west of NW90s	2 x seine (5m x 2mm mesh) hauls longitudinally through the creek.

Following sampling, native fish were returned to the water alive. No attempt was made to handle or measure critically endangered species (red-finned blue-eye and Edgbaston goby), however all sampled spangled perch were measured prior to release (standard length). Sampled gambusia were measured (SL) and euthanased using a dilute oil of cloves solution. Gambusia are a declared noxious species in Queensland and cannot be returned to the water alive. In instances where gambusia samples were very large, only a sub-sample of the first 20 individuals was measured.

Results

Red-finned blue-eye were absent from all springs in the southern section of the Edgbaston complex in March 2009 (Table 3, Figure 1). In all springs where fish were present in the southern springs, gambusia were present in large numbers (Table 3, Figure 1). Edgbaston goby were found in two springs in the southern section, and in both instances co-existed with large numbers of gambusia (Table 3). The southern section included the only areas (2) where spangled perch were sampled from artesian springs at Edgbaston (Table 3).

Red-finned blue-eye were sampled from four springs in the northern section of the Edgbaston complex in March 2009 (Table 3, Figure 1), with a comparatively large population present at NW30 and diminishing numbers present at NW90n, NW90s and NW70 respectively (Table 3). Robust populations of Edgbaston goby were sampled from the same springs and from NW80, where this was the only fish species present. In all other northern springs where fish were present, gambusia was the only species sampled, and all gambusia populations except NE10 were estimated to exceed 1000 individuals (Table 3).

Red-finned blue-eye were absent from all springs in the central section of the Edgbaston complex in March 2009 (Table 3, Figure 1). Edgbaston goby were found in two springs, and in both instances this was the only fish species sampled (Table 3). Gambusia were present in five springs in the central section of the Edgbaston complex in March 2009 (Table 3).

Table 3. Fish species and approximate numbers sampled at springs at Edgbaston where fish were present in March 2009.

Spring code	**Fish species abundance (blank cells = absence)**			
	Gambusia	RFBE	Edgbaston goby	Spangled perch
SW40	>1000			2
SW42	>1000		1	
SW50	>1000			
SW70	>1000		3	
SWn30	>100			
SWn20	>100			
SWn10	>100			
SE10	>100			
SE30	>100			
SE40	>100			1
SE50	>100			
NW90s		~200	~200	
NW90n		~700	~200	
NW100	>1000			
NW80			>50	
NW30		~3000	>200	
NW70		<30	<15	
NW10	>1000			
NE01	>100			
NE20	>1000			

NE40	>1000	
NE50	>1000	
NE60	>1000	
E503	>100	
E522	>100	
E509	>1000	
E508		<100
E523		>50
E504	<50	
E1	>1000	

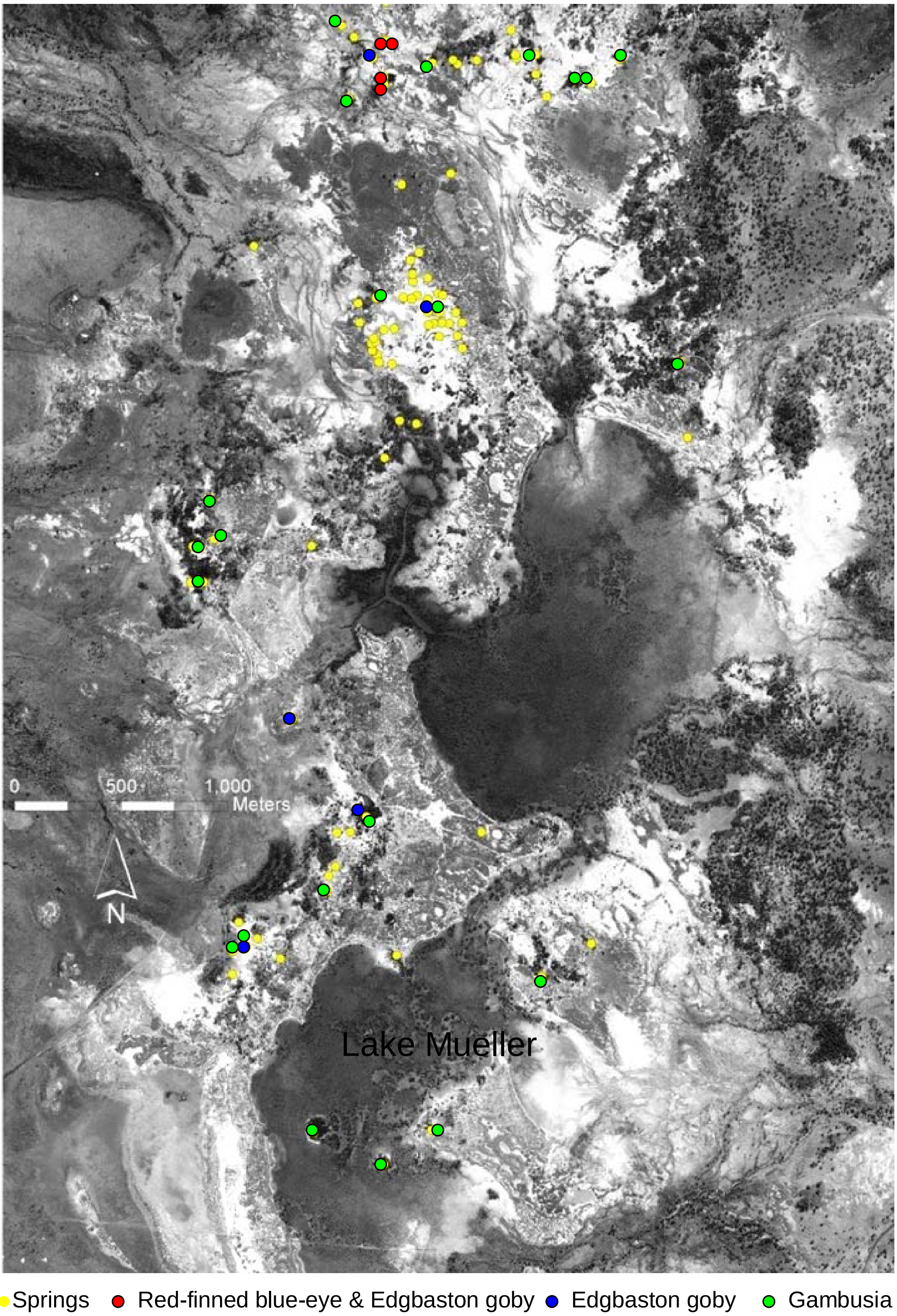

Figure 1. The spring complex at Edgbaston showing the distribution of fish-vacant springs (yellow dots), red-finned blue-eye (red dots), Edgbaston goby (blue dots) and gambusia (green dots) in March 2009.

Ponded surface water was sampled at four sites in March 2009 (Figure 2). Spangled perch were found in a creek close to both NE60 and NW90s, and gambusia were also present adjacent to NW90s (Table 4). In surface water adjacent to NE07 and north of NE60, only crustaceans (blue-claw yabbies and freshwater crabs) were sampled. Endemic species (red-finned blue-eye and Edgbaston goby) were not detected in any surface water on Edgbaston in March 2009.

Figure 2. An ephemeral creek in the vicinity of springs NW80, 90n and 90s in March 2009.

Table 4. Fish species sampled in ephemeral creeks adjacent to springs at Edgbaston in March 2009.

Site	**Fish species abundance (blank cells = absence)**	
	Spangled perch	Gambusia
Creek south-east of NE60	20	
Creek west of NW90s	1	5

Previously unknown springs at Edgbaston in March 2009

A total of 15 new springs were found that were previously un-mapped in March 2009. One new spring (E527) was located in the southern section of the spring complex, two were located in the northern section (NE and Next) and the remainder were located in the central section. Names and co-ordinates of new springs are given in Table 5. With the exception of two new springs (New Big and Smithy's), no new springs contained ponded water. No new springs located in March 2009 contained fish of any species.

Table 5. New springs located during March 2009 at Edgbaston.

Spring name	South	East	Size
E527	N/A*	N/A*	Small (1m x 1m) soak south of SW40.
NE	22 43.145	145 25.712	Soak (0.5m x 0.5m) draining to creek.
Next	22 43.145	145 25.718	Soak (1m x 1m) in claypan
New 1	22 43.961	145 25.687	Soak (1m x 1m) in claypan
New 2	22 43.933	145 25.674	Soak (0.5m x 1m) in claypan
New 3	22 43.935	145 25.670	Soak (1m x 1m) in claypan
New 4	22 43.914	145 25.670	Soak (2m x 1m) in claypan
New 5	22 43.913	145 25.681	Water depth <1cm (8m x 2m) in claypan
New 6	22 43.904	145 25.675	Water depth <1cm (5m x 3m) in claypan
New Big	22 43.928	145 25.919	Water depth <1cm – 10cm. 20m x 4m, east of E509.
New 7	22 43.843	145 25.902	2m x 2m soak area, 0.3m x 0.3m free water (<2cm).
Crab Hole	22 43.484	145 25.892	2m x 2m soak area, 0.3m x 0.3m free water (<5cm) with obvious hole.
New 8	22 43.763	145 25.784	4m x 4m soak, 0.5 x 0.5m free water (<2cm).
New 9	22 43.743	145 25.783	3m x 3m moist mound
Smithy's	22 43.817	145 25.632	4m x 6m, water up to 6cm deep, drains to creek, marked by large tree.

* Co-ordinates for E527 are available from Rod Fensham, Queensland Department of Environment and Resource Management.

Discussion

Red-finned blue-eye currently has a limited distribution at Edgbaston and is restricted to four springs in the northern section of the spring complex. The distribution of this species continues to decline compared with results recorded during prior surveys (Wager 1994; Fairfax *et al*. 2007). In particular, this species appears to have disappeared from all springs in the southern and north-eastern sections of the spring complex. This data suggests that there may indeed be an association between gambusia abundance and red-finned blue-eye absence, as all springs in these areas contain large numbers of gambusia. Edgbaston goby also have a limited distribution at Edgbaston, co-occurring with red-finned blue-eye in the northern section of the spring complex, with gambusia in springs in the southern section of the spring complex and in three locations where other fish species are not present. It is noteworthy that this species appears to be able to co-habit with gambusia at Edgbaston, however in areas where co-habitation occurs the alien species greatly outnumbers the endemic. It is also notable that gambusia do not currently inhabit the four springs where red-finned blue-eye are extant, and this suggests that the two species may be unable to successfully share habitat. Gambusia is the most widely distributed fish species at Edgbaston and occur in springs in the northern, central and southern sections of the spring complex. In most areas where gambusia occur, the populations are large (>1000 individuals per spring).

The springs in the southern section of the Edgbaston spring complex are located either within or close to the Lake Mueller depression which fills periodically due to flooding in Pelican Creek. Springs in this area are characterised by large numbers of gambusia and occasional spangled perch. It therefore appears most likely that migration pathways become open during periods of flooding or high run-off resulting in repeated colonisation events. Attempting to control gambusia in this area is not recommended due to its geographical location close to Lake Mueller. Additionally, although small numbers of Edgbaston goby were recorded in springs such as SW70 and SW42, no red-finned blue-eye were recorded from any spring in the southern section at Edgbaston. This area can therefore be regarded as having the lowest priority with regard to the preservation of endemic fish species.

Springs in the central section of the Edgbaston complex are characterised by a general lack of fish fauna. These springs appear to be under-going a rapid period of expansion as evinced by the number of previously unknown springs discovered in March 2009. It may be possible and prudent to protect this area from future gambusia colonisation. Removal of gambusia at specific springs such as E504 and E509 is desirable as this would create a sub-complex of central springs where alien fish species are not currently present within the Edgbaston system. This cannot be as easily achieved in either the north-eastern, north-western or southern spring clusters as gambusia are widely distributed throughout these areas.

Springs in the north-western section of the Edgbaston complex contain the only populations of red-finned blue-eye, as well as populations of Edgbaston goby.

Consequently, preservation of these areas is a vital component of any attempt to conserve red-finned blue-eye. However, the northern spring cluster at Edgbaston is also heavily infested with gambusia, and controlling the species in this area is also desirable.

Control of gambusia at Edgbaston – physical methods

Abstract

Removal of gambusia using physical methods (netting) commenced in March 2009 in two springs at Edgbaston (NE60 and E504). Physical removal at NE60 was discontinued due to substrate disturbance and concerns relating to the efficiency of such a method in springs with a large surface area and complex within spring architecture. The physical removal effort was continued at E504 in April, May and June and early results suggest that removal may have been successful in this spring. Results from the physical removal trials indicate that this method is likely to be successful in springs with a comparatively small surface area (<3m^2), but that alternative methods may be required in larger springs.

Introduction

Removing alien fish populations from wild habitat is difficult, particularly as the life history attributes that allow such species to be successful colonists are similarly conducive to survival in sub-optimal conditions. These attributes include flexible dietary requirements and recruitment strategies and broad environmental tolerances. In the case of Poecilid fish such as gambusia, the ability to give birth to live young almost certainly confers a competitive advantage over egg-laying species as juvenile gambusia are larger and thus able to consume larger prey at birth. Techniques that may be applicable for the removal of alien fish species currently include chemical treatments that destroy animals, biological control such as disease and gene technology, and physical removal.

Icthyocides – the most commonly-used being Rotenone in Australia and Antimycin A in the United States (Peter Unmack, pers. comm.) – are harmful to use in closed, physically-isolated systems that provide habitat for critically-endangered species such as the springs at Edgbaston, however this removal technique has been suggested previously by Wager (1994). The use of rotenone to eliminate invasive fish populations has had mixed success both in Australia (Rayner and Creese 2006; Pyke 2008) and worldwide (Pyke 2008). In general, eradication has been more successful in small, shallow areas with reduced vegetation (Rayner and Creese 2006). In an English experiment, topmouth gudgeon, *Pseudorasbora parva*, were removed from habitats using two applications of Rotenone a month apart following screening of treatment areas, however the authors of this report caution that Rotenone should be considered a last option for control of invasive fish, and that its application must be accompanied by strategies to prevent re-colonisation (Britton and Brazier 2006). Rotenone asphyxiates all fish species in a target area once dosage rates are determined (Solman 1950), but can also be lethal to non-target organisms such as invertebrates and amphibians (Anderson 1970; Chandler and Marking 1982). In a European study, Rotenone was demonstrated to be toxic to the pond snail, *Lymaea stagnalis*, and affected both locomotion and feeding behaviour (Vehovszky *et al.* 2007). Consequently, although Rotenone application could be a successful technique for eradicating gambusia from certain springs at Edgbaston, the risks associated with using such a chemical in areas where invertebrates may be present are potentially problematic. This is particularly relevant at Edgbaston, where populations of endemic invertebrates such as snails are also extant (Ponder and Clark 1990). Nevertheless, use of icthyocides may be the only way to eradicate gambusia from some springs at Edgbaston. The following considerations should accompany any planned usage of icthyocides:

a) the requirement for experimentally-derived dosage rates, and the risk of mortality to endangered species (eg: invertebrates) if these experiments were carried out.
b) the variability in size and volume of each spring and the consequent calculation of suitable dosage rates by volume, and
c) the inability to remove poison from treated springs and the potential longer-term environmental consequences of applying chemicals to such area-limited ecosystems.

Genetic techniques aimed at eradicating vertebrate pest species using sexually transmitted autocidal genes are being developed in Australia with the 'daughterless' carp program (Thresher 2007). This research-dependent technique aims to genetically manipulate fish such that only male offspring are produced and the population eventually crashes when females die out. Although the springs at Edgbaston would be a suitable trial site for a similar program involving gambusia, the fact that this specific technology (an autocidal technique for gambusia) does not currently exist means that it is not a viable eradication/removal technique in the short term. Although such a program has been suggested for gambusia control in Australia, the reproductive behaviour of gambusia (live-bearers) renders them unsuitable for such work in the short-term (Dean Gilligan, NSW DPI, pers. comm.). Similarly, biological control programs using genetically engineered diseases, though suggested, cannot currently be considered for gambusia due to a lack of research (Susie Ho, Monash University, pers. comm.). Biological control measures for vertebrate pest species such as gambusia may be a useful tool in the future, but their long development times, long application times and the possibility of genetic threats to other species combine to render these technologies impractical, particularly at Edgbaston, where small populations of critically endangered species may potentially become extinct before a genetics-based bio-control is developed.

Physical removal of alien or un-wanted fish species is labour-intensive but has been used effectively in several instances, and again, the development of technology aimed at removal of pest fish species is gaining popularity in Australia. In Lake Crescent in Tasmania a long-term netting and harvesting program has significantly reduced carp numbers, although it should be noted that this endeavour has been less successful in nearby Lake Sorell (Inland Fisheries Service 2004). In the Murray-Darling Basin the development of carp separation cages at weirs fitted with vertical slot fishways has capitalised on the jumping behaviour of carp and facilitated their removal at trial sites (Stuart *et al.* 2003; Stuart *et al.* 2006). Similar netting programs have also been trialled and used overseas on large-bodied alien species such as trout, and as a result they have been recommended for situations where sensitive native species are present (Knapp and Matthews 1998). Removal of small-bodied species such as gambusia is contingent upon designing species and habitat-specific techniques at appropriate local scales, and an advantage of the springs at Edgbaston is the fact that the waterbodies themselves are physically isolated and relatively small groundwater discharge systems. Consequently, techniques (or variations of techniques) such as heat traps deployed in winter (Williams 2008) and the implementation of feeding stations and targeting removal at night (Peter Unmack, University of Arizona, personal communication) may have applicability in such situations.

Given the status of the two extant native fish species at Edgbaston, the status of endemic invertebrates and plants (Table 1) and the small and isolated nature of the springs, physical removal of alien gambusia is recommended as a trial technique above chemical or biological control in the first instance. Although several factors are likely to mitigate the success of such a trial, such as the small size of gambusia at hatching, their relatively constant reproductive cycles and the possibility that re-colonisation of habitat may be facilitated by overland flows, physical removal nevertheless represents the safest trial method in such an ecologically fragile area. It is therefore recommended that physical removal techniques are deployed on site at Edgbaston and trialled and monitored over a suitably extended temporal timeframe depending on available funding. The potential use of chemical control for gambusia at Edgbaston should be considered if evaluation of physical removal indicates these techniques are inadequate. At present, it appears biological methods for potential control of gambusia at Edgbaston are non-existent.

Methods

Removal trials at NE60

In March 2009, black polypropelene garden edging (150mm x 2mm) was installed within NE60 in order to create an area in which physical removal could be trialled in a large spring (Figure 3). The total area sectioned off using garden edging was 26m^2. A smaller 2m^2 section was created by installing shadecloth across the western end of the trial site (Figure 3).

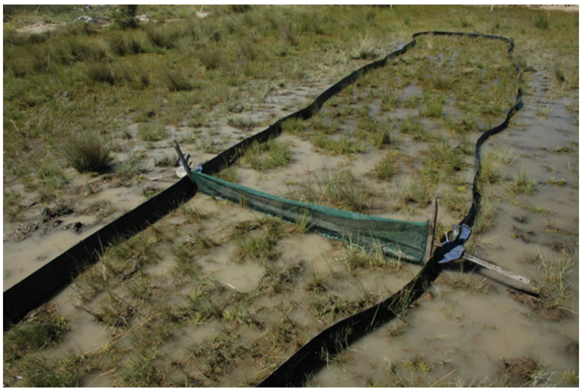

Figure 3. A $2m^2$ sectioned area of NE60.

During the first trial, two operators used small dip nets (150x100mm) with a 1mm mesh to remove all gambusia that could be located in the $2m^2$ section in 30 minutes.

In the second trial, three operators herded gambusia from the eastern to the western side of the enclosure and two operators used small dip nets (150x100mm) with a 1mm mesh to remove all gambusia that could be located in 30 minutes.

All sampled gambusia were euthanased using a dilute oil of cloves solution.. Gambusia are a declared noxious species and cannot be returned to the water in Queensland (QDPI&F).

Removal trials at E504

Physical removal of gambusia from E504 commenced in March 2009 and continued in April, May and June. On each occasion, fish were removed from E504 by two operators using dip nets.

All sampled gambusia were euthanased using a dilute oil of cloves solution. Gambusia are a declared noxious species and cannot be returned to the water in Queensland (QDPI&F).

Results

Removal trials at NE60

A total of 56 gambusia were removed from a $2m^2$ area of NE60 by two operators using dip nets in 30 minutes in March 2009. The population of gambusia included juveniles and adults of both sexes and all large females were close to giving birth (Figure 4). It is estimated that >90% of the gambusia present in the $2m^2$ area were removed, however remaining fish were difficult to detect.

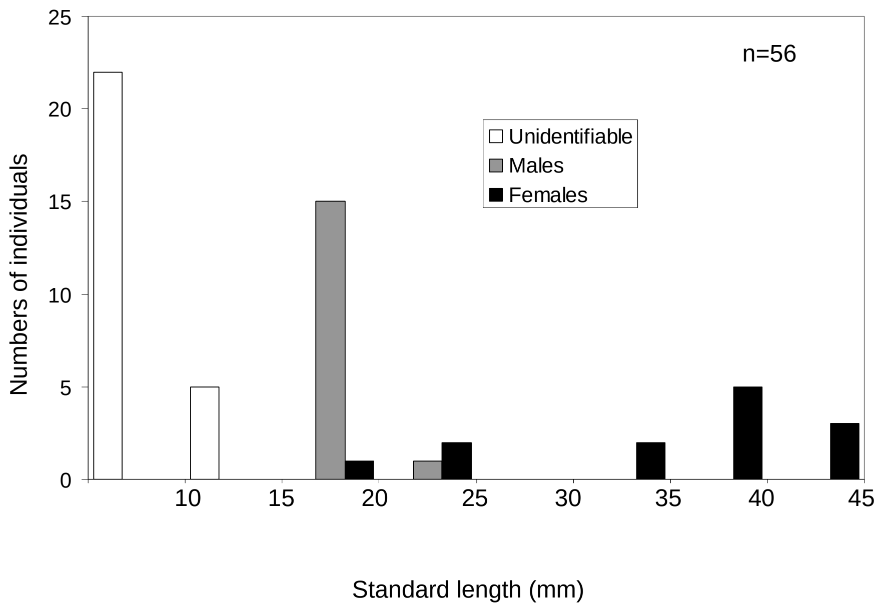

Figure 4. A large (50mm) female gambusia close to giving birth sampled from NE60 (top) and size frequency and sex (where identifiable) of gambusia removed from a $2m^2$ sectioned area of NE60 by two operators in 30 minutes (bottom).

A total of 344 gambusia were removed from a $26m^2$ area of NE60 by five operators herding fish in two passes in March 2009. 316 individuals were removed in the first pass and 18 individuals were removed in the second pass. It is estimated that approximately 70% of the gambusia from the $26m^2$ area were removed using this method.

Removal trials at E504

A total of 44 gambusia were removed from E504 by two operators using dip nets on three occasions in March 2009. 30 individuals were removed during the first netting occasion (Figure 5). 30 minutes later, a further 7 individuals were removed, and an hour later another 7 individuals were removed (Figure 5). The population of gambusia included juveniles and adults of both sexes and all large females were close to giving birth.

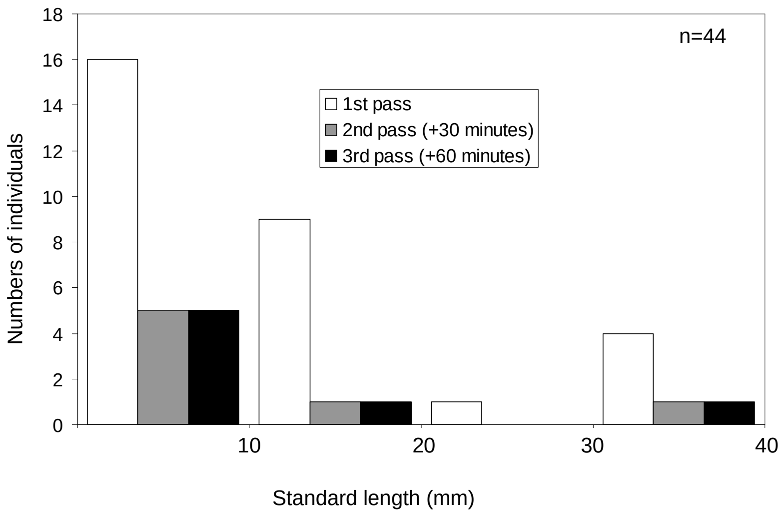

Figure 5. E504 (top) and size frequency of gambusia removed from this spring during 3 successive sampling events using dip nets in March 2009 (bottom).

Gambusia were removed by two operators on 7 occasions at E504 in April 2004. Night sampling was employed and was found to be particularly effective for locating small gambusia (<5mm standard length). A total of 90 gambusia were removed from E504 in 6 man-hours in April (Table 6).

Table 6. Gambusia removed from E504, 20 – 22 April 2009.

Date	Time	Number of operators	Number of gambusia	Comments
20/04/09	17:30 – 18:00	2	35	Sample included a large number of adult/semi-adult fish that had almost certainly grown during the previous month and were therefore more visible.
21/04/09	6:30 – 7:00	1	9	Predominantly small fish <10mm SL.
21/04/09	17:30 – 18:00	2	13	As above
21/04/09	21:30 – 22:00	2	10	Predominantly recently-born fry <5mm SL.
22/04/09	6:30 – 7:00	2	11	As above
22/04/09	17:30 – 18:00	1	1	As above
22/04/09	21:30 – 22:00	2	11	As above
23/04/09	6:30 – 6:45	1	0	No fish visible.

Gambusia were removed by two operators on 1 occasion at E504 in May 2009. On two other occasions, no fish were found. A total of 4 gambusia were removed from E504 in 4 man-hours in May. No gambusia were detected in E504 during June, and subsequent monitoring in July, August and September has confirmed the gambusia-free status of this spring.

Discussion

Results from physical removal trials of gambusia at Edgbaston indicate that this method is likely to be successful in small springs (those with a surface area of <3m^2), but that this success is contingent upon an on-going program aimed at re-sampling target springs at regular intervals. At E504, although a comparatively large number of juveniles were removed in April 2009, at least 4 individuals were not detected and were removed in May after they had grown slightly larger.

Physical removal in larger springs is unlikely to be successful, requires a large investment of manpower and has negative effects upon the substrate of springs.

Additionally, many of the larger springs are characterised by complex within-spring vegetation that is likely to hamper the success of any removal operations

At the very least, it appears that sustained physical removal may be an effective means of gambusia reduction/control in small springs, and this method may be applicable in the future if gambusia are found to colonise such areas. This method may have application in other areas where gambusia are found to colonise small, enclosed waterbodies.

It should be added that physical separation of such areas from potential re-colonisation sources should accompany physical removal (see below).

Control of gambusia at Edgbaston – chemical methods

Abstract and preamble

A decision was made in June 2009 to begin investigating the potential usage of Rotenone to control gambusia at Edgbaston. This decision was primarily driven by the results of the physical removal trials. Although gambusia control can be effected in small springs using physical removal, this method is likely to be impractical in large springs. Staff from the Queensland Department of Primary Industries and Fisheries (QDPI&F) became involved in the project (Peter Kind and Steven Brooks), and a small quantity of 8% active ingredient Rotenone powder was provided to the project by QDPI&F along with advice on usage and dosage rates.

Given the wide range of dosage rates suggested by manufacturers, researchers and agency staff regarding Rotenone application (Pro-Noxfish Dust Fish Toxicant label; Piec 2006; Steven Brooks, Queensland Department of Primary Industries and Fisheries, pers com), a decision was made to conduct experimental work in order to determine the lowest dosage required to achieve 100% mortality in gambusia. In order to complete these experiments, an Animal Ethics Agreement was obtained through the

Griffith University Committee and experiments were commenced in order to determine the minimum dosage of Rotenone required to achieve 100% mortality in gambusia. Following this trial, the experimentally-derived minimum dosage rate will be applied to sampled freshwater invertebrates collected from Edgbaston in order to determine the toxicity of the substance to these animals.

If the experimentally-derived minimum dosage rate is found to be non-lethal to freshwater invertebrates from Edgbaston, it is anticipated that gambusia removal from large springs may commence during summer 2009/10.

Aim

The aim of the described experiments was and is to determine the minimum Rotenone dosage rates required to euthanase gambusia at Edgbaston.

Methods

Powdered Rotenone product was obtained from Queensland Department of Primary Industries and Fisheries staff (Peter Kind and Steven Brooks). The powder contained 8% active ingredient (S. Brooks, pers. com.).

In early August 2009, a preliminary experiment was conducted using six glass aquariums (300 x 300 x 600mm) that were each filled with 50 litres of harvested rainwater at a temperature of 14°C and a dissolved oxygen concentration of 90.1%. Temperature and dissolved oxygen readings were taken using a calibrated TPS meter at the commencement of the experiment and at hourly intervals.

Similarly, in late September 2009, nine glass aquariums (300 x 300 x 600mm) were each filled with 50 litres of harvested rainwater. Temperature and dissolved oxygen readings were taken using a calibrated TPS meter at the commencement of the experiment and at hourly intervals.

Gambusia were collected from Humbybong Creek (Redcliffe, Brisbane) using un-baited bait traps. The fish ranged in size from 15mm SL to 43mm SL and comprised both males and females. 30 gambusia were randomly released into each aquarium following sampling and allowed to acclimatise to captive conditions for 24 hours for each experiment.

The water in the aquariums was not aerated or filtered, primarily because this was considered to best replicate conditions at Edgbaston.

In August 2009, Rotenone powder was mixed at 0.16, 0.32, 0.48, 0.64, 1.28 and 2.56 ppm by combining 0.1, 0.2, 0.3, 0.4, 0.4 and 1.6 milligrams of powder (respectively) with a small quantity of water in separate watertight specimen jars. Each jar was shaken for 60 seconds in order to dissolve the Rotenone powder.

The dissolved Rotenone was added to 5 of the 6 aquariums. The sixth aquarium was considered a control and hence no chemical was added.

Each aquarium was observed at 30, 60, 120, 180, 240 and 300 minutes and dead gambusia were counted and recorded. Inspections were repeated 24 and 48 hours after the Rotenone was first introduced.

At the conclusion of the first part of the experiment (48 hours), all dead fish were removed and dissolved oxygen readings were taken in each aquarium.

Five healthy gambusia were transferred to each aquarium after 48 hours and mortalities monitored at 60, 120, 180 and 240 minutes. This inspection was repeated after 24 hours, afterwhich all aquariums were drained and remaining gambusia euthanased using a dilute oil of cloves solution.

In September 2009, Rotenone powder was mixed at 0.32 and 0.64 ppm by combining 0.2 and 0.4 milligrams of powder (respectively) with a small quantity of water in separate watertight specimen jars. Each jar was shaken for 60 seconds in order to dissolve the Rotenone powder.

The dissolved Rotenone was added to three of the aquariums at a dosage rate of 0.32ppm and to three aquariums at a dosage rate of 0.64ppm. Three aquariums were considered controls and no chemical was added.

Each aquarium was observed at 60, 120, 180 and 240 minutes and dead gambusia were counted and recorded.

Where possible, Analysis of Similarities (ANOVA) in SPSS Version 14 was used in order to investigate variation in dissolved oxygen and temperature in relation to time (hours) and Rotenone dosage. Data was analysed if it conformed to assumptions of homogeneity following the application of Levene's Test.

Results

(i) Preliminary experiment – August 2009

Rotenone powder used at all concentrations was found to be effective for killing gambusia in aquaria (Figure 6). Rotenone powder at 0.16ppm (0.1mg powder/50 litres) was the least effective concentration, and after 48 hours, only 7 of the 30 gambusia (23%) had died (Figure 6). Rotenone powder at 0.32ppm (0.2mg powder/50 litres) resulted in 50% mortality after 24 hours and 97% mortality after 48 hours (Figure 6). Rotenone powder at 0.48ppm (0.3mg powder/50 litres) caused 67% mortality in 24 hours and 100% mortality in 48 hours (Figure 6). Rotenone powder at 0.64ppm (0.4mg powder/50 litres) caused 73% mortality in 24 hours and 100% mortality in 48 hours (Figure 6).

Rotenone used in higher concentrations was found to reduce the time taken to achieve 100% gambusia mortality. Rotenone powder at 1.28ppm (0.8mg powder/50 litres) resulted in 93% mortality in 120 minutes (Figure 6), whereas Rotenone powder at 2.56ppm (1.6mg powder/50 litres) resulted in 70% mortality in only 60 minutes (Figure 6). In both cases, 100% mortality occurred within 180 minutes of the commencement of the experiment (Figure 6).

In the control aquarium, where no Rotenone was added, one fish (3%) died after 24 hours.

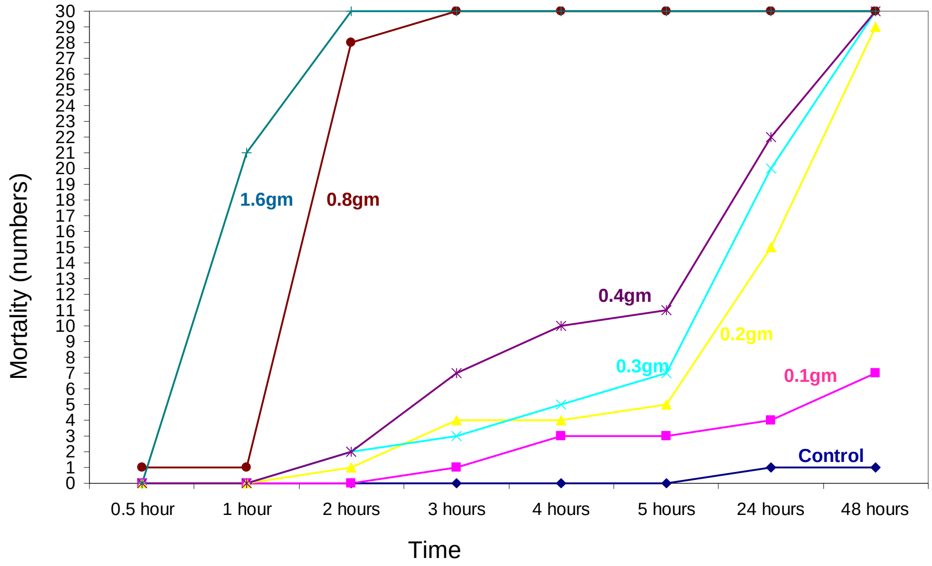

Figure 6. Mortality of gambusia through time exposed to different concentrations of dissolved powdered Rotenone in August 2009.

After 48 hours, dissolved oxygen had dropped in all aquariums, with the greatest decline recorded in the aquarium with Rotenone powder added at 2.56ppm (1.6mg powder/50 litres)(Table 7).

Table 7. Dissolved oxygen concentrations at the commencement and conclusion of the preliminary experiment in August 2009 under different Rotenone treatments.

	Dissolved oxygen (% saturation)	
	0 hours	*48 hours*
Control (no Rotenone)	90.1	83.3
0.16ppm Rotenone	90.1	84.1
0.32ppm Rotenone	90.1	78
0.48ppm Rotenone	90.1	68.2
0.64ppm Rotenone	90.1	77.6
1.28ppm Rotenone	90.1	71.5
2.56ppm Rotenone	90.1	54

Re-introduction of gambusia to the aquariums after 48 hours demonstrated that in most cases the Rotenone product was still active (Table 8). Rotenone at 0.48ppm, 0.64ppm and 1.28ppm resulted in 100% mortality in 180 minutes (Table 8). Rotenone at 0.32ppm was the only concentration where fish remained alive following re-introduction after 48 hours (Table 8).

Table 8. Mortality of gambusia following re-introduction to Rotenone concentrations after 48 hours ('NA' = not applicable due to 100% mortality previously).

Rotenone concentration (ppm)	% Mortality				
	60 minutes	120 minutes	180 minutes	240 minutes	24 hours
0.32ppm	0	20	40	40	60
0.48ppm	20	60	100	NA	NA
0.64ppm	20	80	100	NA	NA
1.28ppm	80	100	NA	NA	NA

(ii) Replicated experiment – September 2009

Rotenone powder used at both concentrations was found to be effective for killing gambusia in aquaria in September 2009 (Figure 7). Rotenone powder at 0.32ppm (0.2mg powder/50 litres) resulted in no mortality after 1 hour but 100% mortality after 3 hours (Figure 7), whereas Rotenone powder at 0.64ppm (0.4mg powder/50 litres) resulted in 100% mortality in 2 hours (Figure 7).

In the control aquariums, where no Rotenone was added, no fish died (Figure 7).

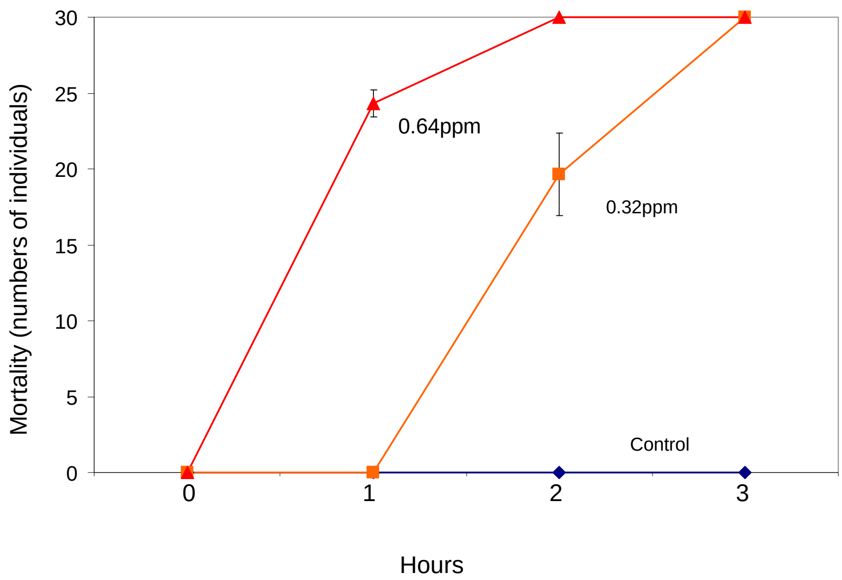

Figure 7. Mean (± standard error) mortality of gambusia through time exposed to different concentrations of dissolved powdered Rotenone.

Water temperature increased along a temporal gradient during the replicated experiment as the work commenced at 10am and concluded at 2pm (Figure 8).

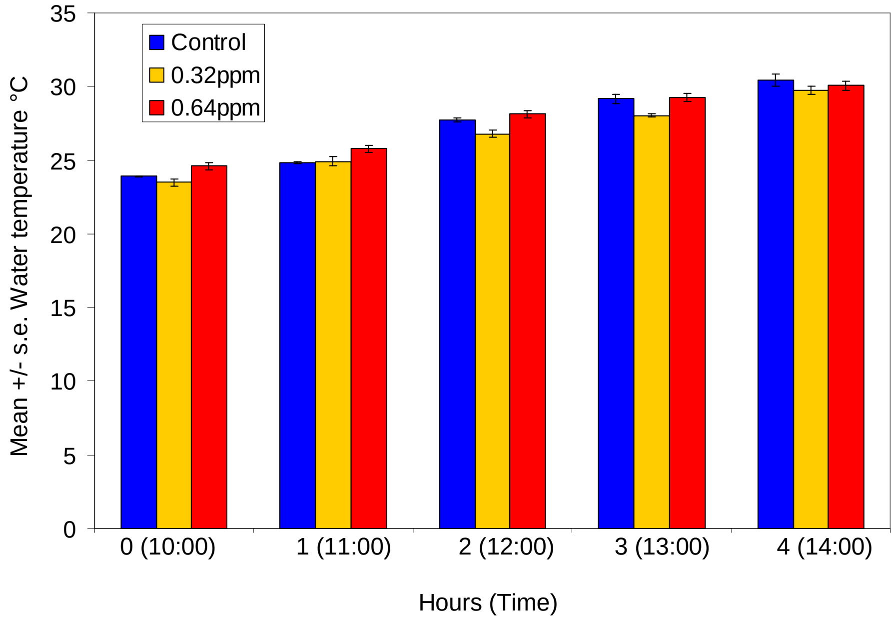

Figure 8. Mean water temperature (± standard error) during the replicated experiment in September 2009.

Dissolved oxygen varied through time during the replicated experiment (df: 4, F: 7.033, $p < .001$), but not in relation to the dosage rate of Rotenone (df: 2, F: 28.613, $p = 0.389$) (Figure 9).

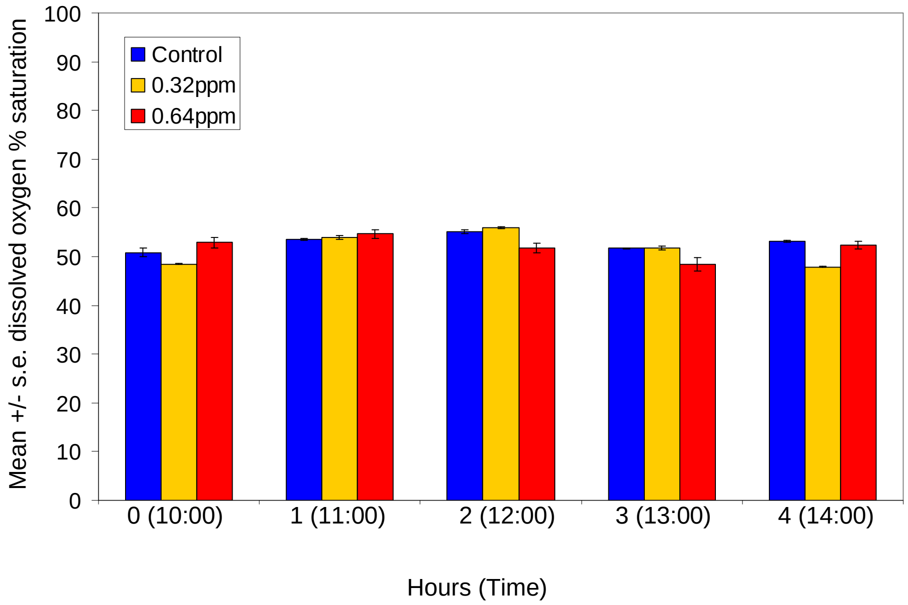

Figure 9. Mean dissolved oxygen (± standard error) during the replicated experiment in September 2009.

Discussion and recommendations

Results from the preliminary Rotenone experiment conducted in winter indicate that using the chemical at dilutions ≤0.32ppm is unlikely to result in 100% gambusia mortality in less than 48 hours. It is therefore recommended that these concentrations are not considered for future use at Edgbaston when water temperatures are lower than 20°C (Table 9). In contrast, results from the replicated experiment conducted in September indicate that 100% gambusia mortality is likely to occur within 3 hours using Rotenone at 0.32ppm when water temperatures range between 25 and 30°C.

Rotenone dilutions ranging from 0.48 – 0.64ppm were effective for euthanasing gambusia in water with an approximate temperature of 14°C, however at both concentrations 100% mortality was not effected until fish had been exposed to the chemical for 48 hours. These concentrations therefore represent the lowest dosage rates that can be considered for effective gambusia control at Edgbaston in winter (Table 9).

Rotenone dilutions of 1.28ppm and higher were highly effective and euthanased all exposed gambusia within 3 hours of exposure during winter. Concentrations of 1.28ppm should be used at Edgbaston in cases where rapid extirpation is required at any time of the year, such as in surface water and/or spring-fed creeks that are likely to re-fill (Table 9). However, usage of high dosage rates (≥1.28ppm) should not be used in springs or other areas where endemic fish or invertebrates are known to be present.

During the preliminary experiment, Rotenone was found to be active and harmful to fish at least 48 hours after the chemical was first applied. This suggests that the Rotenone product used has an as-yet undefined active period which needs to be determined through more thorough experimentation.

Table 9. Recommendations for Rotenone use at Edgbaston and calculated amounts of 8% active-ingredient powder required.

ppm	Recommended usage	Amount of 8% active ingredient powder required by volume (litres)					
		50	100	200	500	1000	2000
0.32	Low-dosage areas (springs) and invertebrate toxicity experimentation. Most likely to be effective when water temperatures exceed 20°C.	0.2mg	0.4mg	0.8mg	2mg	4mg	8mg
0.64ppm	Low-dosage areas (springs). Will act quickly (within 1 -2 hours) when water temperatures exceed 25°C.	0.4mg	0.8mg	1.6mg	4mg	8mg	16mg
1.28ppm	High dosage areas (surface water and spring-fed creeks) where rapid removal is required at any time of the year.	0.8mg	1.6mg	3.2mg	8mg	16mg	32mg

The following observations should guide future work with Rotenone at Edgbaston:

- The chemical appears to far more effective when water temperatures are above 25°C. Application of Rotenone on-site at Edgbaston should therefore be concentrated in summer in order to maximise the effectiveness of the chemical and reduce the amount that needs to be distributed within the landscape.
- Additional experiments are required in order to ascertain the length of time that 8% active-ingredient Rotenone powder is likely to remain toxic following mixing and application.
- Experiments on the toxicity of Rotenone to invertebrates at or from Edgbaston should be conducted using .32ppm solution and at water temperatures >25°C in the first instance.
- Concentrations of Rotenone in excess of .32ppm may have applicability at Edgbaston in ephemeral creeks and surface waters.
- Should rapid application of Rotenone at Edgbaston be required during comparatively cold weather (when water temperature drops below 20°C), higher dosage rates (such as 0.64ppm or higher) are recommended.

Additional relevant work at Edgbaston

Barrier fencing

Polypropelene barrier fencing material (150mm x 2mm) was selected and installed in locations at Edgbaston in order to isolate certain springs from potential gambusia colonisation sources (such as surface water in creeklines), to isolate gambusia populations in order to prevent colonisation of nearby areas and to isolate springs where gambusia removal had commenced between March and July 2009. Polypropelene material was chosen as it is robust. It is envisaged that terrestrial mammals such as pigs and kangaroos may be able to negotiate this barrier material should they wish to access springs.

In order to prevent colonisation of NW90s by gambusia and spangled perch a 30m x 150mm x 4mm plastic barrier was installed across the spring outflow zone (Figure 6). This barrier was lengthened to 150m in June 2009. NW90s contains both red-finned blue-eye and Edgbaston goby. NW90s outflows to a creek where both gambusia and spangled perch were found to be present in March 2009. The distance of the outflow zone is approximately 5 metres (Figure 10).

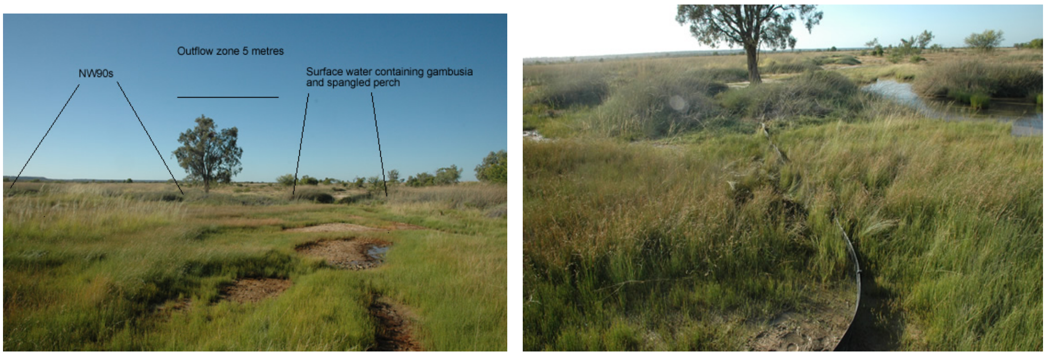

Figure 10. The distance between spring NW90s and the ephemeral creek containing gambusia and spangled perch (left) and the plastic barrier installed in order to prevent colonisation of NW90s (right).

Barrier fencing was installed around E504 in order to prevent future gambusia colonisation of the spring and/or escape of remaining gambusia in June 2009 (Figure 11).

Figure 11. E504 enclosed by barrier fencing.

Plastic barrier material was installed at 4 other sites at Edgbaston during June, as detailed in Table 10 and Figure 12.

Table 10. The location, purpose and length of barrier material installed at Edgbaston in June 2009.

Location	Purpose	Length of material installed	On-going monitoring
E509	Contain existing gambusia population within E509 and prevent colonisation of nearby springs, especially E508.	225m	Fence needs to be checked for: 1. Pig damage 2. Pooling of water in the southern section.
Between NW90 and adjacent creek	Prevent colonisation of NW90 by gambusia in the adjacent creek.	150m	Fence needs to be checked for pig damage.
NW100	Contain existing gambusia population.	125m	Fence needs to be checked for: 1. Pig damage 2. Escape routes in deeper sections.
Southern end of NW10	Prevent/reduce mass dispersal of gambusia via creek at southern end of NW10 during flow events.	50m	Fence needs to be checked for pig damage.

Figure 12. Examples of barrier fencing installed at Edgbaston in June include the encircling of E509 in order to contain a gambusia population (left) and placing a barrier across the southern outflow of NW10 in order to reduce the risk of gambusia accessing the nearby creek (right).

Evaluating the success of polypropelene barrier fencing as a method of quarantining extant gambusia populations and/or preventing colonisation events cannot be easily achieved until Edgbaston receives significant rainfall. At the earliest, this is most likely to occur during summer 2009/10.

It is possible that barrier fences in some areas may require the installation of drainage holes in order to prevent overflowing. It is also possible that barrier fencing may be damaged by terrestrial mammals such as kangaroos and feral pigs.

Depending upon the performance of barrier fencing through summer 2009/10, a recommendation may subsequently be made to install such material around more springs such that fish colonisation is effectively prevented. Although barrier fencing is also likely to limit or prevent invertebrate movement between springs, developing a useful method of limiting or reducing gambusia infestation throughout the Edgbaston complex is currently a higher management priority than facilitating invertebrate movement.

Surveying

Both the northern and central spring complexes were surveyed using a dumpy level in order to determine whether spring height (ASL) was likely to influence the colonisation ability of gambusia. It was determined through this process that proximity to creeklines (and hence potential gambusia colonists during periods of high flow) was the most likely colonisation vector (as opposed to height within the landscape).

Re-location of red-finned blue-eye to vacant springs

A red-finned blue-eye re-location event was commenced in April 2009. A total of 20 individual red-finned blue-eye per spring were re-located to four springs that were uninhabited by fish. Springs were chosen on the basis of their isolation (and hence reduced likelihood of gambusia colonisation). All re-located populations were alive when monitored in May, June, July, August and September 2009, however meaningful results from this re-location event cannot be realistically expected until after summer 2009/10, when rain events and drying events are both most likely. As the project aims to remove gambusia and re-introduce endemic fish species, these re-locations are being undertaken in order to trial the survivorship of red-finned blue-eye populations in different spring environments and simultaneously increase the number of populations of red-finned blue-eye extant at Edgbaston.

Currently, fish-vacant springs are the only sites where endemic fish can be re-located at Edgbaston. Most fish-present springs support large populations of gambusia, and only seven springs support a wholly endemic fish fauna. Although it is possible that re-locating red-finned blue-eye to springs that currently do not support fish may have a deleterious impact on spring invertebrates, accurate data relating to the presence and distribution of spring invertebrates is lacking. At present, increasing the distributional range of red-finned blue-eye is a higher priority than maintaining fish-vacant springs for the potential benefit of other spring biota.

Recommendations – gambusia removal in spring wetlands

The current project has demonstrated that gambusia can be effectively removed from small springs ($<3m^2$) using netting techniques. This technique may be effective in other areas where gambusia have colonised physically isolated waterbodies, but is contingent on the following:

a) Removal must be repeated over several sampling occasions in order to successfully target all size classes. Juvenile gambusia are extremely difficult to see, so allowing these juvenile fish to grow is suggested as a way of ensuring they are removed.
b) Following removal or reduction of gambusia populations, preventing re-colonisation is essential in order to keep areas gambusia-free. Results from the current study are inconclusive regarding the effectiveness of polypropelene barrier fencing for this purpose but should be available following the 2009/2010 wet season.

In larger spring environments, chemical removal of gambusia may be the most efficient method, again accompanied by isolation of target habitats. As detailed above, this method is currently being developed for deployment at Edgbaston. It is anticipated that results from this method may be available in early 2010.

Isolation of extant populations of gambusia has the potential to create more manageable working units in areas where this invasive species is present. Again, results relating to the suitability of polypropelene barrier fencing are likely to be available following the 2009/2010 wet season.

Extrapolating the results of this work to other spring complexes may be possible in cases where springs are similarly shallow and where gambusia colonisation is likely to have occurred as a result of overland migration during periods of inundation. Applying the methods described to other gambusia-affected areas within central Australia such as deep within-channel waterholes or sections of main riverine channels is not recommended.

Recommendations – fish management at Edgbaston

In addition to the general recommendations relating to gambusia removal, the following considerations are specific to Edgbaston.

1. Extant populations of red-finned blue-eye at NW30, NW70, NW90n and NW90s must be preserved using barrier fencing and potentially other methods (eg. exclusion fencing) where appropriate. Monitoring of red-finned blue-eye populations is required on a monthly basis in order to determine population viability in small springs (NW70) and population fluctuations in larger springs (NW90s, 90n and 30).
2. Re-location of red-finned blue-eye and Edgbaston goby populations to springs that are currently uninhabited by fish should continue (but see below), accompanied by accurate record keeping (regarding origin of re-located populations) and monitoring. Installation of barrier fencing around re-located

populations may be recommended pending the performance of barrier fencing during summer 2009/2010.

3. An inventory of aquatic invertebrates present at Edgbaston and their endemicity and rarity is required in order to assess the suitability of potential springs for red-finned blue-eye and/or Edgbaston goby re-location. Fish re-location should not be considered in springs where the suite of invertebrate fauna is found to contain rare species with a limited distribution within the spring complex.
4. Gambusia removal at Edgbaston should be concentrated in areas where gambusia colonisation has been relatively unsuccessful (the central spring cluster) and areas where endemic fish are present (the north-west spring cluster) rather than areas prone to inundation during floods (the southern spring cluster) and areas where gambusia are currently present in large numbers in large springs (the north-east spring cluster).
5. Establishment of captive breeding populations of red-finned blue-eye and Edgbaston goby may be necessary in order to provide a supply of fish for re-stocking in fish-free springs or those where gambusia are successfully removed.

Acknowledgements

The following organisations and individuals have provided funding, labour, equipment and/or expertise to this project and are gratefully acknowledged:

South Australian Arid Lands (Henry Mancini)

Queenland Department of Environment and Resource Management (Rod Fensham, Russell Fairfax, Jenny Silcock, David Akers).

Queensland Department of Primary Industries and Fisheries (Peter Kind, Steven Brooks, Gary Muhling).

Tim Smith, Michael Brigden, Lou Markey, Paul Foreman, Peter Unmack, Rob Wager, Michael Hammer, Angus Emmott, Stephen Balcombe, Martin Denny, Michael and Jo Wills, David Coulton, Joan Powling, Angela Arthington.

Special thanks are due to Allan and Fay Wills, former owners and current occupants of Edgbaston, for their hospitality and friendship throughout 2009.

References

Anderson, R.S. (1970). Effects of rotenone on zooplankton communities and a study of their recovery patterns in two mountain lakes in Alberta. *Journal of the Fisheries Research Board of Canada* **27**, 1335 – 1356.

Arthington, A.H., Balcombe, S.R., Wilson, G.A., Thoms, M.C. and Marshall, J. (2005). Spatial and temporal variation in fish assemblage structure in isolated waterholes during the 2001 dry season of an arid-zone river, Cooper Creek, Australia. *Australian Journal of Marine and Freshwater Research* **56**, 25 - 35.

Allen G.R. Midgley S.H. & Allen M. (2002). *Field Guide to the Freshwater Fishes of Australia.* Western Australian Museum. 394 p.

Britton, J.R. and Brazier, M. (2006). Eradicating the invasive topmouth gudgeon, Pseudorasbora parva, from a recreational fishery in northern England. *Fisheries Management and Ecology* **13**, 329 – 335.

Bush Heritage Australia (2008). Edgbaston Reserve: Interim Management Statement October 2007 – December 2009.

Chandler, J.H.Jr and Marking, L.L. (1982). Toxicity of rotenone to selected aquatic invertebrates and frog larvae. *Progressive Fish-Culturist* **44**, 78 - 80

Costelloe, J.F., Hudson, P.J., Pritchard, J.C., Puckridge, J.T. and Reid, J.R.W. (2004). *ARIDFLOW Scientific Report: Environmental Flow Requirements of Arid Zone Rivers with Particular Reference to the Lake Eyre Drainage Basin.*

School of Earth and Environmental Sciences, University of Adelaide, Adelaide. Final Report to South Australian Department of Water, Land and Biodiversity Conservation and Commonwealth Department of Environment and Heritage.

Davies, R., Craigie, A. Mackay, D., Whalen, M., Cheong, J. and Leach, G. (2007). Resolution of the taxonomy of Eriocaulon (Eriocaulaceae) taxa endemic to Australian mound springs, using morphometrics and AFLP markers. *Australian Systematic Botany* **20(5)**, 428 – 447.

Fairfax, R., Fensham, R., Wager, R., Brooks, S., Webb, A. and Unmack, P. (2007). Recovery of the red-finned blue-eye: an endangered fish from springs of the Great Artesian Basin. *Wildlife Research* **34**, 156 – 166.

Fensham, R, Fairfax R and Wager, R. (2006). Recovery Plan for the Red-Finned Blue-Eye, *Scaturiginichthys vermeilipinnis,* 2007 – 2011. Report to the Department of the Environment and Heritage, Canberra. Queensland Parks and Wildlife Service, Brisbane.

Fensham, R.J., Ponder, W.F. and Fairfax, R.J. (2008). Recovery plan for the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin. Report to Department of the Environment, Water, Heritage and the Arts, Canberra. Queensland Environmental Protection Agency, Brisbane.

Howe, E., Howe, C., Lim, R. and Burchett, M. (1997). Impact of the introduced poeciliid *Gambusia holbrooki* (Girard, 1859) on the growth and reproduction of *Pseudomugil signifier* (Kner, 1865) in Australia. *Australian Journal of Marine and Freshwater Research* **48**, 425 - 434.

Inland Fisheries Service (2004). Carp Management Program Report: Lakes Crescent and Sorell 1995 – June 2004. Inland Fisheries Service, Hobart, Tasmania.

Ivantsoff, W., Aarn (1999). Detection of predation of Australian native fishes by

Gambusia holbrooki. *Australian Journal of Marine and Freshwater Research* **50**, 467 - 468.

Knapp, R.A. and Matthews, K.R. (1998). Eradication of nonnative fish by gill netting from a small mountain lake in California. Restoration Ecology Vol **6,** No **2**, 207 – 213

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*. MDBC Publication No. 10/07.

Ponder, W.F. and Clark, G.A. (1990). A radiation of hydrobiid snails in threatened artesian springs in western Queensland. *Records of the Australian Museum* **42**, 301 – 363.

Pyke, G.H. (2008). Plague Minnow or Mosquito Fish? A Review of the Biology and Impacts of Introduced Gambusia Species. *Annual Review of Ecology, Evolution and Systematics* **39**, 171 – 191.

Rayner, T.S. and Creese, R.G. (2006). A review of rotenone use for the control of non-indigenous fish in Australian fresh waters, and an attempted eradication of the noxious fish *Phalloceros caudimaculatus*. *New Zealand Journal of Marine and Freshwater Research* **40**, 477 – 486.

Roberts, J., Chick, A., Oswald, L. and Thompson, P. (1995). Effects of Carp, *Cyprinus carpio* L., an Exotic Benthivorous Fish, on Aquatic Plants and Water Quality in Experimental Ponds. *Australian Journal of Marine and Freshwater Research* **46**: 1171 – 1180.

Solman, V.E.F. (1950). History and use of fish poisons. *Transactions of the American Fisheries Society* **69**, 141 – 157.

Stuart, I., McKenzie, J., Williams, A. and Holt, T. (2003). Separation cages for the removal of carp from Murray-Darling Basin fishways. Final report on preliminary trials of the Williams' Carp Separation Cage. Murray Darling

Basin Commission. Project R2104.

Stuart, I.G. and Jones, M. (2006). Large, regulated forest floodplain is an ideal recruitment zone for non-native common carp (*Cyprinus carpio* L.) *Australian Journal of Marine and Freshwater Research* **57**, 333 - 347.

Stuart, I., Williams, A., McKenzie, J. and Holt, T. (2006). The Williams' cage: a key tool for carp management in Murray-Darling Basin fishways. Final report on the Williams' Carp Separation Cage to Murray Darling Basin Commission Project R3018SPD. Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Heidelberg, Victoria.

Thresher, R. (2007). Genetic options for the control of invasive vertebrate pests: Prospects and constraints. USDA National Wildlife Research Center Symposia – Managing Vertebrate Invasive Species. University of Nebraska, Lincoln.

Vehovszky, A, Szabo, H, Hiripi, L, Elliot, C. and Hemadi, L. (2007). Behavioural and neural deficits induced by rotenone in the pond snail, *Lymaea stagnalis*. A possible model for Parkinson's disease in an invertebrate. *European Journal of Neuroscience* **25**, 2123 – 2130.

Wager, R. (1994). The distribution of two endangered fish in Queensland. Endangered Species Unit Project Number 276. Final Report Part B: The distribution and status of the red-finned blue-eye. Australian Nature Conservation Agency, Canberra.

Wager, R. and Unmack, P.J. (2000). *Fishes of the Lake Eyre catchment in central Australia.* Queensland Department of Primary Industries, Brisbane.

Williams, R. (2008) Article reproduced from an unknown source regarding Tamar River heat traps. ANGFA News.