Australian Capital Territory region Bush Blitz

Fishes and Crayfish

25 November–6 December 2018

Michael Hammer and Matthew Beitzel

Report submitted to Director of National Parks, 30 June 2019

Contents

List of contributors

List of contributors to this report			
Name	**Institution/affiliation**	**Qualifications/area of expertise**	**Level/form of contribution**
Michael Hammer	**Museum and Art Gallery of the Northern Territory**	**Curator of Fishes**	**Survey participant, fish specimen curation, principal Author**
Matthew Beitzel	**Conservation Research, ACT Government**	**Aquatic Ecologist**	**Survey participant, crayfish specimen curation, principal Author**
Mark Jekabsons	**Conservation Research, ACT Government**	**Aquatic Ecologist**	**Survey participant**
Zohara Lucas	**Conservation Research, ACT Government**	**Aquatic Ecologist**	**Survey participant**
Mark Lintermans and Peter Unmack	**University of Canberra**	**Aquatic Ecologist**	**Advice and assistance with survey design, previous records and local information**

Cover photos: Top Flat, upper Cotter River with aquarium photo of Mountain Galaxias collected at the site

Nomenclature and taxonomy used in this report is consistent with:

The Australian Faunal Directory (AFD)

https://www.environment.gov.au/science/abrs/online-resources/fauna

Abstract

A two week dedicated freshwater fish and crayfish sampling trip was undertaken to the Australian Capital Territory (ACT), focusing primarily on Namadgi National Park, as part of a larger Bush Blitz expedition survey team. The ACT lies on the upper Murrumbidgee River catchment, with a major sub-catchment in the Cotter River exclusive to the region. A total of 20 sites were sampled, ranging from 474–1566 metres elevation, using a combination of helicopter and vehicle access and appropriate gear types (i.e. mainly compact gear including backpack electrofisher and bait traps, with some dip netting). The survey focus was on isolated upland habitats including small to medium sized streams and associated alpine Sphagnum bog wetlands. The objectives were species discovery and to provide information for land management, with a specific focus being to explore the distribution and refuges for two groups, namely (a) native Mountain Galaxias, which have undergone a major range retraction in the region and been shown to harbour many cryptic species, and (b) rare and poorly known species of spiny crayfish (genus *Euastacus*). Three native fishes were recorded, including Macquarie Perch, Twospine Blackfish and Mountain Galaxias, and four introduced fishes were sampled, Rainbow Trout, Eastern Gambusia, Common Carp and Weatherloach. Three species of crayfish were recorded, namely Alpine Spiny Crayfish, Riek's Crayfish and Common Yabby. Mountain Galaxias and spiny crayfish (13 and 7 sites respectively) exhibited a largely mutually exclusive distribution with Rainbow Trout, with several important isolated refuges noted for native species in small streams or above natural barriers. The survey provided a snapshot of the ecology and health of the regional Mountain Galaxias and spiny crayfish populations, with important material for future genetic and taxonomic studies obtained. Specific region and site based management recommendations are made with respect to a specialised alpine aquatic fauna.

1. Introduction

The Australian Capital Territory (ACT) is located in the upper Murrumbidgee River system of the Murray-Darling Basin. Waterways in the region include the Murrumbidgee River proper which dissects the ACT in a south-north direction, with a large area of upland catchments draining from the alpine region of the Great-Dividing Range forming the Cotter River and Gudgenby catchments including the major sub-catchment Paddy River: much of this area is covered in the Namadgi National Park and other regional or forest reserves. The Molonglo River flows east into the Murrumbidgee from New South Wales.

The freshwater fishes of the ACT and upper Murrumbidgee River are reasonably well-known and documented (Lintermans 2000e, 2002; Lintermans and Osborne 2002), although there has been a significant increase in understanding for one group recently. Prior to 2012, Mountain Galaxias (*Galaxias olidus* s.l.) was considered a widespread yet variable species across mainland south-eastern Australia. A comprehensive genetic and morphological appraisal of the group resulted in the recognition of 15 species from one (a hyper-cryptic species complex), many of which displayed contrasting biological traits including specialisation for riffle and alpine environments. Several are also of conservation concern including highly restricted contemporary distributions, with habitat loss, climate change and introduced predatory trout species primary threats (Adams et al. 2014; Raadik 2012, 2014). Trout do appear to have had a major impact on the distribution of Mountain Galaxias in the ACT region (Lintermans 2000a), with the species now patchily distributed from a former wide range (Lintermans 2000e, 2002; Lintermans and Osborne 2002).

At present all galaxias in the ACT are considered to be Mountain Galaxias *sensu stricto*, however several of the newly described species have significance to the survey to demonstrate the potential presence of additional species for the region or the precedent for species new to science based on geographic proximity and or environmental similarities, namely: (a) the Stocky Galaxias (*Galaxias tantangara*) is a narrow range endemic known only from a small alpine tributary of the Murrumbidgee River (elevation 1360 m asl) just to the south of the ACT, (b) the Kosciuszko Galaxias *(Galaxias supremus*) is also endemic to the snowfields of the nearby Kosciuszko National Park (elevation ~1900 m asl), (c) the Riffle Galaxias (*Galaxias arcanus*) is a habitat specialist for large riffles where it occupies interstitial spaces within the substrate of the streambed, known from the mid to upper reaches of the Goulbourn, Ovens and Murray river systems (elevation 150–880 m asl) and similar habitat occurs in the ACT, and (d) the Obscure Galaxias (*Galaxias oliros*) is very widespread in the MDB in low-mid elevation areas (up to 600 m asl), but curiously has so far not been recorded in the Murrumbidgee River system (Raadik 2014). This study provides a fresh opportunity for intensive sampling of ACT galaxias to help map remaining refuge habitats and to collect material for additional taxonomic assessment from remote locations not included in the major review of Raadik and co-authors.

Three families of decapod crustaceans (characterised by a strong carapace and five pairs of legs) are represented in the ACT and upper Murrumbidgee River region, namely shrimps (family Atyidae), prawns (family Palaemonidae) and freshwater crayfish (family Parastacidae). Freshwater crayfish are a significant group for conservation, recreation and management reasons, including the ubiquitous Common Yabby (*Cherax destructor*) which inhabits lower elevation streams, larger rivers and dams, and rarer spiny crayfish (genus *Euastacus*). Spiny crayfish are slow growing, reaching maturity at 5–10 years and may live for more than 30 years, with breeding typically occurring in late autumn whereby mature females carry relatively few eggs then juveniles under the tail for five to eight months (McCormack 2012).

There are three species of spiny crayfish in the ACT. The Murray Crayfish (*Euastacus armatus*) is the second largest crayfish in the world, being reasonably well studied due to its threatened status and recreation fisheries value (Whiterod et al. 2017). In the ACT the species is known from the Murrumbidgee River and lower Cotter River (Lintermans and Osborne 2002). Two smaller species of spiny crayfish are known within the ACT, the Alpine Spiny Crayfish (*Euastacus crassus*) and Riek's Crayfish (*Euastacus rieki*). Both of these occur in upland montane habitats and are poorly understood with limited information available on their ecology, threatening processes, population status and distribution in the ACT or elsewhere (the overall range of each is quite restricted). They are primarily nocturnal and exhibit burrowing behaviour. Alpine Spiny Crayfish inhabit permanent and ephemeral streams with water temperatures less than 21°C at elevations greater than ~600 m asl, while Riek's Crayfish is found in streams and bogs in sub alpine and alpine areas over 1000 msl (McCormack 2012). It is currently unknown as to whether these species overlap in distribution.

A fifth freshwater crayfish from the ACT, the Burrowing Crayfish (*Engaeus cymus*) is generally not found in waterways or bogs.

A berried (eggs) female Riek's Crayfish (*Euastacus rieki*) from an alpine area of the ACT (photo M. Beitzel © ACT Government)

2. Methods

2.1 Site selection

Sites were targeted to parts of the study area where previous minimal survey effort overlapped with unique or interesting habitat that could be included in a rapid survey design; primarily remote alpine areas above waterfalls or associated alpine Sphagnum bogs and fens, but also a mix of riffle and lowland habitats that might house habitat-specific galaxias as per the Introduction (and that had not been sampled in the previous Mountain galaxias research: Adams et al. 2014; Raadik 2014). Site selection was guided by GIS mapping using topographic maps and aerial imagery with stream network and swamp overlays.

Twenty sites were sampled between the 26th November and the 5th December 2018 (Table 1). Sampling occurred after a reasonably dry winter, but with an unseasonal late burst of shower activity resulting in most streams having low to moderate flow at the time of sampling.

2.2 Survey techniques

Sampling employed a rapid assessment design in order to cover as wide a spatial distribution and variety of habitats/environmental conditions as possible, and maximise efficiency with regard to the time window for helicopter access into remote and inaccessible areas:

1) **Backpack electrofishing** using a Smith-Root model LR-20B with voltage and frequency adjusted according to water conductivity. Electrofishing temporarily shocks fish and crustaceans, and allows their targeted capture, with remaining animals quick to recover once electrofishing is ceased. This was the primary survey technique, employed at wade-able sites, being especially effective for smaller streams as most of the habitat sampled.
2) **Bait traps** are collapsible mesh nets with conical openings on each end (45 x 25 x 25 cm coming in multiple colours) that were set on strings amongst vegetation cover, flat on the bottom, overnight and baited with fish. This passive survey technique was used to supplement electrofishing at several sites with the specific target of spiny crayfish.
3) **Dip netting** is an active technique involving a net on a handle with fine mesh (0.5 m diameter, 4 mm mesh). This is quick and effective within small habitats and amongst vegetation and leaf litter, a preferred habitat of small fishes. Ideal for shallow habitats or edge sampling, and often deployed in combination with night spotlighting.

The methods employed at each site are shown in Table 2. Environmental data including physical characteristics, habitat components and water quality was also recorded for each site (Table 2).

Sampling was conducted in accordance with University of Canberra Animal Ethic Committee approval AEC 18-02. Due to the involvement of the ACT Government no direct permit was required for the fish survey work.

2.2.1 Methods used at standard survey sites

There was no water at either of the two standard survey sites.

2.3 Identifying the collections

Captured fishes were sorted to species on site with the majority returned to the point of capture. Subsamples retained as vouchers were held in a bucket with aeration and transported back to the field laboratory where many were photographed in an aquarium. Retained fish were ultimately euthanased using AQUI-S, and vouchers were fixed in 10% formalin solution with a matching genetic tissue sample from the right side of the fish preserved in both 100% analytical grade ethanol and liquid nitrogen. Mountain Galaxias specimens were compared to the literature keys (Raadik 2014) with tissues curated for future genetic characterisation.

To aid in future environmental monitoring and as a snapshot of population health, length frequency information was gathered for all Mountain Galaxias collected prior to release or sub-sampling.

A sub-sample of decapod crustaceans (including spiny crayfish) was retained from each site when recorded, then they were photographed, euthanised with benzocaine (1 g/L) and stored in 100% ethanol. Identification of crayfish was undertaken following Morgan (1997). The key characteristic for identification between the two species involves dissection to reveal the internal gastric mill, with *E. rieki* having fewer broad teeth anterior to the posterior margin of the ossical ear (TAP; count of 2–3) and *E. crassus* having many, small teeth (TAP count of 5.5–11).

Table 1. Fish and crayfish survey sites, WGS84 datum.

Site	Date	Location	Waterway	Elevation (m)	Latitude (S)	Longitude (E)
MH18-39	26/11/2018	Namadgi National Park	Gibraltar Creek, park boundary	699	-35.4630	148.9697
MH18-40	27/11/2018	Namadgi National Park	Cotter River, Top Flat	1566	-35.7443	148.8586
MH18-41	28/11/2018	Kowen Forest	Glen Burn Creek, off track	672	-35.3174	149.3018
MH18-42	29/11/2018	Namadgi National Park	Ginini Creek, above second falls	1544	-35.5161	148.7804
MH18-43	29/11/2018	Namadgi National Park	Creamy Flats Creek, Little Creamy Flats	1316	-35.6644	148.8707
MH18-44	29/11/2018	Namadgi National Park	Rendezvous Creek, headwater swamp	1137	-35.6522	148.9091
MH18-45	29/11/2018	Namadgi National Park	Licking Hole Creek, Rotten Swamp	1448	-35.7085	148.8883
MH18-46	30/11/2018	Namadgi National Park	Blue Gum Creek, firetrail	835	-35.5354	149.0160
MH18-47	30/11/2018	Namadgi National Park	Gudgenby River, Glendale, Boboyan Rd	864	-35.6884	149.0017
MH18-48	30/11/2018	Namadgi National Park	Tidbinbilla River, Fishing Gap	813	-35.4819	148.9000
MH18-49	3/12/2018	Lower Cotter Catchment Reserve	Lees Creek, old weir Warks Road	802	-35.3582	148.8412
MH18-50	3/12/2018	Namadgi National Park	Cotter River, Vanitys Crossing	567	-35.3463	148.8899
MH18-51	3/12/2018	Cotter Reserve	Cotter River, Cotter Ave park	474	-35.3236	148.9421
MH18-52	4/12/2018	Namadgi National Park	Cotter River, Cotters Flat (bridge)	1014	-35.6389	148.8285
MH18-53	4/12/2018	Namadgi National Park	Cotter River, Cotters Hut	1025	-35.6482	148.8315
MH18-54	4/12/2018	Namadgi National Park	Mckeahnie Creek, Mount Franklin Firetrail	1270	-35.6367	148.7948
MH18-55	4/12/2018	Namadgi National Park	Sawpit Creek, Cotter Hut Road	1100	-35.6073	148.9033
MH18-56	5/12/2018	ACT non-reserve	Gudgenby River, Sunshine Road	615	-35.5781	149.0669
MH18-57	5/12/2018	Namadgi National Park	Gibraltar Creek, above falls (carpark)	988	-35.4878	148.9344
MH18-58	5/12/2018	Namadgi National Park	Billy Billy Creek, Corin Road	1096	-35.4999	148.9190

Table 2. Environmental descriptors and sampling methods at survey sites. Method codes: EF= Backpack electrofisher, BT= Bait trap, DN= Dip net, SL = Spot light.

Site	Method	Sampling notes	Depth max (m)	Conductivity (us)	Temp (oC)	pH
MH18-39	DN, SL	Opportunistic	0.5			
MH18-40	EF	Above waterfall	0.3	8.74	13.0	5.5
MH18-41	EF	Eastern ACT site; mid-elevation	1.0	8	15.0	6.5
MH18-42	EF	Above waterfalls	0.3		9.0	6.0
MH18-43	EF	Above waterfalls	0.6		10.0	5.8
MH18-44	EF	No waterfall	1.0		13.0	6.0
MH18-45	DN	Opportunistic	1.0		6.5	
MH18-46	EF, BT	Targeted riffles	1.0		10.0	6.0
MH18-47	EF	Targeted riffles	1.0		12.0	6.5
MH18-48	EF, BT	Small stream	0.5		12.5	6.5
MH18-49	EF	Former trout control site	1.0		10.0	6.0
MH18-50	EF, DN, SL	Targeted riffles	1.0		18.0	6.0
MH18-51	EF	Targeted riffles	1.2		17.0	6.0
MH18-52	EF	Targeted riffles	1.0		17.0	5.5
MH18-53	EF	Targeted riffles	1.0		16.0	6.0
MH18-54	EF	Above small waterfall/s	0.5		12.0	6.0
MH18-55	EF	Swamp meadow	1.0		14.0	
MH18-56	EF	Mid-elevation	0.8		20.0	6.5
MH18-57	EF	Replicated monitoring site	0.6		13.0	6.5
MH18-58	EF	Upper catchment site	0.4		11.0	6.5

Table 3. Fish and decapod crustacean sampling data (* = introduced species).

Species	MH18-39	MH18-40	MH18-41	MH18-42	MH18-43	MH18-44	MH18-45	MH18-46	MH18-47	MH18-48	MH18-49	MH18-50	MH18-51	MH18-52	MH18-53	MH18-54	MH18-55	MH18-56	MH18-57	MH18-58
Fishes																				
Gadopsis bispinosus												20		10	20					
Galaxias olidus	10	10	30		20			20	10	40	300		50			30	50	100		15
Macquaria australasica												2								
*Cyprinus carpio**													2							
*Gambusia holbrooki**													10							
*Misgurnus anguillicaudatus**												10	20							
*Oncorhynchus mykiss**	2					3	2	30				32		20	30				8	
Decapod crustaceans																				
Euastacus crassus				x							x								x	
Euastacus rieki		x			x	x														
Euastacus juvenile														x						
Cherax destructor			x										x					x		
Paratya australiensis			x										x							
Macrobrachium australiense												x								

Alpine Spiny Crayfish (*Euastacus crassus)* from above second Ginini Falls (MH18-42)

Reik's Crayfish (*Euastacus rieki*) sampled from Little Creamy Flats (MH18-43)

3. Results and Discussion

Table 3 and Appendix 1 lists all fishes and decapod crustaceans recorded during the ACT Bush Blitz. Three native and four introduced fishes were recorded along with five native decapod crustaceans.

3.1 Un-named or not formalised taxa

None.

3.2 Putative new species (new to science)

None as yet but future genetic research on different Mountain Galaxias forms found during the survey is required and may reveal new species.

3.3 Exotic and pest species

Four introduced fishes were recorded at the targeted stream sites surveyed, three were fairly restricted in more lowland habitat, with Rainbow Trout widespread in mid to high elevation sites (tables 3 & 4).

Common Carp and Eastern Gambusia were only recorded below Cotter Dam, and this artificial barrier appears to have limited upstream dispersal into habitat containing threatened Twospine Blackfish and Macquarie Perch. Proactive management to prevent upstream illegal translocation is a key management recommendation. Weatherloach has breached this barrier, apparently translocated as a bait bucket introduction for recreational trout fishing.

Rainbow Trout are a large growing predatory species and a nearly mutually exclusive pattern of distribution was observed with Mountain Galaxias either at a system scale (Cotter River main stream), site level (e.g. Rendezvous Creek and Rotten Swamp: MH18-44–45), or in the one case of co-occurrence, by habitat diversity (adult galaxias in riffles, trout in pools at Blue Gum Creek: MH18-46). Similarly, spiny crayfish were also not recorded or were found in low abundance at otherwise suitable sites where Rainbow Trout occurred. One site sampled to contain Mountain Galaxias in March 2002 (Raadik 2012), Gibraltar Creek above Gibraltar Falls (MH18-57), has been lost due to the recent introduction of Rainbow Trout; a small pocket of Mountain Galaxias was found in the very upper reaches of the system (MH18-58). This small sub-catchment would be an ideal area to undertake invasive species control (Jackson et al. 2004; Lintermans 2000a). Another small stream site where trout control has previously been undertaken to provide a small refuge for Mountain Galaxias (Lintermans 2000a) retains a strong population of the native species (Lees Creek: MH18-49). Finally several upland sites above waterfalls in Namadgi National Park contain refuge populations of Mountain Galaxias and spiny crayfish, and proactive management should be undertaken to prevent future trout invasion (i.e. Upper Cotter River at Top Flat, MH18-41 and Little Creamy Flats, MH18-43).

Only limited heavy-hooved animal damage was observed at sensitive high elevation swamp sites, but future invasive potential of larger numbers of feral horses or pigs could impact the condition and quality of this refuge habitat for fishes and spiny crayfish.

Table 4. Exotic and pest species recorded.			
Exotic/pest species	**Location sighted/observed**	**Indication of abundance**	**Comments**
Oncorhynchus mykiss Rainbow Trout	Gibraltar Creek, Rendezvous Creek, Rotten Swamp, Blue Gum Creek, Cotter River.	Common to abundant (up to 30 individuals per site)	Near mutually exclusive distribution with native Mountain Galaxias and spiny crayfish
Misgurnus anguillicaudatus Weatherloach	Cotter River, immediately above and below Cotter Dam	Common	In shallow edges
Gambusia holbrooki Eastern Gambusia	Cotter River, below Cotter Dam	Common	In shallow off-channel pools
Cyprinus carpio Common Carp	Cotter River, below Cotter Dam	Common	Main channel

3.4 Threatened species

Two species of threatened fishes were recorded (table 3 & 5) when targeting riffle habitat for galaxias on the Cotter River, namely Twospine Blackfish (all released at point of capture) and Macquarie Perch (juveniles observed and photographed). The populations of both species in the Cotter are regionally and nationally significant and receive active consideration in regional management (ACT Government 2018).

The two species of spiny crayfish recorded, although not listed under threatened species legislation in the ACT or Australia, are considered Endangered under the IUCN Red List (IUCN 2019) and are protected under the ACT *Fisheries Act 2000*.

Table 5. Threatened species (ACT listings as per ***Nature Conservation Act 2014***).			
Species	**Listing status and level (EBPC, State/Territory)**	**Location sighted/observed**	**Indication of abundance**
Twospine Blackfish *Gadopsis bispinosus*	Vulnerable (ACT)	Cotter River above Cotter Dam	Moderate
Macquarie Perch *Macquaria australasica*	Endangered (ACT), Endangered (EPBC)	Cotter River, Vanitys Crossing	Rare, juveniles recorded opportunistically
Alpine Spiny Crayfish *Euastacus crassus*	Not listed, but Endangered under IUCN Red List; protected under the ACT *Fisheries Act 2000*; and listed as threatened in Victoria	Upper Ginini Creek; Lees Creek; Gibraltar Creek	Rare to common; 802–1544 m asl
Riek's Crayfish Euastacus rieki	Not listed, but considered Endangered under the IUCN Red List; protected under the ACT *Fisheries Act 2000*	Cotter River, Top Flat; Little Creamy Flats; Rendezvous Creek, headwater swamp	Rare to common; 1137–1566 m asl

3.5 Range extensions

New site records and important extant refuge populations were documented for Mountain Galaxias, Alpine Spiny Crayfish and Reik's Crayfish (Table 6).

Table 6. Range extensions or significant infill in distribution records for species.

Species	Location sighted/observed	Distance from nearest known record (km)	Comments
Mountain Galaxias *Galaxias olidus*	Isolated refuge populations at: Cotter River, Top Flat; Little Creamy Swamp; Mckeahnie Creek; Sawpit Creek		Form part of the known historic distribution, but important modern records in the face of large range reduction
Alpine Spiny Crayfish *Euastacus crassus*	Ginini Creek; first record of this species in this drainage and at this elevation (1544)		This creek is the only waterway identified in the ACT with both spiny crayfish species. The site is very close to the potential interface between the two species
Riek's Crayfish *Euastacus rieki*	Rendezvous Creek		First record for this species in this creek

3.6 Genetic information

Tissue material was collected for Mountain Galaxias suitable for future genetic investigation to guide more detailed taxonomic appraisal. Morphological material from the survey all conformed to *Galaxias olidus* s.s. however considerable variability in shape and colour form was noted (see below images), and the characters to split species pairs in the hyper-cryptic species-complex are subtle, meaning that affirmation with genetic information would be desirable. Previous molecular systematic work on the group identified that mitochondrial DNA barcoding approaches have limited value in assessments of species boundaries, and that taxonomic investigations should be guided by bi-parentally inherited, co-dominant and conservative nuclear makers (Adams et al. 2014). Next generation technology is ideally suited to these sorts of studies (Unmack et al. 2017) and would require screening the populations sampled against a reference library of museum tissue samples of described species and previous ACT reference samples (Raadik 2012).

Genetic material was also collected for spiny crayfish that will aid a feedback loop between morphological characters and species recognition for the two similar ACT highland species.

Different phenotypes of Mountain Galaxias in the ACT (tissue vouchered specimens)

4. Information on species lists

Several other freshwater fish species and Murray Crayfish (*Euastacus armatus*) are known from the Murrumbidgee River main channel in the ACT either historically, as remnant populations or as reintroductions (see Lintermans 2000e, 2002; Lintermans and Osborne 2002). Genetic investigations are required to confirm if Mountain Galaxias sampled on the survey in the ACT represent a single variable species or if additional members of this hyper-cryptic species complex occur as new regional records or potentially species new to science.

5. Information for land managers

The importance of protecting refuge habitats for native fish was demonstrated at Lees Creek in Lower Cotter Catchment Reserve. Here trout previously dominated this small stream system, restricting native Mountain Galaxias to tiny habitat pockets. Trout control was undertaken above a small weir allowing habitat expansion protecting a refuge population (Lintermans 2000a). Shifting forward some years under differing climate conditions, the galaxias have survived and expanded their range with trout contracting further downstream (until any future wet sequence). Indeed a few mid-land sites where trout were expected to dominate the fauna, had large numbers of galaxias, perhaps reflective of recent dry conditions and drought differential mortality offering the native species some resilience (Closs and Lake 1996). Identifying key drought and fire refuges and implementing local site control (e.g. temporary stock exclusion fencing) should be considered in management plans for Namadgi National Park. Likewise a population of Mountain Galaxias in the eastern ACT within Kowen Forest should be carefully managed with respect to riparian condition and water quality.

Dispersal and recolonization in the landscape is an important part of population dynamics in variable environments like the ACT. The role of natural and artificial barriers have positive and negative influences on related dispersal and gene flow. Some artificial barriers are clearly beneficial in an altered landscape, for example by preventing upstream dispersal of introduced fishes (Lees Creek trout example above, Cotter Dam limiting upstream spread of Common Carp and Eastern Gambusia). Yet others like road pipe-culverts could create artificial barriers to dispersal required under different seasonal and inter-annual conditions. Specific site assessments should be undertaken to determine a positive or negative role of current and potential barriers, particularly when road upgrades are being undertaken, with fish passage modifications made where appropriate. Genetic rescue could be explored for small populations isolated above artificial and natural barriers in recognition of limited remaining natural populations and the need to preserve and facilitate adaptation in the face of current and future threats and climate (e.g. Weeks et al. 2017); each population would first need to be fully characterised genetically for species boundaries and genetic variation.

Fish stocking is no longer undertaken in natural streams of the ACT, although there is still a recreational fishery for trout linked to local wild recruitment in some areas, with fishing excluded in some water supply and threatened species habitats (ACT Government 2015). Some illegal or unintentional releases evidently still occur though (e.g. Gibraltar Creek). Localised trout management to balance conservation targets and recreational outcomes should continue to be explored.

Fire is considered a significant risk to the fish and aquatic systems of the region (ACT Government 2018). Both wild fire and inappropriate prescribed fires regimes, particularly if followed by heavy rainfall can result in sediment and ash flows. Sedimentation, riparian habitat and water quality changes and alteration to hydraulic connections can be catastrophic to small refuge populations. In addition, increased predation by native and introduced predators has been observed on montane spiny crayfish following removal of riparian habitat in creeks and bogs post fire (Carey et al. 2003).

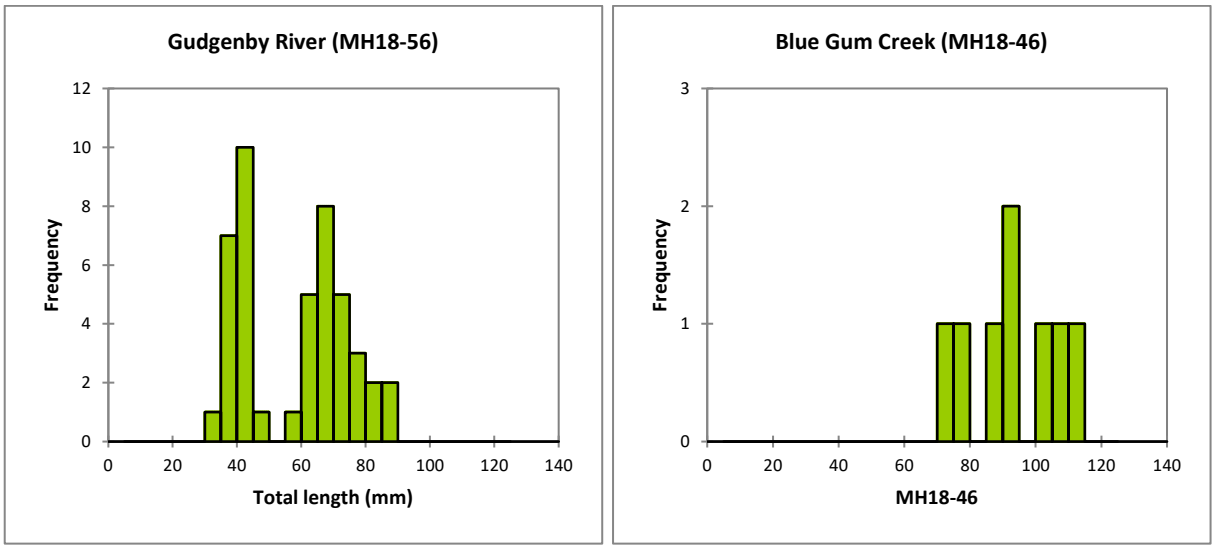
Numerous refuge populations were documented across different land-tenures (Table 1). Future sampling should monitor the status of refuge populations, and continue mapping other small sub-catchments. For example Ginini Falls is an impressive natural barrier that may protect an additional Mountain Galaxias population (or new species), however the prime stream section for investigation between the main and second falls could not be reached by vehicle or helicopter on this survey, and would require a targeted length hike through dense vegetation.

Ginini Falls, Cotter River catchment, ACT

6. Other significant findings

A fish leech was recorded on Twospine Blackfish from sites on the mid Cotter River (MH18-53); previous attempts to obtain an identity as native or introduced and known or undescribed, have proved elusive (M. Lintermans, pers. comm, 2019).

Length frequency information was gathered for 224 Mountain Galaxias ranging from 22–114 mm total length. A small proportion of fish (n= 7) were found to be in reproductive condition, either as running ripe males or gravid females, mostly from higher elevation sites. Recruitment (smaller young of year fish 20–50 mm total length) was detected at most sites, with one exception being Blue Gum Creek as above (co-occurring with trout in different microhabitats).



Example length frequency histograms for Mountain Galaxias – left showing strong recruitment and right only adult fish

Juvenile Mountain Galaxias from Glen Burn Creek (MH18-41)

7. Conclusions

The ACT Bush Blitz successfully sampled a diversity of habitat types including remote high altitude areas to help better map and understand the regional fish and decapod crustacean fauna. Important refuge populations were recorded for Mountain Galaxias including in the Namadgi National Park where introduced trout otherwise heavily dominate the fauna of stream environments. Future changes in feral animal distribution and abundance (aquatic and terrestrial), fire regimes and climate change present challenges to maintaining natural values in the alpine regions of the ACT.

Acknowledgements

We wish to thank the Traditional Owners of Namadgi National Park and surrounds for allowing us to conduct our surveys, and we recognise their continuing connection to land and water, paying our respects to Elders past, present and emerging. We also wish to thank ACT Parks staff for assisting with the survey and also by providing us with on-ground information regarding the terrain. The field assistance and enthusiasm of teachers participating in TeachLive was also gratefully received. We wish to thank the helicopter pilots, Birrigai staff and Bush Blitz team for their help on the survey.

References

ACT Government, 2015. Fish stocking plan for the Australian Capital Territory 2015–2020. Environment and Planning, ACT Government, Canberra. 18 pp.

ACT Government, 2018. ACT Aquatic and Riparian Conservation Strategy and Action Plan. Environment Planning and Sustainable Development Directorate ACT Government, Canberra.

Adams, M., Raadik, T.A., Burridge, C.P., Georges, A., 2014. Global biodiversity assessment and hyper-cryptic species complexes: more than one species of elephant in the room? Systematic Biology 63, 518–533.

Carey, A., Evans, M., Hann, P., Lintermans, M., MacDonald, T., Ormay, P., Sharp, S., Shorthouse, D., Webb, N., 2003. Wildfires in the ACT 2003: report on initial impacts on natural ecosystems. Technical report series. 17. ACT Government, Canberra.

Closs, G.P., Lake, P.S., 1996. Drought, differential mortality and the coexistence of a native and an introduced fish species in a south east Australian intermittent stream. Environmental Biology of Fishes 47, 17–26.

IUCN 2019. The IUCN Red List of Threatened Species. Version 2019-1. (International Union for Conservation of Nature.) http://www.iucnredlist.org, accessed 1 May 2019.

Jackson, J.E., Raadik, T.A., Lintermans, M., Hammer, M., 2004. Alien salmonids in Australia: impediments to effective impact management, and future directions. New Zealand Journal of Marine and Freshwater Research 38, 447–455.

Lintermans, M., 2000a. Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout *Oncorhynchus mykiss*. Marine and Freshwater Research 51, 799–804.

Lintermans, M., 2000e. The status of fish in the Australian Capital Territory: a review of current knowledge and management requirements. Environment ACT, Canberra. 108 pp.

Lintermans, M., 2002. Fishes of the upper Murrumbidgee Catchment: a review of current knowledge. Environment ACT, Canberra. 92 pp.

Lintermans, M., Osborne, W., 2002. Wet and Wild: A Field Guide to the Freshwater Animals of the Southern Tablelands and High Country of the ACT and NSW. Environment ACT, Canberra.

McCormack, R.B., 2012. A Guide to Australia's Spiny Freshwater Crayfish. CSIRO Publishing

Morgan, G.J., 1997. Freshwater crayfish of the genus *Euastacus*. Records of the Australian Museum Supplement 23, 1–110.

Raadik, T.A., 2012. Systematic revision of the Mountain Galaxias Galaxias olidus Günther species complex (Teleostei: Galaxiidae) in eastern Australia (in review). PhD thesis. University of Canberra, ACT.

Raadik, T.A., 2014. Fifteen from one: a revision of the *Galaxias olidus* Günther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species. Zootaxa 3898, 001–198.

Unmack, P.J., Sandoval-Castillo, J., Hammer, M.P., Adams, M., Raadik, T.A., Beheregaray, L.B., 2017. Genome-wide SNPs resolve a key conflict between sequence and allozyme data to confirm another threatened candidate species of river blackfishes (Teleostei: Percichthyidae: *Gadopsis*). Molecular Phylogenetics and Evolution 109, 415–420.

Weeks, A.R., Heinze, D., Perrin, L., Stoklosa, J., Hoffmann, A.A., van Rooyen, A., Kelly, T., Mansergh, I., 2017. Genetic rescue increases fitness and aids rapid recovery of an endangered marsupial population. Nature communications 8, 1071.

Whiterod, N.S., Zukowski, S., Asmus, M., Gilligan, D., Miller, A.D., 2017. Genetic analyses reveal limited dispersal and recovery potential in the large freshwater crayfish *Euastacus armatus* from the southern Murray–Darling Basin. Marine and Freshwater Research 68, 213–225.

Appendices

Appendix 1. List of Fishes and Decapod Crustaceans recorded during the ACT Bush Blitz.

Family	Species	Common name	Putative new species	Threatened (EPBC Act)	Threatened (State/Territory A	Exotic/pest	Record type (G=genetic sample; S=specimen collected; O=observation only)	Namadgi National Park	Lower Cotter Catchment	Cotter Reserve	Kowen Forrest
Fishes											
Cobitidae	*Misgurnus anguillicaudatus*	Weatherloach				Yes	S,G	x		x	
Cyprinidae	*Cyprinus carpio*	Common Carp				Yes	O			x	
Galaxiidae	*Galaxias olidus*	Mountain Galaxias					S,G	x	x	x	x
Percichthyidae	*Gadopsis bispinosus*	Twospine Blackfish			Vulnerable		O	x			
Percichthyidae	*Macquaria australasica*	Macquarie Perch		Endangered	Endangered		S,G	x			
Poeciliidae	*Gambusia holbrooki*	Eastern Gambusia				Yes	O			x	
Salmonidae	*Oncorhynchus mykiss*	Rainbow Trout				Yes	O	x			
Decapod Crustaceans											
ATYIDAE	Paratya australiensis	Glass Shrimp					S,G			x	x
PALAEMONIDAE	Macrobrachium australiense	River Prawn					S,G	x			
PARASTACIDAE	Cherax destructor	Yabby					S,G			x	x
PARASTACIDAE	Euastacus crassus	Alpine Spiny Crayfish					S,G	x	x		
PARASTACIDAE	Euastacus rieki	Reik's Crayfish					S,G	x			