ACT AQUATIC AND RIPARIAN CONSERVATION STRATEGY AND ACTION PLANS

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COMMON TERMS IN THE TEXT REQUIRING CLARIFICATION

Alien species: species that do not belong to the ecosystems in which they are found. The expression 'alien species' is often used in the same way with other terms including exotic, introduced, feral, non-indigenous, non-native or invasive. For the present strategy, an alien species is one not native to the ecosystem under consideration such that the species could have originated from outside Australia or from another region within Australia. The term 'alien' may also be used with other terms (e.g. an alien species may or may not be invasive or a pest). The term alien refers to both plants and animals.

Introduced species: An introduced species (alien species, exotic species, non-indigenous species, or non-native species) is a species living outside its natural distributional range, which has arrived there by human activity, either deliberate or accidental. Non-native species can have various effects on the local ecosystem. Introduced species that become established and spread beyond the place of introduction are called invasive species. The impact of introduced species is highly variable. Some have a negative effect on a local ecosystem, while other introduced species may have no negative effect or only minor impact. (https://en.wikipedia.org/wiki/Introduced_species)

Invasive species: naturalised plants or animals that produce reproductive offspring and may threaten biodiversity and have impact on the environment, economy or human health.

Native or indigenous species: a species found in a particular ecosystem because of natural processes, such as natural distribution and evolution. No human intervention brought the species to the area or influenced its spread to that area. A native or indigenous species is adapted to the habitat where it naturally occurs.

Pest: the concept of a pest is used in the present strategy to describe a plant or animal species, usually alien, that has had a negative impact on the native ecosystem or is unwanted in that ecosystem.

Weed: A weed is any plant that requires some form of action to reduce its negative effect on the economy, the environment, human health and amenity. Weeds are also known as invasive plants. For the purposes of this strategy, invasive plants will generally be referred to as weeds.

PART A

AQUATIC AND RIPARIAN CONSERVATION STRATEGY

VISION

‘Healthy waterways supporting diverse aquatic and riparian flora and fauna, and providing high quality ecosystem services’

Rivers and their ‘riparian’ edges are critical to human health and well-being, the sustainability of our city and nature conservation. Rivers, lakes, wetlands and aquifers are critical habitat for many native plants and animals, provide water for human consumption and are sought out as aesthetically beautiful places. Rivers provide important conduits and connectivity in the landscape for people, plants and animals.

Conservation, protection and rehabilitation of our waterways and riparian areas is essential for the survival of threatened species, maintenance of ecosystems and their services, and provision of recreational opportunities. It is vital to conserve these valuable areas for now and the future.

This Aquatic and Riparian Conservation Strategy focuses on non-urban rivers and riparian zones (see section 1.5) and aims to build on the successful management of ACT waterways undertaken since the original 2007 ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007). A number of advances have been made since the original strategy including the revision of legislation to protect threatened species and habitats, development of management and rehabilitation plans, implementation of on-ground conservation management actions and the completion of extensive research, survey and monitoring.

This revised strategy builds on these considerable achievements across the ACT by providing updated guidance for the conservation and management of aquatic and riparian ecosystems. It addresses current and future issues, such as a changing climate, and focuses on best practice conservation in an adaptive management framework.

The waterways and riparian areas of the ACT are fundamentally important components of our landscape. It is vital to conserve these areas for now and the future.

The ACT Government acknowledges the Ngunnawal people as Traditional Custodians of the ACT. The Ngunnawal people continue to have a strong connection to culture and Country as their ancestors did, with evidence indicating Aboriginals camped at the Birragai Rock Shelter at least 25,000 years ago. The ACT region is significant to other Aboriginal Nations with strong cultural connections to the area, including the Wolgalu, Ngarigu, Gundungurra, Ngambri and Yuin. Ngunnawal Country comprises the northern end of the Australian Alps, where many ceremonies were conducted, and is part of the Murray–Darling Basin, a traditional pathway to neighbouring Aboriginal nations.

1 INTRODUCTION

Angler fly fishing on the Cotter River. Photo: M. Jekabsons, ACT Government

1.1 OVERVIEW

The ACT Aquatic and Riparian Conservation Strategy (the strategy) provides guidance on the conservation of aquatic and riparian areas and component species in the ACT, consistent with the ACT Nature Conservation Strategy 2013–23 (ACT Government 2013a). Relatively large areas of aquatic and riparian ecosystems in the ACT are already protected within reserves, so the emphasis of this strategy is on management and enhancement of these systems, particularly where threatened species occur. This includes managing threats, maintaining and improving ecological connectivity, ecosystem function and biodiversity, undertaking monitoring and research programs, and partnering with the community to support aquatic and riparian conservation. This management and enhancement aims to increase resilience of aquatic and riparian areas to damaging disturbance and climate change.

1.2 OBJECTIVES

This document provides the strategic context for the protection, management and rehabilitation of aquatic and riparian non-urban areas in the ACT. Specifically, the objectives are to:

- provide conservation management guidelines for the protection and enhancement of aquatic and riparian areas
- identify threats to aquatic and riparian ecosystems and provide guidelines for their management
- provide monitoring and research objectives for aquatic and riparian areas in the ACT
- outline strategies to increase engagement of the community in aquatic and riparian activities and projects
- set the strategic context for action plans for threatened aquatic and riparian flora and fauna.

This strategy is intended to be a reference document on aquatic and riparian areas for ACT and Australian government agencies with responsibilities for nature conservation, planning and land management, and for community and other stakeholders with an interest in aquatic and riparian area conservation.

The 2007 Aquatic Species and Riparian Zone Conservation Strategy was highly successful in bringing together key stakeholders, ACT Government and the Australian Government to achieve conservation of the aquatic and riparian ecosystem. A summary of its successful outcomes is in section 7.5. This strategy reviews and builds on work completed for the 2007 strategy. The 2007 strategy contains a large amount of background information about these ecosystems in the ACT. Where necessary, this information has been summarised and used in this strategy.

This strategy is an overarching document that draws together information and provides guidance for the management and conservation of aquatic and riparian species, and their habitat, across a range of ecosystems identified in the scope (section 1.5).

1.3 ECOSYSTEM MANAGEMENT APPROACH

Effective ecosystem management relies on careful consideration of the outcomes for which an ecosystem is being managed. In the context of this strategy, management is for the conservation of aquatic and riparian ecosystems set out in section 1.5. Determining the key components of these ecosystems provides focal points to guide conservation management activities.

Key components of aquatic and riparian ecosystems include:

- water flows (quantity and timing)
- water quality
- habitat
- biota
- connectivity (largely a function of the four components above)
- people.

The condition of these components (see section 7.3) will determine whether management intervention is necessary or, where action has been taken, achieving desired objectives. All these components are also influenced by overarching and large-scale drivers, including climate and geology, which are less amenable to intervention.

Where conservation management interventions are required, the guidelines provided in this strategy are designed to protect or improve the condition of existing ecosystems by targeting the key components.

1.4 DEFINITION OF AQUATIC AND RIPARIAN AREAS

For the purposes of the strategy, an aquatic area is defined as a water course that is covered permanently or intermittently by water and includes the water in the channel, substrate, and plants and animals that are completely or substantially dependent on being covered by water. It also includes the habitat for these plants and animals.

The riparian zone is considered to be any land that adjoins, directly influences or is influenced by a body of water (Land and Water Resources Research and Development Corporation 1998). Specifically for this strategy, the riparian zone is an area of terrestrial land that affects, and is affected by, flowing water of the adjacent waterbody. This land tends to consist of landforms that are caused by river processes and may contain vegetation communities that are characteristic of areas affected by the hydrology of an adjacent waterbody. Further discussion of riparian zone definitions can be found in Appendix 0.

The strategy discusses aquatic and riparian areas, being the land and water covered by both of those ecosystems. When the riparian zone is referred to, that zone alone is being considered.

1.5 SCOPE OF THE STRATEGY

This Aquatic and Riparian Conservation Strategy primarily considers natural water bodies and takes a Territory-wide approach within a regional context for the protection and management of the surface waters of the Murrumbidgee, Molonglo and Cotter rivers, their tributaries and riparian zones and associated native flora and fauna (Figures 1.2 and 1.3).

The strategy does not include the Queanbeyan River, which is almost entirely in New South Wales, though reference is made to it, including the section upstream of Googong Reservoir with regard to threatened fish species. Tuggeranong, Weston, Yarralumla, Sullivans, Woolshed, Jerrabomberra and Ginninderra creeks are also not included. Woolshed and Jerrabomberra creeks have substantial rural catchments, but are now mainly within or adjacent to the Canberra urban area. Their riparian zones are part of the urban open space network. The Cotter, Paddys, Ororral, Naas and Gudgenby rivers, which are partly protected in Namadgi National Park, are included in this strategy. Other smaller streams in higher altitude and montane areas of the ACT that are also protected within Namadgi National Park are not specifically mentioned in this strategy, although strategies and management guidelines discussed in this strategy are relevant to these smaller waterways. The geographic scope of the present strategy is almost identical to the 2007 strategy.

Similar to the 2007 strategy, this strategy does not cover wetlands. Plans of management have been written for significant wetlands, including Ginini Flats Ramsar Wetlands (ACT Government 2016g) and Jerrabomberra Wetlands (ACT Government 2010a). Many other ACT wetlands are within Namadgi National Park (ACT Government 2010b) and/or covered by a bogs and fens recovery plan (DOE 2014). The strategy also omits riparian zones surrounding artificial lakes, large floodplain areas or substantially modified urban water courses. The water supply reservoirs of the Cotter River are, however, considered as they contain threatened species.

Unlike the 2007 strategy, action plans for aquatic and riparian species declared as threatened under the *Nature Conservation Act 2014* (ACT) (View the Act (PDF, 952Kb)), are appended to the strategy as stand-alone documents (see also section 1.8). Action plans for six aquatic animals and two riparian plant species are included (Table 1.1).

Although not declared threatened in the ACT, the strategy includes consideration of Murray Cod (*Maccullochella peelii*), which is declared threatened under Commonwealth legislation (see Table 7.5). The species has special protection status under the Nature Conservation Act because it is listed under the Comonwealth *Environment Protection and Biodiversity Act 1999* and consequently no species action plan has been prepared. The Painted Honeyeater (*Grantiella picta*), a nationally threatened species recorded near the Murrumbidgee River, is omitted from the strategy as this species is included in the ACT Lowland Woodland Conservation Strategy (ACT Government 2016f). The Pink-tailed Worm-lizard (*Aprasia parapulchella*) is not considered under this strategy as the species occurs principally on the slopes above the riparian zone. A separate action plan for *A. parapulchella* is available online (ACT Government 1999c, 2016j).

As well as listed threatened species, the strategy is concerned with the conservation of aquatic fauna more generally, for example, Platypus (*Ornithorhynchus anatinus*), Eastern Water Rat (*Hydromys chrysogaster*), Montane Spiny Crayfish (*Euastacus* spp.), Mountain Galaxias (*Galaxias olidus*), Eastern Snake-necked Turtle (*Chelodina longicollis*), and the maintenance and improvement of aquatic habitat utilised by all fish, invertebrates, mammals, birds, reptiles and frogs (see Lintermans and Osborne 2002 for species). Further discussion of threatened, uncommon and rare species can be found in sections 7.3.2 and 1.1.1.

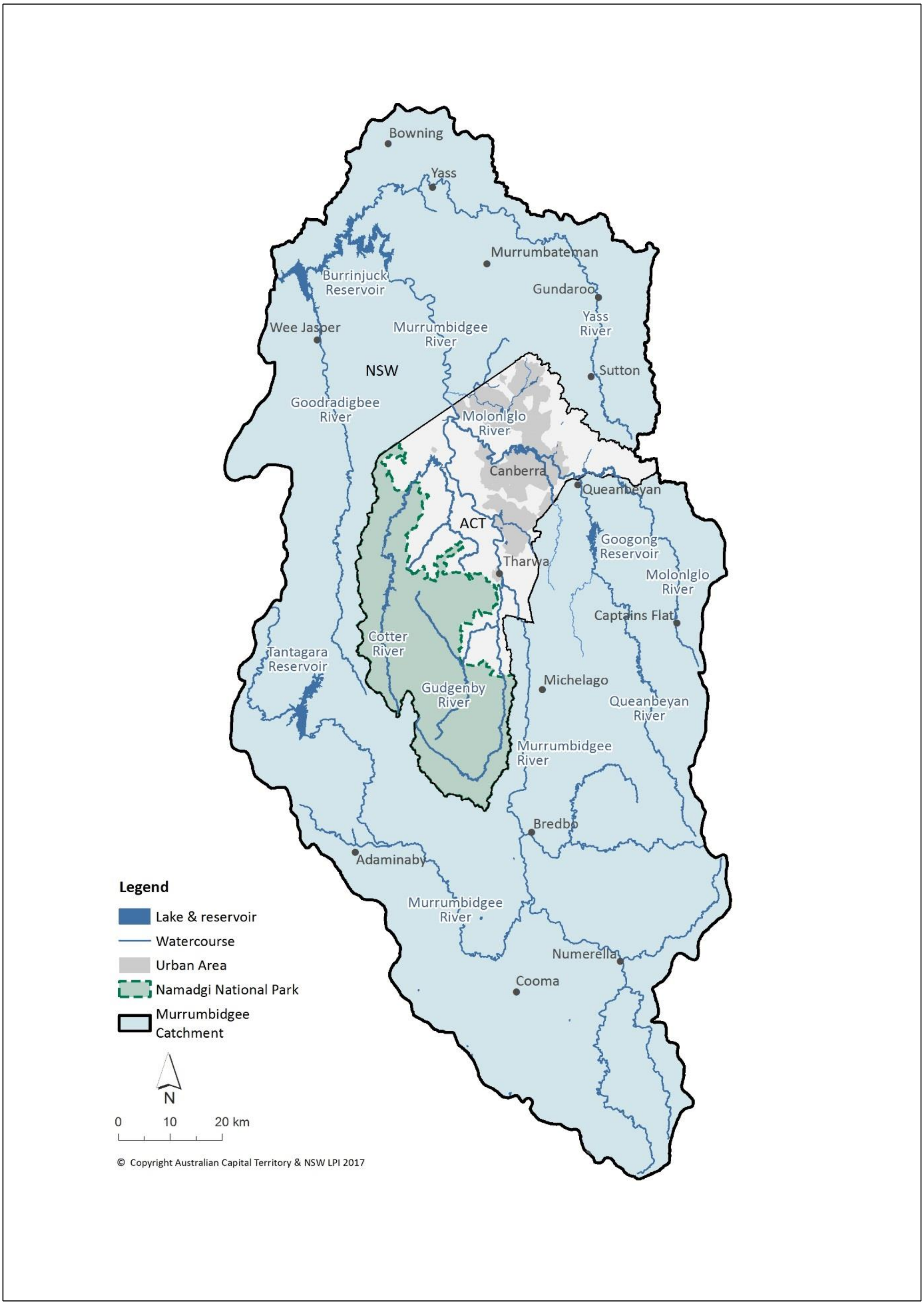

Figure 1.1 Upper Murrumbidgee River Catchment showing major waterways and urban areas.

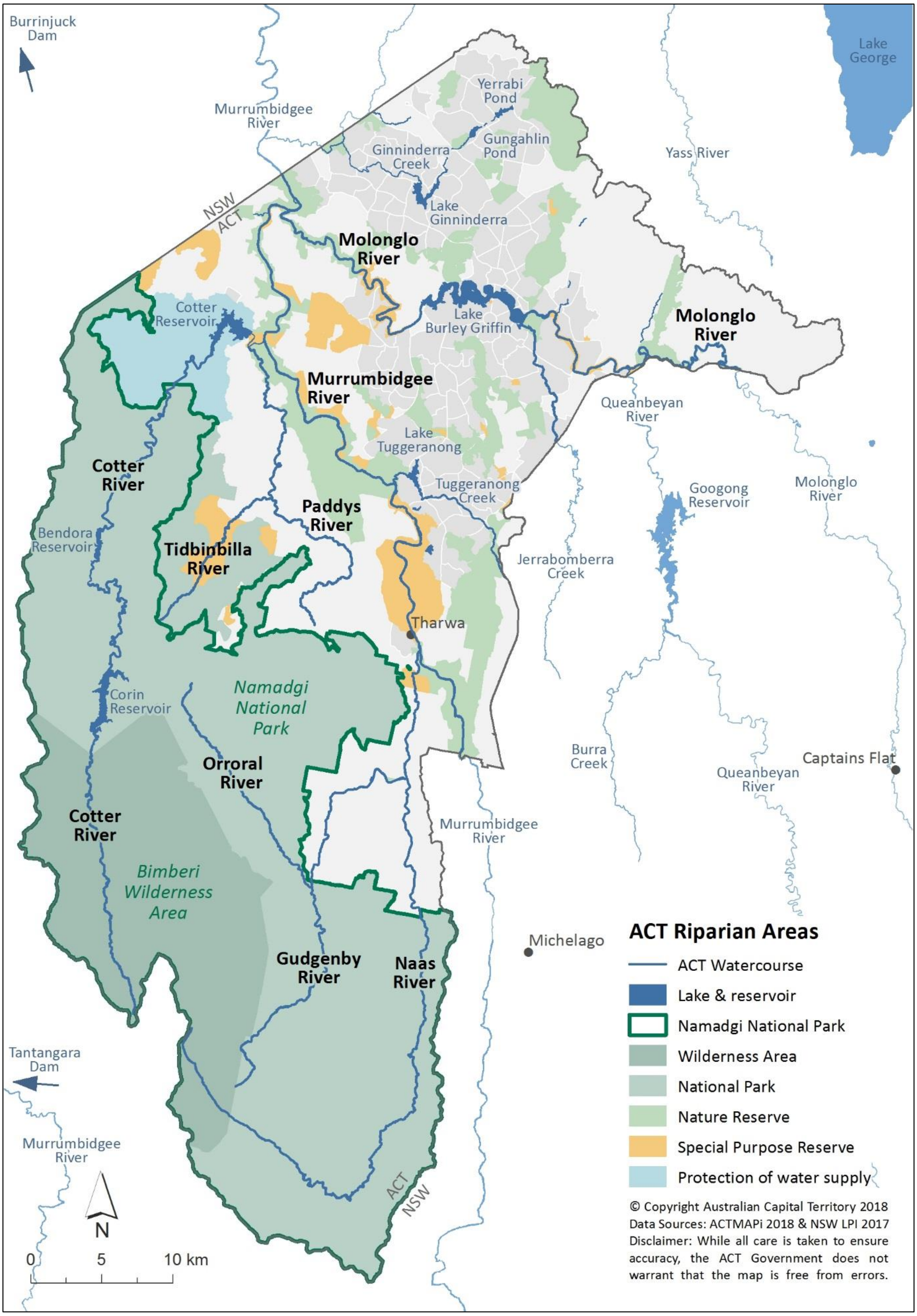

Figure 1.2 ACT rivers considered in this Aquatic and Riparian Conservation Strategy. The streams considered in this strategy are named in black font.

1.6 STRUCTURE OF THE STRATEGY

This document is divided into five main sections—protection, threats, management, research and monitoring, and community engagement—with associated key principles and management guidelines. The chapters provide guidance on:

Chapter 1: Relevant definitions, objectives and scope of the strategy, legislation and policy applying to nature conservation, and the links between the strategy and associated action plans.

Chapter 2: Protection of aquatic and riparian areas and component species as well as related protection goals and guidelines.

Chapter 3: Reduction of threats to aquatic and riparian biodiversity. Examination of primary threats to ecosystem structure and function within aquatic and riparian systems including water extraction, barriers, poor water quality, weed infestation, pest animals, introduced diseases, urbanisation and a changing climate. Provides guidelines for managing and minimising the potential impacts of these threats.

Chapter 4: Management of aquatic and riparian areas and component species for conservation using adaptive management principles.

Chapter 5: Monitoring, research and baseline data collection for aquatic and riparian areas and component species. The chapter also provides an overview of the recently developed Conservation Effectiveness Monitoring Program.

Chapter 6: Engagement with the community in aquatic and riparian conservation by increasing awareness, supporting and promoting citizen science and engaging with local indigenous communities on traditional ecological knowledge.

Chapter 7: Background information on aquatic and riparian areas relevant to their conservation, including the history of land use, distribution and component species. The current condition of ecosystems, communities and species is set out as well as the potential future effects of climate change. Outlines the conservation measures carried out over the last decade and the evidence base for the strategy.

1.7 LINKS BETWEEN THE STRATEGY AND ACTION PLANS

This ACT Aquatic and Riparian Conservation Strategy (Part A) provides overarching conservation goals and principles on which to base the actions in threatened species action plans. It provides a framework for planning and prioritising actions across aquatic and riparian areas in the ACT, including actions for sites where there are multiple threatened species and multiple conservation objectives. Action plans (Part B) provide guidance for undertaking actions to benefit individual threatened species. Many of the generalised management guidelines from the strategy are reflected in specific goals or actions in the action plans.

1.7.1 Development, implementation and review of action plans

Action plans have been developed and implemented for all threatened species found in the aquatic and riparian areas of the ACT.

Reviews of action plans included in the 2007 strategy were undertaken and assessed by the ACT Scientific Committee[1] (a statutory committee under the Nature Conservation Act). This process informed the development of updated actions plans. These action plans will be reviewed by the Scientific Committee after five years, then reviewed and updated after 10 years. The Committee's assessment will be based on objectives and performance indicators set out in the action plans aswell as progress that can reasonably be expected within the review timeframe. Review of species action plans is also the primary means for assessing progress towards the goals of this strategy.

The ACT Government will continue to develop and implement action plans (or conservation advice where appropriate) for threatened species and will regularly review progress in achieving their conservation objectives.

1.8 RELEVANT LEGISLATION AND POLICY

1.8.1 International and national context

Management of threatened species and ecological communities is guided by international, national and ACT agreements, policy and laws.

The United Nations Convention on Biological Diversity is an international legal instrument for the conservation and sustainable use of biological diversity. Australia ratified the Convention in 1993 and, in line with the Convention, prepared the *National Strategy for the Conservation of Australia's Biological Diversity* (1996). This strategy was reviewed and replaced by *Australia's Biodiversity Conservation Strategy 2010–2030* (National Biodiversity Strategy Review Task Group 2010) and the *Strategy for Australia's National Reserve System 2009–2030* (National Reserve System Task Group 2010), which provide frameworks for protecting biological diversity and maintaining ecological processes and systems.

The International Union for the Conservation of Nature (IUCN) establishes criteria for assessing the conservation status of species. Assessment of species in the ACT by the Scientific Committee is now generally consistent with the IUCN criteria and conservation categories.

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the protection of 'matters of national environmental significance' (MNES) and includes criteria for environmental impact assessment. Five of the threatened aquatic and riparian flora and fauna included in this strategy are listed as MNES.

1.8.2 ACT legislation

The *Nature Conservation Act 2014* provides for the protection and management of native plants and animals in the ACT and the identification and management of threatened species and ecological communities. Under the Act, a nature conservation strategy (ACT Government 2013a) must be prepared and implemented. The Act outlines the processes for developing action plans for listed species and ecological communities, and creates key statutory positions: the Conservator of Flora and Fauna, Conservation Officers and the Parks and Conservation Service. The Act also specifies that updates to action plans for threatened species and ecological communities must explicitly

[1] The Scientific Committee (SC) is established under the Nature Conservation Act 2014. The SC has the responsibility to assess the conservation status of nominated species of flora and fauna and ecological communities in the ACT region and the ecological significance of nominated threatening processes. The SC makes recommendations to the Minister for the Environment and Heritage for the listing and management of threatened species according to the level of threat and listing of key threatening processes. The SC reviews action plans every 10 years. It also provides advice to the Minister and to the Conservator of Flora and Fauna in relation to nature conservation issues in the ACT region.

consider the implications of climate change (see 1.8.3).

The *Fisheries Act 2000* is the primary legislation for the regulation of fishing activities in the ACT's public waterways. The Act provides the framework for sustaining and protecting native fish species and providing high quality fishing opportunities in the ACT. The Act also has provision for listing conservation management areas, such as the Gigerline Gorge angling exclusion zone.

The Fisheries Act protects some species from being taken and prescribes bag limits, allowable take lengths and closed angling seasons for species such as Murray Cod (September to November). There are also restrictions on the number of lines that can be used and types of fish and nets, restrictions on the type of bait used, prohibition of fish translocations, and a requirement to return protected fish to the water unharmed.

There is no requirement for a fishing licence in the ACT but fishing in Googong Reservoir is controlled by the NSW Department of Primary Industries and a NSW recreational freshwater fishing licence is required to fish there.

The *Animal Welfare Act 1992* promotes vertebrate animal welfare and controls activities that impose suffering on animals. The Animal Welfare Advisory Committee provides advice to the Minister about animal welfare matters.

The *Environment Protection Act 1997* provides protection for the environment from pollution and other forms of environmental harm. The Act sets water quality guidelines and establishes the Environment Protection Authority.

The *Water Resources Act 2007* provides for the management and use of the water resources of the Territory to sustain the physical, economic and social well-being of the people of the ACT while protecting the ecosystems that depend on those resources. The Act also aims to protect aquatic ecosystems and aquifers from damage and, where practicable, to reverse damage that has already occurred and to ensure that water resources can meet the needs of future generations. The Environmental Flow Guidelines (ACT Government 2013c), a statutory instrument established under the Act, specify the flows required to maintain aquatic ecosystems in the ACT in terms of surface and groundwater. The guidelines are reviewed every five years.

The *Pest Plants and Animals Act 2005* aims to protect the ACT's land and aquatic resources from threats by pest plants and animals and promote strategic pest management.

The *Emergencies Act 2004* requires the development of a Strategic Bushfire Management Plan to guide management for the reduction of risk from fire in the ACT.

The *Human Rights Act 2004* outlines the obligations on public authorities to act and make decisions compatible with human rights, including the cultural rights of Aboriginals and Torres Straight Islanders.

The *Heritage Act 2004* establishes a system for the recognition, registration and conservation of natural and cultural heritage places and values in the ACT. The ACT Heritage Register identifies heritage sites that might be impacted by proposed activities or development works. The Heritage Act also provides for the preparation of conservation management plans and guidelines for the protection of sites of heritage significance.

The *Australian Capital Territory (Planning and Land Management) Act 1988* provides for two categories of land in the ACT: National Land used by or on behalf of the Commonwealth and managed by the Commonwealth, and Territory Land which is all the remaining land of the ACT. The ACT Government manages this land on behalf of the Commonwealth. All the land included in this strategy is Territory Land.

The National Capital Plan (National Capital Authority 2016) prescribes broad land use controls across the whole of the Territory. At its most detailed level, the plan sets out conditions for planning, design and development of those areas (termed 'Designated Areas') identified as having the special characteristics of the National Capital. Planning for areas that are not Designated Areas is the responsibility of the ACT Government. Planning policies are set out in the Territory Plan (ACT Government 2008).

The National Capital Plan contains 'Special Requirements' for the Murrumbidgee and Molonglo River Corridors (National Capital Authority 2014) and includes information on planning for the National Capital Open Space System and the river corridors. This strategy accords with these principles, policies and special requirements.

The *Planning and Development Act 2007* is the ACT legislation that determines decisions about land use planning and the balance between nature conservation and development. It establishes the Territory Plan and makes provisions for the reservation and management of land for nature conservation purposes. This has led to more than 60% of the ACT being set aside in formal conservation reserves, protecting significant areas of conservation value.

The Planning and Development Act provides for environmental impact statements and strategic assessment processes. The Act provides for the use of environmental offsets to address the residual impacts of development where threatened species and ecosystems are impacted. The approach to offsets in the ACT, and nationally, is to avoid impacts wherever possible by, for example, setting aside lands for conservation, mitigating impacts such as avoiding construction within breeding seasons, and providing offsets for any significant residual impacts.

The ACT Planning Strategy provides the broader planning framework through which nature conservation and development needs can be met in a sustainable city. Ecologically sensitive planning approaches, such as urban intensification, will allow for continued urban and economic growth that does not unduly impact upon nature conservation. The Territory Plan contains detailed land use policies for the ACT. The following policies are particularly relevant to this strategy:

Territory Plan Part B13: River Corridors Land Use Policies

Conservation of natural and cultural resources is the primary goal in a system in which recreation is the major use. The policy sets out objectives and controls. The controls cover permitted land uses, land use restrictions, special conditions for environmental protection, recreation development, development conditions, public access and trails and fire protection.

Territory Plan Appendix 1: Water Use and Catchment Policies

Due to competing and often conflicting demands for water resources and past alteration of water quality, it is necessary to allocate waters of the ACT in proportion to particular water uses and protected environmental values. This process necessitates identification of the water quality and stream flow criteria for those uses and full protection of the values.

These and other Territory Plan policies provide the statutory planning framework for the achievement of many of the objectives of this strategy.

For more information, visit the ACT legislation website.

1.8.3 ACT policy on nature conservation and climate adaptation

The ACT Nature Conservation Strategy 2013–23 (ACT Government 2013a) establishes a policy framework for conservation of biodiversity across all tenures in the ACT. The strategy emphasises more resilient landscapes by restoring priority landscapes and enhancing connectivity to enable species and ecosystems to better adapt to climate change. The ACT

Biosecurity Strategy 2016–26 (ACT Government 2016b) further addresses how to manage key threats (weeds, pest animals, disease) across both conservation and production landscapes.

The ACT Climate Change Adaptation Strategy (ACT Government 2016c) aims to guide collective efforts in adapting to climate change. The strategy identifies 'natural resources and ecosystems' as one of five priority sectors and has two relevant key actions:

- Support landscape-scale conservation by identifying, protecting and strengthening potential climate wildlife refuges (biodiversity refugia) and adaptive capacity of ecosystems in our bioregion.
- Care for land and water through: education about climate change impacts and adaptation actions, control of pest animals and weeds that may become more critical under climate change, and monitoring impacts on ecosystems.

The ACT participates in regional and national initiatives such as CSIRO's Adapt National Resource Management or AdaptNRM (CSIRO 2014) to inform best practice management and enhance collaboration in helping biodiversity adapt to climate change.

1.8.4 ACT water management policy and programs

The ACT Government has in place a suite of policy, regulatory and coordination instruments to better manage water resources and catchments in a regional context. Principal among these are the:

- Territory Plan Catchment Code ACT Water Resource Plan. This plan is being finalised as required under the Basin Plan 2012 and will be assessed by the Murray–Darling Basin Authority (MDBA) and accredited by the federal Minister for Agriculture and Water Resources by 2018
- ACT Water Strategy 2014–44 (ACT Government 2014a)
- ACT and Region Catchment Strategy 2016–46 (ACT Government 2016a)
- Water Sensitive Urban Design Code (ACT Government 2009c).

The Water Resource Plan not only sets out how the ACT manages its water resource use as defined by the diversions allowed under the Murray–Darling Basin Plan but also includes a water quality plan and environmental watering plan. The environmental Watering Plan addresses the objectives in the Basin-wide Environmental Watering Strategy (MDBA 2014). These objectives cover river flows, including longitudinal and lateral connectivity, riparian and floodplain vegetation, waterbirds and threatened fish species. This Aquatic and Riparian Conservation Strategy and Action Plans complement the requirements of the ACT Water Resource Plan.

The ACT Healthy Waterways (Basin Project) is a joint initiative of the Australian and ACT governments to protect and improve long-term water quality in the ACT and the Murrumbidgee River system. Through the investment of $93.5 million to construct new water quality control infrastructure and implement a comprehensive education and behaviour change program, the project will reduce the level of nutrients and pollutants entering waterways in the ACT section of the Murray–Darling Basin.

The ACT Water Strategy 2014–44 (ACT Government 2014a) guides:

- catchment management in the ACT and region
- long-term security of water supply
- strategic investment in water management
- planning and design of urban environments which integrates water management
- provision of suitable water quality
- community involvement in water management.

The ACT and Region Catchment Strategy 2016–46 (ACT Government 2016a) guides priority actions for the benefit of the region as a whole. The Catchment Strategy details the key factors predicted to affect the catchment and includes actions to support a healthy catchment.

1.9 IMPLEMENTATION

This strategy is a thematic document which means that it is not site-specific. The goals of the strategy will be achieved through a variety of means tailored to different land tenures.

Achieving the vision and goals of the strategy will depend on allocation of adequate resources to undertake the actions outlined in the action plans. Primary responsibility for implementation and coordination of this strategy on ACT public land lies with the ACT Government.

Achievement of the strategy's goals will also require the participation of Icon Water (ACT Water Utility) and private land managers (rural lessees). Liaison and cooperation with NSW agencies, particularly the Office of Environment and Heritage, is an important element in implementing this strategy.

Community groups in the ACT are instrumental in raising public awareness and undertaking a range of on-the-ground aquatic and riparian management and restoration activities. Continuing community support and participation remains essential to successful outomes in this strategy.

1.10 ACTION PLANS

1.10.1 Overview

Action plans for threatened species and threatened ecological communities are statutory documents under the Nature Conservation Act. The Conservator of Flora and Fauna is responsible for preparing draft action plans with expert input from the Scientific Committee.

Action plans associated with this strategy include those for each of the eight threatened species that are dependent on aquatic and riparian areas in the ACT (see Table 1.1 and Part B of this strategy: Action plans). Each action plan provides a detailed description of the species, its conservation status, ecology and key threats, and outlines the major conservation objectives and intended management actions.

Conservation objectives, management actions and performance indicators in action plans are arranged into five core objectives: protect, manage, increase (for example, population or habitat) and promote knowledge and awareness.

Table 1.1 Relevant ACT listed threatened species and action plans

Species	Status	Action plan number/date	Listing date[1]
Two-spined Blackfish (*Gadopsis bispinosus*)	Vulnerable	No. 11, 1999 (ACT Government 1999f)	6 January 1997
Trout Cod (*Maccullochella macquariensis*)*	Endangered (SPS)	No. 12, 1999 (ACT Government 1999d)	6 January 1997
Murray Cod (*Maccullochella peelii*)*	SPS (ACT)	Native species management plan drafted	
Macquarie Perch (*Macquaria australasica*)*	Endangered	No. 13, 1999 (ACT Government 1999a)	6 January 1997
Murray Crayfish (*Euastacus armatus*)	Vulnerable	No. 14, 1999 (ACT Government 1999b)	6 January 1997
Silver Perch (*Bidyanus bidyanus*)*	Endangered	No. 26, 2003 (ACT Government 2003)	26 October 2001
Tuggeranong Lignum (*Muehlenbeckia tuggeranong*)*	Endangered	No. 24, 1999 (ACT Government 1999e)	19 August 1998
Murrumbidgee Bossiaea (*Bossiaea grayi*)	Endangered	No. 23, 2013 (ACT Government 2013b)	30 January 2012

1 Listed in accordance with section 65 of the Nature Conservation Act 2014 (ACT).
SPS: Special Protection Status under the Environmental Protection and Biodiversity Conservation Act 1999. * Indicates species that are also MNES.

1.10.2 Links between this strategy and action plans

Action plans provide direction to manage threatened species. This strategy provides overarching conservation goals and principles on which to base actions. It also provides a framework for planning and prioritising actions across the aquatic and riparian areas in the ACT.

1.10.3 Development, implementation and review of action plans

Since the 2007 strategy, action plans have been prepared for all threatened species and provided to the ACT Scientific Committee for formal review. The Committee's review is based on objectives and performance indicators in action plans as well as progress that can reasonably be expected within the review timeframe. Review of action plans is also the primary means for assessing progress towards the goals of this strategy.

2 STRATEGY: PROTECT AQUATIC AND RIPARIAN AREAS AND SPECIES

Murray River Crayfish from the Murrumbidgee River. Photo: M. Jekabsons, ACT Government

2.1 OVERVIEW

Statutory protection of areas of high conservation value is key to the conservation of aquatic and riparian areas and their component species. Most ACT aquatic and riparian areas are within conservation or recreation public land. However, some sections of rivers are outside the reserve system and in poor condition — they are often adjacent to areas in good condition and can cause the degradation of these surrounding areas through, for example, the spread of pest plants and animals and by limiting the passage of aquatic species.

2.2 PROTECTION GOAL

Consistent with the requirements for threatened species in the Nature Conservation Act, protection goals of this strategy are to:

- protect and work to rehabilitate aquatic and riparian areas in the ACT that are in moderate or greater ecological condition
- protect and manage viable wild populations of native aquatic and riparian flora and fauna species in the ACT.

2.3 KEY PRINCIPLES

The long term viability of aquatic and riparian ecosytems in the ACT will be maximised by:

- maintaining protection of aquatic and riparian areas in public land reserves and extending this protection where possible
- protecting aquatic and riparian areas from further degradation or modification due to river regulation, infrastructure, urban encroachment and intensive recreation, agricultural practices, or new/upgraded river crossings (mainly addressed in Chapter 0)
- actively managing aquatic and riparian areas to enhance condition (mainly addressed in Chapters 0 and 0)
- enhancing connectivity within and between aquatic and riparian areas and to surrounding native communities (mainly addressed in Chapter 0)
- protecting and managing aquatic and riparian species to prevent the impact of exploitation
- supporting local, regional and national efforts towards conservation of aquatic and riparian species.

2.4 PROTECTION STATUS OF AQUATIC AND RIPARIAN AREAS

Most of the waterways considered under this strategy are on public land reserved under the Planning and Development Act and managed under the Nature Conservation Act. These lands are managed to conserve the natural environment, provide for public and community use and/or water supply. Any development proposal within conservation or special purpose reserves requires assessment under Schedule 4.3 of the Planning and Development Act.

Urban waterways are not covered by this strategy, as discussed in section 1.5. The protection status for waterways considered under this strategy is outlined in Table 2.1. The protection of threatened species is considered under specific action plans (see Part B).

Table 2.1 Protection status of waterways covered under this strategy

Waterway	Protection status	Management plan
Murrumbidgee	Nature reserve. Special Purpose Reserve in higher use recreational areas	Murrumbidgee River Corridor Management Plan
Cotter and tributaries	Wilderness Area in the upper reaches, national park, Protection of Water Supply. Below Cotter Dam Special Purpose Reserve	Namadgi National Park Plan of Management, Lower Cotter Catchment Reserve Management Plan (in preparation), lowest reaches in Murrumbidgee River Corridor Management Plan
Gudgenby, Naas Rivers and tributaries	Upper reaches in national park. Lower reaches nature reserve. Mid reaches are Rural zone (Territory Plan 2008) subject to agricultural use	Namadgi National Park Plan of Management, lowest reaches in Murrumbidgee River Corridor Management Plan, Land Management Agreements
Paddys River and tributaries	National park, Special Purpose Reserve (sections of Tidbinbilla, Cotter). Rural zone (Territory Plan 2008) subject to agricultural use	Namadgi National Park Plan of Management, Tidbinbilla Plan of Management, Land Management Agreements
Molonglo (upstream of Lake Burley Griffin and downstream of Scrivener Dam)	Special Purpose Reserve and nature reserve	Lower Molonglo River Corridor Management Plan to be replaced by Molonglo River Reserve Management Plan (in preparation), lowest reaches in Murrumbidgee River Corridor Management Plan.

The Namadgi National Park protects 51% of the ACT's aquatic and riparian areas and other reserves (nature, special purpose and protection of water supply reserves) protect a further 21.2%. Small lowland streams in the ACT are not well protected in reserved areas (and similar) as they tend to be flowing through urban environments or on leasehold rural properties.

Land Management Agreements between the government and rural lessees specify the management for the 16.4% of the river sections outside public land on rural zoned land (e.g. parts of Gudgenby, Naas, Paddys, and Murrumbidgee rivers). These agreements often have conditions that seek to protect aquatic and riparian values, such as fencing off river frontage, controlling weeds and disallowing the clearance of native vegetation.

2.4.1 ACT Government statutory protection

The wet sections of river corridors also have protection under the ACT Water Resources Act, which helps protect water quality and aquatic habitat through the issuing of Waterway Works licences to minimise the impact works have on the environment. The Nature Conservation Act contains provisions to protect threatened species and their habitat. The Fisheries Act protects fish spawning habitat in public waters. Under the Heritage Act an object or place may be listed as having natural heritage significance. However, if a place or object is protected under the Nature Conservation Act, registration under the Heritage Act can only be made if the place or object also has cultural significance or has natural significance of a type not protected under the Nature Conservation Act.

The management of threats to the condition of ACT river corridors is considered under Chapter 0 (Threats) and Chapter 0 (Management).

2.5 THE NEED FOR FURTHER PROTECTION

Aquatic and riparian areas in the ACT are generally well protected. Some sections of river on rural leases outside of public land are in poor condition and, in the absence of statutory reservation, need active protection measures to reduce degradation. Issues that have contributed to the poor condition include pest plants and animals, loss of riparian vegetation, bank erosion, stock access and poor water quality. For the most part, the Murrumbidgee River above the ACT flows through a ruralised catchment. In the ACT the river is partially surrounded by rural or urban land and also suffers the impacts listed above.

2.6 LOCAL, REGIONAL AND NATIONAL COOPERATION

Rivers are linear and directional landscape features that flow across jurisdictional and tenure boundaries. Protection of aquatic and riparian areas across boundaries requires cooperation between government agencies and other landholders within the ACT and the surrounding region.

Many rivers in the ACT have their headwaters in NSW (e.g. Murrumbidgee, Molonglo) and will therefore benefit from cooperation across jurisdictional boundaries, such as through the ACT and Region Catchment Management Coordination Group, and cross-border community groups such as the Upper Murrumbidgee Demonstration Reach (UMDR), Kosciuszko 2 Coast (K2C), local Aboriginal communities, Waterwatch and regional catchment management groups. UMDR and K2C, in particular, aim to improve aquatic and terrestrial connectivity, while the ACT and Region Catchment Strategy 2016-46 aims to promote a whole-of-catchment approach to improving the catchment's health in the long term.

The ACT Government will work with other land management agencies such as the Commonwealth and NSW governments, Traditional Custodians and other landholders to encourage:

- facilitation of land management and river corridor actions across tenures to improve aquatic and riparian condition
- involvement of Traditional Custodians in management of aquatic and riparian areas
- continued involvement in the ACT and Region Management Catchment Coordination Group, and community groups such as UMDR, K2C, Waterwatch and regional catchment management groups.

The ACT Government will also maintain links with, and participate in, regional and national recovery efforts for aquatic and riparian species and communities.

The Murrumbidgee River in NSW has statutory protection in portions (such as Kosciuszko National Park) but is mostly freehold land and Crown land. The river bed is predominantly owned by Crown Lands. Despite the limited statutory protection, initiatives to protect and improve the river across these land tenures are taking place through local community groups including Landcare, UMDR and Bush Heritage Australia. South East Local Land Services also works to improve the corridor. The NSW Department of Crown Lands has funded river corridor rehabilitation works. Hence, while statutory protection might be limited, locally-based actions are improving the condition and management of the corridor in places.

2.7 HOW PLANNING CAN PROTECT AQUATIC AND RIPARIAN AREAS

2.7.1 Land planning provisions to protect aquatic and riparian ecosystems

Most aquatic and riparian areas on non-urban land are zoned as either River Corridor or Mountains and Bushland in the Territory Plan. There are consequently restrictive development controls within the Territory Plan to protect these areas from inappropriate development. The Territory Plan defines zone objectives, provides a development table on permissible and prohibited development as well as a development code that defines restrictions on use and general development controls.

Development applications in reserved areas require either an Environmental Impact Statement (EIS) or a Conservator's Opinion that negates the need for an EIS. This planning process gives a moderately high level of protection to aquatic and riparian areas. Development approval is also required for non-reserved areas.

2.7.2 Plans of management to protect aquatic and riparian ecosystems

Under the Nature Conservation Act (s. 177) the custodian of a reserve must prepare a reserve management plan. Such plans are critical to manage activities in reserves.

The ACT Parks and Conservation Service is the land custodian of reserves managed primarily for nature conservation and water catchment as well as some areas of unleased public land. In the Nature Conservation Act, a reserve is defined as a wilderness area, a national park, a nature reserve, a catchment area and any other area of public land reserved under the Territory Plan or prescribed by regulation to be a reserve (may include a Special Purpose Reserve).

A reserve management plan identifies what is important about an area (its values), what is proposed to be achieved in the management of the area (objectives) and how the objectives will be achieved (policies and actions). A reserve management plan provides direction and guidance to the land custodian, visitors, neighbours, volunteers and others with an interest in the area. Preparation of a reserve management plan includes consultation with key stakeholders and a statutory requirement to consult members of the public.

The ACT has the following reserve management plans that apply to aquatic and riparian areas particularly covered by this strategy:

- Namadgi National Park Plan of Management 2010 DI2010-192
- Murrumbidgee River Corridor Plan of Management 1998 DI1997-268
- Lower Molonglo River Corridor Plan of Management 2001 DI2001-298
- Lower Cotter Catchment Strategic Management Plan 2007 (non statutory).

The Lower Molonglo River Corridor plan is being revised and will be replaced by the Molonglo River Reserve Management Plan. The revised draft Lower Cotter Catchment Reserve Management Plan 2017 is currently being finalised.

2.7.3 Consideration of the needs for in-stream species passage

Upstream and downstream river passage is important for aquatic animals for breeding migrations and finding food and habitat. Unfortunately, structures used to cross rivers are often not designed and built with aquatic species movement in mind. All new road or other structures such as weirs or dams and those undergoing renovation should provide for unrestricted aquatic species passage, unless there is a pressing ecological reason not to (i.e. the barrier prevents upstream spread of pest species).

Guidelines are available for the construction of various types of new crossings and rehabilitation of existing ones that facilitate passage (Fairfull and Witheridge 2003). Construction of the rock-ramp fishways at Vanitys and Pipeline crossings on the Cotter River are examples of such actions for fish.

Figure 2.1 Fishway at Vanitys Crossing, Cotter River. Photo: M. Jekabsons, ACT Government.

3 STRATEGY: REDUCE THREATS TO NATIVE BIODIVERSITY

Point Hut Crossing. Photo: L. Evans, ACT Government

3.1 OVERVIEW

Riparian and freshwater ecosystems worldwide are threatened by environmental and anthropogenic change (Dudgeon et al. 2006). Global freshwater and riparian biodiversity is particularly vulnerable due to the high value of fresh water as a resource for humans. Humans have diverted, extracted and contaminated waterways for generations, altering the suitability of aquatic and riparian habitats for many plants and animals. These threats have led to population declines and range reduction of global freshwater biodiversity (Dudgeon et al. 2006). Loss of this biodiversity results in the simultaneous loss of irreplaceable ecosystem goods and services, many of which are directly beneficial for humans (Covich et al. 2004a, Covich et al. 2004b). In Australia, a national assessment has found that more than 85% of assessed river reaches are significantly modified (Commonwealth of Australia 2002). This has exposed the majority of Australian aquatic and riparian ecosystems to considerable threat (State of the Environment Committee 2011).

The management of aquatic and riparian areas tends to be structured around threat management. Aquatic and riparian areas are vulnerable to many threats because water resources are in great demand and subject to competing pressures from environmental needs and human activities such as irrigation, recreation, domestic and industrial extraction. The reduction in water availability is a key threat for aquatic and riparian areas in the ACT. These waterways are also threatened by a lack of connectivity, reduced water quality, pest species, adverse land management practices and other anthropogenic impacts. In addition, climate change is likely to exacerbate current and future threats (Mantyka-Pringle et al. 2014). Managing threats is a key strategy for conserving and restoring aquatic and riparian areas in the ACT. Structured around key ecosystem components identified in Chapter 1 (water flows, water quality, habitat, biota, connectivity and people), this chapter outlines realised and potential threats to aquatic and riparian areas, discusses their impacts on aquatic and riparian ecosystems and provides guidelines on how to manage these threats.

A conservation monitoring program is currently being developed for aquatic and riparian ecosystems to report against key indicators to assess change in condition of the ecosystem in response to management intervention (further outlined in Chapter 5).

3.2 THREAT MANAGEMENT GOAL

To prevent or manage the impacts of threatening processes in order to maintain or improve the ecological condition and biodiversity of aquatic and riparian areas, with particular attention to threatened species.

3.3 KEY PRINCIPLES

- Land and river management activities can affect the level of threat at a regional scale (e.g. flow regulation) and so a whole-of-system approach is required to mitigate threats.
- Most biological systems are complex and our knowledge of them is imperfect. The nature of threats is often imprecise and the outcomes of actions to mitigate threats may be uncertain. Priorities and allocation of resources to mitigate threats therefore

requires a risk management and systems approach.

- Prevention, early detection and timely intervention are the most cost-effective threat management techniques.
- Management activities are most effective when evidence-based, integrated and strategically targeted to minimise the impact of realised threats.
- Monitoring and evaluation is required to assess the benefits of management activities against risks and cost. An adaptive management approach is required to achieve continuous improvement.

3.4 RIVER REGULATION AND WATER EXTRACTION

The stream flow regime is the driving ecological process in aquatic and riparian ecosystems. Consequently, alterations to natural flow patterns of streams—including flow magnitude, frequency, duration, timing, variability and rate of change—are a major threat to lotic species (Poff et al. 1997, Naiman et al. 2008).

The construction of large dams and the diversion of water for domestic, hydroelectric or agricultural water supply have dramatically affected flow regimes (Naiman et al. 2008). In southern Australia, capture and storage of waters in reservoirs during the wet season for subsequent release during dry seasons tends to reverse the seasonal flow pattern in rivers (Maheshwari et al. 1995) and reduce short-term variability overall (Poff et al. 2007). Large dams remove the occurrence and magnitude of small–medium flood peaks as well as reducing the size, rate of rise and fall, and duration of flood events (Poff et al. 1997).

Reduced seasonal volumes of water in rivers also results from direct abstraction from rivers via pumping or diversion for irrigation or domestic supply (Malmqvist and Rundle 2002, Baumgartner et al. 2009). Low flows downstream of dams magnify the impacts of barriers to fish passage as previously insignificant barriers fail to 'drown out' under regulated low flows. Changes to flows put systems under stress which amplifies and compounds other threats (Rolls et al. 2012).

All of the larger streams in the ACT region have structures that affect stream flow: Googong Dam and Queanbeyan Weir on the Queanbeyan River, Scrivener Dam on the Molonglo River, Tantangara Dam and Burrinjuck Dam on the Murrumbidgee River, Corin, Bendora and Cotter dams on the Cotter River. Only the smaller Paddys and Gudgenby–Naas rivers (tributaries of the Murrumbidgee River) are not currently affected by significant dams or weirs.

3.4.1 Flow Regime

The seasonal nature of flows is partially reversed by some dams (e.g. Corin Dam). Autumn to spring rain and snowmelt is currently collected and stored for release in summer, during peak urban water demand. In contrast, natural peak flows would have occurred in late winter to early summer. These high-flows and rising water temperatures towards summer are thought to have provided natural environmental 'cues' and sufficient water level for upstream spawning migrations of native fish. ACT fish species such as Murray Cod, Golden Perch, Silver Perch and Macquarie Perch are likely to respond to such cues (Humphries et al. 1999). Higher flows during the naturally high-flow periods also provide opportunity for dispersal and regeneration of plants, animals and other organisms

3.4.2 Sedimentation

A major effect of reduced high-flow events below dams is a build up of sediments (particularly finer material) that previously would have been scoured out of the riverbed. Bed-scouring environmental flows have been included in ACT Environmental Flow Guidelines (ACT Government 2013c) and Icon Water's licence to take water. However, there are no dedicated sediment-scouring flows in the Murrumbidgee River.

3.4.3 Riparian vegetation

Riparian vegetation is dependent on water supplied by an adjacent waterbody, either through groundwater or flood incursion into the riparian zone. To survive, plant species need to tolerate permanently wet roots and/or aspects of flooding, such as inundation and high velocity flows (e.g. Evans 2003). Some plant species in the riparian zone rely on flooding disturbance to remove competition from faster growing species (Evans 2003), allowing them to regenerate on newly formed sand bars or river banks. A lack of sufficient flow to maintain the obligate riparian species community has been observed in the ACT on the Murrumbidgee River where a *Casuarina cunninghamiana* riparian community is being replaced by Apple Box, a species that is not an obligate riparian species and not tolerant to flooding. This replacement began after the 2003 fires and was exacerbated by the 2001–2009 drought (L. Johnston, pers. comm.).

3.4.4 Environmental flows as a management response

Environmental flows are the primary management tool to reduce the negative effects of flow regulation. Environmental flows include releases of stored water and limitations on extraction. They aim to ensure that flows in rivers and streams mimic those that would occur naturally, therefore enabling the healthy functioning of in-stream and riparian ecosystems. Guidelines for flow management to assist biota are available in the ACT Environmental Flow Guidelines (ACT Government 2013c). Googong, Corin, Bendora and Cotter dams all release environmental flows throughout the year and extraction from the Murrumbidgee River and other rivers and groundwater systems is limited through water licensing to maintain adequate flows for the environment.

The Murrumbidgee River has its headwaters above Tantangara Dam, NSW. This dam, which is managed by Snowy Hydro Limited, takes 99% of flow out at the dam wall and by the time the Murrumbidgee River reaches the ACT, it is equivalent to 40% of natural flow. Snowy Hydro Limited is required to release limited environmental flows into the upper Murrumbidgee below Tantangara Dam (Snowy Hydro 2016) under the 2002 Snowy Water Inquiry Outcomes Implementation Deed (View the Deed (PDF, 284Kb)). Zero water releases are accepted for the remainder of the year other than to maintain a flow of 32 megalitres (ML) per day at Mittagang Crossing for Cooma water use.

Flow in the Murrumbidgee River inside the ACT is protected by the ACT Environmental Flow Guidelines (ACT Government 2013c), which limit total extraction to flows above the 80th percentile of water flow in spring to autumn and 90th percentile in winter. However, during drought periods extraction for domestic consumption from Casuarina Sands can exceed these limits. Extraction from the Murrumbidgee to Googong (M2G) pipeline pump station at Angle Crossing is governed by operational rules to protect medium flush events during drought periods as these are identified as being critical for ecological condition and connectivity during periods of restricted natural flow (Eco Logical Australia 2011).

The Molonglo River does not receive dedicated environmental flows downstream of Lake Burley Griffin, partly due to Scrivener Dam being designed without environmental flow releases in mind. Furthermore, the National Capital Plan for Lake Burley Griffin specifies that the lake should be maintained to protect Lake Burley Griffin and Foreshore's visual and symbolic role. There is now a lake abstraction plan in place which has the capacity to restrict abstractions during drought times. The development of specific environmental flow releases from Scrivener Dam to affect downstream processes (e.g. sedimentation, periphyton accumulation, pool water flushing) would help to maintain native fish species in the lower Molonglo River, including Murray Cod, Murray Crayfish and Golden Perch.

3.4.5 Guidelines to manage the consequences of river regulation

- Adhere to the Environmental Flow Guidelines (ACT Government 2013c) for the delivery of flows, including protection or release of volumes to assist ecosystem function such as riffle and pool scouring.
- Investigate feasibility of dedicated environmental flow releases from Lake Burley Griffin and negotiate the possibility of such releases with the National Capital Authority.
- Promote the establishment of environmental flow rules for the entire upper Murrumbidgee above Burrinjuck Dam, including from Tantangara Dam.
- Monitor ecosystem response to environmental flows to determine whether flows are adequate to maintain ecosystem function and aquatic species.
- Monitor riparian zones to determine whether flows are adequate to keep riparian communities intact and determine whether the Environmental Flow Guidelines (ACT Government 2013c) require provisions for the maintenance of riparian vegetation communities.
- Utilise an adaptive management process to update Environmental Flow Guidelines (ACT Government 2013c) based on monitoring findings.

3.5 WATER PUMPING

The pumping of water is a direct threat to the aquatic biota of the Murray–Darling Basin, including the ACT. Pumping or diversion can directly remove fish, particularly juveniles, from river systems. A single high-velocity pump may extract up to 200 fish per day (Baumgartner et al. 2009). Fish caught in pumps are injured during passage through the machinery, caught on screens, or lost from the river system to receiving water bodies. The ACT does not have a large extractive industry; however, several pumps are used in the Murrumbidgee and Molonglo rivers and some urban lakes and ponds. The largest capacity pumps are those at Casuarina Sands and Angle Crossing. Used for Canberra's water supply or inter-basin transfer from Murrumbidgee to Googong Reservoir, they can each extract more than 100 ML per day. These pumps have been designed to have minimal suctioning flow and M2G pipeline extraction has a fine screen to prevent transport of pest fish and eggs. Other pumps operating on the Murrumbidgee and Molonglo rivers within and outside the ACT do not have the same protective design principles as the major pumps and, consequently, have potential for additional negative impacts (Boys et al. 2012).

3.5.1 Guidelines to manage the consequences of water pumping

- Design pumps with screens to minimise impingement and entrainment of fish. Velocity at screen is recommended to be no more than 0.1 metre per second (m/s).
- Implement best management practice for fish protection when pumping.

3.6 WATER QUALITY

Water quality can affect the survival and health of aquatic and riparian biota. Impacts on water quality can take the form of chemical, thermal and water clarity changes. Deaths due to short-term, acute changes in water quality may be readily recognisable. However, sub-lethal water pollution and long-term changes to water quality parameters are less obvious in their effects.

The existing policy framework for water management in the ACT includes the ACT Water Strategy, legislation (Environmental Protection Act and Water Resources Act), planning policies (Water Use and Catchment Policies of the

Territory Plan), guidelines (Environmental Flow Guidelines) and ongoing monitoring and reporting carried out by a range of government agencies and community groups. With the exception of Lake Burley Griffin, which is managed by the National Capital Authority, water quality monitoring is reported in the annual ACT Water Report (e.g. ACT Government 2015a). Overall, the ACT seeks to manage water quality to ensure water leaving the ACT is of the same quality or better than that entering the territory.

3.7 CHEMICAL WATER QUALITY

The release of reservoir water from the bottom of the water column has many effects on water quality. Aside from being cold (discussed below), bottom releases are usually low in dissolved oxygen and may have excessive nutrient loads. This is due to the release of nutrients from bottom sediments under anaerobic conditions (National Capital Planning Authority 1995). Impoundments may also act as nutrient traps by allowing organic particles to settle out, potentially reducing downstream productivity (Koehn and O'Connor 1990).

Urban and agricultural inputs (such as fertiliser, pesticides, herbicides and animal waste) also reduce water quality. These inputs can be reduced by maintaining a functioning and well-vegetated riparian zone that is fenced off from stock access, by using biodegradable pesticides and by applying them according to ChemCert certified practices at labelled application rates.

Intensive land uses associated with adjacent urban use, such as the Pialligo turf farm and landscaping materials storage sites, pose a risk particularly to Molonglo River water quality. These land uses continue to be monitored to ensure good environmental practice.

ACT waterways are also affected by point source pollution inputs, such as those from sewage treatment facilities in Queanbeyan and the lower Molonglo. Water from the ACT sewage treatment plant outflow is generally of good quality, but has a different chemical composition to upstream water. In comparison to its natural condition, water from the plant is higher in nitrogen and phosphorus, has a different and higher salt composition, and contains non-treatable pharmaceutical by-products. Some riparian plant species have been observed to grow faster downstream of the outflow, probably because of higher nutrient levels (L. Evans pers. comm.).

Some pollutants disrupt aquatic ecosystems by mimicking naturally occurring hormones (endocrine disruptors) and so affect sexual development and function as well as reproductive behaviour of aquatic organisms (Mills and Chichester 2005, Söffker and Tyler 2012). Endocrine disruptors have received worldwide attention for their impacts on aquatic communities, with aquatic groups such as frogs, mussels and fish affected. Oestrogenic substances are often found in industrial or sewage treatment plant discharges (Jobling and Tyler 2003, Mills and Chichester 2005).

Figure 3.1 Cotter River above Vanitys Crossing. Photo: M. Jekabsons, ACT Government.

Locally, pharmaceutical products and oestrogenic activity have been documented in the discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC) (Roberts et al*.* 2015, Roberts et al*.* 2016), although the impacts on local aquatic species are, as yet, unknown. Endocrine disruptors have been found up to 4 kilometres downstream from the LMWQCC and may extend further (Roberts et al*.* 2015). Discharges from other sewage treatment plants in the Canberra region (Queanbeyan, Cooma) are likely to have similar oestrogenic activity. Fragmented fish distributions above and below the LMWQCC have been known for many years, but the basis for this remains unknown (Lintermans 2004b).

An historic and catastrophic source of water pollutants was the Captains Flat Mine spoil following the collapse of slime dumps at the mine in 1939 and 1942. These collapses released large quantities of heavy metals, killing virtually the entire fish population in the Molonglo River (Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River 1974). There are still contaminated sediments in Lake Burley Griffin. Projects involving sediment disturbance in the lake should avoid resuspension of the heavy metals.

3.7.1 Guidelines to improve chemical water quality

- Follow guidelines in the ACT Water Strategy to guide the management of water resources for water quality.
- Release water from reservoirs higher in the water column to avoid poor water quality.
- Avoid disturbing Molonglo River and Lake Burley Griffin sediments to prevent resuspension of heavy metals.
- Maintain a native and well-vegetated riparian zone that is fenced off from stock access to filter pollutants.
- Ensure only pesticides and fertilisers containing biodegradable chemicals are applied and done so according to ChemCert practices at labelled application rates.
- Licence sewage discharges to ensure quality meets Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand 2000). Quality of released water should be high enough to support biota such that it should not adversely affect native fish populations from inhabiting and migrating past sewage discharges.
- Investigate means to mitigate the effects and source of endocrine-disrupting chemicals.

3.8 THERMAL POLLUTION

Thermal pollution occurs when water of colder or warmer temperature than natural is released. Cold water pollution usually occurs when water from the bottom of large reservoirs is released into streams. Only cold pollution is a significant problem in the ACT and all that is discussed after this point. Thermal pollution is recognised as having significant impacts on aquatic ecosystems (Lugg 1999, Phillips 2001, Astles et al. 2003, Ryan et al. 2003, Preece 2004). The water stored in large reservoirs tends to stratify between spring and autumn, with a warm surface layer (the epilimnion) overlying cold bottom layers (the hypolimnion). The hypolimnion can be 12–15°C colder than surface water temperatures (Astles et al. 2003). Many dams only have outlets that draw water from the hypolimnion, or operating practices that result in water being preferentially drawn from lower levels.

Water releases from lower levels of thermally stratified impoundments are characterised by low dissolved oxygen and low temperature (Olden and Naiman 2010). Such releases can depress downstream temperatures in warmer months, increase downstream temperatures in winter, delay seasonal maximum temperatures by months, and reduce diurnal temperature variability (Rutherford et al. 2009, Lugg and Copeland 2014). Cold water releases can affect thermal conditions for considerable distances downstream. In the Cotter River, altered thermal regimes were predicted for 20 kilometres downstream of Bendora dam (at flows of 1 m^3s^{-1}, equivalent to 86 ML per day) (Rutherford et al. 2009).

In aquatic animals, lowered water temperatures can delay egg hatching and insect emergence and retard fish growth rates and swimming speeds, increasing predation risk (Todd et al. 2005, Sherman et al. 2007). Thermal pollution is a significant risk in the Cotter Catchment, where there are three large dams (Corin, Bendora and Cotter). A study has demonstrated that the growth rate of Two-spined Blackfish was significantly less under cold water conditions simulating thermal pollution (Hall 2005). Reduced growth rates mean fish will remain longer in a size-class susceptible to predation. A study of Macquarie Perch found cold water reduces swimming capacity (Starrs et al. 2011) and threatens spawning timing and success (Llewellyn and MacDonald 1980, Cadwallader and Backhouse 1983).

3.8.1 Guidelines to manage thermal pollution

- Monitor river water temperature below water outlets for all significant ACT dams to ensure they reflect natural temperatures as much as possible, as outlined in the ACT Environmental Flow Guidelines (ACT Government 2013c).
- Use higher level water offtake gates for water releases.
- Consider other solutions, such as thermal curtains, for dams without suitable infrastructure.

3.9 WATER CLARITY (TURBIDITY)

Turbidity can affect an aquatic ecosystem in a variety of ways. Changes to trophic relationships can be the most detrimental by affecting the photosynthetic ability of primary producers, which has flow-on effects up the trophic chain. Turbidity impacts the feeding success of native fish by reducing visibility and impacting the abundance and diversity of prey items such as invertebrates (Vogel and Beauchamp 1999). This has the greatest impact on visual feeders like Trout Cod and Two-spined Blackfish. Increased turbidity and sediment loads also have detrimental effects on submerged aquatic plant beds through reductions in light penetration, thus reducing an important food source for Murray Crayfish.

3.9.1 Guidelines to manage turbidity

- Support measures to reduce catchment soil erosion, including upstream of the ACT
- Maintain a native vegetated riparian zone that is fenced from stock to reduce sediment inputs to the river.
- Provide sediment and erosion control during construction activities.
- Avoid burning the riparian zone during prescription burn activities as per the Ecological Guidelines for Fuel and Fire Management Operations (ACT Government 2012a) and implement post-burn recovery in large fires to minimise erosion (see section 3.18).
- Carry out catchment and riparian revegetation where necessary.
- Prevent extractive industries on water courses, unless for well-supervised conservation purposes.

3.10 IN-STREAM SEDIMENTATION

Sediment movement and deposition in streams is a natural process but European land management practices and native vegetation clearing have accelerated this process, resulting in extremely high amounts of sediment entering streams. For example, sediment input to the Murrumbidgee River has increased from approximately 2,400 tonnes per year (t/yr) pre-settlement to ~480,000 t/yr 50 years post-settlement and to ~250,000 t/yr in 2003 (Olley and Wasson 2003). Any practice that denudes the soil of vegetation cover will result in erosion of soil into surrounding waterways. These practices include grazing, cropping, forestry, constructing roads and river crossings, and urban development. Erosion of soil from the landscape is exacerbated when vegetation removal is followed by climatic events such as high rainfall, drought or fire. In addition, in-channel sand and gravel mining, while removing some of the accumulated sediment, re-works the sediment particles and decreases water quality by suspending smaller particles, causing turbidity to rise. Turbidity effects are discussed above.

A high level of sediment deposition (sedimentation) is a problem in the ACT in low-gradient areas of rivers and streams, particularly in the Murrumbidgee River past Tharwa and other areas upstream of the ACT in NSW. This sedimentation has caused the channel to become shallow and wide, with the loss of structural habitat (such as rocks and woody debris). This also limits fish passage through the area and increases water temperature.

Construction of regulating structures, such as Tantangara Dam on the upper Murrumbidgee River, has reduced flows such that they are no longer sufficient to flush sediment through the river channel (Pendlebury 1997). The sediment will eventually move through the system, but this process will take centuries and is contingent on a reduction in upstream sediment input. Modification of the channel to reduce the impacts of sedimentation is possible, but rehabilitation of the habitat will ultimately rely on long-term improvement of upstream catchment condition.

Sedimentation can limit breeding of fish species that have demersal (sinking) and adhesive eggs (Cadwallader 1978) requiring a clean gravel or hard substrate for egg survival. These species include Two-spined Blackfish, Macquarie Perch, Mountain Galaxias, Murray Cod and Trout Cod. To improve egg survivability, sediment input to rivers may need to be reduced, structural habitat provided, and passage through to higher quality breeding sites improved. Increased sedimentation is also known to be damaging to benthic macroinvertebrate communities (Doeg and Koehn 1990a, b), which form the majority of the diet of the Two-spined Blackfish and Macquarie Perch.

Options to reduce the impacts of sediment deposition in the upper Murrumbidgee River have been considered (see GHD 2011), including controlled sand and gravel extraction. Such extractive activities are prohibited under the Territory Plan and can only be used primarily for habitat rehabilitation purposes. Well-managed sand extraction may be a way to reduce in-channel sediments for conservation and habitat improvement, however GHD (2011) recommended against sand mining in the ACT due to the volume of extraction required and the difficulty in preventing impact to downstream ecosystems. Consequently, other habitat improvement measures, such as engineered log jams (ELJs), have been trialled and found to be highly successful at a localised scale.

From a relatively early stage, the development of Canberra included plans to reduce the sediment inputs to streams from urban development. These initiatives have included sediment trapping ponds, construction stage sediment and erosion controls and, more recently, sediment trapping urban wetlands. Sediment inputs to streams can also be limited by maintaining adequately vegetated riparian buffer strips (Richardson et al. 2007). Grassy plants are most effective at stopping sediment getting into rivers and the roots of all plants provide bank stability and limit erosion.

3.10.1 Guidelines to reduce sedimentation and its effects

- Support catchment-wide cooperative agreements and activities that will reduce the upstream supply of sediment into the river.
- Follow the Water Sensitive Urban Design Guidelines (ACT Government 2009c) where appropriate.
- Conduct rehabilitation of significant point-sources of sediment (after Murrumbidgee Catchment Management Authority 2012).
- Investigate and employ options to increase river depth and improve structural habitat availability in sediment-affected river reaches (e.g. ELJs, groynes).
- Maintain a native vegetated riparian buffer strip to filter and trap sediment.
- Avoid burning the riparian zone so a filtering buffer strip is available to trap fire-induced sediment (see section 3.18).
- Prevent the re-establishment of commercial extractive industries on water courses, unless well managed for conservation purposes.

- Reduce the number of unsealed roads in sensitive catchment areas to reduce sediment supply.
- Continue to employ sediment and erosion control measures in urban areas.

3.11 RIPARIAN ZONE MODIFICATION

The quality of aquatic habitat is closely related to the condition of both the stream catchment and the riparian zone. Riparian zone vegetation acts as a buffer protecting the stream from surrounding land uses and interacts continuously with the stream (Koehn and O'Connor 1990). Fallen trees, logs, woody debris, leaves, bark and terrestrial animals from surrounding riparian vegetation constitute sources of in-stream nutrients, food and habitat (Gregory et al. 1991). Introduced plant species with deciduous canopy falling in autumn, such as willows and poplars, alter the timing, quality and consistency of this energy supply (Schulze and Walker 1997). The clearing of native riparian vegetation can result in a change to the aquatic food web from one driven by carbon sources from outside the stream to one driven by in-stream carbon production through photosynthesis (Gregory et al. 1991). This change to the base food web resource can cause a change in the biotic community it supports (Vannote et al. 1980).

Riparian-derived large in-stream logs and branches also provide important habitat functions for aquatic ecosystems (Gregory et al. 1991). For fish, this includes spawning sites, shade, formation of scour pools, territorial markers or 'signposts', velocity refuges, ambush sites for predators as well as refuges from both aerial and in-stream predators. The debris also provides substrate for biofilms and invertebrates and when the debris is above the waterline it provides perching sites for animals. Clearing of riparian vegetation, particularly trees, has resulted in limited supply of large woody debris (LWD) for in-stream habitat (Lapointe et al. 2013). The replacement of native tree species with introduced species also affects the supply of LWD — wood from eucalypts persists longer in water than most introduced weeds (such as willows). The roots of willows in small streams can also subsume in-stream habitat (McInerney et al. 2016).

Riparian trees and overhanging shrubs provide shading, reducing summer stream temperatures and providing habitat areas for species avoiding sunlight (Koehn and O'Connor 1990). The dappled sunlight to streams also provides camouflage for in-stream fauna (Pusey and Arthington 2003). As discussed above, streamside vegetation prevents erosion and sedimentation and acts as a buffer strip by filtering sediment, pasture effluent and chemicals in run-off from surrounding areas (Richardson et al. 2007).

3.11.1 Guidelines to manage consequences of riparian modification

- Control weeds and replant with local native species using best management practices where native riparian communities have been cleared or replaced with non-native species.
- Use native species of local provenance for riparian replanting. These should include trees, shrubs and grasses.
- Reduce stock damage to river banks and riparian zones by ensuring riparian zones are fenced off and alternative stock watering points are available.

3.12 GENETIC IMPOVERISHMENT

Small, isolated populations of aquatic and riparian species can suffer from poor genetic health due to loss of genetic diversity. A reduction in genetic diversity can drastically impact on species' survival and reduce their resilience to threats such as climate change

(Frankham 2005, Weeks et al*.* 2011). Genetic rescue through human-assisted translocation and improved habitat connectivity are effective methods for re-establishing gene flow among populations. Such measures can be vital to ensuring the persistence of local populations of threatened species. The use of these genetic management tools are discussed in detail in Chapter 4 (see section 4.5.14).

3.13 WEEDS

Riparian land management over the last 200 years, combined with natural disturbances, have provided conditions conducive to weed invasion. Alterations to water tables, periodic flooding and the dispersal of propagules by water have helped invasive weeds spread (Pyšek and Prach 1993). Drainage lines, watercourses and associated habitats have the greatest infestations of alien species and are the habitats at greatest risk Australia-wide (Humphries et al*.* 1991). Weed species of major concern in the ACT include willows (*Salix* spp.), African Lovegrass (*Eragrostis curvula*), Chilean Needle Grass (*Nassella neesiana*) and Blackberry (*Rubus fruticosus* agg.). These weeds out-compete native plants, do not provide long-lasting large woody debris and alter timing of leaf-fall, affecting in-stream food webs. The ACT Weeds Strategy 2009-19 (ACT Government 2009a) highlights the impact of weeds on waterways and notes that recreational activities are also affected by weed spread along waterways.

ACT riparian zones are susceptible to the establishment and spread of weeds due to many of these factors:

- Riparian zones have a long history of pastoral use, including stock access to streams, with associated plant introductions.
- Native vegetation cover has been cleared, exposing substrate to plant invasions.
- Alien species have been deliberately or accidentally introduced, for example the planting of willows (*Salix* spp.) and poplars (*Populus* spp.) for ornamental or riverbank stabilisation purposes.
- Softwood plantations have been planted adjacent to riparian zones.
- Stream bed environments are naturally unstable, being reworked on a regular basis by water flows. Exposed surfaces provide opportunity for weed species to establish (e.g. African Lovegrass, Chilean Needle Grass and Blackberry), particularly if the species are adapted to flooding (e.g. willows). The upper Murrumbidgee catchment now contains hybrid willows that can reproduce by seed.
- Riparian zones are typically wet and fertile, allowing alien species to out-compete native species, particularly where there is disturbance. Cultivation and fertiliser addition further encourage establishment of non-native weed species.
- Riparian zones are movement corridors for animals, particularly birds, which can be important in transporting plant seeds.
- The watercourse itself is a route by which seeds and other plant material may be transported to new locations.

Aquatic weeds and alga also have the potential to cause serious problems in ACT waterways. Aquatic weeds considered under the ACT Weeds Strategy include: Alligator Weed (*Alternanthera philoxeroides*) and Sagittaria (*Sagittaria platyphylla*).

The diatom Didymo or 'Rock Snot' (*Didymosphenia geminate*) is of serious concern, as the risk of its introduction to ACT waterways has increased with the commencement of international flights from New Zealand. Many rivers in New Zealand's South Island are already infected with Didymo, which can form a thick brown layer that smothers rocks, submerged plants and other materials (Bray et al. 2016). Didymo is a serious risk for the health of ACT waterways, particularly where anglers who have fished in New Zealand subsequently fish in the

ACT. Felt-soled wading boots are banned for use in New Zealand as they have a higher risk of transferring Didymo between water bodies. Didymo disinfection typically involves drying, heating or freezing articles that have come into contact with Didymo-affected waters.

3.13.1 Guidelines to manage weeds

- Follow guidelines in the ACT Weeds Strategy 2009-2019.
- Use species-specific best management practice for the particular species.
- Replant riparian zones with native, locally appropriate species after weed control.
- Evaluate the effectiveness of weed control programs and revise as necessary.
- Work with the Australian Government to ensure biosecurity protocols at Canberra International Airport include Didymo disinfection. Suggest banning felt-soled wading boots.
- Educate the community about the risks of weeds and algae and how not to spread them.

3.14 ALIEN AND PEST ANIMALS

The concept of a pest is used in the present strategy to describe a species, usually alien, that has had a negative impact on the native ecosystem or is unwanted in that ecosystem. All pest species discussed in this strategy are alien species. Conversely, not all alien species discussed in the present strategy are necessarily pests. For example, trout, while an alien species, is not necessarily considered a pest as it maintains social benefits (fishing). Another example is Goldfish which, while not wanted in our waterways, have not demonstrated significant negative impact where they are been introduced.

Figure 3.2 Monitoring of alien fish species. Photo: M. Jekabsons, ACT Government.

3.14.1 Alien aquatic animals

Alien fish species are a threat to freshwater fish both globally (Malmqvist and Rundle 2002, Dudgeon et al*.* 2006) and in Australia (Lintermans 2013a). Alien species compete for food and habitat (spawning areas, territory), prey on native species, introduce and spread diseases (e.g. Epizootic Haematopoietic Necrosis Virus or EHNV) and parasites (such as *Bothriocephalus* and *Lernaea*) and cause habitat degradation (Strayer 2010). Pest fish are listed on the ACT Pest Plants and Animals Declaration 2016.

Control options for alien fish are limited, particularly where threatened native species are present, because of the potential for control measures to affect non-target fauna. Control programs will have a greater chance of success if it is attempted while the population of alien fish is small. Consequently, prevention, early detection and monitoring programs are critical to the successful management of alien fish. Additional research is required into control techniques, along with the development of rapid response plans and training of staff for new pest fish incursions.

The ACT Government works actively with national committees of technical experts that undertake risk assessment of potential pest species, support or restrict the import of alien fish into the country and provide advice on response to alien fish incursions and management strategies. These committees aim to prevent the invasion of new pest species into Australian water bodies.

Carp

Arguably the worst pest fish species in the Murray–Darling Basin is Carp (Invasive Animals CRC). Carp increase water turbidity, disturb macrophyte beds, compete for resources with native fish and spread disease and parasites (Koehn et al. 2000). The Carp Reduction Strategy (Stuart et al. 2010) was developed for the ACT and region by the Murray–Darling Basin Authority to recommend ways to reduce carp numbers.

The Carp Herpes Virus (*Cyprinid herpesvirus* CHV) may be released in coming years after adequate risk assessment and research has been conducted to mitigate the potential impacts of large quantities of dead fish on aquatic and riparian ecosystems and adjacent communities (Australian Government 2016). The Carp Herpes Virus will not be released unless: all legislative approvals have been received, there is a comprehensive plan in place for release and clean up, consultation has been undertaken and there is national agreement on implementation and funding arrangements. While the virus will not completely remove Carp from waterways, it will reduce their numbers and may enable complete removal from some enclosed water bodies.

Trout

Trout are an established non-native species (alien) that support an avid recreational fishery, making their management controversial. Trout are known to prey on the threatened Two-spined Blackfish (ACT Government unpublished data) and native Mountain Galaxias (*Galaxias olidus*). In some streams, trout have completely removed the Mountain Galaxias population. Given that trout are already established, management should focus on preventing spread, reducing populations where critical and reducing impact to threatened species by preventing stocking of the species in mountain streams across the ACT. Trout stocking in public rivers and streams has been prohibited for at least 30 years and stocking for all recreational purposes was discontinued in the 2009 Fish Stocking Plan for the ACT (ACT Government 2009b).

Redfin and EHNV

The Cotter River above Cotter Dam does not contain Carp or Redfin Perch. The absence of these species from the Cotter River allows the persistence of populations of threatened species. In particular, Redfin Perch are carriers of the EHNV virus, which is known to kill Macquarie Perch (Langdon 1989a). Redfin Perch are also highly likely to impact native fish species through predation.

Eastern Gambusia or Plague Minnow

Eastern Gambusia compete with native fish for food and habitat. They also affect other fish by chasing them and nipping fins which can lead to infection and death. They prey on other juvenile fish, eggs, tadpoles and frogs. The species has a high reproductive rate and can breed several times a year. They are found in the Murrumbidgee, Molonglo and Cotter rivers and tributaries. Eastern Gambusia is a listed prohibited species under the Pest Plants and Animals Act, which means that their supply or keeping is prohibited.

Oriental Weatherloach

Oriental Weatherloach are found in most water bodies of the ACT including the Cotter below Bendora Dam and the Murrumbidgee. The species' impacts are not well understood, although the species is expected to compete with native species for resources (e.g. Mountain Galaxias), feed on fish eggs and macroinvertebrates, and carry introduced parasites (Lintermans 2007).

Other Pests

Other potential aquatic pests include invertebrates (e.g. crayfish), turtles (e.g. Red Eared Slider *Trachemys scripta elegans*) and amphibians (e.g. Asian Black-spined Toad *Duttaphrynus melanostictus*). These are managed through the ACT Pest Animal Management Strategy 2012–22 and the ACT Biosecurity Strategy 2016–26.

3.14.2 Vectors for introduction

Release of live fish into public waters without a permit is an offence under the Fisheries Act. A mechanism for the unwanted introduction of alien fish species is the use of live fish as bait by anglers. It is illegal to use live fish as bait under the Fisheries Act but discouraging bait fishing of any kind provides further safeguards against such introductions. To this end, a large section of the Cotter River has been designated as 'trout water' where only artificial fly or lures allowed.

Other mechanisms for release of alien fish into the environment are through so-called Karma releases (see section 6.4.2 for further information) for spiritual benefit, illegal stocking and release of unwanted pets. These mechanisms require education of the public and are discussed in section 6.4.2. Prohibition of the supply or keeping of declared pest fish under the Pest Plants and Animals Act reduces the risk that these species are released, become established or are spread within the ACT.

3.14.3 Distribution monitoring

Understanding species distribution is critical for early detection of new incursions and prioritising water bodies for alien fish control. Distribution can be determined through scientific monitoring and observations reported by anglers and the broader community.

Scientific monitoring is at present conducted by the ACT Government's Conservation Research Unit in select urban ponds, the Murrumbidgee River, Cotter River and, less frequently, in smaller streams. The Australian National University and the University of Canberra also sample various water bodies. Such monitoring has detected invasion of: Redfin Perch and Oriental Weatherloach in the Murrumbidgee and Cotter rivers, Carp into Yerrabi Pond, Rainbow Trout in Banksia St Wetlands and the alien *Lernaea* parasite on Blackfish in the Cotter River. Monitoring resources are typically targeted and of limited geographic scope.

Observations by the public of alien or out-of-area species can be more widespread, pointing to the importance of community observations and support for these observations. 'Feral Fish Scan', a mobile app and website, was developed by the Invasive Animals CRC in conjunction with the Upper Murrumbidgee Demonstration Reach and Upper Murrumbidgee Waterwatch to allow users to note observations of alien (feral) fish.

Fish and other aquatic animals such as turtles, crayfish dragonflies and frogs have been included on the Canberra Nature Map, allowing community reporting and identification of alien species across the region.

3.14.4 Guidelines for management of alien and pest aquatic animals

- Deliver actions from the ACT Biosecurity Strategy 2016–26 where relevant.
- Deliver actions from the ACT Pest Animal Management Strategy 2012–22.
- Avoid further spread of alien species into areas where they are not currently present.
- Only allow artificial fly and lure fishing in the Cotter River above Cotter Dam to reduce the possibility of live bait fish introductions.
- Develop rapid response plans for invasions of high risk species such as Redfin Perch invasion of the Cotter River.
- Do not stock trout into ACT mountain streams as per the 2015 ACT Fish Stocking Plan (ACT Government 2015b).
- Support ongoing community pest fish observations and mapping.
- Analyse Feral Fish Scan data collected by the public.
- Support the CHV release for Carp.
- Understand Carp distribution and density to enable targeted control after CHV release.
- Conduct complementary control activities after CHV release to remove Carp from priority water bodies.
- Continue to work with inter-jurisdictional aquatic pest advisory committees.
- Monitor potential alien fish incursion in high conservation rivers.

3.14.5 Riparian pest animals

Many pest animals occur in riparian zones of the ACT. Pest animals include wild deer, feral cats, foxes, feral pigs and wild dogs. The management of pest animals is addressed through the ACT Pest Plants and Animals Act and the ACT Pest Animal Management Strategy 2012–22.

3.15 PARASITES AND DISEASES

A potentially serious impact of alien species is their capacity to introduce or spread diseases and parasites to native fish species (Strayer 2010). For example, introduced fish are implicated as the probable source of Australian populations of the parasitic copepod *Lernaea cyprinacea* and the Asian Fish Tapeworm *Bothriocephalus acheilognathi*, both of which have been recorded in native fish species in the ACT (Langdon 1989b, Dove et al. 1997).

The most serious current disease threat from alien fish species is the Epizootic Haematopoietic Necrosis Virus (EHNV). This virus, unique to Australia, was first isolated in 1985 on Redfin Perch (Langdon et al. 1986). It is endemic to the upper Murrumbidgee Catchment (Whittington et al. 2011) where it has been recorded from most of Canberra urban lakes (Whittington et al. 1996). Silver Perch and Macquarie Perch are extremely susceptible to the disease (Langdon 1989a, b). Other native species found to be susceptible include Eastern Mosquitofish, Murray–Darling Rainbowfish and Freshwater Catfish (Whittington et al. 2011). The virus's robust characteristics and ease of transmission on nets, fishing lines, boats and other equipment have helped it spread.

Once EHNV is established in a waterbody it is considered impossible to eradicate. The Cotter River and reservoirs above Cotter Dam are not affected by EHNV, with restrictions and prohibitions on recreational fishing in these river sections aimed at maintaining this status. During the construction of the Enlarged Cotter Dam, sterilisation of the river between the old and new dam walls was undertaken to manage the risk of EHNV and Redfin Perch from downstream. In addition, protocols for vehicle cleaning have been implemented during prescribed burning operations to minimise the risk that water-carrying vehicles will provide a vector for the virus.

3.15.1 Plant diseases

There are plant diseases that could potentially affect native riparian vegetation, such as *Phytophthora*. There have been no confirmed cases of *Phytophthora cinnamomi* in ACT riparian zones. Incursions of pests and diseases of plants are managed according to national biosecurity arrangements, such as PlantPlan (Plant Health Australia 2016). In addition, dieback caused by *P. cinnamomi* is listed as a key threatening process under the Commonwealth Environmental Protection and Biodiversity Conservation Act. The Threat Abatement Plan for Disease in Natural Ecosystems caused by *P. cinnamomi* (Commonwealth of Australia 2014) outlines strategies to prevent the disease spreading into uninfested areas, reduce impacts in infested areas and recovery actions for the conservation of affected biodiversity assets.

3.15.2 Guidelines to reduce the chance of spreading introduced diseases

- Deliver actions from the ACT Biosecurity Strategy 2016–26.
- Follow national guidelines for the management of plant diseases (Plant Health Australia 2016).
- Maintain artificial lure fishing regulations in the lower Cotter fishing zone.
- Ensure management activities in the Cotter Catchment follow biosecurity protocols, including the disinfection of boats and aquatic sampling gear and precluding the use of potentially EHNV-infected water for fire fuel management activities.
- Avoid translocating or stocking fish from outside the EHNV-free Cotter Catchment. Exceptions are possible where fish have been tested for EHNV.
- Develop a risk mitigation and incursion response strategy in case of Redfin Perch or Carp incursion into the Cotter River above Cotter Dam.

3.16 CONNECTED AQUATIC POPULATIONS

In many ways connectivity is a function of ecosystem health at a landscape scale. Almost of all the threats discussed above can influence aquatic and riparian connectivity.

Freshwater stream habitats are unique in that they are dendritic, generally narrow, subject to the directional flow of water and therefore extremely susceptible to fragmentation. In-stream barriers to biota movement can be a problem (usually) or a benefit (rarely). Barriers can be structural (e.g. dams, weirs, road crossings) or chemical (e.g. discharge of effluents, pollutants, contaminants) and can be partial (i.e. only operate under some conditions such as low flows or impacting some species) or total (e.g. large dams and weirs, piped road crossings).

Barriers prevent the movement of fish and other organisms, either local movements for feeding or refuge, or larger scale migrations for breeding. However, barriers can be a benefit when they stop pest species and disease moving into a stream. For example, Cotter Dam has prevented the spread of Redfin and Carp, and Bendora Dam has stopped the spread of Brown Trout. If a barrier is a problem, ideally it should be removed or mitigated in a way to allow in-stream passage of native animals. Connectivity is also important to other animals. However, other than fish, most other aquatic-dependent animals are capable of moving around barriers either through, for example, invertebrate aerial life stages or leaving the water and walking (e.g. crayfish, turtles, platypus), although this situation is not always ideal, for example when road crossings are required. The importance of flow for downstream dispersal can also be important for some plant species.

Barriers that are identified as needing mitigation for fish include:

- Point Hut Crossing due to a step under low flows and velocities exceeding most fish swimming abilities at high-flows (Mallen-Cooper 2012).
- Natural barriers upstream of the Cotter Reservoir, particularly in relation to the many natural barriers not sufficiently submerged for Macquarie Perch passage under normal spring regulated flows (Broadhurst et al. 2013).
- Burkes Creek Road Crossing which was constructed in a way that does not allow fish passage.

Barriers that are beneficial include Cotter and Bendora Dam, Molonglo Gorge and Gibraltar Falls.

3.16.1 Guidelines to reduce the effects of in-stream barriers

- Seek to mitigate natural barriers such as sediment deposition zones with appropriate channel modifications such as engineered log jams.

- Mitigate natural barriers by providing sufficient flows to allow species to pass at critical life stages. One example is to assist Macquarie Perch spawning migration through rock barriers above Cotter Reservoir.

- Ensure that any modifications to existing barriers are 'fish friendly' (as per Fairfull and Witheridge 2003).

- Monitor the performance of existing fish passage mitigation measures.

- Communicate the importance of maintaining some of the barriers in the Cotter River, including Cotter Dam and Bendora Dam, to prevent the spread of alien species.

3.17 INAPPROPRIATE FISH HARVEST

Over-exploitation of fisheries is a significant contributor to the decline of native fish across the Murray–Darling Basin (Murray–Darling Basin Commission 2004). Commercial fishing is not known to have operated in the ACT. Illegal take of threatened fish species and illegal 'trade' in some desirable recreational species (e.g. Murray Cod and Murray Crayfish) has previously occurred in the Canberra region and continues to be a threat.

Twenty-five percent of the region's residents go fishing in the ACT (Schirmer and Mylek 2016). Recreational fishing is popular on rivers and lakes and can place significant pressure on fish stocks, especially threatened species. The ACT Government stocks four urban lakes with Murray Cod and Golden Perch to provide recreational angling opportunities and reduce the impact on wild populations in rivers (ACT Government 2015d). Overfishing has been shown to be important in the decline of many native species including the threatened Macquarie Perch (Cadwallader 1978, Harris and Rowland 1996), Trout Cod (Berra 1974, Douglas et al. 1994), Murray Cod (Rowland 1989, Jackson et al. 1993) and the Murray Crayfish (Zukowski, 2011). Misidentification of species by anglers can also be a problem, for example endangered Trout Cod can be confused with Murray Cod, which can be taken legally.

Fishing in the ACT is governed by the Fisheries Act. This legislation and its instruments regulate the use of equipment, set bag and size limits and regulate closed seasons and prohibitions for taking particular species or fishing on particular waterbodies. The fishing regulations and instruments under the Act have been updated periodically. The provisions of the Act are largely kept consistent with the relevant fisheries legislation in NSW and Victoria to minimise potential for confusion amongst anglers. This Act is currently under review.

Murray Cod is a recreationally targeted fish species that is stocked in urban lakes and which occurs naturally in the Murrumbidgee River. While anglers are prohibited from keeping Murray Cod caught during breeding season, waterways remain open to target other species. This makes bans difficult to enforce unless anglers have a prohibited fish in their possession. It is unknown if capture and handling reduces the breeding success in Murray Cod. Murray Cod populations are monitored, which can help to assess the impacts of recreational fishing. If no longer sustainable, management options would include strengthening enforcement actions. Effective enforcement of regulations is critical to successful protection of Murray Cod and other fish species.

3.17.1 Guidelines to reduce over or inappropriate harvesting

- Provide adequate fishing opportunities for angling in the ACT by stocking artificial lakes to reduce the pressure on natural rivers.
- Update regulations, based on best available knowledge, to improve the sustainability of native fish stocks and conservation of threatened species.
- Investigate the impact of take or targeting of native species during spawning season and support and strengthen fisheries' enforcement activities.
- Keep ACT fisheries legislation consistent with relevant NSW and Victorian regulations where they meet ACT requirements.
- Educate the community about regulations and where there might be any important differences between NSW and ACT regulations.
- Improve angler fish species identification skills to minimise accidental take of protected species such as Trout Cod and Macquarie Perch.

3.18 INAPPROPRIATE FIRE REGIMES

Fire can significantly impact both riparian and aquatic ecosystems. In 2003, wildfires burnt 70% of the ACT, including 840 kilometres of streamside vegetation (Carey et al*.* 2003). Prescribed burns of a lower severity can also affect communities, particularly if fire is immediately followed by heavy rainfall. Inputs of sediment and ash can cause fish kills and significantly change habitat. Impacts of fire, including prescribed burns and suppression activities, on aquatic communities include (Bixby et al*.* 2015):

- sedimentation from denuded catchments following rain events
- a decrease in dissolved oxygen concentrations as organic material (leaves, ash) washed into streams begins to decompose
- chemical changes in water quality as ash is deposited in streams
- increased algal growth due to increased nutrient load
- changes to stream flow patterns if upland swamps and bogs are damaged and if reduced vegetative cover and hydrophobic soil conditions increase run-off
- impacts from the loss of riparian vegetation including:
- loss of food resources due to no insect fall from overhanging vegetation
- increase in water temperature and algal abundance due to increased light exposure
- reduced in-stream camouflage from riparian shading.

Positive effects of fire on streams include input of nutrients supporting trophic productivity and input of large woody debris for in-stream habitat (Bixby et al*.* 2015). Additionally, prescribed burns may reduce impacts from large wildfires by removing potential fuel.

Fire-sensitive riparian plant species in the ACT include River Oak (*Casuarina cunninghamiana*) and Black Cypress Pine (*Callitris endlicheri*). The presence of fire-sensitive canopy species suggests the appropriate minimum fire interval is quite long, in the order of 25 years for River Oak and possibly longer for Black Cypress Pine. Shorter intervals between moderate or high intensity fire may threaten the local persistence of these species. The understoreys of the River Oak and Cypress Pine communities also typically contain limited biomass to carry fires. The presence of these sensitive species suggests riparian zones have been fire refuge areas in the past and points to the importance of protecting these areas from too-frequent fire.

3.18.1 Guidelines to avoid impacts from inappropriate fire regimes

- Avoid high intensity and frequent burning in riparian zones.
- Avoid burning during threatened in-stream species spawning and larval rearing periods.
- Maintain biosecurity, foam and retardant application protocols for prescribed burning activities.
- Conduct fire management in or near riparian vegetation consistent with the current Ecological Guidelines for Fuel and Fire Management Operations.
- Use Burnt Area Assessment Teams to rapidly assess and mitigate threats after high intensity burns to assist recovery.

3.19 CLIMATE CHANGE

The aquatic and riparian ecosystems of the ACT are likely to be already experiencing considerable pressure from climate change, with this pressure likely to increase substantially. With a changing climate, potential outcomes for the ACT are increased water temperatures, reduced average river flows, more flash flooding, less snow cover, increase in fire weather severity and an increase in drought effects (ACT Government 2016c). Ecosystems must adapt to fluctuating water availability, higher temperatures and a more variable flow regime. The threats discussed elsewhere in this chapter are likely to be exacerbated. Increase in the human population will also expand demand for water resources for consumption, recreation and amenity.

Possible consequences of climate change include: insufficient water to support fish spawning during crucial reproductive windows, reduced connectivity in streams limiting the dispersal ability of plants and animals, reduced connectivity through the riparian zone as drier conditions reduce vegetation condition and potentially facilitate weed invasion (Lavergne et al*.* 2010, ACT Government 2016c), loss of evolutionary developed triggers and cues based on flow and temperature, heat stress and potential movement or emergence of alien species and disease. The precise ramifications of climate change for species and communities are not well understood, including how biota will interact or evolve due to changed conditions (Lavergne et al*.* 2010).

Figure 3.3 Cotter River above Corin Reservoir. Photo: M. Jekabsons, ACT Government.

Under modelled climate change conditions, rivers and mountainous areas will provide thermal relief during hot periods. It is likely pressure on these areas will grow from people visiting and using these areas throughout hotter episodes, leading to increased threats of over-exploitation and recreational pressures (see Chapter 4).

Cold water releases from reservoirs is generally regarded as reducing water quality. However, under some climate change scenarios, cold water releases from reservoirs may be an appropriate management tool. Traditionally, best management practice for releasing water from dams is to mimic the water temperature of natural flows. The aim of this practice is to avoid thermal pollution caused by the release of unseasonably cold water from the bottom of reservoirs as detailed in section 3.6.3. However, situations may develop under future climate change scenarios where mimicking water temperature may not always be the best option. Extreme temperature changes may push biota beyond thermal tolerances and intentional cold water releases could be used as a method to offset these impacts (Cummings et al*.* 2013).

While it is known that cold water releases reduce maximum water temperatures downstream of dams, the ecosystem-scale effects of such releases are not well understood (Cummings et al*.* 2013). Additionally, the response of threatened fish species, some of which respond to temperature cues for breeding and migration (Llewellyn and MacDonald 1980, Cadwallader and Backhouse 1983), needs further study. Once these knowledge gaps have been addressed, it is possible that intentional cold water releases could become a useful tool for managing thermal conditions in ACT aquatic ecosystems, but would need to be underpinned by an adaptive management approach.

Generally, guidelines for managing the impacts of climate change include strategies that provide broad ecological benefit that are advantageous regardless of future climate scenarios. The approach to managing climate change impacts largely draws on strategies already employed in the ACT to some extent, such as waterways protection, habitat restoration, flow management and species translocation. Good quality refuges will become increasingly important as areas that can mitigate drought and flood disturbances and alleviate thermal stress from climate change (see s. 4.5.16). Effective management of the impacts of climate change can be largely achieved by reviewing and modifying existing approaches, rather than developing new techniques (Mawdsley et al*.* 2009).

3.19.1 Guidelines to manage the potential consequences of climate change

Consider high impact climate change scenarios to inform adaptation responses:

- Optimise connectivity of aquatic and riparian areas where fragmentation does not already protect natural values.
- Use a whole-of-catchment and systems approach to improving ecological condition.
- Improve the resilience of aquatic and riparian biota by reducing the effects of other threats.
- Develop a long-term conservation monitoring plan for monitoring biotic responses to climate-induced changes. Act on these changes by adapting management practices.
- Replant riparian zones to provide shade, temperature mitigation, habitat/refuge connectivity, improve water quality and bank protection.
- Manage conservation activities for representation (of all habitats, species and communities) as well as replication (multiple habitats for important protected species).
- Address knowledge gaps around cold water releases from dams prior to utilisation as a warming climate management tool. Consider local conditions, requirements of biota and ecosystem processes downstream of dams before cold water releases.
- Translocation (assisted dispersal) of threatened species where necessary.

3.20 LAND USE

Rural and urban land use practices result in a suite of threats and impacts on aquatic and riparian areas. Both uses often lead to the same broad threats including: riparian modification, reduction in water quality, sediment input, spread of weeds and pest animals, creation of in-stream barriers and the over-extraction of surface and groundwater. The over-extraction of water has the potential to affect ecosystems local to the extraction point as well as those further downstream. The impact is particularly acute where over-extraction is systemic. Water licensing has been used to date to ensure that water resources in the ACT are not over-exploited (ACT Government 2015a).

3.20.1 Guidelines for managing consequences of land use

- Ensure water licensing processes prevent over-extraction of both surface and ground water resources so water availability is sufficient to support dependent ecosystems in good condition.
- Many of the guidelines set out earlier in this chpater are relevant to reducing the impact of land use.

3.21 RURAL LAND USE IMPACTS

Numerous impacts originate from rural land management. These include land erosion leading to channel sedimentation, riparian clearing, animal nutrient and agricultural chemical inputs and weed incursion. Each of these threats has already been discussed in previous sections.

Specific to rural land use is the impact of uncontrolled grazing of riparian zones and unrestricted livestock access to streams. Uncontrolled grazing has had major detrimental effects on riparian zones (including riverbanks), stream ecology and sediment loads. Specific effects include (Askey-Doran and Pettit 1999, Robertson and Rowling 2000, Jansen and Robertson 2001, MacLeod 2002, Price and Lovett 2002):

- lowered water quality (including increases in turbidity and nutrients)
- deterioration from stock trampling and lack of regeneration of fringing aquatic vegetation important for bank stability and habitat, such as *Phragmites* spp.
- spread of weeds (into and out of riparian zones)
- disturbance to habitat, such as rocks and logs, and loss of ground surface detrital material (litter and woody debris)
- loss of habitat connectivity and impacts on the value of riparian zones as drought refuges for native species
- lack of regeneration of native species, including dominant native tree cover
- loss of invertebrate and other species due to trampling and soil compaction, with associated effects on energy and nutrient cycling processes
- Addition of faecal contamination.

Guidelines relating to the reduction of impacts of rural land use have been discussed in previous sections, including under riparian modification, water quality and weeds.

3.22 URBAN LAND USE IMPACTS

While this strategy does not consider highly urbanised streams, some included streams are affected by adjacent urban development, in particular the Molonglo and Murrumbidgee rivers.

The Molonglo River is affected by urbanisation almost as soon as it enters the ACT. This has led to reduced water quality, creation of barriers, pressure on fish stocks through more intense and illegal fishing, habitat simplification by removal of in-stream large woody debris to allow for recreational activities (in particular water skiing), modified riparian zones to satisfy urban expectations and increased weed invasion and pest animals.

The Murrumbidgee River is affected by adjacent urbanisation. This is likely to increase with further urban development adjacent to waterways. The current pressures on the Murrumbidgee River are similar to those on the Molonglo River, although a wider buffer between the Murrumbidgee River and urban areas reduces potential pressures. Riparian zones need sufficient buffers outside of the riparian zone to reduce pressure on the river. At present, significant urban development only occurs on one side of the Murrumbidgee River. Restricting urban growth to one side of the river is important to contain adverse impacts on aquatic and riparian ecosystem health (Walsh et al. 2005). Development impacts along the Murrumbidgee have been ameliorated through water sensitive urban design—utilising sediment ponds, employing additional sediment and erosion control measures during building and developing intensive areas for riparian recreation.

Additional pressures from urbanisation include increased recreational pressure, input of chemicals such as sewage and road pollutants (e.g. brake dust, tire particles, oil), pesticides, nutrients from gardens, sediments during development phases and introduction of new pest species through illegal releases and stray pets.

3.22.1 Guidelines to manage the consequences of urban land use

- Plan and design urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas. Use best practice water sensitive urban design, including sediment ponds, building phase sediment and erosion controls and adequate buffer width between urban and riparian zones.
- Manage sites adjacent to aquatic and riparian areas to reduce weed invasion and pest animals.
- Manage recreational activities in the riparian zone to minimise impact using measures such as providing non-erodible walking paths where high intensity recreation occurs.
- Educate ACT residents about waterway health, including stormwater run-off, recreational fishing and illegal flora and fauna introductions (see Chapter 0).

4 STRATEGY: MANAGE FOR CONSERVATION OF COMMUNITIES AND SPECIES

Murrumbidgee River below Tharwa Bridge showing constructed Engineered Log Jams. Photo: M. Jekabsons ACT Government

4.1 OVERVIEW

Many aquatic and riparian ecosystems require active management to conserve communities and species. For each ecosystem component (water flows and quality, habitat, biota, connectivity and people—see Chapter 1) there are best practice management tools that can be used to maintain or rehabilitate ecological condition. This chapter will discuss the key principles and approaches to aquatic and riparian ecosystem management in the ACT as well as applicable management tools.

A key objective of this strategy is to provide conservation management guidelines for the protection and enhancement of aquatic and riparian areas. Achieving these outcomes is based on the identification of where management actions are required and which management tools will be most effective. It is important to understand the condition of the ecosystem, component or population in question so that the correct management action can be used. Condition monitoring will help determine whether a management approach is working (section 4.4.3) or needs changing through adaptive management processes (section 4.4.1).

In general, where an aquatic or riparian ecosystem is not threatened, it is only minimally managed. Regulations and monitoring may be in place to conserve its current condition, but it is otherwise likely to be subject to minimal active intervention. As a result, the majority of aquatic and riparian management tools are based on threat management (see Chapter 0). This chapter provides the goals, principles and approaches to guide the selection of management tools where intervention is required.

4.2 MANAGEMENT GOAL

Manage aquatic and riparian areas in the ACT across all tenures to maintain or improve ecological condition and biodiversity, with particular attention to habitat of threatened species.

4.3 KEY PRINCIPLES

- Best practice management involves applying an 'adaptive management' approach linking research and monitoring to management action.
- Natural variation can be essential in maintaining aquatic ecosystems, biodiversity and function, including variation in flow and habitat types.
- Connectivity is a critical component of aquatic and riparian ecosystem health. Well-connected ecosystems should be maintained and protected with rehabilitation undertaken where connectivity is not functional. Rehabilitation should be strategic rather than piecemeal in order to improve connectivity.
- Aquatic and riparian ecosystem management needs to include climate change risk considerations to reduce the impacts of climate change using climate change adaption principles/actions.
- Legislation to protect and manage aquatic and riparian species and habitat is critical to maintaining these ecosystems in good condition. Enforcement is a critical component of effective legislation.

- The availability of species habitat in good condition is necessary for maintaining viable populations of aquatic and riparian biota. It may be necessary to actively improve habitat condition in highly impacted areas.
- In specific circumstances intervention may be necessary to manage species individually. Measures may include translocation, stocking and seed orchards and banks. These should be undertaken in accordance with other relevant ACT regulations, policies and action plans.
- Active management of recreation and provision of suitable infrastructure in aquatic and riparian areas is vital to protecting the ecological values of areas and the biota they contain.
- Fire can be a management tool, a threat and/or a natural ecosystem disturbance in aquatic and riparian ecosystems. It is important that prescribed burn locations and timings are informed by ecological advice.
- Collaboration between jurisdictions, the Commonwealth and research bodies is important for developing and implementing best practice management approaches.

4.4 MANAGEMENT APPROACH

4.4.1 Apply best practice within an adaptive management framework

In the context of ecological conservation, best practice management is that which best promotes biodiversity and healthy ecosystem function. It is underpinned by monitoring and research that provides up-to-date information about the effects of different management practices, which then feeds into an adaptive process where changes can be made based on outcomes. Management should also use the 'precautionary principle' where a reasonable likelihood of unacceptable harm from an action is identified and action is taken to avoid or reduce that harm despite the absence of full knowledge.

Understanding of aquatic ecosystems is constantly improving but there are still many unknowns. Consequently, it is important to use an adaptive management approach that responsively changes as understanding is gained. Adaptive management allows for the testing of management practices *in situ* to determine if they are achieving desired outcomes and modifying them as required. Adaptive management requires clearly defined objectives based on current knowledge of the ecosystem, associated species and their responses to management. The results of the management regime must be monitored so its effectiveness can be assessed and modified as required based on outcomes of monitoring. An important part of an adaptive management approach is the recognition that flexibility is required in management techniques.

An example of adaptive management in an aquatic context in the ACT is the application of the Environmental Flow Guidelines (ACT Government 2013c) to the management of the Cotter River for threatened fish. During the drought of 2002–10, flows needed to be managed to provide for human use yet allow fish to survive and breed. This process was managed through regular meetings of dam managers, catchment managers and ecologists to determine the best possible compromise given the competing demands for a limited water resource. The decisions were informed by carefully designed research and monitoring of flow, water quality, threatened species and other key biota. This management process was successful in both maintaining threatened species populations while providing adequate water supply to Canberra residents. A similar approach is currently being used to manage the recent lack of spawning in Macquarie Perch.

The ACT Government will encourage best practice conservation management to be undertaken in an adaptive framework and facilitate the incorporation of monitoring and research results into management of ACT waterways.

4.4.2 Guidelines for applying best practice within an adaptive management framework

- Use best practice and adaptive management approaches when managing aquatic and riparian areas.
- Ensure management is informed by monitoring and research of habitat and biota.
- Use regular meetings and communication between land, water and species managers and, where appropriate, the community to ensure management actions are compatible and do not cause unacceptable harm to environmental resources.

4.4.3 Importance of condition assessment

Effective assessment of condition underpins all ecosystem management strategies. Understanding the current condition of a community or species is critical for managers to identify what action (if any) is required. Ongoing assessment is necessary to understand how effective management actions have been, whether actions need to be modified (adaptive management) and which threats might be causing decline.

The ACT Government currently makes use of several monitoring programs to make assessments of aquatic and riparian condition (see section 1.1) including surface and groundwater quantity monitoring (including abstraction), AUSRIVAS macroinvertebrate assessment, physical, chemical and biological water quality monitoring, fish assessment and algal monitoring (ACT Government 2015a). Community monitoring programs are undertaken through Waterwatch and Frogwatch. These community activities generally sample at a greater number of locations than government monitoring and are therefore very important for broader condition assessment.

The ACT Government undertook a riparian assessment in 2009–10 and follow-up monitoring in 2016. All monitoring results feed back into management of the species or ecosystem. A discussion of condition in relation to ecological values and how the ACT Government will make use of condition assessment is in the ACT Conservation Effectiveness Monitoring Program (CEMP) overview (Brawata et al. 2017).

The Australian Government Integrated Ecosystems Condition Assessment (IECA) (Department of the Environment and Energy 2017) is a nationally agreed framework to assess the condition of aquatic ecosystems at multiple spatial and temporal scales and be able to compare the condition of aquatic ecosystems in the ACT to those in other states and territories.

4.4.4 Guidelines for integrating condition assessment

- Continue to monitor aquatic and riparian systems for the provision of condition assessment to feed back into management decision making.
- Continue to support community monitoring activities. Consider ways to directly link management actions and indicators with outputs from appropriately targeted community monitoring activities.
- Use the CEMP monitoring program to guide condition assessment and reporting.
- Integrate, where appropriate, IECA principles and recommendations for condition monitoring.

4.4.5 Local and regional cooperation

Actions taken in the ACT to conserve and rehabilitate aquatic and riparian ecosystems are carried out in the context of integrated catchment management for the Murray–Darling Basin as a whole. The degraded state of riverine and riparian ecosystems in the basin is well documented, as is the threatened state of native fish populations (Murray–Darling Basin

Commission 2004). It is important for the initiatives in this strategy to be linked to relevant regional and national policies and programs.

Effective conservation management of aquatic and riparian ecosystems across all tenures in the ACT and region involves commitment and cooperation among government agencies, universities, other landholders and the community. The ACT Government will work with government agencies, landholders (including rural lessees) and the community to encourage and facilitate best practice management.

4.4.6 Guidelines for local and regional cooperation

- Maintain links with, and participate in, national recovery efforts for threatened aquatic and riparian species to ensure ACT conservation actions are coordinated with other state and national programs.
- Liaise with relevant agencies with the aim of achieving a coordinated, regional approach to the conservation of threatened species.
- Maintain Public Land management plans (reserve management plans and land management plans) or similar arrangements (for other tenures) that reflect commitment to active and effective conservation of aquatic and riparian ecosystems.
- Use regional and ACT water and catchment management plans to assist cooperation (e.g. ACT Government 2016a).
- Provide up-to-date best practice management guidelines for managers of all land tenures and community groups to apply when undertaking aquatic and riparian management activities.

4.5 MANAGEMENT TOOLS

4.5.1 Rehabilitation to improve condition

Ideally, it is best to protect river reaches that are in good condition and prevent these areas from becoming degraded. It is more cost-effective to maintain areas in good condition than to rehabilitate them. Also, the rehabilitation of damaged is a long process with variable levels of successful restoration to fully functional systems.

Many important aquatic and riparian areas have already become degraded through direct or indirect human activities, and require rehabilitation. River rehabilitation (restoration) is defined by Speed et al. (2016) as 'Assisting the recovery of ecological structure and function in a degraded river ecosystem by replacing lost, damaged or compromised elements and re-establishing the processes necessary to support the natural ecosystem and to improve the ecosystem services it provides.'

Different levels of river rehabilitation may be needed to improve an aquatic and riparian area to achieve rehabilitation objectives. Decisions require consideration of the scale of action (e.g. whole catchment, local scale), temporal scale (short-term single intervention or several decades with multiple interventions) and the type of action (e.g. passive/policy, active/on-ground or both). This strategy does not prescribe specific rehabilitation activities, however strategic analyses should be conducted into what needs to be rehabilitated, how it can most effectively be rehabilitated and the priority of different actions. Rehabilitation interventions should also be monitored to determine whether objectives have been achieved, understand what a successful intervention looks like and apply learning to new projects.

Rehabilitation planning was undertaken for the Actions for Clean Water (ACWA) Plan (Murrumbidgee Catchment Management Authority 2012). The ACWA Plan aimed to determine and prioritise actions to reduce turbidity and improve water quality in the Upper Murrumbidgee Catchment. ACWA was based on GIS analysis and stakeholder (expert) opinion to identify areas that needed attention. Although developed for the catchment, the plan identified actions that could be implemented at the local scale.

A significant in-stream rehabilitation project was undertaken in the ACT in 2001 in the Murrumbidgee River adjacent to Tharwa to improve fish passage and habitat through a sand affected river reach. The project included the construction of rock deflectors and other habitat improvement actions. This project was only partially successful as the interventions were not aggressive enough to manage this sand-affected river reach. In 2013 rehabilitation of the Tharwa sand-affected river channel was attempted again with the construction of engineered log jams at Tharwa that aimed to improve river depth (hence fish passage) and fish habitat in a degraded river section. Follow-up monitoring has shown the objectives were met in that the river channel was significantly deepened (0.4 m to 2 m) and provided habitat for native fish, particularly Murray Cod.

However, a catchment approach is needed for long-term management of the problem (such as reducing soil erosion upstream). Another larger scale rehabilitation program has taken place in the Lower Cotter Catchment to improve catchment run-off water after fires in 2003 and the removal of pine plantations. This program has involved significant weed and pest animal management, native vegetation replanting, road and other erosion area rehabilitation (ACT Government 2016h).

4.5.2 Guidelines for rehabilitation to improve condition

- Conduct baseline monitoring and condition assessment to determine rehabilitation needs.
- Prioritise rehabilitation for different sites and situations.
- Set goals for rehabilitation activities.
- Investigate and apply different rehabilitation options for different scenarios, with consideration of cost-benefit analyses.
- Conduct follow-up monitoring of rehabilitation activities to guide future adaptive management.

4.5.3 Maintaining and improving connectivity

Connectivity is a critical component of aquatic and riparian ecosystem health. Threats to connectivity and their management have been discussed in Chapter 3. Where connectivity is not functional, rehabilitation may be necessary. However, disconnection may be deliberately maintained to prevent pest fish incursion (e.g. Cotter Dam prevents Redfin Perch and Carp incursion into the Cotter River). As discussed above, rehabilitation should be strategic rather than piecemeal and aim to optimise connectivity.

Maintaining or improving connectivity for aquatic and riparian systems is critical for helping biota adapt to a changing climate. A well-connected aquatic and riparian ecosystem allows biota to move to refuges during times of climate stress and also allows biota to re-distribute to more suitable climatic conditions in the long term. To maintain the ability of the system to provide these adaption services, aquatic areas must have suitable water flow quantity and timing. If this is not available, it must be provided through environmental flow provisions.

Given that climate change will cause increased temperatures, an intact riparian zone is particularly important for providing thermal refuge. The riparian zone maintains a higher water content and is often cooler than surrounding areas, alleviating thermal conditions by both shading the water and providing a terrestrial refuge (Seavy et al. 2009). A sufficiently vegetated riparian zone is necessary for both temperature reduction and for bank protection during flooding

Figure 4.1 Lees Creek weir is a potential barrier to passage for some aquatic species, reducing connectivity. However, the weir can also form a barrier to pest species invading the upstream river section. Photo: M. Jekabsons, ACT Government.

4.5.4 Guidelines for maintaining or improving connectivity

- Investigate options for rehabilitating important in-stream habitat that is affected by discontinuity (e.g. sediment slugs, Point Hut Crossing) and rehabilitate where feasible.
- Identify areas where riparian vegetation is discontinuous to allow strategic prioritisation for rehabilitation.
- Maintain existing fish passages (Casuarina Sands, Cotter Campground, Vanitys and Pipeline crossings) to ensure adequate passage.
- Maintain adequate connecting flow through environmental flow provisions if necessary.
- Maintain and, where practicable, improve lateral connectivity with upslope ecological communities.

4.5.5 Regulations to protect aquatic and riparian ecosystems

Regulations are important for the protection and sustainable use of aquatic and riparian systems and their species. The regulations concerning aquatic and riparian ecosystems are multifaceted. Not only do they cover the protection and conservation of species, but also utilisation of water and fish resources. Fish management in the ACT is guided by the Fisheries Act, Nature Conservation Act (protected animals and plants and their habitat), Pest Plants and Animals Act and Animal Welfare Act. Other aspects of the riparian and aquatic ecosystem are considered under the Environment Protection Act, Water Resources Act and the planning acts. Regulatory approaches are necessary to underpin the sustainable use of resources and the conservation of ecosystems and their components.

4.5.6 Regulations to protect fish

The Fisheries Act is particularly important for the management of recreational angling in the ACT. The objects of the Fisheries Act are to conserve fish and their habitat, sustainably manage ACT fisheries, provide high quality and viable recreational fishing and to cooperate with other jurisdictions regarding sustainable fisheries and protecting native species.

The Fisheries Act and its instruments detail the gear types and quantities that may be used for fishing, along with bag and size limits for fish species, and closed seasons or total prohibitions for particular species or water bodies. These fishing controls, which are based on the best available knowledge, are designed to provide a sustainable recreational experience. The provisions of the Fisheries Act are largely consistent with the relevant fisheries legislation in NSW and Victoria to minimise potential for confusion amongst anglers.

4.5.7 Guidelines for regulations to protect aquatic and riparian ecosystems, including fish

- Update regulations where required by changes to best practice management and the adaptive management process.
- Give particular attention to protecting and managing threatened, uncommon and declining species and their habitats.
- Liaise with relevant NSW, Victorian and federal authorities to ensure consistency in regulations, where practicable.
- Carry out enforcement activities to encourage recreational anglers to fish in accordance with the Fisheries Act provisions, which aim to sustain the resource and ensure ethical angling activities.

4.5.8 Implementation of ecologically appropriate fire regime

Fire can play different roles in aquatic and riparian ecosystems—it can be a management tool, a threat or a natural ecosystem disturbance. Fire as a management tool is directed under the Strategic Bushfire Management Plan (SBMP). The SBMP is a requirement of the Emergencies Act. It is the overarching document that directs bushfire management in the ACT. The SBMP allows emergency services and fire managers to have the flexibility they require to implement measures to reduce bushfire risk in the ACT.

The ACT Government's Environment, Planning and Sustainable Development Directorate has an annual Bushfire Operations Plan (BOP) developed by ACT Parks and Conservation Service Fire Management Unit. The BOP specifies the timing, type and location of fuel reduction burns and other activities (such as grazing, slashing). It is developed from the Strategic Bushfire Management Plan (ACT Government 2014 b) which includes reference to the 10-year regional fire plan for ACT Government lands. Ecological advice on each of the fuel management activities is provided in the BOP and the Ecological Guidelines for Fuel and Fire Management Operations to assist on-ground fire activities to reduce adverse ecological impacts. For example, it is advised that prescribed burn activities are kept at least 30 metres from major rivers to reduce the impact on streams and limit sediment input. The potential threats of fire to aquatic and riparian ecosystems are discussed in section 3.18.

4.5.9 Guidelines for implementing ecologically appropriate fire regime

- Adhere to the Ecological Guidelines for Fuel and Fire Management Operations and update these guidelines when new information becomes available.
- Continue to include ecological advice on burning for fuel management into the fire planning process.
- Continue to conduct monitoring before and after prescribed burns take place in sensitive areas and apply acquired knowledge to how and where prescribed burns are undertaken.
- Conduct research on the effects of planned and unplanned fire on aquatic and riparian ecosystems and threatened aquatic species.

4.5.10 Recreation management to protect aquatic and riparian ecosystems

The aquatic and riparian ecosystems of the ACT are popular recreation areas (Schirmer and Mylek 2016). Promoting natural environments for recreational purposes increases the perceived value of these areas and provides educational opportunities (section 6.5).

However, increased recreational use of aquatic and riparian areas presents a risk of degradation, necessitating careful management of recreational use.

Across the ACT, public land management plans (reserve management plans and land management plans) are used to guide the type and extent of recreation use available in and along different waterways. Visitors are generally encouraged to use centralised areas, which comprise only a small fraction of the entire riparian zone. Higher value riparian conservation areas have limited physical access aimed at reducing visitor impacts. However, many of the major recreation hubs in the riparian zone are centred on deep pool habitats (Kambah Pool, Casuarina Sands, Pine Island and Tharwa Sandwash). These deep pools are limited in the ACT sections of the Murrumbidgee River and may provide refuges and breeding habitat for important aquatic species.

Figure 4.2 Cotter River riparian zone after prescribed burn. Photo: M. Jekabsons, ACT Government.

Appropriate facilities are provided in recreational areas to cater to the expected number of visitors and nature of activities. Toilets, BBQs, picnic tables and walking tracks are provided to encourage recreation in specific areas. Low impact linear walking trails along the river corridors from recreation nodes are an appropriate form of access to the wider area, provided they are sited to avoid damage to sensitive areas.

Visitors are required to behave in accordance with the Nature Conservation Act and Activities Declarations that stipulate restricted and prohibited activities in certain areas. To ensure compliance, recreation areas are regularly supervised by Parks and Conservation Service staff. In general, however, a policy of 'education before enforcement' is adhered to and to this end, educational and Activities Declaration signage is in place at recreational areas. In addition, ranger guided activities are undertaken to engage visitors with aquatic and riparian conservation messages.

Riparian zones and adjoining lands are managed under the Strategic Bushfire Management Plan (see above). Recreational angling is managed in accordance with the Fisheries Act (sections 4.5.6 and 6.4.2). Parks and Conservation Service Rangers undertake education and compliance activities throughout the year, focusing on restrictions that vary seasonally. This is supported by signage in recreational areas commonly used by anglers.

4.5.11 Guidelines for recreation management

- Assess the impact of high use recreational areas in aquatic refuge habitats.
- Continue to encourage and enable appropriate recreational use of riparian and aquatic areas through provision of suitable facilities.

- Use signage and on-ground activities to educate the community about appropriate recreational activities (including angling), fire restrictions and broader conservation messages.
- Where necessary, enforce regulations if encouragement, enablement and education have not been successful.

4.5.12 *Ex situ* measures to safeguard threatened species

For some threatened species, preventing extinction in the wild requires significant *ex situ* actions such as establishing programs for captive breeding, propagation, seed banks and translocation of individuals. Seed banks and captive populations of animals can provide some insurance against the loss of a species if wild populations become locally extinct. In some cases, *ex situ* populations or seed banks can be used to re-establish wild populations. Captive populations have also been used for undertaking essential conservation research that is impractical with wild populations. Captive breeding, propagation or translocation programs can be useful methods (sometimes the only methods) for promoting the recovery of small extant populations.

There are usually significant risks (both to wild and captive populations) and costs associated with establishing *ex situ* populations or undertaking translocations. Critical assessment of the risks, costs, likelihood of success and long-term outcomes of *ex situ* actions should be undertaken prior to implementation. In general, *ex situ* actions should be used only in exceptional circumstances, such as when on site actions have failed or are high risk and the species' survival is likely to depend on *ex situ* solutions (which may include essential research).

Reinstatement of native fish species that have experienced dramatic population decline has been undertaken in the ACT for recreational, ecosystem function and conservation purposes (ACT Government 2015d). Experimental reinstatement of hatchery-bred Trout Cod was undertaken in Bendora Reservoir and the Murrumbidgee River. Trout Cod have survived in Bendora Reservoir and successfully reproduce when conditions are suitable. Macquarie Perch from Cotter Reservoir have been translocated to above Corin Reservoir and Molonglo River at Kowen Gorge to reduce the risk to the population from the Cotter Dam enlargement (Lintermans 2010). Whilst being monitored, the success of these Macquarie Perch translocations is yet to be determined.

In terms of threatened riparian plant species, *ex situ* actions have taken place for the Tuggeranong Lignum and Murrumbidgee Bossiaea. Propagation and translocation has been undertaken for the Tuggeranong Lignum, and a seed bank has been developed and germination trials conducted for Murrumbidgee Bossiaea. Monitoring is required to evaluate the results of these management actions.

Fish are no longer stocked into natural rivers in the ACT other than for conservation purposes. This policy is outlined in the ACT Fish Stocking Plan. Native angling species do not successfully reproduce sufficiently to support recreational angling in Canberra urban lakes, so need to be stocked. Fish are stocked into four urban lakes for angling, to balance the ecology of the urban lakes by introducing native predators and to help reduce the angling pressure on natural fish stocks in the ACT rivers.

4.5.13 Guidelines for *ex situ* measures to safeguard threatened species

- Adhere to current best practice translocation guidelines, such as the IUCN Guidelines for Reintroductions and Other Conservation Translocations (IUCN/SSC 2013) and the ACT Government Translocation Guidelines (in draft).
- Consider factors such as impact on naturally existing species, likelihood of success and cost when assessing translocation and conservation stocking.

- Consider establishment of captive threatened animal populations or translocations of threatened animals only under exceptional circumstances. For example, if the species' survival or ongoing health is likely to depend on such actions.
- Conduct translocations of threatened animals in accordance with approval by the Conservator of Flora and Fauna, as per the ACT Government Translocation Guidelines.
- Develop partnerships with other jurisdictions that may contain translocation source populations of conservation dependant species.
- Develop any proposals to translocate threatened species or establish captive populations and seedbanks in consultation with the ACT Government Conservation Research unit.
- Adhere to guidelines in the ACT Fish Stocking Plan.

4.5.14 Genetic management to improve conservation success

Genetic analysis can be a powerful tool, critical to the successful conservation management of a species. Genetic information can uncover previously unknown species, past and present dispersal, adaptations and distinctive groups within a species or loss of population diversity.

Isolated, disturbed, small or rare populations can suffer from poor genetic health and loss of genetic diversity though various mechanisms (e.g. founder effects, genetic drift and inbreeding depression). This loss of genetic diversity can drastically impact on species' survival, reduce their resilience to threats such as disease and climate change and may also diminish their ability to positively respond to other conservation actions (Frankham 2005, Weeks et al. 2011).

Managing genetic diversity by re-establishing gene flow can improve fitness of individuals and populations as well as increase evolutionary potential (the ability of species to adapt to environmental changes). Ultimately, these will lead to enhanced prospects for population persistence (Frankham 2005, Harrisson et al. 2014, Whiteley et al. 2015). However, genetic rescues should be carefully designed, with consideration of risks including biosecurity and risks to the target species and other environmental, social and economic values.

Genetic analysis also provides a tool for investigating other critical features at both a population and individual level. The development of effective analysis to determine individual, parent and sibling relationships allows for the expansion of genetic tools to help investigate movement of individuals and populations, assess impact of stocked fish into wild populations and hybridisation of closely related species such as Trout Cod and Murray Cod. Additionally, the development of environmental DNA assessment techniques could assist in detecting rare species, new alien incursions and potentially critical habitats such as breeding zones.

In the ACT, genetic information at various levels has been collected on Macquarie Perch, Murray Crayfish, Murray Cod, and Two-spined Blackfish (REF, Pavlova et al, Whiterod et al. 2016, Couch et al. 2016, Beitzel 2000). In relation to Macquarie Perch, genetic analyses highlighted problems within several local populations. The Cotter River population, for example, was shown to have very low genetic diversity and effective population size (Pavlova et al. 2016). The Macquarie Perch genetic data have also assisted in explaining the loss of the Queanbeyan River population following a rescue translocation from Googong Dam (Lintermans 2013b, Farrington et al. 2014). In relation to Murray Cod, research has identified cross-breeding with Trout Cod in the ACT Murrumbidgee (Couch et al. 2016).

4.5.15 Guidelines for genetic management

- Use genetic analyses to investigate population dynamics, assess conservation issues and determine genetic health.
- Assess risks to target species and broader environmental, social and economic values prior to all genetic management activities.
- Consider relevant guidelines outlined for translocation (see section 4.5.13) and undertake the required approval process before undertaking genetic management activities.

4.5.16 Importance of refuges to maintaining biodiversity

Ecological refuges are important environmental assets. They are areas that plants and animals use to escape environmental stresses. Refuges provide protection from contemporary disturbances that might otherwise threaten fitness and survival (Davis et al. 2013). In the riparian and aquatic ecosystems of the ACT, ecological refuges may provide protection from:

- human disturbance (in protected areas)
- low flow (in river pools)
- flood disturbance (in edge habitats, deep pools and behind in-stream structures)
- extreme temperatures (in well-vegetated areas and deep pools)
- predation
- fire
- alien species.

The concept of a refuge tends to be relative to the scale and regime of a disturbance as well as species' adaptations (Magoulick and Kobza 2003). In general, however, refuges are areas in good ecological condition. For example, in riparian zones they may be well-vegetated areas with stable banks—in Australian aquatic systems, refuges often take the form of waterholes that can persist with low (or no) water inflow (Davis et al. 2013).

Refuge habitats will become increasingly important under a changing climate. Climate change predictions for the ACT suggest that the frequency and magnitude of flows will be less predictable while mean and extreme temperatures rise (ACT Government 2016c). Such changes will make species more dependent on refuges as areas that can mitigate drought and flood disturbances and alleviate thermal stress.

Ideally, ecological refuges should be numerous, persistent and distributed such that biota are able to disperse and recolonise the broader ecosystem when refuges are reconnected by suitable external conditions (DSITI 2015). Understanding the spatial distribution and persistence of refuges in the ACT will assist in the management of these environmental assets. Managing riparian and aquatic refuges for optimal condition and persistence is critical for supporting biodiversity in the ACT. Additionally, identifying refuges is a useful way to help prioritise areas for rehabilitation efforts (Speed et al. 2016).

4.5.17 Guidelines for managing refuges

- Identify, map distribution and assess condition of key riparian and aquatic ecological refuges. Where possible, forecast likely persistence of refuges under different disturbance scenarios.
- Continue to protect and conserve well-maintained refuges.
- Identify critical in-stream and riparian refuges in poor condition and prioritise for rehabilitation.

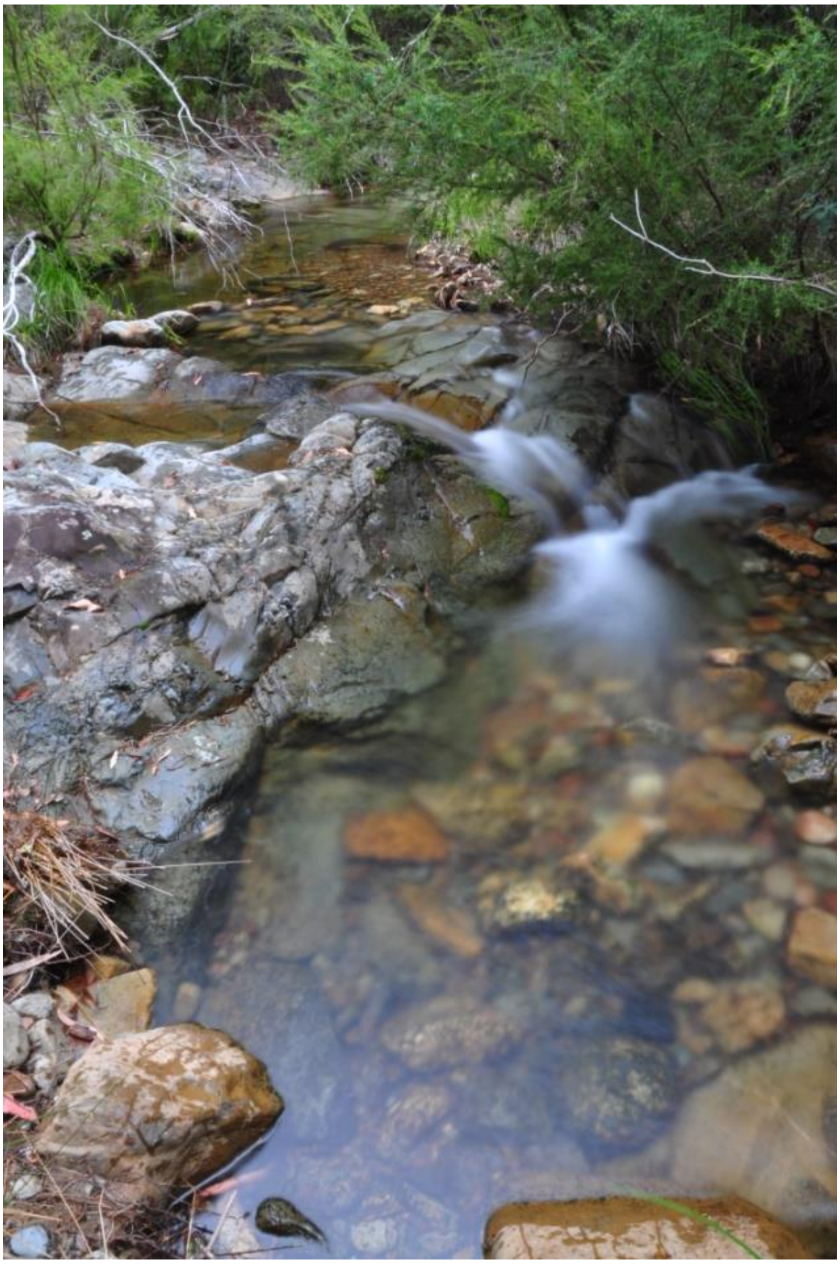

Figure 4.3 Burkes Creek in the Cotter River catchment. Photo: M. Jekabsons, ACT Government.

5 STRATEGY: MONITORING AND RESEARCH

Backpack electrofishing at Lick Hole Track Crossing. Photo: M. Jekabsons ACT Government

5.1 OVERVIEW

Effective conservation planning and adaptive management requires a sound knowledge base. Monitoring and research undertaken by the ACT Government and other research institutions has contributed to the body of knowledge on the ecology and management of aquatic and riparian areas (see section 7.5.4). The dynamic nature of riparian and aquatic environments necessitates ongoing monitoring of these ecosystems to assess any changes in condition. Survey and research is required to fill knowledge gaps relating to the management of aquatic and riparian ecosystems and the ecology of their constituent species.

5.2 MONITOR CONDITION

Monitoring changes in the condition of ecological communities and their biodiversity is a key part of the long-term management of species and ecological communities. Through repeated measurement of an entity, changes can be detected over time. Observation of change in ecosystem condition results in better understanding of underlying processes and indicates when management intervention may be required. Monitoring can also assess the effectiveness of interventions. Thus, monitoring should aim to capture (after ACT Government 2015c):

- threatened species and communities
- threatening processes
- species and communities of conservation concern
- key indicators of biodiversity and ecosystem health
- species and community responses to intervention.

The ACT Government undertakes regular monitoring of its listed flora and fauna species and these programs are outlined in their respective action plans. The ACT Government's Conservation Effectiveness Monitoring Program (CEMP) also incorporates ecosystem condition monitoring programs (Brawata et al. 2017). Data from the monitoring of aquatic and riparian ecosystem condition contributes to CEMP indicators and enables the assessment of ecosystem condition and the status of identified threats. Such assessments provide information on the health of the ecosystem and the effectiveness of management programs (Brawata et al. 2017). The potential indicators considered for aquatic and riparian monitoring in the CEMP are listed in Table 5.1. All monitoring results feed back into the management of species and ecosystems, with changes in management approach arising in response to monitoring outcomes where needed.

Monitoring by community organisations makes an important contribution to the assessment of ACT's aquatic and riparian ecosystems. Organisations such as Waterwatch and Frogwatch undertake monitoring activities at a greater number of sites than government monitoring, helping to inform a broader assessment of ecosystem condition across the ACT and region.

Table 5.1 Monitoring indicators for ACT aquatic and riparian areas from the CEMP.

These indicators are currently being refined. Condition will be given a rating against both a reference and target condition and combined to form an overall assessment of indicator condition. For more information of interpretation of these assessments see CEMP Overview documentation (ACT Government 2017).

Headline indicator	Indicator	Metric
Geomorphology and water quality	Water quality	Water physical and chemical parameters
		Periphyton and beneficial algae
	Stream channel	Stream channel width
		Stream bank stability
Riparian zone	Riparian vegetation	Native species richness
		Width of the riparian zone
		Age class of dominant species
		Structure and cover of habitat
	Riparian Connectivity	Connectivity along riparian zone
		Connectivity with adjacent ecosystems
Aquatic and riparian fauna	Native Fish	Juvenile fish
		Two Spined Blackfish
		Macquarie Perch
		Murray Cod
		Murrumbidgee native fish
		Mountain Galaxias
	Other native fauna	Macroinvertebrates
		Mountain crayfish
		Waterbirds
		Frogs
		Native mammals

Table 5.2 Stressor (threat) indicator metrics used within the Aquatic and Riparian CEMP plan.

The state of the stressor will be assessed against both reference and target state and combined to form an overall assessment of the stressor. For more information regarding the interpretation of these assessments see CEMP Overview documentation (ACT Government 2017).

Headline Indicator	Stressor	Metric
Inappropriate flow regimes	Impaired flow	Aquatic barriers
		Environmental flows
		Sedimentation
Inappropriate fire regimes	Inappropriate fire regimes	Fire frequency in riparian zone
		Fire proximity to aquatic environments
		Fire seasonality
Invasive plants	Invasive plants and algae	Priority weed species
		New incursions
		Invasive algae
	Microbiology	New incursions
Invasive aquatic animals	Alien fish	Carp
		Gambusia
		Trout
		Redfin
Vertebrate pests	Feral herbivores	Feral pigs
		Deer
		Rabbits
Disease and viruses		EHN Virus: distribution

5.2.1 Priorities for current and future monitoring

- Use the CEMP as a framework for monitoring the condition and long-term changes in aquatic and riparian ecosystems.
- Use the CEMP to develop a model for the monitoring of ecosystem which will also help to identify research and monitoring gaps.
- Use action plans to guide monitoring for ACT threatened species (Part B of this strategy).
- Uncommon aquatic fauna:

- Maintain a monitoring program for fish and aquatic macroinvertebrates in the ACT and appropriate external reference sites.
- Uncommon plants and riparian fauna:
- Maintain a database of known occurrences and abundance of uncommon plants and fauna species that use the riparian zone to enable analysis of changes in distribution and abundance.
- Maintain a watching brief on ACT populations of uncommon plants and fauna species that use the riparian zones. Evaluate their conservation status in a regional context.
- Identify and monitor current and emerging threats to:
- riverine and riparian habitats
- native riparian flora, fauna and ecological communities
- native aquatic fauna and ecosystems.
- Ensure monitoring encompasses ecosystem elements that may be affected by future stressors, including climate change and new development. For example, monitoring of montane crayfish populations and thermal refuges for fish may both become increasingly necessary under future climate scenarios. Similarly, the impact of new developments near riparian zones will require monitoring.
- Where threat abatement or rehabilitation actions occur, carry out selected intervention monitoring to determine if aims are achieved. Learn from the outcomes to better apply rehabilitation actions in the future (e.g. the hydrological and ecological effectiveness of engineered log jams). In addition targets to be set for ecosystems in the CEMP which recommend suitable indicators.
- Incorporate findings from monitoring programs into adaptive management approaches to investigate and improve the effectiveness of aquatic and riparian management strategies.
- Collect information which will assist planning. For example, determining critical habitat of species to avoid damage during water resource developments or to assist strategic planning for rehabilitation programs.
- Maintain a monitoring program aimed at understanding recovery of ecological communities and their component species (in particular, fire-sensitive species).
- Maintain ACT flora and fauna databases to support planning, management and research.
- Link data collection to national, state (particularly NSW) and community databases.

Figure 5.1 ACT Conservation Research officer conducting fish monitoring. Photo: M. Jekabsons, ACT Government.

5.3 COLLECT BASELINE INFORMATION

Surveys of aquatic and riparian environments provide baseline information on the distribution and characteristics of ecosystems and their constituent species. This information is a necessary foundation for effective management as it informs future monitoring and research priorities and assists in guiding development applications. The aquatic and riparian areas of the ACT have generally been well surveyed over preceding decades. Maps and databases have been generated for vegetation, bird and fish distributions and much of this information is publicly available on online databases (ACT Government 2015b, Atlas of Living Australia 2016).

There are some remaining baseline information gaps for ACT aquatic and riparian areas, and the ACT Government is committed to the ongoing collection of data and information to inform management and planning. There are a number of projects currently under way that will contribute high quality data for conservation management. Examples inlcude a survey assessing the baseline condition of significant riparian vegetation communities in the ACT, a survey of small stream fish assemblages and a survey of the distribution and habitat associations of upland spiny crayfish of the ACT.

5.3.1 Priorities for collecting baseline information

- Increase resolution of riparian vegetation mapping (in accordance with vegetation communities of Johnston et al. 2009, Armstrong et al. 2013).
- Identify and map spatial arrangement of potential climate change refuges, their connectivity and quality (i.e. relationship to nearby threats).
- Compile identification of barriers to fish dispersal into a map and consider the process for all threatened species.
- Identify critical fish breeding habitat particularly for Macquarie Perch and Murray Cod.
- Collect baseline fish data for areas not accessible by electrofishing boat (after Lintermans 2011).
- Collect baseline data for monitoring future near-river residential expansion.
- Model of Murray Crayfish detection and abundance.
- Survey other aquatic vertebrate distribution and abundance including Platypus, Water Rats and turtles.
- Survey vegetation and habitat in ACT riparian zones to update existing information and provide a baseline for subsequent monitoring. Give priority initially to:
- areas under most threat from current or proposed land uses or activities
- areas subject to frequent use by humans
- areas of high diversity or with threatened species
- areas where data is the most deficient
- areas near future residential expansion.
- Survey uncommon plant species:
- Maintain alertness to the possible presence of uncommon plant species when undertaking surveys in appropriate habitat.
- Survey uncommon riparian zone fauna:
- Maintain alertness to the possible presence of uncommon fauna species when undertaking surveys in riparian zones.

5.4 RESEARCH

Knowledge gained through research and monitoring is improving steadily and a sound evidence base has been established for ACT planning, management and decision making. However, a changing environment coupled with the complexity of managing aquatic and riparian ecosystems means that knowledge gaps remain. Building upon the already strong research foundation, through ACT Government initiatives and partnerships with research institutions, remains a priority of this strategy.

A research gap analysis conducted for the Upper Murrumbidgee Demonstration Reach (Lintermans 2011) highlighted knowledge gaps that are reflected broadly across the ACT region including:

- the current extent and severity of flow-related water quality problems
- how flows can be used to alleviate water quality, sediment and biofilm issues
- the temporal pattern of scouring and deposition around in-stream structures
- the spatial arrangement and distribution of refuges as well as barriers to movement between them.

Additionally, an international literature review by Strayer and Dudgeon (2010) identified future challenges for freshwater conservation globally. In particular, the limited understanding of primary and secondary effects of climate change is pertinent to the ACT's riparian and aquatic ecosystems. As a matter of urgency, there is a need to research and anticipate ecological and human responses to climate change and plan conservation measures accordingly (Strayer and Dudgeon 2010).

Other major threats to freshwater biodiversity globally include invasion by alien species and habitat degradation (Dudgeon et al. 2006). Nearly all riparian and aquatic ecosystems of the ACT have been invaded by alien species and further work needs to be done to determine how best to control invaders or manage their impacts. Poor habitat condition in the ACT is largely an outcome of historical degradation, but is also likely to be impacted by current management techniques. For example, inappropriate fire regimes can reduce vegetation cover in riparian zones, alter soil conditions, increase erosion and produce low quality run-off (Bennet et al. 2004, Cawson et al. 2012). Further research is needed to look at the local impacts of these processes, with a focus on how they may influence native species.

There are some emerging and more obscure localised threats to ACT aquatic and riparian species that also warrant urgent investigation. Pharmaceutical products, often found in industrial or sewage treatment plant discharges, have received worldwide attention for their impacts on aquatic communities, with aquatic groups such as frogs, molluscs and fish affected (Jobling and Tyler 2003, Mills and Chichester 2005). Locally, pharmaceutical products and oestrogenic activity have been documented in the discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC) (Roberts et al. 2015, Roberts et al. 2016). Although the impacts on local aquatic species are as yet currently unknown, disjunct fish distributions above and below the LMWQCC have been known for many years (Lintermans 2004a). Research into the effects of these discharges, as well as similar outputs from other sewage treatment plants in the region, is vital.

Another pressing threat necessitating research is the ongoing dieback of *Eucalyptus viminalis*, an important riparian vegetation community in the ACT. The dieback is currently widespread in south-east Namadgi National Park and particularly devastating in the Naas Valley (L. Johnston, pers. comm.). The causes, extent and spread of *E. viminalis* dieback are not well understood and research is required to address and arrest its spread as a matter of urgency. The Atlas of Living Australia is now collecting information on dieback sightings.

Urban land uses can have a myriad of impacts on nearby aquatic and riparian ecosystems, as discussed in detail in section 3.17. In the ACT, new urban developments have been planned in proximity to waterways. In addition to using ecological knowledge to inform planning and design, research needs to be conducted into the ongoing ecological impacts of such developments. Thorough examination of ecological condition prior to, during and post-construction should be undertaken locally and downstream. Findings can then be used to inform future development proposals.

The biology and ecology of some ACT native species have not been well researched. It is known that riparian zones generally support different biota to surrounding terrestrial areas (Sabo et al*.* 2005) but less information exists on the composition, biodiversity and ecological requirements of some taxonomic groups. Riparian macroinvertebrates of the ACT are generally not well described and understood (ACT Government 2007). Enhanced understanding of invertebrate diversity and function may lead to greater appreciation of the conservation value of these taxa specifically and riparian ecosystems more generally. In other cases, research into specific behavioural aspects of threatened species will assist conservation planning. For example, continuing study of native fish ecology will inform managers on current unknowns (e.g. movement patterns and habitat requirements for spawning) and the effectiveness of management interventions (e.g. artificial habitat provision and targeted environmental flows).

Research on aquatic and riparian ecosystems in the ACT should be focused on determining best management practice for achieving conservation outcomes. Ideally, such research should be designed so that it can most usefully feed back into conservation planning and management through an adaptive process (see section 4.4.1).

5.4.1 Potential research areas

Research topics pertaining to threatened species and communities are outlined in respective action plans. Other research is required for greater understanding of:

Water flows

- effect of changing riverine flows on riparian vegetation and in-stream habitat.

Water quality

- Impacts of pharmaceutical chemicals on aquatic biota.
- Reduction of poor quality waste water discharge and mitigation of impacts on aquatic biota.
- Effectiveness of water quality controls for near river development.
- Impact and management of fire on water chemistry and biota.

Habitat

- Techniques to prioritise areas for rehabilitation to achieve greatest conservation outcome.
- Short- and long-term effects of fire regimes on aquatic and riparian species.
- Spatial, temporal and intensity thresholds for acceptable fire impacts. Such thresholds could be used to guide future prescribed burns.
- Methods to mitigate impact of wildfire and prescribed burns on aquatic ecosystems.

Biota

- Encourage research on ACT aquatic and riparian ecological communities and component species generally, including taxonomy and ecology of riparian invertebrates.
- Use of lower level water releases (colder water) from dams to potentially mitigate effects of climate change on fish, macroinvertebrates, water quality and sedimentation in ACT waterways.
- Potential climate change impacts on species and ecological communities and their habitat.
- Efficacy of interventions to manage climate change impacts.
- Potential changes to evolutionary dynamics of ecological communities induced by climate change (after Lavergne et al. 2010).

- Identification of key breeding and refuge habitats for aquatic biota.
- Estimation of Carp (or fish) biomass to assist in control, particularly in relation to the potential release of the Carp Herpes Virus.
- Techniques to improve control of alien species and management of consequential outcomes (e.g. clean up following release of disease biocontrols). Cost-benefit analysis of removal of alien species.
- Potential of techniques to remove alien species locally and impact of removing aliens on ecosystem condition.
- Types (egg, larval, juvenile) and level of predation by trout and Redfin Perch.
- Impact of fish stocking on wild populations.
- Techniques to increase survival, persistence and promote genetic health of biota.
- Causes, extent and spread of E. viminalis dieback.
- Techniques to prevent spread, arrest E. viminalis dieback and promote community recovery.

Connectivity

- Seasonal and lifetime movement requirements of native species.
- Efficacy of different artificial fish habitats for specific rehabilitation needs.
- Seasonal use of microhabitat by different age classes of fish and crayfish.
- Genetic tracking of movement, parentage, impact of stocking and hybridisation of key species including Trout Cod, Murray Cod, Golden Perch and Macquarie Perch.

People

- Impact of increased recreational access on native fish and riparian zone.
- Angler impact in upstream ecosystems.
- Effectiveness of closed areas in preserving aquatic ecosystems.

6 STRATEGY: ENGAGE THE COMMUNITY

ACT Government Aquatic Ecologist explaining boat electrofishing to members of the community. Photo: L. Johnston, ACT Government

6.1 OVERVIEW

There is a high level of community engagement with aquatic and riparian areas in the ACT. A recent survey of the region's residents found that 80% of participants reported spending time at ACT waterways, and 25% had recently engaged in fishing (Schirmer and Mylek 2016). This suggests there is considerable appreciation of the ACT's aquatic environments, whether it is for aesthetic, recreational or other reasons. However, there is evidence that many residents are unaware of the principles of aquatic and riparian conservation. The ongoing threats augmented by human behaviour (see Chapter 3) indicate that the extent to which aquatic and riparian conservation is understood and exercised by residents varies.

Strengthening community engagement with waterways is central to promoting support and awareness of aquatic and riparian conservation and encouraging volunteer assistance to achieve conservation goals. This strategy outlines the different ways in which individuals and groups can receive, respond and contribute to planning and management processes.

6.2 SUPPORTING COMMUNITY INVOLVEMENT

Community groups are important contributors to a range of volunteer-driven activities in nature conservation in the ACT. The roles of various community groups and their highly valuable conservation outputs are discussed below. Volunteers are more likely to stay motivated and engaged when they know their work is valued, respected and is having a broader impact (Reid 2015). Thus, the activities of these groups and the value of their work should continue to be promoted and supported. The ACT and Region Catchment Strategy and the ACT Water Strategy include specific targets and actions for community engagement and involvement.

A considerable number of volunteer and community groups contribute to conservation outcomes in the ACT. Recent market research found that around one in twenty ACT residents were currently involved as a volunteer in the ACT's reserve system, and 29% of residents expressed interest in becoming a volunteer (Market Attitude Research Services Pty Ltd 2014). Environmental volunteering has a range of benefits for participants as well as the environment, such as social well-being, meeting like-minded people, gaining work experience and learning new skills.

Many of the ACT's community groups contribute to conservation research through citizen science. Citizen science is an increasingly popular and widely-used method in environmental science and land management, with applications in data collection, data processing, monitoring and research (such as the Canberra Nature Map). Enhancing and promoting the use of citizen science is an important strategy in the ACT, particularly because of the wealth of skills and knowledge in the ACT community (ACT Government 2013a).

6.2.1 Upper Murrumbidgee Catchment Network

The Upper Murrumbidgee Catchment Network (UMCN) is a community-based organisation made up of agencies and groups that are responsible for natural resource management (NRM) in the upper Murrumbidgee Catchment. It is also open to interested individuals with applicable skills and knowledge. The UMCN promotes regional cross-border communication among agencies and groups, including a number of those listed individually below. It engages regularly with government and community and prepares submissions to public inquiries, policy and regulatory reviews and develops communication resources for land managers.

6.2.2 Upper Murrumbidgee Demonstration Reach

The Upper Murrumbidgee Demonstration Reach (UMDR) was established with the aim of improving native fish habitat and river health in the upper Murrumbidgee (UMDR 2016). An initiative established under the then Native Fish Strategy (Murray–Darling Basin Commission 2004), the UMDR showcases the cumulative benefits of multiple management interventions at a single site appropriate for our catchment. The reach is used to engage the community in rehabilitation of native fish and aquatic communities, populations, incorporating robust monitoring and evaluation. Through community partnerships and on-ground works reference groups and hands-on activities, the UMDR initiative works across NSW and ACT borders to encourage understanding of aquatic and riparian ecosystems and strengthen community empathy, collaboration and ownership.

6.2.3 Waterwatch

Upper Murrumbidgee Waterwatch is directly involved in the monitoring and conservation management of aquatic and riparian areas in the ACT (Upper Murrumbidgee Waterwatch 2014). Waterwatch collects information on water quality, riparian condition, platypus and carp breeding events (Carp loves 20 degrees campaign). Waterwatch has approximately 170 volunteers monitoring more than 220 sites across the upper Murrumbidgee region, with assessments summarised into an annual Catchment Health Indicator Program report. As well as directly engaging community members with waterway health, the Waterwatch data can be used to inform policy and catchment management. A review of the Waterwatch data found it to form a good quality baseline dataset (Harrison et al. 2013).

6.2.4 Catchment groups

The ACT region has three catchment groups, each an umbrella group of community organisations engaging in terrestrial and aquatic conservation activities. The Ginninderra, Molonglo and Southern ACT catchment groups advance the health of their respective catchments through engagement with government, business, schools and the broader catchment communities. As with other community groups, they achieve this through various educational and hands-on activities. The ACT Government is currently working with the Southern ACT and Ginninderra catchment groups on new strategic plans to guide their work over the next 10 years, with a likely focus on on-ground outcomes.

6.2.5 Angling groups

Recreational angling groups in the ACT vary in focus and membership size, but all have a vested interest in the health of fish habitats. The Capital Region Fishing Alliance (CRFA) was established in 2009 with the aim of being the recognised representative voice for recreational anglers in the region. It comprises the five largest freshwater angling clubs in the ACT region. The organisation's mission is to contribute to the management, conservation and enhancement of fish and fish habitat in the ACT region. Activities focus on improving the quality of fishing in the ACT and have included the installation of artificial fish habitat and stocking of recreational fisheries with support from the ACT Government. The ACT Government regularly engages with the CRFA and other fishing organisations on a range of issues including:

- recent project findings
- recreational fishing regulations
- fish stocking and other ACT Government policies.

6.2.6 Frogwatch

ACT and Region Frogwatch is delivered by the Ginninderra Catchment Group. Frogwatch engages large numbers of volunteers to undertake frog monitoring and help protect frog habitats in the ACT region. ACT Frogwatch also provides materials and volunteers for school education programs designed to help students learn about the conservation of frogs and their habitats.

6.2.7 Canberra Nature Map

Canberra Nature Map (CNM) is a website and smart phone app founded by ACT residents in 2014 which allows citizens to report geo-referenced sightings of flora and fauna through photography. The subject of the photo is identified by a team of volunteer experts. The tool includes vascular and non-vascular plants, fungi, reptiles, frogs, fish, birds, invertebrates, mammals in the ACT and surrounding region (Visit the Canberra Nature Map website). At September 2017 there were 1,146,000 records of 4250 species. CNM is accessed by over 5000 unique users every month. Currently 1100 contributors spend a few hundred hours a week adding to the understanding, protection and shared knowledge of the ACT's wildlife.

6.2.8 ParkCare

ParkCare is a broad umbrella organisation, formed as a partnership between the ACT Government and various community volunteer groups. It was established to care for local nature reserves, Namadgi National Park, Tidbinbilla Nature Park and Googong Foreshores. ParkCare groups undertake a range of environmental activities, many of which are focused on aquatic and riparian environments, including weeding, tree planting, revegetation and water quality monitoring.

6.2.9 Guidelines for supporting community involvement

- Continue to support the participation of community volunteer groups in aquatic and riparian conservation. Provide expertise and material support where appropriate.
- Acknowledge the important contribution of community groups through consultation, open communication and utilisation of citizen science data.

6.3 ABORIGINAL ENGAGEMENT

Aboriginal people view rivers holistically as a part of Country, which is linked to traditional beliefs related to wildlife, lore and land management. Rivers form a part of the cultural landscape and are spiritually related to songlines, pathways and ceremony. River corridors provide travel routes and a wide variety of flora and fauna as a readily available food source. In the ACT, the majority of recorded campsites are within 100 metres of a river, and the Murrumbidgee and Molonglo Rivers helped connect the Ngunnawal, Ngambri, Wiradjuri, Yuin and Ngarigu peoples (ACT Government 2014, p23). It is important that Traditional Custodians can access rivers to teach younger generations about country, dreaming and future land management.

Engagement of local Traditional Custodians is an important aspect of the implementation of this strategy. Traditional Custodians may have cultural values and an interest (e.g. fishing, educational, cultural and environmental connection) or may seek a right (e.g. an entitlement) linked to ACT rivers and riparian areas. The upper Murrumbidgee River corridor and the related waterways continue to play an important role in the cultural landscape of the Ngunnawal people and their neighbours the Wiradjuri. In addition to custodial interests over waterways and fish, Traditional Custodians have important cultural knowledge and wish to continue cultural practices strengthening their connection to Country. Meaningful involvement of Traditional Custodians in consultation and decision making processes facilitate incorporation of traditional knowledge into contemporary management actions.

The ACT Government has been working with Aboriginal communities in natural resource management in partnership with the Australian Government. The ACT Water Resource Plan, under the Commonwealth's Water Act, requires significant engagement and involvement with the Aboriginal people of the ACT region in managing water resources of the region. More specifically, it involves the identification of the objectives of and outcomes for the Aboriginal people in water resource management and also the identification of their water values and uses. The plan is required to ensure there is regard to the views of Indigenous people with active and informed participation. The development of the plan is progressing through a series of workshops and on-site analysis of the ACT waterways with Aboriginal people of the local region. This analysis is helping to understand and ensure the cultural values at selected sites are identified, understood and protected. This will also have an educative role for providing information and understanding for 'on Country' for current and future generations and may be the basis for the provision of cultural water in the ACT. The ACT Water Resource Plan will be identified through the ACT's water resource legislation. The ACT Water Resource Plan is expected to be a Commonwealth legislative instrument in 2019.

Similarly, the ACT and Region Catchment Strategy 2016–46 includes a commitment to 'ensure Indigenous and other values are recognised' by engaging with the Aboriginal community to better understand Aboriginal water and cultural values. This action is focused on celebrating diversity and culture with educational messages and involvement of the community. The Catchment Strategy also aims to build Indigenous engagement as part of developing a regional approach to strategic land and biodiversity management practices. This will be achieved by incorporating and promoting Indigenous culture and landscape management practices into biodiversity and land management to improve outcomes and enhance community inclusion (ACT Government 2016a).

The ACT Nature Conservation Strategy also continues to support and build Indigenous engagement through:

- employment of Aboriginal rangers
- programs to promote traditional ecological knowledge

Ongoing dialogue with Aboriginal representatives in the ACT and NSW will help better understand Aboriginal values and cultural assets and enhance their protection. It will also facilitate incorporation of that traditional ecological knowledge into management of aquatic and riparian areas in the ACT region.

6.3.1 Guidelines for supporting Aboriginal engagement

- Integrate cultural knowledge and perspectives into conservation management of ACT aquatic and riparian areas. Actively engage with representatives to do so.
- Consider the desired outcomes of the Aboriginal people in relation to water management.

6.4 EDUCATION

Education campaigns can help build community awareness about the management and ecological value of aquatic and riparian areas (Schirmer and Mylek 2016). It is vital that campaigns are designed to reach a broad cross-section of the community, not simply those already engaged with conservation. These campaigns can also be targeted to address particular threats to aquatic and riparian ecosystems.

Conversely, knowledge held by the wider community is likely to be beneficial to aquatic and riparian managers. Current education tools, such as publicly available online databases, can be used to facilitate information exchange in both directions. This exchange may be particularly useful where information is disseminated from those sections of the community with specialist knowledge, such as research institutions and the Aboriginal community.

6.4.1 Education approach

Schools

A number of education programs about aquatic conservation have been designed for school-level students in the ACT. The Upper Murrumbidgee Waterwatch group have produced 'Sustaining River Life' (Rucosky Noakes and Phillips 2010), a K–12 curriculum and activities guide for educators. The curriculum has been designed to help students develop awareness, knowledge and skills concerning waterways and the environment (Upper Murrumbidgee Waterwatch 2015).

Outside the classroom, an interactive schools program is conducted at Jerrabomberra Wetlands Nature Park. Ranger-led tours and activities are themed around wildlife, water quality, Indigenous culture, scientific monitoring, evaluation and environmental management and are tailored to align with school curricula (Woodlands and Wetlands Trust 2015). Icon Water also provides tours and interactive education on catchment protection to school groups on request (Icon Water Ltd. 2016). Birragai at Tidbinbilla Outdoor School includes environmental education as part of their curriculum, including instruction about aquatic environments. Waterwatch conducts activities with school groups of all levels and tertiary education.

Digital outreach

The extent of online resources relating to aquatic and riparian conservation in the ACT is expanding rapidly. The majority of community groups discussed above have an online presence, with each coordinating at least some component of their activities through their website. The ACT Government also maintains considerable digital outreach through websites, with conservation policy, strategy and activities publicly available at the Environment website. There is potential to expand this online presence through greater utilisation of social media in the future.

Online databases are useful tools in sharing ecological knowledge amongst interested parties. For example, ACT Government vegetation survey data is made available online through a dedicated website ACTmapi (ACT Government 2015b). Other databases utilise current technology to harness the potential of citizen science. Canberra Nature Map, an internet-based repository for geo-referenced photographs of biota in the ACT and surrounding region (Canberra Nature Map 2016), is contributed to and used by researchers, managers and the wider community, thus facilitating information exchange between these groups. Similar sites include Atlas of Living Australia and FeralScan, both of which contribute to an extensive online store of ecological reference data (Atlas of Living Australia 2016, FeralScan 2016).

Traditional media

While there is potential to expand communication through digital media, these means are not sufficient to communicate with all sections of the ACT community. A 'one size fits all' approach to education is likely to reach only a section of the community. Instead, a communication strategy that uses multiple forms of traditional media, complemented by digital media, will reach a larger audience and increase communication effectiveness. Available approaches include newsletters, television or radio presence, face-to-face communication and public forums.

Figure 6.1 Outreach poster at the launch of the Upper Murrumbidgee Demonstration Reach Plan. Photo: L. Johnston, ACT Government.

6.4.2 Education needs

Stormwater health

Stormwater discharges from urban environments can be detrimental to the health of waterways in the ACT. The ACT Government is leading an ACT and Region Healthy Waterways campaign called 'H2OK' to help educate and change behaviours that impact stormwater health (ACT Government 2017a). The aim of the campaign is to reduce pollutants entering ACT waterways by influencing behaviours and creating a cultural awareness of water quality protection. Key to the program will be education around the role and function of waterways, drawing the connection between such environments and the places where individuals live and play.

The campaign targets urban residents, rural residential dwellers and the building construction and maintenance industries through a comprehensive media campaign, training, on-street initiatives, ambassadors and demonstration sites.

Karma releases

A Karma release is the Buddhist practice of releasing captive-reared animals into the wild as a means of demonstrating piety. While recognising spiritual practices, Karma release of animals (*fang sheng*) can result in the inappropriate release of fish into ACT waterways. These releases potentially impact native aquatic species through the spread of pest species and pathogens, and often result in the death of the released fish. For these reasons it is illegal to release fish in the ACT without a permit.

The ACT Government has developed guidelines for legal Karma releases, to be made available through the Environment, Planning and Sustainable Development Directorate website. These guidelines dictate the appropriate locations and species of fish for safe fish releases in the ACT. Education of the spiritual community regarding legal releases will ensure all releases are appropriate and harmless to native fish.

Release of unwanted pets

Releasing pets into the wild is likely to be damaging to the environment and detrimental to the animal concerned. Released pets have the potential to introduce diseases or pathogens, or become a pest species themselves. Such releases are illegal in the ACT due to the threats they pose as well as the associated cruelty to the pet, which is likely to die from exposure or starvation.

Alternatives to illegal dumping include rehousing or surrender of unwanted pets. In many cases, dedicated pet shelters and rescue groups can assist with rehousing. Some pet stores may also accept unwanted aquatic pets. Educating ACT residents about the environmental impacts of releasing pets will help reduce this threat to ACT aquatic and riparian ecosystems.

Dog zones

The Murrumbidgee River Corridor has many popular recreational areas, a number of which allow dog access. Recreational areas are separated into zones permitting dogs off-leash, dogs on-leash and no dogs. For the comfort of other park users and the welfare of native animals, it is important that dog owners comply with these zones. Dogs may pose a direct threat to native species, and the sight, sound and smell of dogs may disturb some animals. Dog droppings can also pollute waterways.

Signage in recreational areas indicates applicable dog restrictions and the different dog zones are clearly delineated in a Murrumbidgee River Corridor map and guide, available online through the Environment, Planning and Sustainable Development Directorate website. Ongoing awareness education regarding dog zones may assist compliance with this regulation.

Angling regulations

Angling regulations apply to all waterways in the ACT and ensure the longevity of the ACT's natural fisheries. These regulations protect the natural resources enjoyed by all users of ACT waterways, and sustainably enhance the angling experience for fishers (ACT Government 2015e). In order to counter any perception that regulations impinge on the fishing experience, it is vital to educate anglers about the positive fishing and conservation outcomes achieved through regulation. This education gap can be partly addressed by approaching fishing clubs, though a recent survey of residents from the ACT region found that of the 25% of survey participants who fish, fewer than 6% were members of fishing clubs (Schirmer and Mylek 2016). This suggests that other means may be necessary to communicate with the wider fishing community. Effective education about the benefits of angling regulation may be achieved by posting communications in proximity to other angling-related information online and elsewhere.

6.4.3 Education opportunity

Research institutions

Universities are repositories of high quality research data and knowledge that can be used to inform management decisions. The ACT is home to world-class research institutions with considerable specialisation in local environmental issues. The ACT Government continues to collaborate closely with universities through joint research projects, supporting postgraduate research and ongoing information exchange. Strong working relationships with local and regional research institutions assists with the creation of a robust evidence base for policy and public education campaigns.

Aboriginal and Torres Strait Islander perspective

The ACT Government recognises the continuing sense of responsibility of Aboriginal and Torres Strait Islander people to preserve culturally significant areas throughout the landscape. Traditional Custodians need to be able to access Country, reconnect to Country and be involved in and consulted about the management of Country (i.e. conservation of our natural environment, including waterways). Incorporation of traditional ecological knowledge into management strategies will have many benefits, as discussed above.

6.4.4 Guidelines for community education

- Use education tools to target and increase public awareness of specific ecological threats (e.g. Karma releases, dog zones). Use a strong evidence base for all education campaigns.
- Reach out to a broad cross-section of the community, including those not currently engaged with conservation, using a range of traditional and digital media (e.g. online, radio, television, print, community forums).

- Inform the wider community about the value of ACT aquatic and riparian ecosystems. Encompass the diverse ecological, recreational and spiritual values of different community groups (e.g. Traditional Custodians, conservation groups, anglers, religious groups).

6.5 RECREATIONAL USE

Encouraging recreational use of natural areas is a compelling way to engage the community with the natural landscape. Recreation affords the opportunity to broaden understanding, appreciation and support for these areas among the ACT community. However, increasing visitation can also result in negative impacts on flora and fauna. Threats include damage to vegetation, soil loss, damage from recreational vehicles, track formation, spread of non-native species and an increase in fire frequency, littering and water pollution (Sun and Walsh 1998, Anderson et al. 2015, Rankin et al. 2015). Recreational angling may also increase the threat to protected fish species through illegal capture or species misidentification. These threats are discussed in Chapter 0.

In the ACT there are existing plans of management that define appropriate use of reserves. The installation of clear signage, trails and accessible recreation infrastructure help mitigate the impact of increased recreational use and can simultaneously enhance community appreciation of the value of aquatic and riparian areas. Similarly, sustainable recreational angling is encouraged through the publication of reference guides explaining the appropriate timing and location of angling opportunities. The guides also explain which species can be fished, along with legal methods to do so (ACT Government 2015e). Explanation of the issues around appropriate angling assists in maintaining healthy native fish populations while deepening community understanding of the ACT's natural heritage. This synergistic effect will be enhanced through additional strategic guidance, ensuring appropriate recreation and tourism is encouraged that supports conservation management (ACT Government 2013a).

6.5.1 Guidelines for engaging community through recreation

- Continue to develop access to riparian and aquatic areas for recreational use.
- Capitalise on recreational use as an opportunity to develop appreciation of the ACT's riparian and aquatic areas.

Figure 6.2 Native fish for stocking in ACT waterbodies. Photo: M. Jekabsons, ACT Government.

7 BACKGROUND

Cotter River in flood, flowing over the old Cotter Dam prior to construction of the new enlarged Cotter Dam.
Photo: M. Jekabsons, ACT Government

7.1 WHAT ARE AQUATIC AND RIPARIAN AREAS?

7.1.1 Aquatic and riparian ecosystem description

Rivers, streams and their associated riparian zones are distinctive elements in the ACT landscape. Definitions of aquatic and riparian environments are included in section 1.4 and a generalised description of ACT aquatic and riparian ecosystems is provided below. More specific detail can be found in section 7.3.1 and the 2007 ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007, pp.14–19, 35–39).

The rivers and streams of the ACT are defined as upland drainages within the Upper Murrumbidgee River Catchment of the Murray–Darling Basin (MDB). While extensive floodplains are a characteristic of lowland sections of the MDB, they are largely absent from upland sections (Evans 2003). Upland rivers differ hydrologically to lowland rivers, typically rising and falling rapidly in response to rainfall. These differences in geomorphology and hydrology are reflected in distinctive riparian and aquatic habitats and their associated flora and fauna.

While the ACT is predominantly within the upland zone for rivers and streams, it still contains a variety of stream types dictated by the morphology of land adjacent to river reaches. For example, the Murrumbidgee River has a broader river valley than others in the ACT and contains localised floodplain development (e.g. Lanyon floodplain). The Murrumbidgee channel has a lower gradient channel than some of the surrounding mountain tributaries, such as the Cotter and Gudgenby Rivers, but is nevertheless broken by significant gorge sections that have high gradients. Smaller mountain streams may have no floodplain development for much of their course, yet form wetlands (such as bogs or fens) when flowing through low-gradient montane areas. The ACT also contains smaller streams that have lower gradient, such as those that flow through urban and rural areas (e.g. Ginninderra Creek and upper Paddys River).

ACT rivers are strongly affected by reservoir construction. Upstream of the ACT on the Murrumbidgee River is the Snowy Hydroelectric Scheme's Tantangara Reservoir, which drastically reduces flows by 40% at the ACT border. Almost 100% of flow along the Cotter River is altered by ACT water supply infrastructure, including the Corin, Bendora and Cotter dams (ACT Government 2016d). These reservoirs can have substantial effect on aquatic and riparian habitats (Nichols et al*.* 2006).

The riparian zones of the ACT tend to be elongated and narrow and consequently have an extensive interface with adjacent terrestrial and aquatic ecosystems. This physical connectivity means that activities occurring in adjacent ecosystems or elsewhere in the catchment (such as land clearing, agriculture, pasture improvement and urbanisation) can also affect habitats in the riparian zone, either directly or through effects arising from changes to sediment loads, water quality or flow patterns. The narrow width of riparian zones leaves little to buffer them against impacts occurring in adjacent ecosystems. Indeed, the riparian zone itself is important in buffering aquatic environments against erosive or polluting land uses (Osborne and Kovacic 1993, Naiman and Decamps 1997).

Riparian zones and their associated watercourses are 'keystone' ecosystems, with the health of ecological communities elsewhere in the landscape dependent upon the health of riparian zones (MacLeod 2002). Riparian zones wind their way through a variety of ecosystems, forming natural corridors linking habitats. The role of riparian zones as corridors has become increasingly important as surrounding ecosystems are modified for urban and agricultural purposes (Catterall et al. 2006).

7.1.2 ACT rivers and their characteristics

The Murrumbidgee River and its tributaries are key geomorphic, hydrological and ecological features of the ACT. The main tributaries are the Molonglo, Cotter and Gudgenby rivers. A number of creek lines also enter the river, but only a few (Guises, Tuggeranong, Bulgar and Swamp creeks) have catchments extending into the undulating terrain and hills beyond the river valley.

The distribution of major rivers and streams in the ACT is shown in Figure 1.2and their significant characteristics are provided in Table 7.1. Greater detail can be found in section 7.3.1 and the 2007 ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007, pp. 14–19).

Figure 7.1 Cotter River upstream of Vanitys Crossing. Photo: M. Jekabsons, ACT Government.

Table 7.1 Major ACT rivers and their significant characteristics

River	Geology	Topography	Channel morphology	Flow
Murrumbidgee	Volcanic rocks dominate, but sedimentary rocks are present, forming rock bars and rapids.	The river falls from an elevation of 600 m at Angle Crossing to 425 m at the northern ACT border. It is considerably downcut below the Canberra Plain. The valley typically has steep dissected slopes, including gorges, bordering the river. The broad floodplains at Lanyon and Lambrigg are contrasting exceptions. The valley rim is highest in the Bullen Range, rising to over 300 m above the riverbed.	The stream will typically meander in a broad channel when bordered by undulating land, and be confined to a narrow channel in steep valley and gorge sections. Massive rock outcrops commonly line the channel. The substrate varies including rock, boulders, sand and gravel, pebbles and silty material. In some reaches the riverbanks are poorly defined, terraced or may drop vertically for several metres.	Highest flows occur from July to October, lowest in February and March. Flow may stop altogether.
Gudgenby	Granite derived from the Murrumbidgee batholith forms the valley floors, slopes and ridgelines over most of the area. Topsoils are sandy and subsoils, thick clay.	The altitudinal range is from 1777 m at the top of the catchment to 576 m at the Gudgenby–Murrumbidgee confluence. The landscape is characterised by deep open valleys.	The rivers and creeks are relatively small in dimensions, meandering through floodplains in the granite country.	Relatively small flow, which is largely seasonal, with maximum discharge from August to October. The area does not receive high rainfall, though precipitation does increase with elevation.
Cotter	Dominated by Ordovician sediments in central parts of the valley, granite along most of the slopes in the southern half, and volcanic in the far north.	Originates at an altitude of 1760 m and flows into the Murrumbidgee River at an altitude of 460 m. Confined within a deep narrow valley defined primarily by the Cotter Fault. Steep rugged terrain falls directly to the river except in the upper reaches.	The river valley is characterised by steep sides, in some places precipitous. However, the gradient of the river is relatively moderate. The Cotter also flows through three large reservoirs.	Mean annual discharge above Corin reservoir is 46.9 GL (1963–1987) with maximum discharges occurring from August to September, and minimum discharge in February and March.
Molonglo	Ordovician sediments form the underlying geology. Downstream of Lake Burley Griffin, volcanic rocks dominate the geology.	Relatively large catchment, rising to an altitude of approximately 1100 m upstream of the ACT. There are both gorge sections and open sections incised below Canberra Plain.	Various, including steep-sided gorge sections with pools, boulders and rapids, through to open water in Lake Burley Griffin.	Mean annual discharge is 55 GL, with seasonal stream flows peaking between September and November. Flow in the lower reaches is significantly increased by discharge from the LMWQCC.

7.1.3 Riparian vegetation communities

The 2007 Aquatic Species and Riparian Zone Conservation Strategy examined reports, mapping and descriptions of ACT riparian vegetation communities. Subsequent survey and mapping work underpins the description of most vegetation types identified within the present strategy (Johnston et al*.* 2009, Peden et al*.* 2011). In addition, the upper Cotter River Catchment has been the subject of a comprehensive ecological survey (Helman et al. 1988).

The riparian communities shown in Table 7.2 conform where possible to Armstrong et al. (2013). The table provides a description of plant communities in the Upper Murrumbidgee Catchment within the framework of broad-scale classification of native vegetation of New South Wales (Keith 2004). The characteristics of these communities are discussed briefly in Appendix 1.1 and their distribution in the ACT is available online (ACT Government 2015b). New vegetation mapping has commenced within the ACT and will provide enhanced spatial resolution of riparian communities.

7.1.4 Aquatic and riparian native fauna

The aquatic and riparian habitats of the ACT support a diverse array of aquatic, amphibious and terrestrial animal species (see Table 7.3). A number of animals that occur in the riparian zone are also found in a range of non-riparian ecosystems such as forests, woodlands or grasslands. These are not listed in Table 7.3 as this strategy focuses on aquatic fauna and species restricted to, or highly dependent upon, the riparian zone. Greater detail is available in Appendix 9.3, the 2007 strategy and through online mixed-source databases such as the Atlas of Living Australia.

A variety of data sources were used to compile composite information on fauna in aquatic and riparian areas of the ACT region. These sources included scientific papers and books, reports and/or records of observations by government staff, consultants, other government agencies and the community. The detail and accuracy of these data vary depending upon the locations and methods of surveys, and the inclusion of opportunistic observations.

Table 7.2 Vegetation communities occurring in ACT riparian zones

Armstrong et al. (2013) community	Former ACT vegetation community (previous strategy)	Class* (Keith 2004)	Characteristic species	Location in riparian zone
p520: Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion	*Eucalyptus viminalis* Tableland Riparian Woodland	Eastern Riverine Forests	*Eucalyptus viminalis*	Tableland river terraces and narrow incised valleys at higher elevation
p32d: River She-oak riparian forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes bioregions	*Casuarina cunninghamiana* Tableland Riparian Woodland	Eastern Riverine Forests	*Casuarina cunninghamiana*	Tableland river fringes
u181: *Callistemon sieberi-Kunzea ericoides* rocky riparian shrubland in the South Eastern Highlands and upper South Western Slopes bioregions	Tableland Shrubland	Eastern Riverine Forests	*Callistemon sieberi, Kunzea ericoides, Bursaria spinosa*	Gorge environs and river fringes
AFV**: Tableland Aquatic and Fringing Vegetation Complex	Tableland Riparian Fringing Vegetation Tableland Riparian Floating and Submerged Vegetation	No category	*Phragmites australis, Schoenoplectus validus, Typha* spp., *Juncus australis, Vallisneria gigantean, Myriophyllum* spp.	River fringes and pools, off-stream wetlands, lakes, dams, flood runners
a9: *Carex gaudichaudiana – Ranunculus amphirtrichus – Phragmites australis* aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands bioregions	Montane Bogs and Fens	Montane Bogs and Fens	*Carex gaudichaudiana, Ranunculus amphitrichus, Phragmites australis, Nymphoides montana*	Montane swamps
a2: *Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum* wet heathland of the Australian Alps bioregion (bog)	Montane Bogs and Fens	Alpine Bogs and Fens	*Baeckea gunniana, Sphagnum cristatum, Empodisma minus, Richea continentis, Baloskion australe*	Soils with impeded drainage on flat valley floors above 1300 m
r2: *Poa labillardierei – Themeda australis – Juncus* spp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion	Tableland Wet Tussock Grassland and Montane Wet Tussock Grassland	Temperate Montane Grassland	*Poa labillardierei, Carex appressa Juncus* spp.	Colluvium or alluvium on drainage lines in broad plains, valleys associated with creeks and rivers

*Vegetation classes are groups of vegetation defined mainly by overall floristic similarities, although they may also share structural and habitat characteristics (Keith 2004).

**AFV does not correspond to any described community in Armstrong et al. (2013). The description fits most closely with Johnston et al. (2009).

Table 7.3 Native aquatic and riparian fauna found in the ACT

Fauna	Geographic location	Example species	Habitat
Fish	Montane	Macquarie Perch, Trout Cod**, Two-spined Blackfish, Mountain Galaxias	Aquatic
	Lower elevations	Murray Cod, Trout Cod** Golden Perch, Silver Perch*, Australian Smelt, Western Carp Gudgeon, Mountain Galaxias	Aquatic
	Urban	Murray Cod**, Golden Perch**, Western Carp Gudgeon	Aquatic
Crayfish	Montane	*Euastacus crassus, Euastacus rieki*	Mostly aquatic
	Lower elevations	Murray Crayfish, Yabby	Aquatic (will occasionally move out of water)
	Urban	Yabby	Mostly aquatic
Aquatic macroinvertebrates	Generally geographically specific	Snails, water boatmen, dragonflies, caddis flies, stoneflies, mayflies, mites and aquatic worms	Aquatic juveniles and non-aquatic adults. Some permanently aquatic
Amphibians	Broad geographic range	Plains Froglet, Common Eastern Froglet, Eastern Banjo Frog, Spotted Grass Frog, Broad-palmed Frog, Leseur's Frog, Leaf Green Tree-frog, Peron's Tree-frog, Whistling Tree-frog, Smooth Toadlet, Brown-striped Frog	Aquatic juveniles and non-aquatic adults. Some permanently aquatic
Semi-aquatic vertebrates	Broad geographic range	Platypus, Eastern Water Rat, Eastern Snake-necked Turtle	Observed both in aquatic and riparian areas
Birds	Broad geographic range and often migratory	Over 200 species	Mostly riparian (and outside riparian), some obtain food from aquatic areas
Terrestrial reptiles	Montane	Red-bellied Black Snake, Highland Copperhead, Eastern Tiger Snake, Eastern Brown Snake, Gippsland Water Dragon, Heatwole's Water Skink	Mostly riparian, may enter water to escape predators. Red-bellied Black Snakes have been observed hunting and feeding on fish in the Cotter River
	Lower elevations	Red-bellied Black Snake, Eastern Brown Snake, Gippsland Water Dragon, Heatwole's Water Skink	As above
	Urban	Brown Snake, Water dragon	As above
Terrestrial invertebrate	Geographically specific depending on habitat	Not well described or observed	Riparian. May have aquatic juvenile life-stage.

*Now functionally extinct in the ACT. **Stocked population.

7.2 HISTORY

The aquatic and riparian ecosystems of the ACT have changed dramatically from their natural state, particularly since European settlement. Below is a brief history of human use and alteration of river corridors in the ACT region. Extensive historical detail can be found in the 2007 strategy.

Prior to European settlement, ACT rivers were characterised by chain-of-pool systems draining into narrow stream channels. Annual flow cycles were dominated by snowmelt and winter rainfall. Riparian zones were narrow, merging directly into valley slopes. Fish and birds migrated upstream, using well-connected river and riparian corridors.

The ACT region plays a significant role to a number of Aboriginal Nations including the Ngunnawal, Ngambri, Wolgalu, Ngarigu, Yuin and Wiradjuri. Many of them used the rivers to help guide them into the Australian Alps for ceremonies or help them make their way towards areas out west in Wolgaglu and Wiradjuri Country. Many campsites were established along local rivers, as evidenced by the large number of Aboriginal archaeological sites that have been discovered including grinding grooves, stone tools, scarred trees and flaked stone scatters. The age of the Birrigai site has now been dated to 25,000 years. Today, the Aboriginal and Torres Strait Islander community visit riparian zones to collect reeds for weaving in community programs and visit culturally significant areas to maintain their protection.

By the mid-1820s the grasslands of the Southern Tablelands were known to Europeans, and the pastoral advance soon ensued (Hancock 1972). The establishment of the pastoral economy over subsequent decades brought changes to rivers and riparian zones. Valley floors were cleared, fire regimes were altered, soil erosion and stream sedimentation followed clearing, gully erosion developed and new plants, grazing and domestic animals were introduced. Native fish and other riparian animals (particularly waterbirds) were harvested for food and sport and alien animals and plants introduced into the region (King 1946). The drainage system within the ACT altered from swampy meadows and chains-of-ponds feeding creeks and rivers to a connected, channelled system.

During the 20th century the rivers were harnessed for irrigation, hydroelectric power and urban water supply, producing a period of major dam construction. These developments brought changes including altered flow regimes, changes in water temperatures and dislocation of upstream–downstream links.

7.3 CURRENT CONDITION OF AQUATIC AND RIPARIAN ECOSYSTEMS

7.3.1 Ecosystem condition

The condition of aquatic and riparian communities is surveyed as part of ongoing monitoring. Previous sections (7.1.3, 7.1.4 and 1.1) have described the flora and fauna communities of the ACT as well as the broad changes that have occurred since European settlement. A brief description of the current condition of defined river sections is in Table 7.4 (see Figure 7.1 for map of reaches and sampling sites). Conditions are summarised from the ACT water reports for 2012–14 and 2014–15 (ACT Government 2015a, 2016d), Icon Water's *Below Dams* report (Harrison and Broadhurst 2015), the 2015–16 Waterwatch Catchment Health Indicator Program (CHIP) Report (O'Reilly et al. 2016), ACT Government fish monitoring reports (Beitzel et al. 2015, 2016) and expert opinion (M. Beitzel, H. Chester, L. Evans, L. Johnston, W. O'Reilly, D. Starrs, pers. comm.).

Overall river condition in the ACT has dramatically declined since European settlement (Lintermans and Osborne 2002). Aquatic habitats have been altered structurally and functionally, lowering habitat value for native species. The condition of riparian zones in the

ACT has similarly declined since European settlement. Uncertainly remains around the precise nature and condition of pre-European riparian vegetation. However, surveyors' descriptions and other historical records, remnant vegetation, and modelling based on environmental parameters for the growth of particular species or communities may contribute to developing an approximation of past vegetation.

The conservation of riparian and aquatic ecosystems in the ACT is generally approached from a whole-of-ecosystem, regional scale perspective. However, some planning, rehabilitation and conservation activities are imperative in particular sections of river. Table 7.4 outlines potential threat mitigation and management activities that are particularly appropriate to individual river reaches, given the current condition of their ecosystem. Many of these mitigation actions relate to multiple threats and have broad benefits across both riparian and aquatic habitats within a reach.

Figure 7.2 Erosion along the banks of the Murrumbidgee River. Photo: M. Jekabsons, ACT Government.

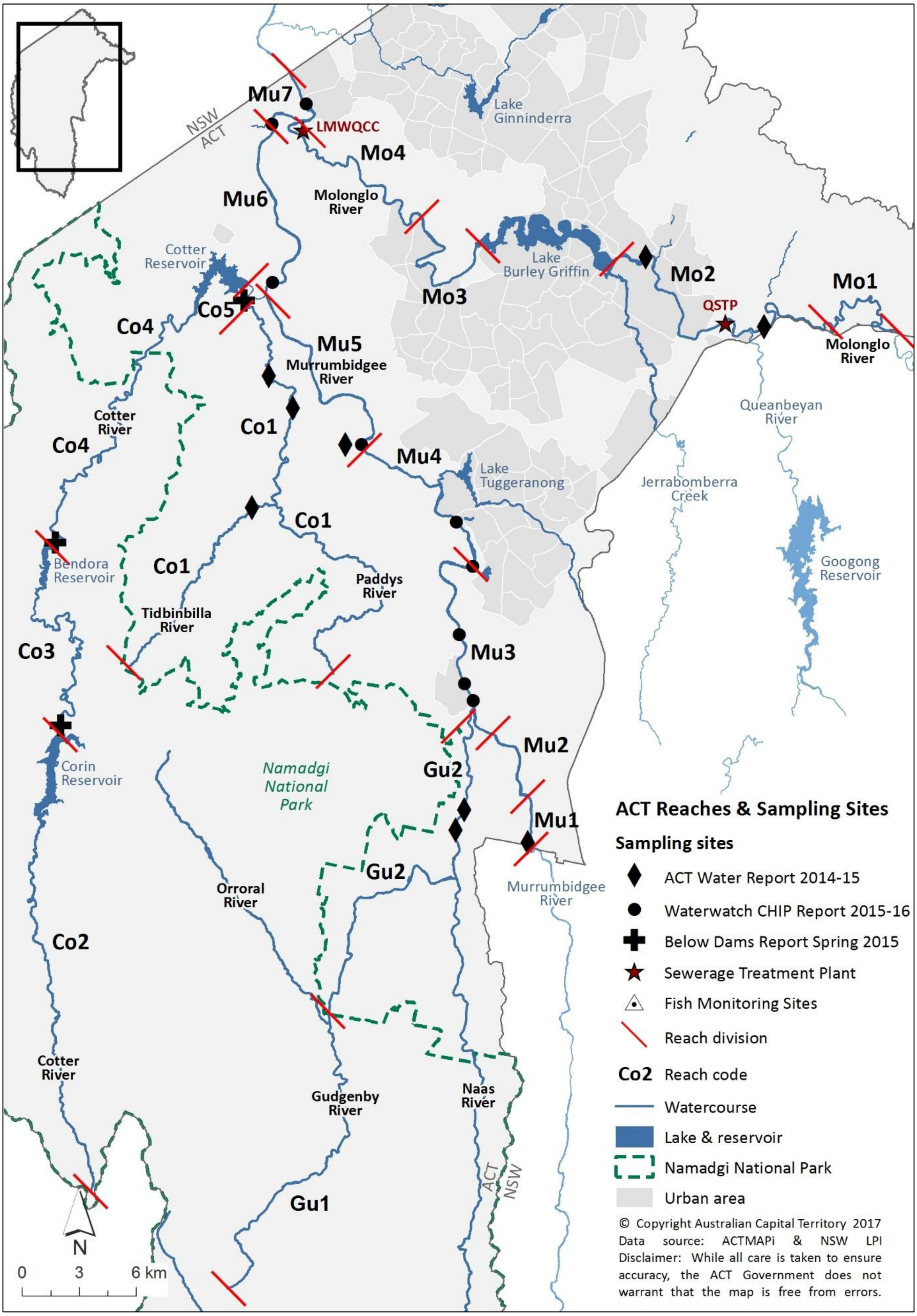

Figure 7.3 ACT reaches and sampling sites used for assessing ecosystem condition (see Table 7.4)

Table 7.4 Aquatic and riparian condition including management guidance by river section (including minor tributaries).

The effects of water extraction and alien species (e.g. deer, pigs, Carp) are ubiquitous throughout all reaches. Biodiversity (macroinvertebrates) and water quality assessments are sourced from the ACT Water Report 2014–15 (#) and 2012-14 (##), Icon Water's *Below Dams* Report Spring 2015 (°) and Waterwatch CHIP Report 2015–16 (*). Methodology and timing varies among sources and assessments typically represent point sampling (see Figure 7.1). A fish population that has been translocated into a reach is indicated by 'trans.'

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
Mu1: Murrumbidgee River: Angle Crossing to Guises Creek				
Territory Plan: Gigerline Nature Reserve Rural leasehold Management: MRC Management Plan 1998	*Aquatic:* For approximately 5 km immediately to the north of Angle Crossing (ACT/NSW border), the Murrumbidgee River is a series of relatively shallow pools with prominent rock bars, rapids and riffles. Some sandy beaches are present with previous small-scale sand extraction activities occurring within the reach. At Angle Crossing, water quality parameters are generally within regulation levels[##]. Macroinvertebrate rating is similar to reference condition[#].	*Maccullochella macquariensis* (trans.) *Macquaria australasica* *Euastacus armatus* *Maccullochella peelii*	- Alien fauna (3.14) - Illegal fishing (3.17) - Lack of native riparian vegetation (3.11) - Reduction in flow due to local & upstream extraction (3.4) - Erosion from past & potential future forestry operations (3.11) - Sedimentation (3.10)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Prioritise and rehabilitate areas for native riparian vegetation regeneration. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
	Riparian: This section has been extensively cleared for pastoral use. Weed cover is prevalent adjacent to grazing land. There is evidence of dieback of *E. viminalis*, which presents a significant ecological concern.	*Eucalyptus viminalis* Tableland Riparian Woodland	- *Eucalyptus viminalis* dieback - Weeds including willows, African Lovegrass, Blackberry and poplars (3.13)	

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
Mu2: Murrumbidgee River: Gigerline Gorge				
Territory Plan: Gigerline Nature Reserve Rural leasehold Management: MRC Management Plan 1998	Steep, rugged gorge with extensive rocky terraces composed of boulders, bedrock and large boulders.	*Maccullochella macquariensis* (trans.) *Macquaria australasica* *Euastacus armatus* *Maccullochella peelii*	- Barriers to fish passage at low flow (3.13) - Reduction in flow due to extraction upstream (3.4) - Illegal fishing (3.17)	- Seek to mitigate barriers to fish passage by providing sufficient flow. - Maintain and, where feasible, improve connectivity through enhanced flow. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery.
	Predominantly native vegetation in good condition. There is evidence of dieback of *Eucalyptus viminalis*, which presents a significant ecological concern.		- *Eucalyptus viminalis* dieback	
Mu3: Murrumbidgee River: Below Gigerline Gorge to Point Hut Crossing				
Territory Plan: Gigerline Nature Reserve Special Purpose Reserve (Tharwa) Special Purpose Reserve (incl. Lanyon Landscape Conservation Reserve) Rural leasehold Management: MRC Management Plan 1998	Upon exiting the Gigerline Gorge, the river abruptly changes, widening to become a depositional stream with a sandy bed, long pools and occasional beaches. Previous sand extraction activities at the old Tharwa Sandwash have resulted in a long, flat sandy terrace. The Gudgenby River enters at this point, although fish access to this river is restricted by the large quantities of sand in the Gudgenby channel. North of Tharwa the river passes through broad river flats in an undulating, pastoral landscape. In this deposition zone, the channel is shallow and contains significant quantities of sand that has filled pools and smothered the previously stony substrate for several kilometres. Engineered log jams constructed to provide habitat and deepen river channel. Stock access to the river has	*Maccullochella macquariensis* (trans.) *Maccullochella peelii* *Euastacus armatus*	- Alien fauna (3.14) - Barrier to fish movement at Point Hut Crossing (3.13) - Lack of native riparian vegetation (3.11) - Reduction in flow due to extraction upstream (3.4) - Sedimentation (3.10) - Illegal fishing (3.17) - Urban discharge (3.7, 3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers (e.g. fishway through Point Hut Crossing). - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	been limited by fencing off the river corridor. Water quality parameters vary, but are generally good*, with a macroinvertebrate rating of fair*.			- Utilise NSW Government report (MCMA 2012) to identify and prioritise sediment/turbidity sources of rehabilitation. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Monitor urban discharge and continue public education about urban water discharge quality. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery. - Control grazing, including fencing off riparian zones where appropriate. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion. - Prioritise and rehabilitate areas for native riparian vegetation regeneration.
	Northern end of this section has been extensively cleared for pastoral use. Areas of *Eucalyptus viminalis* lowland woodland remain, varying from severely modified to partially modified, however willows dominate riverbank vegetation. There is evidence of dieback of *E. viminalis*, which presents a significant ecological concern.	Relict *Eucalyptus viminalis* Tableland Riparian Woodland *Discaria pubescens* *Pomaderris pallida* Lowland Snow Gum Woodland	- *Eucalyptus viminalis* dieback - Grazing (3.21, 3.11) - Weeds including willows, Blackberry, African Lovegrass (3.13)	

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
Mu4: Murrumbidgee River: Point Hut Crossing to Kambah Pool				
Territory Plan: Special Purpose Reserve (Point Hut Crossing to Pine Island, Pine Island, Kambah Pool) Bullen Range Nature Reserve (Pine Island to Kambah Pool) Rural leasehold Management: MRC Management Plan 1998	Downstream from Point Hut Crossing the open valley environments give way to steeper slopes with elevated terraces of sandy or rocky banks, with shrub vegetation and scattered trees. The recreation area at Pine Island Reserve takes advantage of the river's broad channel, deep pools, occasional beaches and rocky substrate. Downstream of the reserve is Red Rocks Gorge, a relatively less accessible area of high cliffs and rugged rock formations. Red Rocks Gorge meets the Bullen Range Nature Reserve near Kambah Pool recreation area. Structural habitat is good, with considerable woody debris from the 2003 bushfires. Water quality parameters are consistently within regulation levels##, though macroinvertebrate rating is only fair to good*, probably reflecting pulse effects caused by urban discharge from Tuggeranong urban areas.	*Maccullochella macquariensis* (trans.) *Maccullochella peelii* *Macquaria australasica* *Euastacus armatus*	- Alien fauna (3.14) - Illegal fishing (3.17) - Lack of native riparian vegetation in some reaches (3.11) - Reduction in flow due to extraction upstream (3.4) - Sedimentation (3.10) - Urban discharge (3.7, 3.22) - Urban development (3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Prioritise and rehabilitate areas for native riparian vegetation regeneration. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	There is a diversity of vegetation related to topography and past land use. Areas of lowland woodland remain, varying from severely modified to partially modified (endangered ecological community on the western side of the river near Red Rocks Gorge) (ACT Government 2004a). Native shrubland is dominant through Red Rocks Gorge, with *Callistemon sieberi* common. *Casuarina cunninghamiana* occurs on sandy river margins to just north of Point Hut Crossing (its natural southern limit on the Murrumbidgee River). This part of the Murrumbidgee River has high ecological, scenic and conservation value, with some elements such as the Peregrine Falcon nesting sites requiring special attention in order to ensure they are protected from human disturbance.	*Muehlenbeckia tuggeranong* *Thesium australe* *Discaria pubescens* *Bossiaea grayi* Relict *E. viminalis* at Kambah Pool *Pomaderris pallida* Lowland Snow Gum Woodland	- Recreational use (6.5) - Unauthorised fires (deliberately lit) - Weeds including willows and African Lovegrass (3.13)	- Monitor urban discharge and continue public education about urban water discharge quality. - Plan and design urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas. - Encourage and enable appropriate recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
Mu5: Murrumbidgee River: Kambah Pool to Cotter River confluence				
Territory Plan: Bullen Range Nature Reserve Special Purpose Reserve (east of Murrumbidgee R. above nature reserve) Special Purpose Reserve (Cotter	The Bullen Range is a controlling influence on the course of the river downstream of Kambah pool. The Bulgar, New Station and McQuoids creeks drain the undulating pastoral land between the river and Weston Creek urban area. The river is deeply entrenched below surrounding terrain. The stream bed is rocky with pools, rapids, rock bars, islands and sandy margins.	*Maccullochella macquariensis* (trans.) *Macquaria australasica* *Euastacus armatus* *Maccullochella peelii*	- Alien fauna (3.14) - Illegal fishing (3.17) - Reduction in flow due to upstream extraction (3.4) - Sedimentation (3.10) - Urban discharge (3.7, 3.22) - Recreational use (6.5)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Maintain and, where feasible, improve connectivity through

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
Reserve/Casuarina Sands) Management: MRC Management Plan 1998	River Oaks and shrub vegetation dominate the riverbanks in this section. Radiata pine wildings are common in this area.	*Discaria pubescens* *Desmodium brachypodum* *Pomaderris pallida*	- Recreational use (6.5) - Weeds including willows and African Lovegrass (3.13)	enhanced flow and rehabilitated in-stream habitat. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers. - Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability. - Encourage and enable appropriate recreational use. - Monitor urban discharge and continue public education about urban water discharge quality. - Undertake weed (including willow) control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
Mu6: Murrumbidgee River: Cotter River confluence to Uriarra Crossing				
Territory Plan: Stony Creek Nature Reserve Swamp Creek Nature Reserve Special Purpose Reserve (Uriarra Crossing) Management: MRC Management Plan 1998	The river passes through deeply dissected slopes cut through the surrounding undulating terrain. Stony Creek Nature Reserve protects much of the river's course as far as Uriarra Crossing where a small recreation area has been developed in association with a road crossing. The aquatic habitat is in largely poor condition, reflected by degraded* macroinvertebrate rating. There is considerable woody debris in Casuarina Weir pool.	*Maccullochella macquariensis* (trans.) *Macquaria australasica* *Euastacus armatus* *Maccullochella peelii*	- Alien fauna (3.14) - Illegal fishing (3.17) - Barriers to dispersal (3.13) - Reduction in flow due to extraction upstream (3.4) - Sedimentation (3.10) - Urban discharge (3.7, 3.22) - Recreational use (6.5)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers. - Maintain and, where feasible, improve connectivity through

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Riverbanks are in parts densely vegetated with Tableland Dry Shrubland dominated by *Kunzea ericoides* and emergent *Callitris enclicheri*. Riverine vegetation consists of *Casuarina cunninghamiana* with shrubs in rocky areas (NCDC 1981). Radiata pine wildings, willows, Blackberry and other weeds are scattered along this section.	*Bossiaea grayi* *Muellerina bidwillii* *Diurus punctata* *Pomaderris pallida*	- Recreational use (6.5) - Reduced overbank flows from water extraction (3.4) - Weeds including willows, Blackberry and African Lovegrass (3.13)	enhanced flow and rehabilitated in-stream habitat. - Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability. - Monitor urban and sewerage treatment plant discharge and continue public education about urban water discharge quality. - Encourage and enable appropriate recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
Mu7: Murrumbidgee River: Uriarra Crossing to ACT/NSW border				
Territory Plan: Swamp Creek Nature Reserve Woodstock Nature Reserve Special Purpose Reserve (Uriarra Crossing) Management: MRC Management Plan 1998	North of Uriarra Crossing, and a few kilometres south of the ACT/NSW border, the Molonglo River joins the Murrumbidgee River. High up on the eastern edge of the confluence is the Lower Molonglo Water Quality Control Centre. Water quality is good*, though macroinvertebrate rating is degraded*, reflecting the sandy substrate and lack of macrophytes. Results may also be a function of sampling point (see Fig. 7.1).	*Maccullochella macquariensis* (trans.) *Macquaria australasica* *Euastacus armatus* *Maccullochella peelii*	- Alien fauna (3.14) - Illegal fishing (3.17) - Barriers to dispersal (3.13) - Reduction in flow due to extraction upstream (3.4) - Sedimentation (3.10) - Sewage treatment plant discharge (3.7) - Future urban development & discharge (3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
			- Future recreational use (6.5)	- Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability. - Monitor urban and Sewage Treatment Plant (STP) discharge and continue public education about urban water discharge quality. - Encourage and enable appropriate recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
	Riverbanks are in parts densely vegetated with Tableland Dry Shrubland dominated by *Kunzea ericoides* and emergent *Callitris enclicheri*. Riverine vegetation consists of *Casuarina cunninghamiana* with shrubs in rocky areas (NCDC 1981). Radiata pine wildings, willows, Blackberry and other weeds are scattered along this section.	*Bossiaea grayi* *Muellerina bidwillii* *Diurus punctata* *Pomaderris pallida*	- Recreational use (6.5) - Reduced overbank flows (3.4.3) - Weeds including willows and African Lovegrass (3.13)	
Gu1: Gudgenby River: Within Namadgi National Park				
Territory Plan: Namadgi National Park Management: Namadgi National Park Management Plan 2005	Landscape characterised by deep open valleys, with small streams meandering through flood plains. Rivers and creeks are small in dimensions and flow, and may partly dry up in extreme dry seasons. There are significant wetland areas in upper reaches, including a morass (Gudgenby) and fens (e.g. Nursery Creek, upper Naas River). Generally good* water quality, though macroinvertebrate surveys in tributaries suggest sensitive taxa are not abundant*. No carp at present, though *Gambusia holbrooki* have been detected.	*Euastacus reiki* *Galaxias olidus*	- Alien fauna (3.14) - Illegal fishing (3.17) - Inappropriate fire regimes (3.18)	- Monitor alien fauna populations, including through use of citizen science data. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Provide ecological advice on prescribed burn location and timing in BOP. - Avoid prescribed burns during threatened species' spawning and larval rearing periods.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Open valley floors in the Naas-Gudgenby Catchment contain a range of grassy vegetation communities as well as limited areas of shrubland and wetland complexes. Grassy vegetation includes natural, semi-natural and pasture-improved areas. Naturally open areas are often low and moist with wet native grassland and swampy communities. There is a diversity of tree cover from open forest to open woodland with woodland usually the result of previous clearing (Ingwersen 2001). A wide range of alien species, many associated with pastoralism, occur in the catchment (Ingwersen 2001). There is considerable dieback of *E. viminalis* in the catchment, which presents a significant ecological concern.	*Viola caleyana* *Discaria pubescens*	- *Eucalyptus viminalis* dieback - Willows and other weeds (3.13)	- Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
Gu2: Gudgenby River: Namadgi National Park to Murrumbidgee River				
Territory Plan: Special Purpose Reserve (possible Tennent Dam site) Rural leasehold	The Naas-Gudgenby River confluence is in undulating to flat terrain north of the Billy Range. The Gudgenby River then follows a northward course through incised gorge-like areas including a rocky gorge near Mt Tennent. Under low flow conditions the river is shallow and the stream bed comprises sand and gravel as well as granitic rocks. Macroinvertebrate surveys are temporally variable, though recently similar to reference condition[#]. Water quality is generally within guideline levels[##].	*Galaxias olidus*	- Alien fauna (3.14) - Degradation of banks from uncontrolled stock grazing (3.21, 3.11) - Sedimentation (3.10)	- Monitor alien fauna populations, including through use of citizen science data. - Monitor fish stocks, particularly threatened species. - Control grazing, including fencing off riparian zones where appropriate. - Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth and improve structural habitat availability.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Vegetation has been extensively modified by pastoral use including introduction of alien pasture species and thinning of tree cover. Lang (1991) reported a complex population of hybrid willow species below the Naas-Gudgenby confluence. There is considerable dieback of *E. viminalis* in the catchment, which presents a significant ecological concern. Riparian condition rating is variable from poor to good.		- Erosion (3.11) - Uncontrolled grazing (3.21, 3.11) - Weeds including willows (3.13) - *Eucalyptus viminalis* dieback	- Ensure land management agreements include aquatic and riparian management issues and are monitored. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion. - Investigate means to prevent spread of *E. viminalis* and promote community recovery.
Co1: Cotter River: Paddys River (& Tidbinbilla River tributary)				
Territory Plan: Tidbinbilla Nature Reserve Rural leasehold Plantation forestry Management: Tidbinbilla Nature Reserve Management Plan 1999	Paddys River is a small stream in a broad valley. Stream bed carries sediments sourced from upper catchment. Bank erosion is common. Stream bed contains pools, sand and gravel (often vegetated) and stretches of boulders. Aquatic macroinvertebrate survey scores are similar to reference condition in both Paddys and Tidbinbilla Rivers[#]. Water quality is generally reasonable, with increases in faecal coliforms & suspended solids associated with rainfall events[##].	*Euastacus armatus* *Euastacus crassus* *Macquaria australasica* (trans.) *Gadopsis bispinosus* (trans.)	- Alien fauna (3.14) - Illegal fishing (3.17) - Inappropriate fire regime (3.18) - Nutrient enrichment (3.7) - Riparian degradation (3.11, 3.21) - Sedimentation due to farming, fire, roads & forestry (3.10, 3.11) - Weeds (3.13)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Provide ecological advice on prescribed burn location and timing in Bushfire Operations Plan. - Avoid prescribed burns during threatened species spawning and larval rearing periods. - Prioritise and rehabilitate areas for native riparian vegetation regeneration. - Investigate and employ options to reduce ongoing erosion and sedimentation, increase river depth
	Vegetation in this catchment has been substantially altered by pastoral and forestry use. *Casuarina cunninghamiana* occurs along the lower reaches of the river. There is a wide variety of weed species e.g. thistles,	*Drabastrum alpestre* *Pomaderris pallida* *Bossiaea grayi* *Thesium australe*	- Erosion (3.11) - Forestry activities (3.11) - Uncontrolled grazing (3.21, 3.11)	

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Briar Rose, Hawthorn, Blackberry, St John's Wort, pine wildings and willows.		- Recreational use (6.5) - Weeds including willows (3.13)	and improve structural habitat availability. - Ensure land management agreements include aquatic and riparian management issues and are monitored. - Control grazing, including fencing off riparian zones where appropriate. - Encourage and enable appropriate recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
Co2: Cotter River: Headwaters to Corin Dam				
Territory Plan: Namadgi National Park Management: Namadgi National Park Management Plan 2005	The Cotter River and tributary streams in the upper catchment are unregulated, narrow, moderately incised, have dense overhanging vegetation (grasses, shrubs), and contain small woody debris where larger shrubs and trees are present. Stream beds may be silty, stony, sandy or be comprised of rocks and cobbles. Wider open reaches have alluvial banks. Stream flows are natural (i.e. not affected by upstream structures).	*Gadopsis bispinosus* *Euastacus reiki* *Macquaria australasica* (trans.)	- Alien fauna (incl. potential future introductions) (3.14) - Illegal fishing (3.17) - Inappropriate fire regime (3.18)	- Develop rapid response plans for high risk invasions. - Prevent spread of alien fish species into new areas through prohibiting recreational angling. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Vegetation of the river flats comprises Black Sally (*Eucalyptus stellulata*), Candlebark (*E. rubida*) and Snow Gum (*E. pauciflora*) open woodland, *Poa labillardieri* tussock grassland, wetland and bog communities. Grassland areas may contain many weed species mostly derived from past pastoral use (Helman et al. 1988). Dense shrub vegetation is typical at stream edges. Characterisitic species include Dagger Wattle (*Acacia siculiformis*), Native Raspberry (*Rubus parvifolius*), Woolly Teatree (*Leptospermum lanigerum*), Common Shaggy Pea (*Oxylobium ellipticum*) and *Epacris breviflora* (Helman et al. 1988; Ingwersen and Ormay 1988).	*Discaria pubescens* *Blechnum fluviatile*	- Inappropriate fire regime (3.18) - *E. viminalis* dieback - Weeds (3.13)	- Provide ecological advice on prescribed burn location and timing in Bushfire Operations Plan. - Avoid prescribed burns during threatened species' spawning and larval rearing periods. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery. - Undertake weed control. - Control factors that facilitate weed invasion and reinvasion.
Co3: Cotter River: Below Corin Dam to Bendora Dam				
Territory Plan: Namadgi National Park Management: Namadgi National Park Management Plan 2005	The river occupies a more deeply incised valley. Stream bed is relatively narrow, commonly containing rocks and boulders. River flow is regulated by environmental flow and transfer flow releases from Corin Dam. There is generally some impairment° of the condition of the macroinvertebrate community immediately downstream of the dam wall (~1 km) but a rapid gradient of recovery means the community is in healthy condition for most of the reach. Water quality parameters generally within guidelines, excepting low pH and high ammonia and nitrogen oxides below Corin Dam°.	*Euastacus reiki* *Gadopsis bispinosus* *Maccullochella macquariensis* (trans.)	- Alien fauna (incl. potential future introductions) (3.14) - Illegal fishing (3.17) - Altered flow patterns (3.4) - Water extraction from Bendora dam (3.4) - Water level variation in Bendora dam - Reservoir water quality (3.6) - Thermal pollution (3.8)	- Prevent spread of alien fish species into new areas by prohibiting recreational angling. - Develop rapid response plans for high risk invasions. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Consider timing and height of offtake when undertaking water releases. Adjust these in order to avoid negatively affecting biota through

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
			- Inappropriate fire regime (3.18.1)	water quality, volume or thermal effects.
	In this section, the vegetation communities characteristic of higher altitude valley areas usually extend down to the river. Variations in tree species present are related to site conditions and aspect. Between Corin Dam and the upper part of Bendora Reservoir, dry forest and variable shrub cover occupies the more deeply incised river valley. The characteristic tree species is the Ribbon Gum (*E. viminalis*).		- Inappropriate fire regime (3.18.1) - Altered flow patterns (4.1)	- Undertake monitoring to determine the impact of transfer flows on biota - Provide ecological advice on prescribed burn location and timing in Bushfire Operations Plan. - Avoid prescribed burns in riparian zones and during threatened species' spawning and larval rearing periods. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery.
Co4: Cotter River: Below Bendora Dam to Cotter Dam				
Territory Plan: Namadgi National Park Special Purpose Reserve (upstream from Cotter Dam to boundary of Namadgi National Park) Management: Namadgi National Park Management Plan 2005 Lower Cotter Catchment Strategic Management Plan 2006	Narrow, deeply incised river valley. Stream bed commonly narrow and rocky but gravelly-bottomed pools occur in areas with gentler gradients. River flow is regulated by releases and diversions from Bendora Dam. There is generally some impairment of the condition of the macroinvertebrate community immediately downstream of the dam wall (~1 km), though most recently it has been similar to reference condition. Typically, the community is in healthy condition for most of the reach. Water quality parameters generally within guideline levels, except for low pH and high ammonia below Bendora Dam°.	*Macquaria australasica* *Maccullochella macquariensis* (trans.) *Euastacus armatus* *Euastacus crassus* *Gadopsis bispinosus*	- Alien fauna (incl. potential future introductions) (3.14) - Illegal fishing (3.17) - Barriers to fish passage (road crossings, natural barriers) (3.13) - Cormorant predation on *Macquaria australasica* - Genetic isolation of fish populations (3.12) - Sedimentation due to fire, roads & forestry (3.10)	- Prevent spread of alien fish species into new areas through monitoring and maintaining live bait bans. - Develop rapid response plans for high risk invasions. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Seek to facilitate fish passage by providing sufficient flow and mitigating barriers. - Investigate feasibility, risks and benefits of genetic management of threatened fish populations. - Investigate and employ options to reduce ongoing erosion and sedimentation, and improve critical habitat availability where necessary.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
			- Altered flow patterns (3.4) - Thermal pollution (3.8) - Water extraction from Cotter Reservoir (3.4) - Inappropriate fire regime (3.18.1)	- Consider timing and height of offtake when undertaking water releases. Adjust these in order to avoid negatively affecting biota through water quality or thermal effects. - Provide ecological advice on prescribed burn location and timing in Bushfire Operations Plan. - Avoid prescribed burns during threatened species' spawning and larval rearing periods. - Investigate means to prevent spread of *E. viminalis* dieback and promote community recovery. - Undertake weed and alien fauna control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed and alien fauna invasion.
	Below Bendora Dam, dry forest and variable shrub cover occupies the river valley in good condition. Closer to Cotter Reservoir, the riparian vegetation is degraded and flanked by former pine plantation. A change in land use has occurred in the Lower Cotter Catchment from pine plantation to native regeneration. The dominant tree in this section is *Eucalyptus viminalus. Casuarina cunninghamiana* stands were lost due to inundation during the filling of the enlarged Cotter Dam.		- Inappropriate fire regime (3.18.1) - *E. viminalis* dieback - Alien fauna, particularly deer (3.14.5) - Blackberry and other weeds (3.13)	
Co5: Cotter River: Below Cotter Dam to Murrumbidgee River				
Territory Plan: Special Purpose Reserve	The river and adjacent riparian zones have been extensively modified related to the construction of the Cotter Dam and the Cotter recreation area. The stream bed is heavily armoured and includes cobbles, low rocky areas, sand and gravel and there are low weirs. Near the Paddys River confluence there is a sandy bottomed pool used for swimming. Generally good water quality condition contrasts with impaired macroinvertebrate biodiversity°. This may be	*Macquaria australasica* *Maccullochella peelii* *Euastacus armatus* *Galaxias olidus*	- Alien fauna (3.14) - Barriers to fish passage (weirs and fish passage to the Paddys River) (3.13) - Recreational use (6.5) - Recreational fishing pressure	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers. - Encourage and enable appropriate recreational use. - Enforce ACT fishing regulations.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	due to rapid and thick algal growth on the substrate during times of low flow releases. River flow is regulated by releases from Cotter Dam.		(on Macquarie Perch) (3.17) - Altered flow patterns (3.4) - Potential thermal pollution (3.8) - Sedimentation (3.10) - Water recirculation from Murrumbidgee River	- Monitor fish stocks, particularly threatened species. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Consider timing and height of offtake when undertaking water releases. Adjust these in order to avoid negatively affecting biota through water quality or thermal effects. - Investigate and employ options to reduce ongoing erosion and sedimentation, armouring increase river depth and improve structural habitat availability. - Undertake weed control, following up with replanting of native, locally appropriate species. Control factors that facilitate weed invasion and reinvasion.
	Native riparian vegetation in this area has been largely replaced by planted alien species. *Casuarina cunninghamiana* lines the stream bed and there is native shrub cover near the Murrumbidgee River and Paddys River confluence.	*Bossiaea grayi* *Pomaderris pallida*	- Weeds (3.13) - Fire (3.18) - Recreational use (6.5)	
Mo1: Molonglo River: Burbong to Blue Tiles (immediately upstream of Molonglo Gorge)				
Territory Plan: Nature Reserve Rural leasehold Pine plantation	The Molonglo River is a relatively small stream in a moderately incised valley containing pools, small rapids and shallow areas. The river may be only a series of pools in extended dry periods. The stream channel is sandy or stony and fringing emergent vegetation is common e.g. *Typha* spp. (Anway et al. 1975). Approaching Molonglo Gorge, valley sides become steeper, more rugged and rocky and flow is confined. Blue Tiles is a large deep pool.	*Macquaria australasica* (trans.) *Galaxias olidus*	- Alien fauna (incl. potential future introductions) (3.14) - Heavy metal pollution events (3.7) - Poor water quality (from upstream land use) (3.6) - Urban edge (3.7, 3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Monitor urban discharge and continue public education about urban water discharge quality. - Plan and design urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	Native vegetation in this section has been affected by previous pastoral use and the establishment of adjacent pine plantations. Vegetation is heavily degraded derived native shrubland.		- Peri-urban development impacts (3.22) - Forestry (3.11) - Weeds (3.13) - Recreational use (6.5)	- Ensure that land management agreements include aquatic and riparian management issues and are monitored. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion. - Encourage and enable appropriate recreational use.
Mo2: Molonglo River: Molonglo Gorge to Lake Burley Griffin				
Territory Plan: Nature Reserve Rural leasehold Other leasehold	Molonglo Gorge has steep valley sides. The stream bed is rocky (including large rock outcrops) with pools and rapids. There are some willows in the river channel. There are extensive areas of river-washed rocks where the river exits the gorge. Downstream of the gorge the Molonglo River is joined by the Queanbeyan River before entering the backed up waters of Lake Burley Griffin. Artificial habitats have been trialled in the reach to mitigate the impacts of willow clearing and de-snagging The Pialligo area contains a former flood plain and old river channels (filled by the waters of Lake Burley Griffin). Water quality parameters are mainly within regulation limits[##] and the macroinvertebrate biodiversity at Queanbeyan is similar to reference condition[#].	*Bidyanus bidyanus* (stocked) *Maccullochella peelii* (stocked and natural) *Macquaria australasica* (trans.)	- Alien fauna (3.14) - Illegal fishing (3.17) - Queanbeyan sewage treatment plant discharge (3.7) - Urban/industrial run-off (3.7, 3.22) - Snag removal - Recreational use (6.5) - Willows (in channel) and other aquatic weeds (3.13)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Monitor urban discharge and continue public education about urban water discharge quality. - Monitor artificial habitat. - Encourage and enable appropriate recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
	The lower slopes of Molonglo Gorge support a scattered shrub understorey. Below Molonglo Gorge there are extensive areas of willow control and replanting of native vegetation. However, willows, Blackberries and other weed species dominate most of the riverine environment down to Lake Burley Griffin.	*Discaria pubescens*	- Agricultural, industrial and urban run-off (3.7) - Grazing (3.21, 3.11) - Peri-urban development (3.22) - Recreational use (6.5) - Weeds, particularly willows, Blackberries & poplars (3.13)	- Control grazing, including fencing off riparian zones where appropriate. - Plan and design peri-urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas - Prioritise and rehabilitate areas for native riparian vegetation regeneration.
Mo3: Molonglo River: Scrivener Dam to Coppins Crossing				
Territory Plan: Urban Open Space (Scrivener Dam to Tuggeranong Parkway) Special Purpose Reserve (Tuggeranong Parkway to Coppins Crossing) Rural leasehold	Stream bed contains shallow areas, pool, rock bars and cobbles. In-stream habitat is heavily altered by a wide variety of woody weeds. Recent willow removal is expected to facilitate improvements for in-stream habitat. Water quality is likely to be affected by bottom releases from Scrivener Dam. No environmental flows are released from Scrivener Dam to maintain downstream river condition. Flow regime is modified by occasional overbank flows due to releases from Scrivener Dam associated with rainfall events.	*Maccullochella peelii* (stocked in Lake Burley Griffin)	- Alien fauna (3.14) - Illegal fishing (3.17) - Barriers to fish dispersal (3.13) - Altered flow patterns with no environmental flow provisions (3.4) - Loss of riparian vegetation (3.11) - Poor water quality discharge from Scrivener Dam (3.6) - Thermal pollution (3.8) - Urban development & run-off (3.6, 3.22) - Urban edge effects (3.6, 3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Seek to facilitate fish passage by providing sufficient flow and modifying barriers. - Maintain and, where feasible, improve connectivity through enhanced flow and rehabilitated in-stream habitat. - Prioritise and rehabilitate areas for native riparian vegetation regeneration. - Consider timing and height of offtake when undertaking water releases.

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
			- Recreational use (6.5) - Willows (in channel) and other aquatic weeds (3.13)	Adjust these in order to avoid negatively affecting biota through water quality or thermal effects. - Monitor urban discharge and continue public education about urban water discharge quality. - Plan and design urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas. - Encourage and enable appropriate recreational use. - Monitor and respond to impacts from recreational use. - Investigate and employ options to reduce ongoing erosion. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion.
	Riparian vegetation in this section is highly modified with only fragments of native vegetation remaining. *Casuarina cunninghamiana* are present in this section. Riparian condition is generally poor, though most sections have had weeds removed.	*Callitris* sp. *Muellerina bidwillii* Lowland Snow Gum Woodland	- Erosion (3.11) - Loss of native vegetation (3.11) - Recreational use (6.5) - Urban edge effects (incl. asset protection zones) (3.6, 3.22) - Weeds including willows (3.13)	
Mo4: Molonglo River: Coppins Crossing to Murrumbidgee River				
Territory Plan: Lower Molonglo River Corridor Nature Reserve Management: Lower Molonglo River Corridor	In this section, the river valley becomes more deeply incised and in the lower sections forms the Lower Molonglo Gorge (approximately 2 km in length) in volcanic rocks. Below the steep gorge sides, the riverbed contains rapids, deep and shallow pools, with rock bars across the river visible in low flow conditions. Terraces border the river from 2–5 m above normal (low) flow (NCDC 1988b).	*Euastacus armatus* *Maccullochella peelii*	- Alien fauna (3.14) - Illegal fishing (3.17) - Lack of environmental flows (3.4) - Discharge from Lower Molonglo Water Quality Control Centre (3.6, 3.22)	- Monitor alien fauna populations, including through use of citizen science data. - Support CHV release and assist post-release clean-up if necessary. - Enforce ACT fishing regulations. - Monitor fish stocks, particularly threatened species. - Maintain and, where feasible, improve connectivity through

Current planning and management	Habitat description and condition	Threatened/uncommon species and communities	Major threats (section reference)	Threat mitigation and management guidance — aquatic and riparian
Management Plan 2001			- Poor water quality discharge from Scrivener Dam (3.6) - Urban run-off (3.6, 3.22) - Urban development (3.22) - Recreational use (6.5) - Willows (in channel) and other aquatic weeds (3.13)	enhanced flow and rehabilitated in-stream habitat. - Monitor urban and STP discharge and continue public education about urban water discharge quality. - Plan and design urban areas that minimise impacts of the urban edge on adjacent riparian and aquatic areas. - Encourage and enable appropriate recreational use. - Monitor and respond to impacts from recreational use. - Undertake weed control, following up with replanting of native, locally appropriate species. - Control factors that facilitate weed invasion and reinvasion. - Control grazing, including fencing off riparian zones where appropriate.
	Protected in the gorge environment, vegetation in this section of the river displays high floristic diversity. Barrer (1992a) recorded 225 plant species in 62 families. The tree cover comprises a number of communities. *Casuarina cunninghamiana* dominates the riverine areas and deeper gullies. There is a diverse shrub cover, including some uncommon species. Also present are grassland remnants including *Poa labillardieri* (now uncommon in the ACT). Near the river and in damp sites are sedges and rushes. Ferns are found in protected locations in the gorge. Weeds typical of the ACT riparian zone are found in this section including *Pinus radiata* wildings, *Ailanthus altissima,* willows (*Salix* spp.), Briar Rose, Blackberry, St Johns Wort (*Hypericum perforatum*), Phalaris (*Phalaris aquatica*) and African Lovegrass (*Eragrostis curvula*).	*Pomaderris pallida* *Bossiaea grayi* *Desmodium brachypodum* *Adiantum hispidulum* *Discaria pubescens*	- Recreational use (6.5) - Weeds including willows and African Lovegrass (3.13) - Uncontrolled grazing (3.21, 3.11) - Urban edge effects (3.6, 3.22)	

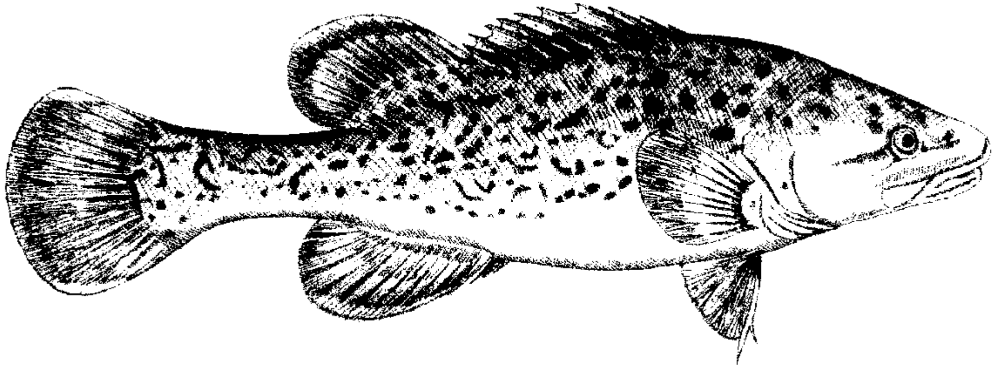

Figure 7.4. Trout Cod. Illustration: M. Crosby-Fairall, ACT Government

7.3.2 Threatened species

Aquatic and riparian ecosystems in the ACT provide important habitat for a range of threatened flora and fauna species. These species include two plant and eight animal species declared as threatened in the ACT under the Nature Conservation Act, and an additional fish species and two flora species listed as threatened under the EPBC Act (Table 7.5). Action plans have been developed for aquatic and riparian species threatened in the ACT, and appended to the strategy (see Part B).

The threatened Northern Corroboree Frog (*Pseudophryne pengilleyi*) occurs in pools and seepages in *Sphagnum* bogs, wet tussock grasslands and wet heath in the Brindabella and Bimberi ranges in the ACT. This species is not included in this strategy as it occurs in wetlands. This species is the subject of a separate action plan (ACT Government 2011). Similarly, the Murray Cod (*Maccullochella peelii*) is the subject of a Native Species Conservation Plan (ACT Government, 2017b) and Conservation Advice has been published for *Pomaderris pallida* and *Thesium australe* (Cwealth 2008, 2013).

While the Pink-tailed Worm-lizard (*Aprasia parapulchella*) and the Painted Honeyeater (*Grantiella picta*) are present in some riparian zones in the ACT, they are typically associated with the adjacent woodland and grassland areas. Separate action plans for *A. parapulchella* and *G. picta* are available online (ACT Government 1999c, 2016j).

Table 7.5 Conservation Status of ACT and Commonwealth threatened flora and fauna species found in ACT aquatic and riparian ecosystems. Species listed as threatened by the Federal Government are also considered Matters National of Environmental Significance (MNES).

Species	Common Name	Federal	ACT	NSW	Vic
Fauna					
Gadopsis bispinosus	Two-spined Blackfish	-	VU	-	-
Maccullochella macquariensis	Trout Cod	EN	EN	EN	CR
Macquaria australasica	Macquarie Perch	EN	EN	EN	EN
Bidyanus bidyanus	Silver Perch	CR	EN	VU	VU
Maccullochella peelii	Murray Cod	VU	SPS	-	VU
Euastacus armatus	Murray Crayfish	-	VU	VU	NT
Pseudophryne pengilleyi	Northern Corroboree Frog	CR	EN	CR	-
Grantiella picta	Painted Honeyeater	VU	VU	VU	VU
Flora					
Muehlenbeckia tuggeranong	Tuggeranong Lignum	EN	EN	-	-
Bossiaea grayi	Murrumbidgee Bossiaea	-	EN	-	-
Pomaderris pallida	Pale Pomaderris	VU	SPS	VU	-

CR: Critically Endangered; EN: Endangered; VU: Vulnerable; SPS: Special Protection Status; NT: Near Threatened (as defined under Victorian legislation).

Legislation: Federal: *Environment Protection and Biodiversity Conservation Act (1999)*; ACT: *Nature Conservation Act (2014)*; NSW: *Fisheries Management Act (1994)*; *Threatened Species Conservation Act (1995)*; VIC: *Flora and Fauna Guarantee Act (1988)* (NB: under this Act, species are listed as 'threatened' or 'near threatened' and specific conservation status (non-statutory) is assessed in advisory lists prepared by the Victorian Department of Sustainability and Environment (Victorian Department of Sustainability and Environment 2013))

7.3.3 Uncommon and rare species

There are many species occurring in the aquatic and riparian ecosystems of the ACT that may be of conservation concern even though they are not listed as threatened under ACT or Commonwealth legislation. These include species that are rare because they occur naturally at low density, have become uncommon elsewhere due to disturbance, or are at the margin of their distribution. They are species that are restricted in the ACT to a few locations or have a small total population of less than a few hundred individuals in the ACT. Some of these species are of conservation concern because they are declining (in the ACT or elsewhere) and because small populations tend to be more vulnerable to disturbance. Minimising threats and monitoring their abundance and/or habitat is required to help prevent these species becoming threatened.

In the ACT two species of montane spiny crayfish *Euastacus crassus* and *Euastacus rieki* have been listed as protected under the Fisheries Act. Recent research has shown that these two species are restricted in their distribution in the ACT region and at risk of impact from fire, pest animals, sedimentation and climate change (ACT Government unpublished data).

A number of plant species have a large part of their known ACT distribution within the riparian zone and have only been rarely recorded locally, despite extensive plant surveys along much of the riparian zone (Table 7.6, detail in Appendix 9.4).

Many declining, uncommon or rare animal species typically associated with ACT woodlands or grasslands are also likely to use adjacent riparian zones to varying extents. Animal species strongly associated with the riparian zone that are uncommon in the ACT region include White-bellied Sea-eagle, Peregrine Falcon, Nobbi Dragon, Rosenberg's Monitor, Southern Leaf-green Tree Frog and Brown Toadlet. Insufficient abundance data exists for many aquatic fauna and while some species are known to be threatened (section 7.3.2), others may be not readily detected rather than rare (section 7.1.4).

Table 7.6 Uncommon and rare aquatic and riparian plant species in the ACT

Common name	Species	ACT distribution
Aquatic Flora		
Common Three-square	*Schoenoplectus pungens*	Murrumbidgee R., constructed Tuggeranong lakes
Quillwort	*Isoetes muelleri*	Murrumbidgee R., Cotter R., Naas Ck, Blue Gum Ck, Gugenby R.
Tall Spikerush	*Eleocharis sphacelata*	Jerrabomberra Wetlands, Upper Naas Ck, Blue Gum Ck.
Water Plantain	*Alisma plantago aquatica*	Murrumbidgee R., Lake Burley Griffin, Ginninderra Ck
Riparian Flora		
Bertya	*Bertya rosmarinifolia*	Murrumbidgee R., Molonglo R., Naas R.
Blady Grass	*Imperata cylindrica*	Murrumbidgee R.
Brook Weed	*Samolus valerandi*	Not recorded since 1972
Bull Oak	*Allocasuarina luehmannii*	Molonglo R., Lake Burley Griffin, Kowen Escarpment
Green-top Sedge	*Carex chlorantha*	One location, Murrumbidgee R.
Native Sowthistle	*Sonchus hydrophilus*	Not recorded since 1970s
Stiff Woodruff	*Asperula ambleia*	Murrumbidgee R. and tributaries
Swamp Millet	*Isachne globosa*	Murrumbidgee R., Paddys R.

7.4 FUTURE CONDITION: POTENTIAL IMPACTS OF CLIMATE CHANGE

The future condition of ACT aquatic and riparian areas is a function of its current condition (discussed above), management activities (see Chapter 0) and the impacts from threats (see Chapter 0). Climate change constitutes a significant threat to natural environments in the ACT and is likely to shape the future of aquatic and riparian ecosystems.

The NSW and ACT Regional Climate Model (NARCliM) project forecasts key climate impacts for the ACT region including increased maximum and minimum temperatures, changed seasonality of rainfall, longer storm and fire seasons and longer periods of hotter weather resulting in a drier environment (ACT Government 2016c). These climate change projections are predicted to affect aquatic and riparian ecosystems in a range of ways, although there remains substantial uncertainty in the exact nature of the effects due to the complex interactions between changes in carbon dioxide, temperature, seasonal rainfall and water availability (Prober et al. 2015).

It is likely that the projected rate of change will threaten the ability of species and ecosystems to adapt. The implications of this are that some species and communities will decline, possibly to extinction, due to water availability, heatwaves, bushfires and chronic degradation of habitat. Other impacts include possible intensification of competition from non-native species and exacerbation of existing anthropogenic pressures. Ecosystems that are able to adapt are likely to experience a shift in floral and faunal composition, potentially altering structure and function (Doerr et al. 2011).

Ecological change is inevitable under a changing climate, but management activities can be implemented to influence trajectories of ecological change toward long-term conservation goals. The aim of such intervention is to facilitate the adaptation of natural environments such that ecosystems are not irreparably degraded or lost. Management guidelines in this strategy are based on best practice recommendations developed by CSIRO's AdaptNRM (CSIRO 2014). These recommendations are consistent with the ACT Climate Change Adaptation Strategy and ACT Nature Conservation Strategy 2013–23, which advocate landscape-scale approaches to enhance resilience of natural ecosystems.

A key recommendation from Adapt NRM is to implement 'climate-ready best practices' that provide ecological benefits regardless of the severity of climate change in the future. As a result, the management guidelines provided throughout this strategy incorporate practices suitable to mitigate climate threats. For example, riparian planting activities will supply shading and offset localised warming in addition to providing numerous structural and functional benefits under any climate change scenario. Consideration of the specific threats posed by climate change is addressed in section 3.19.

7.5 AQUATIC AND RIPARIAN CONSERVATION ACTIVITIES SINCE 2007

The 2007 strategy described a range of conservation activities carried out in the river corridors of the ACT. These activities included legislating protection of threatened species and habitats, development of management and rehabilitation plans, surveys of ecological communities, and research and monitoring of threatened species.

The 2007 strategy also listed priority actions to improve conservation management of rivers and riparian zones in the ACT. In response, a range of new conservation activities have been undertaken in the aquatic and riparian ecosystems of the ACT. The community-level conservation activities undertaken since the previous strategy are summarised below and those activities pertaining to individual threatened species are detailed in the respective action plans.

7.5.1 Rehabilitation activities

A key management goal from the previous strategy was 'Aquatic and riparian communities and habitats in the ACT are maintained and where degraded, rehabilitated to support the range of flora and fauna typical of the ACT.' This goal has been pursued through widespread control of alien species, promotion of native species and habitat construction (Table 7.7).

Figure 7.1 Deployment of artificial fish habitat. Photo: M. Jekabsons, ACT Government.

Table 7.7 Summary of aquatic and riparian rehabilitation activities since 2007

Alien species control	Native species planting	Habitat construction
Murrumbidgee Catchment		
Extensive ongoing willow, Blackberry, Serrated Tussock, African Lovegrass and St Johns Wort control in Murrumbidgee and Gudgenby River Catchments.	Million Trees project: 324,000 native seedlings planted. Replanting 300 riparian plants from Murrays Corner downstream.	Engineered log jams installed at Tharwa to improve fish passage and provide habitat. Casuarina Sands fishway modified to promote fish passage. Habitat lost under the Enlarged Cotter Dam footprint was offset in Paddys River Catchment. Upper Murrumbidgee Demonstration Reach established to showcase management interventions aimed at improving river health and native fish habitat.
Cotter Catchment		
Ongoing weed and pest control in Lower Cotter Catchment Carp and Redfin eradication below Cotter Dam, preventing upstream invasion when old dam overtopped Transfer of EHN virus into new Cotter Dam prevented by disinfection Weed and Poplar control upstream of Murrays Corner down to Cotter Caves.	Lower Cotter Program: community-based revegetation program run by Greening Australia.	Artificial reef fish habitat constructed and monitored in Enlarged Cotter Dam. Fishway constructed and monitored at Pipeline Crossing. Removal of weirs in Cotter avenue and recreational area after 2012 floods. Erosion and sediment control in Lower Cotter Catchment. Reinstatement of the Vanitys Crossing fishway following flood damage in 2011 and 2012.
Molonglo Catchment		
Restoration of Waterways project: invasive plants removed along 26 km of waterway in upper Molonglo Catchment Ongoing control of willow and Blackberry cover in Lower Molonglo River, Molonglo Reach and Molonglo Gorge Blackberry, willow, Poplar, Black Alder and Mexican Water-lily control in Scrivener Dam area and Jerrabomberra Wetlands Weed control in approximately 27 hectares of LBG riparian zone.	Restoration of Waterways project: 20 hectares of riparian zone rehabilitated with 6800 native plants (riparian and emergent) in upper Molonglo Catchment. Revegetation with native trees and shrubs at Jerrabomberra Wetlands, Molonglo Reach and Jerrabomberra Creek. Intensive revegetation of in-stream, edge and riparian flora around areas of Lake Burley Griffin (LBG).	Artificial fish habitat (‘Cod Caves’) deployed and monitored in Molonglo River and Yerrabi Lake.

7.5.2 Management activities

Management plans have been developed and implemented for a range of natural assets in the ACT region, including:

- Murrumbidgee River Catchment Management Plan
- Lower Molonglo Management Plan
- Namadgi National Park Management Plan
- Jerrabomberra Wetlands Nature Reserve Plan of Management
- Googong Foreshores Plan of Management (in draft)
- Lower Cotter Catchment Reserve Management Plan (draft out for public comment)
- Molonglo River Reserve Management Plan (in preparation).

In addition to the above, strategies have been completed to assist the effective execution of specific rehabilitation activities:

- Upper Murrumbidgee Demonstration Reach (various, including the Implementation Plan)
- Molonglo River Rescue Action Plan
- Molonglo River Assessment Strategy
- Molonglo River Restoration Strategy (for Coombs area)
- vegetation strategy for Jerrabomberra Wetlands
- updated ACT Fish Stocking Plan
- review of Environmental Flow Guidelines, being undertaken at the time of writing this document.

The Upper Murrumbidgee Demonstration Reach (UMDR) has been established as a multi-jurisdictional, multi-agency approach to the management of the Upper Murrumbidgee. The UMDR showcases management interventions focused on improving river health and native fish habitat, including sedimentation, fish passage, riparian degradation and alien fish control.

Assessments of development proposals have been conducted as required, and expert ecological advice has been provided to developers on large-scale proposals including the Enlarged Cotter Dam, Murrumbidgee to Googong Pipeline, Murrumbidgee to Cotter River Pipeline and Molonglo Valley urban development.

Management of threatened aquatic and riparian species continues and activities since the previous strategy have included the listing of *Bossiaea grayi* as endangered in the ACT. Action plans for *B. grayi* have been developed and implemented. Another legislated change was an increase in angling size limit for Murray Cod to keep in line with NSW size limits at the time.

7.5.3 Mapping and survey

A range of projects involving mapping and surveying of aquatic and riparian biota in the ACT have been undertaken since the 2007 strategy. These projects range from broad-scale mapping of vegetation communities to surveys of individual species' abundances. Much of this data has been made publicly accessible through online databases:

- Surveys of threatened or uncommon plant species. Distributions of plants identified and mapped, including *Muehlenbeckia tuggeranong, Discaria pubescence, Isoetes muelleri, Thesium australe, Descmodium brachypodum* and *Eucalyptus camphora*. Previously unreported populations of *Pomaderris pallida* were reported, confirming that the species is not considered under threat in the ACT (Canberra Nature Map 2016). Conversely, surveys revealed the rarity of newly described species *Bossiaea grayi* which has subsequently been declared endangered in the ACT (ACT Government 2013b).

- Plant communities of the Upper Murrumbidgee Catchment in NSW and the ACT. Vegetation communities classified, described and mapped with management needs assessed (Armstrong et al. 2013). Reports on the Murrumbidgee and major tributaries have been produced, including maps.
- Mapping Lower Molonglo. In progress, with draft maps available on Molonglo Catchment Group website (Molonglo Catchment Group 2016).
- Mapping of potential barriers to native fish dispersal in the Cotter and Murrumbidgee rivers (e.g. Sangston 2013).
- Annual Platypus Month surveys in Jerrabomberra Creek, Molonglo reach and Murrumbidgee River. This has resulted in the discovery of previously unreported platypus populations.
- Repeat surveys of fish at sites affected by 2003 bushfires.
- Survey and mapping of montane crayfish distribution in the ACT.
- Rapid Assessment of Riparian Condition and macroinvertebrate surveys conducted at all (over 200) Waterwatch sites (O'Reilly et al. 2016).
- Assessment of riparian vegetation at sites included in Rivers of Carbon project (Rivers of Carbon 2016).
- Distributions of ACT biota available through online databases including Canberra Nature Map (2016) and ACTmapi (ACT Government 2015b).
- Waterwatch survey data pertaining to water quality, macroinvertebrate and riparian vegetation made publicly available online through Atlas of Living Australia (2016).

7.5.4 Research projects

Enlarged Cotter Dam Research

Various research projects have been conducted in order to minimise or mitigate the impact of the enlargement of the Cotter Dam on aquatic species. The many projects related to the Enlarged Cotter Dam (ECD) have focused on ensuring the future for threatened fish species in the Cotter Catchment. Research has been conducted into:

- Constructed homes project: an assessment of artificial habitat use by Macquarie Perch. ECD construction activities guided by recommendations (used to design 7 km of artificial reef habitat for fish in the new Cotter Dam). Macquarie Perch use of constructed reef habitat monitored.
- Changes in the diet of Macquarie Perch as terrestrial ecosystems are inundated during ECD filling.
- Cormorant diet, exploring threat of predation to Macquarie Perch.
- Establishment of new populations of Macquarie Perch through translocation.
- Changes in trout numbers linked to a surge in productivity as the ECD fills.
- Impact of trout on threatened species in the Cotter, assessed through trout gut content analysis.
- Swimming capacity of Macquarie Perch and alien fish species (trout, Redfin, Goldfish) in Cotter River was used to help understand and manage fish passage.
- Macquarie Perch spawning, considering barriers to spawning migration out of the new Cotter Reservoir.
- Large Biota Project: radio-tracking methodologies investigated for four fish, one crayfish, one reptile and one mammal species (Broadhurst et al. 2012). Trialled in the laboratory and field. Used to determine daily movements and habitat preferences of Macquarie Perch in Cotter Dam, leading to

flow management recommendations. The project also identified a significant expansion in the range of Macquarie Perch above Vanitys Crossing fishway (Broadhurst et al. 2013).

- Macquarie Perch acoustic monitoring and spawning site characterisation.

Aquatic species studies

The majority of research conducted on aquatic species in the ACT has focused on threatened fish species. A number of these studies were conducted with research partners and are components of more in-depth honours and doctoral theses, such as:

- mapping and analysis of potential barriers to Murray Cod migration in the Murrumbidgee (Sangston 2013)
- mapping and analysis of potential barriers to Macquarie Perch dispersal in the Cotter
- investigation of spawning and larval drift in Murray Cod
- investigation of flow and pool habitat characteristics for Murray Cod habitat
- movement of Blackfish in lake environments investigated using radio telemetry (Broadhurst et al. 2012)
- efficacy of Casuarina Sands fishway investigated, leading to fishway modification
- study of the effectiveness of artificial spawning tubes for Blackfish reproduction
- assessment of Murray Crayfish sampling methodology (Ryan et al. 2013)
- investigation of sampling methodology and distribution of two species of spiny crayfish
- Waterwatch research into habitat use by frogs in urban and peri-urban environments (Hoefer and Starrs 2016)
- Murray Cod use of artificial 'Cod Cave' environments.

Riparian vegetation

The ACT Government is undertaking propagation and replanting trials for threatened species in ACT riparian zones. The Australian National Botanic Gardens have propagated *Muehlenbeckia tuggeranong* and reintroduced the plants into the field. The condition of these plants is reported each year (ACT Government 2016i). Additionally, an *ex situ* seed reserve of *Bossiaea grayi* has been established and germination trials undertaken in collaboration between the ACT Government's Conservation Research unit and the Australian Native Plant Society.

7.5.5 Monitoring

Monitoring of the ACT's aquatic and riparian ecosystems provides data for the systematic evaluation of the effectiveness of management actions aimed at maintaining and improving ecosystem condition. This information supports adaptive, evidence-based decision making. Monitoring is typically carried out by the ACT Government in association with partners such as Icon Water and the University of Canberra.

Long-term threatened species monitoring is undertaken by the ACT Government for all of the ACT's threatened aquatic and riparian species and is outlined in the respective action plan for each species (see Part B).

Ongoing monitoring

Monitoring for fish is undertaken annually or biennially depending on target species or community. A database was developed for fish monitoring data in 2009 and is used for data storage and query. Resulting technical reports assist waterway management by PCS and Icon Water. Trout monitoring by the University of Canberra in the Cotter River continues as part of the Icon Water Enlarged Cotter Reservoir Monitoring Program. Data from monitoring is regularly accessed by external researches and planners.

An assessment of ACT river health is conducted biennially using AUSRIVAS macroinvertebrate protocols. The results are reported in the ACT Water Report. In addition, the Upper Murrumbidgee Waterwatch group monitor 229 sites across the ACT region, reporting their findings for macroinvertebrate biodiversity, water quality and riparian condition in annual Catchment Health Indicator Program reports.

Monitoring of specific threats and initiatives

Monitoring programs are frequently established in connection to rehabilitation activities and potential threats. These have included monitoring of water quality after the 2003 bushfires, riverine biota in response to environmental flows in the Cotter River, fish use of artificial habitats (e.g. 'Cod Caves', engineered log jams), fish response to prescribed burns and various species' responses to the enlargement of the Cotter Dam.

Icon Water conducts ongoing monitoring programs under its licence to take water and authorisations to operate sewage treatment facilities and discharges to the environment. The Icon Water Murrumbidgee Ecological Monitoring Program monitors fish, macroinvertebrates, water quality, hydrology, geomorphology and periphyton. The information is used to track and predict the impacts of current and proposed operations (e.g. response of river biota to the M2G pipeline project).

7.5.6 Community engagement

A broad range of community organisations and dedicated individuals volunteer their time and expertise to activities that support nature conservation in the ACT (ACT Government 2013a). Community organisations supporting grassland conservation activities include Upper Murrumbidgee Waterwatch, Molonglo Catchment Group, Ginninderra Catchment Group and Southern ACT Catchment Group. Members of these groups participate in projects that carry out monitoring, weeding, revegetation, research, advocacy, workshops and conferences and education/outreach.

Since the 2007 strategy, community engagement activities involving aquatic and riparian ecosystems include:

- Restoration of Waterways Project: community meeting and planting days, with ongoing maintenance of revegetated areas by community and volunteer groups.
- Waterwatch activities: over 170 volunteers monitor 229 sites across the upper Murrumbidgee region, a 'Carp Loves 20 Degrees' campaign to encourage reporting of carp sightings on the Murrumbidgee, Platypus Month surveys, education materials and 'Sustaining River Life' curriculum (Upper Murrumbidgee Waterwatch 2014).
- Upper Murrumbidgee Demonstration Reach (UMDR): established to engage the community in rehabilitation of native fish habitats, UMDR runs community meetings and field days, workshops, riparian assessments and fish survey demonstrations, engaged landholders in weed control and produced educational materials (UMDR 2016).
- Million Trees program: approximately 16,500 native seedlings have been planted by community/volunteer groups in the Murrumbidgee River Corridor and 9.4 hectares of private land have been fenced off.
- Jerrabomberra Wetlands Nature Reserve education activities: school programs, university visits, ACT Young Rangers Club, public talks, education pond.
- Recreational fishing regulation stickers and brochure distributed.
- Presentations to fishing clubs including Canberra Fishermans Club and the Australian National Sportsfishing Association NSW annual general meeting.
- Frogwatch: as well as ongoing monitoring, Frogwatch has produced a habitat use study, identifying key ecological attributes of high quality frog habitat (Hoefer and Starrs 2016).

- Weed awareness campaigns and training is aimed at reducing riparian weeds and herbicide run-off.
- Mapping Lower Molonglo project: ecological and geographical data gathering is in progress, with draft maps available on Molonglo Catchment Group (2016) website.
- Glovebox Guide to Waterplants of the ACT Region and willow control material (DVD and guide booklets) has been provided by the Molonglo Catchment Group.
- Lower Cotter Catchment Program: community planting activities.
- Icon Water's community engagement and education program has provided tours and interactive education on catchment protection to the public and schools.
- Canberra Nature Map: a website and app allowing citizens to report sightings of plant and animals species (including fish) in the ACT. The database is available online.

7.6 EVIDENCE BASE FOR AQUATIC AND RIPARIAN STRATEGY

There is a considerable body of scientific literature on aquatic and riparian area conservation and management for streams in Australia and worldwide. This research has resulted in improved knowledge of aquatic and riparian management for long-term conservation. This strategy draws upon this literature to provide guidance on best practice, evidence-based strategies and principles for aquatic and riparian management. Recent publications and reports that have advanced conservation and management techniques relevant to ACT's aquatic and riparian ecosystems include:

- *Australian freshwater ecology: processes and management* (Boulton et al. 2014): a synthesis of the principles of aquatic ecology linked to practical management and conservation of Australian freshwater ecosystems.
- Research on threatened ACT fish species: numerous publications including PhD theses on Macquarie Perch (*Macquaria australasica*) (Ryan 2010) and Honours theses on ACT populations of Murray Cod (*Maccullochella peelii*) (Sangston 2013) and Two-spined Blackfish (*Gadopsis bispinosus*) (Dennis 2013).
- A 10-year review of the Murray–Darling Basin Native Fish Strategy (Koehn et al. 2014).
- Research on other aspects of riparian and aquatic ecology in the ACT: an Honours thesis on the effects of multiple riparian stressors on aquatic macroinvertebrate communities (Florance 2013). PhD theses on the ecological effects of sedimentation (Harrison 2010), reservoir enlargement (Hatton 2016), fluvial seed transport (Groves 2010), and Galaxiidae taxonomy (Raadik 2011).
- Action plans for the ACT's threatened aquatic and riparian flora and fauna.
- The United Nations Educational, Scientific and Cultural Organisation's publication *River restoration: A strategic approach to planning and management* (Speed et al. 2016). This guide is part of a series on strategic water management and draws on evidence and experience sourced globally.

Figure 7.2 Installation of educational signage relating to ACT fishing regulations. Photo: M. Jekabsons, ACT Government.

9 APPENDICES

Carp removed from upper Stranger Pond, ACT Government

9.1 RIPARIAN DEFINITION

The justification below is used to develop a useful definition of riparian zone that applies to ACT riparian zones for the purposes of this strategy and consequent management activities.

Purpose: In the context of the Aquatic and Riparian Conservation Strategy, a definition of the riparian zone (RZ) is required so that:

- the area being discussed in the strategy is understood
- which plants and animals are considered under the strategy is understood
- field staff obtaining funding to work on the RZ under the strategy understand the area they are working on
- staff carrying out monitoring on the RZ for the strategy understand which part of the landscape they are working on
- research and management actions in the RZ can be identified.

To suit this purpose it is therefore important the riparian zone can be defined on a map and in the field.

Geographic location: The definition needs to suit the scope of the strategy. Relevant areas are categorised as upland (the Murrumbidgee River and associated tributaries) to montane and, at the highest points, sub-alpine (e.g. Cotter River and tributaries, Gudgenby/Naas rivers and tributaries. See Figure 1.2).

The water bodies in this geographic area:

- have mostly steep bed gradients
- are generally high stream energy
- rise and fall over a relatively short period of time
- occur in constrained river valleys
- have minimal floodplain development.

The only extensive floodplain development in the ACT is the Lanyon floodplain and Molonglo floodplain near Fyshwick. However, most riparian zones in the ACT will contain some floodplain development, which would still be considered to be within the RZ as they are narrow and active during small floods.

In conclusion, the definition aims to capture areas that are:

- lotic (flowing) as per the scope of the strategy (purpose)
- affected by adjacent stream hydrology including groundwater interactions and as per most previous RZ definitions
- upland high energy streams (geographic location)
- upland streams with minimal floodplain development (geographic location)
- not in highly modified urban areas and so will most likely contain obligate riparian vegetation species (purpose).

9.2 RIPARIAN VEGETATION COMMUNITIES PRESENT IN THE ACT

Community p520: Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion

This community is distributed on creek flats and coarse sandy alluvial soils along drainage channels across eastern parts of the South Eastern Highlands bioregion. In the ACT it occurs along the Murrumbidgee River south of Point Hut Crossing, Cotter River, Gudgenby and Naas rivers and some smaller tributaries (NCDC 1984, Johnston et al. 2009, Peden et al. 2011). A small number of relict stands occur on river terraces around Tharwa and Lanyon (NCDC 1984, Johnston et al. 2009) that have suffered extensive degradation from previous land clearing and subsequent loss of native biodiversity. The community also occurs as narrow bands along rocky river substrates within Namadgi National Park. In this environment it is believed to have retained more intact canopy and native biodiversity (Peden et al. 2011).

Where a remnant canopy has been retained, the community is very tall woodland to open forest characterised by *Eucalyptus viminalis* and occasionally *Eucalyptus rubida*. In a natural state, the shrub layer is sparse or absent and ground cover is dominated by grasses. In the extensively disturbed areas there is little to no native ground cover (Johnston et al. 2009).

The major threats to this community include weed infestation, lack of regeneration, fire and altered hydrology. Widespread *E. viminalis* dieback is of pressing concern—preventing further spread is an urgent priority. The majority of the community in the IBRA Murrumbateman subregion has been lost. Widespread alien species grassland and shrubland has taken its place.

Regionally this community falls under the NSW *Threatened Species Conservation Act 1995* as a component of the Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.

Community p32d: River She-oak riparian forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes bioregions

This vegetation community occurs on alluvial soils along rivers and streams in the central, northern and western parts of the Southern Tablelands and throughout Eastern Australia (Keith 2004). In the ACT the p32d community occurs along the Murrumbidgee River north of Point Hut Crossing, Paddys River, lower Cotter River, the lower Molonglo River and along Uriarra and Swamp creeks (north of Uriarra crossing on the Murrumbidgee River) (NCDC 1984, Johnston et al. 2009, Peden et al. 2011).

The community is characterised by a tall tree canopy of *Casuarina cunninghamiana* (River She-oak). It characteristically forms pure canopy stands in narrow belts along the watercourses. The shrub layer tends to be sparse and the substrate is often dominated by bare soil and rock. The ground may have a thick layer of *Casuarina cunninghamiana* branchlet and leaf litter which contributes to a shady, moist ground environment. The community and associated mistletoe species are important faunal habitat.

The major threats to this community include fire, weed infestation, and altered hydrology. The community was severely burnt in bushfires in 2003 and most of the tree canopy was consumed. While many of the mature trees resprouted, those beyond the observed upper limit of overbank flows have died. As a result, there is a considerable reduction in area of the community with mature canopy, despite having avoided historical felling or clearing.

The p32d community is highly susceptible to invasion by a wide variety of alien plant species (Johnston et al*.* 2009, Armstrong et al*.* 2013) and Willows are found as occasional individuals within the community (NCDC 1984).

Community u181: Callistemon sieberi–Kunzea ericoides rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes bioregions

This shrubland community is restricted to riparian zones of exposed rocky substrate with skeletal or shallow pockets of gravelly soil along tableland streams. Often in confined gorges through hilly country, it may also occur on small bedrock reefs exposed in streams through undulating tableland/slopes country. In the ACT it is well developed along the Murrumbidgee River on riverbanks and where rocky outcrops occur north of Casuarina Sands. It is also found along some sections between Angle Crossing and the junction with the Naas River. Angle Bend and the Gigerline, Red Rocks and Molonglo gorges host high quality examples of this community. It also forms a narrow riparian fringe along the major waterways associated with other riparian wooded communities (Johnston et al*.* 2009, Peden et al*.* 2011). Such shrubland along the river valleys provides important habitat and movement corridors for birds and reptiles (NCDC 1984).

The u181 community has a patchy to dense layer of shrubs commonly dominated by *Callistemon sieberi* and *Kunzea ericoides.* Scattered emergent or flood-stunted trees sometimes occur and the ground cover tends to be dominated by exposed rock and bare sand/gravel alluvium, with scattered or patchy low-moisture tolerant plants including sedge and rush tussocks, grasses and forbs. Where the community occupies elevated bedrock platforms, such as in Gigerline and Red Rocks gorges, it supports a higher cover of low myrtaceous and epacrid shrubs.

Overall, where this community occurs the riparian zone is in good condition, with a high diversity of native species and few introduced species relative to other riparian communities. The community occupies predominantly rocky substrates, hence alien species groundcover is common in adjacent communities has difficulty establishing.

Community AFV: Tableland Aquatic and Fringing Vegetation Complex

Johnston et al*.* (2009) described in detail the aquatic and semi-aquatic species assemblages of the Murrumbidgee River riverine vegetation. The study detailed a vegetation complex consisting of nine common dominance associations that correlate well to hydrological and geomorphic environmental parameters. The complex occurs across a range of permanent, ephemeral, lotic and lentic ecosystems throughout much of the ACT tablelands environment, generally between 400 and 950m Above Sea Level.

The dominant vegetation is typically herbaceous and contains species of both vascular and non-vascular plants, including liverworts, rushes, sedges, grasses, herbs, aquatic floating-leaf species and aquatic submerged vegetation. Almost all species show anatomical and physiological adaptations to inundation. Associated woody riparian communities often contain floristic elements of this complex as fringing or understory components, in particular u181 and p32d.

Overall this complex is common and widespread. However, some elements are both uncommon and vulnerable to loss in the ACT. Furthermore, introduced species have been observed outcompeting native species at some locations (Johnston et al*.* 2009). This complex is identified in part as Tablelands Wetlands in Sharp et al*.* (2007) for which conservation action is required.

Community a9: Carex gaudichaudiana – Ranunculus amphitrichus – Phragmites australis aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands bioregions

This community occurs in and adjacent to permanent waterways at around 1000 metres elevation (e.g. upper reaches of the Murrumbidgee River and its tributaries), in deeper pools along intermittent streams and broad flooded creek flats (Armstrong et al. 2013). In the ACT it occurs on small montane streams such as Sheep Station and Grassy creeks and the upper Gudgenby and Naas systems.

As with most herbaceous aquatic and semi-aquatic communities it is highly variable. It includes true aquatic species with fully submerged, floating or emergent foliage, as well as semi-aquatic species capable of growing as submergents for extended periods. *Phragmites australisica* and *Carex gaudichaudiana* may fringe such vegetation. Plant cover is sporadic and sometimes only one or a few species will be present. Weeds are generally not prevalent in this community (Armstrong et al. 2013).

Community a2: Baeckea gunniana–Epacris paludosa–Richea continentis–Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)

This community is widespread from the Brindabella Ranges in the ACT through to Kosciuszko National Park in NSW (and possibly extending into the South Eastern Highlands at lower altitudes) (Armstrong et al. 2013). In the ACT, examples of this community commonly occur within Namadgi National Park at altitudes above 1300 metres on soils with impeded drainage on flat valley floors (Ingwersen 2001). Free water, either as pools or as slow-flowing streams is usually present.

It generally occurs as a low closed wet heathland dominated by *Baeckea gunniana*, *Epacris paludosa* and *Richea continentis*, with intervening areas dominated by *Sphagnum cristatum* and associated herbs. At lower elevations this community is generally dominated by shrubs. It is typically low in weed diversity apart from occasional pine wildings.

Historically this community may have been used for grazing. Charcoal records within a number of bogs reflect widespread deliberate fire ignition associated with grazing practices of the late 19th century followed by fire suppression in the catchments in the 20th century (Hope et al. 2009).

This community is listed as threatened under the EPBC Act–Alpine Sphagnum Bogs and Associated Fens.

Community r2: Poa labillardierei–Themeda australis–Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion

This community is tall, dense or mid-dense wet tussock grassland found on colluvium or alluvium, and on drainage lines in the footslopes and broad flats associated with creeks and rivers. Poor soil drainage, associated with frequent seasonal waterlogging and winter frosts, drive the distribution of this community. It is distributed widely across the region (Armstrong et al. 2013). In the ACT it is confined to damp, level situations such as near flats, springs and creeks and can be found as small fringing zones of wet areas and creeks (NCDC 1984). Examples include the upper Naas and Grassy creeks.

The upper stratum contains a variety of grasses and forbs in the inter-tussock spaces. Isolated or scattered trees and shrubs may be present, increasing in density where the community merges into adjacent woodlands. Relatively undisturbed sites may have a variety of uncommon grassland forbs (Armstrong et al. 2013).

Regionally much of this community is poorly preserved, has been extensively cleared and remnants are often subject to nutrient run-on from adjacent fertilised crops and pastures, small-scale clearing, weed invasion and grazing pressures. Within the ACT it is predominantly protected within the Namadgi National Park.

Nationally this community is listed as threatened under the EPBC Act as part of Natural Temperate Grassland of the Southern Tablelands of NSW and the ACT. It also qualifies as a component of the ACT described complex Natural Temperate Grassland, listed as threatened under the Nature Conservation Act.

9.3 NATIVE AQUATIC AND RIPARIAN FAUNA PRESENT IN THE ACT

9.3.1 Fish

Historical accounts indicate that rivers in the ACT region sustained large numbers of native fish (Flood 1980). There are 13 species of native fish from 8 families recorded from the Upper Murrumbidgee Catchment (Lintermans 2002, Raddick 2011). Two of these fish are not considered native to the region, but have been translocated from adjacent areas or are rare vagrants. Another of the 13 species was recently identified in the very upper reaches of the Murrumbidgee Catchment, upstream of Tantangara Reservoir. The main groups of native fish in the ACT are:

Large native fish: Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*), Macquarie Perch (*Macquaria australasica*), Two-spined Blackfish (*Gadopsis bispinosus)*, Golden Perch (*Macquaria ambigua*), Silver Perch (*Bidyanus bidyanus*). Natural populations of these fish have all declined dramatically in the ACT and region. Excluding Two-spined Blackfish, these fish species are angling species, with Murray Cod and Golden Perch stocked in Canberra's urban lakes and Googong Reservoir as well as Silver Perch in Googong Reservoir. Trout Cod, Macquarie Perch, Two-spined Blackfish and Silver Perch are listed threatened species.

Small fish of upland streams: Mountain Galaxias (*Galaxias olidus*).

Small fish of lower elevation streams and lakes: Australian Smelt (*Retropinna semoni*), Western Carp Gudgeon (*Hypseleotris klunzingeri*).

9.3.2 Crayfish

Riverine crayfish species found in the ACT are Murray Crayfish (*Euastacus armatus*), Yabby (*Cherax destructor*), and two species of small spiny crayfish. The latter are found in upland areas including the upper Cotter River. One, *Euastacus crassus,* lives predominantly in and near streams while the other, *E. rieki*, also lives in upland bogs. It is known that *E. rieki* can suffer considerable predation by foxes (Carey et al. 2003) and that trout prey on young individuals of *E. crassus* (Lintermans and Osborne 2002). Recent work on these spiny crays in the ACT is generating new knowledge about the ecology of these species (ACT Government, reports in preparation).

The Yabby is the most common freshwater crayfish and is abundant in most lowland freshwater habitats. Also present in the ACT and the upper Murrumbidgee Catchment is the burrowing crayfish *Engaeus cymus* (Lintermans 2002). This species occurs near creeks and seepages in forest areas of south-eastern Australia but little is known of its biology or ecology. Murray Crayfish are listed as a threatened species under the Nature Conservation Act and *E. crassus* and *E. reki* are listed as protected species under the Fisheries Act.

9.3.3 Aquatic macroinvertebrates

Aquatic macroinvertebrates are diverse, representing a range of insect, crustacean and molluscan groups, including snails, water boatmen, dragonflies, caddis flies, stoneflies, mayflies, mites and aquatic worms. They are functionally significant (Covich et al. 1999) and constitute an important food source for fish and Platypus (Ball et al. 2001). The diversity and abundance of aquatic macroinvertebrates are used as indicators of the health of aquatic ecosystems. The composition of an aquatic macroinvertebrate community reflects the aggregate of environmental changes impacting on a stream ecosystem for up to several months prior to sampling (Allan 2004). For details on how this principle is applied in the ACT, see the 2007 strategy.

9.3.4 Semi-aquatic vertebrates

The rivers and streams of the ACT support a number of semi-aquatic vertebrates, including Platypus (*Ornithorhynchus anatinus*), Eastern Water Rat (*Hydromys chrysogaster*) and Eastern Snake-necked Turtle (*Chelodina longicollis*). These species are somewhat elusive and not often readily observed, but none are particularly rare. Platypus are regularly recorded from the Cotter, Murrumbidgee and Molonglo rivers, and annual Platypus Month surveys have led to the discovery of a previously unreported population (Connolly et al. 2016). Past hunting and drainage of wetlands has reduced Eastern Water Rat numbers in the ACT, though they appear to have adapted to drainage swamps and urban lakes, and continue to be reported on the major ACT rivers. The Eastern Snake-necked Turtle is common and widespread throughout the ACT across urban, agricultural and natural sites (Ferronato 2015).

9.3.5 Birds

Riparian zones, particularly the Murrumbidgee and Molonglo river corridors, are noted for their high bird diversity (Taylor and COG 1992). Over 200 bird species have been recorded in the ACT and at least three-quarters of these have been recorded in the riparian zone. Few of the bird species occurring in the riparian zone are restricted to this habitat, although there are exceptions (such as wrens, thornbills, some honeyeaters and other small, non-migratory passerines). Many waterbirds and landbirds rely on aquatic and riparian habitats for breeding, feeding and resting. Additionally, the Molonglo Valley provides critical hunting and breeding habitat for birds of prey due to the mosaic of habitats in the area (rural lands, woodlands, grasslands and river corridor). At least 10 raptor species are known to nest in the riparian zone, including the Wedge-tailed Eagle (*Aquila audax*), White-bellied Sea-eagle (*Haliaeetus leucogaster*) and Peregrine Falcon (*Falco peregrines*). Bird species lists and distributions are available online through mixed-source databases (e.g. Atlas of Living Australia) or the previous strategy (ACT Government 2007).

The autumn exodus of many thousands of honeyeaters from the Canberra region to lower elevations nearer the coast is a special phenomenon (Taws 1999, Wilson 1999). The birds mass together and move from the higher ranges in a general west-to-east direction following various land features, especially the river systems including the Murrumbidgee Valley. This migration is assisted by tree cover along the Murrumbidgee River, as the migrating honeyeaters prefer to make short distance flights between cover rather than crossing extensive open areas.

9.3.6 Terrestrial reptiles

The riparian zone in the ACT provides habitat for many species of reptiles, most of which are also found in other habitats. Snakes typically associated with riparian zones are the Red-bellied Black Snake (*Pseudechis porphyriacus*), Highland Copperhead (*Austrelaps ramsayi*) and Eastern Tiger Snake (*Notechis scutatus*). The Eastern Brown Snake (*Pseudonaja textilis*) is common throughout the ACT.

At least 41 lizard species have been recorded in the ACT region and many of these are present in riparian zones with suitable substrate. The Gippsland Water Dragon (*Physignathus lesueurii howittii*) and Heatwole's Water Skink (*Eulamprus heatwolei*) are riparian species typically associated with watercourses. Stony hillsides within riparian zones of the Murrumbidgee and Molonglo rivers contain key habitat for the threatened Pink-tailed Worm-lizard (*Aprasia parapulchella*).

9.3.7 Amphibians

Frogs occur in a range of wetter habitats in the ACT region. Riparian zones tend to contain moist terrestrial areas that provide habitat for frogs. Most species live on land, although free water is required for their aquatic life stages and for rehydration. Many species prefer shallow, still or slow-flowing aquatic habitats, though there is a component of the ACT frog fauna that occurs along rivers and streams. These are collectively referred to as 'riverine frog species' (Hunter and Gillespie 1999). In the ACT this riverine group includes the rare Leaf Green Tree-frog (*Litoria nudidigita*) and Broad-palmed Frog (*Litoria latopalmata*), both of which are strongly associated with riparian zones.

Also present in the ACT are the Plains Froglet (*Crinia parinsignifera*), Common Eastern Froglet (*Crinia signifera*), Eastern Banjo Frog (*Limnodynastes dumerilii*), Spotted Grass Frog (*Limnodynastes tasmaniensis*), Leseur's Frog (*Litoria lesueuri*), Peron's Tree-frog (*Litoria peronii*), Whistling Tree-frog (*Litoria verreauxii verreauxii*), Smooth Toadlet (*Uperoleia laevigata*) and Brown-striped Frog (*Limnodynastes peronii*). The threatened Northern Corroboree Frog (*Pseudophryne pengilleyi*) occurs in pools and seepages in the ACT and is the subject of a separate action plan. Frog populations are monitored by ACT Frogwatch.

9.3.8 Terrestrial invertebrates

Macroinvertebrates and microbiota account for the majority of biodiversity and are vital for healthy ecosystem function. They are essential for the pollination and reproduction of plants, for nutrient cycling and as a food source. Terrestrial invertebrates are more diverse and abundant in habitats with mature trees and a well-developed ground cover of leaf litter, rocks, logs, branches or tussock grasses. Less information, however, exists on the composition, biodiversity and ecological requirements of invertebrates in most ecosystems than for other faunal groups. Consequently, conservation of most invertebrate species falls under the umbrella of habitat protection for vertebrates and vegetation communities.

9.4 DETAIL OF UNCOMMON AND RARE FLORA

Below is a list of plant species that have a large part of their known ACT distribution within the riparian zone and which have only been rarely recorded locally, despite extensive plant surveys along much of the riparian zone. These include species that are rare because they occur naturally at low density, have become uncommon elsewhere due to disturbance, or are at the margin of their distribution. They are species that are restricted in the ACT to a few locations or have a small total population of less than a few hundred individuals in the ACT.

Alisma plantago-aquatica (Water Plantain) is an erect emergent aquatic herb to 1.5 m high. Leaves are rounded to cordate at the base, 10–25 cm long and 7–10 cm wide, with usually 7 prominent parallel veins connected by numerous transverse veins. The leaf stem is up to 80 cm long, flattened on one side and with small wings at the base. Flowers are a pale pink to white. Scattered across south-eastern Australia, the plant occurs in the ACT along the Murrumbidgee River, Lake Burley Griffin and Ginninderra Creek.

Allocasuarina luehmannii (Bull Oak) is a rough-barked tree of 5–15 m. It has fine wiry foliage, with leaves reduced to tiny pointed scales. Its cones are flattened and woody. A common tree of the Slopes and Riverina, it is at near its south-east distribution limit in the ACT, where it is known from 10 locations with a combined population of about 1500 plants. It occurs along the Molonglo River, around two parts of Lake Burley Griffin and on the Kowen Escarpment.

Asperula ambleia (Stiff Woodruff) is a sub-shrub to 30 cm high. The stems are rigid and minutely hairy. The linear to linear-oblong leaves are mostly 2–5 mm long and 0.3 mm wide and are arranged in whorls of four. Flower stems are 1–3 flowered and usually longer than the leaves. Flowers are white, either male or female with the corolla tube longer than the petal lobes. This plant is largely confined to the ACT and NSW tablelands and in the ACT grows along the Murrumbidgee River and the bottom end of its tributaries.

Bertya rosmarinifolia (Bertya) is a bushy, heath-like shrub to 3 m high. The leaves are linear, 10–25 mm long, mostly 0.5–1.5 mm wide, with a lower surface covered in whitish hairs. Flowers are small and mostly solitary. Confined to eastern NSW and the ACT where it grows mainly along the Murrumbidgee River, but it also occurs along the Molonglo and Naas rivers.

Carex chlorantha (Green-Top Sedge) is a loosely tufted sedge spreading from long underground stems. Its flowering stems are erect to 35 cm, three sided, with a leafy bract below and shorter than the flower head. Leaves are about 1.7 mm wide and shorter than the flowering stems. This sedge is scattered across eastern NSW and Victoria. In the ACT it is only known from one location by the Murrumbidgee River, near Pine Island.

Eleocharis sphacelata (Tall Spikerush) has large green cylindrical upright reeds usually about 1.5 metres high that resemble spikes. It forms large dense swards of foliage and can grow in deep water from creeping culms. The flower and seedhead is on the tip of each reed. It is a widespread and reasonably common plant over much of Australia, but in the ACT has only been recorded from a few locations including Jerrabomberra Wetlands and creeks and swamps in Namadgi National Park (Upper Naas Creek, Blue Gum Creek).

Imperata cylindrica (Blady Grass) is a long-lived perennial grass that spreads by creeping underground stems. Its mostly erect leaves grow to 1 m high and 2 cm wide, green when fresh, orange-brown when dry, with a distinctly paler midrib. It has fluffy white plume-like seedheads in summer and autumn to 25 cm long. A widespread coastal species, in the ACT it is largely confined to the Murrumbidgee River, particularly between Point Hut and Pine Island.

Isachne globosa (Swamp Millet) is a perennial grass spreading by long leafy stems rooting at the nodes, sometimes scrambling to over 1 metre and forming loose mats. It has flat, dark green leaves, 3–10 cm x 3–8mm, scattered along the stem. The flowerhead is open, purplish, much branched and has an overall pyramid shape. A widespread, predominately coastal species, in the ACT it is largely confined to the Murrumbidgee and Paddys rivers.

Isoetes muelleri (Quillwort) A semi-aquatic plant with densely tufted leaves (5–25 per plant) that are always fine (less than 2 mm wide), from 3 to12 cm long and have a very short ligule (membranous sheath) on the inner surface above the swollen base. Plants never have flowers but instead produce spore-bearing sporangia embedded in the swollen leaf bases. Quillwort is widespread across Australia. In the ACT it has been recorded at Red Rocks on the Murrumbidgee, near Vanitys Crossing on the Cotter River and on streams and rivers within Namadgi National Park, including Naas Creek, Blue Gum Creek and Gugenby River.

Samolus valerandi (Brook Weed) is an annual to short-lived perennial herb to 30 cm, with weakly erect stems. The stem leaves are 1–2cm wide. Its white flowers appear at the ends of a largely leafless and branched flower stem. A cosmopolitan species found in wetlands and by the seaside, it has not been recorded in the ACT since 1972, but there are historical records from Molonglo Gorge and Red Rocks, on the Murrumbidgee.

Schoenoplectus pungens (Common Three-square) is a sedge with triangular stems that may be upright or arching to 1.5 m high and 2–6 mm wide in the middle. The narrow (2–4 mm) wide, grass like, basal leaves are all in the lower third of the stem. Leaves are flat to slightly rounded near the base and become cylindrical toward the tip. The flowers are lateral clusters of 1–7 stemless spikelets. A common plant across southern Australia, in the ACT it is largely confined to the Murrumbidgee in the Tuggeranong area, while it is also thriving on the edges of most of the constructed Tuggeranong lakes and ponds, such as Isabella and Gordon ponds.

*Sonchus hydrophilus (*Native Sowthistle) is a short-lived herb to 1.2 metres tall. Leaves are both basal and alternating up the stem. The basal leaves are flat, hairless, 5–30 cm long and 10–30 mm wide, with toothed margin that may be shallowly lobed to entire. The stem leaves attached directly to the main stem are 10–40 cm long and 20–60 mm wide, flat, hairless, lobed, toothed and with pointed tips. It has yellow flower heads. A widespread plant across Australia, it was last recorded in the ACT in the 1970s on the shores of Lake Burley Griffin. It is also known from the Molonglo Gorge.

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Cotter River at Lick Hole Track Crossing. Photo: M. Jekabsons ACT Government

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PERSONAL COMMUNICATIONS

Evans, L. Senior Aquatic Ecologist, Conservation Research Unit, Environment, Planning and Sustainable Development Directorate, ACT Government.

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PART B
ACTION PLANS

The Aqatic and Riparian Conservation Strategy provides a strategic framework for the Action Plans in this section. Action Plans are statutory documents under the Nature Conservation Act 2014.

Two-spined Blackfish (*Gadopsis bispinosis*)

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.

MACQUARIE PERCH

MACQUARIA AUSTRALASICA

ACTION PLAN

Macquarie Perch (*Macquaria australasica*). Photo: E. Beaton, ACT Government

PREAMBLE

Macquarie Perch *(Macquaria australasica*) was listed as an endangered 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 edition of the action plan supersedes earlier editions.

Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Zone Conservation Strategy, and component threatened species action plans such as the Trout Cod (*Maccullochella macquariensis*), Silver Perch (*Bidyanus bidyanus*), Two-spined Blackfish (*Gadopsis bispinosus*) and Murray River Crayfish (*Euastacus armatus*).

CONSERVATION STATUS

Macquaria australasica is recognised and listed as a threatened native species in the following sources:

International: IUCN

Data Deficient (2015–4).

National

Endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
Endangered – Australian Society for Fish Biology (Lintermans 2015)

Australian Capital Territory

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

New South Wales

Endangered – *Fisheries Management Act 1994*.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988* (with an advisory status of Endangered: Victorian Department of Sustainability and Environment 2013).

South Australia

Extinct – Action Plan for South Australian Freshwater Fishes (Hammer et al. 2009).

SPECIES DESCRIPTION AND ECOLOGY

Description

Macquaria australasica is a member of the Family Percichthyidae, which contains the Australian freshwater basses and cods. It is a moderately-sized, deep-bodied, laterally-compressed fish with large white eyes (Figure 1). It occurs in both the inland drainage of the Murray–Darling Basin (MDB) and the coastal drainages of the Shoalhaven and Hawkesbury–Nepean Catchments in New South Wales (Lintermans 2007, Faulks et al. 2010). It is now considered that the morphologically distinct and geographically disjunct forms in inland and coastal drainages are likely to be separate taxa (Faulks et al. 2010), with possibly two taxa present in the coastal drainages.

In the MDB the maximum length is ~550 millimetres (mm) total length (TL) and maximum weight is 3.5 kilograms (kg), but individuals larger than 400 mm TL or one kilogram are uncommon (Harris and Rowland 1996, Lintermans 2007, Lintermans and Ebner 2010). The body colour is generally black-grey or bluish grey on the dorsal and lateral surfaces and some individuals are distinctly mottled, particularly small juveniles. The ventral surface is whitish. The lateral line is obvious and there are conspicuous open pores on the snout and around the eyes. The tail is rounded, the eye is large and white and the mouth is large with the jaws equal in length. Adult specimens possess a distinct 'humped back' and the tail is rounded. The species is not sexually dimorphic.

Figure 1 *Macquarie australacia*. Illustration: curtesy of NSW Government.

Distribution and abundance

M. australasica is currently typically found in the cooler, upper reaches of the Murray–Darling river system in Victoria, New South Wales and the Australian Capital Territory. Historically the species was more broadly distributed with populations in lowland, slower flowing habitats such as the Murray River between Euston and Tocumwal, Edwards and Wakool rivers and Barmah Lakes near Deniliquin (Cadwallader 1977, 1981, Llewellyn and MacDonald 1980). There are also some natural coastal populations in New South Wales, notably the Nepean, Hawkesbury and lower Shoalhaven rivers. The species was introduced into some other coastal drainages from the MDB in the late 1800s and early 1900s.This action plan only relates to the Murray–Darling stock of *M. australasica* in the ACT region.

In the ACT, *M. australasica* is currently restricted to natural populations in three rivers— the Murrumbidgee, lower Paddys and Cotter rivers—with translocated individuals present in the Upper Cotter River (upstream of Corin Dam), the Molonglo River (upstream of Molonglo Gorge in Kowen Forest) and the mid Paddys River (near Murrays Corner) (Lintermans 2000b, 2013d). The species has been recorded along the entire length of the Murrumbidgee River in the ACT (Greenham 1981, Lintermans 2000b, ACT Government unpublished data). The fish found near the confluence with the Cotter River are likely vagrant fish from the established population in Cotter Reservoir. Individuals captured near Angle Crossing are thought to represent the downstream extent of the population that extends from below Yaouk to Angle Crossing.

Translocations

Since the 1980s there have been a number of translocations of *M. australasica* in the Canberra region. In 1985, 41 individuals were removed from Cotter Reservoir when it was drained for maintenance of the dam wall. These fish were released into Bendora Reservoir but this translocation attempt failed (Lintermans 2013d). Another emergency translocation was conducted in the Queanbeyan River in 1980 when it was realised the construction of Googong Dam had inundated the only available spawning sites for the species, and a natural barrier (Curleys Falls) blocked access to the river for reservoir-resident *M. australasica* (Lintermans 2013c). Sixty-six adult *M. australasica* were collected from the newly-formed reservoir and translocated past the waterfall and released approximately 4 kilometres (km) upstream into the Queanbeyan River. After a substantial delay, this translocation appeared to be successful with a reproducing population persisting for approximately a decade. However, genetic investigation of this period indicated significant genetic impoverishment (Farrington et al. 2014). The population was not detected in the last monitoring in 2014.

A planned translocation program was started in 2006 in an attempt to establish additional populations of *M. australasica* outside the lower Cotter Catchment. The program primarily uses juvenile fish (to minimise impacts on the Cotter Reservoir donor population), with approximately 730 fish translocated to the upper Cotter River (upstream of Corin Reservoir) and 430 translocated to the Molonglo River upstream of Molonglo Gorge (Lintermans 2013d).

Habitat and ecology

The current preferred habitat of *M. australasica* across its range is cool, shaded, upland streams and rivers with deep rocky pools and substantial cover. The species also survives well in impoundments with suitable feeder streams in which to breed. Historically the species was more broadly distributed with populations in lowland, slower flowing habitats (Cadwallader 1977, 1981). The species now seems to be largely confined to the upper reaches of catchments, which are more pristine, well-forested and less affected by agriculture and sedimentation (Cadwallader 1981, Lintermans 2007, Faulks et al. 2011).

M. australasica are reported to live for up to 26 years but such age is rare and most individuals would be expected to live less than ~12–15 years (M. Lintermans pers. comm.). Earlier studies recorded that males reach sexual maturity at two years of age and 210 mm total length, and females at three years and 300 mm total length (Harris and Rowland 1996). However, in Cotter Reservoir ripe males have been recorded at 140–150 mm (Lintermans and Ebner 2010). *M. australasica* undertake a spawning migration into flowing rivers (Lintermans et al. 2010, Tonkin et al. 2010) and gather in schools before spawning, which can last several weeks (Battaglene 1988, Tonkin et al. 2010).

Spawning occurs in late spring/summer when day length increases and water temperatures reach approximately 16–16.5°C. The spawning season generally spans October to December (Broadhurst et al. 2012, Douglas 2002, Tonkin et al. 2010). Fish are reported to deposit eggs at the foot of pools or head of riffles or fast-flowing sections of river (Tonkin et al. 2010, McGuffie unpublished data) where males fertilise them. The eggs are then washed downstream where they lodge in gravel or rocky areas until hatching (Cadwallader and Rogan 1977, Douglas 2002, Tonkin et al. 2010). Fecundity is approximately 31,000 eggs per kilogram of fish weight (Cadwallader and Rogan 1977). Larvae hatch in 10 to11 days at water temperatures of 15–17°C (Gooley 1986) with the larvae being about 7 mm long upon hatching (Battaglene 1988).

The diet of *M. australasica* consists predominantly of freshwater prawns and shrimps (*Macrobrachium* and *Paratya*), and small benthic aquatic insect larvae, particularly mayflies, caddisflies and midges. Yabbies, dragonfly larvae, zooplankton and molluscs are also eaten (Battaglene 1988, Butcher 1945, Cadwallader and Eden 1979, Hatton 2016, Lintermans 2006, McKeown 1934, Norris et al. 2012).

Radio-tracking studies in Cotter Reservoir found that adult and sub-adult fish are mostly crepuscular or nocturnal (i.e. active at dusk, dawn and night) with fish moving on average around 500 metres (m) per day (Ebner and Lintermans 2007, Ebner et al. 2011, Thiem et al. 2013), but moving double that in winter (Thiem et al. 2013). The increased winter movement is possibly related to either increased foraging effort to capture preferred food items such as freshwater prawns, which are less abundant in winter (Norris et al. 2012), or reduction in cormorant predation pressure because cormorants are largely absent during winter.

Like most Australian native freshwater fish, *M. australasica* is not known to jump and swimming performance is influenced significantly by fish size (large fish can swim faster and longer) and water temperature, with swimming performance declining below 16°C (Starrs et al*.* 2011). This is an important consideration when considering natural and anthropogenic in-stream barriers to fish movement and how to remediate them.

Recent research indicates that the majority of remaining populations of *M. australasica* in Australia have reduced genetic diversity, most likely as a result of lack of connectivity between populations and/or initially small numbers of founding fish (Pavlova et al*.* in revision). Reduced genetic diversity has been reported for the Cotter Reservoir and upper Murrumbidgee River populations in the Canberra region (Pavlova et al*.* submitted).

Further information about *M. australasica* ecology is in Appendix 1.

CURRENT MANAGEMENT ACTIONS AND RESEARCH

Environmental flow requirements for the Cotter River downstream of Bendora Dam have been in place since 2000. These flows include specific flows for *M. australasica* that target pool and riffle maintenance prior to breeding season.

Regulations prohibiting the take of *M. australasica* by anglers have been in place since the species was listed as threatened in 1997 (ACT Government 1999). Following the completion of construction of the Enlarged Cotter Dam, the total closure to fishing in the Cotter River was extended from the dam upstream to the junction with Condor Creek. To protect a range of threatened fish species including the translocated *M. australasica,* fishing is prohibited in the Cotter Catchment upstream of Bendora Dam in Namadgi National Park. These regulations are still current.

Ongoing annual monitoring of all ACT populations of *M. australasica* has occurred since the mid-2000s by either the ACT Government or the University of Canberra (Lintermans 2013b, Lintermans et al*.* 2013) and is ongoing. A database for fish records has been established by the ACT Government.

Under the ACT *Water Resources Act 2007*, a program of environmental flow releases in the Lower Cotter Catchment make particular provision for threatened fish species with riffle and pool maintenance flows released (ACT Government 2013a). These Environmental Flow Guidelines are reviewed and updated every five years.

The pine forests of the lower Cotter Catchment were severely burnt during 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. The Lower Cotter Program is ongoing until at least 2019.

The Upper Murrumbidgee Demonstration Reach (UMDR) commenced in 2009 as an initiative under the Murray–Darling Basin Native Fish Strategy and involves a partnership of government, university and community groups (ACT Government 2010). The UMDR is approximately 100 kilometres in length, stretching from the rural township of Bredbo in south-east NSW downstream to Casuarina Sands in the ACT, which includes the Murrumbidgee *M. australasica* population. The vision of the UMDR is ‘a healthier, more resilient and sustainable river reach and corridor that is appreciated and enjoyed by all communities of the national capital region’. This initiative is ongoing.

Many sections of the Murrumbidgee through the ACT are affected by accumulations of sand (‘sand slugs’) which cause reductions in water depth and structural habitat diversity. Since

1998 attempts to rehabilitate fish habitat (create scour pools) and improve fish passage through the sand slug downstream of Tharwa have been under way with a series of rock groynes built in 2001 and engineered log jams (ELJs) in 2013 (Lintermans 2004c, ACT Government 2013b). The works at Tharwa have resulted in scour pools with increased depth, and monitoring of the ELJs has found that threatened fish species are now using the area. Funding has been awarded by the ACT Government for more ELJs downstream of those constructed in 2013. Construction is planned to commence 2017–18.

The Cotter Reservoir contains a major population of *M. australasica*. The enlargement of the Cotter Dam (ECD), finished in 2013, required a suite of research and management actions. Current or ongoing projects include:

- a fish monitoring program, focused on the reservoir and upstream river sites
- cormorant management
- *M. australasica* translocation program
- investigation into *M. australasica* spawning and passage requirements.

Appendix 2 provides information on past management and research actions.

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 are considered to have impacted on populations of *M. australasica* nationally and locally. In addition, there are specific local threats to *M. australasica* in the Canberra region, including effects of wildfires, reduced genetic diversity, increased predation from native predators and reduction in spawning habitat availability.

Habitat modification

The Lower Cotter and Murrumbidgee Catchments have been impacted by clearing and weeds. Sedimentation of streams has filled pools, smothered spawning sites as well as reduced light penetration and diversity and abundance of invertebrates. Dams on the Cotter River have reduced flows, particularly high-flow events, although this is partially addressed by environmental flow regulations. Dams also release colder hypoxic water and have flooded previously riverine habitats. Locally, *M. australasica* habitats have been impacted by sedimentation of streams (e.g. the Murrumbidgee sand slug and forestry impacts in the Lower Cotter River) and reservoirs (e.g. excessive sedimentation of the old Cotter Reservoir) and cold water pollution (downstream of Googong, Corin and Bendora dams).

River regulation

Alterations to natural flow patterns of streams, including flow magnitude, frequency, duration, timing, variability and rate of change, are a major threat to lotic species (Naiman et al. 2008, Poff et al. 1997). In the Canberra region Tantangara Dam reduces flows downstream by 99%, diverting water to Lake Eucumbene in the Snowy River Catchment (Anon. 1997). At the Mt Macdonald gauging station, flow in the Murrumbidgee River has recovered to approximately 73% of natural state (ACT Government 2004). In the Cotter River, the flow downstream of Bendora Dam is significantly reduced as water is captured and piped to Canberra for domestic water supply. As a result of these low flows, natural in-stream barriers that would have drowned out in winter and spring now present movement barriers that block upstream spawning migrations by *M. australasica*. Environmental flows are provided downstream of Bendora to improve habitat and assist *M. australasica* breeding.

Barriers to fish passage

Fish habitats are unique in that they are usually linear, narrow and therefore extremely susceptible to fragmentation. Barriers can be structural (dams, weirs, road crossings), or chemical (e.g. discharge of effluents, pollutants, contaminants) partial (i.e. only operate under some conditions such as low flows) or total (e.g. large dams and weirs, piped road crossings). Barriers prevent the movement of fish, either local movements such as for feeding or refuge, or larger scale migrations for breeding. *M. australasica* has been particularly impacted by barriers in the ACT region with local populations impacted by dams (e.g. Cotter, Bendora, Scrivener and Googong), weirs (at Casuarina Sands and in the Queanbeyan town centre) and road crossings (e.g. Vanitys Crossing, Point Hut Crossing, Angle Crossing).

Overfishing

Overfishing is cited as one of the contributing factors in the decline of *M. australasica* (Cadwallader 1978, Harris and Rowland 1996). *M. australasica* was a popular angling species in the Canberra region and was reported to provide both good sport and good eating (Greenham 1981, Trueman 2012). Although the species can no longer be legally retained in the ACT or NSW, it can be difficult to release alive after accidental hooking. Some fish are still being caught and retained—either through ignorance or mistaken species identity or deliberately (Lintermans unpublished data).

Sedimentation

Sediment addition to the Murrumbidgee River has resulted in severe decline of habitat quantity and quality for *M. australasica*. Sediment in streams may derive from point sources (e.g. roads, stock access points, construction activities), from broad-scale land use or as a result of extreme events such as fires, floods and rabbit plagues. High levels of suspended solids in streams may be lethal to fish and their eggs but the major damage is to aquatic habitat. Sediment fills pools, decreases substrate variation and reduces usable habitat areas. Clogging of the substratum removes spaces between rocks used as rearing, refuge and habitat areas by juvenile fish, small species and stream invertebrates (Lintermans 2013a). Sedimentation in rivers is particularly detrimental to fish such as *M. australasica* as sediment may smother the eggs and prevent their lodgement. Increased sedimentation is also known to be damaging to benthic macroinvertebrate communities which form the majority of the dietary items of *M. australasica* (Lintermans 2006, Norris et al. 2012, Hatton 2016).

Reduction in water quality

The major reductions in water quality most likely to have affected *M. australasica* in the Canberra region are sediment addition (see above), pollutant discharges to streams and changes to thermal regimes, either from the operation of impoundments or the clearing of riparian vegetation which shades streams. Some pollutants disrupt aquatic ecosystems by mimicking naturally occurring hormones (endocrine disruptors), consequently affecting sexual development, function and reproductive behaviour (Mills and Chichester 2005, Söffker and Tyler 2012). Locally, pharmaceutical products and oestrogenic activity has been documented in the discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC) (Roberts et al. 2015, 2016), although the impacts on local aquatic species are, as yet, unknown.

Water releases from lower levels of thermally stratified impoundments are usually characterised by low dissolved oxygen levels and lowered water temperature, which can depress downstream temperatures in warmer months, increase downstream temperatures in winter, delay seasonal maximum temperatures by months and reduce diurnal temperature variability (Rutherford et al. 2009, Lugg and

Copeland 2014). In the Cotter River, altered thermal regimes were predicted for 20 kilometres downstream of Bendora Dam (at flows of 1 m^3s^{-1} or 86 ML/day) (Rutherford et al. 2009). Lowered water temperatures can delay egg hatching and insect emergence and retard fish growth rates and swimming speeds (increasing predation risk). Cotter River *M. australasica* swimming capacity is strongly correlated with water temperature (Starrs et al. 2011). Reduced growth rates mean small fish will remain for a longer time in the size-class susceptible to predation, thus exacerbating the impacts of alien predators. Lowered water temperature can also disrupt reproductive behaviour.

Other reductions in water quality likely to have had major effects on *M. australasica* are the addition of sediment (see above) and the catastrophic pollution of the Molonglo River following the collapse of tailings dumps at the Captains Flat mine in 1939 and 1942 in an area that previously supported populations of *M. australasica* (Trueman 2012, Kaminskas 2015).

Introduction of alien species

Locally, *M. australasica* has had its distribution invaded by a range of alien fish species including Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*), 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. Epizootic Haematopoietic Necrosis Virus 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 *M. australasica* is thought to be through all of these interactions with alien fish.

Changing climate

In addition to the above threats, the severe decline of a number of *M. australasica* populations during the millennium drought (1997–2010) (Lintermans et al. 2014) suggests the species is likely to be susceptible to the predicted 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 fresh waters (Buisson et al. 2008, Morrongiello et al. 2011). *M. australasica* eggs lodge in riffles below upland pools and are 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 may persist for decades until the bedload moves downstream (Rutherfurd et al. 2000). This species spawns in response to day length and water temperature. The spawning cues can become decoupled, with predicted earlier seasonal warming resulting in reduced recruitment success.

Fires

Bushfire impacts of consequence to *M. australasica* 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 as ash is deposited in streams
- impacts from the loss of riparian (streamside) vegetation such as increased water temperature due to lack of shade.

As a result of the 2003 bushfires (further information in Appendix 3), fire management practices in the ACT have been amended with road access to remote areas upgraded, new fire trails constructed and an increased frequency of control burns. As a result of increased fire management activities, the impacts of broadscale bushfires are likely mitigated, however even fire mitigation activities can themselves pose a risk to aquatic environments if not planned and conducted carefully. Results of fish monitoring after an escaped hazard reduction burn conducted in the upper Cotter Catchment in 2015 recorded high levels of electrical conductivity in the river (ACT Government 2015). This reflected chemical changes as a result of ash and sediment deposition, which are not well understood for the ACT.

Genetic bottlenecks/impoverishment

Recent genetic studies have shown that almost all remaining populations of *M. australasica* in Australia have low genetic diversity and have undergone recent bottlenecks (Faulks et al. 2011, Pavlova et al. submitted). Estimates of effective population size in Cotter Reservoir also indicate that, in addition to low genetic diversity, only a relatively small number of adults in this population contribute to breeding annually (Farrington et al. 2014, Pavlova et al. in revision). Species or populations with small effective population size and low genetic diversity are at increased risk of extinction (Frankham 2005, Weeks et al. 2011). 'Genetic rescue' is where individuals, cross breeds or genetic material from a donor population are introduced to an impacted population to reduce genetic isolation, increase genetic variation and reduce inbreeding depression. Genetic rescue aims to improve the fitness and evolutionary potential of the recipient population (Weeks et al. 2011). Where populations of *M. australasica* have been mixed via translocation (e.g. Yarra River, Cataract River) there is no evidence of adverse genetic effects (Pavlova et al. submitted).

Reduction in spawning habitat availability

M. australasica require riffles in flowing water for spawning. Therefore reservoir populations require access to upstream riverine habitats to breed. Recent research has also indicated that generally *M. australasica* may only use a subset of available riffles for spawning (Tonkin et al. 2016, P. McGuffie unpublished data). Prior to the enlargement of the reservoir, spawning sites for the Cotter Reservoir population of *M. australasica* were largely concentrated in the kilometre or two of river immediately upstream of the initially impounded waters (Ebner et al. 2007, Lintermans 2012). These spawning sites have been inundated, so fish must seek alternative spawning sites further upstream, traversing a steep-gradient river reach with many natural in-stream barriers that prevent upstream fish migration under low or inappropriate flows (Lintermans 2012, Broadhurst et al. 2013). In-stream barriers are probably contributing to the factors limiting recruitment since 2013 (Broadhurst et al. 2015). The number, location, accessibility or physical characteristics of spawning sites for the riverine population of *M. australasica* in the Cotter River are unknown.

Cormorant predation

Recent research on Macquarie Perch in the Cotter Reservoir has suggested that bird predators such as cormorants may have a potentially significant effect on the small population of *M. australasica* in the reservoir (Lintermans et al. 2011, Ryan et al. 2013). Radio telemetry investigations indicate that a small population of cormorants may prey on a significant proportion of adult fish as they congregate at the top of the reservoir prior to spawning. Investigations of cormorant diet revealed that Macquarie Perch were present in 22% and 14% of Great Cormorant and Little Black Cormorant stomachs respectively, with one Great Cormorant having six *M. australasica* present in its stomach (Lintermans et al. 2011).

Further information on threats is in Appendix 3.

MAJOR CONSERVATION OBJECTIVE

The overall conservation objective of this action plan is to maintain in the long term, viable, wild populations of *M. australasica* 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 existing populations and establish or re-establish new populations.
- Enhance the long-term viability of populations through management of aquatic habitats, alien fish species, connectivity, spawning site access, stream flows and sedimentation in existing habitats as well as those adjacent to known *M. australasica* populations to increase habitat area and connect populations.
- Enhance genetic diversity of Cotter Catchment populations of *M. australasica* to improve long-term viability.
- Improve understanding of the species' ecology, habitat and threats.
- Improve community awareness and support for *M. australasica* and freshwater fish conservation.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

M. australasica largely occurs on Territory Land including Namadgi National Park and the Lower Cotter Catchment (water supply protection area). *M. australasica* is not known to occur on rural leasehold Territory Land, or Commonwealth owned and managed land (National Land).

Conservation effort for *M. australasica* in the ACT is focused on protecting viable populations in the Cotter River and Cotter Reservoir below Bendora Dam. In planning terms, the primary purpose of the Cotter River Catchment is water supply, with conservation a secondary objective. Consequently, protection of this *M. australasica* population is tempered by water supply considerations, but protection of threatened fish in the Cotter River Catchment remains a key issue for both Territory and Commonwealth governments (ACTEW Corporation 2009). The national conservation status of the species provides some protection from 'significant' impacts. The ACT Government will liaise with Icon Water to ensure continued protection and management of *M. australasica* in the Cotter Catchment.

General habitat and water quality improvement works and protection in the Murrumbidgee River and catchment will assist in conserving the Murrumbidgee population in the region.

Recreational harvest of *M. australasica* in the ACT is prohibited by the Nature Conservation Act with fishing completely prohibited on the Cotter Reservoir and inflowing Cotter River up to the junction with Condor Creek. Recreational fishing is also prohibited in the waters of the

Cotter River Catchment upstream of the Bendora Dam wall. Protection from fishing for *M. australasica* will remain a key focus of this action plan.

Survey, monitoring and research

There is a relatively good understanding of the species distribution, ecology and relative abundance in the ACT, with ongoing annual or biennial monitoring of the species within the Cotter Catchment (both Cotter Reservoir and riverine sites) undertaken by ACT Government since 2001 and by the University of Canberra. A representative set of sites with *M. australasica* will need to be monitored to determine long-term population trends and to evaluate the effects of management. The establishment and condition of translocated *M. australasica* at the three current translocation sites (upper Cotter River, Molonglo River above Blue Tiles, Paddys River) (Lintermans 2013d) requires further monitoring. The current biennial monitoring program for the Murrumbidgee River fish community (which started in 1994) should continue to provide information on the status of *M. australasica* in this river within the ACT and at upstream sites where Macquarie Perch are extant.

Regular monitoring of the Cotter Catchment (upstream of Cotter dam) to detect invasion by alien fish species (Carp and Redfin Perch) should also continue, as should monitoring of cormorant abundance on Cotter Reservoir. Investigation of the potential to limit the upstream spread of Redfin Perch in Paddys River should also occur (location of natural barriers, potential sites for constructed barriers), as it may be possible to successfully reintroduce *M. australasica* to this catchment in the future.

While the broad spawning movement ecology of *M. australasica* is understood, recent studies to characterise the location and nature of potential spawning movement barriers (Broadhurst et al. 2016) are hampered by a lack of understanding of the location and characteristics of *M. australasica* spawning sites and the lack of knowledge of the spawning movement patterns (timing, extent, duration) in the Cotter River. Knowledge of the characteristics and spatial distribution of spawning sites will facilitate increased protection and management of these critical habitats. As well as assisting in the identification of spawning sites, study of the spawning movement patterns will help determine where remediation efforts should be focused for fish passage barriers.

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

- population estimates for Cotter Reservoir and Cotter River populations
- spawning site characteristics and distribution along the Cotter River
- spawning migration patterns including timing, extent of migration and duration of migration
- remediation techniques for natural in-stream barriers (flows, barrier modification, barrier removal, fishways)
- impact of temperature on spawning behaviour and success
- impacts of bushfire management
- magnitude and significance of annual *M. australasica* population fluctuations and relationship to seasonal or annual conditions (flow, temperature)
- investigation of the benefits of increasing genetic diversity (genetic rescue) of both riverine and reservoir populations in the lower Cotter Catchment
- the efficacy of environmental flow releases in maintaining recruitment of riverine and reservoir populations
- further investigations of trout predation on larval or juvenile *M. australasica*
- investigation of techniques and the feasibility of rehabilitating and mitigating

sedimentation of Paddys River with a view to population expansion.

Key sites for population monitoring are those that have an established long-term monitoring program (Cotter Reservoir, Cotter River, Murrumbidgee River). Monitoring programs for *M. australasica* should use multiple sampling methods potentially including gill nets, electrofishing and fyke nets. Fyke nets, which capture the greatest number of individuals, are the only method that reliably detects young-of-year fish (Lintermans 2013c, 2016).

Past and present monitoring work in the Cotter River Catchment has demonstrated the broad distributional range of the species, but further survey and monitoring effort is required for the Queanbeyan River to ascertain whether this population is extant (Lintermans 2013c).

Management

Based on current knowledge of the habitat requirements and ecology of *M. australasica,* management actions should aim to maintain riverine habitats with appropriate seasonal flow regimes, intact riparian zones, sufficient pool depths, minimal sediment inputs from roads and surrounding land use, an absence of Redfin Perch and Carp, and connectivity between spawning and non-spawning habitats.

Management of riparian zones will enhance organic matter contributions, which are the basic food supply for many stream invertebrates that form the majority of the diet of *M. australasica*. Intact riparian zones also provide shade, which buffers water temperatures, provides cover, prevents erosion and filters sediment from run-off. Minimising sediment addition will protect pools from becoming shallower and will protect the function of riffles as spawning habitat for *M. australsica*.

Preventing the establishment of Redfin Perch and other alien species, such as Carp, will protect *M. australasica* from predation and resource competition as well as largely eliminating the threat posed by EHN virus.

Management of prescribed burns, particularly in the Cotter Catchment, needs to be carefully considered to avoid impacts on threatened aquatic species. The adequate assessment of risk and resourcing is critical in minimising likelihood of unintended outcomes of prescription burns. The application of buffers for autumn burns and other measures are important to minimise the impact of prescription burns. The aquatic ecology guidelines concerning the Bushfire Operations Plan (under the Emergencies Act) are event-specific and included in the ecological guidelines that accompany the Bushfire Operations Plan.

Continued access to suitable spawning habitats is an essential requirement for a population to be self-sustaining. Once the characteristics of spawning migrations and sites are understood (see research priorities), management actions will likely be necessary to ensure continued spawning success.

Management of fish passage to prevent fragmentation of existing populations and habitats is a priority. There may also be opportunities to expand or reconnect sub-populations. For example, the building of fishways at Vanitys Crossing and Pipeline Road Crossing were intended to ultimately link Cotter River reaches and expand *M. australasica* populations previously fragmented by road crossings. It is also likely that remediation of natural barriers in the river reach between the enlarged Cotter Reservoir and Vanitys Crossing, whose effect is exacerbated by low, regulated flows downstream of Bendora Dam, may be required during the life of this action plan.

Engagement

As with any threatened species, the importance of information transfer to the community and people responsible for managing their 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.
- Keep the guide to fishing in the ACT up-to-date to limit angling target of the species. Ensure that angling signage is up-to-date and placed in relevant areas.
- Report on the monitoring of the species in the Conservation Research Unit's biennial report, which is distributed to a broad audience.
- Liaise with other jurisdictions and departments to increase the profile of native fish conservation.

Further information about conservation and management is in Appendix 4.

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 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 action, 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 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, water supply protected area or an area set aside specifically for conservation of the species.
	1b. Maintain the protected status of the species within Namadgi National Park and the four nature reserves in the Murrumbidgee River Corridor.	1b. Namadgi and Murrumbidgee River Corridor populations continue to be protected in national park or nature reserve areas.
	1c. Ensure all populations are protected from impacts of recreation, infrastructure works, water extraction and other potentially damaging activities, using an appropriate legislative mechanism.	1c. All 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 Bendora reservoir to maintain an appropriate flow regime to conserve the species.	2b. Appropriate timing, volumes and water quality 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 and prescribed burns. Invasive plants (e.g. Willows, Blackberries) are controlled and areas replanted with appropriate native species.
	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 established in Cotter River. Existing alien fish populations are not expanding in abundance or distribution where *M. australasica* is present.
	2e. Impediments to fish passage are managed to minimise impacts on the populations, through	2e. Fish population sustainability is not impacted by barriers to fish movement.

Objective	Action	Indicator
	remediation, flow management or trap and transport.	
	2f. Manage recreational fishing pressure to conserve the species.	2f. Appropriate recreational fishing restrictions are in place and enforced to prevent deliberate or inadvertent harvest.
3. Increase habitat area and connect populations.	3. Manage aquatic habitats adjacent to *M. australasica* habitat to increase habitat area or habitat connectivity.	3. Aquatic habitats adjacent to, or linking, *M. australasica* 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. Establish additional populations through translocation and improve genetic diversity of the Cotter River population.	4a. Translocate *M. australasica* to suitable habitats outside the lower Cotter River and Murrumbidgee River.	4a. One additional population established outside the lower Cotter River Catchment.
	4b. Improve genetic diversity of Cotter Reservoir and lower Cotter River populations through introducing appropriate new genetic stock.	4b. Genetic diversity of *M. australasica* in Cotter Reservoir and lower Cotter River improved compared to 2015 levels.
5. Improve understanding of the species' ecology, habitat and threats.	5. 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 *M. australasica* conservation and management.	5. Research results reported and, where appropriate, applied to the conservation management of the species. Engagement and/or collaboration with other agencies/individuals involved in *M. australasica* conservation and management (recovery teams, state agencies, universities).
6. Improve community awareness and support for *M. australasica* and freshwater fish conservation.	6. Produce materials or programs to engage and raise awareness of *M. australasica* and other freshwater fish threats and management actions.	6. Community awareness materials/programs produced and distributed.

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APPENDIX 1: ADDITIONAL INFORMATION ON *MACQUARIA AUSTRALASICA* ECOLOGY

Distribution and abundance

An early morphometric and genetic study suggested there were three distinct stocks of *Macquaria australasica*, with the Murray–Darling populations being distinct from a Shoalhaven stock and Hawkesbury stock (Dufty 1986). More recent molecular investigations have supported separate specific status for these three stocks (Faulks et al. 2010).

In the Cotter River prior to the 2000s, the species was restricted to the lower section of the river from its junction with the Murrumbidgee up to Vanitys Crossing (including Cotter Reservoir) (Lintermans 2000b). Anecdotal reports indicate that the species did occur further upstream on the Cotter but had disappeared from this area and was unable to pass the high concrete causeway built at Vanitys Crossing in the late 1970s (Lintermans 1991).

The only natural record from the past four decades from the Molonglo River has been from the lower end of the river below the Lower Molonglo Water Quality Control Centre (LMWQCC), where two individuals were captured in 1981. The discharge of treated effluent from the LMWQCC since 1978 is likely to provide a chemical barrier that discourages dispersal of some native fish species from the Murrumbidgee to the Molonglo River (Lintermans 2004a). Scrivener Dam now prevents upstream movement of fish species from the lower Molonglo and effectively restricts access to the majority of the Molonglo River. The species was historically present in the Molonglo River (Trueman 2012) but was likely eliminated along with almost all other fish species by heavy metal pollution from the Captains Flat mines.

M. australasica was reported to be historically present in Paddys River based on angler interviews summarised in Greenham (1981) and confirmed by Lake (P.S. Lake pers. comm. to M. Lintermans). A survey of five sites in 2000 of the lower and mid reaches only recorded the species within 500 metres of the confluence with the Cotter River with these individuals likely to represent upstream dispersal from the Cotter River (Lintermans 2000a).

In the broader Canberra region, *M. australasica* has also been recorded since the 2000s as viable populations from three other locations:

- A population of unknown size in the Murrumbidgee River between Michelago and Yaouk (Lintermans 2002).
- A substantial population in the Abercrombie River below Crookwell (Gilligan et al. 2010).
- A small population in Adjungbilly Creek upstream of Gundagai.

Populations that have declined substantially since the late 1990s–early 2000s and may no longer be present or viable. There may be:

- A possible remnant population in Burrinjuck Dam.
- A remnant population in the lower Goodradigbee River near Wee Jasper.
- A small population in the Lachlan River near Wyangla Dam.
- A small translocated population possibly still present in the Queanbeyan River immediately upstream of Googong Reservoir (Lintermans 2013c).
- A relict translocated population in the Mongarlowe River near Braidwood (Lintermans 2008).

Translocations

To guide the numbers and age-classes of fish to use in this translocation program, a population model has been constructed to provide an estimate of the likelihood of success of various strategies (Todd and Lintermans 2015). In response to the development of this model, since 2015 a small number of adult fish (less than 25) have been translocated to the Upper Cotter site to increase the chance of successful population establishment.

Habitat and ecology

Mature unfertilised eggs are 1–2 mm in diameter and cream coloured. After fertilisation the eggs swell to approximately 4 mm diameter and are amber coloured (Battaglene 1988).

Small groups of larval *M. australasica* (<10 mm length) have been observed to swim in the mid to upper water column along steep rock-faces in deep sections of pools (>1.5 m) and in low or no-flow areas. However juveniles (10–50 mm length) quickly become more benthic in their habitats, becoming closely associated with boulders, cobbles or large woody debris, usually towards the head or foot of pools where some surface flow is present (Broadhurst et al. 2012).

In the Queanbeyan River, larger items such as freshwater prawns and shrimps were eaten by adults, with immature and young-of-year fish consuming mainly larvae of mayflies, midges and caddisflies (Lintermans 2006).

During daylight hours, individuals in Cotter Reservoir shelter in cover provided by fringing reed beds or other cover—individual fish have well-defined home ranges that can change every few months (Ebner and Lintermans 2007). Adult fish in Cotter Reservoir tended to be found in habitats with depths of 2–5 m except in summer when deeper water habitat (mean 7.2 m) was used. This change in depth of habitat use was hypothesised to be influenced by predator avoidance (from cormorants) in summer, or the seasonal interplay between behavioural thermoregulation and limitations of dissolved oxygen available in a reservoir that stratifies over summer and autumn (Thiem et al. 2013).

The effective population size (the number of adults that contribute to breeding in a particular year) of *M. australasica* in Cotter Reservoir before its enlargement was estimated to be 14–65 from samples collected in 2001–07 (Farrington et al. 2014).

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. Modified environmental flows were provided, with ecosystem monitoring including *M. australasica* recruitment. It was feared that lower flows would result in sediment accumulation in riffles, which is critical spawning habitat for *M. australasica*. Consequently the environmental flow releases from Bendora were modified to both maintain riffle quality before the spring spawning season and during the summer larval growth period. Similarly, following the severe 2003 bushfires in the Canberra region, there was significant erosion and sedimentation of streams, particularly in the Cotter River (Carey et al. 2003). Again, concern over conditions for spawning resulted in environmental water releases to maintain riffles in suitable condition to protect spawning in *M. australasica*.

Vanitys Crossing formed a barrier to upstream movement of *M. australasica*. In 2001 a fishway designed specifically for *M. australasica* was constructed at Vanitys Crossing—it has allowed a significant expansion in the species range in the lower Cotter River (Broadhurst et al. 2012, 2013). The species has become established above Vanitys Crossing up to Pipeline Crossing (7.7 river km) and recorded as far as Burkes Creek Crossing (approximately 3.9 km further upstream). Another fishway specifically designed for *M. australasica* was constructed at Pipeline Crossing in 2011 by ACTEW Water. The Vanitys Crossing fishway has been rebuilt following significant damage in floods in 2010 and 2011. The existing fishway at Casuarina Sands on the Murrumbidgee River has also been recently modified to enhance fish passage.

A review of Canberra's water supply options resulted in the construction of an enlarged Cotter Reservoir between 2008 and 2013. As the Cotter Reservoir contained the only self-sustaining population of *M. australasica* in the ACT, a suite of research and management actions were undertaken, which represented a significant investment in knowledge generation and mitigation activities for the species. Projects 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 *M. australasica* in the existing reservoir and the potential effects of cormorant predation (Ryan et al. 2013)
- the sterilisation between the old and new dam walls to prevent transfer of EHN virus
- the investigation into actual levels of predation on *M. australasica* by cormorants (Lintermans et al. 2011)
- the construction of 7 km of rock reef shelter habitat for *M. australasica* in the new reservoir's ECD inundation zone (Lintermans et al. 2010)
- the use of underwater video to investigate artificial habitat use by juvenile *M. australasica* (Lintermans et al. 2010)
- the installation of a fishway at Pipeline Road Crossing to provide access additional riverine habitat for *M. australasica*
- a preliminary project to investigate the timing of the upstream spawning migration of *M. australasica* from Cotter Reservoir (Lintermans et al. 2010)
- the establishment of an ongoing comprehensive monitoring program for threatened and alien fish in the reservoir and the river upstream (Lintermans et al. 2013; Broadhurst et al. 2015)
- the initial development of a genetic test to determine the presence of *M. australasica* in trout stomachs (Macdonald et al. 2014)
- the preparation of emergency translocation plans for *M. australasica* in the event of critically low water quality in the newly filling ECD (ACTEW Corporation 2013)
- the investigation of potential need and design of translocation programs for a range of threatened fish, the development of a population model to guide translocation efforts and the establishment of a translocation program for *M. australasica* to the upper Cotter River and Molonglo River in Kowen Forest (Lintermans 2013d; Todd and Lintermans 2015)
- the investigation of fish food resources and diet of *M. australasica* in the existing Cotter Reservoir (Norris et al. 2012)
- investigations of the swimming capacities of *M. australasica* and other fish species to inform fishway design and management (Starrs et al. 2011, 2017)
- the mapping and characterisation of potential movement barriers that might limit *M. australasica* accessing spawning habitats (Hugh 2010, Broadhurst et al. 2016)
- the preparation of a cormorant management plan for the ECD should cormorant abundance increase to critical levels in the filling reservoir (ACTEW Corporation 2013).
- the preparation of a series of fish management plans for Cotter Reservoir encompassing planning to operational phases (e.g. ACTEW Corporation 2013).

Other research conducted in the 2000s included the movement response of a range of fish species (including *M. australasica*) to environmental flow releases (Ebner et al. 2008), the development of snorkelling as a technique to monitor Macquarie Perch spawning time and larval distribution (Broadhurst et al. 2012), the diel behaviour of small individuals of *M. australasica* and Two-spined Blackfish in the Cotter River (Ebner et al. 2009) and the success of Vanitys Crossing fishway in allowing a significant expansion in the range of *M. australasica* above Vanitys Crossing (Broadhurst et al. 2013).

APPENDIX 3: FURTHER INFORMATION ABOUT THREATS

River regulation

Lake Burley Griffin and Googong Reservoir on the Molonglo–Queanbeyan River system reduce seasonal flows in the lower Molonglo River and adjacent Murrumbidgee, reducing the dilution of effluent discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC). The average daily discharge of treated effluent from the LMWQCC is 90 ML/d or 33 GL/yr, with this effluent comprising approximately 30–40% of flow in the Murrumbidgee River at Mt Macdonald on average, but up to 90% of flow in dry years (e.g. 1998 and 2003) (Consulting Environmental Engineers 2005).

Barriers to fish passage

The construction of Cotter Dam in 1915 isolated the Cotter River population of *M. australasica* from the Murrumbidgee River stock. The subsequent construction of Vanitys Crossing in the late 1970s further fragmented the Cotter River population with *M. australasica* becoming restricted to the Cotter Reservoir and the 5.5 kilometre stretch of river between the reservoir and Vanitys Crossing. The construction of Googong Dam impounded the Queanbeyan River up to the base of a waterfall (Curleys Falls), inundating all suitable spawning areas for *M. australasica* below the falls. Fish had to be translocated past the barrier posed by the waterfall to allow successful spawning to occur (Lintermans 2013c). The effluent discharge from LMWQCC is thought to provide a chemical barrier that reduces movement of some fish species from the Murrumbidgee River into the Molonglo River (Lintermans 2004a).

Barriers can act synergistically with other threats by preventing recolonisation of streams after local declines or extinctions. For example, the collapse of tailings dumps at Captains Flat in 1939 and 1942 effectively sterilised the river downstream and the construction of Scrivener Dam to form Lake Burley Griffin in 1963 effectively isolated the Molonglo and Queanbeyan rivers from the Murrumbidgee River and has prevented any recolonisation by *M. australasica*.

Sedimentation

The impacts of sedimentation on fish in the ACT are particularly obvious in the Murrumbidgee River. The sediment derived from land management practices and the 2003 fires in the Cotter River Catchment (Starr 2003, Wasson et al. 2003).

Introduction of alien species

The establishment of alien fish species is a recognised threat to freshwater fish both globally (Dudgeon et al. 2006; Malmqvist and Rundle 2002) and in Australia (Lintermans 2013a). For some species the evidence is inferred as many alien fish (e.g. salmonids) became established before the distribution and abundance of native fish was documented. However, the number of alien fish species continues to rise, mainly through the release of ornamental species (Lintermans 2004b, 2013a).

The diets of *M. australasica* and alien trout species are similar and competition is likely (Jackson 1981, Lintermans 2006). Trout are also known to prey upon *M. australasica* juveniles (Butcher 1967, S. Kaminskas pers. comm.) and may prey upon larvae (Ebner et al. 2007). Initial research has developed a genetic method for detecting *M. australasica* presence in salmonid stomachs, but further laboratory and field testing is required to establish sensitivity and false detection (both negative and positive) probabilities (MacDonald et al. 2014). Other introduced fish species such as Carp, Goldfish, Redfin Perch and Oriental Weatherloach will also have dietary overlap with *M. australasica* (e.g. Battaglene 1988; Cadwallader 1978). In the Lachlan River system *M. australasica* appears to disappear from streams after the invasion and spread of Redfin Perch but the mechanism for this impact (competition, predation, disease) is unclear.

A major impact of alien species on *M. australasica* is the introduction or spread of diseases and parasites to native fish species. The most serious disease threat to *M. australasica* is Epizootic Haematopoietic Necrosis Virus (EHNV) with experimental work by Langdon (1989b) demonstrating that *M. australasica* was one of several species found to be extremely susceptible to the disease. This virus, unique to Australia (and currently endemic to this region), 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). EHNV is endemic to the upper Murrumbidgee Catchment (Whittington et al. 2011), where it has been recorded from most of Canberra urban lakes (Whittington et al. 1996). The spread of EHNV has been aided by its relatively resistant characteristics and the ease with which it can be transmitted from one geographical location to another on nets, fishing lines, boats and other equipment. Langdon (1989b) found that the virus retained its infectivity after being stored dry for 113 days. Once EHNV has been recorded from a waterbody it is considered impossible to eradicate. The virus is absent from the Cotter River upstream of the enlarged dam (Whittington et al. 2011) but the potential for the virus to be introduced through contaminated fishing gear or illegal movement of Redfin Perch is high (Lintermans 2012).

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 *M. australasica* in the Cotter Reservoir (Lintermans unpublished data).

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).

Fires

Studies on the Cotter River have shown that river regulation has exacerbated the effects of fires and sediment addition. A North American study documented increases in summer water temperatures of 8–10°C following fire, due to the increased light reaching streams as a result of the removal of riparian vegetation (Minshall et al. 1989). Almost 840 km 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). the loss of riparian zone vegetation likely results 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). 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 fill with gravels and cobbles.

Other impacts on aquatic communities include increased clearing for fire breaks leads to bare earth and erosion risk, the use of fire retardants adjacent to streams, the installation of water sources for fire control (dams) or pumping from streams and the escape of controlled burns.

Genetic bottlenecks and impoverishment

Historically, translocation between threatened species populations has not been pursued because of concern over outbreeding depression, but it is now realised that such concerns are deterring management actions to boost or reinforce population size and may be contributing to local population loss (Frankham 2010, Weeks et al. 2011), with translocation now an increasingly common management practice for threatened freshwater fish in Australia (Lintermans et al. 2015).

Cormorant predation

The population of Great Cormorants on the enlarged Cotter Reservoir since it began to fill fluctuates between 20 and 35 birds over the late spring to late autumn period when the species is present (Broadhurst et al. 2015). The effective population size for *M. australasica* in Cotter Reservoir (before its enlargement) was estimated to be between 14 and 65 (Farrington et al. 2014), so the daily consumption of a single *M. australasica* by Great Cormorants alone could represent a substantial proportion of the breeding population.

APPENDIX 4: FURTHER INFORMATION ABOUT CONSERVATION AND MANAGEMENT

Protection

Given that at some ACT sites *M. australasica* has declined to extremely low or undetectable levels, and acknowledging that the species is long-lived (maximum known age 26 years) and that recovery of large-bodied fishes can take decades (see Koehn et al. 2013, Lintermans 2013b), it should be assumed that the species is present at any site where it has previously occurred since 1990 unless this is disproved by rigorous annual survey over at least five years or the habitat has been destroyed.

MURRAY RIVER CRAYFISH

EUASTACUS ARMATUS

ACTION PLAN

Murray River Crayfish *(Euastacus armatus)*. Photo: M. Jekabsons ACT Government

PREAMBLE

The Murray River Crayfish (or Murray Crayfish, *Euastacus armatus* Von Martens 1866) 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 of the Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007). This revised edition supersedes the earlier editions.

Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Conservation Strategy and component threatened species action plans such as Macquarie Perch (*Macquaria australasica*), Trout Cod (*Maccullochella macquariensis*), Silver Perch (*Bidyanus bidyanus*) and Two-spined Blackfish (*Gadopsis bispinosus*).

Murray Crayfish were fished by Indigenous Australians as evidenced by archaeological fossils in South Australia and early explorers' reports (NSW DPI 2014). In the local area, reports from the 1830s show the importance of *Euastacus armatus* to the Ngunawal people (Bennet 1834).

CONSERVATION STATUS

Murray River Crayfish is listed as a threatened species in the following sources:

International: IUCN

Data deficient (trend declining) – previously vulnerable.

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*.

New South Wales

Vulnerable – Schedule 5 of the *Fisheries Management Act 1994*.

Victoria

Threatened – Section 10 of the *Flora and Fauna Guarantee Act 1988.*

South Australia

Protected – Schedule 5 of the *Fisheries Management Act 2007.*

SPECIES DESCRIPTION AND ECOLOGY

Description

The Murray River Crayfish *Euastacus armartus* (Murray Crayfish and also known as Murray Lobster or Mungola) belongs to the family Parastacidae, which includes all the freshwater crayfish within the southern hemisphere. The genus Euastacus is found in eastern states of mainland Australia and contains more than 50 species. They are characterised by sharp spines on heavy claws and often have spines on the carapaces. *E. armatus* is the second largest freshwater crayfish in the world, reportedly growing to 500 millimetres (mm) long (170 mm Occipital Carapace Length, OCL) and 2.7 kilograms (kg) (Geddes 1990) but more generally 200 mm. It has large white claws, the body is generally dark green, brown or black with white spikes on the cephalon, thorax and abdomen (Figure 1 and 2).

E. armatus are a long-lived species which may live for 30 to 50 years. Female *E. armatus* mature at 5 to 9 years of age (60 and 95 mm OCL) and males from 4 years of age. Mating occurs in May and females carry eggs under their tail from late autumn, releasing juveniles in late spring to early summer. In the ACT, egg carrying (berried) females are typically larger than 75 mm OCL (average 92 mm) (ACT Government unpublished data), though smaller berried females have been collected in sections of the upper Murrumbidgee River Catchment (Starrs et al*.* 2015). Fecundity appears to be correlated with female size with between 150 and 1500 eggs per female (McCormack 2012).

Distribution and abundance

E. armatus is found in the southern Murray–Darling Basin (MDB) to approximately 700 metres above sea level. In the local region it is known from the Murrumbidgee River, lower Cotter River below the Cotter Dam, Tumut River, Goobragandra River and the lower Goodradigbee River. The species has been occasionally collected from the Cotter River above the Cotter Reservoir at Bracks Hole and within Cotter Reservoir (ACT Government unpublished data) but it is unknown if it has persisted following the construction of the enlarged Cotter Dam. It has been previously present in the Molonglo River, Queanbeyan River and Yass River and it is reported that several illegal introductions of *E. armatus* have occurred in the local region including to urban lakes and ponds and nearby rivers. Many of these introductions are believed to have been unsuccessful.

Abundance is known to decline with altitude (Raadik et al*.* 2001). The ACT is at the edge of the *E. armatus* upper altitudinal range and currently has a low abundance of the species (Ryan 2005, Gilligan et al*.* 2007, NSW Fisheries Scientific Committee 2013). In the Murrumbidgee at Narrandera 0.1–0.9 crayfish per lift was reported (Asmus 1999, McCarthy 2005). In the ACT, by comparison, crayfish per net lift in the surveys since 1988 are between 0.06 and 0.038 (Lintermans and Rutzou 1991, Lintermans 2000, Ryan 2005, Fulton et al*.* 2010, Ryan et al*.* 2013, ACT Government unpublished data). Prior to 1990 large captures from the ACT region have been reported anecdotally by anglers (Lintermans and Rutzou 1991).

Habitat and Ecology

E. armatus inhabit a wide variety of permanent rivers and large streams and are also known to occur in some lake environments. In lowland areas, clay banks appear to be important for constructing burrows, but in the ACT region boulder/cobble substrate along with other structure such as snags may provide important cover (Fulton et al*.* 2010). The species has a preference for intermediate flow velocities, deeper pools and glides with overhanging vegetation for shading (Noble and Fulton 2016).

Although most recorded movements of *E. armatus* are only a few metres, movements of over 10 kilometres have been recorded (O'Connor 1984). In the ACT, mean home ranges in the Murrumbidgee of 1800–2000 m^2 have been documented (Ryan 2005). The average core area was 370 m^2, with home ranges of individual crayfish often overlapping. No differences between diurnal and nocturnal activity were reported and individuals often remain in one location for more than 24 hours before undertaking a period of activity (Ryan 2005).

A recent genetic population study indicates that *E. armatus* show significant genetic differentiation between major headwaters near the ACT region reflecting low migration rates (Whiterod et al*.* 2016). The upper Murrumbidgee population in the ACT was shown to be related to nearby Murrumbidgee population and tributaries. The population did not display the genetic fixation shown in the tributaries (Talbingo–Tumut River and

Goobragandra and Goodradigbee populations) which are geographically close but genetically isolated.

E. armatus appear to be sensitive to water quality and are occasionally observed leaving the water (crawling onto river banks or snags) during periods of low dissolved oxygen such as after the 2003 bushfire run-off or during a blackwater event in the Barmah–Millewa Forest when dissolved oxygen concentrations fell to 1.8 micrograms per litre (McKinnon 1995, Whitworth et al*.* 2011, King et al*.* 2012).

E. armatus are opportunistic polytrophic detritivores feeding predominantly on woody debris, biofilms and leaf litter. Fish and animal meat is often used to bait nets when fishing for *E. armatus* so animal carcases and invertebrates are likely opportunistic food sources (Gilligan et al*.* 2007). Direct predation of live fish and freshwater molluscs has been observed in tanks (ACT Government observation). Non-antagonistic feeding of up to three *E. armatus* in a one square metre area of small woody debris and course particulate matter (leaf litter) has been observed locally (Starrs et al*.* 2015). The processing of large woody and leafy debris (shredding) assists in nutrient cycling in the aquatic ecosystem and crayfish are the largest shredders in the aquatic environment.

E. armatus are preyed upon by large native and alien fish such as Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*) and Golden Perch (*Macquaria ambiguia*) and predatory alien species such as Redfin (*Perca fluviatilis*) and may be an important prey item for these species (Gilligan et al*.* 2007).

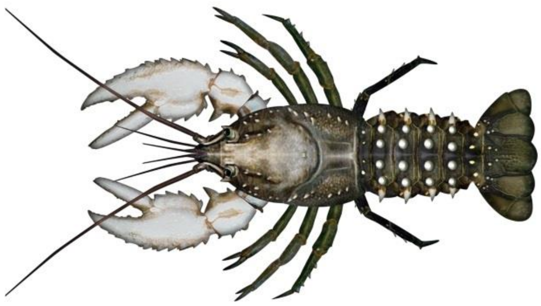

Figure 1 *Euastacus armatus*. Illustration: curtesy of NSW Government.

Previous management actions and additional information about research can be found in Appendix 1.

CURRENT MANAGEMENT

Regulations prohibiting the take of *E. armatus* in the ACT have been in place since 1991 when it was declared a protected invertebrate under the *Nature Conservation Act 1980* (Lintermans 1993). This protection was continued when the species was listed as vulnerable in 1997. Additional protection, originally under the Nature Conservation Act and continued under the *Fisheries Act 2000*, was put in place prohibiting the use of closed traps for yabby fishing in the ACT and the prohibition on the use of lift nets for yabby fishing in five reserves along the Murrumbidgee River. These prohibitions remain current.

Riparian vegetation has been identified as important to *E. armatus* (Fulton et al*.* 2010). Replanting on the Murrumbidgee River as part of the Million Trees program is aimed at improving riparian vegetation and reducing sedimentation run-off and impacts of weed species and improvements in water quality following fires in 2003.

The Upper Murrumbidgee Demonstration Reach (UMDR) commenced in 2009 as an initiative under the Murray–Darling Basin Native Fish

Strategy and involves a partnership of government, university and community groups (ACT Government 2010). The UMDR is approximately 100 kilometres in length, stretching from the rural township of Bredbo in south-east NSW downstream to Casuarina Sands in the ACT, which includes the Murrumbidgee Macquarie Perch population. The vision of the UMDR is 'a healthier, more resilient and sustainable river reach and corridor that is appreciated and enjoyed by all communities of the national capital region'. This initiative is ongoing and the habitat improvement initiatives will benefit *E. armatus*.

Many sections of the Murrumbidgee through the ACT are affected by accumulations of sand ('sand slugs') which cause reductions in water depth and structural habitat diversity. Since 1998 attempts to rehabilitate fish habitat (create scour pools) and improve fish passage through the sand slug downstream of Tharwa have been under way, with a series of rock groynes built in 2001 and engineered log jams (ELJs) and riparian rehabilitation in 2013 (Lintermans 2004a, ACT Govt 2013b). The works at Tharwa have resulted in scour pools with increased depth and monitoring of the ELJs has found that threatened fish species are now using the area. Funding has been granted by the ACT Government for the construction of more ELJs downstream of those constructed in 2013. Construction is planned to commence 2017–18.

E. armatus are positively correlated to flowing waters which are assumed to improve habitat conditions. Under the *Water Resources Act 2007* environmental flow provisions in the ACT section of the Murrumbidgee protect the 80th percentile or 90th percentile of flow (dependent upon season). In addition, extraction is not to exceed 10% of flow above this level. These guidelines are reviewed and updated every five years.

THREATS

Freshwater crayfish and their habitats are imperilled globally (Richman et al*.* 2015). The major threats affecting native crayfish are habitat destruction or modification, river regulation, overfishing, alien species, disease, barriers to passage, and climate change (Furse and Coughran 2011). These threats are considered to have impacted on populations of *E. armatus* (NSW DPI 2014). General information about these threats regionally can be found in the Aquatic and Riparian Conservation Strategy.

Overfishing

Overfishing is a direct threat to *E. armatus*. Historic commercial fishing in the lower Murrumbidgee and Murray systems from the 1920s to the 1970s resulted in significant declines in Murray Crayfish including extinction in the lower Murray (Zukowski et al*.* 2011). Despite not having a commercial fishing industry, the lack of any protection measures in the ACT before 1991 allowed for overfishing by recreational anglers including reports of unlicensed selling of catches of *E. armatus* in the local area (Lintermans 2002). Currently, in NSW, limited take is permitted in the Murrumbidgee River from the Hume Highway to Balranald Weir and the Murray River from Hume Weir to Newell Highway from June to August (inclusive). In Victoria take is allowed north of the Great Dividing Range. In both jurisdictions a bag limit of two per day, between 10 and 12 cm carapace length is in place and the take of berried females is prohibited.

Recreational take has been prohibited in South Australia (SA) and the ACT with regulations and area bans in place in Victoria and NSW for over 20 years. Despite this, limited or no recovery of populations has been reported. Recreational take has also been found to alter the size classes and abundance of *E. armatus* (Zukowski et al*.* 2013) (see Appendix 1 for more information).

A partial recovery of the ACT population was described following protection in 1991 (Lintermans 2000) but this recovery was not sustained into the 2000s (Lintermans 2000, Ryan et al*.* 2013). In the ACT, Victoria, SA and many parts of NSW there has been no recovery of populations despite closures of recreational fishing (NSW DPI 2014). Despite protection, the lower population density in the ACT means illegal angling and overfishing remains a threat.

Riparian vegetation removal

Removal of riparian vegetation is a major threat to freshwater aquatic ecosystems. The degradation of riparian vegetation in the upper Murrumbidgee Catchment includes historical clearing, grazing, weeds and urbanisation. For *E. armatus*, riparian vegetation provides cover, thermal refuge and food. Shading by riparian vegetation has been found to be positively correlated to crayfish density in smaller rivers in the Canberra region (Fulton et al*.* 2010, Noble and Fulton 2016).

Sedimentation

Sediment addition to the Murrumbidgee River has resulted in severe decline of aquatic habitat (ACT Government 2010). Sediment in streams may derive from point sources (e.g. roads, stock access points, construction activities), from broad-scale land use or as a result of extreme events such as fires, floods and rabbit plagues. High levels of suspended solids in streams may be lethal to fish and their eggs but the major damage is to aquatic habitat. Sediment fills pools, decreases substrate variation and reduces usable habitat areas. Clogging of the substratum removes spaces between rocks used as refuge and foraging areas (Noble and Fulton 2016). Excessive addition of sediment to rivers has been identified as detrimental to *E. armatus* (Fulton et al*.* 2010, Noble and Fulton 2016).

Residential development

Residential development near rivers has the potential to impact on *E. armatus,* particularly through increases in recreational and illegal fishing, in addition to urban water run-off, changes in water quality, sedimentation and alteration to the riparian vegetation. It is likely that future riverside development would be detrimental to *E. armatus*.

River regulation

Dams alter flow regimes, sediment and nutrient regimes and can result in cold water pollution which impacts on aquatic ecosystems downstream. The Murrumbidgee River in the ACT region is regulated by Tantangara Dam, which diverts 99% of the flow to Eucumbene Dam in the Snowy River Catchment. This diversion results in approximately 40% reduction in flow at the ACT border.

Tantangara Dam has also reduced the frequency of winter flooding and increased the occurrence of low flows (<1000 megalitres/day) in winter (Pendlebury 1997, Olley and Wasson 2003). This has probably exacerbated the continued accumulation of sediments in the river as there are fewer and smaller high-flow events that previously would have scoured the finer sediments out of the riverbed (Pendlebury 1997). Reduction in flows also increases the pool habitat and reduces suitable flowing habitat. The creation of lotic environments such as weir pools has been shown to be detrimental to the species (NSW DPI 2014). *E. armatus* show a preference for flowing waters and are consequently impacted by weirs and dams. In the ACT region *E. armatus* have been positively associated with deep glide pool habitats. Enhancing environmental flow provisions for the Murrumbidgee River would assist conservation of *E. armatus*.

Reduction in water quality

The major reductions in water quality which are most likely to have affected *E. armatus* in the ACT region are sediment addition (see above) thermal pollution and pollutant discharges to streams. Some pollutants disrupt aquatic ecosystems by mimicking naturally occurring hormones (endocrine disruptors) and so affect sexual development, function and reproductive behaviour of aquatic animals (Mills and Chichester 2005, Söffker and Tyler 2012).

Locally, pharmaceutical products and oestrogenic activity has been documented in the discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC) (Roberts et al. 2015, Roberts et al. 2016). Although the impacts on local aquatic species including *E. armatus* are as yet unknown, endocrine disruptors have been implicated in delaying moulting in crayfish (Rodriguez et al. 2007).

It has been noted that there are major declines in *E. armatus* populations below lowland irrigation districts (Asmus 1999). The cause of this decline has been attributed to the run-off of pesticides and herbicides from agricultural districts in conjunction with the lotic environments created by the weir pools (O'Connor 1984, King et al. 2012, NSW DPI 2014). The ACT region has limited irrigation areas in the Molonglo and upper Murrumbidgee rivers, and the precise impact of these areas on *E. armatus* is unknown. Despite this, protecting water quality from urban and rural run-off will assist the ongoing conservation of this species.

Fires

Fire impacts of consequence to *E. armatus* 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 as ash is deposited in streams
- impacts from the loss of the riparian (streamside) vegetation such as increased water temperature due to lack of shade and reduction in food source.

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, and an increased frequency of prescribed burns. As a result of increased fire management activities, the impacts of broadscale bushfires are likely reduced, but fire mitigation activities can themselves pose a risk to aquatic environments if not planned and conducted carefully.

E. armatus are known to leave the water during periods of poor water quality such as during blackwater events or during the run-off following fires (Geddes 1990, McKinnon 1995, Carey et al. 2003, Gilligan et al. 2007). Out of the water they are exposed to high predation pressure and desiccation. Post-fire recovery teams have recently been established following many high intensity fires. The key goals of these teams are to limit the impact of run-off and erosion, and to improve and hasten post-fire recovery of natural ecosystems. Such recovery actions will help mitigate the impact of these events on the aquatic ecosystem and *E. armatus*.

Invasive species and disease

It is likely that introduced fish species such as trout, Carp (*Cyprinus carpio*) and Redfin Perch prey upon *E. armatus*, particularly juveniles (Merrick 1995). Introduction of non-native or non-local crayfish through introduction of competitive or predatory species or through the introduction of disease is considered a major risk to crayfish conservation (Furse and Coughran 2011). Two alien yabby species, Smooth Marron (*Cherax cainii*) and Redclaw (*Cherax quadricarinatus),* are widely used in aquaculture and aquaponics systems. These species have potential to establish introduced populations in the ACT that may negatively impact local crayfish species. The increase of unregulated aquaponics in the ACT increases the risks that these species may become established.

The crayfish plague *Aphanomyces astaci* (Soderhall and Cerenius 1999) is a fungus endemic to North America that has had a severe impact on crayfish populations in Europe (Soderhall and Cerenius 1999, Pârvulescu et al. 2012). Crayfish plague is not present in Australia and imports of any live crayfish from the Northern Hemisphere should be prevented. The recent potential illegal importation of Dwarf Mexican Crayfish (*Cambarellus patzcuarensis*) into Australia highlights the risk of the introduction of disease to the conservation of Australian Crayfish (R. McCormack pers. comm.).

Changing climate

Climate change is recognised as a major threat to freshwater crayfish worldwide (Richman et al. 2015). The *Euastacus* genus is considered particularly at risk (Furse and Coughran 2011). Overall climate change is predicted to make the ACT drier and warmer with an increase in severe summer storms and fire risk (NSW OEH and ACT Government 2014). *Euastacus* are known to use thermal cues (a drop in water temperature in autumn) to initiate breeding and the species has already been lost from downstream warmer areas of the Murray–Darling Basin in South Australia. In addition, wildfires increase the risk of blackwater events due to ash and fire debris run-off.

MAJOR CONSERVATION OBJECTIVES

The overall conservation objective of this action plan is to maintain in the long term, viable, wild populations of *Euastacus armatus* 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 the species from harvest.
- 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 *E. armatus* 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 *E. armatus* and freshwater fish conservation in general.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

General habitat and water quality improvement works and protection in the Murrumbidgee River and catchment will assist in conserving the Murrumbidgee population in the region.

E. armatus are protected from angling (recreational, commercial and illegal) though the listing under the Nature Conservation Act. Locations where *E. armatus* occur are mostly protected as Territory Land in the Murrumbidgee River corridor nature reserves and special purpose reserves and the Lower Cotter Catchment (water supply protection area). *E. armatus* are not known to occur on rural leasehold Territory Land, or Commonwealth owned and managed land (National Land).

Protection of the species and its habitat, including riparian zones in the Murrumbidgee River Corridor and associated nature reserves, is critical given the increase in access for recreation and near river residential development.

Survey, monitoring and research

Previous hoop net surveys have not been shown to be robust enough to adequately monitor the populations in the Murrumbidgee River (Ryan et al. 2013). Increasing sampling effort at a site by reducing soak times and sampling each site twice has not improved the confidence in the survey results sufficiently (ACT Government unpublished data). Other methods that have been trialled are not generally suitable for turbid waters (baited cameras or snorkelling) or populations at low levels (Munyana Traps) (Fulton et al*.* 2012, Ryan et al*.* 2013).

The monitoring should be reviewed with the potential to change to an intensive mark and recapture survey to estimate density within a discrete number of indicator pools. The aim would be to monitor the predicted impacts of increased residential growth in nearby river developments and other threats on the density of *E. armatus*.

Assessment of novel survey methods for abundance should be undertaken as they become available. *E. armatus* are known to be more available to trapping following a drop in temperature in late autumn (Asmus 1999, Ryan et al*.* 2013). It is not know why this increase in catchability is observed, if the crayfish have different seasonal movement patterns or bait response, and if this response may differ between sexes (Ryan 2005). Previous fish surveys of the Murrumbidgee River using gillnets caught *E. armatus* as bycatch during spring and summer (Lintermans 2000) indicating that crayfish are active at this time (Ryan et al*.* 2013). Understanding the increased catchability is important for understanding the biology of the species and the efficacy of the survey method.

Because there is little known of the habitat, movement and growth of juvenile *E. armatus* and their maturation, further investigation is required. Recent information on the microhabitat and mesohabitat preferences and feeding behaviours of *E. armatus* has been undertaken in small, clear waterways (Fulton et al*.* 2012, Starrs et al*.* 2015, Noble and Fulton 2016). Confirmation of habitat preference in larger, more turbid rivers such as the Murrumbidgee is required.

There are several residential housing developments being planned in proximity to the Murrumbidgee River. The increase in recreational activity and run-off from developments has the potential to impact on the species. Monitoring efforts and research effort should focus on these threats. Additionally, the effect of effluent and micro pollutants is unknown in many species including *E. armatus*.

Management

Based on current knowledge of the habitat requirements and ecology of *E. armatus* in the ACT region, management actions should aim to maintain riverine habitats with appropriate seasonal flow regimes, intact riparian zones, with minimal sediment and pollution from roads, urban areas and surrounding land use. The prohibition of importation and keeping of introduced crayfish would help prevent diseases and potential competitors becoming established in the ACT. The species should also continue to be protected from illegal fishing, which has the potential to drastically impact recovery.

Protection and revegetation of riparian zones will enhance organic matter contributions for food, provide shade which buffers water temperatures, provide cover, prevent erosion and filter sediment from run-off. Minimising sediment addition will protect pools and maintain habitat in and around rocks and boulders, which are critical habitat for the species.

Engagement

As with any threatened species, the importance of information transfer to the community and people responsible for managing their 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.
- Update and maintain the guide to fishing in the ACT to limit angling target of the species.

- Ensure angling signage is up-to-date and placed in relevant areas.
- Report on the monitoring of the species in the 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.

Further information about conservation and management is in Appendix 4.

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 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 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, Conservation Area) to protect the population in the Murrumbidgee River and Cotter River.	1a. The Murrumbidgee River corridor and Cotter River populations are protected for conservation.
	1b. Maintain the protected status of the species.	1b. Species remains listed as protected.
	1c. Ensure all populations are protected from impacts of recreation, residential expansion, infrastructure works, water extraction and other potentially damaging activities, using an appropriate legislative mechanism.	1c(i) All other populations are protected by appropriate measures (Conservator's Directions, development applications) from unintended impacts. 1c(ii) Awareness and enforcement of fishing regulations on the Murrumbidgee River.
2. Conserve the species and its habitat through appropriate management.	2a. Monitor abundance at key sites to gauge the effects of management actions and emerging threats.	2a(i) Assessment of additional methods for suitability in monitoring key locations and threats. 2a(ii) Trends in abundance are known for key sites and management actions recorded. 2a(iii) Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations and monitoring methods).
	2b. Manage to conserve the species and its habitat, by for example, enhancing riparian vegetation, managing in-stream sedimentation, protecting flow, fish passage and disease and pests management (recognising current knowledge gaps).	2b(i) Assessment of potential crayfish introductions and listing of high risk species under appropriate legislation. 2b(ii) Riparian vegetation improved 2b(iii) Fish passage improved.
	2c. Manage recreational and illegal fishing pressure to conserve the species.	2c. Appropriate education, fishing closures, enforcement, gear and take prohibitions and prevention of take are in place to prevent inadvertent or illegal harvest.
3. Increase habitat area and connect populations.	3. Identify core areas of habitat and increase habitat area or habitat connectivity between these areas.	3. Aquatic habitats and riparian revegetation adjacent to, or linking, key habitat is managed to improve suitability for the species (indicated by an appropriate sedimentation and flow regime, presence of or

Objective	Action	Indicator
		establishment of good quality riparian vegetation and in-stream habitat). Indicators are specified in the CEMP plan.
4. Improve understanding of the species' ecology, habitat and threats.	4a. Undertake or facilitate research on habitat requirements, recruitment, monitoring techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species particularly juvenile ecology. 4b. Collaborate with other agencies and individuals involved in *E. armatus* conservation and management.	4. Research undertaken and reported and, where appropriate, applied to the conservation management of the species. Engagement and/or collaboration with other agencies and individuals.
5. Improve community awareness and support for *E. armatus* and freshwater fish conservation.	5. Produce materials or programs to engage and raise awareness of *E. armatus* and other freshwater fish threats and management actions.	5. Community awareness materials/programs produced and enhanced community awareness evident.

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APPENDIX 1

Ecology

Euastacus armatus are often observed with large numbers of external commensal platyhemliths called temnocephalons (McCormack 2012). Temnocephalons are not considered to be parasitic and occur on a large number of crayfish species. However, female *Euastacus* crayfish are known to shed their shells and temnocephalon load immediately prior to breeding season (Wild and Furse 2004, McCormack 2012).

Past management and research actions

Monitoring of *E. armatus* by the ACT Government and the Australian National University in the Murrumbidgee River has been undertaken periodically since 1988 (Lintermans and Rutzou 1991, Lintermans 2000, Fulton et al*.* 2010, Ryan et al*.* 2013, ACT Government unpublished data 2015).

In the ACT, the 1988 survey determined that crayfish were present in low numbers and that recreational access correlated with lower numbers. Prior to this survey there were no restrictions on recreational take of *E. armatus* in the ACT. As a result of the study, recreational fishing was prohibited for the species by declaring it a protected invertebrate under the *Nature Conservation Act 1980* in 1991. In 1998, the monitoring program indicated a partial recovery in *E. armatus* numbers (Lintermans 2000). However, the ongoing monitoring of the Murrumbidgee River has shown significant variation in the catch per unit effort within sites, between sites and between years, and no consistent pattern of recovery has been observed in follow-up surveys in 2005, 2008 and 2013–15.

Research projects and surveys have been undertaken in the ACT Region, primarily to refine survey techniques. These include radio-tracking of *E. armatus* in the Murrumbidgee to describe their home range and diel movement patterns (Ryan 2005) and trials of baited underwater video cameras and observation via snorkelling (Fulton et al*.* 2010). Both these methods were found to be effective in clear shallow habitats. Additional projects have used snorkelling and underwater video to describe habitat preferences and feeding behaviour. In 2013 a trial was undertaken using munyana traps and hoop nets and changes in lift times to improve monitoring effectiveness. The result of these surveys was that munyana traps did not increase sampling efficiency and were not appropriate due to bycatch issues. The lift times of 30 minutes did increase sampling efficiency but follow-up surveys in 2015 showed high variability within sites visited on multiple occasions (ACT Government unpublished data).

Recent research indicated that recreational fishing in NSW alters the size class and abundance of crayfish. In NSW, where limited recreational fishing is still permitted (Zukowski et al*.* 2013, NSW DPI 2014), the previous regulations of 9 cm minimum size and season of May to September were found not to be protecting female crayfish from harvest prior to reaching maturity or breeding. Updated regulations (bag limit of two and slot size of 10–12 cm carapace length, season June–August) has reduced this effect, however fishing take still impacts the sex ratio of crayfish. It is suggested that checking for eggs (berried or egg carrying females are protected) may be harmful to the eggs.

Ex situ conservation and translocation

A number of translocations of *E. armatus* were recorded in the 1920s including several in the local region to Burrinjuck Dam. There is no information that these translocations were successful although the recent genetic study indicates the ACT population is reasonably genetically diverse and not suffering from founder effects (Lintermans 2002, Whiterod et al*.* 2016). There is anecdotal information of illegal or unsanctioned translocation by recreational fishers into the Canberra area from the Tumut region (Lintermans 2002). The recent genetic study indicates some potential support for this with the ACT population linked to all the nearby populations whereas the smaller tributaries of the Tumut and Goodradigbee are not closely related to the lower Murrumbidgee. Such a genetic structure may have resulted from natural barriers and localised migration or translocation from Tumut and the Goodradigbee River to the Murrumbidgee in the ACT.

Other *ad hoc* localised translocations have been conducted for management or conservation reasons. During the construction of the enlarged Cotter Dam in 2010, 10 *E. armatus* were rescued from the works area and translocated to the Murrumbidgee River at Casuarina Sands, approximately 3 kilometres downstream. There are no ongoing conservation-related translocations of *E. armatus* in the ACT.

SILVER PERCH

BIDYANUS BIDYANUS

ACTION PLAN

Silver Perch *(Bidyanus bidyanus)*. Illustration: courtesy of NSW Government

PREAMBLE

The Silver Perch (*Bidyanus bidyanus* Mitchell 1838) was listed a vulnerable species on 26 October 2001 (initially Instrument No. 299 of 2001 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 2003 (ACT Government 2003). The species was included in Action Plan 29 Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007). This revised edition supersedes earlier editions.

Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Conservation Strategy, and component threatened species action plans such as the Macquarie Perch (*Macquaria australasica*), Trout Cod *(Maccullochella macquariensis*), Two-spined Blackfish (*Gadopsis bispinosus*) and Murray River Crayfish (*Euastacus armatus*).

CONSERVATION STATUS

Bidyanus bidyanus is recognised as a threatened species in the following sources:

International: IUCN

Data Deficient (trend declining) – Previously vulnerable.

National

Critically endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
Vulnerable – Australian Society for Fish Biology (Lintermans 2015).

Australian Capital Territory

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

New South Wales

Vulnerable – Schedule 5 of the *Fisheries Management Act 1994*, regulated take permitted in selected listed stocked impoundments.

Victoria

Threatened – Section 10 of the *Flora and Fauna Guarantee Act 1988*.

South Australia

Protected – Schedule 5 of the *Fisheries Management Act* 2007.

Queensland

Protected – Paroo and Warrego River. Regulated take elsewhere, *Fisheries Act 1994*.

SPECIES DESCRIPTION AND ECOLOGY

Description

Bidyanus bidyanus is a moderate to large fish (maximum length of about 500 millimetres (mm) and a maximum weight of around 8 kilograms (kg)) which commonly reaches 300–400 mm and 0.5–1.5 kg in rivers (Figure 1). The body is elongate and slender in juvenile and immature fish, becoming deeper and compressed in adults. The head is relatively small, jaws are equal in length and eyes and mouth are small. In larger specimens the head is reduced in comparison to the body giving a humped shouldered look. The scales are thin and small (compared to Macquarie Perch or Golden Perch) and the tail is weakly forked. The lateral line follows the profile of the back. Colour is generally silvery grey to black on the body, with the dorsal, anal and caudal fins also grey. The pelvic fins are whitish (Merrick 1996, Merrick & Schmida 1984).

Distribution and abundance

B. bidyanus are endemic to the Murray–Darling Basin and were formerly widespread through the Basin's rivers and major streams (DEE 2013). The ACT is toward the upper altitudinal limits of the species distribution. Historic and anecdotal reports indicate *B. bidyanus* was found in the Murrumbidgee River as far upstream as Cooma (800 metres above sea level) during the species' annual migrations in the early and mid-1900s (Trueman 2012).

In the ACT region they are historically known from the Murrumbidgee and Molonglo rivers and also from the lower Yass and Goodradigbee Rivers in NSW. *B. bidyanus* have been stocked into many impoundments in the region and continue to be stocked into Burrinjuck and Googong Dams by the NSW Department of Primary Industries (DPI) to provide a recreational fishery. They are also extensively used in the aquaculture and aquaponics industries and are available through the aquarium and live retail restaurant trades (Rowland 2009, Davies et al*.* 2012).

B. bidyanus have not been recorded in the ACT Government's Murrumbidgee monitoring since 1988. *B. bidyanus* are still caught in Googong Reservoir where they are stocked. There were several angler records and a ranger report of *B. bidyanus* around Casuarina Sands on the Murrumbidgee River in 2002. The occasional report of this species by anglers in the urban lakes and Molonglo River are attributed to fish displaced from NSW DPI stocking in Googong Dam, illegal stocking (including karma releases) or contamination of government stocking (ACT Government unpublished data).

Habitat and ecology

B. bidyanus is found over a broad area of the Murray–Darling Basin and is often found in similar habitats to Murray Cod (*Maccullochella peelii*) and Golden Perch (*Macquaria ambigua*), i.e. lowland, turbid rivers. There are some reports that suggest that *B. bidyanus* prefers faster, open water, but the general scarcity of information on the habitat preferences of the species makes generalisation difficult. The species is not currently found in the cool, fast-flowing, upland streams and rivers of the Murray–Darling Basin, although there are historical sightings up to 700 metres above sea level (M. Lintermans pers. comm.).

B. bidyanus is slow-growing and long-lived in rivers, with a greatest age of 17 years recorded from the Murray River and 27 years recorded from Cataract Dam. A 1.4 kg fish could be 17 years old (Mallen-Cooper et al*.* 1995). Growth rates in Googong Dam have been variable, with a 2.3 kg fish captured and estimated to be approximately six years old (ACT Government unpublished data).

B. bidyanus undertake a wide range of migrations as juveniles and adults and have been recorded moving over 200 kilometres (km). Adults move upstream in late spring and juveniles move upstream in late summer (Mallan Cooper et al*.* 1995). *B. bidyanus* mature at 3 years of age for males and 4–5 years of age for females. Spawning commences in spring to early summer, often associated with upstream migrations when large schools of fish were historically observed. Schools of fish spawn in shallow water with a preference for gravel substrate. Approximately 170,000–250,000 eggs per kg of bodyweight are laid (Rowland 2009, Merrick and Schmida 1984). The eggs are approximately 2.7 mm in diameter and semi-pelagic but will sink in non-flowing environments and hatch in 30 hours at 26^{o}C (Lake 1967).

The construction of Burrinjuck Dam in the 1920s effectively isolated the upper catchment from downstream populations. Scrivener Dam isolated the Molonglo and Queanbeyan rivers, and Cotter Dam isolated the Cotter River. The former 'run' of *B. bidyanus* upstream from Lake Burrinjuck has not been recorded since the early 1980s (Lintermans 2002).

This species has been bred artificially in a number of government (non-ACT) and commercial hatcheries and is widely stocked in farm dams and reservoirs in the Murray–Darling Basin and eastern drainages (DEE 2013). The species is of considerable value to aquaculture, estimated at more than $3 million in NSW for the year 2014–15 (Rowland 2009, NSW DPI 2016). Genetic population analysis of *B. bidyanus* populations has indicated significant differences between wild populations and some hatchery or stock impoundment populations. There have also been differences recorded between the wild population in the Paroo Catchment in the northern and those of the wider Murray–Darling Basin (Bearlin and Tikel 2003). The widespread use of the species in aquaculture and stocking has potential to further develop domestic production strains of *B. bidyanus*

B. bidyanus is omnivorous, consuming aquatic plants, algae, molluscs, crustaceans and aquatic insect larvae (DEE 2013). Reports suggest the species becomes mainly herbivorous once they reach lengths of 250 mm (DEE 2013, Clunie and Koehn 2001). However, their diet in Googong Reservoir shows little change with fish size (ACT Government unpublished data).

The Australian Government's Conservation Advice: *Bidyanus bidyanus* (Australian Government 2013) contains a comprehensive compilation of information on the ecology and biology of Silver Perch.

CURRENT MANAGEMENT ACTIONS AND RESEARCH

Fishing closures

Regulations prohibiting the take of *B. bidyanus* by anglers have been in place since the species was listed as threatened in 2001 (ACT Government 2003). Limited recreational take is permitted in Googong and Burrinjuck reservoirs in nearby NSW, where the species is stocked. However, the species is protected in all NSW rivers including the Murrumbidgee River.

Habitat rehabilitation

Many sections of the Murrumbidgee through the ACT are affected by accumulations of sand ('sand slugs') which cause reduced water depth and structural habitat diversity. Since 1998 efforts have been under way to rehabilitate fish habitat (create scour pools) and improve fish passage through the sand slug adjacent to Tharwa with a series of rock groynes built in 2001 and, subsequently, two engineered log jams in 2013 (Lintermans 2004a, ACT Government 2013). Such works are intended to link fish habitat in good condition downstream of Point Hut Crossing with similarly good habitat in the Gigerline Gorge. The works at Tharwa have resulted in scour pools with increased depth.

Monitoring

The Murrumbidgee River through the ACT has been monitored biennially since 1994 using methods suitable for detecting *B. bidyanus* (e.g. ACT Government 2015). If *B. bidyanus* were to become re-established, this monitoring program is likely to detect the species at low to moderate population densities. A database for all ACT fish records has been established by the ACT Government.

Cross-border management

The Upper Murrumbidgee Demonstration Reach (UMDR) commenced in 2009 as an initiative under the Murray–Darling Basin Native Fish

Strategy and involves a partnership of government, university and community groups (ACT Government 2010). The UMDR is approximately 100 km in length, stretching from the rural township of Bredbo in south-east NSW downstream to Casuarina Sands in the ACT. The vision of the UMDR is 'a healthier, more resilient and sustainable river reach and corridor that is appreciated and enjoyed by all communities of the national capital region'.

The UMDR initiative has so far completed a number of documents including an implementation plan, community engagement plan, Carp management plan, monitoring literature review and monitoring strategy, an assessment of fishways in the ACT, study on the effectiveness of the Casuarina Sands fishway, revegetation and weed control, assessment of the sampling methodology for Murray Crayfish and the Tharwa Fish Habitat Project, and successfully worked across the ACT–NSW border to implement its aims. Improvement of upper Murrumbidgee River habitat will benefit the native fish community.

THREATS

River regulation

In the Canberra region, Tantangara Dam reduces flows downstream by 99%, with water from the upper Murrumbidgee River diverted to Lake Eucumbene in the Snowy River Catchment (Pendlebury 1997). At the Mt McDonald gauging station (near the confluence of the Cotter River with the Murrumbidgee River), flow in the Murrumbidgee River has recovered to approximately 73% of natural levels (ACT Government 2004). Flow diversion infrastructure such as the Murrumbidgee to Googong (M2G) pipeline, with the pumping station at Angle Crossing and the Cotter Pumping Station at Casuarina Sands, also affect riverine flows by diverting flow out of the Murrumbidgee River for domestic water supply.

Reduced flows downstream of dams also contribute to reduced fish passage when natural barriers (rock bars, small cascades) that would normally drown out under natural flows cease to do so. Lake Burley Griffin and Googong Reservoir on the Molonglo–Queanbeyan River system reduce seasonal flows in the lower Molonglo River and adjacent Murrumbidgee, reducing the dilution of effluent discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC). The average daily discharge of treated effluent from the LMWQCC is 90 megalitres/day or 33 gigalitres/year, comprising approximately 30–40% of flow in the Murrumbidgee River at Mt McDonald on average, but up to 90% of flow in dry years (e.g. 1998 and 2003) (Consulting Environmental Engineers 2005).

The large areas of still water created by dams may also impact egg and early larval stages of *B. bidyanus*. The drifting semi-buoyant eggs and newly hatched larvae may settle in unfavourable habitats such as the backed up waters of dams and weir-pools, making them susceptible to sedimentation, predation and low oxygen levels.

Barriers to fish passage

Fish habitats are unique in that they are often linear, narrow, subject to directional flow and therefore extremely susceptible to fragmentation. Barriers can be structural (e.g. dams, weirs, road crossings) or chemical (e.g. discharge of effluents, pollutants, contaminants) and can be partial (i.e. only operate under some conditions such as low flows) or total (e.g. large dams and weirs, piped road crossings). In the Canberra region there are a series of barriers that potentially block fish movements on a number of rivers including the Murrumbidgee (Burrinjuck, Tantangara, Point Hut Crossing, and Casuarina Sands weir) and Molonglo (Scrivener Dam) rivers. Only one of these barriers has a fishway installed (Casuarina Sands weir) but maintenance and/or modifications are periodically required to optimise its usefulness. The isolation of fish habitats and fragmentation of fish populations caused by such barriers makes populations more vulnerable to random extinction events. The effluent discharge from LMWQCC is also thought to provide a chemical barrier that reduces movement of some fish species from the Murrumbidgee River into the Molonglo River (Lintermans 2004b).

Barriers can act synergistically with other threats by preventing recolonisation of streams after local declines or extinctions. For example, the collapse of tailings dumps at Captains Flat in 1939 and 1942 effectively sterilised the river downstream, and the presence of Scrivener Dam has prevented any natural recolonisation by native fish species from the Murrumbidgee River. For *B. bidyanus*, Burrinjuck Dam has prevented connection between the lower and upper Murrumbidgee River.

Introduced species and disease

The establishment of introduced fish species is often cited as a cause of native fish decline in Australia, although much of the evidence is anecdotal. This is because the majority of introduced species became established in the mid to late 1800s when the distribution and abundance of native fish was poorly known or documented. Introduced fish species such as Carp (*Cyprinus carpio*) and Redfin Perch (*Perca fluviatilis*) have relatively recently become established in the Canberra region (Lintermans et al*.* 1990, Lintermans 1991) and may compete for food with *B. bidyanus*. Redfin Perch may also prey on juveniles of *B. bidyanus.*

Another potentially serious impact of introduced species is their capacity to introduce or spread foreign diseases and parasites to native fish species. Carp or Redfin Perch are considered to be the source of the Australian populations of the parasitic copepod *Lernaea cyprinacea* (Langdon 1989a). Carp, Goldfish (*Carassius auratus*) or Eastern Gambusia (*Gambusia holbrooki*) are implicated as the source of the introduced tapeworm *Bothriocephalus acheilognathi,* which has been recorded in native fish species (Dove et al. 1997). This tapeworm causes widespread mortality in juvenile fish overseas. *B. bidyanus* are also known to be susceptible to a number of diseases including Epizootic Haematopoietic Necrosis Virus (EHNV) and *Aphanomyces invadans* (EUS or 'red-spot disease') and Saprolegnia water moulds.

EHNV is unique to Australia and was first isolated in 1985 on the introduced fish species 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). Experimental work by Langdon (1989 a, b) demonstrated that *B. bidyanus* was one of several species found to be extremely susceptible to the disease. Seasonal outbreaks are regularly detected in local waterbodies (primarily in Redfin Perch). Its relatively resistant characteristics and the ease with which it can be transmitted from one geographical location to another on nets, fishing lines, boats and other equipment have helped EHNV spread. Langdon (1989b) found that the virus retained its infectivity after being stored dry for 113 days. The Murrumbidgee and the Googong Reservoir populations of *B. bidyanus* have been exposed to the virus.

EUS and Saprolegnia cause ulcers on the body of fish, often leading to mortality. EUS was first recorded in Bundaberg in 1972 and in 2008 was recorded in the Murray–Darling Basin. It has not yet been recorded in the upper Murrumbidgee River (Boys et al*.* 2012).

Habitat modification

Alteration or destruction of fish habitat is widely regarded as one of the most important causes of native fish decline in Australia (MDBC 2004, Lintermans 2013) and overseas (Dudgeon et al*.* 2006). Locally, *B. bidyanus* habitats have been impacted by sedimentation of streams (e.g. the Tharwa sand slug), cold water pollution (downstream of Scrivener Dam) and riparian degradation (clearing of the Murrumbidgee riparian zone).

Reduction in water quality

The major reductions in water quality which are most likely to have affected the species in the Canberra region are sediment addition (see below), pollutant discharges to streams and changes to thermal regimes, either from the operation of impoundments or the clearing of riparian vegetation which shades streams. 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. Some pollutants disrupt aquatic ecosystems by mimicking naturally occurring hormones (endocrine disruptors) and so affect sexual development and function and reproductive behaviour (Mills and Chichester 2005; Söffker and Tyler 2012). Locally, pharmaceutical products and oestrogenic activity has been documented in the discharge from the LMWQCC (Roberts et al. 2015, 2016), although the impacts on local aquatic species are as yet unknown. Endocrine disruptors have been found up to 4 kilometres downstream of the LMWQCC and may extend further (Roberts et al. 2015).

Other reductions in water quality that are likely to have had major effects on *B. bidyanus* in the ACT and region are the addition of sediment (see below) and the catastrophic pollution of the Molonglo River following the collapse of tailings dumps at the Captains Flat mine in the mid-twentieth century. These collapses released large quantities of heavy metals including zinc, copper and lead, which virtually removed the entire fish population in the Molonglo River (Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River 1974).

Historical overfishing

Overfishing is unlikely to have played a major initial role in the decline of *B. bidyanus*, either nationally or locally. However, once a population has declined, even relatively low levels of fishing can pose a threat to recovery of the species. There is anecdotal evidence that local anglers targeted the spawning run of *B. bidyanus* from Lake Burrinjuck (Trueman 2012). The current protective management regimes by NSW Fisheries (which prohibits the taking of *B. bidyanus* in rivers and imposes bag and size limits in stocked dams) and the ACT Government (which prohibits the taking of *B. bidyanus* in any public waters) are considered appropriate. Illegal fishing targeting breeding migrations or impacting low population levels is of concern for the conservation of *B. bidyanus* in the local region.

The ACT Government will continue to liaise with NSW Fisheries to ensure cross-border management and protection of *B. bidyanus* is maintained.

Sedimentation

Sediment addition to the Murrumbidgee River has likely resulted in significant decline of habitat quantity and quality for *B. bidyanus.* Sediment in streams may derive from point sources (e.g. roads, stock access points, construction activities), from broad-scale land use or as a result of extreme events such as fires, floods and rabbit plagues. High levels of suspended solids in streams may be lethal to fish and their eggs but the major damage is to aquatic habitat. Sediment fills pools (important refuges for larger native species), decreases substrate variation and reduces usable habitat areas.

Poor land management practices in the mid to late 1800s in the upper Murrumbidgee Catchment resulted in extensive erosion and sediment addition to the river (Starr 1995, Prosser et al. 2001). Wasson (2003) estimated that sediment yield in the Southern Tablelands increased from 10 tonnes/km^2 before European settlement to around 1000 tonnes/km^2 by 1900 before declining again to their present value of 20 tonnes/km^2.

Tantangara Dam has reduced the frequency of winter flooding and increased the occurrence of low flows (<1000 megalitres/day) in winter (Pendlebury 1997). This has probably led to the continued accumulation of sediments in the river as there are now fewer and smaller high-flow events that previously would have scoured the finer sediments out of the riverbed (Pendlebury 1997).

More recent sources of sediment addition have been from urban development immediately adjacent to the Murrumbidgee River in Tuggeranong in the 1980s and the Canberra bushfires of 2003 (Starr 2003, Wasson et al. 2003).

Changing climate

In addition to the above threats, the species is likely to be susceptible to the predicted impacts of climate change (Koehn et al. 2013). Overall climate change is predicted to make the ACT region drier and warmer (Timbal et al. 2015).

Fish (as ectotherms) have no physiological ability to regulate their body temperature and are therefore 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). Burnt catchments and increased rainfall intensity will result in increased sediment loads in streams (Carey et al. 2003, Lyon and O'Connor 2008), which may persist for decades until the bedload moves downstream (Rutherfurd et al. 2000). As *B. bidyanus* is thought to spawn in response to day length and water temperature, there is a risk that spawning cues can become decoupled with earlier seasonal warming from climate change, resulting in reduced recruitment success.

MAJOR CONSERVATION OBJECTIVES

The major conservation objective of this action plan is to assist, where possible, the re-establishment of *B. bidyanus* in the upper Murrumbidgee Catchment by providing suitable habitat and assisting in-jurisdictional actions to re-establish the species, should resources become available.

The objective is to be achieved through the following strategies:

- Support projects aimed at improving understanding of the biology and ecology of the species as the basis for managing its habitat.
- Protect sites and habitats that are critical to the survival of the species.
- Manage activities in the Murrumbidgee Catchment in the ACT to minimise or eliminate threats to fish populations.
- Increase community awareness of the need to protect fish and their habitats.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

Bidyanus bidyanus no longer occur as a viable population in the ACT. The species is protected as a threatened species under the Nature Conservation Act. Ongoing improvement to fish habitat in the Murrumbidgee River would also support the species.

Monitoring and research

Knowledge of the distribution of *B. bidyanus* in the upper catchment is generally complete. The ACT *B. bidyanus* population is thought to be largely dependent on the status of the Lake Burrinjuck population, which is itself supported by recreational stocking. Further investigations in Lake Burrinjuck and any migrations from this waterbody are necessary to place the ACT populations into a regional context.

The decline of *B. bidyanus* in the ACT raises concerns about the success of species conservation management and actions. With the exception of recreational fishing regulation and minor barrier remediation, few dedicated management measures have been directed at the declining *B. bidyanus* since the 1980s. It is unclear if local actions could have been effective in reducing the decline given the many threats to the species (sedimentation, flow and fish passage) and the dependence upon the NSW population in Burrinjuck. The ACT Government will continue to monitor the Murrumbidgee River, which is likely to detect *B. bidyanus* should a viable population re-establish. The ACT Government will liaise with Victorian and NSW fisheries agencies to ensure there is exchange of relevant information on the species.

The ACT Government will support relevant research activities by research organisations that may lead to the successful re-establishment and management of *B. bidyanus* in the upper Murrumbidgee River.

Management

Based on current knowledge of the habitat requirements and ecology of *B. bidyanus,* management actions should aim to maintain riverine habitats with appropriate seasonal flow regimes, intact riparian zones, pool depths, and minimal sediment inputs from roads and surrounding land use.

Protection and revegetation of riparian zones will enhance organic matter contributions and provide shade, which buffers water temperatures, provides cover, prevents erosion and filters sediment from run-off. Minimising sediment addition will protect pools from becoming shallower, thus retaining a critical habitat for the species.

From an ecological community perspective, a low sediment with intact pools and riparian zones, will also benefit other threatened aquatic species such as Macquarie Perch, Trout Cod and Murray Crayfish.

Facilitation of fish passage to connect habitats and assist migration, for example, by improving fish passage past Point Hut Crossing, will assist species re-establishment. Provision of and protection of flow is likely to be critical to allow passage through natural barriers including sand slugs and improve habitat and breeding outcomes for the species.

Engagement

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

- Provide advice on management of the species and maintain contact with land managers responsible for areas on which populations presently occur.
- Keep the guide to fishing in the ACT up-to-date to limit angling target of the species
- Ensure angling signage is up-to-date and placed in relevant areas.
- Report on the monitoring of the species in the 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.

Further information about conservation and management is in Appendix 4.

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 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 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 may re-establish.	1a. Apply formal measures (nature reserve) to protect the habitat in the Murrumbidgee River.	1a. The potential Murrumbidgee habitat is protected in nature reserve, or an area set aside specifically for conservation of the species if it re-establishes.
	1b. Maintain the protected status of the species within the four nature reserves in the Murrumbidgee River Corridor.	1b. Murrumbidgee River Corridor populations continue to be protected in nature reserve.
	1c. Protect re-establishing populations from impacts of recreation, infrastructure works, water extraction and other potentially damaging activities, using an appropriate legislative mechanism.	1c. Populations are protected by appropriate measures (Conservator's Directions, Conservation Lease or similar) from unintended impacts.
2. Conserve and improve species potential re-establishment habitat through appropriate management.	2a. Monitor the fish community of the Murrumbidgee River and the effects of management actions.	2a. Trends in abundance are recorded for fish species and management actions. Detection of *B. bidyanus* is highlighted.
	2b. Manage volumes, quality and timing of water in the Murrumbidgee River by managing extraction to maintain an appropriate flow regime to conserve the species.	2b. Water extraction from the Murrumbidgee River is managed to prevent over extraction within the ACT.
	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. Invasive plants (e.g. Willows, Blackberries) are controlled and are replanted with appropriate native species.
	2d. New 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 the Murrumbidgee River.
	2e. Impediments to fish passage are managed to minimise impacts on the populations.	2e. Fish population re-establishment is not impacted by barriers to fish movement.
	2f. Manage recreational fishing pressure to protect the species.	2f. Appropriate recreational fishing restrictions are in place and enforced to prevent deliberate or inadvertent harvest.

Objective	Action	Indicator
3. Support the re-establishment of riverine populations in the ACT through stocking if it is decided at a regional level that this is feasible.	3. Stock *B. bidyanus* of appropriate genetic provenance as a conservation stocking program if it is considered by all regional jurisdictions to be feasible.	3. Species stocked, if feasible, at a regional level.
4. Improve understanding of the species' ecology, habitat and threats.	4. Collaborate with other agencies and individuals involved in *B. bidyanus* conservation and management. Support research on habitat requirements, techniques to manage habitat and aspects of ecology directly relevant to conservation of the species in the Upper Murrumbidgee.	4. Collaboration with other agencies and individuals involved in *B. bidyanus* conservation and management (Recovery teams, State agencies, universities) where relevant to the Upper Murrumbidgee.
5. Improve community awareness and support for *B. bidyanus* and freshwater fish conservation.	5. Produce materials or programs to engage and raise awareness of *B. bidyanus* and other native freshwater fish threats and management actions.	5. Community awareness materials/programs produced and enhanced community awareness evident.

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TROUT COD

MACCULLOCHELLA MACQUARIENSIS

ACTION PLAN

Trout Cod *(Maccullochella macquariensis).* **Photo: E. Beaton, ACT Government**

PREAMBLE

Trout Cod *(Maccullochella macquariensis*) was listed as an endangered 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 edition supersedes earlier editions.

Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Conservation Strategy and component threatened species action plans such as the Macquarie Perch (*Macquaria australasica*), Silver Perch (*Bidyanus bidyanus*), Two-spined Blackfish (*Gadopsis bispinosus*) and Murray River Crayfish (*Euastacus armatus*).

CONSERVATION STATUS

Maccullochella macquariensis is listed as a threatened species in the following sources:

International: IUCN

Endangered C2a ver 2.3 (needs updating).

National

Endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
Critically Endangered – Australian Society for Fish Biology (Lintermans 2015).

Australian Capital Territory

Endangered – Section 91 of the *Nature Conservation Act 2014*.

Special Protection Status Species – Section 109 of the *Nature Conservation Act 2014*.

New South Wales

Endangered – *Fisheries Management Act 1994*.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988* (with an advisory status of Critically Endangered: Victorian Department of Sustainability and Environment 2013).

South Australia

Extinct – Action Plan for South Australian Freshwater Fishes (Hammer et al*.* 2009).

SPECIES DESCRIPTION AND ECOLOGY

Description

Maccullochella macquariensis is a member of the Family Percichthyidae, which contains the Australian freshwater basses and cods. *M. macquariensis*, along with three closely related freshwater 'cod' species in the genus *Maccullochella* (Eastern Freshwater Cod *M. ikei*, Mary River Cod *M. mariensis* and Murray Cod *M. peelii*), are all listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999*. *M. macquariensis* is a large, deep-bodied fish that has been recorded to 850 millimetres (mm) in total length and 16 kilograms (kg), but is now usually less than 5 kg (Lintermans 2007). It has a large mouth reaching to below the back of the eye, the head profile is straight and the upper jaw overhangs the lower. The tail is rounded and the pelvic fins are located below the pectorals. The species is not sexually dimorphic. The species was formally recognised as a separate species from Murray Cod in 1972 (Berra and Weatherley 1972) and is still often confused with this species. Hybrids between the two species are also known. The overhanging upper jaw and a speckled body pattern which is blue-grey, rather than yellow-green, distinguishes *M. macquariensis* from the otherwise similarly-shaped Murray Cod. Most individuals have a dark stripe through the eye, although this feature is also present in young Murray Cod (Lintermans 2007) (Figure 1).

Figure 1 *Maccullochella macquariensis*. Illustration: curtesy of NSW Government.

Distribution and abundance

M. macquariensis is endemic to the southern Murray–Darling river system. This species has suffered major declines in range and abundance with only a single 'natural' remnant population remaining (the Murray River between Yarrawonga and Barmah) (Koehn et al*.* 2013). Other populations have been re-established either through historic translocation (1920s) or through the national recovery program beginning in the late 1980s in Victoria, the Australian Capital Territory and New South Wales (Douglas et al*.* 1994, Koehn et al*.* 2013). Historically, the species was also recorded in the lower Murray River in South Australia.

M. macquariensis is broadly found in rivers and larger streams and rarely in smaller creeks. It has previously been stated that *M. macquariensis* was a species of cooler, upland reaches of the Murray–Darling Basin, but the sole remnant population occurs in the mid-Murray below Yarrawonga, which is not a river that is considered cool or upland. Similarly, surveys in the 1940s and 1950s recorded the species as widespread in the Murray River between Echuca and Yarrawonga, but less plentiful in the Murrumbidgee (Cadwallader 1977).

In the Canberra region *M. macquariensis* formerly occurred along the length of the Murrumbidgee River in the ACT and in adjoining reaches in NSW (downstream to Lake Burrinjuck and beyond, upstream to above Cooma) where it was recorded up until the 1970s (Berra 1974, Greenham 1981, Lintermans 2000, 2002, Gilligan 2005, Koehn et al. 2013, Trueman 2012). Greenham (1981) surveyed several experienced ACT anglers who reported *M. macquariensis* were not considered to be present in the Queanbeyan, Molonglo, Cotter, Naas/Gudgenby or Paddys rivers, but were present in the Murrumbidgee River and more abundant in the reach from the Molonglo confluence to Tharwa. Its abundance in these reaches was never considered common and became rarer after the 1950s (Greenham 1981).

The most recent naturally occurring population recorded in the ACT (and in fact the entire catchment) was near the Gigerline Gorge upstream of Tharwa, where a population persisted until the mid to late 1970s (Berra 1974, Lintermans et al*.* 1988), but there are Australian Museum records of individuals from Angle Crossing and Casuarina Sands in 1970. In the ACT, *M. macquariensis* is currently restricted to the Murrumbidgee and Cotter rivers, where it has been reintroduced as part of a national recovery program (Koehn et al*.* 2013). In the Murrumbidgee River in the ACT, scattered individuals are occasionally captured in government fish monitoring and by recreational anglers throughout the Murrumbidgee, particularly near Kambah Pool and Gigerline Gorge downstream of Angle Crossing, both of which are reintroduction sites in the ACT. Similarly, in the Cotter River, individuals are regularly recorded in Bendora Reservoir (a restocking site) and occasional individuals are sampled downstream of Bendora Dam, presumably of fish displaced out of the reservoir

(Lintermans 1995, ACT Government and University of Canberra unpublished data).

Conservation stocking

A total of 99,500 hatchery-bred fingerlings were released in the ACT from 1996 to 2005 (ACT Government 2007). Prior to this, hatchery-bred fingerling were also stocked into Bendora Reservoir (1989–1990, 8740 fish) in an attempt to establish a refuge population not subject to angling pressure. Stocking ceased at Angle Crossing in 2005 to facilitate easier recognition of potential natural recruitment and the stocking site was moved downstream to Kambah Pool where 44,000 fish were released between 2005 and 2007. Since 2008 no release of hatchery-bred *M. macquariensis* has occurred in the ACT.

In the broader Canberra region, *M. macquariensis* has been restocked by NSW Fisheries into locations on the Murrumbidgee River including:

- near Cooma (2 sites, 7 releases,1988–2005)
- near Adaminaby (1 site, 4 releases, 1992–95)
- near Michelago (1 site, 2 releases, 2005–08)
- below the ACT (2 sites, 5 releases, 2005–08).

Stocking has also been conducted in Talbingo Reservoir on the Tumut River (four releases, 1990–2015) (Koehn et al*.* 2013), in the Lower Murrumbidgee and in other rivers in the Murray–Darling Basin (e.g. Ovens River and Macquarie River) under the National Recovery Plan (Trout Cod Recovery Team 2008).

The national recovery plan for *M. macquariensis* was the first national recovery plan for a freshwater fish in Australia, with recovery efforts now spanning almost 30 years (Koehn et al*.* 2013).

Habitat and ecology

M. macquariensis is essentially a riverine species, although some lacustrine-stocked populations exist (Bendora and Talbingo reservoirs and historically in Lake Sambell). In lowland rivers the species has a preference for in-stream structural woody habitat (Growns et al*.* 2004, Nicol et al*.* 2004, 2007, Ebner and Thiem 2009, Koehn and Nicol 2014). They also have a preference for deeper habitats (greater than 2.4 metres) and slower water surface velocities, but *M. macquariensis* use slightly faster water velocities than Murray Cod, Golden Perch or Carp (Koehn and Nicol 2014). In the lower Murrumbidgee River adults occupy small areas of less than 500 metres centred on a 'home snag' and demonstrate site fidelity with limited movement. However, individuals can also occasionally undertake exploratory movements of 20–70 kilometres involving a return to their home site (Ebner and Thiem 2009). In a study in the mid-Murray region, 75% of tagged adults moved less than 25 metres over the four-year study period (Koehn and Nicol 2014). Fish are most active during low light (dusk to dawn) (Thiem et al*.* 2008).

M. macquariensis is a large-bodied carnivore that, as an adult, is a 'sit-and-wait' predator (Lintermans 2007). The diet includes fish, yabbies, aquatic insect larvae, shrimps, freshwater prawns and terrestrial organisms. A study based in the Murrumbidgee River found that *M. macquariensis'* diet comprised smaller items than that of Murray Cod, and was more similar to the diet of Golden Perch than Murray Cod (Baumgartner 2007).

M. macquariensis is thought to have a maximum lifespan of 20–25 years although very few individuals older than 12 years have been confirmed (Todd et al*.* 2004). Sexual maturity is reached at 3–5 years of age, with males thought to mature earlier and at a smaller size than females (Douglas et al*.* 1994). Mature females have been recorded at 330 mm Total Length (TL) and males at 315 mm TL, with spawning occurring in spring at a water temperature of around 15°C (Ingram and Rimmer 1993, Koehn and Harrington 2006). *M. macquariensis* spawn demersal and adhesive eggs (2.5–3.6 mm in diameter) onto a hard surface (based on hatchery observations) and, like other *Maccullochella* species (Murray Cod, Eastern

Freshwater Cod), it is assumed that there is parental care of the eggs. Between 1138 and 11,338 eggs have been stripped from females of 330–645 mm TL. Hatching commences approximately five days after fertilisation and continues for up to 10 days at 15.5–23°C. *M. macquariensis* spawning occurs at a similar time to that of Murray Cod but *M. macquariensis* larvae have only been collected in the drift in November, suggesting a shorter spawning period than Murray Cod (Douglas et al. 1994, Koehn and Harrington 2006).

CURRENT MANAGEMENT ACTIONS AND RESEARCH

The ACT has been an active partner in implementing the National Recovery Plan for *M. macquariensis* (Trout Cod Recovery Team 2008), with activities included in this plan outlined below.

Stocking

Stocking for conservation purposes was conducted in the ACT between 1989 and 2007 (see section on Conservation Stocking, above).

Fishing closures

Regulations prohibiting the take of *M. macquariensis* by anglers have been in place since the species was listed as threatened in 1997 (ACT Government 1999). Spatial fishing closures that protect the species from recreational take have also been implemented. To protect a range of threatened fish species, including the stocked population of *M. macquariensis* in Bendora Reservoir, fishing has been banned since August 1986 in the Cotter Catchment upstream of Bendora Dam in Namadgi National Park. This closure to fishing in Bendora Reservoir was a key factor in its selection as a refuge stocking site in 1989 (Lintermans 1995). In 2000, the reach of the Murrumbidgee River between Angle Crossing and the Gudgenby River confluence was also closed to recreational fishing to provide a safe haven for stocked *M. macquariensis* to establish.

The prohibition on take of Murray Cod during their breeding season, September to November (inclusive), under the *Fisheries Act 2000* is assumed to also provide some protection for *M. macquariensis*.

Habitat rehabilitation

Many sections of the Murrumbidgee River through the ACT are affected by accumulations of sand ('sand slugs') which cause reduced water depth and structural habitat diversity. Since 1998, strategies to rehabilitate fish habitat (create scour pools) and improve fish passage through the sand slug downstream of Tharwa have been under way with a series of rock groynes built in 2001 and, subsequently, two engineered log jams in 2013 (Lintermans 2004b, ACT Government 2013). Such works are intended to link fish habitat in good condition downstream of Point Hut Crossing with similarly good habitat in the Gigerline Gorge. The works at Tharwa have resulted in scour pools with increased depth and monitoring has shown that threatened fish species, including *M. macquariensis*, are now using the area.

Monitoring

Monitoring of all ACT populations of *M. macquariensis* has occurred since the early 1990s by the ACT Government (e.g. Lintermans 1995, ACT Government unpublished data) with supplementary information on the Bendora Reservoir population collected by the University of Canberra (Broadhurst et al. 2016, Lintermans et al. 2013). There is evidence of sporadic natural recruitment in Bendora on at least three occasions since the early 2000s (Lintermans unpublished data) but no reliable evidence of wild recruitment in riverine populations in the upper Murrumbidgee River (see discussion of hybridisation in Local Threats). A database for all ACT fish records has been established by the ACT Government.

Other research conducted in the 2000s includes the movement ecology of *M. macquariensis* in the Murrumbidgee River (Ebner and Thiem 2009, Ebner et al. 2007b) and Cotter River (Ebner et al. 2005, 2009) and the impacts of native predators on hatchery-reared adults released to the wild (Ebner et al. 2007a, 2009). A recent PhD study at the University of Canberra directed primarily at Murray Cod spawning ecology has also collected important information on *M. macquariensis* hybridisation with Murray Cod (Couch et al. 2016)

Cross-border management

The Upper Murrumbidgee Demonstration Reach (UMDR) commenced in 2009 as an initiative under the Murray–Darling Basin Native Fish Strategy and involves a partnership of government, university and community groups (ACT Government 2010). The UMDR is approximately 100 kilometres in length, stretching from the rural township of Bredbo in south-east NSW downstream to Casuarina Sands in the ACT. The vision of the UMDR is 'a healthier, more resilient and sustainable river reach and corridor that is appreciated and enjoyed by all communities of the national capital region'.

The UMDR initiative has so far completed a number of documents including an implementation plan, community engagement plan, Carp management plan, monitoring literature review and monitoring strategy, an assessment of fishways in the ACT, study on the effectiveness of the Casuarina Sands fishway, revegetation and weed control, assessment of the sampling methodology for Murray Crayfish and the Tharwa Fish Habitat Project (see below), and successfully worked across the ACT–NSW border to implement its aims. Improvement of upper Murrumbidgee River habitat will benefit the native fish community, including *M. macquariensis*.

THREATS

Freshwater fish and their habitats are threatened 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 are considered to have potential impacts on populations of *M. macquariensis* nationally and locally. In addition there is a specific local threat to *M. macquariensis* in the Canberra region with the risk to reintroduction efforts through hybridisation between Trout Cod and Murray Cod.

Habitat modification

Alteration or destruction of fish habitat is widely regarded as one of the most important causes of native fish decline in Australia (MDBC 2004, Lintermans 2013a) and overseas (Dudgeon et al. 2006).

Locally, *M. macquariensis* habitats have been impacted by sedimentation of streams (e.g. the Tharwa sand slug), cold water pollution (downstream of Bendora Dam) and riparian degradation (clearing for pine forests in the Cotter River Catchment, fire, Blackberry and Willow invasion along most rivers, and clearing of the Murrumbidgee riparian zone). Further information is provided in Appendix 1.

River regulation

In the Canberra region, Tantangara Dam reduces flows downstream by 99%, with water from the upper Murrumbidgee River diverted to Lake Eucumbene in the Snowy River Catchment (Anon. 1997). At the Mt Macdonald gauging station (near the confluence of the Cotter River), flow in the Murrumbidgee River has recovered to approximately 73% of natural flow (ACT Government 2004). Flow diversion infrastructure such as the Murrumbidgee River to Googong Reservoir (M2G) pipeline and pumping station at Angle Crossing and the Cotter Pumping Station at Casuarina Sands also affect riverine flows by diverting flow out of the Murrumbidgee River for domestic water supply.

Reduced flows downstream of dams also contribute to reduced fish passage when natural barriers (rock bars, small cascades) that would normally drown-out under natural flows cease to do so. Lake Burley Griffin and Googong Reservoir on the Molonglo–Queanbeyan River system reduce seasonal flows in the lower Molonglo River and adjacent Murrumbidgee, reducing the dilution of effluent discharge from the Lower Molonglo Water Quality Control Centre (LMWQCC). The average daily discharge of treated effluent from the LMWQCC is 90 megalitres/day or 33 gigaliters/year, with this effluent comprising approximately 30–40% of flow in the Murrumbidgee River at Mt Macdonald on average, but up to 90% of flow in dry years (e.g. 1998 and 2003) (Consulting Environmental Engineers 2005). Reservoirs, such as Lake Burley Griffin and Googong, provide large areas of non-flowing habitat and favour the establishment and proliferation of alien fish species such as Carp, Goldfish, Redfin Perch and Gambusia. Further information is provided in Appendix 1.

Barriers to fish passage

In the Canberra region there are a series of barriers that potentially block fish movements on a number of rivers including the Murrumbidgee (Tantangara, Point Hut Crossing, Casuarina Sands weir), Cotter River (3 dams and several road crossings) and Paddys River (weirs at the lower Cotter). Some of these barriers have had fishways installed (Vanitys Crossing, Casuarina Sands weir, Cotter Reserve weir, Pipeline Road Crossing) but maintenance and/or modifications are periodically required to optimise their usefulness. The isolation of fish habitats and fragmentation of fish populations caused by such barriers makes populations more vulnerable to random extinction events. The effluent discharge from LMWQCC is also thought to provide a chemical barrier that reduces movement of some fish species from the Murrumbidgee River into the Molonglo River (Lintermans 2004a).

Barriers can act synergistically with other threats by preventing recolonisation of streams after local declines or extinctions. For example, the collapse of tailings dumps at Captains Flat in 1939 and 1942 effectively sterilised the river downstream, and the presence of Scrivener Dam has prevented any recolonisation by native fish species from the Murrumbidgee River. For further information see Appendix 1.

Overfishing

Overfishing is cited as one of the contributing factors in the decline of *M. macquariensis* (Berra 1974) and has been shown to be important in the decline of other native fish species such as Murray Cod (*M. peelii*) (Rowland 1989). *M. macquariensis* was subject to heavy angling pressure directed primarily at Murray Cod (Berra 1974, Trueman 2012). Because of the confusion over taxonomic status and the limited ability of anglers to distinguish between the two cod species, anglers almost certainly took many *M. macquariensis*. In the Canberra region it was reported to provide good sport (Berra 1974), with anglers commenting on the reliability of being able to catch 'cod' in the 1950s prior to the widespread availability of refrigeration in rural areas (Greenham 1981). Greenham (1981) reported that ACT anglers perceived major declines in native recreational fisheries in the mid to late 1960s, particularly in the Murrumbidgee River, as a result of its popularity as a fishing location. Although the species can no longer be legally retained in the ACT or NSW, *M. macquariensis* can be difficult to release alive after accidental hooking when bait fishing, and some fish are still being caught and retained through ignorance or mistaken species identity (Lintermans unpublished data).

Sedimentation

Sediment addition to the Murrumbidgee River has likely resulted in significant decline of habitat quantity and quality for *M. macquariensis.* Sediment in streams may derive from point sources (e.g. roads, stock access points, construction activities), broad-scale land use or as a result of extreme events such as fires, floods and rabbit plagues. High levels of suspended solids in streams may be lethal to fish and their eggs but the major damage is to aquatic habitat. Sediment fills pools (important refuges for larger native species), decreases substrate variation and reduces usable habitat areas. Clogging of the substratum removes spaces between rocks used as rearing, refuge and habitat areas by juvenile fish, small species and stream invertebrates which are the primary food of juvenile *M. macquariensis* (Lintermans 2013a). Addition of sediments to rivers is particularly detrimental to fish such as *M. macquariensis* 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 a significant part of the diet of *M. macquariensis* (Baumgartner 2007).

Poor land management practices in the mid to late 1800s in the upper catchment resulted in extensive erosion and sediment addition to the river (Starr 1995, Olley 1997). Wasson (page 38 in Starr et al*.* 1997) estimated that sediment yield in the Southern Tablelands increased from 10 tonnes/km^2 prior to European settlement to around 1000 tonnes/km^2 by 1900 before declining again to their present value of 20 tonnes/km^2. Tantangara Dam has reduced the frequency of winter flooding and increased the occurrence of low flows (<1000 megalitres/day) in winter (Pendlebury 1997). This has probably led to the continued accumulation of sediments in the river as there are now fewer and smaller high-flow events that previously would have scoured the finer sediments out of the riverbed (Pendlebury 1997).

More recent sources of sediment addition have been from urban development immediately adjacent to the Murrumbidgee River in Tuggeranong in the 1980s and the Canberra fires of 2003 (Starr 2003, Wasson et al*.* 2003).

Reduction in water quality

The major reductions in water quality most likely to have affected the species in the Canberra region are sediment addition (see above), pollutant discharges to streams and changes to thermal regimes, either from the operation of impoundments or the clearing of riparian vegetation which shades streams. 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. Some pollutants disrupt aquatic ecosystems by mimicking naturally occurring hormones (endocrine disruptors), and so affecting sexual development and function and reproductive behaviour (Mills and Chichester 2005, Söffker and Tyler 2012). Locally, pharmaceutical products and oestrogenic activity has been documented in the discharge from LMWQCC (Roberts et al*.* 2015, 2016), although the impacts on local aquatic species are as yet unknown. Endocrine disruptors have been found up to 4 km downstream of the LMWQCC and may extend further (Roberts et al*.* 2015). Disjunct fish distributions above and below the LMWQCC have been known for many years, but the basis for this remains unknown (Lintermans 2004a).

Water releases from lower levels of thermally stratified impoundments are usually characterised by low dissolved oxygen levels and lowered water temperature, which can depress downstream temperatures in warmer months, increase downstream temperatures in winter, delay seasonal maximum temperatures by months and reduce diurnal temperature variability (Rutherford et al*.* 2009, Lugg and Copeland 2014). In Australia, cold water pollution has been reported as impacting river temperatures for hundreds of kilometres downstream of large dams (Lugg and Copeland 2014). In the Cotter River, altered thermal regimes were predicted for 20 km downstream of Bendora Dam (86 megalitres/day)

(Rutherford et al. 2009).

M. macquariensis are possibly impacted by cold water releases from Corin Dam and also Bendora Reservoir. Lowered water temperatures can delay egg hatching and insect emergence, and retard fish growth rates and swimming speeds (increasing predation risk) (Starrs et al. 2011, Hall 2005). Reduced growth rates mean that small fish will remain for a longer time-period in the size-class susceptible to predation, thus exacerbating the impacts of alien predators. Lowered water temperature also can disrupt reproductive behaviour, with many Australian fish cued by water temperature.

Other reductions in water quality likely to have had major effects in the ACT and region are the addition of sediment (see above) and the catastrophic pollution of the Molonglo River following the collapse of tailings dumps at the Captains Flat mine in 1939 and 1942. These collapses released large quantities of heavy metals including zinc, copper and lead, which virtually removed the entire fish population in the Molonglo River (Joint Government Technical Committee on Mine Waste Pollution of the Molonglo River 1974).

Introduction of alien species

Locally, *M. macquariensis* has had its distribution invaded by a range of alien fish species including trout, Carp (*Cyprinus carpio*), Goldfish (*Carassius auratus*), Redfin Perch (*Perca fluviatilis*), Eastern Gambusia (*Gambusia holbrooki*) and Oriental Weatherloach (*Misgurnus anguillicaudatus*).

The main interactions between alien species and *M. macquarienis* are likely to be via competition, predation, disease and parasite introduction. Introduced fish species such as Carp, Goldfish, Redfin Perch, Oriental Weatherloach and trout are likely have dietary overlap with *M. macquariensis* and trout likely preyed upon them historically.

A major impact of alien species on native fish is the introduction or spread of diseases and parasites to native fish species. A serious disease threat to a number of Australian freshwater fish species is Epizootic Haematopoietic Necrosis Virus (EHNV). Recent testing of a number of native species reported that *M. macquariensis* was not susceptible to EHNV under the test conditions (Whittington et al. 2011). Other viruses that have recently been introduced to Australia by alien fish include Dwarf Gourami Iridovirus (DGIV) that has been shown to cause mortality to farmed Murray Cod (Go and Whittington 2006) and can infect other native fish of the family Percichthyidae such as Golden Perch, Macquarie Perch and possibly Southern Pygmy Perch (*Nannoperca australis*) (Rimmer et al. 2016). *M. macquariensis* has not been tested for susceptibility to DGIV.

C. carpio or *P. fluviatilis* are considered to be the source of the Australian populations of the parasitic copepod *Lernaea cyprinacea* (Langdon 1989) 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* occasionally recorded on *M. macquariensis* in the Murrumbidgee River (ACT Government unpublished data).

Further information regarding alien species is in Appendix 1.

Changing climate

In addition to the above threats, the species is likely to be susceptible to the predicted impacts of climate change (Koehn et al. 2013). 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 therefore 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). Species with demersal adhesive eggs are 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 may persist for decades until the bedload moves downstream (Rutherfurd et al. 2000). *M. macquariensis* is known to favour deep habitats, further from the bank and faster flowing habitats than Golden Perch and Murray Cod (Koehn and Nicol 2014), with such habitats at risk of infilling from increased sedimentation and reduction in flows. As *M. macquariensis* is thought to spawn in response to day length and water temperature there is a risk that spawning cues can become decoupled with earlier seasonal warming, resulting in reduced recruitment success. For further information see Appendix 1.

Hybridisation and genetic diversity

M. macquariensis and Murray Cod were distinguished as separate species relatively recently (Berra and Weatherley 1972), but the presence of hybrids between the two species is well known from Cataract Reservoir (where both species are translocated) and occasional hybrids have been reported from natural 'wild' populations (Douglas et al. 1995). In Cataract Reservoir, *M. macquariensis* exhibits high levels (32–50% of the population) of hybridisation with Murray Cod (Wajon 1983).

Hybridisation with Murray Cod was perceived as a significant risk to the *M. macquariensis* recovery program in the first national recovery plan (Douglas et al. 1994), so a criterion for the selection of stocking sites was the absence of Murray Cod (Douglas et al. 1994). This criterion has subsequently been relaxed, and *M. macquariensis* are now extensively stocked where Murray Cod are known to be present (Koehn et al. 2013). Murray Cod are thought to have been historically absent or very rare in the upper Murrumbidgee Catchment upstream of Gigerline Gorge (Lintermans 2002), which was an important consideration in the selection of *M. macquariensis* stocking sites in this sub-catchment. However, in response to recreational angler requests, Murray Cod stocking by NSW Fisheries commenced in the Numeralla Catchment in 2008–09, with 16,000 fingerlings stocked across three rivers (Big Badja, Kybeyan, Numeralla) between 2009 and 2015 (NSW Fisheries unpublished data).

Fieldwork in recent years has captured a number of 'odd' looking juvenile cod (less than 150 mm length) and anecdotally these were referred to as hybrids, but no morphological or genetic confirmation of their hybrid status was undertaken. As part of research into the reproductive characteristics of Murray Cod in the ACT, genetic investigations of larval cod sampled from the Murrumbidgee River in the ACT in 2011–2013 recorded a number of first and second generation hybrids between *M. macquariensis* and Murray Cod (Couch et al. 2016). This is the first time hybrid Trout Cod–Murray Cod larvae have been detected in Australia, and the first record from a natural wild population (as opposed to an artificial reservoir environment) that hybrid offspring are fertile (Couch et al. 2016). Stocked *M. macquariensis* have been recorded as breeding in the upper Murrumbidgee River (Beitzel et al. 2011), although it is not known whether the juvenile caught was pure *M. macquariensis* or a hybrid with Murray Cod.

There were no pure *M. macquariensis* larva found in the 251 larvae that were genetically examined, meaning all reproductively active *M. macquariensis* were hybridising with Murray Cod (Couch et al. 2016). The proportion of these hybrid larvae that survive and go on to reproduce is unknown. At least some must survive as demonstrated by second generation hybrids. At best, hybridisation represents wasted reproductive effort by reintroduced *M. macquariensis*, at worst, it indicates the genetic integrity of the two cod species in the Upper Murrumbidgee River is at risk.

The population of *M. macquariensis* in Bendora Reservoir was established from a very small number of individuals (8740) stocked in 1989 and 1990. These juveniles were sourced from the initial breeding experiments on the species and the number of adults available for breeding was limited (S. Thurston pers. comm.). These factors increase the likelihood that the population in Bendora would have limited genetic variability and, when added to the limited breeding events recorded since introduction, the risk that the population would be genetically impoverished is high and may impact on its sustainability.

MAJOR CONSERVATION OBJECTIVE

The overall conservation objective of this action plan is to re-establish and maintain in the long term, viable, wild populations of *Maccullochella macquariensis* 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 existing populations and re-establish new populations.
- Enhance the long-term viability of populations through management of aquatic habitats, alien fish species, connectivity, stream flows and sedimentation in habitats contiguous to known *M. macquariensis* populations to increase habitat area and connect populations.
- Establish additional populations through stocking or translocation.
- Improve understanding of the species' ecology, habitat and threats.
- Improve community awareness and support for *M. macquariensis* and freshwater fish conservation.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

M. macquariensis largely occurs on Territory Land within Namadgi National Park and in nature reserves and special purpose reserves in the Murrumbidgee River Corridor. The fish is not known to occur on rural leasehold Territory Land, or Commonwealth owned and managed land (National Land).

Conservation effort for *M. macquariensis* in the ACT is focused on protecting reintroduced populations in Bendora Reservoir and the Murrumbidgee River, and allowing these populations to establish and expand in distribution. Although there are some individual *M. macquariensis* that get displaced out of Bendora Reservoir, there is almost certainly no downstream connectivity between the Cotter River and Murrumbidgee populations and the barrier formed by Cotter Dam prevents any upstream connectivity. However, protection of the Cotter River habitats for other threatened fish species including Macquarie Perch, Two-spined Blackfish (*Gadopsis bispinosus*), and potentially Murray River Crayfish (*Euastacus armatus*) also provides opportunities to protect habitat for the expansion of the Bendora *M. macquariensis* population.

The primary reproducing population of *M. macquariensis* in the ACT is in the Bendora Reservoir, where water is managed by Icon Water but the catchment is managed by ACT Parks and Conservation Service. Juvenile 'Trout Cod' have been found in the Murrumbidgee River around Angle Crossing and Tharwa but it is suspected that juveniles may be hybrids with Murray Cod. In planning terms, the primary purpose of the Cotter River Catchment is water supply, with conservation a secondary objective. Consequently, protection of this *M. macquariensis* population is tempered by water supply considerations, but protection of threatened fish in the Cotter River Catchment remains a key issue for both Territory and Commonwealth governments (ACTEW Corporation 2009). The national conservation status of the species provides some protection from 'significant' impacts. The ACT Government will liaise with Icon Water to ensure continued protection and management of *M. macquariensis* in the Cotter Catchment.

Recreational harvest of Trout Cod in the ACT is prohibited by the Nature Conservation Act, and fishing is completely prohibited in Bendora Reservoir and the Murrumbidgee River between Angle Crossing and the Gudgenby River confluence. Protection from fishing for Trout Cod will remain a key focus of this action plan.

Survey, monitoring and research

There has been considerable research, survey and monitoring directed at Trout Cod over the last 25 years, resulting in the fifth-largest number of on-ground recovery actions directed at a single species nationally (Lintermans 2013b). There is a relatively good understanding of the species distribution, ecology and relative abundance within the Murray–Darling Basin and the ACT, with ongoing regular monitoring of the species within the Cotter Catchment (both Bendora Reservoir and downstream riverine sites) undertaken by ACT Government since 1992 with additional surveys by the University of Canberra since 2010.

A representative set of sites where *M. macquariensis* is known or suspected to occur will need to be monitored to investigate the success of reintroductions, determine long-term population trends and to evaluate the effects of management. Key sites for population monitoring are those that have an established long-term monitoring program (Bendora Reservoir, Murrumbidgee River). Monitoring programs for *M. macquariensis* should use multiple sampling methods to sample a range of age classes (larvae, juveniles, sub-adults and adults) as done for other ACT threatened fish species (e.g. Beitzel et al. 2015, 2016, Lintermans 2013c, 2016, Broadhurst et al. 2016). The current biennial monitoring program for the Murrumbidgee River fish community (which commenced in 1994) should continue to provide information on the status of *M. macquariensis* in this river within the ACT and at upstream sites where the species has also been stocked.

Knowledge of the characteristics of spawning movement patterns (timing, extent, environmental cues or correlates) for *M. macquariensis* is derived from studies in lowland rivers (e.g. Koehn and Harrington 2006, King et al. 2016), with little or no information available from upland rivers. Monitoring of larval cod populations in the ACT would provide valuable information on whether wild spawning of reintroduced *M. macquariensis* is occurring locally and would inform environmental flow management and potentially identify key spatial areas for spawning management.

A range of recent research has been targeted at *M. macquariensis* populations and their ecology. Further research and adaptive management is required to better understand the habitat requirements for the species. Research priorities include:

- further investigations into whether reintroduced populations in the Murrumbidgee River are reproducing (requires regular monitoring at key sites)
- population estimates and genetic diversity for the Bendora Reservoir population
- monitoring of frequency, level and genetic diversity of wild recruitment in the Bendora Reservoir population
- movement and dispersal of adult and juvenile fish in riverine habitats

- breeding biology including timing, location and migration
- the importance of natural in-stream barriers (e.g. Red Rocks Gorge, Gigerline Gorge) to population connectivity in the Murrumbidgee River (see Dyer et al. 2014)
- impacts and drivers of hybridisation with Murray Cod, and the contribution of hybrids to juvenile, sub-adult and adult age classes
- effect of recreational stocking of Murray Cod on the levels of hybridisation in riverine populations on Trout Cod and Murray Cod
- the efficacy of environmental flow releases in maintaining recruitment of riverine and reservoir populations.

Management

Based on current knowledge of the habitat requirements and ecology of *M. macquariensis,* management actions should aim to maintain riverine habitats with appropriate seasonal flow regimes, intact riparian zones, pool depths, and minimal sediment inputs from roads and surrounding land use.

Protection and revegetation of riparian zones will enhance organic matter contributions, provide shade, which buffers water temperatures, provides cover, prevents erosion and filters sediment from run-off. Minimising sediment addition will protect pools from becoming shallower, which is essential in providing a critical habitat for the species.

From an ecological community perspective a low sediment, with intact pools and riparian zones, will also benefit other threatened aquatic species such as Macquarie Perch, Two-spined Blackfish and, Murray River Crayfish.

There has been no stocking of *M. macquariensis* in the ACT since 2008 and the issue of hybridisation between Trout Cod and Murray Cod in the Murrumbidgee River potentially suggests that reproductive effort by adult *M. macquariensis* may be influenced by a scarcity of conspecific mates (Couch et al. 2016).

Additional riverine stocking of *M. macquariensis* may be required to address a shortage of adult fish, with a long-term stocking approach more likely to be effective (Lyon et al. 2012, Lintermans et al. 2015). Liaison with NSW Fisheries in relation to stocking of Murray Cod upstream of the ACT is also required. The predicted low genetic diversity of the *M. macquariensis* population In Bendora Reservoir (resulting from few founding individuals) would also benefit from introduction via stocking of additional more genetically diverse individuals.

Management of fish passage to facilitate habitat connectivity and promote expansion of small re-established populations is important. For example, the building of fishways at Vanitys Crossing and Pipeline Road Crossing on the Cotter River were intended to ultimately link Cotter River reaches and Macquarie Perch sub-populations previously isolated by road crossings, but such fishways will also provide fish passage for *M. macquariensis* if the population expands downstream of Bendora Reservoir. If this population expansion occurs, further fishways (e.g. at Burkes Creek Road Crossing) may be required for similar aims. Alternatively, active translocation of *M. macquariensis* could be pursued if deemed necessary.

Engagement

As with any endangered species, the importance of information transfer to the community and people responsible for managing their 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.
- Update and maintain the guide to fishing in the ACT to limit angling target of the species
- Ensure that angling signage is up-to-date and placed in relevant areas.

- Report on the monitoring of the species in the 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.

Further information about conservation and management is in Appendix 4.

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 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 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. Maintain the protected status of the species within Namadgi National Park and the four nature reserves in the Murrumbidgee River Corridor.	1a. Namadgi and Murrumbidgee River Corridor populations continue to be protected in national park or nature reserve.
	1b. Ensure all populations are protected from impacts of recreation, infrastructure works, water extraction and other potentially damaging activities, using an appropriate legislative mechanism.	1b. All 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 and external parasite loads/disease of key populations, together with the effects of management actions.	2a. Trends in abundance and fish health are known for key populations, management actions recorded.
	2b. Manage to conserve the species and its habitat, including appropriate flow patterns and temperature, preventing in-stream sedimentation, alien fish management, and fish passage practices (recognising current imperfect knowledge).	2b. Habitat is managed appropriately (indicated by low rates of sedimentation, maintenance of appropriate riparian cover, provision of suitable flows, availability of suitable pool habitat, maintenance of fish passage).
	2c. Where appropriate, stock *M. macquariensis* to increase population numbers, genetic diversity and chance of establishment of wild reproducing populations.	2c. Wild recruitment detected in reintroduced populations.
	2d. Continue to not stock Murray Cod in ACT riverine environments where *M. macquariensis* are known to occur and liaise with NSW Fisheries about stocking of Murray Cod upstream of the ACT.	2d. Murray Cod not stocked in riverine environments. Incidence of hybrid adult cod (Murray/Trout cod) is investigated.
	2e. Manage recreational fishing pressure to conserve the species.	2e. Appropriate fishing closures, prevention of take and keep, fish stocking and gear restrictions are in place to prevent fish harvest.

Objective	Action	Indicator
3. Increase habitat area and promote population connectivity.	3. Manage aquatic habitats adjacent to known *M. macquariensis* locations to increase habitat area.	3. Aquatic habitats adjacent to known *M. macquariensis* habitat is managed to improve suitability for the species (indicated by an appropriate sedimentation and flow regime, absence of priority alien fish species, maintenance of appropriate riparian cover, 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 *M. macquariensis* conservation and management.	4. Research results reported and where appropriate applied to the conservation management of the species. Engagement and/or collaboration with other agencies/individuals involved in *M. macquariensis* conservation and management (i.e. recovery teams, state agencies, universities).
5. Improve community awareness and support for Trout Cod and freshwater fish conservation.	5. Produce materials or programs to engage and raise awareness of *M. macquariensis* and other freshwater fish threats and management actions.	5. Community awareness materials/programs produced and enhanced community awareness evident.

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APPENDIX 1: THREATS—FURTHER INFORMATION

Habitat modification

In the ACT, riparian zones have been cleared and what remains is modified by weed invasion (e.g. Blackberries, African Lovegrass, Willows). Siltation has filled pools and smothered spawning sites, reducing light penetration and the diversity and abundance of invertebrates. Dams on the Cotter River and upper Murrumbidgee River have reduced flows, lessening the frequency of overbank flow events and so reducing connectivity between spawning, nursery and feeding habitats. Dams have altered sediment and nutrient regimes and may release cold, hypoxic water, impacting the habitats of downstream native fishes. Dams have also flooded previously riverine habitats, rendering them unsuitable for critical ecological functions such as reproduction (e.g. blackfish could not breed in Cotter dam as a result of sediment smothering spawning sites).

River regulation

Alterations to natural flow patterns of streams, including flow magnitude, frequency, duration, timing, variability and rate of change, are a major threat to lotic species (Naiman et al. 2008, Poff et al. 1997). The construction of large dams and the diversion of water for domestic, hydroelectric or agricultural water supply has dramatically affected flow regimes downstream (Naiman et al. 2008) with approximately 450 large dams (wall height greater than 10 metres) now present in Australia (Kingsford 2000). In southern Australia, capture and storage of waters in reservoirs during the wet season for subsequent release during dry seasons tends to reverse the seasonal flow pattern in rivers (Maheshwari et al. 1995) and reduce short-term variability overall (Poff et al. 2007). Reduced seasonal volumes of water in rivers are not only the result of dams, but can also be the result of direct abstraction by pumping (Malmqvist and Rundle 2002, Baumgartner et al. 2009). Large dams remove the occurrence and magnitude of small–medium flood peaks as well as reducing the size, rate of rise and fall and duration of flood events (Poff et al. 1997). Low flows downstream of dams can magnify the impacts of barriers to fish passage, as previously insignificant barriers fail to 'drown out' under regulated low flows. Low flows, particularly during drought, also can cause serious water quality problems (high temperatures, low dissolved oxygen that can result in substantial fish mortality. Altered flow regimes also favour generalist alien species with broad tolerances and a capacity for rapid growth and reproduction (e.g. Carp and Eastern Gambusia) (Gehrke et al. 1995).

Barriers to fish passage

Fish habitats are unique in that they are often linear, narrow, and therefore extremely susceptible to fragmentation. Barriers can be structural (dams, weirs, road crossings) or chemical (e.g. discharge of effluents, pollutants, contaminants) and can be partial (i.e. only operate under some conditions such as low flows) or total (e.g. large dams and weirs, piped road crossings). Barriers prevent the movement of fish, either local movements such as for feeding or refuge or larger scale migrations for breeding.

Alien species

Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) were introduced to the Canberra region in the late 1800s and have been established in south-eastern NSW for a century or more. Trout are known to prey upon several native fish species including Macquarie Perch juveniles (Butcher 1967, S. Kaminskas pers. comm.) and may prey upon native fish larvae (e.g. Ebner et al. 2007a). Initial research has developed a genetic method for detecting Macquarie Perch presence in salmonid stomachs (MacDonald et al. 2014), but no such test has been developed for Trout Cod.

Changing Climate

The uplands of the ACT (above ~500 metres elevation) are generally characterised by seasonal rainfall patterns with maximum precipitation in winter and spring with 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 RCP4.5 (Representative Concentration Pathways) 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).

The daily intensity of rainfall, time spent in meteorological drought and the frequency of extreme drought are also predicted to increase by 2090 in the Murray Basin (which includes Canberra) (Timbal et al. 2015). By 2090 rainfall in winter in the Murray Basin is projected to change by -20 to +5 % under RCP4.5 and -40 to +5 % under RCP8.5. A harsher fire weather climate in the future is predicted for the Murray Basin (Timbal et al. 2015) and Marcar et al. (2006) predict that a 5% reduction in evapotranspiration in the upper Murray Catchment following bushfire would result in a 20% reduction in run-off, without factoring in any effect of reduced rainfall. In the Snowy Mountains, snow depth in spring declined by ~40% between 1962 and 2002 (Nicholls 2005) with such declines predicted to continue (Hennessy et al. 2003, Fiddes et al. 2015, Timbal et al. 2015), resulting in changed flow regimes from altered snowmelt patterns.

MURRUMBIDGEE BOSSIAEA

BOSSIAEA GRAYI K.L. MCDOUGALL

ACTION PLAN

Murrumbidgee Bossiaea *(Bossiaea grayi)*. Photo L. Johnson, ACT Government

PREAMBLE

Murrumbidgee Bossiaea *(Bossiaea grayi*) was first described by McDougall (2009) following a review of herbarium specimens and new collections in NSW and the ACT of *Bossiaea bracteosa*. Four new species were described during this review including Murrumbidgee Bossiaea. As such, no previous listings occur for this species. *Bossiaea grayi* was listed as an endangered species on 30 January 2012 (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 action plan must include proposals for the identification, protection and survival of a threatened species or ecological community, or, in the case of a threatening process, proposals to minimise its effect. The first action plan for this species was prepared in 2013 (ACT Government 2013a). This revised edition supersedes the earlier edition. While the legal authority of this action plan is confined to the Australian Capital Territory, management considerations are addressed in a regional context. Measures proposed in this action plan complement those proposed in the Aquatic and Riparian Conservation Strategy.

CONSERVATION STATUS

Bossiaea grayi is listed as a threatened species in the following sources:

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*.
Special Protection Status native species – *Nature Conservation Act 2014*.

SPECIES DESCRIPTION AND ECOLOGY

Description

Bossiaea grayi K. L. McDougall (Figure 1) is an upright shrub to 1.5 metres high. Its winged and predominantly glabrous stems are flattened into cladodes with dark brown leaf scales between 1 and 2.2 millimetres (mm) long. Its yellow and red flowers are solitary occurring at the nodes with 1 to 2 mm long glabrous pedicels that are obscured by dark brown imbricate floral bracts (Figure 2). The floral bracts are mostly persistent and glabrous apart from marginal hairs, increasing in size from outer to inner and the largest (approximately 2.5 mm) with a broadly acute apex. The calyx is mostly glabrous (5–6.5 mm long), green and sometimes tinged with red. The glabrous corolla consists of a standard (9.5–11 mm long). It includes a claw 3–3.5 mm long, and 11–12.5 mm wide, exceeding the other petals, with deep yellow with red markings near the base and faint red longitudinal striations radiating from the base to the edge of the lamina. Wings are 9–10 mm long including a claw 3–3.5 mm long, yellow with red markings at the base; and dark red keel 9–10 mm long, including a 3–3.5 mm long claw.

B. grayi flowers from September to October and produces 20–29 mm long oblong pods with tan to dark brown seeds (2.8–3 mm long) that shed in December (McDougall 2009)(Figure 3).

Distribution

Bossiaea grayi occurs exclusively in the Australian Capital Territory in sandy and skeletal soils amongst rock outcrops near and above the edge of the riparian zone (high flood level) along the Murrumbidgee River and its tributaries.

Eleven extant populations were described in the 2013 Murrumbidgee Bossiaea Survey Report (ACT Government 2015a): five locations on the Murrumbidgee River, five locations along the Paddys River and one location on the Cotter River. The known distribution along the Murrumbidgee

River is from Red Rocks Gorge north to Woodstock Nature Reserve. An estimated 2500 individuals occur along the Paddys River, making this the largest contributor to total population size for the species. Survey of previous records of *Bossiaea bracteosa* along the Lower Molonglo River and at Googong Foreshores did not detect the presence of *B. grayi* at these locations.

Habitat and ecology

B. grayi has been recorded at elevations between 445 metres and 575 metres above sea level. All sites are located within incised river valleys, most are steep (15–45 degrees) and rocky with skeletal soils. Gradients vary with landscape position, with individuals in the riparian flood zone on lower gradients. All soils were observed to have a high proportion of sand indicating a preference for well-draining substrates. Sites on the Murrumbidgee River have skeletal medium to coarse soils over exposed ignimbrite volcanics. The largest populations on the Paddys River occur on shallow to skeletal coarse sand over granodiorite or interbedded metasandstone and shale. All of the smallest populations comprising only one or a few individuals (Paddys and Cotter Rivers) are associated with recent coarse alluvium (ACT Government 2013).

CURRENT MANAGEMENT ACTIONS

Prior to being listed as a threatened species, *B. grayi* (formerly *Bossiaea bracteosa*) did not have a formal action plan in place. However, being a species with special protection status it attracted monitoring and protection that was periodically undertaken by local parks and conservation rangers. Since being listed as a threatened native species there has been an increased focus on survey, identification of threats or threatening processes, monitoring and research.

The majority of *B. grayi* sub-populations occur within nature reserves of the Murrumbidgee River Corridor. Others, including the sub-populations with the largest number of individuals, occur within land currently designated as Plantation Forestry under the ACT Territory Plan (ACT Government 2008).

Figure 1 Murrumbidgee Bossiaea (*Bossiaea grayi*). Illustration: ACT Government.

Figure 2 Murrumbidgee Bossiaea (*Bossiaea grayi*): in flower at Australian National Botanical Gardens (above) and bearing young fruit at Paddys River (below). Photos: L. Johnston, ACT Government.

Ex situ conservation and translocation

Since the original production of Action Plan 34: Murrumbidgee Bossiaea (ACT Government 2013a), a collaborative effort between the Australian National Botanic Gardens, ACT Government and the Australian Native Plant Society has instigated an *ex situ* reserve via the collection and storage of seed at the National Seed Bank. An initial investigation into seed germination requirements has been undertaken by a member of the Australian Native Plant Society.

THREATS

The main threat to *B. grayi* is population range reduction and further fragmentation of the already disjunct populations. Previous surveys have already identified that the species may have undergone a range reduction when previously recorded sub-populations along the Molonglo River valley could not be found (ACT Government 2013b). Recent monitoring indicates that small sub-populations along the Paddys River valley are currently at risk of loss due to reducing number of individuals (ACT Government 2015b).

Recent monitoring in 2016 has revealed the susceptibility of the species to dieback in one sub-population. Initial investigations have failed to identify the cause, although soil analyses have been negative for the presence of *Phytophthora cinnamomi* (ACT Government 2015b).

Several sub-populations are subject to heavy weed infestations. This creates competition for resources such as water, nutrients and light. Management of weeds also creates the potential for inadvertent application of foliar herbicide on *B. grayi*, which has been reported in the past (ACT Government 2013b).

Three extant sub-populations occur within land designated as Plantation Forestry under the ACT Territory Plan. Mechanical disturbance associated with forest harvesting and plantation management has also been identified as a potential threat along the Paddys River valley. Additionally, recreational vehicle use occurs along management trails that either bisect or are immediately adjacent to *B. grayi* individuals and poses a threat if not managed appropriately.

MAJOR CONSERVATION OBJECTIVES

The overall objective of this action plan is to maintain viable, wild populations of Murrumbidgee Bossiaea in the ACT.

Specific objectives of the *Bossiaea grayi* action plan:

- Conserve all sub-populations in the ACT.

- Manage habitat to conserve existing sub-populations and facilitate expansion into adjacent habitat.
- Arrest decline in sub-populations which have reduced in population size and increase the number of sub-populations overall.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

It is important to ensure existing populations within protected areas are managed to enhance survival and natural recruitment. This includes mitigating threatening processes and maintaining suitable conditions for reproduction and expansion. These actions will be assisted on reserved land by: targeted sensitive weed management within and around known populations in river corridor reserves, monitoring native vegetation encroachment, appropriate collection and propagation of material for revegetation projects and continuing to monitor and manage for known threatening processes.

Sub-populations occurring on unreserved land need special attention to ensure long-term survival. In addition to measures listed above, raising and maintaining awareness of the presence of populations among land managers and field workers is essential. Demarcating areas or erecting barriers to ensure land management or road maintenance operations may aid protection of the species.

Implementing the proposed extension of the Bullen Range Nature Reserve would assist the protection of a proportion of the individuals on currently unreserved lands.

Environmental offsets requirements

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents, including the ACT Environmental Offsets Assessment Methodology and the Significant Species Database.

An Environmental Offsets Assessment may result in a development being flagged. A flag identifies an area of land with significant protected matter values. If a proposed impact is flagged, it will require additional consideration by the Conservator of Flora and Fauna as to whether offsets are appropriate in the particular instance. Given the fragmented and vulnerable nature of *B. grayi* sub-populations across the ACT, it has been determined that a development proposal that may have an impact on this species should be flagged for consideration by the Conservator.

If threatened species numbers are observed to change dramatically (either increase or decrease), a review of the threshold for that particular species in the Assessment Methodology and Database would be undertaken.

Survey, monitoring and research

Surveys have been undertaken at all sites where *B. grayi* (or *Bossiaea bracteosa*) had previously been recorded. From this an estimated baseline population size, extent and physiographic environment for the species was documented (ACT Government 2013b). Known extant populations continue to be monitored by the Conservation Research Unit and the Parks and Conservation Service to identify and assess any threatening processes and evaluate the effects of management.

Surveys in 2013 failed to detect the species at a number of sites where it had previously been recorded (ACT Government 2015a). Due to the coarseness of the original spatial records it is plausible that the species may still be present in the vicinity but further broader-scale investigations would be required for confirmation.

It is also possible the species exists at previously undocumented locations elsewhere in the ACT but surveys aimed solely at finding additional populations are unlikely to be practical. Discovery of new populations is likely to be through unrelated surveys or from opportunistic observations from field workers, naturalists and other interested persons.

An initial investigation into seed germination of the *B. grayi* has successfully demonstrated optimal techniques for both manual and bulk seed imbibitions (ACT Government 2015b). There is scope to further develop this research as it will provide useful information for both small and larger scale propagation. *B. grayi* has only been recently taxonomically described so there is also much scope for research into various physiologic, life history and ecological aspects of the species.

Priority research areas include:

- Improved knowledge of life history and ecology, such as plant longevity, seed longevity, conditions associated with germination and recruitment and effects of surrounding vegetation biomass.
- Methods for reintroducing or establishing additional populations, such as translocation of plants.
- More detailed investigations of chemistry, composition and structure of soil at the known sites, to assist with identification of similar sites for establishment of other populations.
- Identify genetic diversity and population structure among the disjunct sub-populations.
- Further investigate causes of dieback in some subpopulations and investigate possible management responses.

Management

Due to the fragmented distribution of the species across its range, management actions need to be directed towards maintaining conditions that minimise loss or degradation of the small sub-populations. This will involve managing threats such as invasive plants, and managing activities to prevent adverse impact on the sites.

Priority management actions include:

- Sensitive management of weeds to reduce species competition and maintain a suitable habitat structure.
- Management or restriction of incompatible activities such as recreational use near the sites, particularly where activities may damage individuals or sub-populations.
- Maintaining a suitable public profile for the sites where the species is located. The appropriateness of signage and fencing will need careful consideration.
- Incorporating appropriate management actions in relevant plans and strategies
- Continuing field collection and management of seed for storage in the National Seed Bank.
- Maintaining an *ex situ* 'insurance' population (plants and/or seed bank) whilst there is a high risk of further extant sub-populations becoming extinct.

IMPLEMENTATION

Implementation of this strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of this (and other) threatened species.
- Allocation of adequate resources to undertake the actions specified in the Aquatic and Riparian Conservation Strategy and action plans.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake research required to inform management of the species.
- Collaboration with non-government organisations such as Greening Australia 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 for this species.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1 Objectives, actions and indicators.

Objective	Action	Indicator
1. Protect all ACT sub-populations.	1a. Apply legal measures to protect all populations.	1a. All populations protected by appropriate legal measures.
	1b. Ensure legal protection measures require land management to conserve the species.	1b. Legal protection measures include requirement for conservation management.
	1c. Monitor existing populations for changes in size, numbers and health and any observable threatening processes.	1c. Production of research reports documenting outcomes of regular population monitoring and evaluation of management practices.
	1d. Maintain alertness to the possible presence of the species in previously undocumented locations or sites where surveys have indicated sub-population loss.	1d. Communication with land managers, community groups and individuals that are or may undertake operational or research work in areas likely to discover the species.
	1e. Maintain a seed bank as insurance against loss of extant sub-populations.	1e. The seed bank of *Bossiaea grayi* in the National Seed Collection is maintained and seed collected at regular intervals (determined by seed longevity).
2. Manage habitat to conserve the species.	2. Manage sites to reduce competition from introduced (and where suitable native) species.	2. Extant populations are stable or increasing.
3. Maintain and enhance geographic area of the population.	3a. Increase the number of individuals at sites where sub-populations are susceptible to loss due to very low numbers.	3a. Documentation of sites where additional numbers of individuals would greatly decrease the chance of loss of entire sub-populations. Plants propagated and trial plantings and maintenance undertaken and documented.
	3b. Facilitate trials to re-establish sub-populations in locations from which sub-populations have been lost.	3b. Trial re-establishment of sub-population/s has been undertaken.
4. Improved understanding of the species' ecology, habitat and threats.	4a. Undertake or facilitate research on appropriate methods for managing the species and its habitat such as life history, germination, recruitment and genetics.	4a. Research results reported and where appropriate applied to the conservation management of the species.
	4b. Continue to monitor observed dieback occurrences.	4b. Populations regularly monitored for dieback and potential causes tested for and documented.

Objective	Action	Indicator
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in, the conservation needs of the species.	5. Undertake or facilitate stakeholder and community engagement and awareness activities and promotions.	5. Engagement and awareness activities and promotion undertaken and reported.

ACKNOWLEDGMENTS

Luke Johnston contributed to the preparation of this action plan. The illustration of the species (Figure 2) was prepared for the ACT Government by John Pratt.

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TUGGERANONG LIGNUM

MUEHLENBECKIA TUGGERANONG

ACTION PLAN

PREAMBLE

The Tuggeranong Lignum *(Muehlenbeckia tuggeranong)* was listed as an endangered species on 19 August 1998 (initially Instrument No. 192 of 1998 under the *Nature Conservation Act 1980* 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). This revised edition supersedes the earlier edition. Measures proposed in this action plan complement those proposed in the ACT Aquatic and Riparian Conservation Strategy (2018 revision).

CONSERVATION STATUS

Muehlenbeckia tuggeranong (Tuggeranong lignum) is listed as a threatened species in the following sources:

National

Endangered – *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).

The species is eligible for listing as Endangered because before the commencement of the Environment Protection and Biodiversity Conservation Act, it was listed as Endangered under Schedule 1 of the *Endangered Species Protection Act 1992* (Cwlth).The main factors that lead to the species being eligible for listing in the Endangered category are its small population size with a very low total number of mature individuals, and restricted area of occupancy (TSSC 2015).

Australian Capital Territory

Endangered – Section 91 of the *2014*.

Special Protection Status native species – Section 109 of the *Nature Conservation Act 2014* (ACT Government 2016b).

SPECIES DESCRIPTION AND ECOLOGY

Description

The Tuggeranong Lignum *Muehlenbeckia tuggeranong* Mallinson (Figure 1) is a sprawling or procumbent shrub, eventually becoming a mounded loosely tangled mass to approximately 1 metre high and 1–2 metres across. Stems are wiry, brownish and weakly and irregularly longitudinally striate. Leaves are alternate, persistent, green, not glaucous, simple, petiolate, solitary and well-spaced along the stems. Petioles are 0.5–3 millimetres (mm long and leaf blades 5–13 mm long by 2–4 mm wide, showing considerable variation in form. Inflorescences are terminal (sometimes on short lateral branches) or very rarely auxillary, simple or 2-branched; range from 12–20 mm from the subtending leaf to the apex; and bear 3–9 flowers in a lax spike. Flowers are unisexual or rarely hermaphrodite, and cream–green in colour. Plants are also mostly unisexual (Makinson and Mallinson 1997).

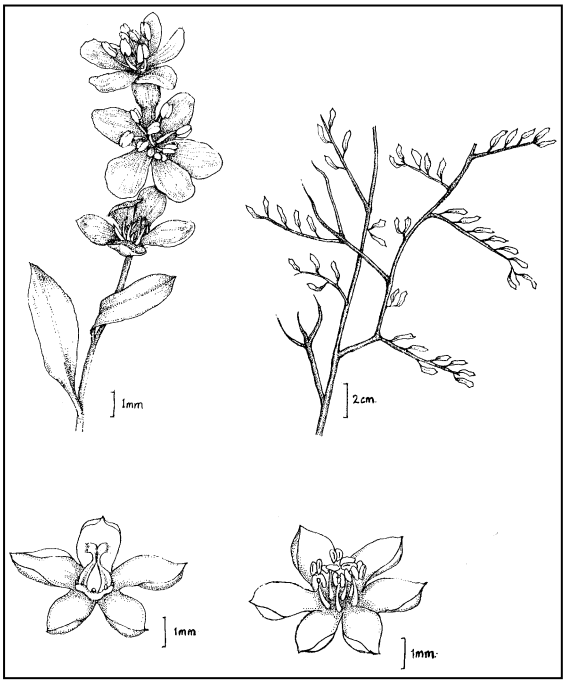

Figure 1 *Muehlenbeckia tuggeranong.* Top left – flowers and leaves. Top right – stems and leaves. Bottom left – detail of female flower. Bottom right – detail of male flower. Illustration: ACT Government.

Distribution and abundance

M. tuggeranong was described from a single female plant and six male plants discovered in the Murrumbidgee River Corridor (MRC) near Tuggeranong in 1997. In May 1999, an additional male plant was discovered in the MRC a short distance from the other seven plants. ACT Government staff located additional plants in 2010 and 2012 within the corridor, bringing the total number of known individuals to 11 (it can be very difficult to determine if a plant is an individual or two plants grown together). A single plant located in Bullen Range Nature Reserve in 1998 has not been located since and is not counted in the total of 11 wild plants. Although extensive searches for other specimens have been undertaken, this MRC population appears to be the only one in existence (ACT Government 2015).

Three attempts have been made to translocate this species. One involved five separate clusters of plants along the eastern side of the river between the northern and southern car parks at Pine Island. Another was in a small tributary of the Murrumbidgee River within Bullen Range Nature Reserve about 1 kilometre west of the confluence of Freshford Creek. The third was on the western slope of Point Hut hill within MRC. In 2016 the only surviving plants were on Point Hut hill (ACT Government 2016a).

Habitat and ecology

The species' known habitat is restricted to flood terraces, altitude about 550 metres, on the eastern bank of the Murrumbidgee River near Tuggeranong in the ACT, in areas of rocky outcrops with pockets of silty sandy soil (Makinson and Mallinson 1997).

M. tuggeranong is found in a highly disturbed riparian shrubby woodland association, heavily invaded by weeds. The species is found on nearly bare rock, or tangled amongst other vegetation (ACT Government 1999)

Associated native species include River Oak *Casuarina cunninghamiana*, Burgan *Kunzea ericoides,* Silver Wattle *Acacia dealbata*, *Grevillea juniperina*, Purple Loosestrife *Lythrum salicaria,* Narrow-leaved Cumbungi *Typha domingensis*, a sedge *Isolepis* sp., Tussock Grass *Poa labillardieri* and Common Reed *Phragmites australis.* There are also a range of introduced species including White Willow *Salix alba*, Sweetbriar *Rosa rubiginosa*, Great Mullein *Verbascum thapsus*; *Oenothera* sp., Viper's Bugloss *Echium vulgare*, Fennel *Foeniculum vulgare*, Lamb's Tongue *Plantago lanceolata*, Curled Dock *Rumex crispus*, St John's Wort *Hypericum perforatum*, Umbrella Sedge *Cyperus eragrostis*, Toowoomba Canary Grass *Phalaris aquatica*, African Lovegrass *Eragrostis curvula* and Yorkshire Fog *Holcus lanatus* (ACT Government 1999).

The species appears to tolerate extreme shading. It grows within very dense patches of African Lovegrass and may benefit from reduced grazing pressure when growing amongst this grass. Floods in 2012 deposited more than 10 centimetres of silt and woody debris that completely covered one plant (ACT Government

2012). While this individual grew up through the deposit with no apparent ill effects, another flood in July of 2016 deposited additional material on this plant and at the time of writing it is not known if the plant will survive.

The species does appear to be negatively impacted by grazing and mesh cages have proven effective in improving the condition of individual plants (ACT Government 2015). The 2003 bushfires burnt all of the known habitat with an intensity that killed many of the River Oaks. All the known *M. tuggeranong* plants survived this fire and regrew to their former size.

Translocation attempts have been disappointing. However, the translocation has shown that plants are more successful when planted on southern aspects or with protection from the afternoon sun provided by large rocks (G. Baines pers. comm.).

M. tuggeranong appears to be a long-lived species. Since the first plants were identified in 1997 only one wild growing plant has died. This plant was growing in sand just above the waterline and was overgrown by Blackberry (*Rubus* sp.). The plant may have been washed away in floods, out-competed by the Blackberry or killed in an attempt to poison the Blackberry (ACT Government 2016).

M. tuggeranong is generally dioecious but only one female plant has been found. This plant is not known to have ever set seed. The plant does grow readily from cuttings but it is not known if it disperses vegetatively in the wild.

CURRENT MANAGEMENT ACTIONS

The Murrumbidgee River Corridor (Environment ACT 1998) contains the only population of *M. tuggeranong*. The MRC has planning and management history dating back to 1964 when the river was first designated an 'Area of Special National Concern' by the Commonwealth Government (Environment ACT 1998). A number of policies and plans have been applied to the MRC since 1964 including the establishment of the Lanyon Landscape Conservation Reserve in 1985 (which includes the habitat at Pine Island) and the gazettal of Bullen Range Nature Reserve in 1991. This legislation has protected *M. tuggeranong* from urban development. However, public recreation is encouraged at Pine Island with public toilets, BBQ facilities, car parking, public swimming beaches and the Centennial Trail all within a short distance of the remaining populations of *M. tuggeranong*.

Grazing by macropods appears to represent a significant threat to the lignum (D. Roso pers. comm., ACT Government 2012, 2016). Anecdotal evidence points to a large increase in macropod numbers in the MRC over the last 20 years (D. Roso pers. comm.). Lignum shows regular evidence of browsing and exclosure cages noticeably increase the condition of the plants (ACT Government 2012, 2016).

Drought during the early part of the 21st century had little detrimental effect on the plants (D. Roso pers. comm.).

The area was heavily impacted by the 2003 bushfires. Canopy cover of River Oak was significantly reduced along much of the MRC and is only slowly recovering. Fuel reduction and ecological burns have been very rarely implemented in the MRC in the last ten years but before this time, the plants near the northern Pine Island car park were regularly burnt in fuel reduction burns.

Floods in the Murrumbidgee River are relatively common and all the wild plants are within the flood zone of the river. Smothering of plants by flood debris is a constant risk, as is the chance of them being washed away. No flood protection measures are taken for this species (ACT Government 2016).

Weeds are possibly the largest management problem in the MRC and often dominate the groundcover around the *M. tuggeranong* population. The most widespread is African Lovegrass, which is not generally controlled throughout the MRC. Currently, the Parks and Conservation Service makes no attempt to remove African Lovegrass around individual Lignum plants as the grass seems to provide support for the Lignum's wiry stems, hides the plant from possible grazers and may shelter the plant from weather extremes. It is possible that the Lignum once relied on native grasses such as Snow Grass (*Poa labillardierei*) for these functions. The tangled growth of the Lignum stems through the African Lovegrass tussocks also makes it impossible to remove the weed without damaging the lignum.

Blackberry is a potential threat to the species because it can completely overrun a Lignum plant. For this reason, the Parks and Conservation Service prioritises Blackberry control around the plants. Large colonies of other weeds such as Soapwort (*Saponaria officinalis*), Californian Poppy (*Eschscholzia californica*) and Great Mullein (*Verbascum thapsus)* are also common and are controlled around plants where they are deemed to pose a threat (ACT Government 2016). These species are physically removed if chemical control is likely to damage the lignum.

A number of management actions have been undertaken to conserve *M. tuggeranong*. These include cages to reduce grazing of mature plants, education of contractors undertaking construction or weed spraying activities in the area, growing cuttings and translocating over 100 tube stock into MRC and Bullen Range Nature Reserve and collecting additional cuttings from all individuals (wild and planted) to establish a living collection at the Australian National Botanic Gardens (ANBG). This collection will provide the source material for any future translocation attempts.

All wild *M. tuggeranong* in the reserve have been labelled with individual tags to aid in monitoring (see Appendix 1) (ACT Government 2016) and are inspected at least once a year by Conservation Research or Parks and Conservation Service rangers to identify any management that needs to be addressed. Conservation Research maintains monitoring records, reports annually on the condition of all plants and co-ordinates research and translocation activities. The locations of individual *M. tuggeranong* are not made available to the general public.

Ex situ conservation and translocation

In 2006 cuttings were taken from all known wild plants and propagated at the ANBG. Large numbers of clonal propagates have since been grown from these original cuttings. In October 2010 staff from Conservation Research, the Parks and Conservation Service, ANBG and Southern Murrumbidgee Parkcare members translocated 93 clonal propagates into five separate areas along the eastern bank of the Murrumbidgee River between the Pine Island north and south car parks. An effort was made to place a mix of male and female plants at each site and all plants were marked with individual tags (ACT Government 2010). This program was conducted according to the principles outlined in the Australian Network for Plant Conservation's *Guidelines for the Translocation of Threatened Plants in Australia* (Vallee et al 2004) and *Plant Germplasm Conservation in Australia* (Offord and Meagher 2009, Cook 2013) and the reintroduction objectives outlined in *Issues and Options for Genetic Conservation of Small Populations of Threatened Plants in the ACT* (Young 2001).

There were a number of high level flood events in the MRC during spring and summer 2011–12. Surveys of the translocated plants conducted in May 2012 revealed that only 19 plants had survived. By 2013 this number had declined to 4 plants and by 2015 no plants could be located. Many plants had been washed away by the floods or covered by more than 5 centimetres of sediment. Surveys at the time noted that African Lovegrass did not seem to inhibit the plants and shading appeared to enhance survival (ACT Government 2012 and 2015).

In September 2013 Conservation Research and the Parks and Conservation Service staff translocated 18 clonal propagates to a site above the flood zone near Point Hut Crossing and another 18 propagates to a site on a tributary of the Murrumbidgee River in Bullen Range Nature Reserve. All of these plantings used Terra Cottem soil conditioner and tree guards for grazing protection (Cook 2013).These plants were watered on a number of occasions over the following 12 months. By February 2015 ten translocated plants survived at Point Hut Crossing whilst all of the plants in Bullen Nature Reserve had perished (ACT Government 2015). By May 2016 the translocated population at Point Hut Crossing had declined to seven plants. Tree guards enhanced plant survival but required regular maintenance due to damage from wild animals and the elements (ACT Government 2016).

THREATS

M. tuggeranong faces a number of threats in the wild. The species ability to sexually reproduce appears to be very limited. The plants are predominantly dioecious and only one female plant is known to exist (Young 2001). The female is not known to have ever produced seed (ACT Government 2006). It is also likely that genetic variation in the population is very restricted due to the extremely low population size—the maximum number of wild plants know to be alive at any one time is 13 (Young 2001).

The habitat of the *M. tuggeranong* is prone to physical disturbance from periodic flooding, which can kill individual plants by washing them away or smothering them under flood debris. Physical disturbance can also result from recreational activity, particularly where plants occur in river sand near popular swimming areas. Wildfire has altered the vegetation structure at Pine Island, reducing canopy cover and possibly increasing shrub cover. Decreased cover may have an impact on *M. tuggeranong* by drying out the microclimate around individual plants.

Grazing by macropods is an ongoing threat. Plants are sometimes almost completely defoliated and growing stems damaged by close grazing (ACT Government 2012 and 2015).

Weeds such as Blackberry can out-compete the Lignum, potentially shading it out. Other weeds such as African Lovegrass may occupy suitable habitat niches making it difficult for lignum to recruit or possibly shade out young less vigorous plants such as translocated tube stock.

Urban and infrastructure development or weed spraying may pose a risk if the Lignum is not explicitly considered in the planning of such activities.

MAJOR CONSERVATION OBJECTIVES

The overall objective of this plan is to preserve the species in perpetuity in the wild across its natural geographic range in the ACT. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan:

- Protect all ACT populations because the species is not known to occur outside the ACT.
- Manage habitat to conserve populations and facilitate expansion of populations into adjacent habitat.
- Increase the number of populations by establishing new populations.

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

Protection

The *Muehlenbeckia tuggeranong* population is protected within the Murrumbidgee River

Corridor. The first objective of the current management plan is to conserve the endemic, riparian and riverine ecosystems (ACT Government 1999). ACT Parks and Conservation Service manages the site in accordance with this plan.

Survey, monitoring and research

It is possible that the species exists elsewhere in the ACT or NSW. However, because the species is small and difficult to detect, surveys aimed solely at finding additional populations are unlikely to be practical. Discovery of new populations is likely to be through surveys for other plant species or from opportunistic observations from naturalists and other interested persons. All known populations of *M. tuggeranong* will need to be monitored to determine population trends and to evaluate the effects of management.

Recovery of the species will rely largely on expanding the size/area of the existing population and establishing new populations. Research is required to determine optimal habitat conditions for the species (to maintain and expand existing populations) and how to establish new populations.

Priority research areas include:

- Improved knowledge of life history and ecology including:
- how many individual plants compose the current population (genetic comparisons will probably be required to ascertain this information)
- how many females exist and are there any fertile females
- whether the species reproduce sexually
- whether shading influences the growth or survival of small plants
- whether the species is reliant on any micorrhizal symbiotes.
- Methods for establishing additional populations, such as translocation of plants, in association with the ANBG, Greening Australia and other parties.

Management

Due to the small size of the population, management actions will be directed towards maintaining existing conditions and ensuring activities occurring nearby do not adversely affect the sites.

Priority management actions include:

- Placing and maintaining tree guards around all plants, wild and translocated.
- Weed control (focusing on Blackberry) if weeds pose a threat to the populations or the site.
- Avoiding incompatible activities such as development of facilities, recreational use or access tracks in or near the sites.
- Maintaining a low profile for the sites where the species is located; the appropriateness of signage and fencing will need careful consideration.
- Incorporating appropriate management actions in relevant plans and strategies.
- Maintaining an *ex situ* 'insurance' population whilst there is a high risk of extant populations becoming extinct.

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 plans.
- Liaison with other jurisdictions (particularly NSW) and other landholders (such as 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 Scientific Committee must review the action plan.

OBJECTIVES, ACTIONS AND INDICATORS

Table 1 Objectives, actions and indicators.

Objective	Action	Indicator
1. Protect all ACT populations.	1a. Maintain legal and site measures to protect all populations.	1a. All populations protected by appropriate legal measures.
	1b. Ensure protection measures are maintained to conserve the species.	1b. Legal protection measures include requirement for conservation management.
	1c. Maintain alertness to the possible presence of the species while conducting vegetation surveys in suitable habitat.	1c. Vegetation surveys in suitable habitat are carried out with a good understanding of the species description.
	1d. Establish an *ex situ* population as insurance against the loss of the extant population.	1d. *Ex situ* population at the Australian National Botanic Gardens is maintained with representatives from all know individuals.
2. Manage habitat to conserve the species.	2a. Monitor populations and effects of management actions.	2a. Trends in abundance are known and management actions are recorded.
	2b. Manage threats, especially grazing, weeds and recreation impacts.	2b(i) All plants to be covered with grazing exclosure cages and plants health monitored regularly. 2b(ii) Blackberry controlled where it impacts on lignum. 2b(iii) Lignum to be considered in all works plans for the Pine Island area. Staff and contractors made aware of its presence.
	2c. Undertake or facilitate research on lifecycle, recruitment, genetics and effect of vegetation biomass management.	2c. Research results reported, and where appropriate applied to the conservation management of the species.
3. Increase the number of populations.	3. Undertake or facilitate research and trials into establishing new populations.	3. Research and trials have been undertaken to establish new populations or new population(s) established.
4. Promote a greater awareness and community engagement in the conservation of the species.	4. Provide opportunities for community involvement in conservation activities.	3. Community stakeholders such as Greening Australia and local Parkcare groups engaged in *Muehlenbeckia tuggeranong* conservation activities.

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Personal communications

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APPENDIX 1: INDEX OF WILD *MUEHLENBECKIA TUGGERANONG* AT PINE ISLAND RESERVE

Plant ID	No. of plants	Sex	Date recorded
W_a	1	Female	24 January 1997
W_b W_c	2	Male	08 January 1997
W_d	1	Male	08 Janaury 1997
W_e	2	Male	24 January 1997
W_f W_g W_h W_j W_k	5	unknown	30 June 2010 2 more found 31 May 12 when tags were placed.
W_i	1	unknown	10 May 2012