Before the Independent Hearing Panel

Under	the Resource Management Act 1991
In the matter of	the Proposed Otago Regional Policy Statement 2021

Statement of evidence of Ami Coughlan on behalf of Otago and Central South Island Fish and Game Councils

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Introduction

1 My full name is Ami Coughlan. I am the Resource Officer with the Wellington Fish and Game Council (WFG) in Palmerston North. I have worked with WFG since 15 December 2018, providing services related to field work, policy, planning, and consenting processes as they relate to Fish and Game.

2 I have a Master of Science in Ecology (with Distinction), and a Bachelor of Science with a Major in Environmental Science and a Minor in Ecology, both from Massey University, Palmerston North.

3 My Masters in Ecology was focussed on freshwater ecology, and my thesis concerned interactions between trout and native fish in flowing water in New Zealand. The published thesis was predominantly concerned with negative population level impacts of trout predation on indigenous freshwater fish species; however, habitat mitigations of these predation impacts became a strong research thread throughout. The thesis led to the creation of a Risk Assessment Framework to prioritise the most vulnerable native species to trout predation, finding in which waterbodies trout co-occurred with native species, and mapping to provide a tool for managing species interactions and habitats in the most important reaches.

Code of conduct for expert witnesses

4 I confirm I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2014 and that I have complied with it when preparing my evidence. Other than when I state I am relying on the advice of another person; this evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Scope of evidence

5 I have prepared this evidence in relation to:

(a) providing an ecological overview habitat, fish passage, and species interactions

(b) providing an ecological overview of predation impacts on native freshwater fish populations by trout in rivers and streams in New Zealand

(c) in-stream and out-of-stream factors affecting species interactions

(d) options for resolving species interactions

(e) limitations on resolving species interactions

(f) a risk assessment framework to prioritise most at-risk species for management

(g) comments on NPS-FM Policies 9 and 10 from an ecological perspective

(h) comment on whether protections for habitat of trout and salmon can be consistent with protections of habitat for indigenous species

(i) comment on scale in interactions between trout and native fish

(j) whether trout and salmon habitat can form part of the ecological health of a freshwater ecosystem

(k) comment on LF-FW-MX from a practical and ecological perspective

6 In preparing this statement I have reviewed:

(a) The submission of Fish and Game relevant to interactions between trout and native fish species, and trout and salmon habitat.

(b) The section 42A reports for chapters relevant to Fish and Game's submission as relevant to trout and salmon habitats, and species interactions

(c) The evidence of Mr Paragreen as it relates to trout and salmon habitat and species interactions

(d) The evidence of Mr Couper as it relates to species interaction and trout and salmon habitat.

(e) The relief as now sought by Fish and Game as it relates to trout and salmon habitat and species interactions.

Executive summary

7 There can be conflict between the need to restore New Zealand's freshwater ecosystem and threatened indigenous fish species, and to manage a highly valued trout and salmon fishery.

8 Indigenous freshwater fish populations are negatively impacted by degraded and destroyed freshwater habitat, and the impact of introduced fish species.

9 Restoring habitat helps both indigenous fish and salmonid species.

10 Freshwater habitat (abiotic factors) and species interactions (biotic factors) are often perceived as separate management issues, however each impacts with the other in complex and nuanced site, species, and community specific ways.

11 A Risk Assessment Framework has been developed to triage those indigenous fish species most at risk of deleterious population level impacts from trout predation in flowing water. The New Zealand Freshwater Fish Database was used to determine where trout presence overlapped with the presence of native fish species, and this information was used to create maps indicating reaches where trout may co-occur with species which are at high, moderate, or low risk of deleterious impacts from trout predation.

12 This can assist river managers in decision making regarding which sites have a priority for management to help restore threatened native fish species.

13 A range of environmental management strategies to increase abundance and distribution of freshwater fish species are listed, including habitat restoration, allowing river disturbance, increasing food and mesohabitat resource availability, minimising nutrient, sediment, and pollutant inputs to freshwater, and removing fish passage barriers where appropriate to allow diadromous species migrations.

14 Species interaction management strategies are also discussed, including accurately ascertaining where the presence of trout and salmon are likely to be negatively impacting native fish populations, ensuring fish passage barriers which protect threatened upstream native fish populations from predatory fish species remain intact, and increasing protections of species deemed at high risk of population level negative impacts from trout predation as assessed via the Risk Assessment framework.

15 The ecological interactions are complex, however a framework can assist managers in determining and providing for the needs of species, environment, and human values. Where risks of deleterious impacts on native populations is low, protection of trout and salmon habitat will improve the habitat for native species as well.

The three threads of habitat protection and species interactions

Linkages between habitat and species

16 People appear to think of habitat and species as separate concepts. For example, the National Policy Statement for Freshwater Management (**NPS-FM**) directs the protection of habitat (with caveats) in Policies 9 and 10 and

action on species interaction, via fish passage, in section 3.26. However, these concepts are integrated, each thread impacting, and being impacted by, the others.

17 The concept of habitat defines the location or home of an organism and is to the reason behind creating legal protections for places or species inhabitating a particular area in order to prevent or halt species loss (Wallace, 2007). Species interactions within this habitat can be important in determining the diversity of the local ecosystem (Bairey et al., 2016).

18 Fish passage is an important factor when discussing both species interactions and habitat. In-stream barriers result in a loss of access to habitat for migratory species, and a reduction in fish biodiviersity where they prevent species from accessing and inhabiting waterways – these barriers can be chemical or physical in nature and impact migratory species which comprise a large part of freshwater fish biodiversity (Joy & Death, 2013).

19 While fish barriers prevent access by fish to habitat, they also prevent access to fish by other fish, in other words, barriers moderate species interactions. Removal or placement of barriers needs to be carefully and comprehensively thought through at a site level to avoid undesired ecological consequences.

20 Species can exist and persist where a set of abiotic and biotic factors allow them too (Wiens, 2011). Habitat and species interactions are intertwined, whereas climate (and environment) predominantly determines where species can survive.Within favourable environments complex species interactions affect both individual performance, and population dynamics (Louthan et al., 2015). Species interactions are mediated by environment and resource availability, but also by the presence, actions, and behaviours of other species (Bairey et al., 2016).

21 Because of this, it is helpful to think of the protection of habitat and species interaction together. This is a useful point to have front of mind when reading this evidence.

22 Generally, when discussing the impacts of trout on native fish species in New Zealand, the concurrent introduction of trout with large scale land use have made attributing decline to specific stressors difficult. There is a need to consider the requirements for a highly valued trout fishery within the context of an increasingly threatened native fish fauna, and to prioritise where impacts of trout are likely to be greatest to focus management actions.

Habitat Protection

23 The majority of New Zealand freshwater fish species are endemic and suffer population fragmentation (Joy & Death, 2013., Moffat et al., 2020), with many species locally extinct over much of their pre-European range (Canning, 2018), largely attributed to loss of habitat, eutrophication, sedimentation, hydrological changes, and introduced species (Foote et al., 2015, Joy et al., 2019).

24 Because of this, protection of the freshwater environment is an important aspect of increasing native species abundance and distribution. Degraded environments, which being potentially harmful to the species themselves, can increase negative impacts of interspecies interactions, as constricting and homogenising river habits via flood management schemes or water abstractions can increase the vulnerability of native fish to the impacts of predators (David et al., 2019; Gluckman et al, 2017; Speirs, 2001).

25 In practice, habitat protection often takes the form of action in areas such as:

(a) Reducing contaminants (including nutrients, sediments, pesticides, heavy metal etc) being discharged to water;

(b) water quality;

(c) environmental flows; and

(d) physical stream characteristics such as it’s meandering nature, flow profile or riparian habitat

Species Interaction

26 Species interactions are complex and dynamic, and mediated by the environment and other stressors on those species. Species interactions can be positive or negative, and interactions between two species are often altered by the presence of other species within the same habitat (Bairey et al., 2016). When focussing on trout and native fish species interactions, the potential impacts of trout on native species are via predation, competition, and disease or parasite transmission.

27 Interactions between trout and native fish species are likely to be species-specific. The frequency and extent of interactions between the species, and the population dynamics and behaviour of native species will alter likelihood and severity of impacts. The ability of all species to withstand floods and drought, and the availability of food and habitat will also influence the

resilience of native fish to trout predation (McIntosh et al., 2010; Joy & Death, 2013).

28 Predation seems likely the main trout-induced stressor on native fish (McDowall, 2003; Townsend & Crowl, 1991). Piscivorous predation is the act of one fish eating a fish of another species. This will negatively impact the consumed individual, however whether it has a negative impact on the population of the species depends on a variety of other factors, including the abundance, distribution, and life strategies of that prey species.

29 Competition for food and space will likely have a negative impact on different native fish species in differing environments, however where food and habitat resources are plentiful competition is unlikely to have deleterious impacts on native populations (Jones & Closs, 2018; Richardson &Taylor, 2002; Woodford, 2009). It should be noted that even where food and habitat is plentiful, the presence of trout could still contribute to changes in the behaviour of native fish species such as limiting time spent drift feeding or foraging for food I the open, and spending more time in refuge habitats (McIntosh et al., 1992; Davis, 2003)..

30 There is limited research into the impact of trout on disease and parasite loads in native fish species in New Zealand; however, the presence of brown trout has been implicated in reductions of certain species of parasite in some native fish species, (Kelly et al., 2009).

Species involved:

31 If looking at predation impacts on extremely vulnerable / endangered native fish species, then any impacts will potentially affect a population. This could be predation by trout, larger bodied native species such as tuna/eel species, koaro, kokopu etc (Whitehead et al., 2002), as well as by piscivorous birds, who remain an apex predator of freshwater fish (McIntosh and Townsend, 1995). Humans can also greatly impact species populations directly via fishing and harvesting (Haggerty, 2007; Jellyman, 2012).

In-stream and out-of-stream factors affecting species interactions:

32 Multiple factors contribute to the persistence of indigenous fish populations within New Zealand, of which species interactions are a subset. Environmental factors such as river flow and form, availability of mesohabitat and food resources, the presence and connectivity of source and sink populations and trout size influence those interactions and have major implications for the likelihood of those interactions being deleterious to the native species population.

33 *River flow and form*: riverine environments with unstable, natural river flows and form, high levels of habitat heterogeneity, riparian vegetation adding natural food inputs, and plentiful interstitial substrate spaces will sustain diverse freshwater fish populations and communities, including larger bodied native or introduced predators freshwater fish species (Jones & Closs, 2018; Richardson & Taylor, 2002; Woodford, 2009, Smith, 2014).

34 *Mesohabitat and food resources*: where the location and circumstances do not provide good habitat or food resources, species interactions are likely to become more deleterious to populations. Lack of water in rivers forces species into closer proximity to each other, limited food resources increases the chances of fish occupying the same habitat and seeking the same foods, this increased proximity and lack of food options will increase predation by larger fish species on smaller fish, and also expose all freshwater fauna to predation via birds (David et al., 2019; Gluckman et al, 2017; Speirs, 2001).

35 *Source and sink populations*: local extirpation can be prevented by recruitment into the local (sink) population from a connected highly productive (source) site, source populations can form in a favourable area (Goodman, 2002; Allibone et al., 2010). Increasing the health of upstream populations of vulnerable species could mitigate impacts of predation on downstream populations (Woodford & McIntosh, 2010). For source populations to enhance sink populations it is vital that connectivity between the populations is maintained, and the source population is monitored, as rapid species decline in the sink population can occur if the source population can no longer sustain the sink population (Joy et al., 2019, Boddy et al., 2019).

36 *Trout size:* most studies agree trout do not become piscivorous until they are ~150 mm FL (Klemetsen et al., 2003, Mittelback & Persson, 1998). Prey selection and capture by trout is restricted by the gape and gill raker sizing of trout, and large or abundant prey are preferred as they offer greater energy return for foraging effort; the size of the prey increases as the trout size does (Bannon & Ringler, 1986; Montori et al., 2006). Post piscivory onset fish make up <10% of the diet of brown trout, invertebrates remain the main prey sources, particularly in the middle to upper reaches of New Zealand rivers: amount of fish consumed by trout increases with trout body size and prevalence of small bodied prey, mediated by availability of refuge for the prey (Crowl et al., 1992; Shearer & Hayes, 2019).

37 Therefore, it is vital that management of species interactions is location and fish community specific and nuanced to the wider environment.

38 *Flow*: low flow in riverine environments and destruction of wetlands can be induced by water abstraction with significant negative impacts on all freshwater fauna (McDowall, 1984; McEwan & Joy, 2014; Howard, 2014; Xu, 2018). Native generalist fish populations dominate unregulated rivers; therefore, patterns of floods and flushes that come with undisturbed river flow regimes are vital for allowing healthy cohabitation of species and increased biodiversity (Boddy et al., 2019; Woodford & McIntosh, 2010).

39 *Habitat*: complicated and unstable riverine environments promote species coexistence via providing habitat, refuge, and optimal microhabitats for a variety of species throughout differing life stages (Jones & Closs, 2018; Woodford, 2009; Boddy & McIntosh, 2017). Water level reduction and channelisation removes edge and backwater habitat needed for juvenile spawning and rearing habitats and can be especially problematic in small streams where non-diadromous high country fish can be found (Allibone et al., 2010).

40 *Sediment and substrate size:* larger substrate supports greater diversity where the interstitial spaces have not been infilled with sediment, as the spaces between substrate creates microhabitats used preferentially by several native species and invertebrates (Joy & Death, 2013). Fewer interstitial spaces make the biota of the waterway more vulnerable to disturbance (Allibone, 2002). Silt and sand dominated sites have the lowest invertebrate diversity and abundance (Jowett & Richardson, 1989; Quinn & Hickey, 1990), a lack of abundant, large, healthy macroinvertebrates may increase predation risk for small fish of any species. Heavy siltation can eliminate fish spawning habitat (Hickford & Schiel, 2011; Warburton, 2015). Certain native freshwater fish species, particularly vulnerable non-diadromous species (lowland longjaw and alpine galaxiids), can only burrow or inhabit reaches with large, loosely consolidated substrate with minimal sediment (Dunn & Brien, 2006; Boddy & McIntosh, 2017).

41 *Nutrients and pollutants*: sediment, nitrogen, phosphorus, pesticides, and heavy metals can negative impact riparian and waterway habitat and ecology (Joy, 2009, Allan, 2004). Water soluble metals can disrupt the ability of fish to forage, migrate, and recognise and respond appropriately to predation risk (Greig et al., 2010, Yui et al., 2017). Nitrogen and phosphorus can contribute to excessive algal growth which traps sediment, eliminates interstitial spaces, and lead to dissolved oxygen depletion during nocturnal periods leading to injury or death of local aquatic fauna (Ausseil & Clark, 2007; Death et al., 2018).

42 *Connectivity:* Diadromy prevalence in the freshwater fish species of New Zealand indicates that access between marine and freshwater habitats may

be the most important habitat attribute for fish community and increased biodiversity (Franklin & Gee, 2019; Jowett & Richardson, 2003; Joy & Death, 2001). Fish passage barriers at low elevation potentially deleteriously impact fish communities more than those further from the sea (Baker, 2003; Joy & Death, 2001), restricting upstream access to those species with the ability to pass the barrier, and may also prevent movement of fish seeking refuge from high flow events (David, 2003). However, barriers to prevent access to threatened non diadromous species by trout, salmon, or other species likely to negatively impact that population may be an effective management tool in the mitigation toolbox.

43 *Riparian vegetation*: fish species richness and abundance declines in pasture sites and improves in scrub and native forested streams (Joy et al., 2019; Larned, 2020). Riparian vegetation shades and cools waterways, reducing algal growth, contribute allochthonous[1] inputs including terrestrial invertebrates, stabilises banks, and increases habitat diversity via root structures and woody debris (Canning, 2018; Montori et al., 2006; Smokorowski & Pratt, 2007, West et al., 2005). Streams with added food inputs could decrease competitive and predatory interactions (David, 2003; Montori et al., 2006). Riparian trees should extend as far up the headwaters and cover as much of the catchment as is practical to have the largest impact on stream health (Niyogi et al., 207; Orchard, 2017).

44 *Temperature*: heated discharges, water abstraction, and removal of riparian shading alters the thermal regime of a waterway and limits the abundance and distribution of aquatic invertebrates via their thermal tolerances and the decreases in macroinvertebrate size, abundance and quality as food resource for fish as macrophytes and algae become more abundant (Quinn et al., 1994; Piggott et al., 2015). Water temperature affects fish behaviours, growth rates, survival and abundance (Ausseil & Clark, 2007, Richardson et al., 1994). Any temperature outside of the preferred temperature range of each species will override any top-down control by fish despite any abundance of predators (Hayes et al., 2019; Young et al., 2010). Most native fish species have lethal temperatures at higher ranges than that of trout (Richardson et al., 1994). Warmer water temperatures in waterways where trout may be larger may help assist cohabitation with more thermally tolerant species, however this needs to be weighed carefully with the sublethal population impact on the native species and the impacts on invertebrate food resources. Shading streams with riparian vegetation is the

[1] Allochthonous inputs relates to organic materials added or imported into a waterbody from outside of that waterbody, including from terrestrial environments.

most effective method of reducing water temperature in streams narrower than 10 m (Richardson & Jowett, 2005).

Options for resolving species interactions:

45 Environmental management should be a key focus of any intervention, while specific and potential biotic interactions and actual freshwater community data are assessed in the field. Once vulnerability level of native fish to trout predation was defined using the risk assessment framework, we accessed the New Zealand Freshwater Fish Database (NZFFD) (Stoffells, 2022) to find where each species co-occurred with trout. This information was then used to create models predicting reach level information on co-occurrence to allow river and species managers to prioritise sites containing highly vulnerable species for assessment and intervention as required. The NZFFD may not capture current status; in the field assessment will be needed to inform management needs. Restoration of those environments can begin immediately if deemed necessary while species interactions and implications are being rapidly assessed.

46 The models and maps show the extent of trout and highly vulnerable species overlaps is ~10% of waterways.

47 Efforts which improve the quality and extent of native fish habitat will not only help native fish resilience to trout predation, but also to any other disturbances they face. Concerns have been raised regarding whether improving habitat will benefit trout and cause more predation impacts on native species. However, it is well documented that waterbodies with a dynamic range of form and flow and bed instability appear to promote coexistence by reducing trout population densities and biotic interactions (McIntosh, 2000; Leprieur et al., 2006). Native fish species may be less affected by disturbances than introduced species, thus protections of habitats which allow for disturbance and other location specific managements should encourage healthy and abundant native fish populations and coexistence with trout.

48 Table 1 demonstrates a range of management strategies which can moderate the impact, frequency, or likelihood of species interactions.

Table 1: Actionable management strategies to mediate and mitigate impact of trout predation on native fish species

Mitigation	**Actions**	**Rationale**
Flow variability	Provide for a less disturbed flow regime,	Streamflow is a major variable affecting abundance and

	reduce water abstraction for any use, and allow a return to a less constrained cycle of drought and flood.	distribution of freshwater species. Trout are linked to significant negative impacts on native species in stable streams. Flood flow peaks and droughts assists cohabitation with native species and native species spawning and recruitment.
Stream morphology and size	Provide for the full variety and variability of stream processes to positively influence biological diversity by providing for species specific habitat and life history needs. Discourage and find alternatives to channelisation and water abstraction where possible.	Habitat heterogeneity allows cohabitation of many species, including trout and native fish species across differing life stages. Edgewater habitats increases recruitment potential to bolster populations. Dynamic river structure vital for fish species.
Sediment and substrate size	Provide for reduced sediment and a range of substrate sizes, minimise sediment inputs into waterways, and allow riparian overhanging structures and wood inputs.	Interstitial space provides habitat, access to food, and refuge for many native fish species and is thus necessary for multi-species communities. Sediment infills substrate, reduces waterway depth, and homogenizes habitat, which may preclude cohabitation.
Nutrients and pollutants	Provide for minimised inputs of nutrients and pollutants from any source.	Nutrient inputs can infill waterways and interstitial spaces with aquatic flora and cause hypoxic conditions overnight. Metal and chemical pollutants impair fish species

		greatly decreasing predator avoidance ability.
Source and sink populations	Tools: Correctly identify source vs sink populations and connectivity between them, maintain source populations and work to bolster recruitment for sink populations. Ensure fish abundance alone isn't the metric for population health, analyse age groups and site fecundity.	Sink populations of species lose more individuals than they create, and therefore must be bolstered by immigration from healthier populations (source populations). Sink populations are highly vulnerable to extirpation from any threat, including trout or other predator. Source populations may sustain other populations in the face of pressures.
Marine - freshwater connectivity	Provide for increased marine - freshwater connectivity in both upstream and downstream directions and remove fish passage barriers where possible	The high incidence of diadromy in freshwater fish indicates the importance of access between marine and freshwater environments in replenishing freshwater communities in the face of biological and environmental pressures.
Riparian vegetation	Provide for appropriate riparian vegetation extending throughout as much as the catchment as is practicable.	Many fish species require robust riparian vegetation, inputs of food and woody debris as shelter can sustain inter-species cohabitation as well as partially mitigate other environmental impacts.
Temperature	Provide for temperature fluctuations, reduce or remove anthropogenic sources of thermal pollutants into	Water temperature outside any species' preferred range overrides any biological interactions by changing all species behaviours (including feeding and breeding), and

	waterways, ensure water abstraction does not interfere with the riverine ecosystem.	negative impacts of these unfavourable conditions will increase any impact of predation.
Trout size	Large trout (>150mm FL) in deep, stable rivers may pose a threat to threatened native fish if any such are inhabiting the same waterbody. Therefore, removal of large trout may avoid species interactions. Barriers to prevent trout from moving into vulnerable native fish populations should be left in place while required for the health of that population.	Trout can become piscivorous once over 150mm FL. After this size, fish remain a small portion of trout diet (<10%, on average), and this proportion is governed primarily by the abundance of small fish and the availability of refuge for the prey. Non-diadromous species with highly fragmented and impacted habitats need to be protected from introductions of any large piscivorous fish, including trout.

Limitations to interventions:

49 Interventions should be possible where needed. Those interventions will be determined by the needs of each specified location. Conflicts between the needs of the waterbody and the fauna inhabiting it and human needs may complicate how intervention is undertaken, however these should still fall within the realm of achievable. Widespread removal of trout will likely not be practical due to their widespread and migratory nature, nor would it be financially or socially acceptable (Chadderton, 2001). However, there will be sites, particularly in some small headwater streams and tributaries where trout should be removed as part of a suite of management tools to bolster vulnerable native fish populations.

50 While some highly vulnerable species populations may require exclusion of predators such as large trout or koaro to ensure their survival, attempted eradications may not achieve enhanced biodiversity outcomes, and may have unanticipated negative ecological impacts on the food web. A holistic focus on ecosystem health of the designated area (and then the wider catchment and connections) is strongly recommended for any management program.

51 Fish passage barriers can be left in place where they give protections to vulnerable upstream native fish populations, it is important attempt to ensure there are no predatory species upstream of the endangered population where possible.

52 It is important that robust ecological consideration is given to each site where species interactions are to be managed, to attempt to avoid creating trophic cascades via removal or addition of species to an area. There are also limits to human ability to remove fish from desired locations. Salmonids can avoid nets, and electrofishing cannot be performed in deep water or pools (Joy et al., 2013) which is the usual habitat for trout.

53 Wholesale removal of trout via poisoning (e.g., rotenone) is likely to also result in deaths of aquatic invertebrates and vulnerable native non-target species (Ling, 2003; Dalu et al., 2015). In some cases, these populations can be so fragile that any losses will be unacceptable. The cost and limited availability of rotenone constrain it’s use to small waterbodies (Ling, 2003).

54 Genome editing has the capacity to self-propagate (York et al., 2021), so it’s use for population control of trout would be socially anathema given the high probability of altered individuals affecting valuable mainstem trout populations, and the legally protected state of trout.

55 Any species interaction management actions should be undertaken as a collaborative, science-based event with iwi, relevant council bodies, the Department of Conservation, and Fish and Game councils.

Categorising species interaction risk:

56 My masters thesis focussed on the possible impacts of trout predation on indigenous fish populations New Zealand rivers. My evidence below is informed by this thesis and the research required to complete it .

57 Introduction of trout has been associated with declines in native species abundance and distribution, particularly that of non-diadromous galaxiids, predominantly based on research finding a negative association between brown trout and Canterbury galaxiids (Townsend & Crowl, 1991). Information regarding indigenous fish species prior to trout introduction is scarce, further confounding attempts to ascertain extent and triggers of reductions in native fish abundance and distribution.

58 Native fish can co-occur with trout in some locations, but not at others (McIntosh, 2000; Townsend, 2003). Many of New Zealands native fish species are highly threatened (Dunn et al. 2017), so protecting them and restoring their populations to abundance is urgent.

59 A risk assessment matrix was created to utilise a systematic approach to assessing the risk of substantial population level impacts of trout predation on native biodiversity in New Zealand rivers, and to aid in focussing and prioritising management actions. Risk assessment is required to be species-specific, and with the awareness that multiple interconnected factors will affect trout predation impacts.

60 Literature was used to appraise the risk of substantial negative impacts at local population-level by trout predation for all native New Zealand fish species. Native fish species were scored and triaged based on their biological traits that could make their populations vulnerable to trout predation (see Table 2 for risk factors, scoring, weighting and justification). The overall impact of trout predation on a given native fish population is mediated by population dynamics, which are governed by fecundity of individuals and frequency of spawning events throughout a season and lifetime (Stevens et al., 2016). Rapid growth, early maturation, short life span, high fecundity, and widespread dispersal and distribution (r-selected traits) allow for high population resilience to disturbance events (Rowe and Wilding, 2012). However, migratory and long lived, late maturing fish (K-selected traits) are exposed to increased ontogenetic jeopardy due to movements between very different habitats or increased time spent in vulnerable life stages (Arthington et al., 2016). In addition to population

growth strategies, the initial health of the population will also affect recovery from disturbance as impacts are often cumulative. In the risk assessment framework, initial population health was indicated by the New Zealand Threat Classification System (NZTCS) conservation status, which indicates the current risk of extinction for each species (Dunn et al., 2018).

61 For each risk factor, species were assigned a score from 1-3, with 1 indicating little to no risk, and 3 indicating high risk. Not all risk factors were considered equal: fecundity and egg size, age at reproductive maturity, threat status and adult body size were of increased importance when considering interactions with trout and were therefore given twice the weighting in overall scoring. Each species was, therefore, scored between zero and 31, composed of the weighted sum of nine potential risk factors (see Table 2), and scores were assigned using literature-informed judgement. Once scores were assigned, species were then triaged into risk groups of high (scoring between 26 and 31), moderate (scoring between 21-26) and minor (scoring between 16 -20), indicating potential of population level detrimental impacts from trout predation (Table 3).

62 The most highly vulnerable species were non-diadromous galaxiids and mudfish, whereas lamprey, eel species and black flounder were considered unlikely to be negatively impacted at a population level by trout predation (see Table 3 for complete species list and vulnerability scoring).

63 The Risk Assessment scores showed mahinga kai species (tuna/eels, smelt, lamprey, black flounder, and the diadromous galaxiids) are considered to have minor to moderate risk of negative population level impacts from trout predation (see Table 3), although many will compete for similar food resources (Main, 1988). The galaxiid species deemed at moderate risk are: shortjaw kokopu due to reduced abundance, koaro due to threat ranking and diet similarities with trout, and giant kokopu due to late onset of breeding, threat ranking, and similarities of food and habitat requirements with trout (West et al., 2005).

64 Mahinga kai species are generally widely dispersed, large, and/or occupy different mesohabitats to trout. Competition for food and habitat is likely to play a role in interactions between trout and the large bodied galaxiids, as trout drift feed on stream and terrestrial invertebrates in much the same manner as the large bodied diadromous galaxiids, and trout and giant kokopu adults both prefer pool habitat (Bonnett & Sykes, 2002, Whitehead et al, 2002). While kokopu adults grow too large for predation by trout, the juveniles are at risk of predation, particularly as they migrate upstream It should be noted that predation of juvenile giant kokopu by adult conspecifics is considered a significant threat (Whitehead et al, 2002),

adding emphasis to the importance of nuance when considering species interactions impacts. Smelt and inanga are consumed by trout, particularly spent adults after spawning, their fast life strategies can maintain a robust population despite predation by trout and other fish, birds, and humans (McDowall 1990; spawning habitat will be critical however, as the short lifespan of these species indicate that any large decreases in recruitment could lead to heightened threat status within a few years (Yungnickel et al., 2020). Tuna/eels, lamprey, and black flounder occupy differing habitats and are too large as adults for trout to consume (Jellyman, 1989; McDowall 1990, Closs et al., 2015), eels are the apex instream predators (Jellyman, 2012) and trout are frequently prey of these wonderful animals (Jellyman, 1996).

Table 2: Native fish vulnerability table and weightings

Mediating factors	**Assessment**	**Score**	**Weighting**
Overlapping physical habitat with trout (micro-niche habitat proximity increases interaction likelihood)	No or rare overlap	1	1
	Intermittent overlap	2	
	Persistent overlap	3	
Diel activity patterns (activities at similar times as trout: e.g., crepuscular activity patterns increase likelihood of interactions)	No or rare overlap	1	1
	Intermittent overlap	2	
	Similar diel patterns to trout	3	
Diet similarities (increase potential for competitive interactions)	No or few similarities	1	1
	Similar (aquatic inverts)	2	
	Very similar (aquatic & terrestrial inverts/piscivorous)	3	
Fecundity & egg size (many small eggs aid population resilience by increased numbers of larvae)	Many	1	2
	Few, small eggs	2	
	Few, large eggs	3	
Age at reproductive maturity (longer maturation time increases likelihood of individuals not surviving to breed)	1 year	1	1
	1-3 years	2	
	>3 years	3	

Larval dispersal ability (source/sink repopulation potential, population replenishment and resilience)	Diadromous	1	2
	Non-diadromous, widespread dispersal	2	
	Non-diadromous, limited dispersal	3	
Threatened species ranking (Dunn et al, 2018)	Not threatened	1	2
	Declining	2	
	Naturally uncommon	2	
	Nationally vulnerable	2	
	Data deficient	2	
	Nationally endangered	3	
	Nationally critical	3	
Adult body length (smaller adults more easily predated)	>12 cm	1	2
	8-12 cm	2	
	<8 cm	3	

Table 3: Risk assessment scores for native New Zealand fish species to screen their vulnerability to impacts by trout, as per the criteria and weightings introduced in Table 2.

Species	**Risk factors and weightings**								Score	Vulnerability rating
	Overlapp	**Diet**	**Diel**	**Fecundit**	**Age at**	**Larval**	**Threat**	**Adult**		
	1	**1**	**1**	**2**	**1**	**2**	**2**	**2**		
Dusky galaxiid (*Galaxias pullus*)	2	2	2	3	3	3	3	2	31	High
Lowland longjaw galaxiid (*Galaxias cobinitis*)	2	2	2	3	1	3	3	3	31	High
Eldon's galaxiid (*Galaxias eldoni*)	2	2	2	3	2	3	3	2	30	High
Bignose galaxiid (*Galaxias macronasus*)	2	2	2	3	2	3	2	3	30	High
Upland longjaw galaxiid	2	2	2	3	1	3	2	3	29	High

(*Galaxias prognathus*)										
Canterbury mudfish (*Neochanna burrowsius*)	2	2	1	3	2	3	3	2	29	High
Brown mudfish (*Neochanna apoda*)	2	2	1	3	2	3	2	2	27	High
Black mudfish (*Neochanna diversus)*	2	2	1	3	2	3	2	2	27	High
Northland mudfish (*Neochanna heleosis*)	2	2	1	3	2	3	2	2	27	High
Chatham Island mudfish (*Neochanna rekohua*)	2	2	1	3	2	3	2	2	27	High
Taieri Flathead galaxiid (*Galaxias depressiceps*)	2	2	2	2	2	3	2	2	26	High
Dwarf galaxiid (*Galaxias divergens*)	2	2	2	1	2	3	2	3	26	High
Roundhead galaxiid (*Galaxias anomalus*)	2	2	1	1	2	3	3	2	25	Moderate
Gollum galaxiid (*Galaxias gollumoides*)	2	2	2	1	1	3	2	3	25	Moderate
Tarndale bully (*Gobiomorphus alpinus*)	2	2	2	1	1	3	2	3	25	Moderate

Canterbury galaxiid (*Galaxias vulgaris*)	2	2	2	1	2	2	2	3	24	Moderate
Alpine galaxiid (*Galaxias paucispondylus*)	2	2	2	1	2	3	2	2	24	Moderate
Upland bully (*Gobiomorphus breviceps)*	2	2	2	3	1	2	1	2	23	Moderate
Koaro (*Galaxias brevipinnis*)	3	3	2	1	2	1	2	2	22	Moderate
Giant kokopu (*Galaxias argenteus*)	3	3	3	1	3	1	2	1	22	Moderate
Shortjaw kokopu (*Galaxias postvectis*)	3	3	2	1	3	1	2	1	21	Moderate
Bluegill bully (*Gobiomorphus hubbsi*)	2	2	2	1	1	1	2	3	21	Moderate
Inanga (*Galaxias maculatus*)	3	2	2	1	1	1	2	2	20	Minor
Torrentfish (*Cheimarrichthys fosteri*)	2	2	2	1	2	1	2	2	20	Minor
Stokell's smelt (*Stokellia anisodon*)	3	1	3	1	1	1	2	2	20	Minor
Banded kokopu (*Galaxias fasciatus*)	3	3	2	1	3	1	1	1	19	Minor
Cran's bully (*Gobiomorphus basalis*)	2	2	2	1	1	2	1	2	19	Minor

Common smelt (*Retropinna retropinna*)	3	2	3	1	1	1	1	2	19	Minor
Longfin eel (*Anguilla dieffenbachii*)	2	3	1	1	3	1	2	1	19	Minor
Giant bully (*Gobiomorphus gobiodes*)	2	2	2	1	2	1	2	1	18	Minor
Redfin bully (*Gobiomorphus huttoni*)	2	2	2	1	2	1	1	2	18	Minor
Shortfin eel (*Anguilla australis*)	2	3	1	1	3	1	1	1	17	Minor
Common bully (*Gobiomorphus cotidianus*)	2	2	2	1	1	1	1	2	17	Minor
Black flounder (*Rhombosolea retiarii*)	1	3	2	1	2	1	1	1	16	Minor
Pouched lamprey (*Geotria australis*)	1	1	1	1	3	1	2	1	16	Minor

65 A Risk Assesment matrix like this one stands as a transparent, easy to utilise tool to prioritise those species that are most vulnerable to trout predation, and to locate where those highly vulnerable species are likely to interact with trout. This tool is designed to be flexible: while the mudfish and non- diadromous galaxiids listed as highly vulnerable require urgent protections, it does not follow that those designated as moderately vulnerable do not. In some cases, those listed here as moderately vulnerable may have very vulnerable populations, which should be urgently assessed and managed. It is my profound hope that by protecting habitat and mitigating species interactions, those species currently noted here as highly vulnerable will become much more abundant and widely distributed, and the triage will then require a focus on moderately vulnerable species and so on, until we have a healthy, thriving, fish community with native species and valued introduced species throughout the country.

Comment on NPS-FM Policies 9 and 10 from an ecological perspective.

Tying together the threads of habitat protection and species interaction

66 The three threads of habitat protection, species interactions, and fish passage are artificially separated by humans in order to attempt to make sense of the world around us. While this can be helpful, particularly when ensuring policy captures all aspects needed to protect the environment, it can be profoundly unhelpful if it leads to perceptions whereby species interactions are not seen within the much vaster impacts of environmental and biological factors.

67 Where waterbodies contain small or fragmented populations of threatened freshwater fish species, who are thus more vulnerable to impacts of any kind, managing species interactions will be more urgent than in other locations.

68 The size of any deleterious impact will inevitably depend on numerous factors including the production rates of other prey fish and invertebrates and the local trout population density, which are all, in turn, affected more generally by primary production, allochthonous input rates, nutrients, sediment, available habitats, migratory connectivity – barriers and passage, temperature and the hydrological regime. The interaction of each factor in determining the impact of trout on native fish would be notoriously difficult to predict. Monitoring fish populations at high-risk locations and adaptively responding to any low or declining populations through the identification and adoption of multiple mitigations would likely provide the most robust approach going forward.

Is it possible to protect the habitat of trout and salmon, insofar as it consistent with protecting the habitat of indigenous species. If so, under what conditions?

69 Healthy, abundant, protected habitat is key for healthy freshwater fish species. Where the risk from species interaction is low it is very likely that actions to improve habitat for trout and salmon will benefit native species. After all, in this situation they inhabit the same river and benefit from the same river resources. Habitat interventions, as discussed previously, provide for increased in-stream habitat diversity, food resources, river flow and disturbance, an aim to reduce nutrient, sediment, and pollutant inputs, and minimise overgrowths of macrophytes and algae, which will help provide optimal conditions to increase aquatic invertebrate and vertebrate diversity and abundance.

70 In my experience, the habitat needs for trout – particularly in terms of water quality and quantity – are often higher than the needs of indigenous

species. In circumstances where anthropogenic demand for abstraction or the discharge of contaminants is significant, the habitat retained in rivers is often driven down to the absolute need of the species within. When this situation occurs, the presence of trout and management of the waterbody to meet the habitat needs of trout, can lead to more healthy and resilient river habitats, benefiting both trout and natives, because the overall habitat requirements of the river are greater than if trout were not present.

71 There are limited places where protections of <u>habitat</u> of trout and salmon would be inconsistent with protecting the <u>habitat</u> of indigenous species. There are likely places where the <u>presence</u> of trout and salmon would be currently incompatible with allowing highly vulnerable native species to thrive and regain abundance and population health. Fish passage barriers preventing access to highly vulnerable species may help to create species and habitat reserves to protect these species.

72 However, solely focussing on biological interactions as a priority over environmental factors could potentially lead to removal or reduction of protections for habitat for native species, such as allocating more water takes from rivers, which will likely have a negative impact on that species, and the ecosystems they inhabit and impact.

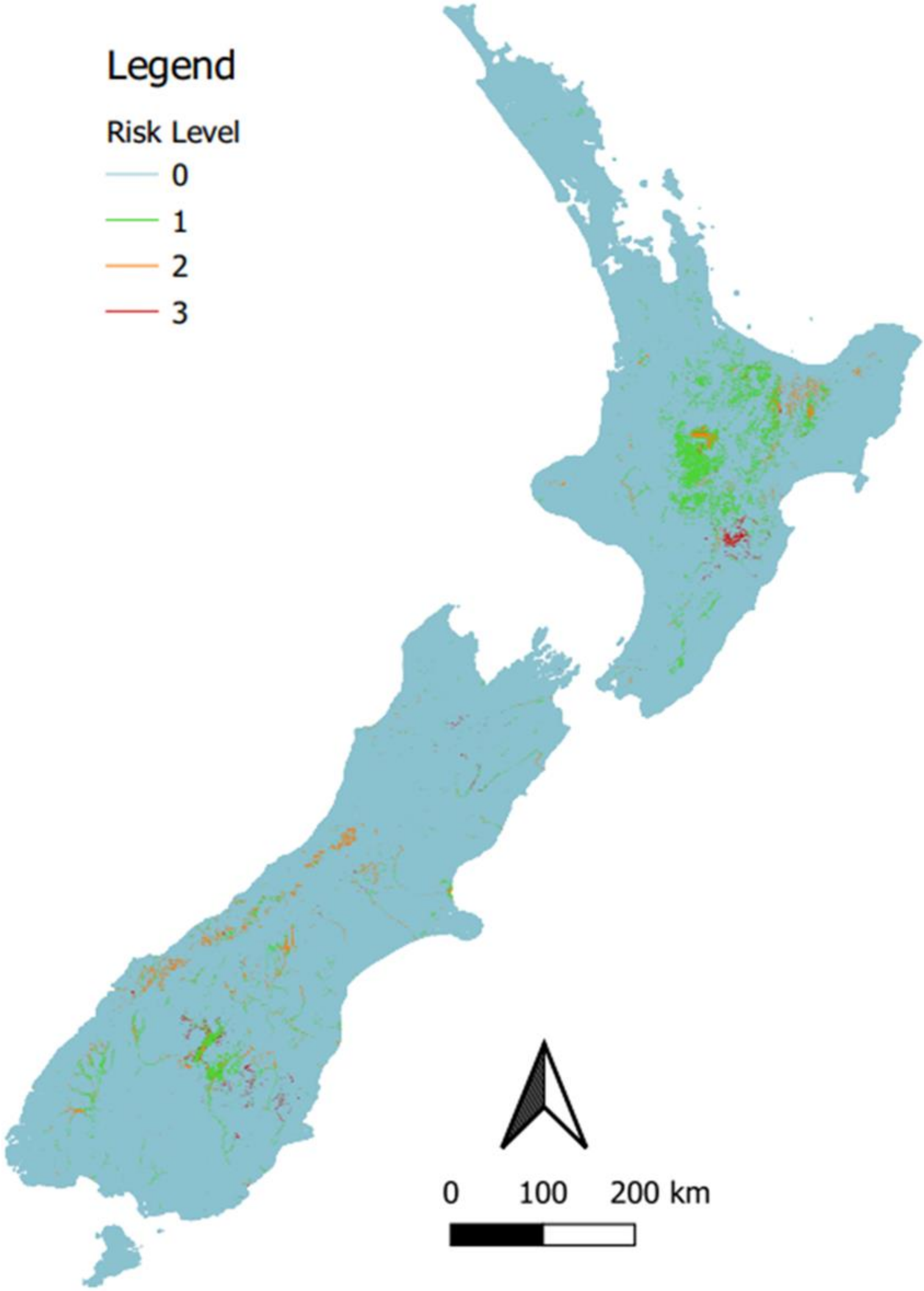
73 A risk assessment matrix can help ascertain which species are most vulnerable. This matrix looks at which species are most vulnerable to trout predation impacts at a population level. This can triage those waterbodies which most urgently need management. As mentioned in paragraph 44, a map was created using QGIS utilising the risk scores assigned here, and species location data from the NZFFD. These maps are an attempt to locate where the most vulnerable species overlap in habitat with trout and prioritise these reaches for in-field assessment and management where required.

Scale of interactions between trout and native fish:

74 My risk assessment suggests there is approximately 10% of waterways nationally where trout (of any size) overlap with those species graded as having highly vulnerable populations to trout predation, which would require urgent attention to both environmental restoration to increase native fish populations, and to species interactions to minimise the threats of predation. On the map (Figure 1), reaches lodged in the NZFDD containing highly vulnerable species and trout are shown in red, the orange reaches contain moderately vulnerable species, and the green shows overlapping trout and those species considered to be a low level of vulnerability to population level impacts of trout predation. The blue areas are where trout are not present (land areas, or trout presence not indicated in the NZFFD).

75 I have created maps of Otago rivers, in an attempt to home in on particular rivers (Figure 2), tributaries, and reaches (Figure 3), where trout may co-occur with highly vulnerable native fish species. The majority of highly vulnerable species are located in Otago; thus, species interactions and habitat protection are vital to protect these species.

Figure 1: Map of New Zealand showing river reaches where native species at high (3), moderate (2), or low (1) risk of negative population impacts due to trout predation overlap with trout presence. A no possible impact score (0) is in place where there are no trout known to be present.



Can trout and salmon habitat can form part of the ecological health and well-being of a water body or freshwater ecosystem?

76 There are differing definitions of ecosystem health, and ecosystem health means many things to different people. Schallenberg et al (2011) state that the concept of ecosystem health defines an ecosystem in terms of the stresses put on it, and its ability to keep providing products and processes for both economic and ecological needs: it is indicative of the sites which have been modified by human activity, ensuring that ongoing activities do not degrade them for future use. The NPS-FM states that ecosystem health consists of five biophysical components which require managing: water quality, water quantity, habitat, aquatic life, and ecological processes. This definition does not exclude introduced species, providing that indigenous aquatic life expected in the absence of human alteration is sustained.

77 A healthy river has been defined as an ecosystem that is sustainable and resilient, maintaining its ecological structure and function over time while continuing to meet societal needs and expectations. These values can be intrinsic (species have the right to exist) or instrumental (tourism value). Different groups typically have differing values and conceptions of what nature should look like that reflect their background, needs and aspirations, and disagreements around introduced fish is likely due to differing assumptions regarding that species role in the ecosystem (Harmsworth et al., 2011; Tadaki et al, 2022).

78 Utilising these definitions and concepts, where the risk of species level negative interactions to native species by trout and salmon is low, and the value provided to the community by the salmonids is high, then protection of trout and salmon habitat does form part of the ecological health and wellbeing of a water body or freshwater ecosystem. I would not consider trout and salmon habitat to form part of the ecological health of a site if the presence of trout and salmon was not permitting indigenous aquatic life to be sustained. Ecosystem health therefore is nuanced and site specific, rather than black and white and species specific.

79 Clapcott & Hay (2014) report states the United States Environmental Protection Agency water quality criteria for salmonid waters should protect New Zealand aquatic fauna, as trout are more sensitive to water quality changes than most native fish, and as sensitive as the most sensitive native fish. These water quality parameters consist of maintaining healthy water temperature, dissolved oxygen, clarity and turbidity levels, a MCI of >120, diatom film mats not periphyton or algal covers, low nitrogen and phosphorus levels, healthy pH levels, 99% protection level for ‘other toxicants’ as per the ANZECC (2000) guidelines, and low levels of faecal

contaminants (Hay et al, 2006). Thus, in the majority of circumstances, these habitat recommendations which support trout and salmon would allow waterways to also support native freshwater fish populations.

80 Integrating further environmental management for native species in these areas designated for trout and salmon habitat protections would increase the protections for native species and encourage cohabitation and increase biodiversity. These managements could include riparian planting, removing substrate sediment infill and preventing further sediment inputs driven by human landscape use, allowing a minimally constrained river flow, and encouraging habitat heterogeneity. I would imagine this could also be in alignment with Te Mana o te Wai and giving primacy to the health of the water for itself, and the National Policy Statement – Freshwater Management (2020) requiring protections for habitat for native species (Policy 9) and protections for habitat for trout and salmon insofar as this is consistent with Policy 9 (Policy 10).

What is the scale in Otago where you might consider T&S habitat to form part of the health and well-being of water bodies?

81 Figure 2 and Figure 3 show maps created using the risk assessment matrix to focus on a section of the Otago, New Zealand. These maps show river reaches where native species at high (3, red), moderate (2, orange), or low (1, green) risk of negative population impacts due to trout predation overlap with trout presence. A no possible impact score (0, blue) is in place where there are no trout present. Figure 3 was designed to be used to focus on individual reaches in waterways for in-field assessment and management.

82 Above, I described the conditions in which I'd expect that trout and salmon habitat would form part of a healthy ecosystem. These are generally: mainstem waterways and larger tributaries with less vulnerable and more resilient native fish populations. Using the mapping in Figures 2 and 3, I would expect the blue and green designated reaches to be places where trout and salmon habitat could form part of a healthy ecosystem and the places in red where this would not be the case. Where the map shows orange reaches the sites should be noted for assessment as soon as practicable, as some moderately vulnerable species may require site management for species interaction as a matter of urgency.

Figure 2: Otago region map, Taieri River catchment.

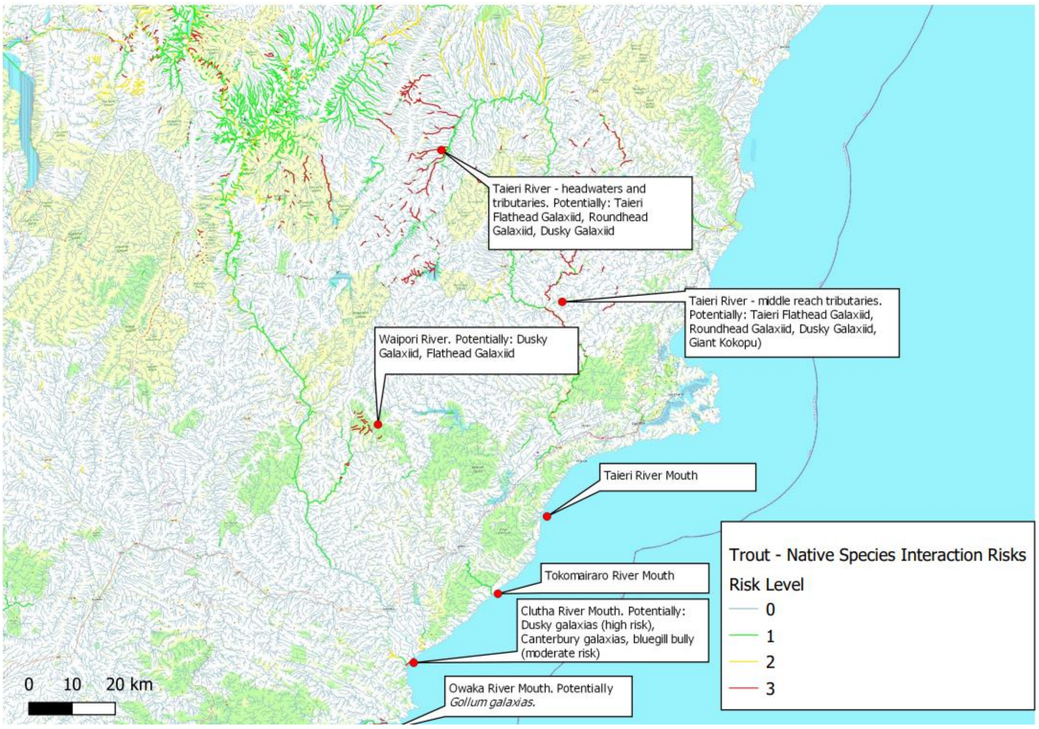
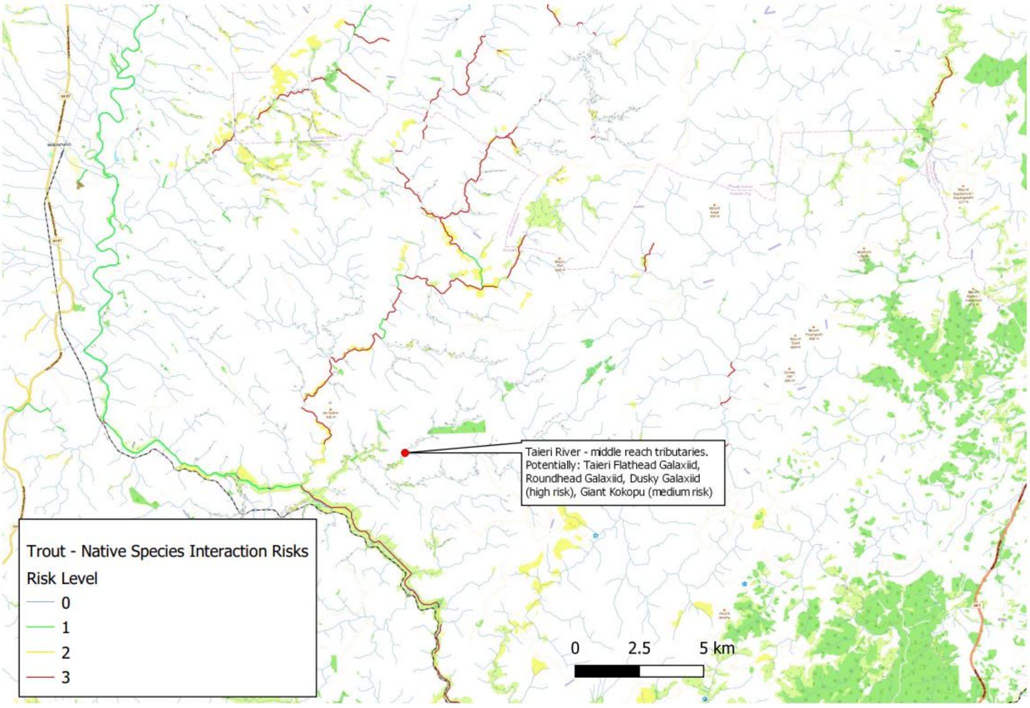


Figure 3: Map of the middle section of the Taieri River and tributaries.



Provide comment on the T&S framework sought by F&G. Would you expect it to work in practice?

83 In the sections above, I have described the key issues surrounding species interaction and the nuances of location and circumstance that need to be considered to address it effectively.

84 Having protections for trout and salmon habitat where consistent with the needs for protection for native fish habitat and restoring those environments if degraded will be important to keep this Regional Policy Statement consistent with national level legislation and policy, in particular the Resource Management Act (1991) and the National Policy Statement – Freshwater Management (2020). Developing a framework to consider and manage species interactions between trout and native species will also be important to strengthen ecosystems and species, and increase native species abundance and distribution, while allowing for a strong trout fishery in appropriate places.

85 Restoring connectivity is vital for freshwater fish communities, however there will be places where predatory species should be excluded to protect highly vulnerable native species. These excluded species will include trout and should also look to potentially exclude large bodied galaxiids and eel species if necessary. Again, a nuanced, individualised, food-web and ecosystem focussed approach will be needed if legislation and management is to create healthy environments. A blanket approach could potentially be highly detrimental.

86 Looking at the requirements of LF-FW-Mx from a practical perspective, I see the method as a helpful way forward in collaboration to create a practical well-functioning framework to allow for healthy freshwater fish communities and provide for the needs of ecosystems and the communities and individuals who enjoy them in diverse and profound ways. The process directed by the method helpfully captures the nuance required to properly address the issues of habitat protection, fish passage and species interaction with respect to trout and salmon.

Ami Coughlan

28 June 2023

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