CAWTHRON

A Framework for Flow Management in the Takaka River Catchment

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EXECUTIVE SUMMARY

Until recently the demand for water in the Takaka Catchment has been low, especially when compared to the drier eastern parts of the Tasman District. However, demand for water has increased substantially over the last few years resulting in the need for an appropriate framework for managing instream flows and water allocation. This report identifies a framework for flow management that should be applicable and practical for the Takaka Catchment.

Instream values vary considerably in different parts of the Takaka Catchment and it is sensible to group waterways with similar values together so they can be managed in a similar fashion. Six groups of waterways are proposed based on a combination of local knowledge, source of flow, waterway size and freshwater fish distribution. These groups are the Takaka North rivers, Spring-fed rivers, East Takaka streams, Pohara Flats streams, Small Headwater streams, and Major rivers and their tributaries. Instream values and management objectives have been suggested for each of these groups, along with critical values that, if protected, should sustain the other significant values. Protection levels are suggested for each group of streams based on whether the values are considered to be high, medium or low. Consultation with the local community and other stakeholders is required to finalise these suggestions. Further sampling of some waterways would also be helpful in accurately determining appropriate values upon which to base instream management objectives.

Hydrological analyses would be appropriate for setting flow regimes for the East Takaka streams, while generalised habitat models would be appropriate for the Pohara Flats and Small Headwater Streams. A water quality model such as WAIORA would be appropriate to manage flows in the Spring-fed streams, on the basis of the relationship between flow and dissolved oxygen concentration, although the low levels of dissolved oxygen in groundwater may make this problematic. Detailed habitat analyses and modelling is required to determine appropriate minimum flows for the Takaka North rivers and Major Rivers and their tributaries. If the expense of detailed habitat analyses cannot be justified for these rivers then a conservative approach would be to set the minimum flow at the MALF.

Sensible allocation limits are required to maintain the security of supply for water users and avoid flows being held at the minimum flow for prolonged periods (i.e. flat-lining). The difference between the minimum flow and the summer 7-day Q_{95} (flow exceeded 95% of the time over summer) could be used as an allocation limit because it gives users a clear expectation of the security of their supply. Other allocation options such as flow sharing, flow rostering and primary/secondary allocation limits could also be used to maximise the effectiveness of water use without compromising minimum flows.

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1. INTRODUCTION

Rivers and streams in the Takaka Catchment support a wide range of instream values that need to be protected when considering the sustainable management of these systems. Until recently the demand for water in the Takaka Catchment has been low, especially when compared to the drier eastern parts of the Tasman District. However, the benefits of irrigation for pasture growth have become obvious on the few farms that have been irrigated during recent dry summers. This has led to a substantial increase in demand for water. The Tasman District Council (TDC) has recognised that an appropriate framework for managing instream flows and water allocation is now needed in this area. TDC is aware that a range of different methods are available to guide flow management, but have sought advice from Cawthron on appropriate methods that will be applicable and practical for the Takaka Catchment. This report identifies a framework for flow management that should be suitable for the Takaka Catchment.

2. MFE FLOW GUIDELINES FOR INSTREAM VALUES

The Ministry for the Environment's (1998) guidelines suggest the following approach to flow management (Figure 1). Key steps are the identification of the values present and an assessment of the Instream Management Objective (IMO) for the stream. Jowett & Hayes (2004) suggest the additional consideration, in defining the IMO, of identifying a critical value, or values. The concept of critical values is that by providing sufficient flow to sustain the most flow sensitive, important value (species, life stage, or recreational activity), the other significant values will also be sustained (Jowett & Hayes 2004). Candidates for critical value status might include flow sensitive rare or endangered species, or species with high fishery value. The next step is to identify a critical, flow related, factor (or factors) which need to be maintained to ensure that the Instream Management Objective is achieved (provision of physical habitat for a fish species of interest would be an example of a critical factor, if the IMO was to maintain populations of that fish species). A variety of technical methods can then be used to determine features of the flow regime (e.g. minimum flows, flow variability) that are required to sustain the Instream Management Objective. Jowett & Hayes (2004) also suggested that consideration should be given to the current and potential abstraction demand before selecting the appropriate technical method. This may circumvent the need for complex and expensive technical methods to be applied in situations where demand is low, and consequently a conservative minimum flow based on a simpler technical method is unlikely to impinge significantly on out-of-stream water use. This general approach has been used widely throughout the country, although there often appears to be some overlap between determining the Instream Management Objectives and identifying critical factors.

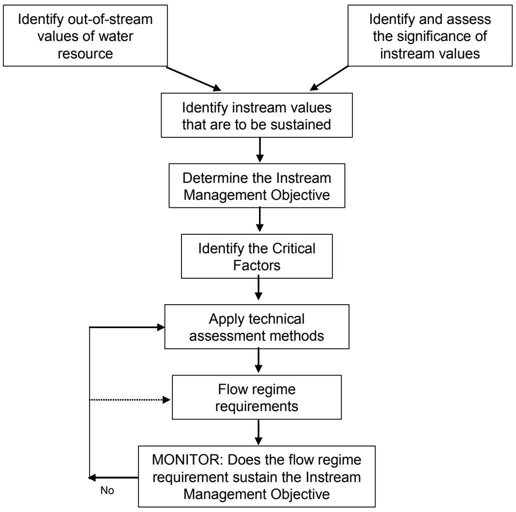

Figure 1. Approach to managing instream values in MfE (1998) guidelines.

3. FISH DISTRIBUTION IN THE TAKAKA CATCHMENT

For the purposes of this report the Takaka Catchment refers to all the rivers and streams that flow into Golden Bay between the Tukurua River in the west and Abel Tasman Point in the east (Figure 2). I used data from the New Zealand Freshwater Fisheries database (http://www.niwascience.co.nz/services/nzffd) and a report related to the re-consenting of the Cobb Power Scheme (Young et al. 2000) to establish some of the instream values associated with rivers and streams in the Takaka Catchment. These two sources of information provided 163 records of fish distribution at about 140 sites throughout the Takaka Catchment (Figure 2). Most of the native freshwater fish require access to and from the sea to complete their life cycles. The only exceptions to this are the upland bully, which spends its entire life in freshwater, and the koaro, which in some circumstances can form landlocked populations (e.g. Cobb Reservoir). Therefore, the presence of a species at a particular location usually indicates that it will also be present downstream.

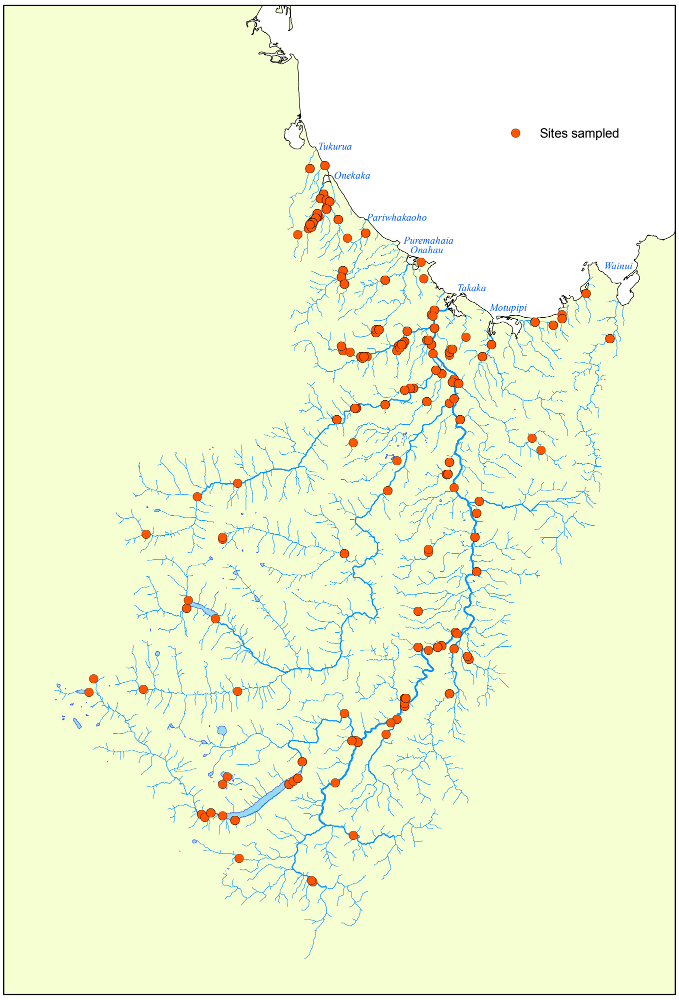

Figure 2. Sites in the Takaka Catchment and adjacent small stream catchments where information on the distribution of freshwater fish is available.

Longfin eels (*Anguilla dieffenbachii*) are widely distributed around the catchment and would be expected to occur in almost all of the waterways where they have access, although perhaps not in the eastern parts of the catchment that dry up regularly (Figure 3). In contrast, shortfin eels (*Anguilla australis*) appear to be more common around the coastal parts of the catchment and not present in the high altitude areas (Figure 3). This distribution pattern is typical in other parts of the country and reflects the exceptional ability of juvenile longfin eels to migrate considerable distances inland and negotiate rapids, waterfalls, weirs and dams that present barriers to most other fishes. However, it appears that the few longfin eels that remain above the Cobb Reservoir migrated there before the dam was built (Young et al. 2000). Longfin eels are listed as being in gradual decline in DoC's threatened species classification.

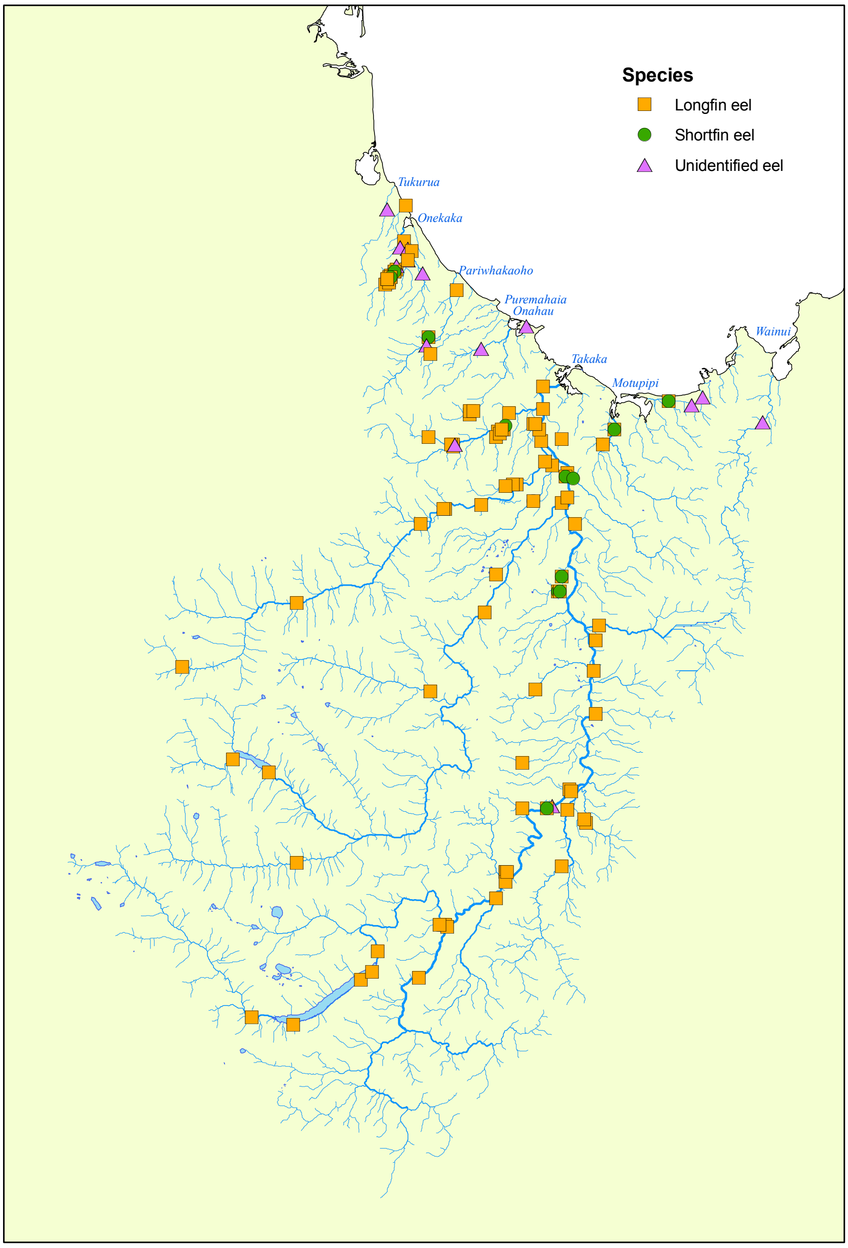

Figure 3. Distribution of eels throughout the Takaka Catchment and adjacent small stream catchments.

Five species of galaxiid fish are found in the Takaka Catchment (Figure 4). These fish are all components of the whitebait fishery and include giant kokopu (*Galaxias argenteus*), banded kokopu (*Galaxias fasciatus*), shortjaw kokopu (*Galaxias postvectis*), koaro (*Galaxias brevipinnis*), and inanga (*Galaxias maculatus*). Apart from koaro, these species are restricted to low elevation parts of the catchment (Figure 4). Like longfin eels, koaro are exceptional migrants and are commonly found at considerable distances inland from the coast and above waterfalls. Giant kokopu and shortjaw kokopu are both listed as being in gradual decline in DoC's threatened species classification.

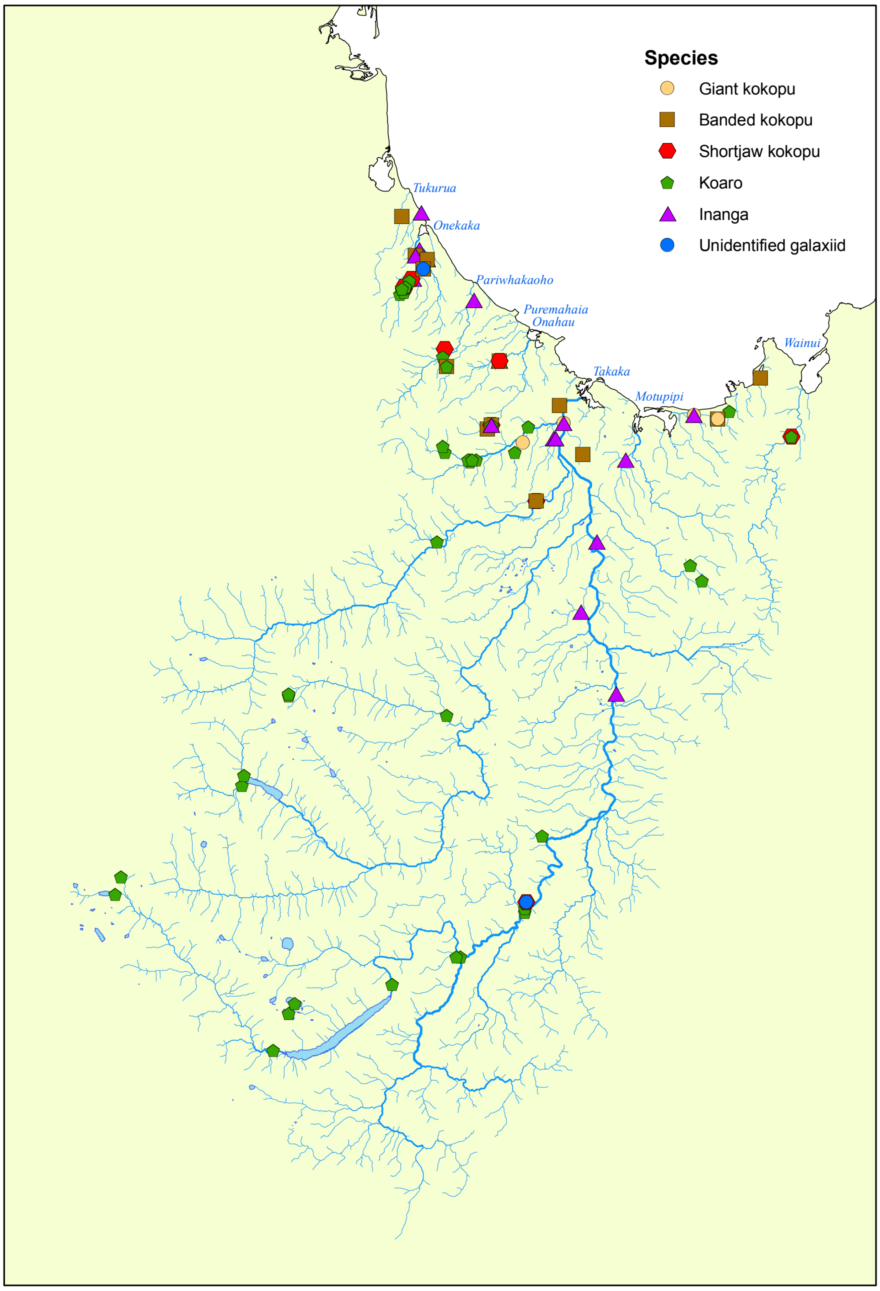

Figure 4. Distribution of galaxiid fish throughout the Takaka Catchment and adjacent small stream catchments.

Five species of bullies are found throughout the Takaka Catchment (Figure 5). These include the redfin bully (*Gobiomorphus huttoni*), common bully (*Gobiomorphus cotidianus*), giant bully (*Gobiomorphus gobioides*), bluegill bully (*Gobiomorphus hubbsi*), and upland bully (*Gobiomorphus breviceps*). Most of these species are found in the lower reaches of the rivers and streams reflecting their need to access the sea to complete their life cycle and their limited ability to migrate (Figure 5). In contrast, upland bullies do not need to access the sea and have been found in the mid-reaches of the Takaka River and in the Cobb Reservoir. Nevertheless, their distribution seems relatively limited with no records of them being found in the upper Anatoki, Waingaro or Takaka rivers (Figure 5).

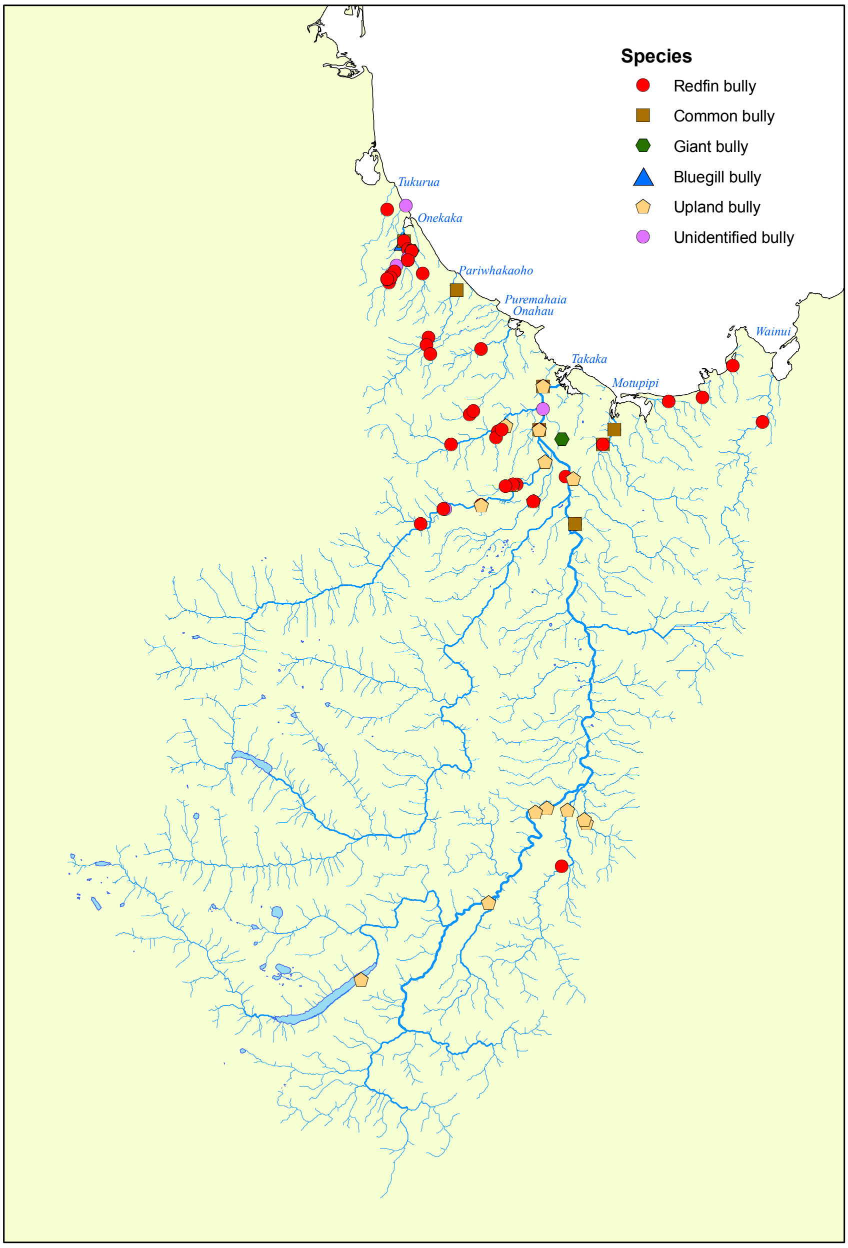

Figure 5. Distribution of bullies throughout the Takaka Catchment and adjacent small stream catchments.

Lamprey (*Geotria australis*), torrentfish (*Cheimarrichthys fosteri*), yelloweye mullet (*Aldrichetta forsteri*) and freshwater crayfish or koura (*Paranephrops planifrons*) are also found in the catchment (Figure 6). Once again, the majority of these species are typically found in the lower parts of catchments with only koura found upstream of the confluence of the Waingaro and Takaka rivers. Lamprey are listed as sparse in DoC's threatened species classification.

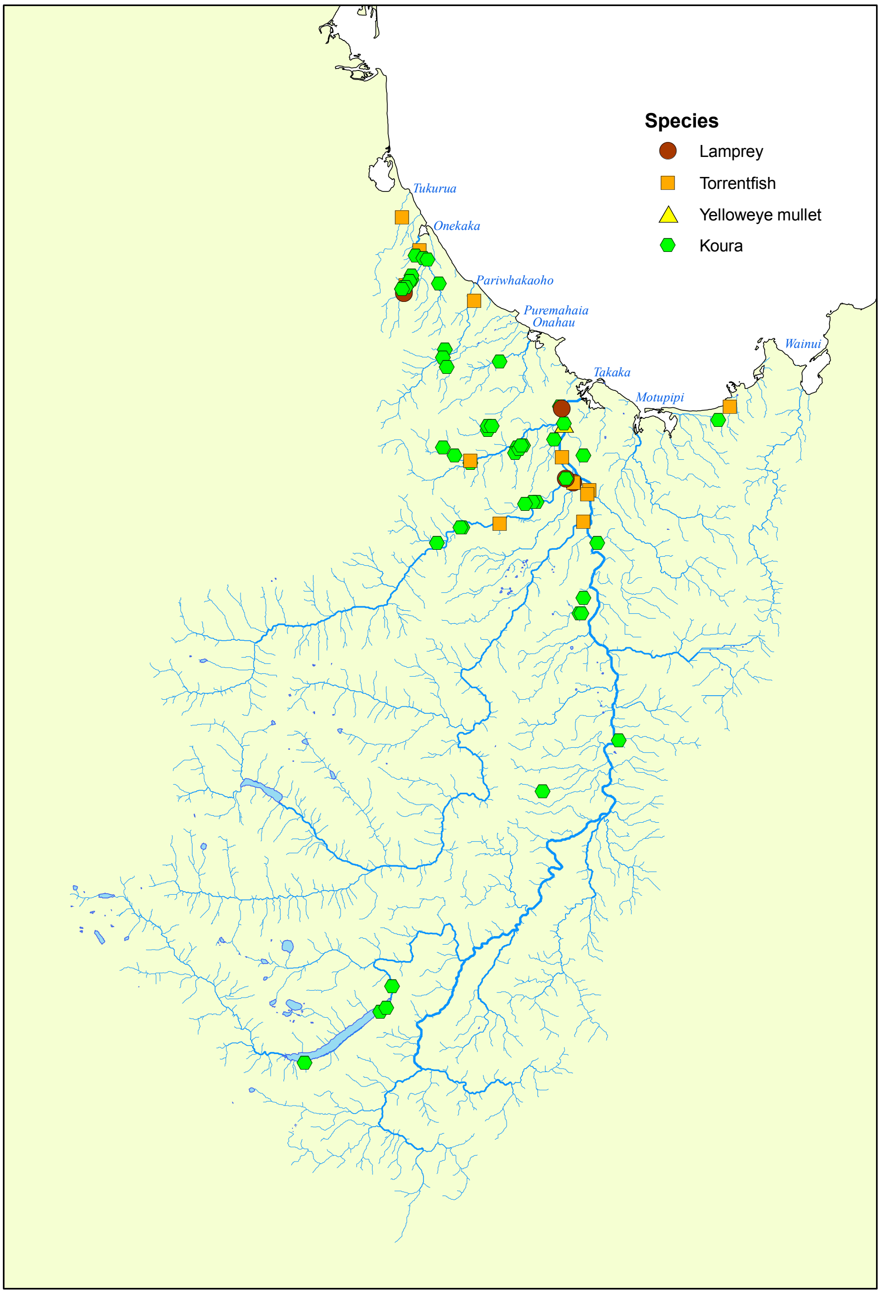

Figure 6. Distribution of lamprey, torrentfish, yelloweye mullet and koura throughout the Takaka Catchment and adjacent small stream catchments.

Three species of introduced fish have been recorded from the Takaka Catchment, including brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and chinook salmon (*Onchorhynchus tshawytscha*). Brown trout are found in the mainstem and larger tributaries of the Takaka, Waingaro, Anatoki, Waikoropupu and Onekaka rivers, while rainbow trout are found only in the Cobb Reservoir and River upstream of the dam (Figure 7). There is only one record of chinook salmon from the Takaka Catchment which is probably related to a release from the salmon farm at the Pupu springs, although anglers commonly report catching them in the lower river (thought to be escapees from the salmon farm). There are no records of brown trout in several of the small rivers draining into Golden Bay (Wainui, Motupipi, Onahau, Puremahaia, Pariwhakaoho, Tukurua). This may be an artefact of a lack of official reporting from these areas, but if not then the streams could represent examples of relatively rare trout-free systems that deserve a high level of protection. Trout are known to have adverse effects on native fish communities and alter the structure and functioning of river ecosystems (Simon & Townsend 2003).

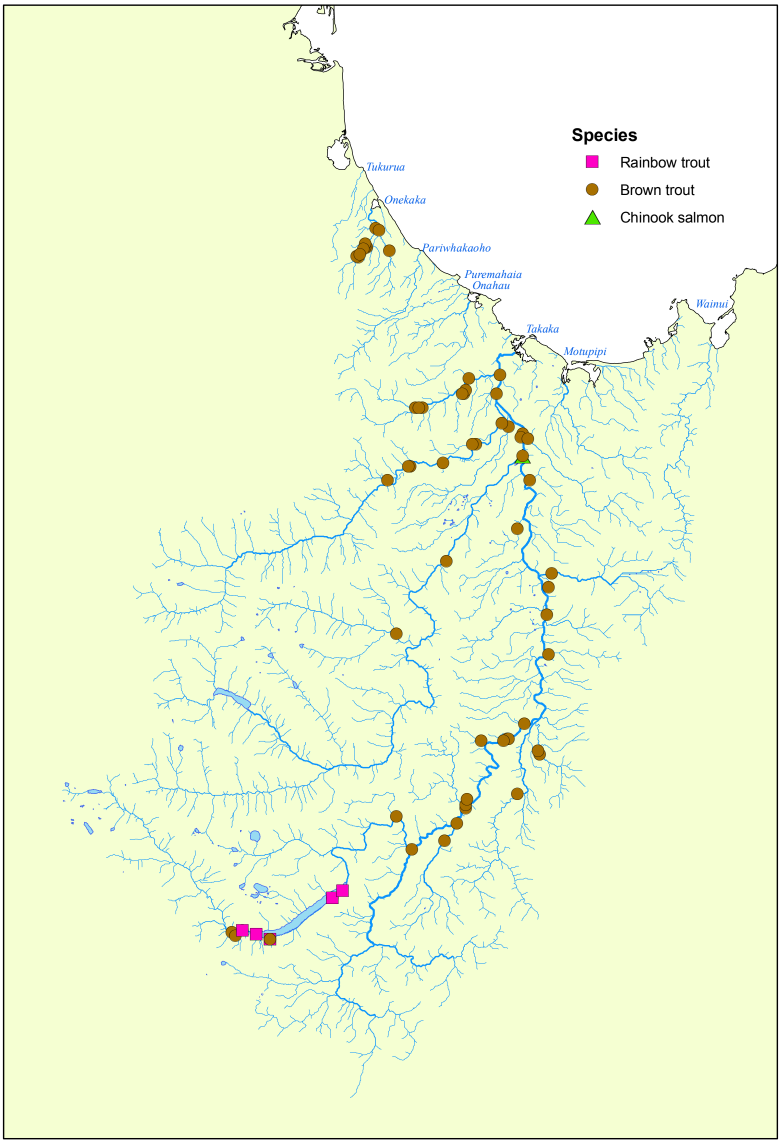

Figure 7. Distribution of introduced fish in the Takaka Catchment and adjacent small stream catchments.

4. A FRAMEWORK FOR FLOW MANAGEMENT

4.1. Instream Values

When considering a catchment-wide approach to flow management it is helpful to group waterways with similar values together so they can be managed in a similar fashion. As shown above, there is a substantial difference in the diversity of fish populations between sites near the coast and sites in the high altitude parts of the Takaka Catchment. Instream values will also differ among streams in different parts of the catchment. Six groups of waterways are proposed based on a combination of local knowledge, source of flow, waterway size and freshwater fish distribution (Figures 8 and 9). These groups are the Takaka North rivers, Spring-fed rivers, East Takaka streams, Pohara Flats streams, Small Headwater streams, and Major rivers and their tributaries.

The instream values listed for each waterway group are based on my knowledge of the area (Young et al. 2005) and discussions with Tasman District Council staff (Figure 8). However, they should be updated after consultation with relevant stakeholders and aligned with any values identified for these waterways in the Tasman Resource Management Plan. The majority of these values are based on fish communities (as summarised above), although wading birds, customary and landscape values are also shown (Figure 8). Aquatic invertebrate communities will be present in all these streams. However, I have not specifically listed these as values – although they do have intrinsic values and provide food for fishes and birds. If flows are managed to protect fish habitat and water quality then the habitat for invertebrates should also be protected by default. This same situation applies for the algae and micro-organisms that also constitute an important part of stream communities.

4.2. Instream Management Objectives and Critical Values

There are a range of instream management objectives for the groups of streams. They are based on my experience and understanding of the waterways in the catchment, but may need to be altered after input from stakeholders and the community. I have chosen what I believe is the primary instream management objective for each group of streams. I recognise that there are other instream objectives that may need to be considered. However, I believe that by providing sufficient flow to sustain the most flow sensitive, important value, (i.e. the critical value) the other significant values will also be sustained (see also Jowett & Hayes 2004).

The instream management objective for four groups of waterways is based on retaining a proportion of the natural habitat for a particular species (Figure 8) (i.e. habitat is the critical factor). The species chosen for the critical values are those that are highly valued and, in the case of trout and torrentfish, have high flow requirements meaning that values supported by lesser flows will also be protected, as suggested by Jowett & Hayes (2004). This is the most common situation and ideally suited to a habitat modelling approach.

River group

	Takaka North Rivers ***Tukurua, Onekaka, Pariwhakaoho, Puremahaia, Onahau***	**Springfed Rivers** ***Motupipi,Te Kakau, Wai Tapu, East Takaka Springs, Spring Brook, Spittals***	**East Takaka Streams** ***Gorge, Ironstone, Rameka, Scott, Dry***	**Pohara Flats** ***Kite Te Tahu, Gibson, Ellis, Winter***	**Small Headwater Streams** ***Tributaries of Anatoki, Waingaro, Takaka and Cobb***	**Major Rivers and their Tribs** ***Waikoropupu, Takaka, Anatoki, Waingaro, Cobb***
Typical Instream Values	Eel Migratory galaxiids (including shortjaw and giant kokopu) Redfin/Common bully Lamprey Torrentfish Koura Trout (Onekaka only) Absence of trout Whitebaiting/Eeling Native biodiversity Landscape values	Eel Migratory galaxiids Redfin/Common/ Giant bully Koura Bird habitat Customary values Watercress Whitebaiting/Eeling Native biodiversity Landscape values	Eel (lower reaches) Koaro (upper reaches) Trout spawning/rearing (lower reaches) Native biodiversity Landscape values	Eel Migratory galaxiids (including giant kokopu) Redfin bully Torrentfish Koura Whitebaiting/Eeling Native biodiversity	Eel Koaro Upland bully (upper Takaka) Redfin bully (lower Anatoki tribs) Koura Trout spawning/rearing Native biodiversity Landscape values	Eel Migratory galaxiids (including giant kokopu) Common/Redfin bully (lower reaches) Upland bully Lamprey Torrentfish Koura Large adult trout Trout spawning/rearing Bird habitat and corridor Customary values Whitebaiting/Angling/Eeling Kayaking/Rafting/Swimming Landscape values
Instream Management Objective	Maintain available natural habitat to sustain the diverse native fish community	Protect groundwater recharge, spring flows and water quality	Protect groundwater recharge, maintain natural frequency and duration of drying	Maintain available natural habitat to sustain the diverse native fish community	Maintain available natural habitat for trout spawning/rearing	Maintain available natural habitat to sustain a productive trout fishery
Critical Value	Torrentfish	Native biodiversity	Landscape values	Migratory galaxiids	Trout spawning/rearing	Large adult trout
Critical Factors	Torrentfish habitat	Minimum dissolved oxygen concentration	Duration and frequency of drying	Migratory galaxiids habitat	Trout spawning/rearing habitat	Large adult trout habitat
Protection level	High (90% retention of habitat at natural MALF)	Medium (Maintain minimum dissolved oxygen above critical levels)	Low (<20% change in duration and frequency of drying)	Medium (70% retention of habitat at natural MALF)	Medium (70% retention of habitat at natural MALF)	High (90% retention of habitat at natural MALF)
Likely Demand	Medium	High	Low	Medium	Low	High
Technical method	Detailed instream habitat analysis and models, or set minimum flow at MALF	Water quality modelling and Surface/Groundwater model	Hydrological analysis	Generalised habitat models	Generalised habitat models	Detailed instream habitat analysis and models

Figure 8. Potential waterway groupings, their associated instream values and suggested technical methods for flow management. There is no information on the fish fauna of the streams marked with a blue font.

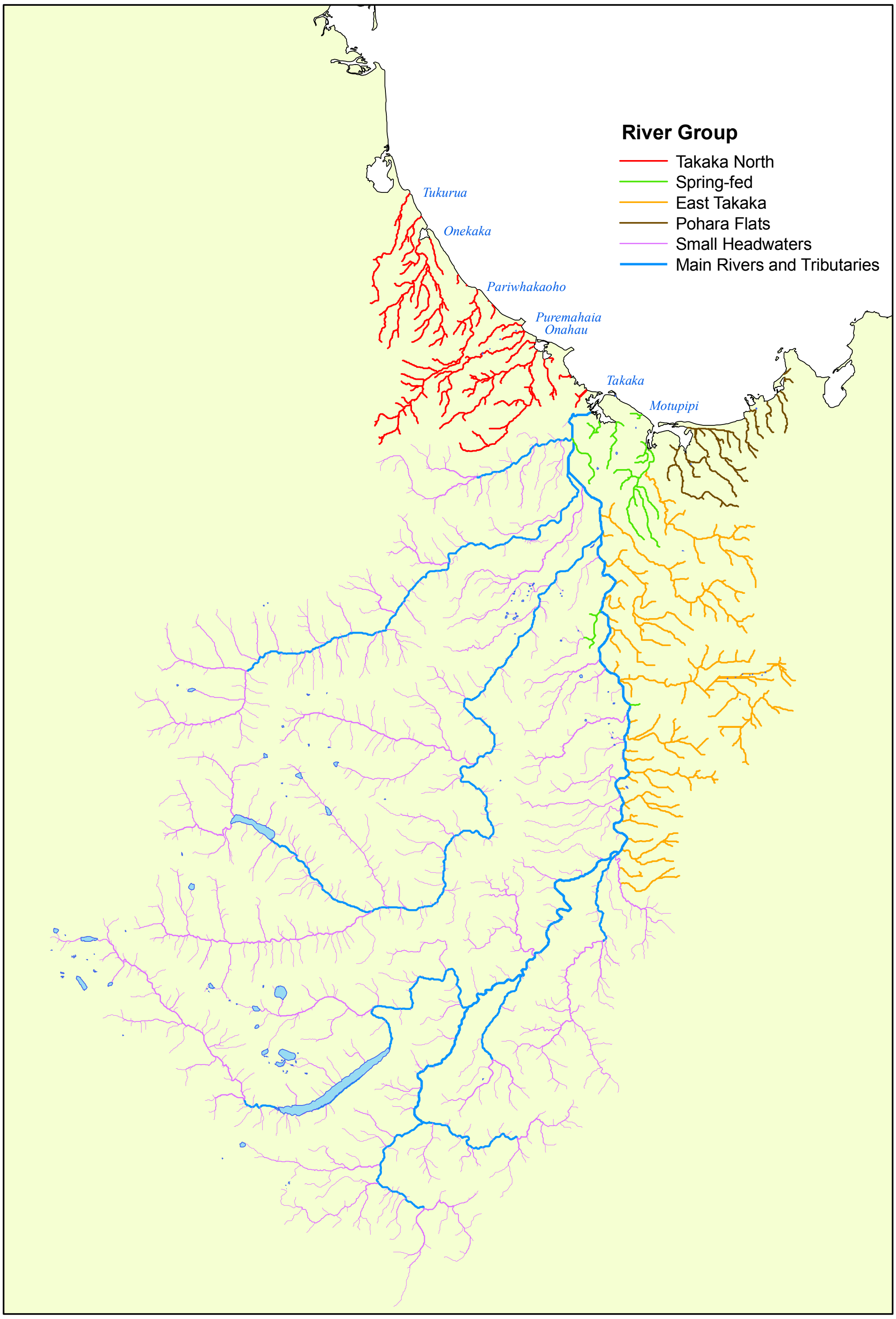

Figure 9. Location of the different river groups throughout the Takaka Catchment.

The instream management objectives for the two other groups of streams – Spring-fed rivers and East Takaka streams, are somewhat different. The landscape values of the East Takaka streams are probably more important than the ecological values of these sites and therefore the objective should be to maintain the natural frequency and duration of drying. For example, a reduction in the frequency or amount of time that these streams contain flowing water might cause vegetation encroachment into the stream channels and damage the existing landscape values. However, the landscape values associated with these streams and their dependence on flow is poorly understood. Therefore, the suggested approach for these streams is rather conservative.

The spring-fed rivers support a variety of values, however the biggest threat is probably associated with groundwater abstraction and degradation of water quality. Due to the large accumulation of aquatic plants in some of these systems, and the low concentration of dissolved oxygen in the groundwater, there is potential for flow reductions to cause severe breaches of dissolved oxygen guidelines and possibly also problems associated with high pH and accumulation of fine sediment.

4.3. Protection levels

I have proposed protection levels for each group of streams depending on whether the values are high, medium or low. These levels are based on my perception of the significance of the values present in each group. However, it would be wise to consult with stakeholders and the community before finalising these protection levels. It might be appropriate to alter protection levels for some sites within groups if there is more detailed information on the relative values of some streams within a group. For example, the Motupipi River is part of the Spring-fed rivers group, but due to its relatively large size and proximity to the coast (thus providing high value native fish habitat) it may deserve a higher level of protection than what is suggested for the group as a whole. The protection levels suggested here are relatively conservative and flows could potentially be drawn lower if detailed assessments demonstrate that any effects are no more than minor.

For most of the groups I have suggested protection levels that are related to the amount of available habitat at the natural mean annual low flow (MALF) following the approach of Jowett & Hayes (2004). The MALF is a hydrological parameter that approximates the minimum flows that are likely to occur annually or near annually. Other parameters such as the natural annual recurrence interval (lowest flow expected to occur on average each year) may be even more useful as an index of annual minimum flows, but have not been typically used in the past. The existing ecological community has evolved under these conditions and the minimum annual flow may be the factor that limits the maximum size of the population. For example, there is some evidence that the habitat available at the MALF is an important factor controlling adult trout abundance (Jowett 1992). Whether the same is true for other species is debateable. However, it seems reasonable that the MALF should be similarly relevant to native fish species with generation cycles longer than one year, at least in situations where habitat declines toward the MALF. If the minimum flow restricts habitat for any species, there is potential for a detrimental effect on that population. NIWA research in the Waipara River, where habitat is limited at low flow, showed that the detrimental effect on native fish numbers increased with the magnitude and duration of low flow (Jowett & Hayes 2004).

Jowett & Hayes (2004) recommended maintaining a proportion of the habitat available at the MALF or of the habitat optimum, whichever occurs at the lower flow (Figure 5). This approach aims to retain a proportion of the habitat that the stream is naturally capable of providing during periods of low flow, thus providing for some allocation of water to out-of-stream uses, with the proportion of habitat retained depending on the relative significance of the instream values.

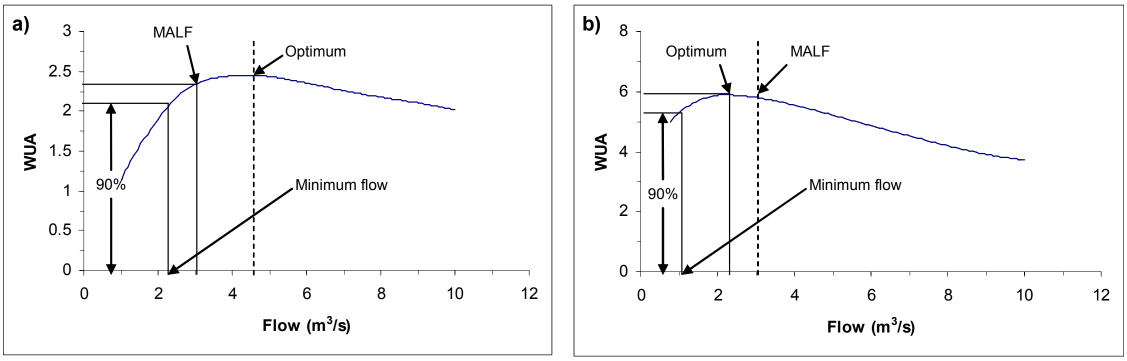

Figure 10. Derivation of minimum flow based on retention of a proportion (90% in this case) of available habitat (WUA) at a) the MALF, or b) the habitat optimum, whichever occurs at the lower flow, as recommended by Jowett & Hayes (2004).

I believe that the values supported by the Takaka North rivers are highly significant and deserve a high level of protection. The presence of shortjaw and giant kokopu and the apparent lack of trout in these systems (apart from the Onekaka River) are the main reasons for this decision. I have suggested that 90% of the habitat naturally available at the MALF should be retained to meet the instream management objectives for this group of waterways (Figure 8). A 90% protection level allows for some abstraction during normal flow years, but it is unlikely that this reduction in habitat would cause a noticeable reduction in fish abundance or other instream values given the high natural temporal and spatial variability in fish populations. For example juvenile trout abundance in the Kakanui River, North Otago, varied by a factor of 5–92 between sites and by a factor of 3.6–23 between years (Hayes 1995), and adult trout abundance varied by a factor of 10 between sites and by a factor of four between years (Jowett 1995). Ultimately the decision on appropriate protection levels rests with TDC after consultation with stakeholders.

The Major Rivers and their Tributaries group also support some highly significant values and deserve a high level of protection. As above, I have suggested that 90% of the habitat naturally available at the MALF should be retained to meet the instream management objectives for this group (Figure 8). This level of protection aligns with the protection level that was suggested by Jowett & Hayes (2004) for critical values with high significance rankings. A 90% protection level allows for some abstraction during normal flow years, but it is unlikely that this reduction in habitat would cause a noticeable reduction in fish abundance or other instream values.

The Spring-fed rivers support a range of instream values that I consider deserve a medium level of protection. As mentioned above, degradation of water quality rather than loss of habitat is the critical value to consider. A minimum dissolved oxygen criterion (I initially suggest >60% saturation) should be used to ensure that water quality in these waterways does not harm aquatic life. This water quality criterion is based on studies showing that native fish can tolerate low dissolved oxygen concentrations (Dean & Richardson 1999). However, some recent data on the fluctuations in dissolved oxygen concentration that I collected in the Motupipi River earlier this year suggests that this criterion may be currently unachievable because of the naturally low concentrations of dissolved oxygen in the groundwater. Therefore, further studies may be needed to set a realistic trigger level for controlling abstraction from these systems.

I consider that the instream values supported by the Pohara Flats and Small Headwater streams groups are of moderate significance and following Jowett & Hayes (2004) suggest that 70% of the available natural habitat should be retained for certain species or life stages (Figure 8). This protection level would involve a greater risk that impacts on the instream values may be observed (compared with a 90% protection level), but would allow a greater security of supply for water abstraction even in dry years.

I suggest that the values in the East Takaka streams are relatively low compared to the values in the other streams. Again, this would need to be checked with stakeholders/community and perhaps also considering the results from work on ephemeral streams that is currently underway in Auckland. The Instream Management Objective and critical value for this group that I have proposed is related to landscape value and is based on allowing only a small change (<20%) in the duration and frequency of drying. The 20% level is arbitrary, but seeks to set a level where the change in landscape values is minimised while still allowing a reasonable security of supply for water abstraction during most years. Hydrological analyses and modelling may help to determine if this level meets the management objective.

4.4. Technical methods

The technical methods chosen to determine the flow requirements within each group of waterways will differ according to the critical values and protection levels identified.

4.4.1. Hydrological analyses

For the East Takaka streams the protection levels are based on hydrological statistics, so a hydrological analysis would be required to determine appropriate minimum flows and/or allocation limits. Existing hydrological data and records of current abstraction levels would be required to determine the existing frequency/duration of drying and predict the natural frequency/duration of drying in the absence of abstraction. The frequency/duration of drying will also have to be referenced spatially, since some sections of these streams will have more variable flow regimes than other sections.

4.4.2. Generalised habitat models

Generalised habitat models have been suggested as the appropriate technical method for two of the stream groups (Pohara Flats and Small Headwater Streams) for several reasons, including:

- At its simplest this method requires only the measurement of stream width at one flow. Therefore, implementation of the method is relatively cheap and feasible for a large number of sites.
- The method is expected to provide a better estimate of the effects of flow on habitat availability than simpler historic flow statistics or hydraulic methods.
- The values identified are only considered to be moderate and therefore not sufficient to justify detailed instream habitat surveys and modelling.

The minimum requirement for using this approach is a measurement of stream width at a single known flow. A New Zealand average hydraulic geometry relationship (Jowett 1998) can be used to estimate how width will change with flow. This relationship works reasonably well for unconfined gravel bedded rivers, but will not provide accurate estimates of changes in width with flow in streams/rivers with different shaped channels. To overcome this, measurements of width at several different flows can be used to calculate a site-specific hydraulic geometry relationship. Once the relationship between flow and width is calculated, a dimensionless index of habitat value over a range of flows can be calculated for particular species using the following equation:

$$HV = \left(\frac{Q}{W}\right)^{c} \times e^{-k\frac{Q}{W}}$$

where *HV* is the habitat value (dimensionless, but often referred to with units of m^2/m), *Q* is the discharge (m^3/s), *W* is the width (m), and *c* and *k* are coefficients that describe the shape of the curve and have been derived for particular species (Jowett & Hayes 2004; Table 2). The dataset that was used to determine the *c* and *k* coefficients for particular species included streams/rivers with a mean annual discharge ranging from 0.6–54 m^3/s. Therefore, there may be substantial error in applying these models to small streams with flows outside this range (Lamouroux & Jowett 2005).

Table 1. Coefficients that can be used to determine the shape of flow habitat curves for particular species of fish or invertebrates that are found in the Takaka Catchment (modified from Jowett & Hayes 2004).

Species	***c***	***k***
Inanga	0.19	19.74
Shortjaw kokopu[+]	0.19	16.35
Upland bully	0.11	8.63
Banded kokopu (juvenile)	0.19	13.3
Longfin eel (< 30cm)	0.07	2.07
Redfin bully	0.26	7.39
Shortfin eel (< 30cm)	0.13	2.32
Common bully	0.39	6.51
Brown trout fry	0.86	10.21
Brown trout yearling	0.4	4.18
Nesameletus[*]	0.26	2.62
Brown trout spawning	1.24	9.89
Bluegill bully	1.01	6.13
Rainbow trout spawning	1.49	8.78
Deleatidium[*]	0.33	1.92
Torrentfish	0.88	4.05
Brown trout adult	1.17	4.35
Food producing habitat	1.19	4.25
Rainbow trout feeding (30–40 cm)	0.93	2.89
Coloburiscus humeralis[*]	1.35	4.17
Aoteapsyche[*]	1.44	3.17
Zelandoperla[*]	1.71	3.4

* large river habitat suitability curves (see Jowett 2000), + suitability for cover locations only

A comparison of the output from generalised habitat models and detailed habitat modelling at the same sites showed broadly similar habitat response to flow for given species (Jowett & Hayes 2004). However, there were some differences in the shapes of the curves which could lead to different interpretations of suitable minimum flows. This presumed inaccuracy of the generalised models must be weighed up against the reduced requirements for fieldwork and modelling when using this approach.

4.4.3. Water Quality Modelling - WAIORA

The U-shaped channel of the Spring-fed rivers means that a large change in flow would be required to cause a significant change in the availability of habitat. However, the abundance of aquatic plants in many of these spring-fed waterways, combined with the relatively low dissolved oxygen concentration of the groundwater entering these systems, means that reductions in flow could cause regular and severe breaches of dissolved oxygen guidelines. Diurnal changes in pH may also be a problem.

WAIORA is a model that has been designed to predict the impacts of flow reduction on habitat availability (using hydraulic and generalised models), temperature, dissolved oxygen and ammonia concentrations (Jowett et al. 2004). The dissolved oxygen component of the model requires habitat and water temperature data and an estimate of the ecosystem respiration rate, production/respiration ratio, and the reaeration coefficient, which describes the rate at which oxygen is exchanged between the atmosphere and the stream. These latter values can be calculated from analyses of the change in oxygen concentration over 24 hours at a reference flow using the model itself or alternative approaches (e.g. Young & Knight 2005). If oxygen data are not available to calibrate the model, default values from similar stream types can be used as a last resort.

The model assumes that changes in the concentration of dissolved oxygen are the result of oxygen production from photosynthesising plants, oxygen uptake via respiration from all the members of the ecosystem, and oxygen exchange through the water surface as described by the following equation:

$$\frac{dO}{dt} = P - R + kD$$

where dO/dt is the rate of change of oxygen concentration, P is the rate of gross primary production, R is the rate of ecosystem respiration, k is the reaeration coefficient and D is the oxygen deficit (or difference between the observed oxygen concentration and the concentration at 100% saturation).

The model assumes that with reduced flows the rates of gross primary production and ecosystem respiration remain the same, while the reaeration coefficient will either increase (shallower water) or decrease (less current and turbulence). The habitat data is used to predict the direction and degree of change in the reaeration coefficient. The daily fluctuations in oxygen concentration are generally expected to increase in amplitude with decreased flows because the same amount of biological activity is limited to a smaller volume of water. The low oxygen concentration in groundwater entering these systems will also influence the patterns in dissolved oxygen concentration.

4.4.4. *Detailed instream habitat analysis and modelling*

I suggest that detailed instream habitat analysis and modelling is required to determine appropriate minimum flows for the Takaka North rivers and the Major Rivers and their Tributaries groups. If the expense of detailed habitat analysis can not be justified then a conservative approach would be to set the minimum flow at the MALF. Detailed habitat analysis and modelling is often referred to as the Instream Flow Incremental Methodology (IFIM). There is a large amount of information on this approach available in the literature, and we suggest that readers requiring more information consult Jowett & Hayes (2004) for a thorough summary of the approach. A summary is given below.

The first step in this process involves selecting the river reach of interest. Detailed surveys of the river bed are then required although the type of survey used depends on whether a 1-

dimensional (1-D) or 2-dimensional (2-D) approach to habitat modelling is used. The 1-D approach to habitat modelling includes measurements of depth, velocity and substrate composition across marked cross-sections throughout the study reach at the 'survey' flow. Cross-sections are selected so the range of habitat types present are represented in the survey. Water levels are measured at the survey flow and again at one or more calibration flows. A hydraulic model (e.g. RHYHABSIM) is then used to predict how depths and velocity will change with flow, and related with habitat suitability criteria for particular species to predict how habitat availability for that species will change with flow.

The 2-D approach to habitat modelling is a more recent development and involves a detailed survey of the bed topography throughout an entire river reach. Substrate composition also needs to be mapped throughout the reach. Water levels at the top and bottom of the reach are measured at the survey flow and at calibration flows. In order to test the model further water level measurements should be taken at the survey and calibration flows either across cross-sections or at random points in the survey reach. A 2-D hydraulic model (e.g. River2D) is then used to predict the depths and velocities occurring at any flow in the reach and related to habitat suitability criteria for particular species to predict how habitat availability will vary with flow.

There has been some discussion of the pros and cons of 1-D and 2-D approaches to habitat modelling in recent consent and environment court hearings throughout New Zealand. The recent Trustpower hearing on the Wairau River is a good example. The 2-D approach is particularly appropriate in a braided river where the 1-D approach would struggle to cope with the complexity of the channel. The 2-D approach is also expected to perform better than the 1-D approach for flows outside the calibration range, although there is little evidence to either support or refute this. On the other hand, the 1-D approach requires less field and modelling effort and can be applied to a longer reach of river. The 1-D approach is also considered to be more accurate within the range of calibration flows than the 2-D approach. This is because its predictions are constrained by actual measurements of water level (at the calibration flows). Inaccuracies in 2-D model predictions arise mainly from errors in the measurement of bed topography and these are sensitive to the spatial resolution of the topographical survey.

4.5. Allocation limits

Appropriate allocation limits are an important component of flow management, otherwise there is the potential for abstraction to result in 'flat-lining' of the hydrograph at the minimum flow. Maintaining some degree of flow variability is generally considered to be important, especially maintaining moderate and large floods that are sufficiently powerful to scour periphyton from the stream bed. The physical habitat for benthic invertebrates sustained by flow recessions following these events is also expected to benefit a river's productivity [i.e. those that elevate the base flow for 30 days or more which is sufficiently long for benthic invertebrates to fully colonise previously dry or scoured river bed (Sagar 1983)]. However, there is currently little scientific evidence supporting the need to maintain small scale flow variability.

The allocation limit is also important for determining the security of supply for abstractors. As more water takes are consented, the security of supply for existing consents is reduced.

There is little clear guidance on appropriate allocation limits. Many councils use 'rules of thumb' to define allocation limits (e.g. 33% of the MALF, or 10% of the MALF). Hawke's Bay Regional Council use the difference between the minimum flow and the summer 7-day Q_{95} as the allocation limit, since the frequency of this flow is clearly defined (exceeded 95% of the time in summer) and gives users clear expectation of their security of supply. Jowett & Hayes (2004) also considered allocation limits in their report to Environment Southland. They suggested that there is a relationship between allocation limits and minimum flows. If demand for abstraction is high then conservative minimum flows should be used. However, if demand is low then lower minimum flows could be set. This approach may have merits, and assumes that both the minimum flow and its duration are important in limiting instream values. However, this approach is relatively complicated and would require considerable analysis on a site-by-site basis for implementation. Environment Southland have not used this approach in their plan.

5. SUMMARY

Instream values vary considerably in different parts of the Takaka Catchment and it is sensible to group waterways with similar values together so they can be managed in a similar fashion. Six groups of waterways were proposed based on a combination of local knowledge, source of flow, waterway size and freshwater fish distribution (Figure 8). These groups are the Takaka North rivers, Spring-fed rivers, East Takaka streams, Pohara Flats streams, Small Headwater streams, and Major rivers and their tributaries. Instream values and management objectives have been suggested for each of these groups, along with critical values that, if protected, should sustain the other significant values. Protection levels are suggested for each group of streams based on whether the values are considered to be high, medium or low. Consultation with the local community and other stakeholders is required to finalise these suggestions. Further sampling of some waterways would also be helpful in accurately determining appropriate values.

Hydrological analyses are considered to be the best approach for determining an appropriate flow regime for the East Takaka streams, while generalised habitat models should be used for the Pohara Flats and Small Headwater Streams. A water quality model such as WAIORA could be used to predict the effects of flow on dissolved oxygen concentrations and should be used to manage flows in the Spring-fed rivers. Detailed habitat analyses and modelling is the appropriate method to determine minimum flows in the Takaka North rivers and the Major Rivers and their tributaries.

Sensible allocation limits are required to maintain the security of supply for water users and avoid flows being held at the minimum flow for prolonged periods. The difference between the minimum flow and the summer 7-day Q_{95} (flow exceeded 95% of the time over summer) could be used as an allocation limit because it gives users a clear expectation of the security of their supply. Other allocation options such as flow sharing, flow rostering and primary/secondary allocation limits could also be used to maximise the effectiveness of water use without compromising minimum flows.

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