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).

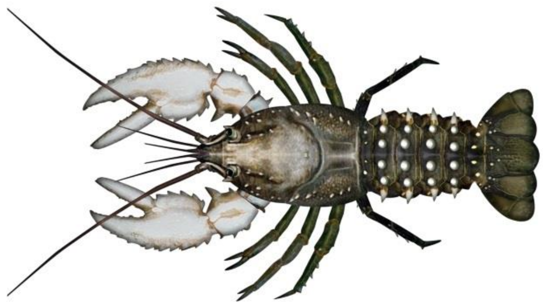

Figure 1 *Euastacus armatus*. Illustration: curtesy of NSW Government.

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.

ACKNOWLEDGMENTS

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Personal communications

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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.