08 November 2019

To: Anthony Ko
Major Projects
NSW Department of Planning, Industry and
Environment

Submission on Snowy 2.0 Main Works Environmental Impact Statement: initial submission

Please find attached an initial submission on the **Snowy 2.0 Main Works Environmental Impact Statement**

As discussed previously , this submission is submitted after the official closing date as a result of my ill health over the last 10 days.

I thank Major Projects, NSW Department of Planning, Industry and Environment for granting me a small extension to provide this initial submission. I intend to provide a subsequent submission by 13/11/2019 including additional details of concerns with the Snowy 2.0 Main Works Environmental Impact Statement.

Yours sincerely

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Preamble

Initiatives to reduce Australias reliance on fossil fuels for electricity generation are welcomed, but initiatives that result in further degradation of natural heritage assets are problematic and warrant the highest level of scrutiny and mitigation if they must proceed. The original Snowy Scheme significantly altered upland rivers and aquatic ecosystems and the Snowy 2.0 proposal has significant likelihood of causing further damage. The original Snowy Scheme was designed and constructed before threatened species issue and legislation or upland ecology was well understood however this is no longer the case. If the Snowy 2.0 proposal is to proceed, I ask that the following issues in this submission be explicitly addressed.

Credentials

I am a senior practitioner in freshwater fish ecology (35 years) specialising in threatened and alien fish ecology and management, particularly in the Murray-Darling Basin. I am a member or Chair of two State/Territory threatened species committees, was the convenor of the Australian Society for Fish Biology (ASFB) Threatened Fishes Committee for 10 years and convenor of the ASFB Alien Fishes Committee for 4 years and was the past Oceania Chair of the IUCN Freshwater Fish Specialist Group. I am a member of several national recovery plans for EPBC-listed freshwater fish (including Macquarie perch) and am the primary supervisor of a PhD student describing the ecology of the Stocky galaxias *Galaxias tantangara*. In 2019 I organised the first IUCN Red List assessment for Australian freshwater fishes.

Statement

I contributed to two small independent consultancy reports on freshwater fish for Snowy 2.0.

Apologies that this submission may not hang together seamlessly and may appear intemperate in places. That is not my intent, but I have been in ill health and admitted to hospital twice during its preparation (including over the final submission date). I thank Major Projects, NSW Department of Planning, Industry and Environment for granting me a small extension to provide this initial submission. I intend to provide a subsequent submission by 13/11/2019 including additional details of concerns with the Snowy 2.0 Main Works Environmental Impact Statement.

Submission Details

The Snowy 2.0 Main Works Environmental Impact Statement (hereafter referred to as the EIS) lacks much of the essential information required to adequately assess the potential environmental impacts of the proposal. This submission focusses only on aquatic fauna impacts, primarily relating to threatened freshwater fish.

Lack of availability of primary research reports

The proponent has commissioned a significant body of research to inform the EIS but a major issue evident in the EIS is the apparent reticence by the proponent to exposing to public or peer review the scientific work they have commissioned. It may be that the decision not to include the primary research reports reflects a desire by the proponent to not further inflate the page count of the EIS (approximately 9400 pages in length including appendices), but given the current length the documentation could already be considered to be so large as to be user-unfriendly, adding additional page length by including the primary research reports is irrelevant (in my opinion). The EIS contains very little of the primary research reports commissioned by Snowy Hydro, with the EIS needing to include access to the full evidence set of the primary research reports. Without these reports it is not possible to transparently scrutinise the extent, robustness and validity of a range of research addressing critical knowledge needs and gaps.

I requested access to the primary research reports in the aquatic ecology content area on 18/10/2019 but it was 25/10/2019 (7 days of the total submission period of ~41 days) before some of the primary research reports to be provided (another 441 pages). Upon reading these reports it became apparent that there were even more primary research reports that were required to enable adequate assessment of the aquatic ecology findings stated in the EIS (request submitted 27 October 2019). After waiting another 9 days after requesting an additional report it still had not been received (by 04/11/2019), with only 1.5 days left until EIS submissions closed. This was now 16 out of the ~41– day submission period that I had been waiting on primary research reports. The report was finally received on 5/11/2019, the afternoon before submissions closed, and after I had to go into hospital for emergency surgery. I acknowledge that my personal circumstances are irrelevant to other submissions on Snowy 2.0, but it highlights that the relatively short timeframe for submissions (considering the approximately 10,000+ pages (EIS, appendices, primary research)to be read and digested) if shortened again by delays in provision of essential research information makes it unlikely that full and informed consultation and consideration has been achieved on the Snowy 2.0 proposal. If all the primary reports had been available at the start of the consultation/submissions process, more people would likely have lodged submissions, with these submissions being better informed and likely leading to improved mitigation or management outcomes. It is of interest to note that one of the major primary research reports supplied upon request [THA Aquatic 2019] is dated after the Public exhibition of the EIS commenced, indicating that this was not the version that was used in informing the preparation of the EIS.

The public availability of the primary research reports is critical for a number of reasons:

- It facilitates understanding of the scope and findings of the commissioned research
- It allows scrutiny of the methods and approaches used to see that they are appropriate

- It provides assurance that the claims made in the EIS based on the research are in fact supportable/accurate

For example, it was only the public availability of the primary research for the initial Snowy 2.0 (Exploratory Works) EIS that highlighted the inappropriate survey methods used for Murray Crayfish in Talbingo (Lintermans 2019), resulting in a false conclusion that the species was absent.

This level of non-transparency in the availability of the primary research in the Snowy 2.0 EIS does nothing to engender trust in the accuracy of the EIS. As the Kosciuszko National Park and its fauna potentially impacted by the proposal are public assets, as are the waterways that flow from it, and as one must assume that the cost of researching, building and operating Snowy 2.0 will draw to some extent upon the public purse, this lack of availability of the primary research information information to the public is vexing.

The lack of primary research information in the EIS is critical to a number of considerations:

A. fish screening options considered
B. the potential for live fish transfer and survival
C. the design and suitability of the barrier to mitigate impacts from Climbing galaxias
D. the design and sample size of EHN virus investigations

which are crucial in assessing the potential likelihood and impacts on 3 focal threatened fish species listed both under EPBC and NSW Fisheries Management Act. The major potential direct and indirect impacts are:

- Potential spread of undesirable alien fish species between Talbingo and Tantangara Reservoir
- Potential transfer of parasites and pathogens associated with transfer of undesirable fish species
- Inadequate extent of risk assessments within the EIS (i.e. no evidence of preparedness for future changes in the Talbingo fish community and how this will affect future risk)
- apparent deficiencies in addressing cumulative effects of potential threats
- Lack of detail in proposed planning (Weed, Pest and Pathogen Management' and 'Aquatic Habitat Management' plans) and offset documentation

Each of these EIS information deficiencies, issues and threats is addressed below.

Background to threatened fish species

The Tumut River Catchment and the upper Murrumbidgee River Catchment have a number of listed threatened fishes both under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) *and the NSW Fisheries Management Act 1994* (FM). Both Macquarie perch (*Macquaria australasica*) and Trout cod (*Maccullochella macquariensis*) are listed as endangered under the EPBC Act and the NSW FM Act, and Stocky galaxias (*Galaxias tantangara*) and Murray crayfish (*Euastacus armatus*) are listed as

Critically Endangered and Vulnerable (respectively) under the FM act. Stocky galaxias has also recently been listed on the Finalised Priority Assessment Lists for the EPBC, with an assessment due to be completed by October 2020. As an NSW endemic, it is likely that the EPBC assessment will result in the same status as in NSW (Critically Endangered). Macquarie perch are now highly fragmented with only a few self-sustaining populations remaining, with the upper Murrumbidgee population considered a relative stronghold of the species (Commonwealth of Australia 2018). Kosciuszko National Park contains the only population of the Stocky galaxias; now restricted to a single 3 km stream segment of the headwaters of Tantangara Creek (Allan and Lintermans 2018, 2019; Raadik 2014). Hence, the entire global population of Stocky galaxias and significant populations of Macquarie perch and Murray crayfish could be impacted by the construction and operation of Snowy 2.0.

Major issues with the EIS

The major threat to Macquarie perch and Stocky galaxias from Snowy 2.0 is the transfer of undesirable fish species through water transfer via the Snowy 2.0 tunnel. Translocation of freshwater fish via water transfers is a well-known pathway for the spread of alien fish species in Australia (Lintermans 2004; Waters *et al*. 2002) and globally (Gozlan *et al*. 2010). The impacts from transfer of fish via Snowy 2.0 can be divided into threats associated with two specific fish taxa (Redfin perch, Climbing galaxias) and then a more diffuse mechanism associated with the general transfer of alien fish.

a) <u>Transfer of Redfin perch</u>. Redfin perch is present in Talbingo Reservoir but absent from Tantangara Reservoir (Lintermans 2019), and the pumping of water via Snowy 2.0 from Talbingo to Tantangara is likely to transfer this species (according to the Snowy EIS). Tantangara Reservoir would provide suitable habitat for Redfin perch to survive and reproduce (Baumgartner et al. 2016). Redfin perch is a known predator of small bodied native fish and crayfish (Lintermans 2007; Morgan *et al*. 2002; Pearce 2015) and may impact conservation efforts for the threatened Stocky galaxias as well as impacting spiny crayfish (*Euastacus* spp.) populations. If Redfin perch establish in Tantangara, they are also likely to spread downstream into the upper Murrumbidgee River (where a significant population of Macquarie perch is present (Lintermans 2016)). Once transferred and established, there is no acceptable method (or likelihood) for eradication of Redfin perch from Tantangara Reservoir or the upper Murrumbidgee River. The proposed mitigation measures in the EIS are totally inadequate. There is no primary mitigation proposed at the source location for this species (Talbingo) to prevent Redfin perch establishing in Tantangara (see later discussion about fish screening options). As a declared noxious species in NSW and a notifiable species under the *NSW Biosecurity Act 2015* (Biosecurity Regulation 2017) it is illegal to move this pest in NSW. Consequently, the absence of primary mitigation to prevent the movement of Redfin perch from Talbingo to Tantangara would not appear to meet General Biosecurity Duty specified under the Act.

   The secondary mitigation measure proposed at the Tantangara outlet works (fish screening) contains no detail on the proposed design or documented efficacy of the proposed screen (will it prevent downstream transfer of eggs, larvae, juveniles or only adults?). Additionally, the installation of screens of any design is totally redundant should the dam overtop (which it has done twice since construction) or should anglers use individual from the newly established Redfin population as live-bait in downstream reaches (a common angling practice) (Lintermans 2004).

a) Transfer of Climbing galaxias. Climbing galaxias (*Galaxias brevipinnis*) is present in the Yarrangobilly River (and likely Talbingo Reservoir) (Cardno 2019). This species is native to the coastal drainages of eastern Australia but was transferred into the Murray-Darling Basin via the original Snowy Mountains Hydroelectric Scheme (Waters *et al.* 2002). Climbing galaxias is considered to have detrimental impacts on other fish species (notably other galaxiids) when translocated and the species is listed as a threat to Stocky galaxias by the NSW Fisheries Scientific Committee (NSW FSC 2016 and the references therein). The Snowy EIS proposes that a mitigation measure is to construct a barrier to prevent Climbing galaxias invading the sole remaining habitat for Stocky galaxias, but gives no detail on what the design specifications for the barrier are; whether such a barrier has been previously constructed, or if so, whether the barrier was successful and over what time period such assessment of success has occurred. Upon receiving the relevant primary research report (Raadik 2019; not provided as part of the EIS documentation) it becomes evident that the design criteria specified were preliminary only with the following caveat: "The following design criteria and considerations are preliminary only and have been compiled from an aquatic biological perspective to aid further engineering interpretation and design". The design criteria are not final, appear to be based primarily on New Zealand interventions (for climbing aquatic species), with inference also drawn from Australian aquatic predator exclusion studies (preseumably salmonid) and the anti-climbing components appear to not have been tested or constructed in Australia. The efficacy of the New Zealand barriers is questionable as there are *ad hoc* observations to suggest the Climbing galaxias can get past them (unpubl pers. comms. to Lintermans). The lack of peer-reviewed or field studies for other barrier designs investigated by the Snowy EIS for Redfin exclusion was used to eliminate such barrier designs from further consideration (see discussion of AFBs on page 57 of THA Aquatic 2019) but this does not seem to have been applied by the proponent to the concept design for the Climbing galaxias barrier. This inconsistency in barrier evaluation needs to be explained in the EIS for the proposed Climbing galaxias barrier: the continued existence of Stocky galaxias may depend on it.

The proposed barrier to Climbing galaxias on Tantangara Creek (if effective) will potentially protect the last remaining population of Stocky galaxias but will allow other streams upstream of Tantangara Dam to become infested with Climbing galaxias. The Stocky galaxias is currently confined to a single 3 km stream segment of Tantangara Creek, and therefore is at extreme risk from stochastic events such as wildfire or other localised impacts resulting in habitat loss (Allan and Lintermans 2019; NSW FSC 2016; Raadik 2014). To mitigate such localised threats, it is necessary to establish additional populations of the species in streams other than Tantangara Creek (Allan and Lintermans 2019). However, if Climbing galaxias becomes established in Tantangara Reservoir and invades upstream tributaries, then there will be little or no availability of potentially suitable new sites to establish additional populations of Stocky galaxias. This lack of potential reintroduction sites will likely severely compromise Stocky galaxias conservation efforts (including potential offset measures (see later)).

b) Transfer of other non-native fish species and associated parasites and pathogens. As described above for Redfin perch and Climbing galaxias, the transfer of water between Talbingo and Tantangara provides a mechanism for the establishment of other non-native species (e.g. Goldfish and Eastern gambusia, and any associated pathogens and parasites) currently present in Talbingo but absent from Tantangara. The introduction of parasites and pathogen co-invaders with fish introductions is a global concern, with impacts of introduced parasites often more severe on new hosts than on their original hosts (Lymberry *et al.* 2014). The total absence of primary fish transfer mitigation measures at Talbingo (e.g. fish screens or equivalent) also means that any future changes in the fish community in Talbingo must be dealt with in the receiving waters of Tantangara using measures not designed or necessarily applicable for such future changes. For example, the spread of Eastern gambusia (and its associated parasite co-invaders) from Talbingo to Tantangara, or other as yet unknown species that are likely to establish in Talbingo (e.g. Carp) may introduce a range of parasites not found in other Tantangara fish species. Control and eradication of co-invaders is difficult (if not impossible) once they become established or spread to native species. There appears to be little consideration of the potential for introduction of co-invaders (other than EHNV; see below) in the Snowy 2.0 Main Works EIS and this needs to be rectified.

c) Transfer of EHN virus. The Snowy EIS notes that epizootic hematopoietic necrosis virus (EHNV) has not been recorded from Talbingo Reservoir, based on "*limited testing undertaken for this project*". I attempted to source the primary scientific report on this disease testing (Song *et al.* 2018) but it was delivered 1.5 days before submissions closed and too late to be included in this submission. This virus can be difficult to detect with passive surveillance. There is no detail in the Snowy EIS of the testing regime (how many fish from Talbingo were tested for EHNV; what the sampling strategy was (stratified random, ad hoc?); how many seasons/years were samples collected) so the validity of this 'negative' result (i.e. virus is not present) is unknown. The virus has previously been recorded from Blowering Reservoir (downstream of Talbingo) on the Tumut River where it is presumed to be endemic and has caused multiple outbreaks of disease in redfin perch (Whittington *et al*. 1996; Whittington et al 2011). This virus is extremely hardy and can survive outside its fish host for prolonged periods. EHNV has been shown to retain its capacity to infect fish for 97 days at 15°C and 300 days at 4°C (Langdon 1989). The virus can also survive dry for extended periods with experiments showing it retains its infectious potential after drying for 113 days at 15°C (Langdon 1989). This high infectivity and resistance to dessication means that the virus can likely be transported between water bodies on boats and nets (Whittington et al. 1996) and there is no reason to suggest it could not be spread on angling equipment (waders, rods and lines).
If the virus appears in Talbingo during the operational life of Snowy 2.0 (i.e. the next 100 years?) and is transferred to Tantangara (where a population of Redfin perch has

established), the spread of the virus from Tantangara downstream to the upper Murrumbidgee River is almost certain as both Rainbow trout and Redfin perch are known hosts to the virus (Langdon 1989; Whittington *et al*. 2011). The upper Murrumbidgee River downstream of Tantangara contains a significant population of the EPBC-listed Macquarie perch (Lintermans 2002, 2016; Pavlova *et al*. 2017), which is documented to experience widespread and rapid mortality when exposed to EHNV (Langdon 1989). EHNV is considered a serious risk to Macquarie perch populations in the upper Murrumbidgee catchment, and considerable effort has been made to prevent the introduction of the virus to existing Macquarie perch populations (ACT Government 2018, ACTEW Corporation 2009; Lintermans 2012). EHNV has previously been shown to be carried by Mountain galaxias (*Galaxias olidus*) from which Stocky galaxias has been recently identified and split as a separate species (Raadik 2014). It is accepted that the susceptibility of Stocky galaxias to EHNV is currently unknown, and some congeneric Australian species have been shown to have differential susceptibility to EHNV (e.g. *Macquaria* species) (Becker *et al.* 2013; Langdon 1989), the taxonomy of the *Macquaria* genus has changed with some *Macquaria* species now considered to be part of *Percalates*, and not even considered to be is the same family (Percichthyidae) (Near *et al*. 2012). Consequently, the differing susceptibility to EHNV by supposed congenerics should not be any cause for optimism that Stocky galaxias will not be susceptible. While it is not known if Stocky galaxias is susceptible to EHNV, it is possible given its <u>very close</u> taxonomic affinity to Mountain galaxias and testing of Stocky galaxias for EHNV susceptibility should be an urgent priority.

d) <u>Effects of Tunnel spoil despoil in Talbingo Reservoir</u>. The large quantity of tunnel and dredge spoil being disposed in Talbingo may impact Murray crayfish habitat in the reservoir by disturbing their shallow littoral habitats and affecting water quality (suspended sediment) over a much larger area. Although it is acknowledged the Snowy EIS proposes to relocate Murray crayfish away from the disturbance area in the reservoir, the details of such translocations are not outlined (how much suitable unoccupied crayfish habitat occurs) and the fate or success of such relocations is unknown.
e) <u>Capacity to deal with future changes in fish communities</u>
The EIS does not address the risk or what the management response will be to future changes of fish ecology or status. The lack of primary fish transfer mitigation measures at Talbingo means that other future significant changes in the fish community at Talbingo or Tantangara will have to be retrospectively dealt with (if possible). Examples include:
    - the establishment of a self-sustaining population of Trout cod in Talbingo. At the moment the EIS largely dismisses the need for mitigation of Snowy 2.0 impacts on this EPBC-listed species on the basis that it is maintained by stocking. Trout cod is the subject of a national recovery strategy (Trout Cod Recovery Team 2008) which after 30 years is showing promise. Freshwater fish recovery is long-term process (Koehn & Lintermans 2012) and other Trout cod populations in upland reservoir environments have moved from stocking reliant to self-sustaining over decades (e.g. ACT Government 2018).

- if EHNV establishes in Talbingo then the subsequent establishment of this virus in Tantangara Reservoir and downstream upper Murrumbidgee River habitats becomes much more likely with a Snowy 2.0 mediated establishment of Redfin perch in Tantangara.
- the potential existence of undescribed narrow-range Galaxias spp. in the upper Murrumbidgee (Raadik 2018), and so downstream transfer of such taxa may affect fish conservation or fish communities in the Tumut River catchment.
- The future dynamics of fish communities and their pathogens in Talbingo and Tantangara are unknown (as the existence of EHNV and establishment of Oriental weatherloach in the wild was unknown until the early 1980s) (Hicks *et al*. 2019; Lintermans *et al*. 2007).

  For example, the Oriental weatherloach (*Misgurnus anguillicaudatus*) is currently not established in either Talbingo or Tantangara, but its illegal use as baitfish by anglers (Lintermans 2004) makes it likely that it will establish in either Tantangara or Talbingo in the future. It is also possible that this species may establish independently in Tantangara via the Tantangara-Eucumbene tunnel, as the species is known to be present in Lake Eucumbene (Swales 1992). This species is a hindgut-respirer (McMahon and Burggren 1987) that allows it to survive in low oxygen environments and potentially move overland to colonise new environments. Oriental weatherloach is known to carry a range of parasites not found in other Australian fish species (Dove and Ernst 1998). If the species establishes in Talbingo first (the Tumut catchment has a higher visitation by recreational anglers than Tantangara), there is a relatively high likelihood that it could be transferred from Talbingo to Tantangara. The current secondary mitigation screening in the Tantangara Reservoir outlet may not be effective at preventing subsequent downstream spread of this species into the Upper Murrumbidgee River below Tantangara. Control and eradication of introduced non-native fishes is costly and usually ineffective (Rytwinski *et al*. 2018). There appears to be little consideration of the potential for future changes in fish communities in Talbingo in the Snowy 2.0 Main Works EIS and this needs to be rectified.

Consequently, the acceptance in the EIS of inter-catchment fish transfers (by having no primary mitigation measures) means that the reliance on secondary mitigation methods is a poor risk-management strategy for such ‘known unknowns’ as well as ‘unknown unknowns’.

How the absence of primary research literature in the EIS results in misleading scenarios in the EIS

Following receipt of some of the primary research reports highlighted some critical examples of how the absence of the primary research reports (discussed earlier) facilitates potentially misleading statements in the EIS to go unchallenged: Four are presented below.

1. Primary mitigation options to prevent fish transfer between Talbingo and Tantangara.

A substantial report (commissioned by Snowy 2.0) has investigated the available primary mitigation options to prevent the transfer of alien fish (THA Aquatic 2019) This report examined a range of mitigation options including a variety of fish screens and deterrence measures such as electric, bio-acoustic, Synchronised Intense Light and Sound (SILAS) systems and euthanasia systems to kill any fish that passed the screening or deterrence options. The report concluded that most of the investigated options did not warrant further investigation but did conclude that 3 options (flat panel wedge wire screens, drum screen and SWIFF screens were considered the most likely screening options to minimise the risk of redfin entrainment and warranted further investigation with manufacturers. The EIS records that "flat-panel wedge wire screens, drum screens and submerged water intake, fish friendly screens were considered technically feasible" but that "high construction costs and environmental impacts render these options not feasible" [my emphasis]. Given that the original research report does not include costings, how is a 'high' cost defined; is it a proportion of the total construction cost (again, unspecified); How is the future in-perpetuity management cost of dealing with invasive fish impacts considered? What is the dollar value of the potential loss of threatened fish populations? Such questions need to be considered and reported in the EIS.

The proposal not to proceed with any primary mitigation measures to prevent fish transfer is in my opinion, the most important environmental decision within the EIS as it then triggers multiple secondary interventions of dubious efficiency (see earlier discussion of fish barriers, Tantangara outlet screen, EHNV establishment). The EIS states "the transfer of these [fish] species could lead to populations establishing in Tantangara reservoir and some distance upstream" but then concludes "the installation of barriers [at Tantangara outlet, Eucumbene tunnel and Tantangara Creek] will limit the potential range expansion and prevent these fish from entering Lake Eucumbene or the known habitats of any threatened species" This conclusion is undefendable on the information supplied given the lack of any design specifications and/or proven efficacy of the secondary barriers. Therefore, the decision not to implement primary mitigation must be open to the most rigorous scrutiny and approval of the EIS must be contingent on a transparent cost-benefit analysis of detailed barrier designs.

2. Likely survival of alien fish species to transfer between Talbingo and Tantangara via pumping

An intensive series of laboratory and modelling trials were conducted to examine the survival of two fish species (Redfin perch and Eastern gambusia) to a range of stressors (shear-stress, blade-strike, pressure-change) expected to be encountered in fish transfer from Talbingo to Tantangara via the Snowy 2.0 intake, tunnel and turbines. Ning *et al*. (2019) did not examine all life stages for each of the two fish species with all stages tested for Redfin perch (eggs, larvae, juveniles, small adults) but only adults tested for Eastern gambusia. No Goldfish or Climbing galaxias were tested.

The EIS states "Overall, they [Ning *et al*. 2019] concluded that based on the results of their experiments and modelling, if entrained into the intake at Talbingo Reservoir, a proportion [my emphasis] of redfin perch or eastern gambusia could survive the shear-stress, blade-strike and pressure-change expected to occur within the pumped hydro system". The primary research report reported the proportion of fish estimated to survive under a modelled combination ranged for Redfin from 15-36% of eggs; 34-58% larvae; 83-75% juveniles; 63-71% adults, and for Eastern gambusia adult survival was estimated at 86-94% (Ning *et al*. 2019). This is considerably more convincing as an argument for survival of transferred fish than 'a proportion' as stated in the EIS. A conclusion of Ning *et al*. (2019) is "the results of this study indicate that it is likely that a large proportion [my emphasis] of any redfin or gambusia entrained at the intake in Talbingo Reservoir would survive the shear, blade strike and pressure impacts expected to occur within the Snowy 2.0 facility" Note the omission of the word 'large' from the EIS statement. The EIS also states that "The key ecological concern relating to water transfer is the potential transfer of undesirable species (redfin perch, gambusia, goldfish and climbing galaxias) from Talbingo to Tantangara which is considered likely for redfin perch and possible to unlikely for other species" The basis for the distinction in likelihood for transfer of the four species is puzzling as the EIS notes elsewhere that "Fish larvae in the vicinity of the intake, would be susceptible to entrainment when the station was operating" with no distinction between species, and that Ning et al.(2019) state that "Consequently, results obtained for redfin and gambusia in the current experiments, in combination with results from previous studies……cannot be used to predict the impact of the proposed Snowy 2.0 facility on the passage other species, such as Climbing galaxias." The EIS conclusion that 3 of the four species are even partially in the 'unlikely' category of potential transfer seems not to be well supported and is a high-risk conclusion. Primary screening at Talbingo is the obvious solution.

3. EHNV testing

A critical issue in the EIS is whether EHNV is present in Talbingo Reservoir, and therefore available to be transferred to Tantangara Reservoir, and subsequently downstream to a significant population of endangered Macquarie perch. The EIS notes "EHNV is not known to occur in Tantangara or Talbingo reservoirs and was not detected in limited testing undertaken for this project." The citation for the testing regime report (Song *et al.* 2018) is present in another primary research report by Hicks *et al*. (2019) which specifically provides advice on the potential for EHNV to establish. As stated earlier, my request for access to the Song *et al.* (2018) report on EHNV testing in Talbingo and Tantangara was not provided to me in time to review it. Fortunately an eminent team of world-leading authorities on EHNV (Hicks *et al*. 2019) report on the sampling design and numbers of fish tested by Song *et al.* (2018) and reported that there was only a 'convenience' sample of 50 Redfin perch obtained from Talbingo and only 26 relevant samples (i.e. of a species known to be susceptible to EHNV) of rainbow trout from Tantangara. Hicks *et al*. (2019) then calculate that sample sizes of 530 and 131 fish per population are required to meet the international standard of being able to detect a 2% or 5% prevalence respectively of EHNV with 95% confidence. So the actual sample sizes on which the EIS statement that each reservoir is EHNV-free is based on

5-10% of the numbers required under international best practice! Hicks *et al*. (2019) also note that EHNV outbreaks are most severe in naïve populations of the virus amplification host (Redfin perch) which "results in a large disease outbreak that amplifies the virus to a quantity that can be transmitted large distances, including free in water, and over long time periods". So presumably when Redfin perch likely establish in Tantangara (because of the lack of primary mitigation at Talbingo to prevent fish transfer), and EHNV is transferred via water transfers we can anticipate a significant EHNV disease event in Tantangara in the future, and subsequent downstream impacts on Macquarie perch in the Murrumbidgee River. The EIS states that "A monitoring program for EHNV is proposed as part of the project" but again no details is provided on what such a program will look like, cost, and who will oversee, design or conduct it. The likely deficiencies or limitations of the initial testing program have been outlined above (Hicks et al. 2019).

4. <u>Barriers to prevent climbing galaxias invasion of Stocky Galaxias habitat</u>

As a result of the lack of primary mitigation at Talbingo to prevent fish transfer, protection of the sole remaining population of critically endangered Stocky galaxias is totally reliant on the construction of a barrier (or multiple barriers) to prevent invasion by Climbing galaxias. Table 6.10 of the EIS main report states that "… the installation of barriers will limit the potential range expansion and prevent these fish [redfin perch, gambusia, goldfish and climbing galaxias] from entering Lake Eucumbene or the known habitats of any threatened species" This is an extremely optimistic view of the efficacy of the 3 barriers proposed (Eucumbene tunnel, Tantangara outlet, Tantangara Creek) given that there are absolutely no details of the screen/barrier designs within the EIS (other than mention in Mitigation Measure AE18 which states the screens are to be 'fine mesh'). I can find no primary research reports relating to the design of the Eucumbene Tunnel or Tantangara outlet screen designs. Fortunately, the report about the Tantangara Creek barrier design to exclude Climbing galaxias was supplied upon request. The primary research report of Raadik (2019) used a series of 3 location characteristics (presence of a natural constriction, steep catchment slope, steep stream gradient) to select potential barrier sites and then specified a series of 8 design criteria for the barrier itself. The three location characteristics are logical and defendable. The 8 design criteria are similarly sensible, but as noted earlier, "are preliminary only and have been compiled from an aquatic biological perspective to aid further engineering interpretation and design" (Raadik 2019).

Potential barrier sites were assessed and all but one eliminated. The one site selected is an obvious choice because it represents the largest natural barrier in the study area (a waterfall) but the conclusion that no other site was suitable requires further consideration as the project brief and scope is unknown. It appears that only sites on Tantangara Creek were investigated, where tributary investigations may have revealed more potential barrier sites (see Allan and Lintermans 2019).

A single barrier to conserve Stocky galaxias is high risk and should breach of the barrier by Climbing galaxias occur then there is no fall back or early warning potential for subsequent conservation action other than emergency rescues (and to where?) (Raadik 2019).

Other potential barrier sites on Tantangara Creek itself were excluded (Raadik 2019), presumably based on the cost of constructing wider or higher barriers that would prevent overtopping or outflanking. This is a sensible, approach, but with no project brief of barrier costings provided one that is impossible to closely examine, and so the cost differential in an expensive vs ideal barrier is unknown. The cost of the barriers deemed unsuitable may be totally irrelevant in terms of the 'value' of conserving the sole remaining population of a species (which is also not costed). Raadik (2019) discusses the characteristics of similar barrier programs to keep salmonids out of threatened galaxiid habitats (multiple barriers). If the multiple barrier considerations discussed by Raadik (2019) were included in the Snowy 2.0 investigations, then the mitigation approach adopted in the EIS might be defendable. Multiple barriers would allow some capacity for redundancy in barrier numbers (i.e. if 1 barrier (of preliminary and untested design) is breached there is another to prevent total invasion of the sole remaining population; or possibly additional barriers constructed to conserve other streams for the establishment of additional populations (see Allan and Lintermans 2019)). The mitigation option for Stocky galaxias appears to have been hastily derived (by Snowy 2.0) and does not represent a secure or reliable mitigation option for Stocky galaxias conservation. More work is required to test such barrier design criteria before deployment as the ultimate solution for stocky galaxias. Field trials of such barrier designs are required in non-critical habitat (i.e. where the future of a species is not dependant on the outcome), including an assessment of the benefits of multiple barriers. A more holistic approach to protecting the Stocky galaxias population from invasion would be to assemble a small multidisciplinary team with expertise (or access to expertise) of ecologists, engineers, economists etc with a broader remit to investigate and cost a range of barrier designs for various locations that protect more than the sole remaining small population of Stocky galaxias. Comparative approaches (for enhancing rather than preventing fish passage) have been successfully applied at the broader scale to managing fish movement in the Murray-Darling Basin (Barrett & Mallen-Cooper 2006; Barrett 2008; Jones & O'Connor 2017) and globally (see Silva *et al*. 2018) and could be scaled down to produce a more defendable conservation strategy. Such a team could also give guidance on remediation costs should the barrier fail (eradication/control of climbing galaxias, captive husbandry and research costs should habitat in the wild be lost; a dollar value of Stocky galaxias, adverse publicity and reputational damage to Snowy Hydro, etc), and monitoring costs, so that an inclusive and realistic cost-benefit analysis is available. As the Snowy 2.0 scheme will not be completed for many years, there is ample time to follow such an approach. The approval of the Snowy 2.0 EIS should be contingent on a further detailed analysis of barrier options, location, and costs so adequate mitigation measures to conserve stocky galaxias can be implemented.

Cumulative, contingent and long-term impacts

Whilst the impacts of any single threat may be able to be partially mitigated when considered in isolation, the cumulative effect of multiple impacts must be considered as part of the assessment process. For example, while the presence of the EHN virus has not been detected in Talbingo Reservoir, this virus is known to be undetectable at times, but then reappears at a later date. The moderate to high risk of transferring Redfin perch from Talbingo to Tantangara, and the subsequent establishment of this species means that the likelihood of the virus establishing in Tantangara at some stage in the future is much higher than if Redfin were not present in Tantangara. If the virus establishes in Tantangara, then there is no mitigation able to prevent its spread into downstream populations of the endangered Macquarie perch in the upper Murrumbidgee River. Hence, the potential impacts of transfer of Redfin and subsequent establishment of EHNV may not become readily apparent until many years/decades after the Snowy 2.0 project has been constructed. The current EIS contains commitments to prepare and implement plans for 'Weed, Pest and Pathogen Management' and 'Aquatic Habitat Management' but the scope (cost, intensity, longevity, responsibility for implementation) and implementation details are absent (see below) and so their efficacy in addressing cumulative long-term impacts is unknown. A long-term, cumulative assessment of impacts and subsequent management requirements and costs is required for the true costs of the Snowy 2.0 proposal to be evident.

Planning to have a plan is not a plan

As noted immediately above, a prominent component in the EIS of proposed mitigation measures for the Transfer of water between Talbingo and Tantangara Reservoirs is the preparation and implementation of an Aquatic Habitat Management Plan. This plan would guide management of impacts to aquatic habitat, with a series of dot points to outline the potential scope of such a plan. Similarly there is an EIS commitment to prepare and implement a Weed, Pest and Pathogen Management Plan "to minimise and manage the spread of weeds, pest fish and pathogens which will include a description of measures that would be implemented to minimise the spread of weeds and pest via vehicle and plant movements" This would be an incredibly valuable plan nationally and internationally as the control and management of invasive species is a major threat globally and a 'wicked' problem (Dudgeon et al. 2006; McDowall 2006; McGeoch et al. 2010; Woodford et al. 2016).

Approving a proposal like Snowy 2.0 that is of a 'world-first' scale (according to the EIS) without knowing the details of important plans such as the two mentioned above is high risk. I wouldn't buy a house just knowing the components it might contain (walls, a roof, windows and doors, landscaping services): before I committed to buying it I would want to see the detail (how many doors and windows, where are they, how many rooms, when will it be ready, what are the inclusions and what are the extras that will cost me more).

The description of both of these plans is too imprecise to sign off on; the mitigation details need to be understood and committed to prior to the works, not after the works have been approved. There is provision within the Aquatic Habitat Management Plan to include "a trigger action and response plan for the Murray crayfish, which would be implemented if monitoring shows the development is adversely affecting the species" but there is no such provision for triggers or responses should other threatened fish (Stocky Galaxias, Macquarie perch) be impacted by the transfer of Redfin perch or climbing galaxias. The content in the plan of a "program to monitor and report on the effectiveness of these measures" has no detail on what will be monitored and how. Recent reviews of threatened species monitoring in Australia have shown existing monitoring programs to be inadequate (Legge et al. 2018;

Lintermans and Robinson 2018; Scheele et al. 2019), and without knowing the details, financial commitments and legislative backing for the proposed monitoring this seems to be a non-binding commitment that will be difficult to measure or enforce. The approval of the Snowy 2.0 EIS should be contingent on the provision of approved, costed, at least advanced drafts of both of these plans.

Potential offsets and conservation actions

Similar to the discussion above around the lack of detail or commitment for the Aquatic Habitat Management Plan and Weed, Pest and Pathogen Management Plan, the aquatic potential actions or measures identified in Table 2.2 of Appendix M3 Offset strategy (reproduced below) are similarly vague, and are much less detailed than the potential conservation measures identified for EPBC-listed species (terrestrial?) (Table 2.1). Macquarie perch is EPBC- listed; the potential transfer via Snowy 2.0 of redfin perch and EHNV meets the criteria for significant impact (defined under the EPBC Matters of National Environmental Significance) as it will:

- adversely affect habitat critical to the survival of a species;
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- interfere with the recovery of the species.

It is confusing why this species is not listed in Table 2.1, but instead listed in Table 2.2. For currently Non-EPBC-listed taxa this lack of detail for aquatic species may be related to the low residual risk assigned by the EIS after consideration of the proposed mitigations (discussion of which forms a considerable part of this submission (secondary as opposed to primary screening, EHNV risk, pest and habitat plans, etc). Note that I believe some of the residual risks identified in the EIS are incorrect (details to be provided in supplementary submission).

The lack of detail about what is proposed as offset conservation measures for aquatic species is not acceptable and needs to be revised and expanded including identification of and consultation with other stakeholders outside NSW DPI and recreational anglers (e.g. national Macquarie perch recovery team, University of Canberra (Stocky galaxias); other stakeholders for Murray crayfish). The level of commitment by the proponent to ‘proposed conservation measures’ also needs clarifying.

Table 2.2 reproduced from Snowy 2.0 Main Works EIS appendix M3 Offset strategy.

Table 2.2 Potential actions for residual impacts to aquatic ecology

Species	Potential measures
Murray crayfish	• Monitoring and surveillance of Talbingo Reservoir population.

Table 2.2 Potential actions for residual impacts to aquatic ecology

Species	Potential measures
	• Contribute to research into habitat usage, population structure and habitat utilisation.
Macquarie perch	• Surveillance and sampling of Tantangara Reservoir, Murrumbidgee River and Tantangara Creek. • Contribute to local / regional insurance population program.
Stocky galaxias	• Surveillance and population monitoring. • Habitat enhancement (fencing) in Tantangara Creek. • Contribute to translocation program and establishment of insurance population.
Recreational fishing in Tantangara	• With stakeholders (in particular Monaro Acclimatisation Society) develop a program for stocking of large fish (rainbow trout) in Tantangara Reservoir. • Improve boat launching access at Talbingo and Tantangara reservoirs.

The proposed actions will be developed and implemented further in consultation with key stakeholders, including DPIE, DPI Fisheries and the local fishing community through the Monaro Acclimatisation Society.

Conclusions

I am concerned that the Snowy 2.0 EIS does not adequately evaluate, address or mitigate many impacts of the proposed Snowy 2.0 development. The EIS appears to have been completed to meet an arbitrary deadline before adequate consideration or liaison with many threatened fish stakeholders (outside of NSW DPI) which could have assisted with highlighting or fleshing out of many of the issues identified in this submission. Aquatic habitats have already been significantly impacted though past management practices and the original Snowy Hydro Scheme and the learnings from such historical actions have not been fully incorporated into this EIS.

A potential way forward

Recognising the political will for Snowy 2.0 to proceed, before the risks and impact issues outlined above are potentially adequately dealt with; a potential way forward is to provide conditional approval that would allow some works to proceed subject to conditions for finalisation of identified deficiencies in the EIS. A mechanism to engender public trust in such a process would be to ensure that there is independent professional oversight of the finalisation of outstanding issues. This was done in the approvals for the enlargement of Cotter Dam in the ACT (which required ACT Government and Commonwealth Government (EPBC) approvals) which also had commissioned a wide body of research to inform an EIS and a subsequent Public Environment Report (ACTEW Corporation 2009a, b). Critical to such an approval was the funding by the water utility of an independent senior fisheries scientist, establishment of a stakeholder steering group, independent peer review processes, and dedicated staff within the design and construction proponents to ensure fish requirements were considered in dam design, construction, and operation. The establishment of an independent, collaborative science-driven process coupled with the establishment of a long-term monitoring program in an adaptive management framework is considered a model for other infrastructure projects worldwide that threaten riverine fish (Lintermans 2012) with Snowy 2.0 an obvious subsequent candidate. The Cotter Dam project differed from Snowy 2.0 in that such a process of getting independent external review commenced very early in the process, with independent fish review of a range of initial infrastructure options and risks (Lintermans 2005) and full involvement before the subsequent final EIS was released. This opportunity for early comprehensive involvement has passed to some extent for Snowy 2.0, but an independent process is till of considerable value.

I am happy to provide further advice on fish issues or the establishment of an independent, collaborative science-driven process, coupled with the establishment of a long-term monitoring program.

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8 November 2019

References

ACT Government (2018). *ACT Aquatic and Riparian Conservation Strategy and Action Plans.* ACT Government, Canberra.

ACTEW Corporation. (2009a). *Enlargement of the Cotter Reservoir and associated works. Environmental Impact Statement.*

ACTEW Corporation. (2009b). *Enlargement of Cotter Reservoir and associated works. Final public environment report 2008/4524*.

Allan, H. and Lintermans M. (2018). The threat from feral horses to a critically endangered fish. pp 88-89 in Worboys, G.L., Driscoll, D. and Crabb, P. (eds) Feral Horse Impacts: The Kosciuszko Science Conference — Conference Abstracts. 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 tantangara*. Consultants report to EMM Consulting Pty Ltd.

Barrett, J. (Ed.) (2008). *The Sea to Lake Hume: Restoring Fish Passage in the Murray River. MDBC Publication No. 32/08*: Murray-Darling Basin Commission, Canberra.

Barrett, J., & Mallen-Cooper, M. (2006). The Murray River's 'Sea to Hume Dam' fish passage program: Progress to date and lessons learned. *Ecological Management & Restoration, 7*(3), 173-183.

Baumgartner L.J., Boys, C.A., Gilligan D.M., Silva, L.G., Pflugrath B. and Ning N. (2016). Fish transfer risk associated with Snowy 2.0 pumped hydro scheme: a report prepared for Snowy Hydro Ltd. Institute for Land, Water and Society, Charles Sturt University. 35 pp.

Becker, J. A., Tweedie, A., Gilligan, D., Asmus, M., & Whittington, R. J. (2013). Experimental Infection of Australian Freshwater Fish with Epizootic Haematopoietic Necrosis Virus (EHNV). *Journal of Aquatic Animal Health, 25*(1), 66-76.

Cardno (2019). Aquatic Ecology Assessment Snowy 2.0 Main Works. 59918111, Prepared for EMM Consulting Pty Ltd. Appendix M3 Snowy 2.0 Main Works environmental Impact Assessment.

Commonwealth of Australia (2018). *National Recovery Plan for Macquarie Perch* (Macquaria australasica).

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A. H., Soto, D., Stiassny, M. L. J. and Sullivan, C. A. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Reviews of the Cambridge Philosophical Society, 81*(2), 163-182.

Gozlan, R.E., Britton, J.R., Cowx, I. and Copp, G.H., (2010). Current knowledge on non-native freshwater fish introductions. *Journal of Fish Biology*, *76*(4): 751-786.

Hick, P., Whittington, R. & Becker, J., (2019). *Assessment of the potential for increased distribution of Epizootic haematopoietic necrosis virus (EHNV) associated with Snowy 2.0.* University of Sydney. Revised Report.

Jones, M.J. and O'Connor, J.P. (2017). *Monitoring the performance of fishways and fish passage works.* Arthur Rylah Institute for Environmental Research. Technical Report Series No. 257. Department of Environment, Land, Water and Planning, Heidelberg, Victoria

Koehn, J.D. and Lintermans, M. (2012). A strategy to rehabilitate fishes of the Murray-Darling Basin, south-eastern Australia. *Endangered Species Research* 16: 165–181

Koehn, J.D., Lintermans, M, Lyon, J.P., Ingram, B.A., Gilligan, D.M., Todd, C.R. and Douglas, J.W. (2013). Recovery of the endangered trout cod *Maccullochella macquariensis*: What have we achieved in more than 25 years*? Marine and Freshwater Research* **64**: 822-837

Langdon, J. S. (1989). Experimental transmission and pathogenicity of epizootic haematopoietic necrosis virus (EHNV) in redfin perch *Perca fluviatilis* L., and 11 other teleosts. *Journal of Fish Diseases, 12*(4), 295-310.

Legge, S., Robinson, N., Lindenmayer, D., Scheele, B., Southwell, D. and Wintle, B. (eds.) (2018). *Monitoring threatened species and ecological communities*. CSIRO Publishing. Collingwood.

Lintermans, M. (2002). *Fish in the Upper Murrumbidgee Catchment: A Review of Current Knowledge***.** Environment ACT, Canberra. 92 p.

Lintermans, M. (2004). Human-assisted dispersal of alien freshwater fish in Australia. *New Zealand Journal of Marine and Freshwater Research* 38: 481-501.

Lintermans, M. 2005. *ACT Future Water Options Fish Impact Study:* A *Review of Potential Impacts on Fish and Crayfish of Future Water Supply Options for the Australian Capital Territory: Stage 1*. ACTEW Corporation. Canberra.125 p.

Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: an introductory guide*. Murray-Darling Basin Commission, Canberra. 166 p.

Lintermans, M. (2012). Managing potential impacts of reservoir enlargement on threatened *Macquaria australasica* and *Gadopsis bispinosus* in southeastern Australia. *Endangered Species Research* 16: 1-16.

Lintermans, M. (2016). Finding the needle in the haystack: comparing sampling methods for detecting an endangered freshwater fish. *Marine and Freshwater Research, 67*(11), 1740-1749.

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

Lintermans, M., Raadik, T., Morgan, D. and Jackson, P. (2007). Overview of the ecology and impact of three alien fish species in Australia: Redfin perch, Mozambique mouthbrooder (Tilapia) and Oriental weatherloach. Pp 22-32 *In* Ansell, D. and Jackson, P. (Eds). 2007. *Emerging Issues in Alien Fish Management in the Murray-Darling Basin: Statement, recommendations and supporting papers.* Proceedings of a workshop held in Brisbane QLD, 30-31 May 2006. Murray-Darling Basin Commission, Canberra.

Lintermans, M. and Robinson, W. (2018). The extent and adequacy of monitoring of Australian threatened freshwater fish. Pp 85-99 in Sarah Legge, David Lindenmayer, Natasha Robinson, Ben Scheele, Darren Southwell, & Brendan Wintle (eds.) *Monitoring Threatened Species and Ecological Communities*. CSIRO Publishing, Collingwood.

Lymbery, A.J., Morine, M., Kanani, H.G., Beatty, S.J. and Morgan, D.L., (2014). Co-invaders: the effects of alien parasites on native hosts. *International Journal for Parasitology: Parasites and Wildlife* 3(2): 171-177.

McDowall, R. M. (2006). Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? *Reviews in Fish Biology and Fisheries, 16*(3-4), 233-422.

McGeoch, M.A., Butchart, S.H., Spear, D., Marais, E., Kleynhans, E.J., Symes, A., Chanson, J. and Hoffmann, M., (2010). Global indicators of biological invasion: species numbers, biodiversity impact and policy responses. *Diversity and Distributions*, *16*(1), pp.95-108.

McMahon, B.R., & Burggren, W.W. (1987). Respiratory physiology of the intestinal breathing in the teleost fish *Misgurnus anguillicaudatus*. *Journal of Experimental Biology,* 133, 371-393.

Morgan, D. L., Hambleton, S. J., Gill, H. S., & Beatty, S. J. (2002). Distribution, biology and likely impacts of the introduced redfin perch (*Perca fluviatilis*) (Percidae) in Western Australia. *Marine and Freshwater Research,* 53(8): 1211-1221.

Near, T.J., Sandel, M., Kuhn, K.L., Unmack, P.J., Wainwright, P.C. and Smith, W.M. (2012). Nuclear gene inferred phylogenies resolve the relationships of the enigmatic pygmy sunfishes, Elassoma (Teleostei: Percomorpha). *Molecular Phylogenetics and Evolution* **63**: 388–395.

Ning N, Doyle K., Silva L.G., Boys C.A., McPherson J., Fowler A., McGregor C., Brambilla E., Thiebaud I, du Preez J., Robinson W., Deng Z.D., Fu T., Baumgartner L.J. (2019). *Predicting invasive fish survival through the Snowy 2.0 pumped hydro scheme.* Confidential report prepared for Snowy Hydro Limited. Institute for Land, Water and Society, Charles Sturt University. 93 pp.

NSW FSC (2016). Final Determination: Galaxias tantangara - Stocky Galaxias as a Critically Endangered Species. NSW Fisheries Scientific Committee.

Pavlova, A., Beheregaray, L. B., Coleman, R., Gilligan, D. M., Harrisson, K. A., Ingram, B. A., Kearns, J., Lamb, A. M., Lintermans, M., Lyon, J., Nguyen, T., Sasaki, M., Tonkin, Z., Yen, J. D. L. & 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.

Pearce, L. (2015). *Surveys, monitoring and conservation status of Southern Pygmy Perch (Nannoperca australis) within Blakney and Pudman Creeks* NSW Department of Primary Industries, Albury, Australia.

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), 1-198.

Raadik, T.A. (2018). *Identification of galaxiid species (Teleostei, Galaxiidae) from the area of the proposed Snowy 2.0 Project*. Unpublished Client Report for EMM Consulting. Arthur Rylah Institute for Environmental Research

Raadik, T.A. (2019) *Tantangara Creek fish barrier design criteria – Snowy 2.0 Project*. Unpublished Client Report for EMM Consulting, Arthur Rylah Institute for Environmental Research

Rytwinski, T., Taylor, J.J., Donaldson, L.A., Britton, J.R., Browne, D.R., Gresswell, R.E., Lintermans, M., Prior, K.A., Pellatt, M.G., Vis, C. and Cooke, S.J., 2018. The effectiveness of non-native fish removal techniques in freshwater ecosystems: a systematic review. *Environmental Reviews*, 27(1): pp.71-94.

Scheele, B. C., Legge, S., Blanchard, W., Garnett, S. T., Geyle, H. M., Gillespie, G. R., Harrison, P. L., Lindenmayer, D. B., Lintermans, M., Robinson, N. M., and Woinarski, J. C. Z. (2019). Continental-scale assessment reveals inadequate monitoring for threatened vertebrates in a megadiverse country. *Biological Conservation* 235: 273-278

Silva, A.T., Lucas, M.C., Castro-Santos, T., Katopodis, C., Baumgartner, L.J., Thiem, J.D., Aarestrup, K., Pompeu, P.S., O'Brien, G.C., Braun, D.C. and Burnett, N.J., 2018. The future of fish passage science, engineering, and practice. *Fish and Fisheries*, *19*(2), pp.340-362.

Song, S., Weeks, A., Griffiths, J., (2018). *Epizootic haematopoietic necrosis virus testing in the Talbingo Reservoir area.* Confidential report prepared by EnviroDNA for Snowy Hydro Limited.

Swales, S. (1992). *Report on the occurrence of oriental weather loach (Misgurnus anguillicaudatus) in Lake Eucumbene*. Unpublished report, Fisheries Research Institute, New South Wales Fisheries.

THA Aquatic (2019) *Review of Options to Prevent the Entrainment of Redfin (Perca fluviatilis) at the Proposed Snowy 2.0 Pumped Hydro-electric Generation Plant*. THA Document No: 801R0305; Submitted to: EMM and Snowy Hydro.

Trout Cod Recovery Team. (2008). *Recovery Plan for Trout Cod Maccullochella macquariensis*. http://www.environment.gov.au/biodiversity/threatened/recovery-plans/national-recovery-plan-trout-cod-maccullochella-macquariensis

Waters, J.M., Shirley, M., & Closs, G.P. (2002). Hydroelectric development and translocation of Galaxias brevipinnis: a cloud at the end of the tunnel? *Canadian Journal of Fisheries and Aquatic Sciences,* 59(1) 49-56.

Whittington, R. J., Kearns, C., Hyatt, A. D., Hengstberger, S., & Rutzou, T. (1996). Spread of epizootic haematopoietic necrosis virus (EHNV) in redfin perch (*Perca fluviatilis*) in southern Australia. *Australian Veterinary Journal* 73(3), 112-114.

Woodford, D.J., Richardson, D.M., MacIsaac, H.J., Mandrak, N.E., Van Wilgen, B.W., Wilson, J.R. and Weyl, O.L., 2016. Confronting the wicked problem of managing biological invasions. *NeoBiota* 31: 63–86.