Freshwater fish taxonomic workshop

Focussing on New Zealand non-migratory galaxias taxonomic issues

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1. Introduction

Since the early 1990s, new information has been gained from surveys, research, and genetic analyses resulting in descriptions of new non-migratory galaxias species and the identification of distinct groupings within non-migratory galaxias (Appendix 1).

The Department of Conservation (DOC) has been involved in many meetings with key external agencies and experts to try to prioritise New Zealand non-migratory galaxias taxonomic work, with the aim of determining the taxonomic status of the outstanding indeterminate groups. Several pieces of work have provided useful guidance towards sorting out the taxonomic issues (e.g. standardised common names for distinct groupings, and confirmation of distributions). However unfortunately, the methods used in these analyses did not result in formal descriptions, and a number of indeterminate groupings still remain for non-migratory galaxias (McDowall & Hewitt 2004; McDowall 2006; Waters & Craw 2008).

In 2009, reassessment of the New Zealand conservation status (threat of extinction ranking) of native and introduced freshwater fish was undertaken (Allibone et al. 2010). As part of this assessment, a decision was made to include taxonomically undescribed/indeterminate taxa that showed high (~3%) mitochondrial DNA (mtDNA) divergence (Allibone et al. 2010; Appendix 2).

To help effectively prioritise and manage freshwater fisheries and their habitat, DOC identified the need to confirm the current non-migratory galaxias groupings and determine the species status of non-migratory galaxias taxonomically indeterminate taxa (including identifying knowledge gaps for taxonomic indeterminate taxa unable to be formally described).

To do this DOC identified that the first step was to hold a freshwater fish taxonomic workshop with experts that have been involved in the area of the taxonomy of non-migratory galaxias. The aim of the workshop was to identify the current agreed situation, and determine what process would allow decisions to be made on the species status of the indeterminate taxa. Non-migratory galaxias were the focus of these discussions as this group currently has the greatest taxonomic uncertainty. In addition, it was hoped decision-making processes for these taxa could be applied to all New Zealand freshwater fish in the future.

Key experts from DOC, Otago University, NIWA and Golder Associates met in Dunedin on the 14th May (Appendix 3). The key objectives of the workshop were to:

- Establish distinct groupings of non-migratory galaxias.
- Establish a process to 'identify a minimum set of criteria judged sufficient to identify a freshwater fish species/Evolutionary Significant Unit (ESU)/Management Unit (MU)'.
- Formulate consistent terminology and definitions for freshwater fish taxonomy.
- Identify key actions required to determine the taxonomic status for all non-migratory galaxias taxa .
- Provide information and guidance on non-migratory galaxias lineages to the revision of the Conservation Status 2010 freshwater fish list.

These proceedings summarise the information presented at the workshop, agreed future actions and direction, and discussion held during this workshop.

Collectively, the workshop attendees have been referred to as the 'workshop group' throughout this document. Workshop attendees are referred to by their initials throughout the text - refer to Appendix 3 for workshop group attendee list.

2. Overview of genetic and morphological data used for current non-migratory galaxias groupings

2.1 Background

To date, non-migratory galaxias have been formally described using morphometric and meristic techniques, with more recent descriptions incorporating genetics analyses (Tables 1–4). The genetic analyses methods/techniques used have varied, but most groupings have been based on mitochondrial DNA cytochrome *b* (mtDNA cyt *b*) data.

Table 1. Taxonomic and genetic methods used to identify groupings of pencil non-migratory galaxias. Taxa in bold are formally described species.

Species name	Linear morphometrics	Meristics	Genetics
Galaxias paucispondylus	Yes	Yes	
G. paucispondylus (Canterbury, Marlborough, West Coast)			mtDNA cyt *b*
G. aff. paucispondylus "Manuherikia" (Manuherikia River)			mtDNA cyt *b*
G. aff. Paucispondylus"Southland" (Southland)			mtDNA cyt *b*
Galaxias divergens	Yes	Yes	
G. divergens (West Coast)			Isozyme electrophoresis and mtDNA cyt *b*
G. aff. divergens "northern" (Nelson, Marlborough, North Island)			Isozyme electrophoresis and mtDNA cyt *b*
Galaxias cobitinis	Yes	Yes	mtDNA cyt *b*
G. cobitinis (Kakanui River)			mtDNA cyt *b*
G. aff. Cobitinis"Waitaki" (Waitaki River)			mtDNA cyt *b*
Galaxias prognathus	Yes	Yes	
G. prognathus (Canterbury, West Coast)			mtDNA cyt *b*
G. aff. prognathus "Waitaki" (Waitaki River)			mtDNA cyt *b*
Galaxias macronasus	Yes	Yes	mtDNA cyt *b*, 16S rRNA, control region

Table 2. Taxonomic and genetic methods used to identify groupings of roundhead non-migratory galaxias. Taxa in bold are formally described species.

Species name	Linear morphometrics	Meristics	Genetics
Galaxias eldoni	Yes	Yes	
Galaxias pullus	Yes	Yes	
Galaxias anomalus	Yes	Yes	Isozyme (when re-instated by McDowall & Wallis 1996)
Galaxias gollumoides	Yes	Yes	
Galaxias "Nevis" (Nevis River)			mtDNA cyt *b* and mitochondrial control region

Table 3. Taxonomic and genetic methods used to identify groupings of flathead non-migratory galaxias. Taxa in bold are formally described species.

Species name	Linear morphometrics	Meristics	Genetics
Galaxias vulgaris	Yes	Yes	Isozyme (McDowall & Wallis 1996)
Galaxias depressiceps	Yes	Yes	Isozyme
Galaxias "northern" (Marlborough, Nelson, West Coast)			Isozyme and mitochondrial control region
Galaxias "southern' (Southland, Otago)			Isozyme and mitochondrial control region
Galaxias "Teviot" (Teviot River)			mtDNA cyt *b*
Galaxias "sp. D" (Clutha River)			Isozyme and mtDNA cyt *b*

Table 4. Taxonomic and genetic methods used to identify groupings of non-migratory inanga galaxias derivatives. Taxa in bold are formally described species.

Species name	Linear morphometrics	Meristics	Genetics
Galaxias maculatus	Yes	Yes	
Galaxias gracilis	Yes	Yes	
Galaxias gracilis (North Kaipara Head dune lakes)			mtDNA D-loop region
Galaxias "dune lakes" (Kai Iwi Lakes)			mtDNA D-loop region

Most formally described non-migratory galaxias species have some morphological distinguishing features. However, as *Galaxias* are morphologically conservative most of these species can be confused with others in the field—this is likely due to morphological plasticity (Appendix 4).

2.2 Workshop group conclusion

From information presented above the workshop group conclude that:

Genetic analysis techniques have improved over time and freshwater fish species descriptions are now able to use improved genetic and morphological analyses techniques in addition to traditionally accepted methods.

2.3 Non-migratory galaxias data management

ND led a discussion on the *Galaxias* samples collection information database ("Internal GAL number database"), originally set up at the University of Otago.

Key discussion points:

- University of Otago runs an internal GAL number database in the form of an Excel spreadsheet. The data is not on GenBank but can be collated and put together if required (TK).
- DOC has a copy of this internal GAL number database and is working on improving the quality of information fields collated, especially grid references of sample collection localities. Grid references of sample collection localities are vital for mapping out where samples have previously been collected from, and where possible future collection work should be prioritised. As a result there may be requests sent out seeking this information (ND).
- It would be useful if DOC put a copy of the internal GAL number database (plus any additional information collated above) on 80-20 Document Management System (docDM) or somewhere readily accessible to all staff so this could be updated over time (SB). ND agreed. ND also offered to provide updated docDM versions of the database back to University of Otago.
- The genetics laboratory at the University of Otago can create an atlas of mtDNA results but it's a forever changing story so it is best for DOC to maintain a spreadsheet of all analysis undertaken, and samples collected (JW).
- There is currently no vetting process for the input of fish records into the National Institute of Water and Atmospheric Research (NIWA) administered New Zealand Freshwater Fish Database (NZFFD). Therefore, it cannot be guaranteed that species records entered into the database have been identified correctly (RA). NZFFD is currently being revised which offers the opportunity to include a new field where fish genetic results can be recorded. However until this is up and running it is best for DOC to maintain a record of genetic analysis.
- In the past there has been an internal NIWA vetting process for new fish records entered into the NZFFD. . This process will be re-established again next financial year (2014/15). No new fish record cards will be added to the NZFFD until this vetting process has been re-established (SC).
- DOC Coastal Otago Office currently put the GAL number for all *Galaxias* genetic results they receive into the corresponding NZFFD records they submit (PR).

3. **Groupings of non-migratory** Galaxias

3.1 Background

Of the 74 freshwater fish taxa assessed for conservation status in 2009, twelve taxonomically indeterminate taxa were ranked—this included 11 non-migratory galaxias and one bully (upland bully (West Coast South Island, North Island); Allibone et al. 2010). One grouping of alpine galaxias was left out of the formal revision paper but was ranked (*G. aff. paucispondylus* "Southland").

Other than 'indeterminate taxa' status, other freshwater fish around the world have also been grouped into Evolutionary Significant Units (ESU) and Management Units (MU) to help the protection, management and security of these taxa. For example, looking at the management of diadromous Pacific salmon, Waples (1995) identified that where genetic structure is known it is sometimes possible to refine conservation priorities to distinct population segments within a species.

General definitions of common groupings, in addition to species status, that have been assigned by others include:

- Evolutionary Significant Unit

A group of organisms that have been isolated from other conspecific groups for a sufficient period of time to have undergone meaningful genetic divergence from those other groups (Ryder 1986).

- Management Unit

Populations with significant differences in allele distributions (Moritz 1994).

New Zealand's mudfish species have been grouped into ESU's to assist management (O'Brien & Dunn 2007). In this situation ESU was defined as a reproductively isolated group of populations displaying unique evolutionary characteristics (Ling et al. 2001). The degree of genetic distinctiveness identified in the mudfish species was based on mtDNA in the D-loop region.

ESU's have not been commonly used or formally identified for New Zealand non-migratory galaxias. However;

- Since Environment Court proceedings in 2012, the Nevis galaxias (*Galaxias* "Nevis") was stated as being an ESU of Gollum galaxias (*Galaxias gollumoides)*, (P. Ravenscroft, DOC, Dunedin, pers. comm.). This was not a formal decision but came as a result of the hearing.
- Three distinct evolutionary significant units (ESU) of dwarf īnanga exist (Poutu lakes, Rototuna and Kai iwi lakes ESUs) (Gleeson et al. 1999, Ling et al. 2001).

3.2 New Zealand non-migratory galaxias

New Zealand non-migratory galaxias are colloquially referred to as belonging to one of four groups, based on similar morphological form (Figure 1). Often roundhead and flathead groups are referred to collectively as the *Galaxias vulgaris* species complex (Appendix 1). The majority of the non-migratory galaxias are managed through the New Zealand non-migratory galaxiid recovery plan, 2003–13 (DOC 2004). This plan was developed by DOC and sets out the strategic direction and prioritised actions for the conservation of these fish.

The numbers of taxa recognised within the four groupings are[1]:

[1]Further discussion on groupings were held during the workshop (see section 4.5), and this section describes the final current agreed groupings.

Pencil galaxias (Figure 2)

Five species are formally described, with four taxa being further separated (5 taxonomically indeterminate taxa).

Upland longjaw galaxias presence in the Maruia or Hurunui Rivers has not been reconfirmed for several years. There is an upland longjaw galaxias specimen stored from each catchment that can be used to help determine taxonomic status of this taxa. The Maruia River specimen is thought to be in the University of Otago, Department of Zoology collection (RA), and the Hurunui River specimen is at NIWA (SB gave it to Bob McDowall).

Flathead galaxias (Figure 3)

Two formally described species and four taxonomically indeterminate taxa are recognised.

Roundhead galaxias (Figure 4)

Four formally described species and one taxonomically indeterminate taxon are recognised. Some have described this indeterminate taxon as an ESU of Gollum galaxias.

Inanga Grouping - Landlocked inanga (Figure 5)

Diadromous inanga and non-diadromous derivatives are found in New Zealand. Non-diadromous derivatives are commonly known as landlocked inanga.

Genetic research has shown three distinct evolutionary significant units (ESU) of dwarf īnanga exist (Poutu lakes, Rototuna and Kai iwi lakes ESUs) (Gleeson et al. 1999, Ling et al. 2001).The Kai Iwi Lakes ESU has been determined as being the most genetically distinct of the three ESUs, and as a result it is identified by the Department as interdeterminate "dune lakes galaxias", while the other two ESU make up "Dwarf inanga".. However they are formally described as a single species. A recent genetic and morphometric study showed only meristic measurements are consistent with the current species classification, whereas morphometric and genetic measurements suggest dwarf inanga is in fact a phenotypically diverged form of inanga (Ling et al., 2001). So both approaches used for landlocked inanga groups have been recently questioned (Ling et al., 2001), and further research is needed to resolve the taxonomy of these groups.

Therefore of the non-diadromous inanga groups, one formally described species (dwarf īnanga), and one taxonomically indeterminate taxa with self-sustaining populations (Dune lake galaxias) are currently recognised.

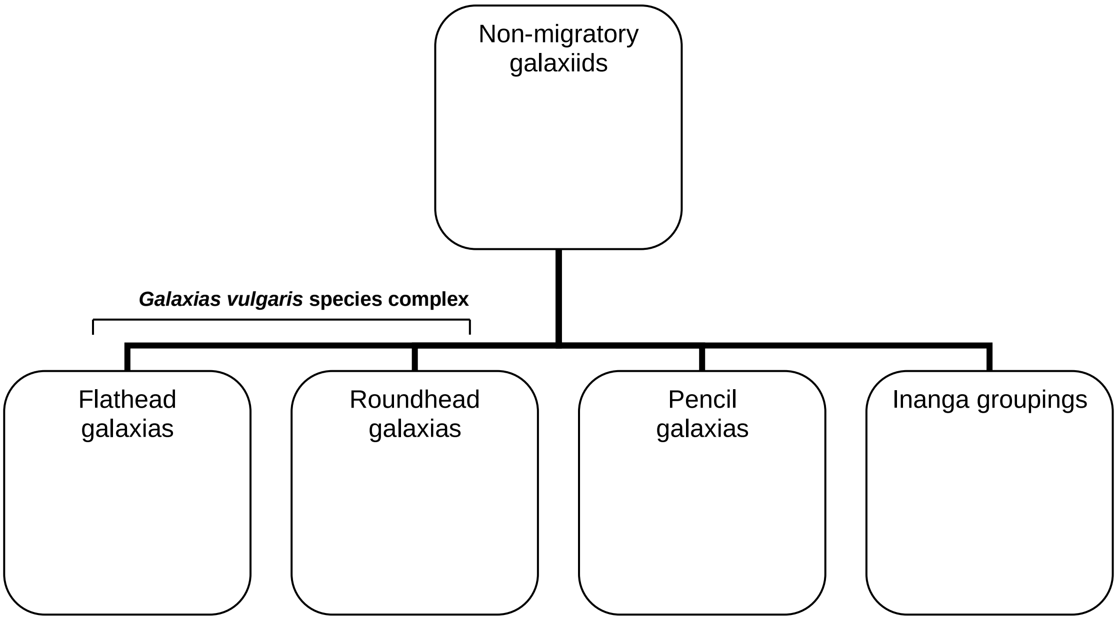

Figure 1. Recognised groups within New Zealand non-migratory galaxias.

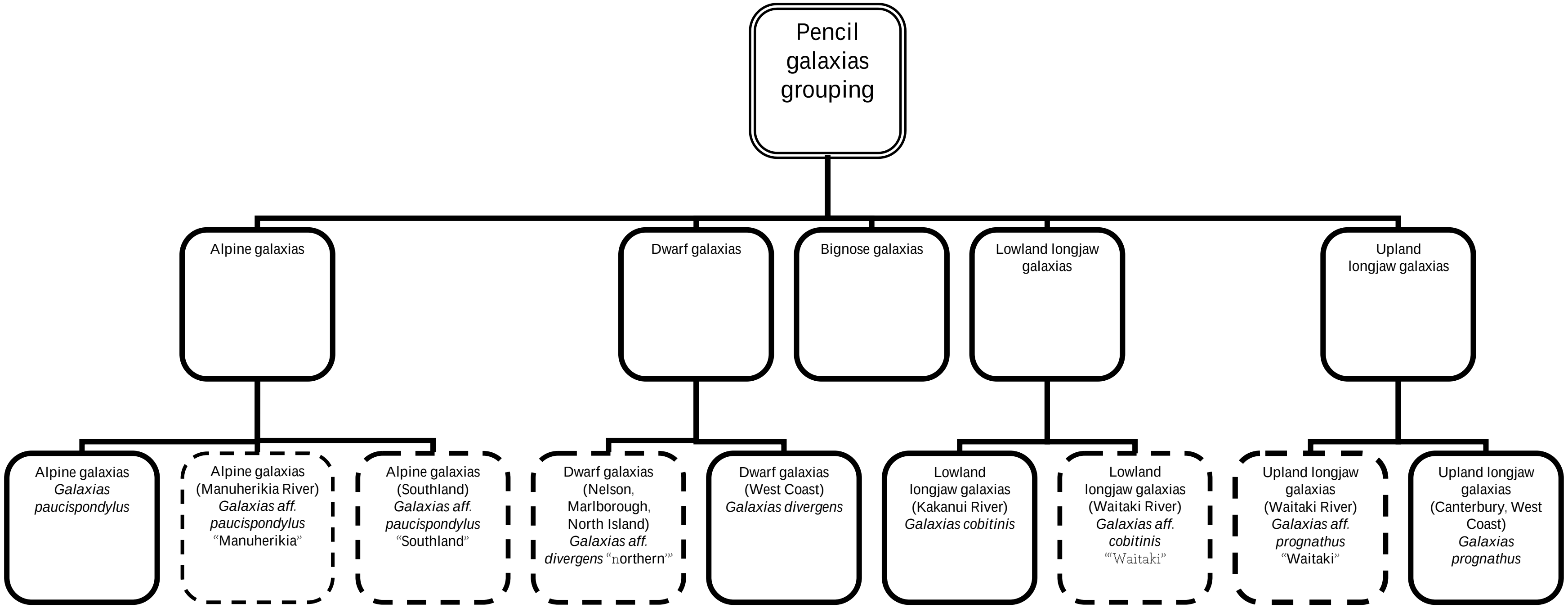

Figure 2. Agreed groupings within pencil-form non-migratory galaxias (Double line box—morphological grouping; dashed line border—taxonomically indeterminate; solid line border—determinate)

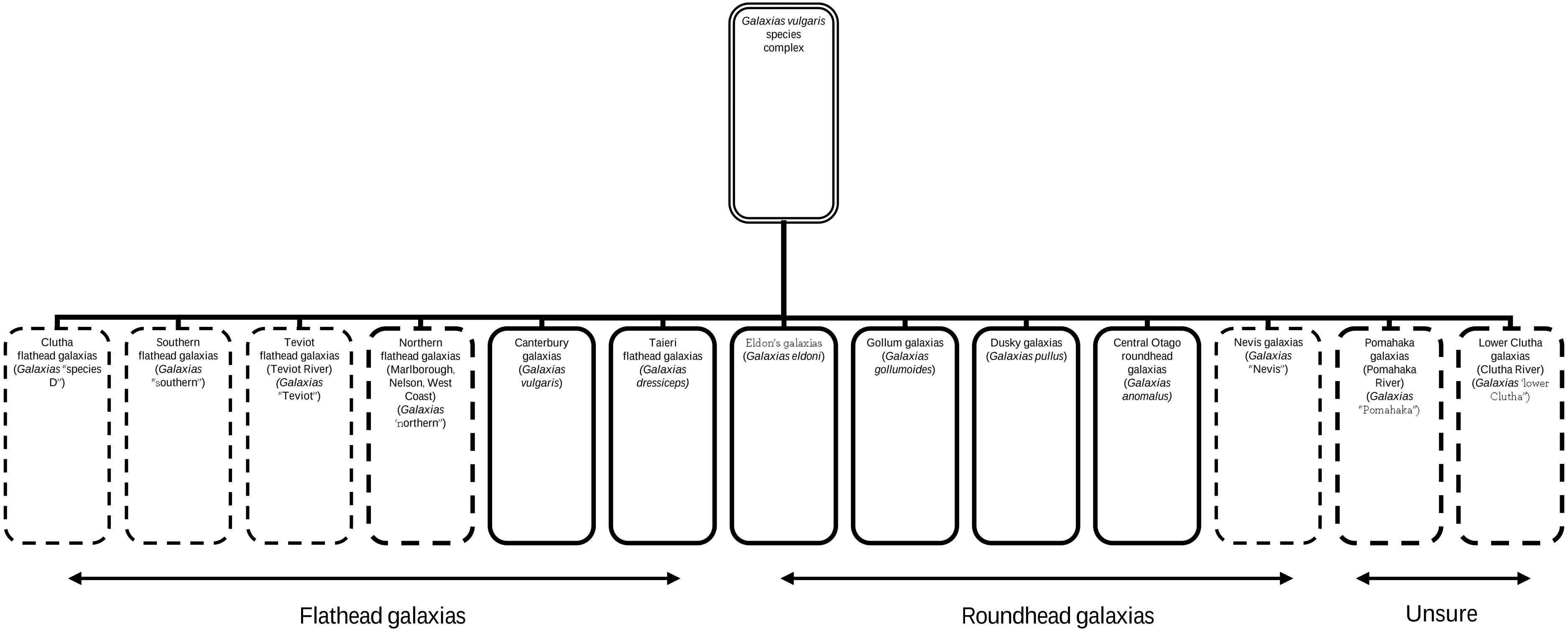

Figure 3. Agreed groupings within *Galaxias vulgaris* species complex non-migratory galaxias (Double line box—morphological grouping; dashed line border—taxonomically indeterminate; solid line border—determinate)

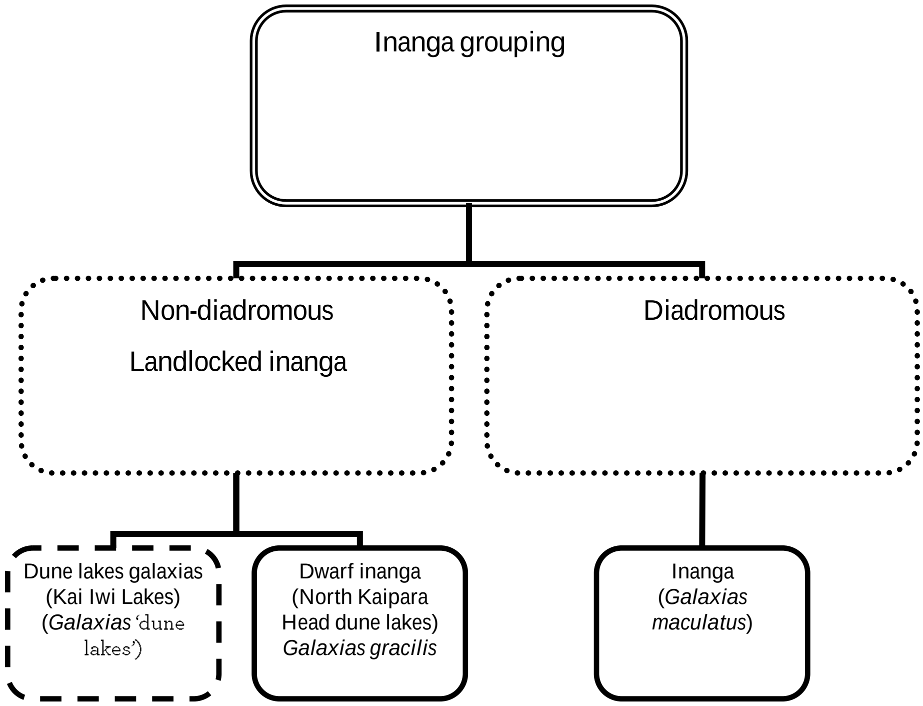

Figure 4. Agreed groupings within inanga grouping, showing the non-diadromous and diadromous inanga groupings for completeness (Double line box—morphological grouping; dashed line border—taxonomically indeterminate; solid line border—determinate).

3.3 Key discussion points on current non-migratory galaxias groupings:

- DOC wants to ensure consistent terminology is used across freshwater fish groupings (SB).
- ESU's are used for New Zealand mudfish species. Brown (*Neochanna apoda*), Chatham's (*Neochanna rekohua*), and Canterbury (*Neochanna burrowsius*) mudfish species are all geographically distinct with no overlaps. Black (*Neochanna diversus*) and Northland (*Neochanna heleios*) mudfish distribution ranges overlap in the Northland region. Definition of ESU's for these species are quite straight forward using genetic information (RA).
- Until knowledge gaps are filled for the indeterminate taxa and we can determine species status, then we are best not to identify indeterminate taxa as ESU's, or any other type of grouping. If we identified groups as an ESU they would not be given a conservation status ranking.
- It was agreed that the terms pencil galaxias, *Galaxias vulgaris* species complex (roundhead and flathead groupings), and landlocked inanga groupings are often used and this makes sense especially from a field identification point of view.
- The inanga grouping includes landlocked inanga and diadromous inanga split (RA). They are really more eco-types (GW). Dune lake galaxias (*Galaxias* "dune lakes"), are more closely related to diadromous inanga than other landlocked inanga. Same thing exists for kōaro (*G. brevipinnis)* (RA).

Dune lake galaxias and dwarf inanga (*G. gracilis*), have diverged from inanga (*G. maculatus*), due to isolation over time. Non-diadromous populations of normally migratory species should be considered for management and conservation status ranking separately, to ensure consistency with other freshwater fish. Until further genetic analysis is undertaken on landlocked inanga groupings, no formal decisions on what these groupings will be called can be made.

- Nick Ling (University of Waikato) did get Data Deficient/Conservation Management Unit funding last year to progress sorting out the taxonomic status of Dune lake galaxias and dwarf inanga. This involved a proposal to survey and get a catch per unit effort at all lakes where dune lake galaxias and dwarf inanga have been recorded, and to collect samples for next generation sequencing (genetic analysis). However, he had to pull out from completing this work due to over commitment. DOC still undertook most of the surveys and collected samples, so hopefully this further genetic analysis will occur soon so the taxonomic status of these non-diadromous inanga groupings can be confirmed (SB).
- South African ESU's and upcoming species descriptions are based on shallow genetic divergence relative to New Zealand *Galaxias* (SC).
- If dune lake galaxias and dwarf inanga were treated how taxa groupings are in the Northern Hemisphere (e.g. stickleback situation), they would likely be separate ESU's. From a phylogenetic point of view dune lakes galaxias would not be an individual species (GW).
- Management units (MUs) are locations of species that are not in direct contact. From a species status perspective it is not thought to be that useful to identify MUs, and if any grouping is used it is best to use species or ESU (GW). Different populations are often MU's. It's not saying they are both really important and different, it's saying the management you apply to one population will not affect the other.

3.4 Conclusion on groupings

Workshop participants discussed the current non-migratory galaxias groupings and agreed that;

- They should continue to be recognised as belonging to the flathead, roundhead, pencil, or landlocked inanga groupings.
- The collective term, *Galaxias vulgaris* species complex, is still appropriate for the combined flathead and roundhead groupings.

Wider consideration of assignment of groupings should be given to other landlocked populations of migratory species, such as giant kōkopu (*Galaxias argenteus*) and kōaro that form both migratory and landlocked populations in New Zealand waterways. A consistent approach for taxonomic groupings should be decided for all freshwater fish, and considered in future assessment of conservation status and prioritisation of management.

Consideration as to whether ESU, MU, or other groupings should be used for genetic clusters that could not be formally described was discussed. The workshop group agreed that;

- The most appropriate groupings to be used for freshwater fish would either be an ESU or 'species'. MU does not provide anything additional to an ESU, and ESU's are already used for some New Zealand fish species (e.g. mudfish)
- ESU's cannot be identified until all knowledge gaps have been filled, and a decision can be made on whether it is a species or not. Until this takes place they should remain an '*indeterminate taxa*'. When a decision is made that it cannot be identified as a species, ESU status should be considered.

4. Finding a way of assessing the species status of freshwater fishes

Shannon Crow (with assistance from Richard Allibone) investigated the possible/most appropriate options DOC could use to assess the species status of freshwater fish in New Zealand. This information was presented at the workshop to provide background information and options to base any decisions on.

The following section is a summary of the full report supplied to the Department (Crow, 2013; DOCDM-1224503).

4.1 Background

- International confusion and debate over the existence and definition of a species dates back to the 1800s.
- Although management of indeterminate taxa can be justified on the basis of unique genetics (Moritz 1994; Moritz 1995), formal recognition of a species gives more weight to conservation issues (Avise 1989).
- The progression of species descriptions is further complicated by the rigorous and ongoing debate about which species concept(s) should be used by researchers. The problem is often evaded by taxonomists by simply not discussing any species concepts in the description; this can lead to taxonomic confusion.
- There is still no consensus over which species concept(s) should be used to test the taxonomic status of an organism (Mallet 1995).
- Internationally there are 25 plus species concepts.
- The Biological Species Concept (BSC) (Dobzhansky 1937; Mayr 1942; Mayr 1963), is perhaps the most widely discussed and utilised species concept, while the recently proposed Genotypic Cluster Concept (GCC) (Mallet 1995) is probably the biggest contender to the BSC (Coyne & Orr 2004). Both species concepts have their limitations (Coyne & Orr 2004), but seeking character concordance in traits that relate to both species concepts may be a robust method of testing the species status of taxa.
- BSC is based on the idea that a species is a group of interbreeding individuals that do not interbreed with other individuals. This has been met with criticism and has been adapted over time to consider interbreeding—'species are characterised by substantial but not necessarily complete reproductive isolation'. It is suggested that unique morphological, genetic and/or ecological characters indicate that pre-mating barriers exist, justifying separate species status under BSC.
- GCC defines a species as 'distinguishable groups of individuals that have few or no intermediates when in contact' and suggests that distinguishing species should be based on genetic and/or morphological data (Mallet 1995). This species concept focuses on the existence of diagnostic characters and does not require reproductive isolation. It is suggested that concordant differences in morphological and/or several genetic traits justifies species status under GCC.

- Testing species status of taxa under the BSC and GCC can be done simultaneously.

4.2 Recommendations

Crow (2013) recommended species status of taxa should be tested under both the BSC and GCC;

- The definition of the BSC proposed by Coyne & Orr (2004) should be adopted as it permits some degree of gene exchange. Species are '…characterised by substantial but not necessarily complete reproductive isolation'.
- Species under the GCC are defined as distinguishable morphological and/or genetic groups of individuals that have few or no intermediates when in sympatry.

The status of taxa should be tested under both species concepts simultaneously by identifying concordant differences across several independent genetic and/or morphological clusters.

Assessing species status across morphological and/or genetic traits will result in taxonomic decisions that are evolutionary defensible (Grady & Quattro 1999), as they will be based on two of the most dominant species definitions (BSC and GCC).

4.3 Key workshop discussion points on defining New Zealand freshwater fish species

- Bob McDowall has been involved in many freshwater fish species descriptions in New Zealand and these have been based on differences in morphology and meristic counts. The workshop group needs to consider this with any decisions on how we propose to formally describe new freshwater fish species to ensure consistency where possible (RA).
- There are many species concepts, but to test a species status consideration of both GCC and BSC should be looked at as these cover the key minimum aspects (SC).
- There is no clear minimum level of difference (spatially or phylogenetically) that the workshop group can use to consistently consider freshwater fish taxa clusters. Species status needs to be assessed on a case by case basis while being aware of the levels of differences found. Specific guidelines for a set of minimum criteria for defining freshwater fishes are probably not possible (JW).
- For roundhead galaxias it is accepted that there are sound morphological differences and that is why most species are formally described, except one – Nevis galaxias. Could the formally described roundhead galaxias species be benchmarked and used to assess other groupings? If genetic differences reflect evolutionary time, are roundheads older than others (e.g. flatheads)? Are flatheads more recent radiation? (RA).
- The problem is different nuclear genes give different histories, so the answers are not simple (GW).

- Specialists wanting to define fish species want the average (a line in the sand to guide decisions)—rather than be biased by one gene. Average measure is better than a single gene. They could use the average difference across species groups and use it against other groups? (RA).
- Non-migratory galaxias species described based on morphology in the past have also been reflected in genetic analysis undertaken. Specialists involved in describing non-migratory galaxias species have generally been really conservative, but there is no right answer so pragmatically the workshop group should go with what we see as differences (JW).
- Molecular evidence is crucial for any species description (SC).
- Mitochondrial DNA differences are key for defining freshwater fish species at a minimum; nuclear is useful, and then geographical distributions (JW).
- Traditional linear morphological and meristic measures are not crucial when defining fish species but are beneficial if possible (SC).
- If morphological differences are clear, like has been the case for many New Zealand freshwater fish Bob McDowall has described, then the decision on whether it is a species has also been clear (SB). Decisions on whether it is an individual species have become harder recently due to not being able to find clear, consistent morphological differences (Bob McDowall's work in recent years). However, I hope that if the experts are happy with distinct genetic differences and these are supported by some morphological characteristics, geographic distribution, and other ecological information, then there is scope to define as a species or decide on some other type of grouping (e.g. ESU). This was one of the key aims of getting all the experts together in this workshop, so the workshop group could try and come up with an agreed decision-making criteria or process for determining species status in the future to ensure consistency and allow decisions to be made on indeterminate taxa (SB).
- *Galaxias vulgaris* species complex is really clear cut and results on taxa groupings have stayed consistent for 10 years (RA). An important issue is can the workshop group get a consistent approach that has worked for defining the *Galaxias vulgaris* species complex groupings (Figure 3), and can also be applied to the pencil galaxias (e.g. the three alpine galaxias groups (Figure 2), and landlocked inanga groupings (Figure 4)).
- All distinct genetic lineages identified within the *Galaxias vulgaris* species complex are congruent with known distributional range and make sense to people with knowledge of these fish (RA). There is now enough reliable genetic, morphology, distributional and ecological data for all the groupings of the *Galaxias vulgaris* complex to make decision on their species status. Genetic data shows clear groups and patterns in distribution, and then the morphological knowledge is useful for field identification (i.e. relying only on fin ray counts). The working group need to accept that using combined knowledge (genetic, morphology, distribution and ecology) to make decisions on species status is acceptable and we do not need to solely rely on morphological differences alone as has been done with some freshwater fish species descriptions historically (RA).

- Over the last 10 years, with further knowledge gained, the lineages identified within the *Galaxias vulgaris* complex have not changed (GW).
- Freshwater fish groupings and species status should be assessed on a situation by situation basis rather than making specific rules/criteria, and trying to make everything sit within it (GW).
- It is important to not get hung up geographic boundaries of taxa groupings. It is best to identify distinct groups, and fill in the gaps in knowledge and distributional limits over time (GW).

4.4 Process to identify if a freshwater fish is a species or not

The workshop group agreed that there are many species concepts applicable to defining New Zealand freshwater fish. Where possible it was agreed it is beneficial to use genetic, morphological, and ecological information to describe a species. If more than one species concept has been met it makes the description stronger.

When considering if a freshwater fish grouping could be formally described as a species or something else (e.g. ESU), the general consensus from the workshop group was, where possible to consider genetic differences in the first instance, followed by geographic location and other ecological information. Morphological differences are useful to support genetic differences if available. Decisions need to be made on a case by case basis. There was no agreement by the workshop group on what the set of minimum criteria to define a species was.

Key questions

As a result of the workshop group discussion on defining freshwater fish species, a number of key questions to consider when assessing species status were identified (Figure 5). These are:

- Is there a genetic difference present (mtDNA or nuclear)?
- Is there a geographical or other ecological difference between this freshwater fish group and other related groups?
- Are there morphological differences to support species status?
- Are there gaps in information that would enable a better decision?

The decision framework/questions should be worked through when considering whether a freshwater fish group can be formally described as a species. If a decision is made that species status could be considered, then information known for the group should be considered in relation to the key criteria of two key species concepts (Biological Species Concept and Genotypic Species Concept) (Table 5).

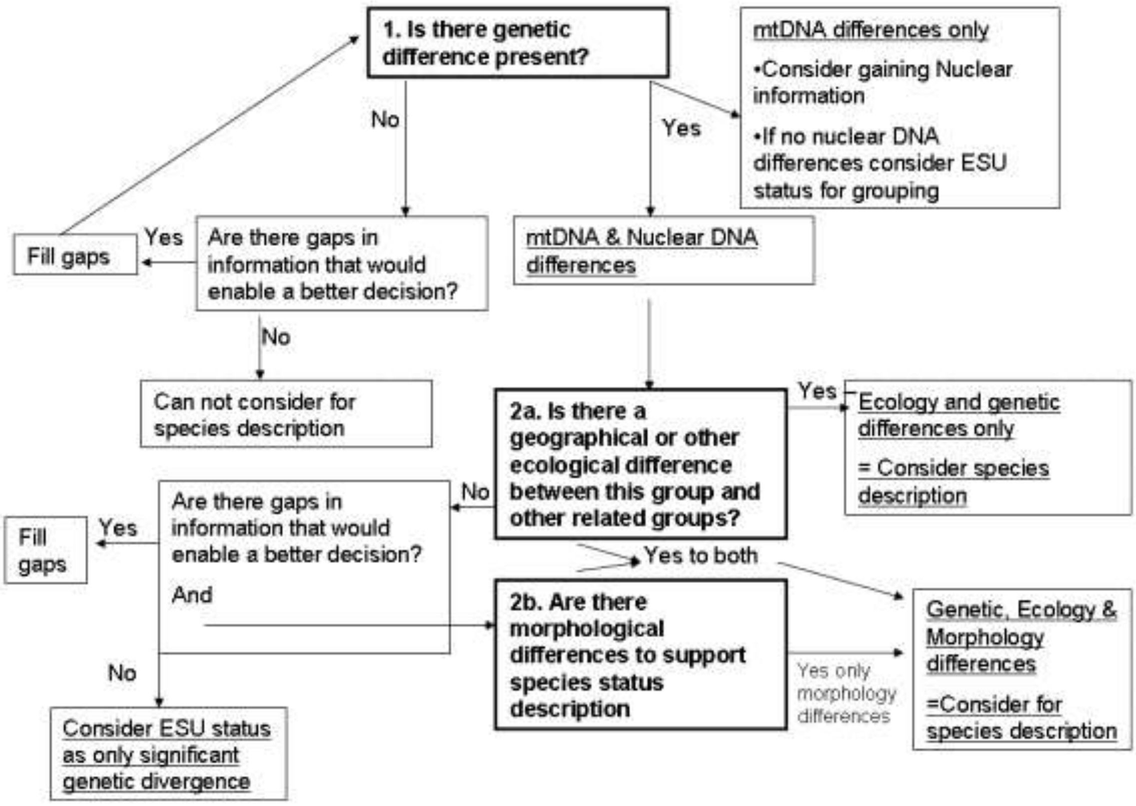

Figure 5. Decision framework to assess the species status of freshwater fish in New Zealand.

Table 5. Key information required to meet Biological Species Concept (BSC) and Genotypic Cluster Concept (GCC).

Species concept	Definition	Information	Data/techniques available	Crucial or useful
BSC	Group of potentially inter-breeding individuals that are reproductively isolated	Molecular	1. mtDNA? 2. Allozyme/nuclear DNA	Crucial
		Morphological	1. Meristic counts 2. Linear morphometric 3. Geometric-morphometrics	Useful
		Ecological	1. Behavioural 2. Habitat 3. Life-history	Useful
GCC	Distinct morphological and genotypic clusters	Molecular	1. mtDNA? 2. Allozyme/nuclear DNA	Crucial
		Morphological	1. Meristic counts 2. Linear morphometric 3. Geometric-morphometrics	Useful

4.5 Decisions on species status of non-migratory galaxias

The workshop group discussed the taxonomic status of currently indeterminate taxa for all groups of non-migratory galaxias. The key questions (Figure 5) were thought about in discussions, and where species status was thought possible, consideration was given to whether the taxa met the BSC and/or GCC species concepts (Table 5).

Galaxias vulgaris *species complex*

Specific thoughts of the workshop group;

- Roundhead grouping – only Nevis galaxias yet to be described (ND).
- *Galaxias vulgaris* species complex groupings have mainly been identified using mtDNA (JW).
- From the genetic data available, fish currently called Clutha flathead galaxias should be split into three groups (Clutha flathead galaxias; lower Clutha galaxias & Pomahaka galaxias). Based on Figure 2 of Waters et al. (2010), known fish sites in the Pomahaka River (a lower Clutha River tributary) are very distinct from fish populations located above Benger Burn (in the upper Clutha River catchment). Benger Burn is the distinction point. I am satisfied that the upper Clutha flathead galaxias is a clear lineage found in the upper catchment and this species can be described on this basis.
- However further genetic, morphological and ecological data is needed from the lower Clutha River catchment to determine the status of the lower Clutha galaxias and Pomahaka galaxias groups (RA). Both these groups should now be indeterminate taxa groups (RA). The workshop group agreed at this stage to call these groups the lower Clutha galaxias (Clutha River) (*Galaxias "lower clutha"*) and Pomahaka galaxias (Pomahaka River) (*Galaxias "Pomahaka"*) (Figure 3).
- JW & GW know where the lower Clutha galaxias fits genetically with others in the Galaxias vulgaris complex, but we don't know its distributional extent or if is distinct enough to be a species (JW).
- Waterways around the Beaumont Station area would be a good location to gain further genetic, morphological and ecological data to determine the status of these groups, if access could be gained (PR).
- Known Clutha flathead galaxias information could be collated by using Figure 7 on page 10 of Waters et al. (2010). Focus on what we do know and are certain of, and go from there (JW).
- Systematic review of the whole *Galaxias vulgaris* species complex would be the best way to approach formal description of Clutha flathead galaxias, southern flathead galaxias, northern flathead galaxias,Teviot flathead galaxias and Nevis galaxias indeterminate taxa (GW). The workshop group agreed formal description of these taxa would be possible now.
- A key action required for any formal description is to determine the type locality and these need to be secure populations (RA).

- Teviot flathead galaxias is data deficient (GW). If PR could get some samples of larvae or fin clips then Otago University can carry outgene expression work to obtain nuclear DNA information. This will hopefully provide enough support to describe the Teviot flathead galaxias as a species. This work will be separate to the current genetic analysis presented in Waters et al. 2010. In summary, this work will be an independent genetic analysis that will sit alongside other work of this type (GW).
- Southern flathead galaxias and Clutha flathead galaxias are distinct groups from genetic analysis and both should be formally descrbed as a species (JW). The workshop group agreed that these taxa should be formally described with morphological and genetic experts writing the formal description paper together.
- Nevis galaxias was termed an ESU at the Kawarau River Water Conservation Order hearing in the Environment Court (PR). This is currently described as an ESU of Gollum galaxias (JW). This grouping has been distinct for half a million years.
- To qualify as an ESU there needs to be additional adaptations or differences rather than simply genetic differences (GW). There is genetic and morphological data available for Nevis and Gollum galaxias, and this data needs to be analysed to confirm whether the Nevis galaxias can be formally described. It was thought that this would be likely.
- Nevis galaxias is phylogenetically distinct (JW). Is there other evidence? Morphologically, yes, there is evidence that they are distinct from 10 Gollum galaxias populations in Southland (SC).
- The Nevis galaxias affinity with Southland Gollum galaxias is important. Is highlighting its distinctiveness important too? (JW)
- If you look forward in evolutionary time, the likelihood of Nevis galaxias going back (mixing) into Southland Gollum galaxias is highly unlikely (RA).
- Be aware of historic bias. If we started afresh and saw a distinctly different species, I don't think we'd have a problem calling it a different species (JW).
- With the work I've done on Nevis galaxias in the last several years, they are not the same as Gollum galaxias (RA). Gollum and Nevis galaxias are distinct. Nevis galaxias is larger, not due to altitude alone. Gollum galaxias is generally found in low gradient pastoral streams in Southland. Nevis galaxias is on its own evolutionary track. It has characteristics separate to Gollum galaxias. Nevis galaxias deserves its own species status. There are also likely to be life-history differences if we looked into it (RA).
- We shouldn't go down the critical threshold number track for differences. We need to look across all the evidence (JW).
- Nevis galaxias is on its own ecological trajectory (DJ).
- It doesn't need to be shown that Nevis galaxias is distinct from every lineage—it just needs to be distinct from Gollum galaxias (GW).

- For northern flathead galaxias, there is enough consistency in mtDNA data and knowledge of geographical distribution to formally describe as a species (RA).

Conclusions for Galaxias vulgaris complex:

Consistent and clear answers were obvious for the *Galaxias vulgaris* species complex.

The workshop group agreed to investigate formal species descriptions for indeterminateClutha flathead galaxias, southern flathead galaxias, Teviot flathead galaxias, northern flathead galaxias, and Nevis galaxias. Consideration of the key questions (Figure 5) and information available/needed to met the BSC and/or GCC species concepts (Table 5) was discussed for these five groups (Table 6). Table 6 shows distinct differences are present between groups and once minor gaps in information is gained, and distinct differences are confirmed, formally describing Clutha flathead galaxias, southern flathead galaxias, Teviot flathead galaxias, northern flathead galaxias, and Nevis galaxias is possible (Figure 3).

Further genetic, morphological and ecological data is required to confirm the status of Pomohaka galaxias and lower Clutha galaxias. Populations upstream of Benger Burn will now be formally described as Clutha flathead galaxias; while populations located downstream of the Benger Burn will become indeterminate taxa referred to as Pomahaka galaxias, and lower Clutha galaxias groupings.

Pencil galaxias group

There is currently distinct genetic divergence in the pencil galaxias groupings, however further morphological and ecological data is required before any formal decision can be made on species status.

- The genetic divergence between the lowland longjaw galaxias groupings are as divergent as differences between the *Galaxias vulgaris* species complex members (refer to Figure 6, p. 8 of Waters et al. 2010) (JW).
- Dwarf galaxias and alpine galaxias in the northern South Island overlap in distribution. These species are often found –in the same location and this appears to be simply dependant on how many samples are collected (GW) —some are rare so only get in a larger sample. The two species can be identified morphologically (RA). Addition samples from the Clarence and Maruia rivers would be useful to determine the range and extent of these two species.
- Lowland longjaw galaxias genetic differences for example, are as distinct as *Galaxias vulgaris* species complex (~5-6%) (JW).
- Alpine galaxias show three deep lineages (~4% differences) (JW).
- Upland longjaw galaxias—genetic differences between “Canterbury” and “Waitaki” lineages is 3% (JW).
- Lowland longjaw galaxias—genetic differences between “Waitaki” and “Kakanui” lineages is 5%. (JW).
- There is currently not enough data to formally described “Waitaki” and “Kakanui” lowland longjaw galaxias as distinct species. In the meantime they are to be referred as indeterminate taxa until we can say we have

filled all information gaps and can make a call whether it is a species or ESU.

Conclusions for pencil galaxias complex::

Indeterminate taxa in the pencil galaxias groupings require further information and analysis before a formal decision can be made on species or ESU status (Figure 2).

Landlocked inanga

Further genetic and morphological information is required before decisions on species status for landlocked inanga derivatives can be made.

- The inanga derivative grouping needs to be looked at on a much broader scale than specialists have previously done (JW).
- Some lakes are very isolated and some are interconnected.
- Any decisions made on dune lake galaxias and dwarf inanga need to consider other non-diadromous populations of other diadromous species (e.g. giant kokōpu (*Galaxias argenteus*) and banded kokōpu (*Galaxias fasciatus*)). Any decisions need to be consistently applied across all New Zealand freshwater fishes, as well as being taken into account during New Zealand conservation status freshwater fish reassessments (SB).
- If non-migratory inanga are referred to as different species, we cannot ignore landlocked giant kokōpu as then we're being inconsistent (RA).
- Creating a myriad of ESUs is fine, but doing the same for species doesn't make sense and is not appropriate (GW). They are monophyletic.
- Separate geological events led to the isolation of dune lake galaxias and dwarf inanga (RA).
- Currently three ESUs are identified from dwarf inanga, one of these being the dune lake galaxias group (SB).
- It may be difficult to assign an ESU if isolation has been very recent. ESUs should have distinct genetic pathways. In the Falklands Islands landlocked inanga had really big eyes but specialists never thought to classify them as a new species—rather they were referred to as landlocked inanga. A key point for landlocked inanga is that dune lakes are a geological process that have a finite life. It's more an ecosystem process you want to protect rather than a species protection process—but much more difficult (RA).
- In 2009, during the reassessment of the conservation status of freshwater fish Bob McDowall coined the common name dune lakes galaxias to distinguish a distinct group of fish found in isolated dune lakes that showed genetic difference and colonisation processes to the remaining dwarf inanga. The type locality may be extinct. Evolutionary pathways of the *Galaxias vulgaris* species complex are obvious, but this is not as clear with dune lakes galaxias species (RA).

Conclusions for Landlocked inanga complex:

Indeterminate taxa in the landlocked inanga groupings require further information and analysis before a formal decision can be made on species status (Figure 4).

Table 6. Summary of known information and knowledge gaps for the *Galaxias vulgaris* species complex indeterminate taxa.

Vernacular	Southern flathead galaxias
Genetics (mtDNA)	Yes
Genetics (nuclear)	Yes
Geographical	Yes. Distinct cluster. Not hybridizing with sympatric species.
Morphology	Morphologically distinct from all sympatric species (e.g. alpine galaxias and Gollum galaxias), and all other flathead groups using geometric morphometrics.
	Life-history may be different to other groups but needs investigation.
Other key points	Some differences observed, compared with Taieri flathead galaxias, Central Otago roundhead and Canterbury galaxias, yet to be compared to Clutha flathead galaxias.
	No hybridization with sympatric Gollum galaxias (Crow et al. 2009).
	Ecologically and behaviourally distinct (life-history may be different).
	Possible names—Murihiku galaxias or -named after Bob McDowall? Need to consult with Ngāi Tahu, or could let them determine name.
Gaps	Linear morphometrics (McDowall 2006).
	Undertake morphometric anlaysis comparing to Southern flathead galaxias
Information sources/samples	Shannon Crow (NIWA) has morphology samples (geometrics and linear).
	Otago University has undertaken genetic analysis and has fish stored.
Describe	To be considered.

Vernacular	Clutha flathead galaxias
Genetics (mtDNA)	Yes
Genetics (nuclear)	Yes
Geographical	Yes (altitude and distribution).
	Downstream limit not confirmed.
Morphology	Have samples but not analysed (Comparisons with Taieri flathead galaxias and southern flathead galaxias only completed to date).
	Shannan Crow does not have any morphology analysis planned but would be useful.
Other key points	Maori Creek has more than one taxa present.
	Genetic basis strong (morphology would support description).
	Show divergence from all flatheads including lower Clutha River sites.
	Genetic analysis indicates Clutha flathead galaxias has been confirmed in the Pool Burn in upper Clutha River as far downstream as Benger Burn.
Gaps	Downstream geographic limit uncertain.
	Analysis of morphology samples.
	Linear morphometrics (McDowall 2006).
Information sources/samples	Shannon Crow (NIWA) has morphology samples .
	Otago University has undertaken genetic analysis and has fish stored
	DOC has monitoring data.
Describe	To be considered.

Vernacular	Lower Clutha galaxias and Pomahaka galaxias
Information is summarised for what is known from the lower Clutha River to cover both these taxa that were recognised during this workshop for the first time	
Genetics (mtDNA)	No—Galaxias samples from the Pomahaka area does not come out as distinct.
Genetics (nuclear)	Yes—based on nuclear DNA distinct grouping from the Pomahaka area; uncertain of how widespread/distribution.
Geographical	Downstream limit not confirmed, but upstream limit around Benger Burn.
Morphology	Can't resolve distribution until further samples and analysis is undertaken. Have some samples but not analysed yet.
Other key points	Occurs with other species (Dusky galaxias, Gollum galaxias, and Central Otago roundhead galaxias), but uncertain of any differences until analysis is undertaken. Can't resolve distribution with current data.
Gaps	Delimit distribution and extent of lower Clutha and Pomahaka galaxias. Further genetic analysis. Morphological analysis to compare upper and lower Clutha River and other taxa group samples. Linear morphometrics (McDowall 2006).
Information sources/samples	Shannon Crow (NIWA) has morphology samples. Otago University has undertaken genetic analysis and has fish stored DOC has monitoring data. Richard Allibone and Peter Jones (Otago University) have data..
Describe	No

Vernacular	Northern flathead galaxias
Genetics (mtDNA)	Yes (4–5% divergence).
Genetics (nuclear)	Yes, but not clear cut. Differences have been published noting nuclear fine-scale differences.
Geographical	Yes (Nelson, Marlborough, West Coast).
Morphology	Distinct from Canterbury galaxias, Taieri flathead galaxias, and southern flathead galaxias. More similar to Canterbury galaxias than others using geometric morphometrics.
Other key points	
Gaps	Linear morphometrics (McDowall 2006).
Information sources/samples	Shannon Crow (NIWA) has morphology samples. Otago University has undertaken genetic analysis and has fish stored.
Describe	To be considered.

Vernacular	Nevis galaxias
Genetics (mtDNA)	Yes (phylogenetically).
Genetics (nuclear)	Yes—it generally aligned with Gollum galaxias.
Geographical	Yes, very distinct.
Morphology	Small differences but consistent using geometric morphometrics. Unknown if any morphological differences compared to Dusky galaxias.
Other key points	More koaro like.
Gaps	Linear morphometrics (McDowall 2006). Determine if any morphological differences exist between Nevis galaxias and Dusky galaxias.
Information sources/samples	Shannon Crow (NIWA) has morphology samples.

	Otago University has undertaken genetic analysis and has fish stored
Describe	To be considered.

Vernacular	Teviot flathead galaxias
Genetics (mtDNA)	Yes—most similar to Taieri flathead galaxias.
Genetics (nuclear)	Lack of data but one individual came out as a distinct sequence.
	Need further samples.
Geographical	Yes
Morphology	Have samples but not analysed (10 fish).
	Need more samples.
Other key points	Terrestrial spawners.
Gaps	Linear morphometrics (McDowall 2006).
	Further fish samples required for morphological, nuclear and Larval Glyco Protein (LGP) DNA analysis.
Information sources/samples	Otago University has undertaken genetic analysis and has fish stored
Describe	To be considered.

5. Where to from here?

The workshop group agreed the following future direction and key priorities were required to resolve non-migratory galaxias and freshwater fish taxonomy issues.

(initials of the workshop attendee(s) assigned the action is provided in brackets)

5.1 Data collection

- Ensure a copy of the GAL number database (plus any additional information collated above) is readily accessible to all DOC staff and updated copies are provided back to the University of Otago.
- Continue work on collating species identification and geospatial location information for all genetically sequenced non-migratory galaxias samples. This will require input from Otago University, so DOC can maintain a current picture of the confirmed species identification (ND).
- Fill gaps (e.g. add grid references) in the University of Otago's internal GAL number database to ensure complete record of where and what genetic analysis has been undertaken (ND).
- Liaise with NIWA to ensure vetting process is being undertaken for new fish records entered into the NZFFD and genetic results field is being filled out (ND).

5.2 Groupings

- Ensure agreed names (Figure 2, 3 & 4) are used widely and consistently.
- Determine if non-diadromous and diadromous populations of diadromous fish species should be considered separately for conservation status assessment and management. There is a need to ensure consistency for all freshwater fish, and results of further investigations into taxonomic status of the inanga grouping should be considered in any decisions made (ND & Conservation status reassessment panel for freshwater fish).
- A consistent approach for taxonomic groupings should be decided and used in the conservation status assessments across all freshwater fish e.g. Mudfish and non-migratory galaxias groupings based on genetics/ ESUs etc.

5.3 Assessment of species status of freshwater fish

To determine the species status of a freshwater fish it was agreed by the workshop group that the key questions (Figure 5), and whether the taxa met the BSC and/or GCC species concepts (Table 5) should be considered.

Workshop group decisions and recommendations on species status:

- The workshop group agreed that the highest priority action was to resolve the taxonomic status of all indeterminate taxa.
- Formal description of five indeterminate taxa within the *Galaxias vulgaris* species complex was identified as possible and should be undertaken for southern flathead galaxias, Clutha flathead galaxias, Teviot flathead galaxias, northern flathead galaxias, and Nevis galaxias. The outcome of this will be a revision paper covering the *Galaxias vulgaris* species complex. Clutha flathead galaxias will be described from the upper Clutha River only. The lower Clutha River fish, previously identified

as Clutha flathead galaxias, will now be identified as taxonomically indeterminate until further information is obtained.

- The other indeterminate non-migratory galaxias taxa (Lower Clutha galaxias, Pomahaka galaxias, Upland longjaw galaxias (Waitaki River),Lowland longjaw galaxias (Waitaki River), Dwarf galaxias (Nelson, Marlborough,North Island), Alpine galaxias (Southland), Alpine galaxias (Manuherikia River), Dune lakes galaxias) will remain so until information gaps are filled and a decision can be made on whether is a species or not (e.g. morphological characteristics have been investigated to determine if there are any distinct differences, and genetic divergence quantified using the same or comparable methods to the present data sets).

Key actions required to assist formal description of southern flathead galaxias, Clutha flathead galaxias, Teviot flathead galaxias, northern flathead galaxias, and Nevis galaxias:

(initials of the workshop attendee(s) assigned the action is provided in brackets)

- JW and GW will lead the description paper and will provide genetic analysis results. ND and SC will undertake the morphological analysis and input into the revision paper.
- Identify robust type localities for all taxa being described (Table 7). Type localities should be secure, have good numbers, and be where genetic and morphological samples had previously been collected from (and subsequent analysis completed where possible) (Table 7).

Table 7. Possible stream type localities agreed upon by the workshop group. (Initials of workshop attendee that suggested the type locality is provided in brackets)

Vernacular	Suggested type localities	Agreed type locality	Type locality characteristics
Clutha flathead galaxias	Lagoon or Schoolhouse Creeks (RA)		
Southern flathead galaxias	Excelsior Creek, Etal Stream, Hamilton Burn, Gorge Burn, headwaters of Mataura River	Wash Creek	Highest numbers, QEII Trust covenant
Northern flathead galaxias	Acheron River	Acheron River	Good numbers
Teviot flathead galaxias	Lake Onslow unnamed tributary (DJ)	Lake Onslow unnamed tributary (DJ)	
Nevis galaxias	Potters Creek (PR), Whittens Creek (JW, SC)	Potters Creek (PR)	DOC covenant. Very safe due to 40-50 m waterfall

- Formal taxonomic requirements for formal species description revision should be identified (ND & SC).
- Confirm with the journal editor (or other source) whether it is necessary to include line drawings and pictures in the formal description paper (ND). Commission line drawings of Clutha flathead galaxias and Nevis galaxias if required (ND).
- Contract Te Papa to undertake drawings of the five taxa for the formal descriptions (ND).
- Produce a map of the current known distribution for each species (JW. Figure 2 of Waters et al. (2010) will be used, but revised to include the type localities).

- Update genetic trees from Waters et al. (2010) (JW).
- Provide draft notes relevant to the introduction of the revision paper to GW (SC).
- Collect further samples of Nevis galaxias from Potters Creek (minimum number 10; >60 mm length) (PR, CC, DJ), and courier overnight to SC for morphological analysis. Once analysis complete these samples need to be sent to Te Papa, Wellington for creation of drawings (ND).
- Collect further Teviot flathead galaxias samples are required for morphological, nuclear and Larval Glyco Protein (LGP) DNA analysis (PR).
- Larval Glyco Protein (LGP) analysis for 10–12 lineages should be undertaken (GW). Results combined with existing genetic analysis (JW) to provide the full genetic situation for the *Galaxias vulgaris* species complex.
- Undertake nuclear DNA analysis for Teviot flathead galaxias and northern flathead galaxias (GW).
- Undertake geometric morphometric analysis for Clutha flathead galaxias and Teviot flathead galaxias, and compare Clutha flathead galaxias with southern flathead galaxias. Teviot flathead galaxias morphological information is all digitised but the analysis needs to be run (SC).
- Undertake linear morphometric analysis of southern flathead galaxias, Clutha flathead galaxias, northern flathead galaxias, Nevis galaxias and Teviot flathead galaxias (ND).
- Combine with geometric and linear morphometric results to ensure the minimum criteria are met when formally describing a species (SC & ND). Species descriptions are stronger with multiple methods (e.g. geometric, linear and genetic) supporting the formal description.
- Analyse the genetic and morphological data available for Nevis galaxias and Gollum galaxias (GW).
- Determine if any morphological differences exist between Nevis galaxias and Dusky galaxias (SC & ND).

Key knowledge gaps and actions required to determine species status of other non-migratory galaxias groups (in no particular order):

- Undertake linear and geometric morphometric analysis of the morphological differences between fish from the upper and lower Clutha River (Pomohaka galaxias and lower Clutha galaxias) (SC & ND). These results are to be combined with the available genetic analysis information to determine if any conclusions on the status of the fish in this area can be made.

– Collect further samples from within the lower Clutha River to determine status of lower Clutha and Pomahaka galaxias groups. Beaumount Station would be a good location for collection (PR), and Figure 7 page 10 of Waters et al (2010) can be used to identify what we do know and where the gaps are we need to fill.

– Delimit distribution and extent of lower Clutha and Pomahaka galaxias.

– Undertake nuclear DNA analysis for lower Clutha River fish collected in the past and held at Otago University (GW/JW).

- Consider whether an application for a Conservation Management Unit or Data Deficient funding should be developed to support the taxonomic description of southern flathead galaxias, Clutha flathead galaxias, Teviot flathead galaxias, northern flathead galaxias, and Nevis galaxias and/or to fill the priority knowledge gaps for the remaining eight indeterminate taxa (alpine galaxias (Southland), alpine galaxias (Manuherikia), dwarf galaxias (Nelson, Marlborough, North Island), lowland longjaw galaxias (Waitaki), upland longjaw galaxias (Waitaki), dune lake galaxias, Pomohaka galaxias, and lower Clutha River species) so decisions on the taxonomic status of these groups can be made (SB, ND & PR).
- Ensure at least ten specimens are available for all indeterminate taxa. Collect further samples if ten specimens are not available and undertake morphological analysis to determine if there are any key differences (ND).
- Collect and get genetic analysis undertaken for dune lake galaxias and dwarf inanga samples to determine species status. (Michael Pingram (DOC) is trying to progress this work with support from Nick Ling (Waikato University), Dianne Gleeson (Landcare Research) and SB).
- Collect additional samples of dwarf and alpine galaxias from the Clarence and Maruia rivers (DOC).
- Undertake further surveys in the Maruia and Clarence for upland longjaw galaxias (DOC).
- Ensure upland longjaw galaxias specimens from the University of Otago, Department of Zoology collection (Maruia River), and NIWA (Hurunui River) are available and can be used to help determine taxonomic status in future (SC).
- Research into life history differences between species needs to continue to fill gaps to support taxonomic decisions e.g. research into Gollum and Nevis galaxias life
- Identify any additional knowledge gaps for indeterminate taxa, and collate and prioritise these gaps for future action (ND).

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Appendix 1

Table A1.1. Non-migratory galaxias groupings, key description, and genetic references (full references below).

Species name	Vernacular	Grouping	Year described	Formal description reference	Genetic analysis references
Galaxias anomalus	Central Otago roundhead galaxias	*Galaxias vulgaris* species complex	1959	Stokell 1959	McDowall & Wallis 1996
Galaxias cobitinis	Lowland longjaw galaxias (Kakanui River)	Pencil galaxias	2002	McDowall & Waters 2002	Waters & Craw 2008
Galaxias aff. cobitinis 'Waitaki'	Lowland longjaw galaxias (Waitaki River)	Pencil galaxias	Undescribed	Undescribed	Waters & Craw 2008
Galaxias depressiceps	Taieri flathead galaxias	*Galaxias vulgaris* species complex	1996	McDowall & Wallis 1996	McDowall & Wallis 1996
Galaxias divergens	Dwarf galaxias (West Coast)	Pencil galaxias	1959	Stokell 1959	Allibone 2002 Waters et al. 2006
Galaxias aff. divergens 'northern'	Dwarf galaxias (Nelson, Marlborough, North Island)	Pencil galaxias	Undescribed	Undescribed	Allibone 2002 Waters et al. 2006
Galaxias eldoni	Eldon's galaxias	*Galaxias vulgaris* species complex	1997	McDowall 1997	Waters & Wallis 2001a
Galaxias gollumoides	Gollum galaxias	*Galaxias vulgaris* species complex	1999	McDowall & Chadderton 1999	Waters & Wallis 2001a
Galaxias 'Nevis'	Nevis galaxias	*Galaxias vulgaris* species complex	Undescribed	Undescribed	Waters et al. 2001
Galaxias gracilis	Dwarf inanga (North Kaipara Head dune lakes)	Landlocked inanga	1967	McDowall 1967	Gleeson et al. 1999
Galaxias macronasus	Bignose galaxias	Pencil galaxias	2003	McDowall & Waters 2003	McDowall & Waters 2003
Galaxias paucispondylus	Alpine galaxias	Pencil galaxias	1939	Stokell 1939	McDowall & Waters 2003
Galaxias aff. paucispondylus 'Manuherikia'	Alpine galaxias (Manuherikia River)	Pencil galaxias	Undescribed	Undescribed	
Galaxias aff. paucispondylus 'Southland'	Alpine galaxias (Southland)	Pencil galaxias	Undescribed	Undescribed	
Galaxias prognathus	Upland longjaw galaxias (Canterbury, West Coast)	Pencil galaxias	1940	Stokell 1940	Waters & Craw 2008
Galaxias aff. prognathus 'Waitaki'	Upland longjaw galaxias (Waitaki River)	Pencil galaxias	1940	Stokell 1940	Waters & Craw 2008
Galaxias pullus	Dusky galaxias	*Galaxias vulgaris* species complex	1997	McDowall 1997	Waters & Wallis 2001a
Galaxias 'dune lakes'	Dune lakes galaxias (Kai Iwi Lakes)	Landlocked inanga	Undescribed	Undescribed	Gleeson et al. 1999
Galaxias 'sp. D'	Clutha flathead galaxias	*Galaxias vulgaris* species complex	Undescribed	Undescribed	Allibone & Wallis 1993

Species name	Vernacular	Grouping	Year described	Formal description reference	Genetic analysis references
Galaxias 'northern'	Northern flathead galaxias (Marlborough, Nelson, Wrest Coast)	*Galaxias vulgaris* species complex	Undescribed	Undescribed	Waters & Wallis 2000
Galaxias 'southern'	Southern flathead galaxias	*Galaxias vulgaris* species complex	Undescribed	Waters & Wallis 2001	Waters & Wallis 2001a
Galaxias 'Teviot'	Teviot flathead galaxias	*Galaxias vulgaris* species complex	Undescribed	Undescribed	Waters & Wallis 2001b
Galaxias vulgaris	Canterbury galaxias	*Galaxias vulgaris* species complex	1949	Stokell 1949	Waters & Wallis 2000

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Appendix 2

Table A2.1. Current Conservation status of non-migratory *Galaxias* from Allibone et al. (2010)

Species name	Vernacular	Conservation Status	Status criteria	Qualifiers	Taxonomic status
Galaxias anomalus	Central Otago roundhead galaxias	Nationally Vulnerable	D (3)	EF	Taxonomically determinate
Galaxias cobitinis	Lowland longjaw galaxias (Kakanui River)	Nationally Critical	A (1)	CD, EF, OL	Taxonomically indeterminate
Galaxias aff. cobitinis ”Waitaki”	Lowland longjaw galaxias (Waitaki River)	Nationally Critical	A (3)	CD	Taxonomically indeterminate
Galaxias depressiceps	Taieri flathead galaxias	Not Threatened		CD	Taxonomically determinate
Galaxias divergens	Dwarf galaxias (West Coast)	Declining	B (2)	DP, RR	Taxonomically determinate
Galaxias aff. divergens “northern”	Dwarf galaxias (Nelson, Marlborough, North Island)	Declining	C (1)	DP	Taxonomically indeterminate
Galaxias eldoni	Eldon’s galaxias	Nationally Endangered	A (3)		Taxonomically determinate
Galaxias gollumoides	Gollum galaxias	Declining	B (2)	DP	Taxonomically determinate
Galaxias aff. gollumoides “Nevis”	Nevis galaxias (Nevis River)	Nationally Vulnerable	B (3)	DP, RR	Taxonomically indeterminate
Galaxias gracilis	Dwarf inanga (North Kaipara Head dune lakes)	Naturally Uncommon		DP, EF	Taxonomically determinate
Galaxias macronasus	Bignose galaxias	Nationally Vulnerable	C (3)	RR	Taxonomically determinate determinate
Galaxias paucispondylus	Alpine galaxias	Not Threatened		RR	Taxonomically determinate
Galaxias aff. paucispondylus “Manuherikia”	Alpine galaxias (Manuherikia River)	Nationally Endangered	B (3)	DP, OL	Taxonomically indeterminate
Galaxias aff. paucispondylus “Southland”	Alpine galaxias (Southland)	Not included in Allibone et al. (2010)			
Galaxias prognathus	Upland longjaw galaxias (Canterbury, West Coast)	Nationally Vulnerable	C (3)	DP	Taxonomically determinate
Galaxias aff. prognathus “Waitaki”	Upland longjaw galaxias (Waitaki River)	Nationally Vulnerable	B (3)	DP, RR, Sp	Taxonomically indeterminate
Galaxias pullus	Dusky galaxias	Nationally Endangered	A (3)	CD	Taxonomically determinate
Galaxias “dune lakes”	Dune lakes galaxias (Kai Iwi Lakes)	Naturally Uncommon		EF	Taxonomically indeterminate
Galaxias “sp. D”	Clutha flathead galaxias (Clutha River)	Nationally Vulnerable	C (3)		Taxonomically indeterminate
Galaxias ‘northern’	Northern flathead galaxias (Marlborough)	Naturally Uncommon		RR	Taxonomically indeterminate
Galaxias “southern.”	Southern flathead galaxias (Southland)	Not Threatened		DP	Taxonomically indeterminate
Galaxias “Teviot”	Teviot galaxias (Teviot River)	Nationally Critical	A (3)	DP, RR	Taxonomically indeterminate
Galaxias vulgaris	Canterbury galaxias	Not Threatened		DP	Taxonomically determinate

Appendix 3 Freshwater fish taxonomic workshop details

Venue: Department of Conservation (DOC)

Conservation House

77 Lower Stuart Street

Dunedin

New Zealand

Time: 14 May 2013

9am–5pm

Attendees:

Name	Abbreviation used within proceedings	Organisation	Role
Sjaan Bowie	SB	Department of Conservation, Science & Capability (DOC)	Technical advisor (Freshwater); non-migratory galaxiid recovery group leader
Nicholas Dunn	ND	DOC, Science & Capability	Science advisor (Freshwater)
Pete Ravenscroft	PR	DOC, Coastal Otago Area;	Freshwater ranger; Non-migratory galaxiid recovery group member
Daniel Jack	DJ	DOC, Coastal Otago Area	Freshwater ranger
Jane Goodman	JG	DOC, Science & Capability	Technical advisor (Freshwater), non-migratory galaxiid recovery group member; freshwater fish conservation status assessment panel leader
Ciaran Campbell	CC	DOC, Coastal Otago Area	Freshwater ranger
Graham Wallis	GW	Otago University;	Professor in Genetics
Jon Waters	JW	Otago University	Professor in Genetics
Tania King	TK	Otago University	Molecular Genetics Technician
Shannan Crow	SC	NIWA	Freshwater fish ecologist
Richard Allibone	RA	Golder Associates	Freshwater fish ecologist
Lan Pham	LP	Department of Conservation	Minute taker

Appendix 4

Table A3.1. Key morphological identification traits, and species that can cause confusion with identification in the field.

Species name	Vernacular	Morphological identification	Species causing confusion
Pencil galaxias			
Galaxias paucispondylus	Alpine galaxias	16 principal caudal fin rays. 7 pelvic fin rays . White chevron in front of dorsal fin.	Bignose galaxias, dwarf galaxias, other non-migratory galaxias. Other populations of alpine galaxias, but geographically disjunct distributions.
Galaxias aff. paucispondylus "Manuherikia" geographically	Alpine galaxias (Manuherikia River)	16 principal caudal fin rays. 7 pelvic fin rays. White chevron in front of dorsal fin.	Other populations of alpine galaxias, but disjunct distributions.
Galaxias aff. paucispondylus "Southland" geographically	Alpine galaxias (Southland)	16 principal caudal fin rays. 7 pelvic fin rays. White chevron in front of dorsal fin.	Other populations of alpine galaxias, but disjunct distributions.
Galaxias macronasus	Bignose galaxias	4–6 pelvic fin rays (usually only 5). 11–14 caudal rays. Distinctly rounded head profile.	Alpine galaxias.
Galaxias divergens	Dwarf galaxias (West Coast)	6 pelvic fin rays compared to the more usual 7 for others. 15 caudal fin rays (16 upwards in others).	Alpine galaxias; other non-migratory galaxias.
Galaxias aff. divergens "northern"	Dwarf galaxias (Nelson, Marlborough, North Island)	Chevron sometimes before dorsal fin.	Dwarf galaxias.
Galaxias cobitinis (Kakanui River)	Lowland longaw galaxias (Kakanui River)	Lower jaw long; distinctly upturned. Dorsal fin origin behind anal fin origin.	All upland longjaw galaxias, lowland longjaw galaxias (Kakanui)
Galaxias aff. cobitinis "Waitaki"	Lowland longjaw galaxias	Lower jaw long; distinctly upturned.	All upland longjaw galaxias, lowland longjaw galaxias

	(Waitaki River)	Dorsal fin origin behind anal fin origin.	(Waitaki)
Galaxias prognathus	Upland longjaw galaxias (Canterbury, West Coast)	Lower jaw long; distinctly upturned. Dorsal and anal fin origin even.	Lowland longjaw galaxias
Galaxias aff. prognathus "Waitaki"	Upland longjaw galaxias (Waitaki River)	Lower jaw long; distinctly upturned. Dorsal and anal fin origin even.	Lowland longjaw galaxias
Flathead galaxias			
Galaxias "sp. D"	Clutha flathead galaxias (Clutha River)	Snout blunt. Lower jaw little shorter than upper jaw.	
Galaxias "southern"	Southern flathead galaxias (Southland)	Snout blunt. Lower jaw little shorter than upper jaw.	
Galaxias "Teviot"	Teviot flathead galaxias (Teviot River)		
Galaxias "northern"	Northern flathead galaxias (Marlborough)	Snout blunt. Lower jaw little shorter than upper jaw. Dorsal origin distinctly forward of anal origin (same as Canterbury galaxias base only distribution and genetics).	Canterbury galaxias. koaro
Galaxias vulgaris	Canterbury galaxias	Snout blunt. Lower jaw little shorter than upper jaw. Dorsal original distinctly forward of anal origin.	Kōaro, northern flathead galaxias
Galaxias depressiceps	Taieri flathead galaxias	16 principal caudal fin rays. 7 pelvic fin rays. Golden mid-dorsal stripe. Flattened head profile. Green transparent snout common.	Other flathead species
Roundhead galaxias			
Galaxias eldoni	Eldon's galaxias	15 principal caudal fin rays.	

		No pyloric caeca. Diffuse spotting creates colour patterns with diffuse boundaries between colours.	
Galaxias gollumoides	Gollum galaxias	6 and 7 pelvic fin rays in Stewart Island and Southland populations, respectively.	
Galaxias pullus	Dusky galaxias	14 principal caudal fin rays.	Eldon's galaxias, Central Otago roundhead
galaxias			
		Halo and mid-dorsal colour patter discontinuity. Dark colour patches have clearly defined boundaries.	
Galaxias anomalus	Central Otago roundhead galaxias	Rounded head. 16 principal caudal fin rays. Mid-dorsal colour pattern discontinuity.	
Galaxias aff. gollumoides "Nevis"	Nevis galaxias (Nevis River)	Golden ring on pectoral fins.	Kōaro
Landlocked inanga			
Galaxias maculatus	Inanga		
Galaxias "dune lakes"	Dune lake galaxias (Kai Iwi Lakes)		
Galaxias gracilis	Dwarf inanga (North Kaipara Head dune lakes)		
Galaxias maculatus	Inanga		