Stocky Galaxias – review of existing information, Snowy 2.0

T.A. Raadik and M. Lintermans

December 2022

Arthur Rylah Institute for Environmental Research
Published Client Report

Arthur Rylah Institute for environmental research

VICTORIA State Government | Environment, Land, Water and Planning

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.ari.vic.gov.au

Citation: Raadik, T.A. and Lintermans, M. (2022). Stocky Galaxias – review of existing information, Snowy 2.0. Published client report for Snowy Hydro Ltd, Cooma. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: (clockwise from top) Murrumbidgee River at junction with Tantangara Creek; Macquarie Perch; alpine plain in snow; Stocky Galaxias (Images: Tarmo A. Raadik).

© The State of Victoria Department of Environment, Land, Water and Planning 2022

This work is licensed under a Creative Commons Attribution 3.0 Australia licence. You are free to re-use the work under that licence, on the condition that you credit the State of Victoria as author. The licence does not apply to any images, photographs or branding, including the Victorian Coat of Arms, the Victorian Government logo, the Department of Environment, Land, Water and Planning logo and the Arthur Rylah Institute logo. To view a copy of this licence, visit http://creativecommons.org/licenses/by/3.0/au/deed.en

Edited by David Meagher, Zymurgy SPS.

ISBN 978-1-76136-199-9 **(pdf/online/MS word)**

Disclaimer
This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Accessibility

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136 186, email customer.service@delwp.vic.gov.au or contact us via the National Relay Service on 133 677 or www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
Heidelberg, Victoria

Stocky Galaxias – review of existing information, Snowy 2.0

Tarmo A. Raadik[1] and Mark Lintermans[2]

[1] Arthur Rylah Institute for Environmental Research
123 Brown Street, Heidelberg, Victoria 3084

[2] Threatened Fish Services
60 Turallo Terrace, Bungendore, NSW 2621

Caveat: This report was completed in October 2021 and consequently does not contain more recent information which may have become available, such as the discovery of a second population of Stocky Galaxias (see Lintermans, M., Raadik, T.A. and Unmack, P.J. (2021). Taking stock of Stocky's: The discovery of a second population of the threatened Galaxias tantangara in the upper Murrumbidgee catchment. *Fishes of Sahul* 35(4), 1812–1826).

Arthur Rylah Institute for Environmental Research
Published Client Report for Snowy Hydro Ltd, Cooma, Department of Environment, Land, Water and Planning

Acknowledgements

We wish to thank Luke Pearce (NSW DPI) and Hugh Allan (University of Canberra) for the provision of valuable information on recent activities related to Stocky Galaxias. Daniel Stoessel (DELWP-ARI), Lizzie Pope (Snowy Hydro) and Lachlan Barnes (SLR), are thanked for providing comments on earlier drafts of this report. Lindy Lumsden (ARI) provided invaluable additional comments on the final draft of this document.

Contents

Figures

1 Introduction

Snowy Hydro Limited received approval in 2020 to construct a new large-scale pumped hydro-electric storage and generation scheme (Snowy 2.0), to increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme. This will involve the connection of the existing Talbingo and Tantangara reservoirs via a series of underground pipes and an underground power generation station. Water will be transferred in both directions between the reservoirs, which are in separate river catchments.

The Arthur Rylah Institute for Environmental Research has been engaged by Snowy Hydro Limited to provide specialist advice that can inform the selection of options and preparation of various aquatic Management Plans required as part of the NSW and Commonwealth approvals for the Snowy 2.0 project. This report provides a review of existing information on Stocky Galaxias (*Galaxias tantangara*) to July 2021.

1.1 Relevance to priority conservation actions

Priority actions for Stocky Galaxias identified by NSW DPI (2017) that are relevant to this document include:

- *Collate existing data on the habitat, abundance and population parameters and identify knowledge gaps for the purpose of targeting future research activities (High priority).*

A summary of all priority actions is detailed in Appendix A.

2 Methods

Here we review and summarise key documents that have detailed the species appearance, biology, ecology, threats, and recovery actions specific to the study area. Documents used for this exercise were the aquatic assessment for the Main Works Environmental Impacts Study (Cardno 2019), Raadik (2018), Allan and Lintermans (2019), and Lintermans and Allan (2019). Additional knowledge gaps identified in these documents, including developments since these publications, such as Allan et al. (2021) and Zukowski et al. (2021), were also considered and included in the review.

Very little published information is available on the distribution, biology, and ecology of Stocky Galaxias, besides that included in the original description of the species (Raadik 2014), with many recent general publications largely repeating this information (e.g., Zukowski et al. 2021). Consequently, only a few sources of primary literature are currently known for this species (i.e., Raadik 2014, Allan and Lintermans 2019, Lintermans and Allan 2019, Allan and Lintermans 2021, Allan et al. 2021).

This review provides a summary of the following information about Stocky Galaxias:

- Description.
- Distribution.
- general ecology (habitat, movement, reproduction and growth, density, diet, parasites).
- conservation status.
- Threats.
- recovery priorities.
- current management.
- key knowledge gaps.

3 Description

Stocky galaxias is a small (up to 115 mm, commonly 75–85 mm in length, up to 17 g in weight), scale-less, native freshwater fish. Only recently formally described as a new species 2014 (Raadik 2014), Stocky Galaxias is part of the Mountain Galaxias (*Galaxias olidus*) complex, that presently comprises 15–18 species (both described and undescribed) in south-eastern Australia. Species in the complex are very similar morphologically (Raadik 2014, 2018), and accurate identification can be difficult without expert morphological assessment (Raadik 2018). The species (Figure 1) has translucent fins, numerous dark brown/black blotches over the top and sides of its body, dark grey blotching extending over the top and sides of its head, lips, and extending beneath the lower jaw, and the body and head on larger fish can be quite stout, with a short and deep tail (Raadik 2014).

Figure 1. Stocky Galaxias (*Galaxias tantangara*), Tantangara Creek, November 2016 (image: Tarmo A. Raadik).

4 Distribution

Stocky Galaxias is known from an extremely small range, in one small creek in the headwaters of the upper Murrumbidgee River, upstream of Tantangara Reservoir (Raadik 2014, Lintermans 2019). This single population is restricted to a short (approximately 3 km), narrow (1.0 m wide), shallow section of the upper reaches of Tantangara Creek (Figure 2), upstream of a natural waterfall approximately 4 m high (Raadik 2014, Raadik 2019). The species is thought to have been historically more widespread in the upper Murrumbidgee River catchment before the introduction of trout (Raadik 2014, Lintermans and Allan 2019) and is thought to have undergone a decline of > 90% of its range (NSW FSC 2016, Lintermans 2019). Occasional, additional surveying in this area since the species was first discovered in 2002 (Raadik 2014), has not detected additional individuals or populations (Raadik 2018, Lintermans 2019, M. Lintermans unpublished data, T. Raadik, unpublished data).

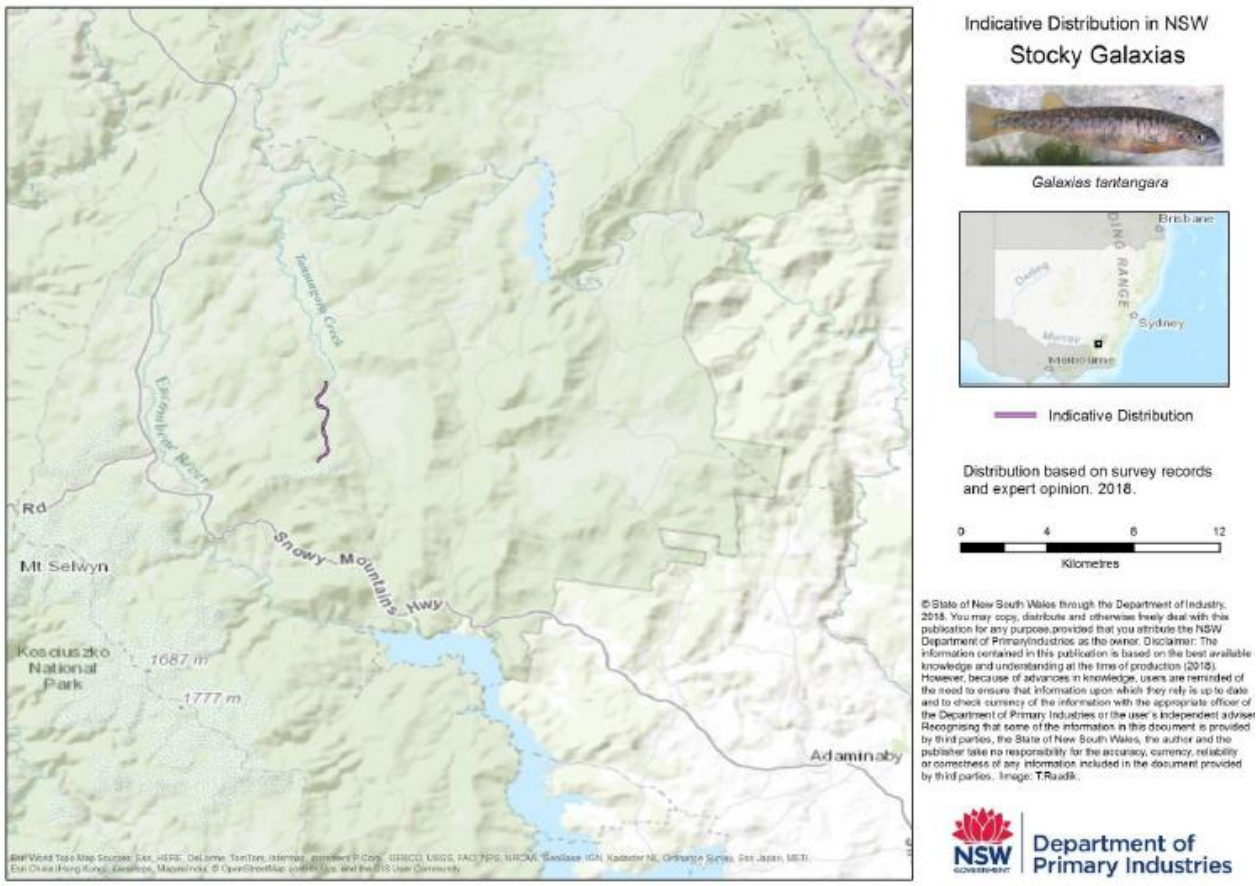

Figure 2. Known distribution of Stocky Galaxias in the upper reaches of the Murrumbidgee River, upstream of Tantangara Reservoir (from NSW DPI 2018).

5 General ecology

Although very little has been published on the biology and ecology of Stocky Galaxias, it is expected to be like that of other higher-elevation species in the Mountain Galaxias complex (Raadik 2014).

5.1 Habitat

The species is found at an elevation of 1360 m, extending upstream to about 1500 m, and experiences persistent snow between mid to late-May and early- to mid-October (Raadik 2014, H. Allan unpublished data). Water temperature during this period regularly declines to < 2 °C (Allan et al. 2021), and ice may form on the top of shallow pools in upper reaches. Summer water temperatures are regularly recorded up to 18° C, and occasionally higher (approaching 20 °C). The habitat of the only known population is a small, cold, fast-flowing, clear, alpine creek (Tantangara Creek) that flows through an open forest of eucalypts, low shrubs, and tussock grasses located in the headwaters of the Upper Murrumbidgee catchment upstream of Tantangara Reservoir (Raadik 2014, Lintermans and Allan 2019, Allan et al. 2021). Within the habitat upstream of the waterfall, the first 200 m is relatively steep, with faster flow, and a substrate composed predominantly of bedrock and boulder and is considered marginal habitat. This differs to the rest of the system further upstream which has a gentler grade, a substrate predominantly composed of boulders, cobbles, pebbles, and smaller amounts of gravel and silt. Stream flow in this section consists largely of glide and riffle habitats, with smaller areas of quieter flow along the edges of some pools. Instream cover for fish is predominantly provided by instream rocks and bank and vegetation overhang (Raadik 2014, Lintermans and Allan 2019).

Water temperature during the spawning and egg development stages (mid-November to late December) varied from 6.8–16.3 °C. Limited water quality data collected in autumn indicate Stocky Galaxias are found in very fresh (electrical conductivity < 25), clear (turbidity < 5 NTU), well oxygenated (> 8.0 mg/L) and soft (hardness < 15 ppm $CaCO_3$) water with a slightly elevated pH of 8 (T. Raadik, unpublished data).

Like other species of galaxiids in the Mountain Galaxias complex, Stocky Galaxias is the only species of native fish found within its headwater distribution (Raadik 2014). As such, it potentially plays a crucial role in the ecology of Tantangara Creek, as it is the only primary aquatic predator. Importantly, it also represents 100% of the native fish diversity in the headwaters of the Tantangara catchment, although Mountain Galaxias are known from further downstream in the Murrumbidgee River (Raadik 2018).

5.2 Movement

Stocky Galaxias is confined to freshwater and is not known to migrate long distances as part of its life cycle. Its local movement patterns are probably like that of Mountain Galaxias, with a potential home range limited to less than 100 m (NSW DPI 2018). The species also appears to lack fin ray lamellae on the pectoral and pelvic fins, which are found in most of species in the Mountain Galaxias complex. These structures assist upland galaxiids in climbing over moist rocks when out of the water in steep, fast-flowing catchments, and may also assist in overland dispersal during wet weather between close headwater tributaries (Raadik 2014). The likely inability to climb may therefore limit the upstream movement and dispersal of Stocky Galaxias.

5.3 Reproduction and growth

Like all species of *Galaxias*, spawning is thought to be annual and to occur over a short time. The spawning period of Stocky Galaxias appears to be in mid to late spring (late October to mid- November), although this is from a study undertaken over a single spawning season (Allan et al. 2021). Allan et al. (2021) also found the sex ratio averaged 3.9 : 1 (males/females), males were found to mature at about 50 mm in length, and females at about 70 mm in length. Males can be reproductively ripe in all months of the year whilst females were found with ripe gonads also in November, February, and March. Peak gonad development for males was in March/April and October for females, and spent females and eggs were found in mid-late November (Allan et al. 2021). Fecundity is relatively low, ranging from 211 to 810 oocytes in fish 76 and 100 mm in length, respectively.

Based on observations of a single egg mass found laid on the underside of a cobble which was slightly raised off the stream substrate at the upstream end of a riffle in mid-November, water hardened eggs are

spherical, sticky, range in diameter between 1.2–2.2 mm (*n* = 256), and can be composed of multiple clusters, each of multiple layers (Figure 3) (Allan and Lintermans 2019, Allan et al. 2021). All eggs had hatched 27 days after being found (possibly 35–40 days after being laid based on back-calculation to when spent fish were first noticed). Free-swimming larvae, about 10.1 mm in length, were found in late December, swimming in schools of about 20 individuals, in slow flowing sections of stream.

Figure 3. Stocky Galaxias egg mass on the underside of cobble (adapted from Allan and Lintermans 2019).

The following May (approximately 5 months post-hatch), juveniles were between 25–43 mm in length (*n* = 21) and presumed 1 year old fish averaged 44 mm in length in December (Allan et al. 2021).

5.4 Density, diet, parasites

Little is known about variation in fish density, although Raadik (2014) recorded 1.8 fish/m^2 in mid-March 2002. The species' diet is thought to comprise aquatic insect larvae and terrestrial insects that fall into the water from stream edges (NSW DPI 2018). A fish was found to be infected with a parasitic worm (possibly a trematode) in the mouth and more amongst fat deposits around the stomach in the body cavity (Raadik 2014).

6 Conservation status

Stocky Galaxias is known from a single, small population in Tantangara Creek, occupying approximately 3000 m^2, but is considered to have once been more widespread. It has been listed as critically endangered in NSW since 2016 under the *Fisheries Management Act 1994* (NSW FSC 2016), assessed in detail as critically endangered nationally (NSW FSC 2019) and globally (Lintermans and Allan 2019), nationally listed as critically endangered under the *Environment Protection Biodiversity Conservation* (EPBC) *Act 1999* in 2021 (TSSC 2021). It is also considered as one of Australia's most threatened freshwater fishes (Lintermans et al. 2020).

The species is at an extremely high risk of extinction from stochastic events such as predator invasion, fire, or drought, given its extremely small global range (0.003 km^2) which supports one small population (Lintermans and Allan 2019). The population is protected from predatory introduced trout (primarily Brown Trout, *Salmo trutta*) by a natural waterfall which prevents trout moving further upstream (Raadik, 2014, Raadik 2019).

Further, due to the small size of the remaining population, the species is projected to have reduced adaptive potential and genetic fitness due to a loss of genetic diversity, and therefore its ability to persist and adapt to environmental changes is likely compromised (sensu Pavlova et al. 2017).

7 Threats

Stocky Galaxias is at high risk of extinction from threatening processes, which are exacerbated by its single, small global population (Lintermans and Allan 2019).

The primary threat to its persistence, and the reason for its restricted distribution, is **predation by introduced trout.** One natural waterfall is preventing trout access to the existing stocky galaxiid population, thereby preventing their extinction (Raadik 2014, Lintermans and Allan 2019, Lintermans et al. 2020).

Other important threats are:

Other introduced fish species – competition and predation by the native Climbing Galaxias (*Galaxias brevipinnis*), and competition with Oriental Weatherloach (*Misgurnus anguillicaudatus*) should they establish within habitat of the Stocky Galaxias at some point in the future (Lintermans and Allan 2019). Climbing Galaxias is present in the Tumut River system upstream of Blowering Dam, and oriental Weatherloach is known to occur up to the mid-reach of the Murrumbidgee River system near Cooma (Cardno 2019).

Drought – degradation or loss of the last known aquatic habitat in which the species exists (Lintermans and Allan 2019).

Intense rainfall events – increased risk of soil erosion and instream sedimentation, flushing of fish over the waterfall into the predator zone below.

During **fire** – mortality caused by increasing water temperature, particularly in shallow sections of stream, and the temporary loss of surface water due to evaporation in small shallow tributaries.

Genetic decline – Loss of evolutionary potential and adaptability through decline in effective population size and isolation, leading to inbreeding and loss of genetic diversity.

Habitat degradation – through loss of riparian vegetation and bank degradation and erosion by trampling from hard hoofed pest animals and bushfires (Driscoll et al. 2019; M Lintermans, unpublished data).

Increased **instream sedimentation** – including mesohabitat alteration or loss from sediment from pest animals (see above) and particularly during intense post-fire rainfall events (Allan and Lintermans 2018, Driscoll et al. 2019; M. Lintermans, unpublished data).

Climate change – a long-term threat influencing changes in many environmental parameters within the species range (Lintermans and Allan 2019).

8 Recovery priorities

Draft recovery priorities for Stocky Galaxias have been identified by NSW DPI (2017) in the NSW Priorities Action Statement (PAS) for Stocky Galaxias. This is a statutory document setting out the strategies and actions for promoting the recovery of the species and establishes priorities for the implementation of actions relating to consent authorities, collating information, community and stakeholder liaison, compliance/enforcement, habitat protection and rehabilitation, pests, research/monitoring, stocking/translocation, and survey/mapping. For specific details of actions for each of these, see Appendix A.

Nationally, TSSC (2021) has not recommended a national species recovery plan for Stocky Galaxias but refers to the Conservation Advice document for the species (TSSC 2021). This conservation advice reproduces the CAM Assessment for *Galaxias tantangara* (NSW FSC 2019), which in turn contains 10 management and research recommendations for Stocky Galaxias, as well as referring to the draft PAS for the species (NSW DPI 2017).

All actions in the draft PAS and CAM Assessment/Conservation Advice are provided in Appendix A, given numbers corresponding to the order of their appearance in the documents, and with similar actions grouped under the headings from the draft PAS and mapped between the documents.

Essentially, many of the key actions are like those in the national recovery plan for Barred Galaxias (*Galaxias fuscus*), a critically endangered, headwater, trout-impacted species in the Mountain Galaxias complex from Victoria (Raadik et al. 2010).

The specific critical actions dealing with directly protecting Stocky Galaxias, some of which are of relevance to this project, can be summarised as follows:

- Collation of existing data.
- Predator (trout) control – incursion surveillance and removal if found.
- Barrier construction or enhancement to prevent the upstream incursion of trout and other species.
- Searching for additional, remnant populations or potential translocation sites.
- Monitoring populations to assess trends in abundance and distribution to identify emerging issues.
- Improvement of potential translocations sites (if needed) – works required to improve the condition of potential translocation sites, such as barrier modification (improve barrier efficacy), and predator removal.
- Establishing new populations to spread extinction risk (wild to wild, or hatchery to wild).
- Captive breeding – developing a captive breeding technique and producing captive bred fish when required.
- Genetic management – management of population genetic diversity to maximise evolutionary potential.
- Sedimentation management – preventing sediment input to, or soil disturbance within, the catchment, from roading, mechanical works or feral animals.
- Protection and restoration of riparian habitat in Tantangara Creek.
- Research to inform management.

9 Current management

There is no currently funded conservation program for Stocky Galaxias. The following work has recently been undertaken albeit limited and sporadic in nature and extent based on the availability of funding:

- Establishment of an unofficial Threatened Galaxias Advisory Team in July 2020, chaired by NSW DPI's Threatened Species Unit.
- Some biological research and barrier detection/characterisation method development as part of an ongoing PhD research project (Hugh Allan, University of Canberra), although all field work involving fish collection is completed (see Allan et al. 2021, Allan and Lintermans 2021).
- Salvage of about 140 Stocky Galaxias during the 2019/20 Fires (Mark Lintermans and NSW DPI) . and continued captive management at the NSW DPI Gaden Trout Hatchery at Jindabyne, and at Charles Sturt University campus at Albury (Thurgoona).
- Additional collection from the wild of about 40 early juveniles in late January 2021 to improve knowledge of captive husbandry requirements (M. Lintermans) which are current housed at Charles Sturt University campus at Albury (Thurgoona), and NSW DPI Gaden Trout Hatchery at Jindabyne.
- Completion of feral horse exclusion fences at two locations on Tantangara Creek to manage habitat destruction and sediment input (M. Lintermans, NSW DPI, NSW National Parks and Wildlife Service).
- Rapid post-fire population persistence assessment (M. Lintermans and H. Allan, unpublished data).
- Preliminary investigation by NSW DPI of the suitability of an area in the Eucumbene River catchment next to Eucumbene Reservoir, known as The Borrows, as a potential refuge translocation site for Stocky Galaxias (L. Pearce, pers. comm.).
- Recent sampling for freshwater fish at four sites in the mid reaches of the nearby Cotter and Gudgenby river catchments (Hammer and Beitzel 2019) — only Mountain Galaxias were recorded at each location.
- Detection of a population of galaxiids in the Mountain Galaxias complex from a headwater stream in the Goodradigbee River catchment in 2021; species identification not fully confirmed but may include Stocky Galaxias (M. Lintermans, unpublished data).
- Publication of a national assessment of the conservation status of Stocky Galaxias (NSW FSC 2019, TSSC 2021).
- Publication of draft actions for the conservation of Stocky Galaxias (NSW DPI 2019, TSSC 2021).
- Publication of the international conservation status and threats of Stocky Galaxias (Lintermans and Allan 2019).
- Recognition of Stocky Galaxias as one of the 22 most threatened Australian freshwater fishes (Lintermans et al. 2020).

10 Key knowledge gaps

With respect to the species, four key knowledge gaps have been identified.

10.1 Distribution

Whilst Stocky Galaxias is only known from a single, small, population in the headwaters of a narrow headwater stream, its former distribution is considered to have been much larger (Raadik 2014, NSW FSC 2016), extending across and further downstream in the upper Murrumbidgee River catchment (i.e., above and below Tantangara Dam down to approximately Adaminaby), and possibly also into the headwaters of adjacent catchments such as the Goodradigbee, Goobarragandra, upper Tumut, upper Eucumbene, and upper Geehi.

Similar multi-catchment headwater distributions are also known from another upland fish (*Gadopsis bispinosus*) in the Snowy Mountains with multiple historic headwater catchment capture events suspected. This historical distribution of Stocky Galaxias was almost certainly subsequently severely fragmented and reduced by trout following their introduction. While populations of galaxiids would have initially remained in small, isolated areas where trout could not reach, some may still persist although most would have been eliminated due to further trout incursion, genetic decline, or a range of other stochastic events such as fire or drought. Consequently, detailed catchment surveys are required to determine if other small, isolated populations of Stocky Galaxias remain across this landscape, within the predicted, or potential, former range.

10.2 Captive breeding

Artificial production of fish is a valuable conservation tool to enable population recovery and expansion, particularly if natural source populations are too small to be harvested for individuals without causing an impact. Whilst some aspects of the wild breeding biology of Stocky Galaxias are known (Allan et al. 2021), the ability to maintain fish in captivity, and to produce viable offspring from captive breeding, remains largely unknown.

10.3 Age

The age at sexual maturity, or longevity of Stocky Galaxias is unknown. These parameters are critical for developing a population model for the species, for determining the status of populations for conservation assessments, and to identify age cohorts to understand recruitment success over time. A collection of otoliths, ear bones used for ageing fish, is available for Stocky Galaxias from fish sacrificed for recent reproductive work (see Allan et al. 2021); these remain un-analysed.

10.4 Genetic diversity

The genetic diversity of the remnant population is unknown. This knowledge is important to understand the genetic health, or evolutionary potential, of the species, and is valuable to document and monitor over time to establish a baseline against which to compare potential declines. A sudden decline in genetic diversity, particularly for a short-lived species such as Stocky Galaxias, is an earlier warning of population deterioration than that provided by metrics such as the persistence, size, and number of individuals. A collection of tissue samples appropriate for genetic analysis may be available from previous surveys (H. Allan, University of Canberra, pers. comm.); these remain un-analysed.

11 References

Allan, H., Duncan, R.P., Unmack, P., White, D. and Lintermans, M. (2021). Reproductive ecology of a critically endangered alpine galaxiid. *Journl of Fish Biology* **98**, 622–633.

Allan, H. and Lintermans, M. (2018). The threat from feral horses to a critically endangered fish. In: Worboys, G.L., Driscoll, D. and Crabb, P. (eds), Feral Horse Impacts: The Kosciuszko Science Conference , pp. 88-89. Australian Academy of Science, the Australian National University and Deakin University, Canberra.

Allan, H. and Lintermans, M. (2019). *Current ecological knowledge of the critically endangered Stocky Galaxias* Galaxias trantangara. Consultancy repor to EMM Consulting Pty Ltd.

Allan, H. and Lintermans, M. (2021). *Investigating the utility of drones to identify potential fish refugia.* A Report to the Threatened Fishes Committee, Australian Society for Fish Biology. University of Canberra, Canberra, ACT.

Cardno (2019). *Appendix M.2 Aquatic Ecology Assessment, Snowy 2.0 Main Works*. Prepared for EMM Consulting Pty Ltd. Cardno, St Leonards, NSW.

Driscoll, D.A., Worboys, G.L., Allan, H., Banks, S.C., Beeton, N.J., Cherubin, R.C., Doherty, T.S., Finlayson, C.M., Green, K., Hartley, R., Hope, G., Johnson, C.N., Lintermans, M., Mackey, B., Paull, D.J., Pittock, J., Porfirio, L.L., Ritchie, E.G., Sato, C.F., Scheele, B.C., Slattery, D.A, Venn, S., Watson, D., Watson, M. and Williams,, R.M. (2019). Impacts of feral horses in the Australian Alps and evidence-based solutions. *Ecological Management & Restoration* **20**(1), 63–72.

Hammer, M. and Beitzel, M.(2019). *Fish and crayfish. Australian Capital Territory Region Bush Blitz, 25 November – 6 December 2018*. Report submitted to the Director of National Parks.

Lintermans, M. (2019). *A review of fish information from the Upper Murrumbidgee and Upper Tumut catchments*. Consultant's report to EMM Consulting Pty Ltd.

Lintermans, M. and Allan, H. (2019). *Galaxias tantangara*. The IUCN Red List of Threatened Species 2019: e.T122903246A123382161. http://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T122903246A123382161.en

Lintermans, M., Geyle, H.M., Beatty, S., Brown, C., Ebner, B., Freeman, R., Hammer, M., Humphreys, B., Kennard, M.J., Kern, P., Martin, K., Morgan, D., Raadik, T.A., Unmack, P.J., Wager, R., Woinarski, J.C.Z., and Garnett, S.T. (2020). Big trouble for little fish: Australian freshwater fishes in imminent risk of extinction. *Pacific Conservation Biology* **26**(4), 365–377.

NSW DPI. (2017). *Priorities Action Statement – Draft Actions for Stocky Galaxias*. NSW Department of Primary Industries, Crows Nest. Available at: https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/critically-endangered-species/stocky-galaxias/priorities-action-statement-draft-actions-for-stocky-galaxias (accessed 14 May 2021).

NSW DPI. (2018). *Stocky galaxiid* – Galaxias tantangara*.* Primefact 1443. October 2018. NSW Department of Primary Industries, Crows Nest. Available from: https://www.dpi.nsw.gov.au/fishing/threatened-species/what-current/critically-endangered-species/stocky-galaxias/primefact-stocky-galaxias

NSW FSC (Fisheries Scientific Committee). (2016). *Final determination:* Galaxias tantangara – *stocky galaxias as a Critically Endangered species*. NSW Fisheries Scientific Committee. Part 7A of The NSW Fisheries Management Act 1994. NSW Department of Primary Industries, Crows Nest, NSW.

NSW FSC (Fisheries Scientific Committee). (2019). *CAM Assessment* Galaxias tantangara. NSW Department of Primary Industries, Crows Nest, NSW.

Pavlova, A., Beheregaray, L.B., Coleman, R., Gilligan, D., Harrisson, K.A., Ingram, B.A., Kearns, J., Lamb, A.M., Lintermans, M., Lyon, J., Nguyen, T.T.T., Sasaki, M., Tonkin, Z., Yen, J.D.L., and Sunnucks, P. (2017). Severe consequences of habitat fragmentation on genetic diversity of an endangered Australian freshwater fish: A call for assisted gene flow. *Evolutionary Applications* **10**(6), 531–550.

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**, 1–198.

Raadik, T.A. (2018). *Identification of galaxiid species (Telostei, Galaxiidae) from the area of the proposed Snowy 2.0 Project*. Unpublished client report to EMM Consulting Pty Ltd. Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Raadik, T.A., Fairbrother, P.S. and Smith, S.J. (2010). *National recovery plan for the Barred Galaxias (*Galaxias fuscus*)*. Department of Sustainability and Environment, Heidelberg, Victoria. Available from: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=26168#recovery_plan_loop

Threatened Species Scientific Committee (TSSC) (2021). *Conservation Advice* Galaxias tantangara *Stocky Galaxias*. Department of Agriculture, Water and the Environment, Canberra. Available from: http://www.environment.gov.au/biodiversity/threatened/species/pubs/87879-conservation-advice-03032021 (accessed 4 May 2021).

Zukowski, S., Whiterod, N., Ellis, I., Gilligan, D., Kerezsy, A., Lamin, C., Lintermans, M., Mueller, S., Raadik, T.A. and Stoessel, D. (2021). *Conservation translocation handbook for New South Wales threatened small-bodied freshwater fishes*. A report to the New South Wales Department of Primary Industries Fisheries. Aquasave–Nature Glenelg Trust, Victor Harbor.

Appendix A. Management and research actions recommended for Stocky Galaxias in NSW in the Priorities Action Statement, and nationally in the National Recovery Plan.

Actions are numbered in the order they appear in the documents, and similar actions from each document are mapped to each other.

Priorities Action Statement (NSW DPI 2017)	Common Assessment Method (NSW FSC 2019) / federal Conservation Advice (TSSC 2021)
Advice to consent and determining authorities	
1. Provide information on the distribution of the Stocky Galaxias to local councils and determining authorities to ensure appropriate consideration during development assessment processes (High priority).	
Collate and review existing information	
2. Collate existing data on the habitat, abundance and population parameters and identify knowledge gaps for the purpose of targeting future research activities (High priority).	
Community and stakeholder liaison, awareness and education	
3. Implement education initiatives to improve awareness of the status of Stocky Galaxias and ways to minimise impacts on the species by preparing and distributing appropriate advisory material (High priority).	
4. Communicate the impact that salmonid invasion upstream of the delimiting waterfall will have on the only known population of Stocky Galaxias (**High priority)**.	
5. Install signs and/or interpretive displays at appropriate locations to assist with identification and awareness of Stocky Galaxias **(High priority)**.	
6. Ensure research findings are publicised and incorporated into catchment management and river health programs where appropriate **(High priority)**.	
7. Encourage community reporting of Stocky Galaxias via the NSW DPI Threatened and Pest Species Sightings Program online form **(Medium priority)**.	
Compliance / enforcement	
8. Maximise compliance with the ban on collecting Stocky Galaxias by communicating with aquarium enthusiasts using a number of communication mediums (e.g. aquarium industry journals, newsletters, conferences) (Medium priority).	
Habitat protection	
9. Protect and restore riparian habitat in Tantangara Creek which supports the only known habitat for Stocky Galaxias (High priority).	9. Management measures to reduce the abundance of feral horses within the distribution of *G. tantangara*.

Priorities Action Statement (NSW DPI 2017)	Common Assessment Method (NSW FSC 2019) / federal Conservation Advice (TSSC 2021)
10. Ensure Stocky Galaxias conservation requirements are included in fishway programs (Medium priority).	
Habitat rehabilitation	
11. Undertake work to identify, restore and protect known and potential Stocky Galaxias habitats and address key threats such as habitat degradation and loss (High priority).	9. Management measures to reduce the abundance of feral horses within the distribution of *G. tantangara*.
12. Actively seek funds through grant schemes or other sources to implement riparian vegetation and water quality improvement projects in priority areas **(High priority)**.	
13. Undertake priority rehabilitation, restoration and enhancement work at Tantangara Creek **(High priority)**.	9. Management measures to reduce the abundance of feral horses within the distribution of *G. tantangara*.
Pest eradication and control	
14. Investigate and implement integrated management of introduced species in and adjacent to identified Stocky Galaxias habitat and take action to prevent the spread of introduced species into these habitats	4. Undertake predator (trout) removal, if present, from potential translocation sites. 10. Measures to prevent the transfer of invasive *G. brevipinnis* during water transfers.
	6. Assessment of all populations for security from trout incursion: implement annual predator detection and removal for less secure sites, and every 5 years (or following 1: 50-year rainfall events) at other locations.
	3. Identification of streams suitable for trout barrier installation (or augmentation)
Research / monitoring	
15. Actively seek grants or investor partnerships to fund research and monitoring programs for Stocky Galaxias **(High priority)**.	
16. Investigate spawning cues, particularly the influence of river flows **(Medium priority)**.	1. Study…the species' ecology… (reproduction, growth, habitat use, age, movement).
17. Investigate distribution, habitat and movements **(Medium priority)**.	1. Study…the species' ecology…(reproduction, growth, habitat use, age, movement).
18. Monitor the population at Tantangara Creek over time to assess trends in abundance and distribution and to identify emerging threatening processes **(Medium priority)**.	7. Population genetic analysis of current and new populations, to inform translocation plan and specific population management.
19. If other populations are discovered, undertake a genetic assessment of population structure throughout the species' range **(Low priority)**.	7. Population genetic analysis of current and new populations, to inform translocation plan and specific population management.
20. Actively encourage community involvement in aspects of Stocky Galaxias recovery including for example, research and monitoring programs **(Low priority)**.	

Priorities Action Statement (NSW DPI 2017)	Common Assessment Method (NSW FSC 2019) / federal Conservation Advice (TSSC 2021)
Stocking / translocation	
21. Undertake emergency rescues of Stocky Galaxias in response to droughts, oil spills/ pollution, detection of biosecurity threats (e.g. disease or pests), or to avoid other detrimental impacts **(High priority)**.	
22. Prevent salmonid stocking into Stocky Galaxias habitat areas, including above the delimiting waterfall which is currently the only natural barrier for invasion to the habitat of the Stocky Galaxias **(High priority)**.	
23. Ensure important populations and locations are protected from stocking of trout **(High priority)**.	
24. Implement the NSW Freshwater Fish Stocking Fishery Management Strategy to prevent significant impacts from stocking on Stocky Galaxias populations **(High priority)**	
25. Identify potential candidate sites for possible future translocation of Stocky Galaxias **(Medium priority)**	2. Further survey work to locate potential trout-free sites for future translocation.
	8. Formulation of a detailed translocation plan and undertake translocations to establish additional, viable populations to spread extinction risk.
Survey / mapping	
26. Survey similar habitat areas to Tantangara Creek to determine if other populations of Stocky Galaxias occur **(High priority)**.	5. Broadscale fish survey work in upper Murrumbidgee catchment to locate additional populations.
27. Identify and map important habitat (rivers/locations), particularly for recruitment and as potential drought refuge habitat **(High priority)**.	5. Broadscale fish survey work in upper Murrumbidgee catchment to locate additional populations.
28. Collect data on the presence/absence of Stocky Galaxias during incidental surveys **(Medium priority)**.	5. Broadscale fish survey work in upper Murrumbidgee catchment to locate additional populations .
Community and stakeholder liaison, awareness and education	
3. Implement education initiatives to improve awareness of the status of Stocky Galaxias and ways to minimise impacts on the species by preparing and distributing appropriate advisory material (High priority).	

www.delwp.vic.gov.au

www.ari.vic.gov.au