TWO-SPINED BLACKFISH

GADOPSIS BISPINOSUS

ACTION PLAN

Two-spined Blackfish (*Gadopsis bispinosis*). Illustration: M. Crosby-Fairall, ACT Government

PREAMBLE

Two-spined Blackfish (*Gadopsis bispinosus* Sanger (1984)) was listed as a vulnerable species on 6 January 1997 (initially Instrument No. 1 of 1997 and currently Instrument No. 265 of 2016). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing, where required, a draft action plan for a relevant listed species. The first action plan for this species was prepared in 1999 (ACT Government 1999). The species was included in Action Plan 29, Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007). This revised action plan supersedes earlier editions.

Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Conservation Strategy and component threatened species actions plans such as the Trout Cod (*Maccullochella macquariensis*), Silver Perch (*Bidyanus bidyanus*), Macquarie Perch (*Macquaria australasica*) and Murray River Crayfish (*Euastacus armatus*).

CONSERVATION STATUS

G. bispinosus is recognised and listed as a threatened native species in the following sources:

Australian Capital Territory

Vulnerable – Section 91 of the *Nature Conservation Act 2014*.
Special Protection Status native species – Section 109 of the *Nature Conservation Act 2014*

SPECIES DESCRIPTION AND ECOLOGY

Description

G. bispinosus is a member of the Family Percicthyidae which contains the Australian freshwater basses and cods. It is a small to medium-sized fish with a yellowish-brown to olive green back and sides, often spectacularly mottled with two to three rows of dark brown blotches ('giraffe' spots), running the entire body length and extending onto the dorsal, anal and caudal fins. The ventral surface is uniformly pale (cream to light grey) to the origin of the anal fin (Lintermans 2007) (Figure 1).

The recorded maximum length of the species is 325 millimetres (mm) total length (TL), maximum weight is ~200 grams (g) and individuals larger than 240 mm TL and 50 g are uncommon (Lintermans 1998, 2007).

Distribution and abundance

G. bispinosus is found in the cooler, upper reaches of the Murray–Darling river system in Victoria, New South Wales and the Australian Capital Territory (Jackson et al. 1996, Lintermans 2007).

In the ACT, *G. bispinosus* is currently restricted to the Cotter River upstream of Cotter Reservoir (Lintermans 2000). It is present in two of the three reservoirs on the Cotter River (Bendora and Corin) but is absent from the Cotter Reservoir, presumably as a result of excess sedimentation of substrate smothering suitable spawning sites (Lintermans 1998).

Habitat and ecology

This species is restricted to cool, clear upland or montane streams with abundant in-stream cover, usually in the form of boulders and cobble (Sanger 1990, Koehn 1990, Lintermans 1998, 2007) (see Figure 2). It also occurs in upland reservoirs with suitable rocky margins

(Broadhurst et al. 2012). *G. bispinosus* is generally found in forested catchments, where there is little sediment input to the stream from erosion or land management practices.

Figure 1 *G. bispinosus* sheltering in natural habitat in the Cotter River. Photo: M. Jekabsons, ACT Government.

The species is largely nocturnal or crepuscular (i.e. active at dusk, dawn and night) (Ebner et al. 2009, Broadhurst et al. 2012). Their diet is characterised by a predominance of aquatic insect larvae, particularly mayflies, caddisflies and midges. Terrestrial insects also make up a significant part of the diet, indicating the importance of intact riparian vegetation communities for their associated insect fauna, which fall onto the water (Lintermans 1998). Young-of-year and juvenile *G. bispinosus* eat proportionally more mayfly and midge larvae than adult fish, which consume larger items such as caddisfly larvae and terrestrial invertebrates (Lintermans 1998).

Movement of *G. bispinosus* is extremely limited, with the home range of adult fish estimated at 15–23 metres (Lintermans 1998, Broadhurst et al. 2011). *G. bispinosus* can potentially persist in small refugia during dry periods, as it appears to rapidly recolonise when conditions improve, but movement is likely to be on local rather than on larger scales. Further information about home range is in Appendix 1.

G. bispinosus is a relatively sedentary species and is not known to undertake a spawning migration. Breeding is seasonal with egg-laying commencing in November. Likely cues for spawning include day length and rising water temperature. Fecundity is low and is positively correlated with fish length. Females commence breeding in their second or third year. Between 80 and 420 eggs are laid (Sanger 1986, 1990, Lintermans 1998, Dennis et al. 2016) in a single egg mass. The spawning site is usually in the spaces between cobbles or boulders where the eggs are attached to the upper surface of a rock. (O'Connor and Zampatti 2006). *G. bispinosus* live for approximately eight years (Lintermans 1998). Further information is in Appendix 1.

CURRENT MANAGEMENT ACTIONS AND RESEARCH

Past management actions and information about research projects can be found in Appendix 2.

Regulations prohibiting the take of *G. bispinosus* by anglers under the *Fisheries Act 2000* and the Nature Conservation Act have been in place since the species was listed as threatened in 1997. Following the completion of the Enlarged Cotter Dam, the total closure to fishing in the Cotter River was extended upstream to the junction of the Cotter River with Condor Creek to protect fish in the enlarged reservoir. To protect a range of threatened fish species, including *G. bispinosus,* fishing is also banned in the Cotter Catchment upstream of Bendora Dam in Namadgi National Park.

Ongoing monitoring of both the Cotter River and Bendora Reservoir populations has occurred since the mid-2000s by either the ACT Government or the University of Canberra (Beitzel et al. 2013, Lintermans 2001, 2005, Broadhurst et al. 2015). Additional monitoring is undertaken to address potential localised threats such as prescription burns. An ACT Government database has been established.

Under the ACT *Water Resources Act 2007*, a program of environmental flow releases in the Lower Cotter Catchment makes particular provision for threatened fish species with riffle and pool maintenance flows released (ACT Government 2013). These Environmental Flow Guidelines are reviewed and updated every five years and the effects of the flows on fish are monitored by the ACT Government in association with Icon Water (e.g. Beitzel et al. 2016).

The pine forests of the Lower Cotter Catchment were severely burnt after fires in 2003 leading to erosion and then sedimentation of the Cotter River. Substantial revegetation with native plants and reduction of forestry roads was conducted to reduce sediment getting to the lower Cotter River. In addition to improved water quality, less sediment in the river also provides better fish habitat.

THREATS

Freshwater fish and their habitats are imperilled globally, with many concurrent and overlapping threats operating across many countries and locations (Malmqvist and Rundle 2002, Dudgeon et al. 2006, Lintermans 2013a). The major threats affecting native fish are habitat destruction or modification, river regulation, barriers to fish passage, overfishing, alien fish species and climate change. These threats, with the possible exception of overfishing, are considered to have impacted on populations of *G. bispinosus* nationally and locally. In addition the effects of wildfires are a specific threat to *G. bispinosus* that is magnified in the Canberra region as a result of the extremely limited distribution (a single catchment) of blackfish in the ACT. General information about these threats regionally can be found in the Aquatic and Riparian Conservation Strategy.

Habitat modification

In the Lower Cotter Catchment riparian zones have previously been cleared for pine production. Although the area is being rehabilitated, the remaining non-rehabilitated area is modified by weed invasion (e.g. Blackberries, pines). Sedimentation of streams from forestry practices and following fires has filled pools and smothered spawning sites, reducing light penetration and the diversity and abundance of invertebrates. Dams on the Cotter River have reduced flows, particularly high-flow events, although this is addressed by environmental flow regulations. Dams have flooded previously riverine habitats, potentially impacting critical ecological functions (e.g. blackfish could not breed in Cotter Dam, likely as a result of sediment smothering spawning sites).

River regulation

The ACT *G. bispinosus* population in the Cotter River is affected by the river regulation effects of Corin, Bendora and Cotter dams. *G. bispinosus* are present in Corin and Bendora reservoirs, but not in Cotter Reservoir (Lintermans 2002). Dams alter sediment and nutrient regimes and may release cold or hypoxic water (inadequate oxygen), impacting the fish downstream. In the flowing water sections up to a kilometre below Bendora Dam wall the numbers of *G. bispinosus* are lower than upstream (ACT Government unpublished data). It is unknown why this reduction in numbers occurs but it may be from water quality or habitat impacts from the dam. Fortunately, *G. bispinosus* numbers further downstream in the regulated sections of the Cotter River are in reasonably good condition, supported by provision of effective environmental flows (Beitzel et al. 2013).

Barriers to fish passage

The construction of Cotter Dam in 1915 prevented upstream movement between the population of *G. bispinosus* above and below the dam. Similarly, the subsequent construction of various road crossings (Vanitys Crossing, Pipeline Road Crossing, Burkes Creek Crossing) and Bendora and Corin dams has further

fragmented the Cotter River population. Barriers can act synergistically with other threats by preventing upstream recolonisation of streams after local declines or extinctions.

Sedimentation

Addition of sediments to rivers is particularly detrimental to fish such as *G. bispinosus* that lay adhesive eggs on the substrate as sediment may smother the eggs and prevent their attachment. Increased sedimentation is also known to be damaging to benthic macroinvertebrate communities which form the majority of the dietary items of *G. bispinosus* (Sanger 1990; Lintermans 1998). Sedimentation also fills in refuge habitat between rocks that *G. bispinosus* relies on for cover and spawning (Lintermans 2013a).

Reduction in water quality

The major reductions in water quality that are most likely to have affected *G. bispinosus* in the ACT region are sediment addition (see above) and changes to thermal regimes, either from the operation of impoundments or the loss of riparian vegetation which shades streams.

In the Cotter River a study of growth of *G. bispinosus* recorded that the growth rate of this species was significantly less under cold water conditions that simulated thermal pollution (Hall 2005). Similarly, in the Cotter River, swimming capacity of another threatened fish (*Macquaria australasica*) decreased substantially with decreased water temperature (Starrs et al. 2011). This may also be the case for *G. bispinosus*. Reduced growth rates mean small fish will remain in the size class susceptible to predation for longer, thus exacerbating the impacts of alien predators. Lowered water temperature can also disrupt reproductive behaviour.

Introduction of alien species

Locally, *G. bispinosus* has had its distribution invaded by a range of alien fish species including Rainbow Trout and Brown Trout (*Oncorhynchus mykiss* and *Salmo trutta*), Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Redfin Perch (*Perca fluviatilis*), Eastern Gambusia (*Gambusia holbrooki*) and Oriental Weatherloach (*Misgurnus anguillicaudatus*). Alien fish can have impacts on native fish species due to:

- competition for food and habitat (spawning areas, territory)
- predation
- introduction and spread of diseases (e.g. EHNV) and parasites (e.g. *Bothriocephalus* and *Lernaea*)
- habitat degradation (e.g. uprooting of aquatic vegetation and increased water turbidity by Carp feeding).

The main impact on *G. bispinosus* is thought to be through all of these interactions with alien fish.

Further information about the threat of alien species is in Appendix 3.

Changing climate

In addition to the above threats, *G. bispinosus* is likely to be susceptible to the impacts of climate change. Overall, climate change is predicted to make the ACT region drier and warmer (NSW OEH and ACT Government 2014, Timbal et al. 2015).

Fish (as ectotherms) have no physiological ability to regulate their body temperature and are thus highly vulnerable to the impacts of climate change, particularly given their dispersal is generally constrained by linear habitats in freshwaters (Buisson et al. 2008, Morrongiello et al. 2011). *G. bispinosus* with demersal adhesive eggs is likely to be negatively impacted by the increased occurrence of extreme summer rainfall events, coupled with likely increases in bushfire occurrence. Burnt catchments and increased rainfall intensity will result in increased sediment loads in streams (Carey et al. 2003, Lyon and O'Connor 2008) which is known to have impacted *G. bispinosus*. Also, as

G. bispinosus spawns in response to day length and water temperature, spawning cues may become decoupled with earlier seasonal warming, resulting in reduced recruitment success.

Fire

Fire impacts of consequence to *G. bispinosus* include:

- sedimentation from denuded catchments following rain events
- a decrease in dissolved oxygen concentrations as organic material (leaves, ash) washed into streams following rain events begins to decompose
- chemical changes in water quality such as ash and fire run-off is deposited in streams
- impacts from the loss of riparian (streamside) vegetation such as increased water temperature due to lack of shade.

Further information about the impacts of bushfires in 2003 is in Appendix 3.

As a result of the 2003 bushfires, fire management practices in the ACT have been amended with road access to remote areas upgraded, new fire trails constructed, river crossings upgraded and constructed and an increased frequency of prescribed burns. Preliminary results of fish monitoring after a hazard reduction burn conducted in the Upper Cotter Catchment in 2015 indicate that *G. bispinosus* numbers were reduced in the waters within the burn area immediately afterwards. Also, a local rainfall event resulted in record levels of electrical conductivity and turbidity downstream of the burn (ACT Government 2015), reflecting chemical changes as a result of ash and sediment deposition.

Reduction in spawning habitat availability

G. bispinosus requires clean rock substrates for spawning and is severely impacted by sedimentation in non-flowing habitats such as reservoirs. The species was not able to persist in Cotter Reservoir, presumably because of the high sediment loads from surrounding forestry activities, but has persisted in Bendora Reservoir and, to a limited extent, in Corin Reservoir where native vegetation persists around the reservoirs.

The construction of the enlarged Cotter Reservoir has impounded approximately five kilometres of riverine habitat that previously supported breeding of *G. bispinosus*. This newly impounded habitat is unlikely to provide suitable habitat for *G. bispinosus* as it will be subject to sedimentation as the flowing water enters the impoundment and suspended sediment settles out (Lintermans 2012). It is possible that *G. bispinosus* may be able to spawn in the margins of the enlarged Cotter Reservoir as there is no longer active commercial forestry in the catchment. However, research into spawning of this species in Bendora Reservoir highlighted that fluctuating water levels over the extended spawning and larval development period (which takes approximately six weeks) resulted in spawning sites around the edge of the reservoir becoming desiccated as water levels dropped rapidly. Sedimentation of near-bank spawning sites was also problematic, likely as a result of wave action (Lintermans et al. 2010).

MAJOR CONSERVATION OBJECTIVES

The overall conservation objective of this action plan is to maintain in the long-term, viable, wild populations of *G. bispinosus* as a component of the indigenous aquatic biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes and resilience.

Specific objectives of the action plan:

- Protect sites in the ACT where the species occurs.
- Manage habitat to conserve populations.

- Enhance the long-term viability of populations through management of aquatic habitats, alien fish species, connectivity, stream flows and sedimentation in habitats both known to support existing *G. bispinosus* populations and areas contiguous with such populations to increase habitat area and where possible connect populations.
- Improve understanding of the species' ecology, habitat and threats.
- Improve community awareness and support for *G. bispinosus* and freshwater fish conservation.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

G. bispinosus largely occurs on Territory Land almost entirely within Namadgi National Park and the Lower Cotter Catchment (water supply protection area).

G. bispinosus is not known to occur on rural leasehold Territory Land or Commonwealth owned and managed land (National Land).

Conservation effort for *G. bispinosus* in the ACT is focused on protecting viable populations in the Cotter River and associated reservoirs. There is almost certainly some downstream connectivity between the populations in Bendora and Corin reservoirs and those in the Cotter River but there is no upstream connectivity between the rivers and reservoirs as a result of the dam walls that prevent upstream movement.

Previously, parts of the ACT *G. bispinosus* range have been the subject of development proposals including the enlargement of Cotter Dam, building of fishways on the Cotter River, upgraded road networks, dam maintenance or upgrades, and provision of recreational facilities or opportunities (jet-skis, fishing lodges, recreational fishing).

Bendora and Corin reservoirs contain viable populations of *G. Bispinosus.* Both reservoirs are managed by Icon Water. In planning terms, the primary purpose of the Cotter River Catchment is water supply, with conservation a secondary objective. Consequently, protection of *G. bispinosus* populations is tempered by water supply considerations. However, protection of threatened fish in the Cotter River Catchment remains a key issue. The ACT Government will liaise with Icon Water to ensure continued protection and management of *G. bispinosus* in the Cotter Catchment.

Harvest of *G. bispinosus* in the ACT without a licence is an offence under the Nature Conservation Act, and recreational fishing is completely prohibited on the Cotter Reservoir and inflowing Cotter River up to the junction with Condor Creek under the Fisheries Act. Bait fishing is prohibited in the Cotter River under the Fisheries Act. Recreational fishing is also prohibited in the waters of the Cotter River Catchment upstream of the Bendora Dam wall. *G. bispinosus* is not a significant target for recreational fishing, but might be taken as bycatch of illegal bait fishing for other species. Consequently, protection from angling take for *G. bispinosus* is likely to provide some benefits for the species and will remain a management activity under this action plan.

There may be opportunities to reconnect current or historic suitable habitats for this species. For example, the building of fishways at Vanitys Crossing and Pipeline Road Crossing were intended to ultimately link Cotter River reaches and native fish populations previously isolated by road crossings. When existing road crossings are upgraded or replaced, replacements will be designed to provide effective fish passage.

Management

Based on current knowledge of the habitat requirements and ecology of *G. bispinosus,*

management actions should aim to maintain riverine habitats with appropriate seasonal flow regimes, intact riparian zones with minimal sediment inputs from roads and surrounding land use, and an absence of alien fish species such as Redfin Perch and Carp. These actions will also protect other threatened fish species in the Cotter River.

Management of riparian zones will maintain organic matter contributions, which are the basic food supply for many stream invertebrates that form the majority of the diet of *G. bispinosus*. Intact riparian zones also provide shade, which buffers water temperatures, provides cover, prevents erosion and filters sediment from run-off. Minimising sediment addition will prevent smothering of the cobble and boulder substrates and will protect spawning and refuge habitat for the species.

Management and planning of prescribed burns, particularly those conducted in the Cotter Catchment, need to be carefully considered to avoid having an impact on threatened aquatic species. The aquatic ecology guidelines concerning the Bushfire Operations Plan (under the *Emergencies Act 2004*) are event-specific and included in the ecological guidelines that accompany the Bushfire Operations Plan.

Survey, monitoring and research

Further information about survey, monitoring and research is in Appendix 4.

Regular monitoring of the Cotter River to detect and act on *G. bispinosus* population trends should continue. Monitoring is currently undertaken to monitor the effects of environmental flows, the enlarged Cotter Dam and prescribed fires. Potential incursions or range expansions of alien fish are monitored as a consequence of these other programs.

Further research and adaptive management is required to better understand the habitat requirements for the species. Specific research priorities include:

- the susceptibility of the species to EHN virus
- impacts of fire management on populations
- the efficacy of environmental flow releases in maintaining recruitment of riverine and reservoir populations
- whether the establishment of a recruiting population in the Enlarged Cotter Reservoir occurs
- further development of genetic tests to investigate trout predation on *G. bispinosus*
- localised genetic structure and genetic viability
- investigation of techniques and the feasibility of rehabilitating and mitigating sedimentation of Paddys River with a view to population re-introduction
- lifetime movement patterns of *G. bispinosus* in the Cotter River
- microhabitat use during breeding season.

Engagement

As with any threatened species, the importance of information transfer to the community and people responsible for managing the species' habitat is critical. Actions include:

- provide advice on management of the species and maintain contact with land managers responsible for areas in which populations presently occur.
- ensure the guide to fishing in the ACT is understandable so that anglers understand not to target the species.
- ensure angling signage is up-to-date and placed in relevant areas.
- report on the monitoring of the species in the ACT Government's Conservation Research Unit's biennial report, which is distributed to a broader audience.
- liaise with other jurisdictions and departments to increase the profile of native fish conservation.

IMPLEMENTATION

Implementation of this action plan and the ACT Aquatic and Riparian Conservation Strategy will require:

- collaboration across many areas of the ACT Government to take into consideration the conservation of threatened species.
- allocation of adequate resources to undertake the actions specified in the strategy and action plan.
- liaison with other jurisdictions (particularly NSW) and other landholders (such as the National Capital Authority) with responsibility for the conservation of threatened species.
- collaboration with Icon Water, universities, CSIRO and other research institutions to facilitate and undertake required research.
- collaboration with non-government organisations to undertake on-ground actions.
- engagement with the community, where relevant, to assist with monitoring and other on-ground actions and to help raise community awareness of conservation issues.

With regard to implementation milestones for this action plan, in five years the Conservator will report to the Minister about the action plan and this report will be made publicly available. In ten years the ACT Scientific Committee must review the action plan.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1 Objectives, actions and indicators

Objective	Action	Indicator
1. Protect sites in the ACT where the species occurs.	1a. Apply formal measures (national park, nature reserve, water supply protected area) to protect the large population in the lower Cotter River.	1a. The lower Cotter population is protected in national park, nature reserve, or an area set aside specifically for conservation.
	1b. Maintain the protected status of the species within Namadgi National Park.	1b. Namadgi populations continue to be protected in the national park or nature reserve.
	1c. Protect populations from impacts of recreation, infrastructure works, water extraction and other potentially damaging activities using an appropriate legislative mechanism.	1c. Other populations are protected by appropriate measures (Conservator's directions, Conservation Lease or similar) from unintended impacts.
2. Conserve the species and its habitat through appropriate management.	2a. Monitor abundance of key populations and the effects of management actions.	2a. Trends in abundance are recorded for key populations and management actions. Populations are stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
	2b. Manage volumes, quality and timing of water releases from Corin and Bendora reservoirs to maintain an appropriate flow regime to conserve the species.	2b. Appropriate timing, volumes and water temperatures of water releases minimise sediment accumulation and thermal impacts to maintain appropriate riffle and pool habitat.
	2c. Maintain the integrity of the riparian vegetation and reduce erosion and sedimentation through appropriate land management (i.e. run-off, fire and weeds).	2c. Riparian zones are protected from impacts of erosion, sedimentation, prescribed burns, and invasive plants (e.g. Willows, Blackberries) are controlled.
	2d. Alien fish species are prevented from establishing and existing alien populations are managed where feasible to reduce impacts or population expansion.	2d. No new alien fish species establish in Cotter River. Existing alien fish populations are not expanding in abundance or distribution where *G. bispinosus* is present.
	2e. Impediments to fish passage are managed to minimise impacts on the populations through provision of fishways, flow management or trap and transport.	2e. Fish population sustainability is not impacted by barriers to fish movement.
	2f. Manage recreational fishing pressure to conserve the species.	2f. Appropriate recreational fishing management measures are in place and enforced to prevent deliberate or inadvertent harvest.

Objective	Action	Indicator
3. Increase habitat area and connect populations.	3. Manage aquatic habitats adjacent to *G. bispinosus* habitat to increase habitat area or habitat connectivity.	3. Aquatic habitats adjacent to, or linking, *G. bispinosus* habitat are managed to improve suitability for the species (indicated by an appropriate sedimentation and flow regime, absence of priority alien fish species, and fish passage).
4. Improve understanding of the species' ecology, habitat and threats.	4. Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species. Collaborate with other agencies/individuals involved in *G. bispinosus* conservation and management.	4. Research undertaken is reported and, where appropriate, applied to the conservation management of the species. Engagement and/or collaboration is undertaken with other agencies and individuals involved in *G. bispinosus* conservation and management (e.g. recovery teams, state agencies, universities).
5. Improve community awareness and support for *G. bispinosus* and freshwater fish conservation.	5. Produce materials or programs to engage and raise awareness of *G. bispinosus* and other freshwater fish threats and management actions.	5. Community awareness materials are produced and distributed.

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APPENDIX 1: SPECIES ECOLOGY—HISTORICAL AND NSW DISTRIBUTION

Species description

Similar to all blackfish species, the pelvic fins of *Gadopsis bispinosus* have been reduced to a pair of fine, white, divided filaments located under the throat. The dorsal and anal fins are low and long, with the dorsal reaching almost to the tail. The outer edges of the dorsal, anal and caudal fins are pale or white and are often bordered by an intense dark stripe. The mouth is large, with fleshy lips, with the upper jaw overhanging the lower. The tail is rounded and the dorsal fin has from 1 to 3 but usually 2 spines. The body is covered in very small scales with a thick mucous coating. The species is not sexually dimorphic, but in gravid females the large orangeish eggs can be seen through the semi-transparent body wall (Lintermans 2007).

Historical and NSW *Gadopsis bispinosus* distributions

Blackfish (of unknown species) were reported to be historically present in Paddys River and possibly the Gudgenby and Orroral rivers based on angler interviews summarised in Greenham (1981). The presence of blackfish (presumably *G. bispinosus*) in the 1950s in the Paddys River was confirmed by P.S. Lake (Lake pers. comm. to M. Lintermans).

In the broader Canberra region, *G. bispinosus* has also been recorded as viable populations from three other locations:

- A population of unknown size in the Goodradigbee valley (Lintermans 2002).
- A population of unknown size in the Goobarragandra River valley (Lintermans 1998).
- A population of variable abundance in the Mountain Creek drainage flowing into Lake Burrinjuck (Lintermans 2002).

Populations that have declined substantially since the late 1990s and early 2000s or may not be present or viable remnant population in the upper Murrumbidgee River between Tantangara Dam and Yaouk (Lintermans unpublished data).

Further species ecological information

In streams the species is commonly found in pools, runs and riffles as long as suitable cobble substrate is present. *G. bispinosus* has also been recorded using inundated riparian vegetation during high-flow (Broadhurst et al. 2011). In reservoirs rock, fallen timber and macrophytes have been found to be the most commonly used daytime shelter habitat (in order of preference) (Broadhurst et al. 2012).

Home ranges in rivers are maintained from year to year, with fish thought to avoid the high velocity winter flows by sheltering amongst the rocks and boulders on the stream bed. A radio-tracking study in Bendora Reservoir found that adults displayed two movement strategies: movements from diurnal home-shelter habitats (predominantly rock) to macrophytes at night, and occupation of macrophytes during the entire 24 hour period and restricted movement (Broadhurst et al. 2012).

The species will lay eggs inside PVC pipes (spawning tubes) placed into streams (Lintermans 1998). In spawning tubes it is thought that all eggs are released at once and that each egg mass is from a single female (Lintermans 1998). The eggs are large (~3.5 mm diameter), yolky and adhesive, and are guarded by the male fish until the larvae have almost fully exhausted the yolk reserves and are free-swimming. Hatching occurs after approximately 16 days at a water temperature of 15°C, with the large yolk sac remaining inside the ruptured egg membrane, effectively tethering the young to the spawning substrate until the yolk has been consumed (Lintermans 1998). The larva

have almost fully consumed the yolk after approximately three weeks and then leave the spawning site, with the male guard fish also leaving.

APPENDIX 2: PAST MANAGEMENT AND RESEARCH ACTIONS

During the 1997–2010 millennium drought, flows in the Cotter River downstream of Bendora Dam were greatly reduced. It was feared that lower flows would result in sediment accumulation in riffles and pools—critical spawning habitat for *G. bispinosus*. Consequently the environmental flow releases from Bendora were modified to both maintain riffle quality prior to the spring spawning season and during the summer larval growth period. The capacity of the Bendora Dam valves (~300 ML/day) is insufficient to provide pool-scouring flows (approximately 550 ML/day is required to move fine sediment in pools), but provision was made to piggyback environmental releases on natural flows should river flow reach 250 ML/day. Similarly, following severe bushfires in 2003 in the Canberra region, there was significant erosion and sedimentation of streams, particularly in the Cotter River (Carey et al. 2003). Again, concern over the condition of riffles resulted in environmental water releases to maintain riffles in suitable condition to protect spawning in both *G. bispinosus* and *Macquaria australasica* (Macquarie Perch).

A review of Canberra's water supply options resulted in the construction of an enlarged Cotter Reservoir between 2008 and 2013. As the enlarged reservoir would potentially impact threatened fish species, including the inundation of approximately of ~4.5 kilometres of the Cotter River containing *G. bispinosus*, a suite of research and management actions was undertaken that represented a significant investment in knowledge generation and mitigation activities for this species and with *M. australasica*. Projects relevant to *G. bispinosus* included:

- the identification of risks and benefits to fish populations of various enlargement options (Lintermans 2005, 2012)
- an investigation of the movement patterns and habitat use of a reservoir population of *G. bispinosus* in Bendora Reservoir (Broadhurst et al. 2012)
- the sterilisation between the old and new dam walls to prevent transfer of EHN virus
- the construction of 7 km of rock reef shelter habitat in the new ECD reservoir inundation zone (Lintermans et al. 2010)
- the establishment of an ongoing comprehensive monitoring program for threatened and alien fish in the reservoir and the river upstream (Broadhurst et al. 2015)
- the investigation of potential need and design of translocation programs for a range of threatened fish including *G. bispinosus* (Lintermans 2013c)
- preparation of a blackfish population model to predict the potential impacts of loss of spawning habitat and increased trout predation following the construction of the enlarged Cotter dam (Lintermans 2013bc)
- the preparation of a series of fish management plans for Cotter Reservoir spanning from planning to operational phases (e.g. ACTEW Corporation 2013).

Other research conducted in the 2000s includes the movement response of a range of fish species (including *G. bispinosus*) to environmental flow releases (Ebner et al. 2008, Broadhurst et al. 2011), the impacts of cold water pollution on *G. bispinosus* (Hall 2005), genetic population structure (Beitzel 2002) and the diel behaviour of small individuals of *G. bispinosus* and *M. australasica* in the Cotter River (Ebner et al. 2009). In 2013 research confirmed that *G. bispinosus* spawns slightly

earlier in the lower Cotter River (below Bendora Dam) than in the upper Cotter River (Dennis et al. 2013).

APPENDIX 3: THREATS—FURTHER INFORMATION

Overfishing

Overfishing has been shown to be important in the decline of other native fish species such as Trout Cod (*Maccullochella macquariensis*) (Berra 1974) and Murray Cod (*M. peelii*) (Rowland 1989), but is unlikely to have played a significant role in the decline of *Gadopsis bispinosus* or to be a factor that may hinder recovery in this species. *G. bispinosus* is a relatively small species (generally less than 100 g in weight) and is not targeted as a recreational angling species. Although the species can no longer be legally retained in the ACT, *G. bispinosus* is occasionally taken by illegal bait-fishing in the Cotter Catchment, and can be difficult to release alive after accidental hooking (Lintermans unpublished data).

Sedimentation following the January 2003 bushfires in the ACT smothered submerged macrophyte beds in the Cotter River Catchment and contributed large volumes of fine and coarse material, filling pools and blanketing riffles (Starr 2003, Carey et al. 2003, Wasson et al. 2003). *G. bispinosus* in the lower reaches of the Cotter River that were affected by sedimentation from 2003 bushfires were not found to recover until 2007 and it was not until 2010 that juveniles were caught, indicating successful spawning (Beitzel et al. 2012). The recovery of the species in the lower reaches of the Cotter Catchment after 2003 is attributed to the management of environmental flows during the drought and the sedimentation control and improved land management in the lower Cotter Catchment.

Point source (e.g. such as discharges from industries and sewerage works) or diffuse (e.g. agricultural chemicals) input of pollutants can also have significant impacts, although these are minimal on the Cotter River where *G. bispinosus* occurs.

In the Cotter River altered thermal regimes were predicted for 20 kilometres downstream of Bendora Dam (at flows 86 ML/day) (Rutherford et al. 2009).

Alien species

Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) were introduced to the Canberra region in the late 1800s. The diets of *G. bispinosus* and the alien trout species are similar and competition is likely (Jackson 1981, Lintermans 1998). Trout are also known to prey upon *G. bispinosus* juveniles, sub-adults and adults (Lintermans 1998, unpublished data, Lintermans et al. 2013, ACT Government unpublished data). Other introduced fish species likely had historic dietary overlap with *G. bispinosus* but few currently occur in the same geographic area as the species.

A major impact of alien species is the introduction or spread of diseases and parasites to native fish species. Epizootic Haematopoietic Necrosis Virus (EHNV), unique to Australia and currently apparently endemic to the upper Murrumbidgee, was first isolated in 1985 on Redfin Perch (Langdon et al. 1986). It is characterised by sudden high mortalities of fish displaying necrosis of the renal haematopoietic tissue, liver, spleen and pancreas (Langdon and Humphrey 1987). The virus is absent from the Cotter River upstream of the enlarged dam (Whittington 2011) but the potential for the virus to be introduced through contaminated fishing gear or illegal movement of Redfin Perch is high (Lintermans 2012). Experimental work has demonstrated that a number of native fish species are susceptible to the disease (Langdon 1989b, Becker et al. 2013), but the susceptibility of *G. bispinosus* is unknown.

Cyprinus carpio or *Perca fluviatilis* are considered to be the source of the Australian populations of the parasitic copepod *Lernaea cyprinacea* (Langdon 1989a) and Carp, Goldfish or Eastern Gambusia are probably implicated as the source of the introduced tapeworm *Bothriocephalus acheilognathi,* which has recently been recorded in native fish (Dove et al. 1997). This tapeworm causes widespread mortality in juvenile fish overseas. Both *Lernaea* and *Bothriocephalus* have been recorded from native fish species in the Canberra region, with *Lernaea* commonly recorded on *G. bispinosus* in the Cotter Reservoir. The Oriental Weatherloach is recorded as hosting a number of parasites not native to Australia (Dove 1997, Dove and Ernst 1998), but it is unknown whether these can infect *G. bispinosus*.

Changing climate

The uplands of the ACT (above ~500 m elevation) are generally characterised by seasonal rainfall patterns with maximum precipitation in winter–spring and maximum stream flow in spring. In part of the uplands, winter precipitation may comprise significant quantities of snowfall, followed by spring snowmelt. By 2090, the number of days above 35°C in Canberra more than doubles under the Representative Concentration Pathways 4.5 (RCPs) used by the Intergovernmental Panel on Climate Change (IPCC) and median warming, and the number of days over 40°C more than triples (Timbal et al. 2015), with associated impacts on summer–autumn water temperature. Similarly, by 2090 the average number of frosts is expected to fall (Hennessy et al. 2003, Timbal et al. 2015).

2003 fire impacts

In 2003 bushfires burnt 70% of the ACT including 90% of Namadgi National Park (Cotter, Gudgenby, Naas rivers) and Tidbinbilla Nature Reserve (Tidbinbilla River) (Carey et al. 2003).

Studies on the Cotter River have shown that river regulation has exacerbated the effects of the fires and sediment addition. A North American study documented increases in summer water temperatures of 8–10ºC following fire, due to the increased light reaching streams as a result of the removal of riparian vegetation (Minshall et al. 1989, Malison and Baxter 2010). Almost 840 kilometres of streamside vegetation was burnt in 2003 with only 31% of stream length likely to have retained its riparian canopy cover (Carey et al. 2003), with the loss of riparian zones likely resulting in increased stream temperature.

Significant erosion and sediment input to the Cotter River and tributaries occurred following the fires (Starr 2003, Wasson et al. 2003, Ogden et al. 2004) and even though water turbidity levels can recover relatively rapidly (Harrison et al. 2014), coarser sediment addition can significantly change fish habitats in the long term as pools become in-filled with gravels and cobbles.

APPENDIX 4: MONITORING AND RESEARCH—FURTHER INFORMATION

There has been considerable research, survey and monitoring directed at *Gadopsis bispinosus* over the last 25 years, resulting in a significant number of on-ground recovery actions (Lintermans 2013b). There is a relatively good understanding of the species' distribution, ecology and relative abundance within the ACT, with a number of research theses aimed at the species (Lintermans 1998, Beitzel 2002) and ongoing annual monitoring of the species within the Cotter Catchment (both Cotter Reservoir and riverine sites) undertaken by the ACT Government since 2001 and the University of Canberra since 2010.

Past and present survey and monitoring work in the Cotter River Catchment has demonstrated the broad distributional range of the species (Lintermans and Rutzou 1990) and its response

to environmental flow releases, fire management, and inundation by the enlarged Cotter Reservoir (e.g. Lintermans 2001, Beitzel et al. 2010, 2013, 2016, Lintermans et al. 2013, Broadhurst et al. 2015). Such monitoring programs are essential to understand the likely impacts of management interventions and should continue.