Department of Sustainability and Environment

Improving spawning success for Barred Galaxias (*Galaxias fuscus*) in streams affected by bushfire – an aid to recovery

Black Saturday Victoria 2009 – Natural values fire recovery program

Daniel Stoessel, Renae Ayres, Tarmo Raadik

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Improving spawning success for Barred Galaxias (*Galaxias fuscus*) in streams affected by bushfire – an aid to recovery

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Front cover photo: (main) Artificial substrate – river cobble cluster (Daniel Stoessel), (inset) Close up of a Barred Galaxias egg cluster adhered to a natural substrate-cobble (Joanne Kearns).

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Acknowledgements

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Summary

Barred Galaxias is a small native freshwater fish endemic to the Goulburn River system in north central Victoria. The specie's former distribution has been greatly fragmented and as a consequence, only a small number of remnant populations remain in isolated headwater creeks. All populations are currently under threat and the species is listed as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999.

Bushfires during 2006 and 2007 impacted approximately 45% of Barred Galaxias populations and subsequent bushfires in February 2009 impacted virtually all remaining populations. Fire affected streams suffer from sedimentation and infilling, causing fish death, reduced fish recruitment by reducing available spawning habitat, and killing eggs. Given that Barred Galaxias lay eggs on the substrate and the incubation period is long, populations in fire affected areas are thus susceptible to these impacts. As the spawning biology of Barred Galaxias is not well documented specific information on attributes of egg deposition sites and spawning substrates in the wild is required, as is information on whether artificial spawning substrates could compensate for the loss of spawning substrates in streams impacted by sedimentation.

This study aimed to identify key Barred Galaxias spawning sites and spawning substrates in streams variously impacted by fire/sediment, validate the incubation time of eggs prior to hatching, and to investigate the use of different artificial spawning structures as egg deposition sites. The reproductive condition of Barred Galaxias was monitored in three study streams (Luke, Kalatha and S creeks), with 20 repetitions of five different artificial structures (sandstone tile, brick cluster, cobble cluster, woollen mop and PVC pipe cluster), added to two streams once the majority of fish in each system had reached an advanced stage of gonad development. Once spent females were detected, intensive egg searches were undertaken within the stream channel.

Thirteen spawning sites were identified in moderate to fast flowing, shallow, well oxygenated water in riffle sections immediately upstream of pools. Egg clusters were adhered close to the stream bed on the downstream side of cobbles, including on one cobble in an artificial cobble cluster. Egg incubation time was found to be longer than previously recorded, taking a maximum of 49 days to hatch from the time they were located, and information on other aspects of the spawning biology of Barred Galaxias were also described.

The addition of appropriate sized rock (~180 mm in diameter) into suitable locations in fire affected streams may improve Barred Galaxias spawning success by temporarily increasing the amount of preferred egg deposition sites during the spawning period. Placing rocks into high energy, faster flowing riffle areas potentially reduces the likelihood that they are smothered by sediment, thus minimising impacts on developing Barred Galaxias eggs, which will improve spawning success.

1 Introduction

The Barred Galaxias (*Galaxias fuscus*) is a small (maximum 160 mm TL, 40 g), endemic, scaleless, non-migratory, native fish (Raadik *et al.* 2010) (Figure 1). Remnant populations are restricted to 12 geographically isolated headwater streams, above 400 m in altitude, in the Goulburn River system in south-eastern Australia (Raadik *et al.* 1996, Koehn and Raadik 1995, Allen *et al.* 2003). This range is likely to represent an extreme fragmentation of a much wider and continuous historic distribution within headwater streams within the catchment (Raadik *et al.* 2010).

Predation of adults and juveniles by alien Rainbow Trout, *Oncorhynchus mykiss*, and Brown Trout, *Salmo trutta*, is considered the primary cause of the decline of Barred Galaxias (Raadik 1993, Raadik *et al.* 1996, Raadik *et al.* 2010). Changed water regimes, genetic isolation and deleterious stochastic events such as bushfire and drought also represent significant long term threats to the species (Raadik *et al.* 2010). This interplay between biotic threats and likely increasing frequency and severity of physical threats related to climate change, combined with the severely fragmented and isolated nature of remaining populations in fragile headwater catchments, create a very high extinction risk (Raadik *et al.* 2009). Barred Galaxias are listed as endangered under the *Commonwealth Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and by the Australian and New Zealand Environment Conservation Council 1991 (ANZECC).

Knowledge of the species biology is based on one short-term study (Shirley 1991, Shirley and Raadik 1997), additional information gathered during annual monitoring of populations, and earlier distributional surveys . As such information on the species is limited. Of relevance to this study, spawning occurs in late winter-early spring, and is triggered by an increase in day length and water temperature (Shirley 1991, Shirley and Raadik 1997). Fecundity is low (mean approximately 500 mature ova), and eggs are adhesive and large, with unshed oocytes approximately 2.2 mm in diameter (Raadik 1993). A largely unpublished pilot study conducted in the Rubicon River at the end of August 1995 located clusters of eggs underneath and on the downstream side of two large rocks in fast-flowing, shallow, cold (1–5 °C) water (Raadik, T. unpublished, Raadik 1993, Raadik *et al.* 1996, Raadik *et al.* 2010). No eggs were located on timber debris, exposed roots in undercut banks, overhanging vegetation, or on smaller cobbles or pebbles. Incubation time of eggs was approximately 30 days in water sustained at a temperature of 7 °C in a an aquarium (Raadik, T. unpublished data). Larvae are usually noted to be present in wild populations by December (Raadik 1993).

In addition to the long incubation period of eggs the demersal position of spawning sites increases the susceptibility of Barred Galaxias populations to impacts from instream sedimentation and infilling. High sediment input into streams can reduce spawning success due to loss of suitable substrates, and may result in recruitment failure due to loss of eggs through asphyxiation or increased abrasion. Such processes are prevalent following bushfire because vegetative cover that stabilises soil is burnt and soil is easily eroded (Lyon and O'Connor 2008). Consequently, natural population recovery may be reduced following bushfire if the spawning substrate becomes smothered by coarse sand and sediment fluxes in times of higher stream flows, which are common over the spawning period of Barred Galaxias.

Figure 1. Barred Galaxias (Tarmo Raadik).

Natural materials such as wood, boulders and gravel, and artificial materials such as concrete, tiles and pipes, have previously been used to rehabilitate instream habitat for fish (Koehn 1987, DeWaal *et al.* 1988, Pillar and Burr 1999, Cowx and Welcomme 1998, Nicol *et al.* 2002, Pretty *et al.* 2003, Nicol *et al.* 2004; Roni *et al.* 2006, Lintermans 2008). As detailed knowledge on the spawning biology of Barred Galaxias, including their preferred spawning substrates, is incomplete, habitat augmentation to improve spawning success is problematic and requires additional investigation. This is particularly important given that bushfires in 2006/7 impacted approximately 45% of all streams known to contain Barred Galaxias, and a subsequent bushfire in February 2009, the Kilmore-Murrindindi bushfire, impacted virtually all remaining populations.

Consequently, more information is required to identify attributes of egg deposition sites and spawning substrates in the wild, and the effectiveness of artificial spawning substrates. If successful, this information can be used to design and implement post bushfire recovery efforts to temporarily improve Barred Galaxias spawning success in sediment impacted streams until reinstatement of existing spawning substrate by natural scouring. This information will also be of value to the overall Barred Galaxias recovery, as greater knowledge of aspects of spawning biology will improve the selection of potentially suitable translocation sites (see Ayres *et al.* in review) and may positively guide management actions to improve spawning success at non-sediment impacted sites which display low levels of recruitment.

1.2 Project objectives

This study specifically aimed to improve Barred Galaxias population recovery in fire impacted streams by:

- Identifying key spawning sites in coarse sand impacted and un-impacted streams;
- Assessing the use of artificial structures as temporary spawning substrates; and,
- Verifying the incubation time of eggs prior to hatching.

The results of this project are to be published in greater detail in a scientific paper. Therefore this report provides an overview of the results.

2 Methods

2.1 Study area and sites

The study was conducted in the headwaters of three tributary streams (S Creek, Kalatha Creek and Luke Creek) of the Goulburn River system in south-eastern Australia (37° 28′ S, 145° 28′E) (Raadik *et al.* 2010) (Figure 2). Barred Galaxias is the only fish species present in the study reaches (Raadik *et al.* 2010), which were at altitudes above 400 m (AHD) and located upstream of significant natural instream barriers which have prevented the headwater colonisation of other native fish, and importantly, alien fish species. The clear freshwater streams are heavily shaded, well oxygenated, cool, narrow (1–4 m wide), moderately to fast flowing and with an alternating pool and riffle sequences and substrates typically composed of boulder, pebble, gravel and a small amount of sand (Raadik *et al.* 1996).

A study reach was established within each stream, located from 1–2 km upstream of instream barriers. Within each reach a 100 m long monitoring site was established which was surveyed repeatedly during the study to document the reproductive status of the fish population. A second site, 200 m in length, was established in each reach which was to be augmented with artificial spawning structures and later searched for newly laid eggs.

Each study reach differed with respect to bushfire related disturbance. S Creek was most impacted, with high intensity fire in February 2009 resulting in the complete loss of riparian vegetation and tree canopy cover. Luke Creek was moderately impacted, with loss of approximately 50 % of riparian and tree canopy cover, while Kalatha Creek was unburnt (Figure 3). The presence of coarse sand within the stream channel was most prevalent in the S Creek study reach, and least noticeable at Kalatha Creek.

Figure 2. Location of the study reaches in the headwaters of three tributaries of the Goulburn River system.

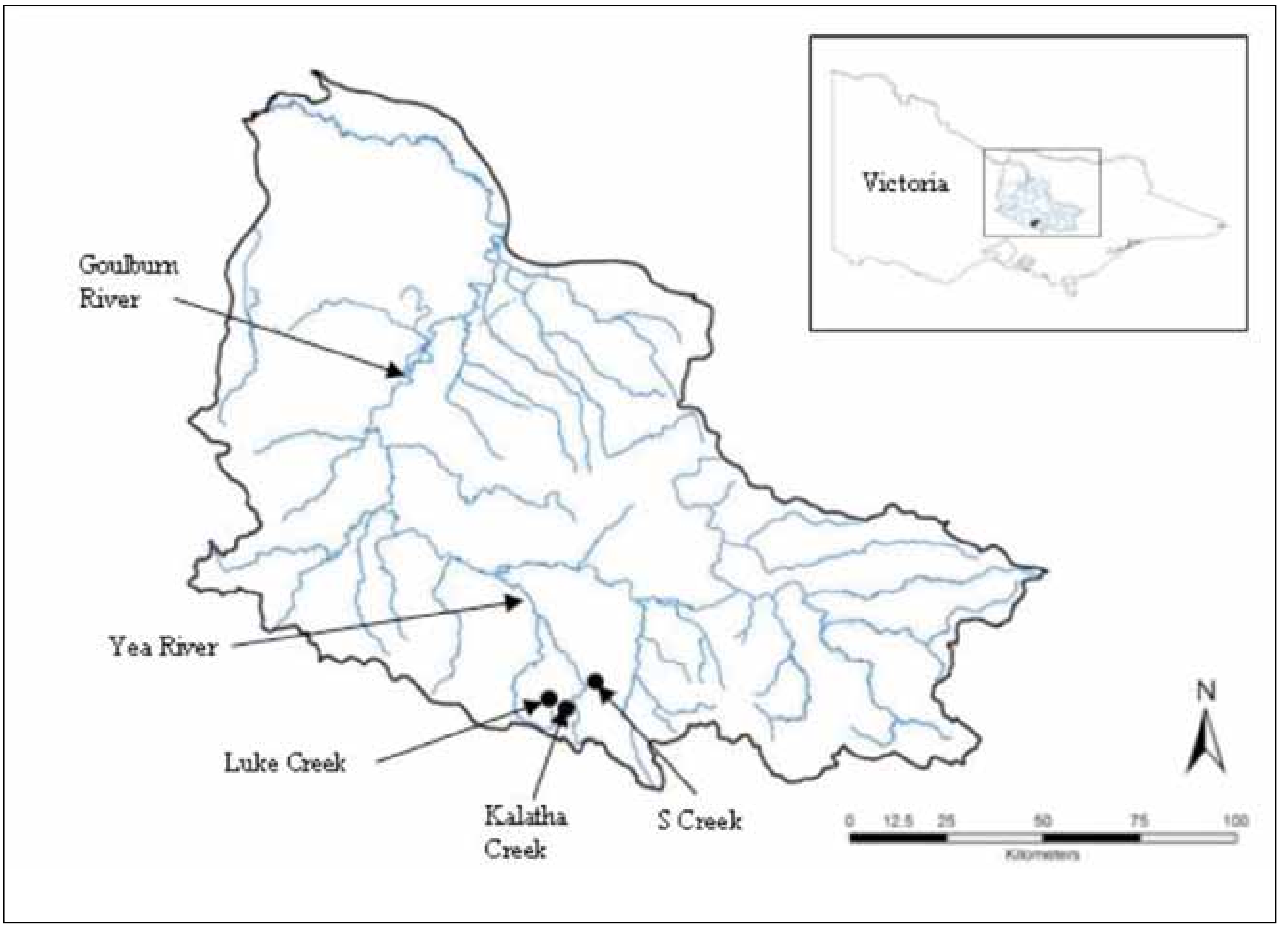

Figure 3. Habitat of Barred Galaxias within the three study reaches: Kalatha Creek (A – Daniel Stoessel), Luke Creek (B – Renae Ayres) and S Creek (C – Renae Ayres).

2.2 Monitoring of fish spawning condition

Barred Galaxias were surveyed weekly from July to September 2010 at the monitoring site in each study reach. They were captured using a Smith Root® model LR20B portable electrofishing backpack unit operated at settings of 70 Hz and 500 to 1000 V (Figure 4). Fish length (mm) and weight (g) were recorded, and maturation stage was determined by observing the degree of gonad development through the body wall and categorising reproductive stage following descriptors in Table 1. All Barred Galaxias collected were released once processed. Weekly monitoring of fish was not undertaken in the augmentation reaches to avoid disturbance which may affect natural spawning.

Figure 4. Surveying for Barred Galaxias using backpack electrofishing (Dean Hartwell).

Table 1. Reproductive stage descriptors, modified from Pollard (1972).

Reproductive stage	Stage description
I	*Immature virgin* – Applies to all fish less than 45 mm TL, and to males less than 55 mm TL. Smallest length of females not yet determined. Testes and ovaries not visible.
II	*Developing virgin and recovering spent* – Sex of fish cannot be determined, particularly in smaller individuals (usually 75 mm or less). Testes and ovaries indistinguishable, but can be seen that some reproductive tissue is present, filling less than 0.25 of body cavity. Eggs or lobes of testes not clearly distinguishable. (Stage 2 is difficult for some fish by external examination only)
III	*Developing* – Testes thickening, fill more than 0.25 if body cavity. Ovaries fill less than 0.25 of body cavity and are opaque/slightly yellowish, eggs very small and granular in appearance.
IV	*Maturing* – Testes enlarged, whitish and lobes clearly visible, filling less than 0.5 of body cavity. Ovaries small, filling less than 0.5 of body cavity, opaque/yellowish, eggs small but distinctly visible to naked eye.
V	*Mature* – Testes fill 0.5 or more of body cavity (can be a little less), lobes visible and white, no milt extruded by gentle pressure. Ovaries fill 0.5 to 0.75 of body cavity, eggs large but body cavity not distended, and eggs not extruded by gentle pressure (but may be by stronger pressure). Spawning vent in males and females enlarged.
VI	*Ripe* – Testes fill 0.5 or more of body cavity (can be a little less), lobes clearly visible and creamy-white, milt extruded by gentle pressure on body wall. Ovaries fill almost all of body cavity, eggs large and body cavity clearly distended, eggs extruded by gentler pressure on body wall. Spawning vent in males and females enlarged and extended.
VII	*Spent* – Testes thin and flaccid. Ovaries thin and flaccid. Body of fish skinny, and no more milt or eggs extruded by pressure.

2.3 Artificial spawning structures

Five artificial structures, with varying form, texture, surface orientations and overall surface area, were chosen to trial based on the pilot study in 1995 (Raadik, T. unpublished, Raadik 1993, Raadik *et al.* 1996, Raadik *et al.* 2010), and the successful use of structures as artificial fish spawning substrates in other studies (Jackson 1979, Bowman 1987, Koehn 1987), (Figure 5). Artificial structures represented rock substrate (single sandstone tile, brick cluster and a cluster of river cobbles), fine tree roots or aquatic vegetation (woollen mop), and hollow logs (a bundle of three PVC pipes). Timber debris was included as a potential spawning substrate but was not augmented as it was abundant at all sites.

Twenty repetitions of each artificial structure were randomly placed throughout the augmentation site in Kalatha and Luke creeks on the 28–29th July 2010 at different orientations and conditions of flow and depth (Figure 6). Due to access difficulties associated with remoteness and terrain, including post-fire fallen timber, structures were not trialled in S Creek.

Figure 5. Artificial spawning structures: A – sandstone tile, B – house brick cluster, C – cobble cluster, D – woollen mop and E – PVC pipe cluster (Renae Ayres/Daniel Stoessel).

Figure 6. Example of instream artificial structure placement in a pool section (Daniel Stoessel).

2.4 Spawning habitat search

Once spent females were observed during monitoring surveys, intensive searches to locate eggs were conducted within the augmentation sites. Searches were completed by a team of five people: two teams of two members each were assigned a 100 m stretch of the augmentation site in each stream and the remaining member undertook kick sampling (see below). All instream structures, including artificial substrates, timber debris, undercut banks, and closely associated riparian habitat, were examined for the presence of eggs. Where eggs were found on substrate, they were left instream and their location marked with flagging tape so the site could be avoided during kick sampling (see below).

A drift net (50 cm mouth opening, 150 µm mesh) was deployed at the most downstream point of each augmentation reach within each stream over the duration of the search period in an attempt to capture drifting eggs or newly hatched larvae (Figure 7). The content of drift net was sorted at the completion of the search period. Substrate kick sampling over multiple, randomly chosen 1 x 1 m stream sections was also undertaken though each augmentation reach to search for eggs potentially laid on sand or gravel beds. This technique involved gently disturbing an area of stream bed immediately upstream of a dipnet for approximately 10 seconds, and each kick sample was sorted at the end of each 1 x 1 m sampling event.

Where eggs were located, water depth, flow (Hydrological Services Current Meter Counter Model CMC-20), the type and dimensions of the spawning structure, and the characteristics of the placement of eggs on the structure, were recorded. Water quality parameters, including electrical conductivity (EC standardized to 25ºC µS.cm^{-1}), pH, dissolved oxygen (mg/L and % saturation), turbidity (NTU) and temperature (ºC), were measured in situ at a maximum depth of 0.2 m during each spawning condition monitoring event, and immediately adjacent to egg nest sites using a TPS 90FL-T Field Lab Analyser.

Figure 7. Placement of drift net within Luke Creek (Daniel Stoessel).

2.5 Egg incubation

On completion of recording habitat attributes at nest sites, the substrate on which eggs were laid was removed from the stream, placed into an aerated 20 L plastic bucket containing stream water, and transferred to secure aquarium facilities at the Arthur Rylah Institute for Environmental Research in Heidelberg. On arrival, individual egg clusters were carefully removed from spawning substrates and placed into indoor 20 L aquaria (Figure 8). Each aquarium contained a Perspex holder containing eight individual egg holders made of 90 mm diameter PVC piping cut into 80 mm lengths, and covered at the bottom end with 0.5 mm nylon mesh netting (see Bacher and O'Brien 1989). A single batch of eggs was placed into each egg holder and labelled with the stream name and a unique identification number. Aquarium water was aerated, recirculated and chilled to between 9.5–10.5 °C. Egg holders were removed each day from aquaria, placed under a microscope and eggs inspected for fungus, then placed into a10 g/L salt solution for 20 minutes to sterilise the eggs and reduce the likelihood of future infection, before returning the egg holder to the same aquaria. Eggs found to be infected and killed by fungus were immediately separated from healthy eggs using sterilised tweezers and subsequently disposed of. Eggs were visually inspected for development and the time and date of hatching was also recorded.

3 Results

The majority of females captured on the 28th–30th September 2010 were found to be at stage VII (spent). Egg searches conducted on these dates located 13 spawning sites in the augmentation reaches; eight in Luke Creek, four in Kalatha Creek, and one in S Creek. These were all located in riffles immediately upstream of pools, in moderate to fast flowing (0.4–2.0 m/s), shallow (70–310 mm deep), cool water (8.4–10 °C), which was fresh (35.3–56.6 EC), slightly acidic (pH 5.7–7.1), well oxygenated (dissolved oxygen 10.8–12.4 mg/L) and clear (turbidity 1.2–6.3 NTU).

Egg clusters were generally adhered on the downstream side of cobbles (diameter: range 115–280 mm, mean 180 mm) close to the stream bed (Figure 9). The maximum number of eggs in a cluster was 218 (average of 78 eggs) and clusters were coated with sand and fine gravel particles.

An egg cluster was located on one cobble in an artificial cobble cluster in Luke Creek, indicating that Barred Galaxias will potentially use this type of structures when available. The cluster contained 13 eggs and the cobble (160 L x 90 W x 85 H mm) was positioned immediately upstream of a pool (Table 2, Figure 10). Eggs were not found attached to any other artificial structures, nor found on timber debris, aquatic plants, moss, or other instream or closely associated structure. No eggs or larvae were collected in kick samples or within larval drift nets.

Water hardened and fertilised eggs were spherical, approximately 3 – 4 mm in diameter, adhesive, demersal, and transparent to relatively opaque. Embryos in approximately half of the egg clusters from Kalatha Creek, and the majority from Luke Creek, were sufficiently developed to visually observe their eyes. Embryos in the egg cluster from S Creek were fully developed and hatched within 30 minutes of being located and removed from the creek on the 29th September 2010.

At ARI, eggs from Luke Creek hatched from the 6th October–11th November 2010, those from Kalatha Creek from the 1st – 17th November 2010, and those from S Creek from 29th September–5th October. Ninety percent of eggs in captivity had hatched 44 days after being brought into captivity, with the last eggs hatching by day 48. Newly hatched larvae were approximately 9 mm in total length (Figure 11).

Figure 8. Barred Galaxias egg incubation aquaria at ARI.

Figure 9. Egg cluster adhered to a cobble (Joanne Kearns).

Figure 10. Artificial river cobble cluster utilised by Barred Galaxias as a nest site in Luke Creek (Daniel Stoessel).

Figure 11. One day old Barred Galaxias larvae (Tarmo Raadik).

Table 2. Dimension of spawning substrates and water quality recorded immediately adjacent to nest sites.

Site name	Flow (m/s)	Water depth (mm)	EC	Temperature (°C)	D.O. (mg/L)	D.O. (% sat.)	pH	Turbidity (NTU)	No. of eggs	Dimensions of spawning substrate (LxWxH mm)
Luke Creek	0.4	310	48.6	10.0	11.2	101.9	5.8	6.3	208	200x130x100
	1.0	140	48.6	10.0	11.2	101.9	5.8	6.3	13	160x90x85*
	1.9	300	38.6	9.4	10.8	95.7	5.8	5.9	3	210x160x140
	0.8	210	48.8	9.3	10.9	94.3	5.7	4.1	94	250x190x70
	1.2	250	48.7	9.4	10.8	94.9	5.7	3.4	89	210x120x80
	0.9	70	49.0	9.1	10.9	94.4	5.7	3.7	12	150x90x120
	1.0	180	49.0	9.1	10.9	94.4	5.7	3.7	5	240x200x110
	0.4	200	49.9	9.0	11.2	96.5	5.8	4.8	218	280x250x200
Kalatha Creek	1.1	130	35.7	8.4	12.4	107.3	5.9	2.2	82	120x100x50
	0.9	250	36.7	8.5	11.6	98.8	5.8	2.1	125	115x100x50
	1.2	130	35.9	8.5	11.2	95.9	5.9	1.2	158	140x120x80
	0.8	70	35.3	8.5	12.0	101.4	5.9	1.9	2	150x85x45
S Creek	2.0	20	56.6	9.5	12.0	105.8	7.1	3.4	11	155x130x50
Average	1.0	174	44.7	9.1	11.3	98.7	5.9	3.8	78	183x136x91

*Artificial structure

4 Discussion

This study has enhanced our knowledge of the spawning biology of Barred Galaxias. It confirmes that they are a demersal egg layer, preferring to use nest sites on loose rock substrates located in moderate to fast flowing water. Eggs are relatively large and generally laid in a tight cluster, spawning occurs during late winter to early spring, and the time of larval development is relatively long. Importantly, eggs are laid on similar hard substrates where available in sediment impacted and unimpacted streams, and were also laid on rock introduced into one stream moderately impacted by the 2009 bushfires. This indicates that augmentation of rock into sediment impacted streams, where naturally occurring rock substrates have been partially or completely smothered by sediment, may be a beneficial management option to improve one aspect of spawning success.

Individual nest sites located within this study were found to have an average of ~80 eggs despite the average fecundity of mature females being ~500 (Raadik *et al.* 1996). It appears likely that females spawn at multiple sites, laying many, small clusters of eggs, thereby reducing the risk of potential loss of all eggs deposited by an individual if laid in one cluster. This strategy appears uncommon in Galaxiidae, only documented in the Flat-headed Galaxias (*Galaxias rostratus*). This species is, however, comparatively highly fecund, and lays batches of eggs over an extended spawning period of up to a month (Llewellyn 1971). As the proportion of mature/ripe females declined rapidly within monitored populations in this study once spawning began at individual reaches, the spawning period in Barred Galaxias is likely to be relatively short. Therefore if individuals undertook multiple spawnings, it is likely that these occur over a period of days, rather than weeks.

Water hardened Barred Galaxias eggs are larger than that described for other non migratory galaxiids, including the Canterbury (*Galaxias vulgaris*), Roundhead (*Galaxias anomalus*), and Flathead Galaxias (*Galaxias depressiceps*) from New Zealand (Benzie 1968, Allibone and Townsend 1997). Larger eggs, and hence larger size of newly hatched larvae, can be advantageous in colder climates due to the positive relationship between egg size and survivorship (Ware 1975, Wootton 1984, Humphries 1989). Therefore the reproductive strategy employed by Barred Galaxias may maximise the chance of offspring survival in the comparatively harsh, cold environment of the upland streams of the Goulburn River system.

Eggs collected from the wild took a maximum of 48 days to hatch in captivity. Assuming eggs which hatched last were spawned just prior to collection, this finding extends the suggested approximate 30 day egg incubation period by at least 18 days (Raadik 1993, Raadik *et al.* 1996, and Raadik *et al.* 2010). A strong relationship between development of larvae and ambient water temperature is however known to exist for many fish species (Pauly and Pullin 1988, Pepin 1991, Pepin *et al.* 1997), and therefore annual differences in stream temperatures would likely alter the incubation period of eggs of the species. Back calculating by the egg incubation period of 30–48 days suggests a spawning period for Barred Galaxias lasting from about mid August to the end of September.

Differences in the stage of maturation, and in the subsequent date of hatching of eggs from the three study streams suggest that spawning did not occur synchronously across populations, with the S Creek population probably spawning several weeks prior to the Luke Creek population, which in turn spawned one to two weeks earlier than the population in Kalatha Creek. Similar variation in the time of breeding in other galaxiid species has been attributed to water temperature (O'Connor and Koehn 1991, Allibone and Townsend 1997) and changes in stream levels (Moore *et al.* 1999). However, environmental cues that initiate spawning were not obvious in this study and could not be directly associated with changes in water flow or water temperature, although spawning did occur at a time when water temperature was increasing. Photoperiod may be influential (Shirley and Raadik 1997), however the lack of synchronicity across the populations in the current study suggests additional stimuli could be responsible. As fire had destroyed much of the riparian vegetation and canopy cover at S Creek, and to a lesser extent at Luke Creek, it is possible that such differences may be attributed to increases in light intensity, and changes to photoperiod at these sites. Similar changes in the time of spawning as a consequence of photoperiod alterations, often independent of temperature, have also been shown in several fish species (see Björrnsson *et al.* 1998, Davies and Bromage 2002, Elliot *et al.* 2003, Howell *et al.* 2003).

Nest site characteristics of Barred Galaxias are similar to that described for the Mountain Galaxias (*G. olidus*). Both lay a small number of relatively large, adhesive eggs in a protected site, usually on rock (see O'Connor and Koehn 1991). In addition, both Barred and Mountain Galaxias lay their eggs predominantly in riffles, where the surrounding water is relatively fast flowing and well oxygenated (O'Connor and Koehn 1991). Adhering eggs to large stone substrates can be advantageous because they are stable/immobile and thus eggs remain within the area chosen by the parent. However, demersal egg-laying may result in eggs being susceptible to environmental disturbances to streambeds, such as siltation (Growns 2004). In addition, reduced water levels during the breeding season may expose spawning habitat or eggs at nest sites, thus limiting spawning habitat availability and reducing egg survival and overall spawning success (Moore *et al.* 1999). Similarly, post-fire sedimentation can reduce the availability of spawning habitat thus limiting spawning potential, or smother eggs at nest sites causing egg mortality and decline in spawning success (O'Connor and Koehn 1991).

Although the success of the artificial spawning structures appears limited, the choice and placement of these structures was undertaken with minimal knowledge of the reproductive behaviour of the species. Therefore, although eggs were deposited on only one introduced cobble during the trial, a relatively small number of cobbles were placed at sites, and only a small proportion of these, by chance, would have been in areas preferred as spawning habitat. The results of this study suggest that rock ~180 mm in diameter, placed in moderate to fast flowing sections upstream of pools, may provide usable spawning habitat for Barred Galaxias.

The addition of appropriate sized cobbles at suitable locations within streams would likely benefit spawning success for Barred Galaxias at sand and silt affected sites. We can transfer this knowledge to inform the site selection process of Barred Galaxias translocation programs to ensure that translocations sites provide suitable spawning habitat. The results of this study are currently being incorporated into a more detailed manuscript which will be submitted to a scientific journal for publication, as the outcomes have widespread, importance to the conservation management of threatened, demersal egg laying freshwater fish in upland catchments.

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