Proposed
Hurunui and Waiau River Regional Plan

And Proposed Plan Change 3 to the Canterbury Natural Resources Regional Plan

Section 42A Report
September 2012

Effects of mid-range flow changes on fish migration

Prepared by

Donald John Jellyman

Freshwater Fish Scientist, NIWA.

Environment Canterbury
Regional Council
Kaunihera Taiao ki Waitaha

1. Introduction

1.1 Author

1 My name is Donald John Jellyman. I am a fisheries biologist with over 40 years of experience in fisheries science. I hold a B.Sc (Hons), and Ph. D. (1974) from Victoria University of Wellington; I am a member of the New Zealand Freshwater Sciences Society, and the American Fisheries Society

2 I have been employed as a freshwater fisheries scientist with the National Institute of Water and Atmospheric Research Limited (NIWA) from July 1992 to the present. My role is science leader, freshwater fish. Prior to that I was employed as a fisheries scientist with the Ministry of Agriculture and Fisheries (1972 – 1992). My area of expertise is the biology and ecology of New Zealand freshwater fish, especially native species, with a considerable focus on freshwater eels and their associated fisheries. I have carried out a number of freshwater fish surveys of South Island rivers (e.g. Grey, Buller, Arahura, Clutha, Aparima, Oreti, Waiau, Wairau), during the 30 years I have been resident in Christchurch.

3 Although this is a Council Hearing, I have read the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note dated 1 November 2011. I have complied with that Code when preparing my written statement of evidence and I agree to comply with it when I give any oral evidence.

4 The scope of my evidence relates to the effects of mid-range flow changes on the migration of fish in the Hurunui and Waiau Rivers. I confirm that the issues addressed in this statement of evidence are within my area of expertise. The data, information, facts, and assumptions I have considered in forming my opinions include the flow regime scenarios and predictions outlined in the evidence of my colleagues Mr Duncan, Dr Hicks and Dr Snelder.

5 I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

1.2 Content of the officer's report

6 This report is prepared under the provisions of section 42A of the Resource Management Act 1991 (RMA). Section 42A allows council officers to provide a report to the hearing commissioners on the proposed Hurunui and Waiau River Regional Plan and allows the commissioners to consider the report at the hearing.

1.3 Explanation of terms and coding used in the report

CRC	Canterbury Regional Council or Environment Canterbury (ECan)
CWMS	Canterbury Water Management Strategy
DRP	Dissolved Reactive Phosphorous
HWRRP	Proposed Hurunui and Waiau River Regional Plan
L/s	Litres per second
Log Scale	A logarithmic scale is a scale of measurement using the logarithm of a physical quantity (in this case river flow) instead of the quantity itself. Take a chart whose vertical y-axis has equally spaced increments that are labeled 1, 10, 100, 1000, instead of 1, 2, 3, 4. Each unit increase on the logarithmic scale thus represents an exponential increase in the underlying quantity for the given base (10, in this case). Data presentation on a logarithmic scale is helpful when the data covers a large range of values, for example a river which might have a mean annual low flow of around 70 m^3/s, a mean flow of around 200 m^3/s, and a peak flood flow of around 4000 m^3/s. The use of the logarithms of the values rather than the actual values therefore reduces a wide range to a more manageable size, and provides for better interpretation around key values (flows) of interest.
m^3/s	Cumec (A measure of river flow. One (1) cumec is the equivalent to one (1) cubic metre per second or alternatively 1,000 L/s)
MALF or MALF7d	Mean Annual Seven Day Low Flow
'Threatened or at risk'	A generic term describing the sum of classifications used by the Department of Conservation to define species at various stages of population decline, conservation threat etc. Full definitions of all classifications are given in Miseklly et al. (2008)

Scope of evidence

7 I have been asked by CRC to prepare evidence in relation to the effects of the water allocation that could occur in the Hurunui and Waiau Rivers under the proposed Hurunui Waiau River Regional Plan (HWRRP). I have been asked to provide evidence concerning the effects of plan implementation on the migration of fish in both rivers.

8 Specifically, my evidence includes;

- A description of the freshwater fish in the Hurunui and Waiau catchments
- The patterns of fish migration in these rivers
- The features of mid-range flows that effect fish migration
- An evaluation of flow scenarios with respect to fish migration and river mouth closure

Freshwater fish of the Hurunui and Waiau catchments

9 At least 19 species of fish inhabit the Hurunui and Waiau River catchments, and it is very likely that two further species (lamprey and bluegill bully) are also present. Table 1 presents names, occurrence, and status of these fish in the two catchments. In my opinion the species assemblage is typical of braided rivers in the Canterbury region.

Common name	Scientific name	Status			Threat classification (Allibone et al. 2009)	No. of records	
Reported as present		diadromous	native	endemic	classification	Hurunui	Waiau
Alpine galaxias	*Galaxias paucispondylus*	n	y	y	not threatened	17	10
Brown trout	*Salmo trutta*	n	n	n	introduced and naturalised	42	25
Canterbury galaxias	*Galaxias vulgaris*	n	y	y	not threatened	29	42
Chinook salmon	*Oncorhynchus tshawytscha*	y	n	n	introduced and naturalised	4	9
Common bully	*Gobiomorphus cotidianus*	y	y	y	not threatened	1	5
Common smelt	*Retropinna retropinna*	y	y	y	not threatened	4	2
Goldfish	*Carassius auratus*	n	n	n	introduced and naturalised		1
Inanga	*Galaxias maculatus*	y	y	n	at risk - declining		3
Koaro	*Galaxias brevipinnis*	y	y	n	at risk - declining	24	5
Longfin eel	*Anguilla dieffenbachii*	y	y	y	at risk - declining	12	17
Perch	*Perca fluviatilis*	n	n	n	introduced and naturalised	1	
Rainbow trout	*Oncorhynchus mykiss*	n	n	n	introduced and naturalised		
Rudd	*Scardinius erythrophthalmus*	n	n	n	introduced and naturalised		2
Shortfin eel	*Anguilla australis*	y	y	n	not threatened	9	8
Stokells smelt	*Stokellia anisodon*	y	y	y	at risk - naturally uncommon	1	1
Torrentfish	*Cheimarrichthys fosteri*	y	y	y	at risk - declining	1	1
Upland bully	*Gobiomorphus breviceps*	n	y	y	not threatened	38	42
Upland longjaw galaxias	*Galaxias prognathus*	n	y	y	threatened - nationally vulnerable	1	1
Yelloweye mullet	*Aldrichetta forsteri*	n	y	n	not threatened	1	1
Not reported but likely to be present							
Bluegill bully	*Gobiomorphus hubbsi*	y	y	y	at risk - declining		
Lamprey	*Geotria australis*	y	y	n	at risk - declining		

Table 1. . Fish species present or likely to be present, in the Waiau and Hurunui catchments, their conservation status, and frequency of occurrence (from records contained in the New Zealand Freshwater Fish Database)

10 Many of the fish in the Waiau and Hurunui Rivers make substantial migrations during their lives, and these I refer to as "migratory" fish. This group includes diadromous fish (e.g. salmon and eels), which migrate between freshwater and ocean environments as part of their normal life cycle, and other species (e.g. brown trout) which make substantial migrations entirely within freshwater environments, usually as part of a key life-history event such as spawning.

Fish migration patterns in Canterbury Rivers

11 In Canterbury rivers a diversity of migration patterns occurs, as outlined briefly in the following sections.

Upstream migrations

Estuarine and lower river migrants

12 Of the migratory species listed in Table 1, there are four (common smelt, Stokell's smelt, inanga, and yelloweye mullet) that are mostly restricted to lower river habitats close to the sea or in the estuaries; these species do not make extensive migrations upstream, and their migrations are unlikely to be affected by any change to flow regimes further inland.

Progressive upstream migrants

13 Bluegill bullies, common bullies, and torrentfish are all migratory species that may be found considerable distances upstream from the sea (> 80 km inland). Upstream movement of these species is best described as progressive rather than migratory, as they enter freshwater from the sea as very small juveniles, and grow as they gradually progress upstream and colonise suitable habitat.

"True" migrants

14 Two species make distinct upstream migrations – – as opposed to progressive: Koaro migrate from the sea into freshwater as whitebait, then migrate upstream in order to find habitat in high-country tributaries or lakes. Their migration is relatively rapid (i.e. a kilometre a day or more), and thus the mainstem of the river is more “highway” than habitat. Adult lampreys migrate from the sea into rivers, then move upstream. Like koaro, lampreys use the mainstem of the river as a conduit to small tributary streams, rather than as habitat.

Eels (longfin and shortfin)

15 The life of eels in rivers is a mixture of migrations and progressive movement. Some juvenile longfins (“elvers”) will make quite rapid migrations well upstream to find suitable habitats; however most will be more “progressive”, colonising habitats as they move upstream.

Salmon and trout

16 Chinook salmon adults migrate from the sea and move upstream in Canterbury rivers to reach headwater tributaries, where they spawn. They mostly return to their natal stream (i.e. where they were born), and after spawning the adults die. Their migration upstream may be relatively quick (days to a few weeks), as they are large, very strong swimmers.

17 Trout also make a spawning migration, and for most trout this means an upstream migration from lower parts of the catchment into smaller tributaries, particularly in the high country. Trout generally spawn more than once during their lives, and for adult trout there may be a series of upstream spawning migrations. Subsequent movements downstream are mainly by females as they tend to move more extensively than males.

Downstream migrations

18 For fish that are diadromous (i.e. which migrate between the sea and freshwater), the upstream migration of one life stage is followed by a downstream migration of a later stage. For many species, the downstream migration involves the larval life stage, and is thus a very passive migration. Koaro, for example, spawn in small tributary streams; the eggs hatch during floods and the larvae are swept downstream to the sea.

19 In contrast, eels migrate downstream as adult fish. After many years of life in various parts of the catchment, large, sexually maturing eels migrate downstream to go to sea and spawn. The downstream migration occurs in late summer and autumn, and is mainly initiated by floods or freshes.

Seasonality of migrations and movements

20 In the previous sections I have outlined the species of migratory fish that occur in the Hurunui and Waiau Rivers and the variety of migrations they make. There is also considerable variety in the timing of fish migrations throughout the year. Figure 1 summarizes the approximate timing of various upstream and downstream migrations and movements for common species of fish in the Hurunui and Waiau Rivers. While some migration occurs throughout the year, fish movements are more common in the warmer months (November to April).

Species	Life stage	Movement	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Longfin eel	glass eel	from sea												
	elver	gradual upstream												
	adult	downstream												
Shortfin eel	glass eel	from sea												
	elver	gradual upstream												
	adult	downstream												
Koaro	whitebait	from sea												
	post-whitebait	upstream												
	larvae	downstream												
Lamprey	adult	upstream												
	ammocete	gradual downstream												
	macropthalmia	out to sea												
Torrentfish	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Bluegill bully	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Common bully	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Chinook salmon	adult	upstream												
	juvenile	downstream												
Brown trout	adult	upstream												
	juvenile	downstream												

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Figure 1. Probable fish migration periods (black bars) in the Hurunui and Waiau Rivers over a year. Migration periods are denoted by the black bars, and gradual or progressive colonisation upstream is represented by green bars; dark green over the warmer periods when active upstream movement occurs, and light green for cooler periods when less movement occurs.

Effects of changes to river flow regimes on fish

Fish movements

21 Most fish migrations are in response to flow variability, with increased flow stimulating or enabling fish movement (variously recruitment from the sea, or up- or downstream movement within rivers). Fish are high in the trophic order (i.e. the food chain), so their behaviour is complex and depends on the interactions of physical and chemical events at lower levels (e.g availability of food and space). Accordingly, predicting the response of fish to changing flow variability is difficult due to the various factors involved. Specific threshold flows can be identified for only a few aspects of fish behavior and angling success including flows that provide:

- minimum depths to enable passage of large species like chinook salmon or female longfin eels
- some water discoloration to enhance catchability of salmon
- clear water to enhance fly fishing for trout
- sufficient flow to open river mouths and facilitate fish movements

22 Specific threshold flows that “trigger” other fish life history events are not well understood, and will vary between species, life history stages, and probably river types. For example, relatively small increases of 2 to 3 times the preceding flow can result in movements of juvenile and adult eels and lampreys, while flows of 10 times the preceding (or base flows) have been found to inhibit movement of adult lampreys (Jellyman et al. 2002), but not Chinook salmon (Glova et al. 1988).

23 During high flows events (e.g. > 10 x preceding flows), fish will usually seek refuge and “ride out” the flood – any upstream movement will be confined to the receding flow after the flood has peaked. In contrast, smaller flow events (e.g. < 10 x preceding flows) will facilitate much fish movement.

24 Changes to the magnitude, duration, and frequency of flows are all important components of flow variation to be considered when assessing the significance of water allocation regimes on fish populations. In addition, the

frequency and duration of low flows is important, especially when these constitute periods during which the river is held at the minimum flow for extended periods of time ("flat-lining"). Prolonged periods without flow variation can negatively impact on a range of physical and chemical conditions that influence fish behaviour and well-being including lack of movement stimuli, increased algal growth and sediment accrual that can reduce food availability and spawning success, increased temperatures, decreased dissolved oxygen, and increased daily variation in pH. Stressful effects on fish are likely to be exacerbated by the crowding of fish that may occur as available habitat shrinks.

25 As stated previously, with our present state of knowledge, it is not possible to nominate specific flows that will trigger specific responses. However, we do know that any substantial reduction in the frequency of mid- range flows can have negative impacts on fish movements. While low flows are considered to provide an "ecological bottleneck" (i.e. physical limits to food and space availability), flow variability is also of considerable importance in determining fish communities. A recent analysis of flow regimes on the presence or absence of migratory and non-migratory native species throughout New Zealand found that flow variability was substantially more important than the effects of low flow (Crow et al. in review).

26 The following assessment of the impacts of the various flow scenarios for the Hurunui and Waiau Rivers is based on estimated changes to the duration and frequency of high flows (freshes and floods) and low flows. However, given the above limitations, translating these hydrological changes to effects on fish and fishery values, is partly subjective.

Passage depth

27 With regard to minimum passage depth for large species (25 cm for adult salmon moving upstream, 10 cm for adult eels moving downstream), I note that in his evidence, Mr Duncan considers that the proposed minimum flows in the Hurunui River should provide adequate depths of water to facilitate salmon passage. In contrast, in the Waiau River during February and March, when the proposed minimum flow is 15 m^3/s, Mr Duncan considers it "is most likely that there will be locations where there is insufficient water depth at a flow of 15

m^3/s, for salmon passage". To allow salmon passage in these locations, I agree that a greater minimum flow in February and March is required.

Mouth closure

28 For diadromous fish, the prolonged closure of river mouths can disrupt or prevent the completion their life cycle, and even intermittent mouth closure has the potential for serious disruption for species that migrate over a short season (McDowall 1995). Research in the Waipara River, North Canterbury, over several years demonstrated that the mouth closure influenced periods of downstream migration as well as restricting opportunities for recruitment of migratory species (Jowett et al. 2005).

29 To determine the likely impacts of the various scenarios on mouth closure and the associated effects on fish, I have relied upon evidence of Dr Hicks. That evidence does not include the seasonality of changes to the likelihood of mouth closure. Most out-migration of species occurs during February – May, while most inward movement is during August – November (Figure 2). Emigration of downstream moving fish generally takes place during freshes/floods when there is a strong likelihood of the mouth being open – if not, then a delay in escapement to sea is unfortunate but usually not critical. In contrast, although species migrating from the sea into freshwater usually have a recruitment season of several months, if immigration of individuals into the river is not possible due to mouth closure, these fish will disperse along the coastline in search of other rivers. The spring period is the time of most recruitment into freshwater and also the period of the year when the natural flows of the Hurunui and Waiau rivers are highest (evidence of Dr Snelder).

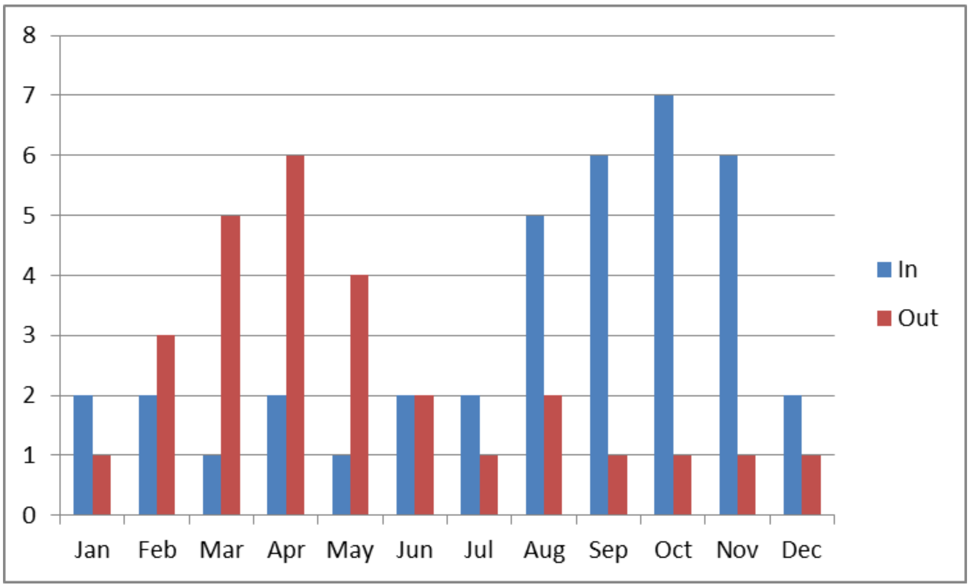

Figure 2. The number of fish species moving in or out of the Hurunui or Waiau River mouths per month.

Assessment of effects of changes to flow regimes on fish

Fish movements

30 To assess the effect on fish migration I have considered the hydrographs for the Hurunui and Waiau Rivers for 1987 as a typical year (Figures 3 and 4). I have also viewed the hydrographs of a particularly dry year (1973; Figures 5 and 6). In all four figures the hydrographs show the differences between the natural flow regimes and simulated flow regimes for each of the management scenarios.

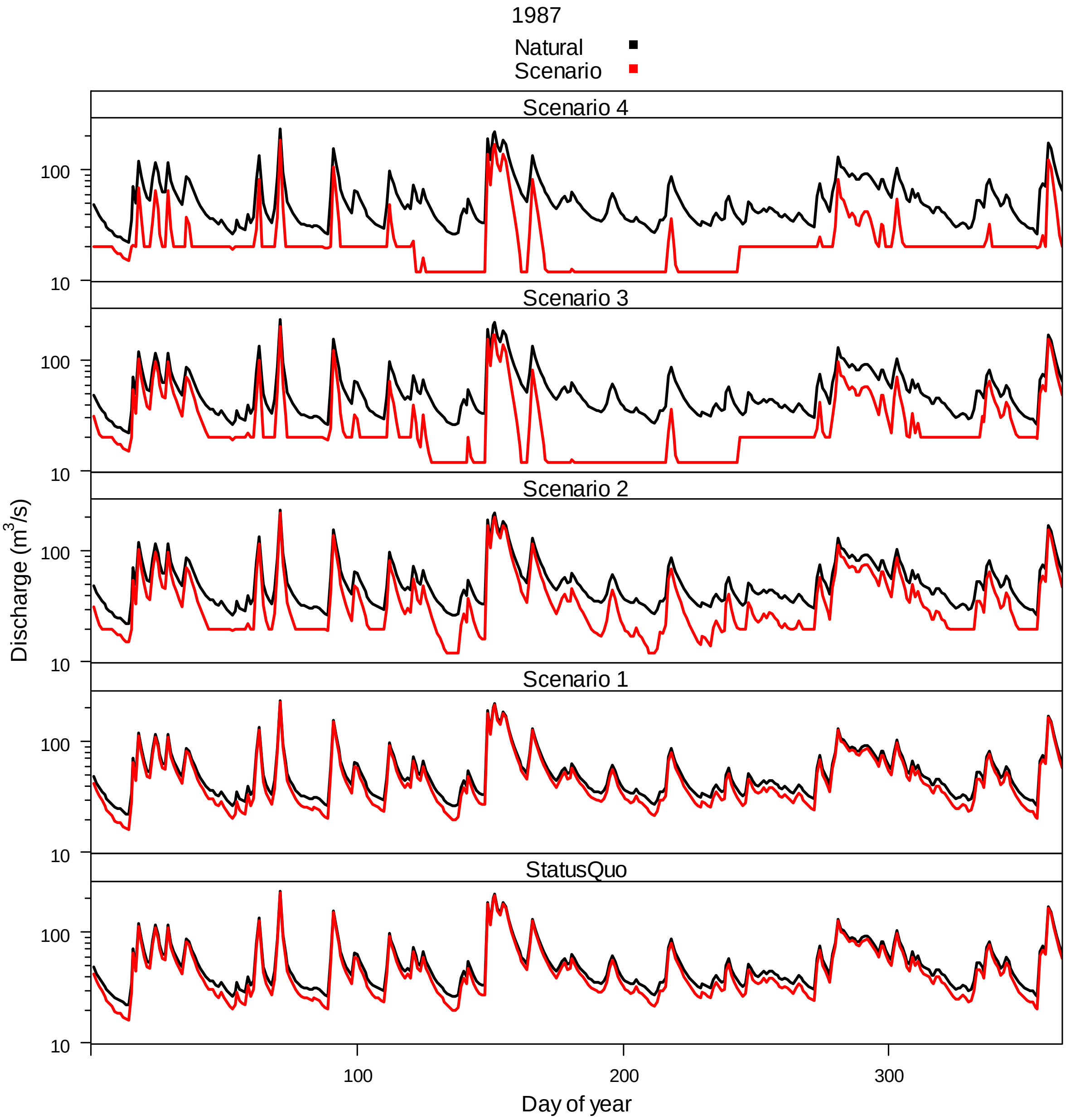

Figure 3. **Annual** hydrograph for the Hurunui River at Mandamus for 1987, which was chosen to represent a typical year. The plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for the status quo and each of the four management scenarios. Note that the vertical axis (discharge) is a log scale.

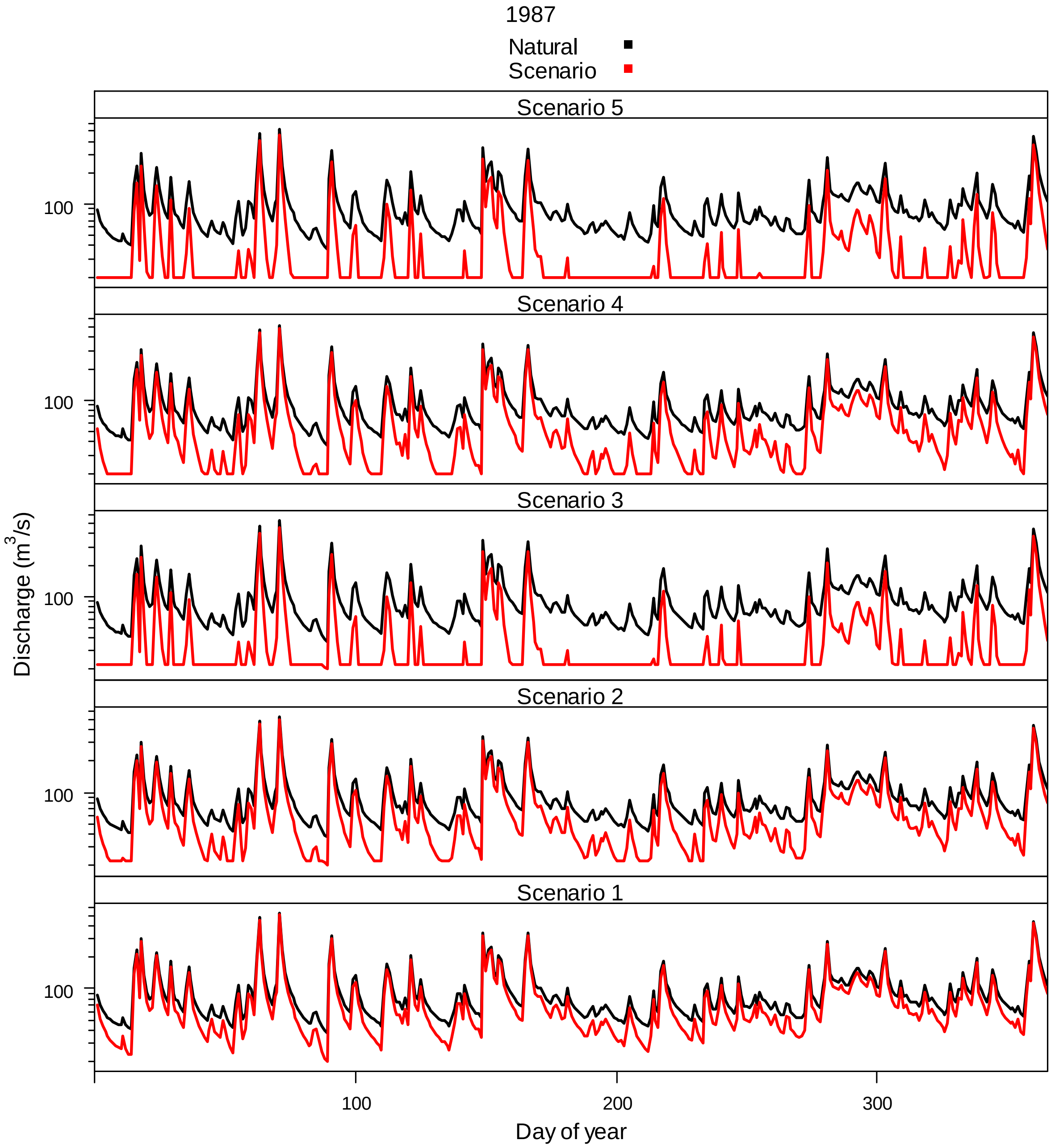

Figure 4. Annual hydrograph for the Waiau River for 1987, which was chosen to represent a typical year. The plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios. Note that the vertical axis (discharge) is a log scale.

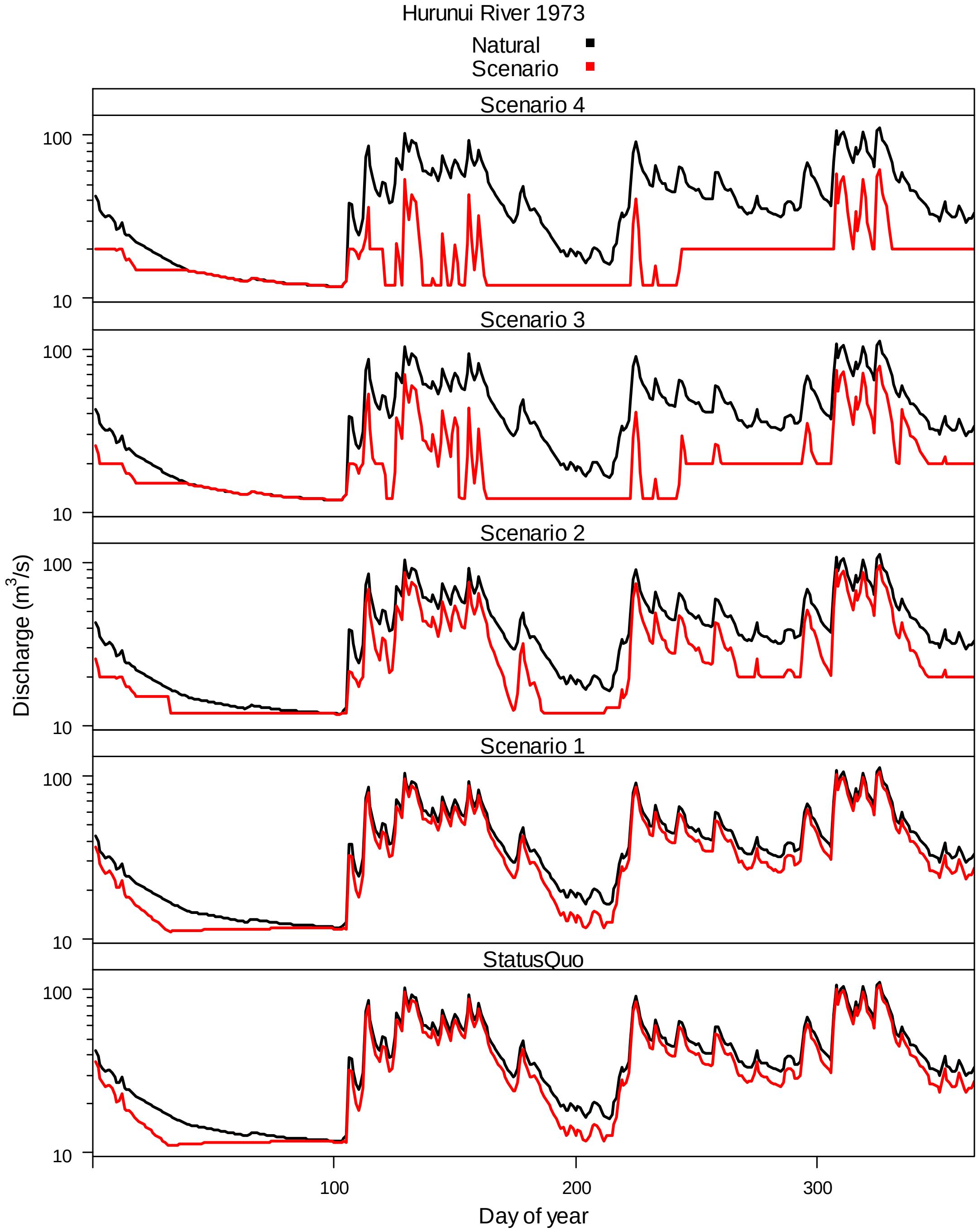

Figure 5. Annual hydrographs for the Hurunui River at Mandamus for 1973, which was chosen to represent a particularly dry year. The plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the four management scenarios. Note that the vertical axis (discharge) is a log scale.

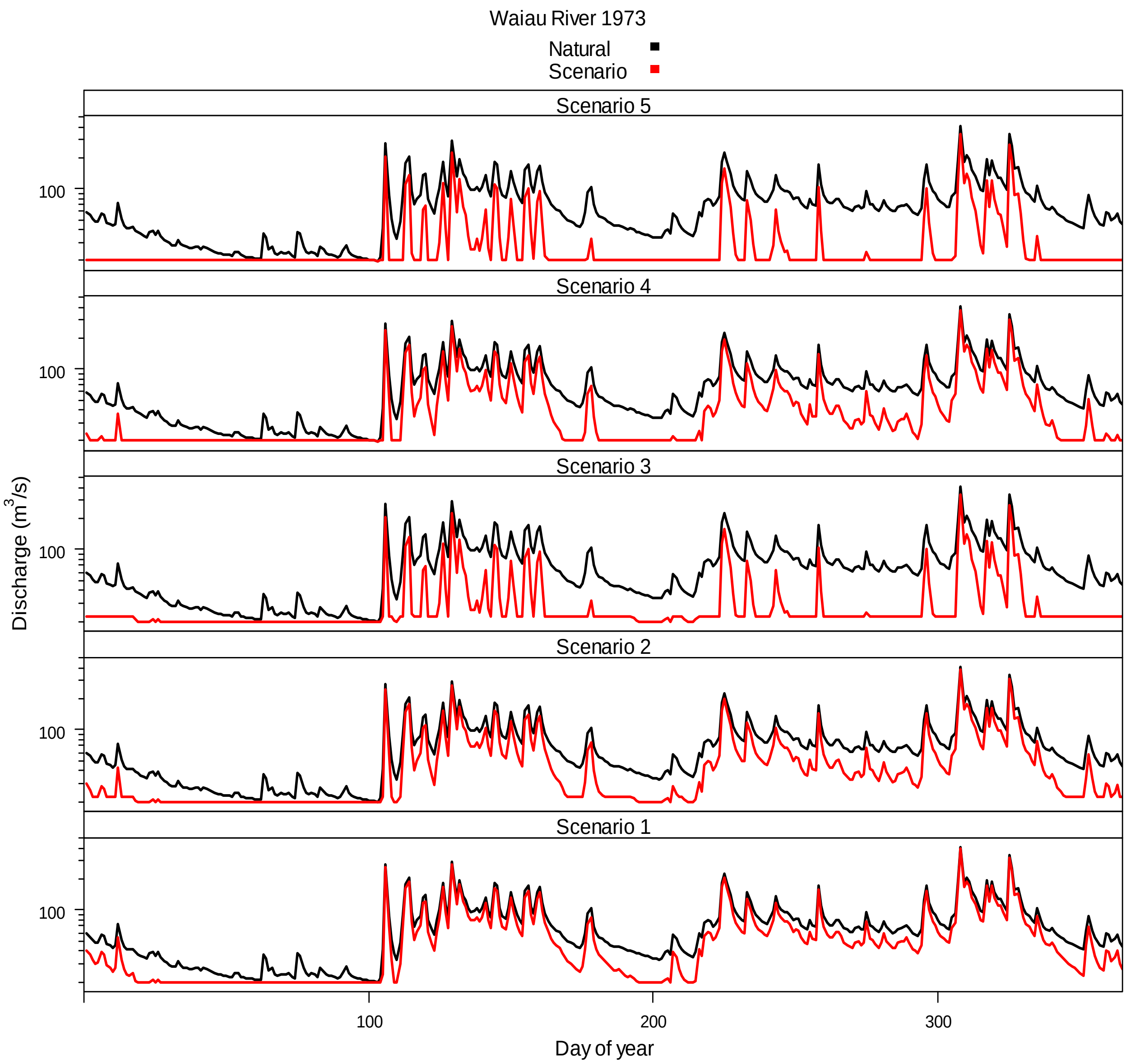

Figure 6. Annual hydrographs for the Waiau River for 1973, which was chosen to represent a particularly dry year. The plots show the natural flow hydrograph (black) and the simulated hydrographs (red) for each of the five management scenarios. Note that the vertical axis (discharge) is a log scale.

32 I have also used indices that describe the frequency of flood flow events and the duration between flood flow events (Table 2, taken from the evidence of Dr Snelder), to provide some numerical indices of the key events in these hydrographs (i.e. the frequency of floods of given magnitudes, and the length of time between particular flood magnitudes). The indices FRE2 and FRE3 are the mean frequency of flow events per year equal to or greater than two and three times the natural median flow respectively. The indices DB2Q50 and DB3Q50 are the mean duration

between flow events of two and three times the median respectively. I based my assessment on these indices because they represent increases in flow above the most commonly occurring flow (the median) that are likely to be sufficient to act as a trigger for movements of fish.

33 FRE3 for the natural flow regimes of the Hurunui and Waiau Rivers is the frequency of events greater than 219 and 118 m^3/s respectively (Table 2). While FRE3 generally decreases as the total allocation rate increases for both indices, there are two exceptions i.e. there is no difference in FRE2 or FRE3 for the Waiau River for: a) scenarios 2 and 4; and b) scenarios 3 and 5. These scenarios have the same total allocations but differ with respect to the gaps between the allocation blocks. Table 2 also shows that the mean duration between events of 2 and 3 times the median flow increases in both rivers as the total allocation increases, again with the proviso that indices for scenarios 3 and 5 are identical, and indices for scenarios 2 and 4 are rather similar

Table 2. The mean frequency of flow events per year equal to or greater than two (FRE2) and three (FRE3) times the natural median flow and the mean duration between flow events of two ($DB2Q_{50}$) and three ($DB3Q_{50}$) times the median for natural and the simulated flow regimes for the management scenarios of the Hurunui and Waiau rivers.

River	Scenario	FRE2	FRE3	$DB2Q_{50}$	$DB3Q_{50}$
Hurunui River	Natural	8.5	5.8	33.9	68.1
	Status Quo	8.2	5.5	37.6	71.2
	Scenario 1	8.1	5.5	39.6	71.8
	Scenario 2	7.1	5	47.4	78
	Scenario 3	5.9	4.5	62.9	96.4
	Scenario 4	5.3	3.9	73.7	112
Waiau River	Natural	11.3	7.9	20.5	39
	Scenario 1	10.4	7.2	24.7	45
	Scenario 2	9.7	6.8	27.9	48.9
	Scenario 3	7.9	6	38.8	58.4
	Scenario 4	9.7	6.9	26.9	48
	Scenario 5	7.9	6	38.8	58.4

34 In 1987, a typical year (Figures 3 and 4), the natural flow of both rivers varied frequently, and there were no extended periods of low flow. I consider that there is nothing to suggest that there would be significant effects on fish migration. However with some flow scenarios, periods of flat-lining will occur in

both rivers during the summer and autumn of a typical year Flat-ling would occur under scenarios 2, 3 and 4 in the Hurunui (Figure 3), and scenarios 3,4 and 5 in the Waiau River (Figure 4). These periods of flat -lining are mostly of 10 to 15 days duration. I do not consider periods of flat-lining of this duration will be very deleterious for fish migration. However, in years with lower than average flows, these periods of flat-lining will be longer, probably to the extent that fish migration will be affected.

35 In 1973, a dry year (Figures 5 and 6), both rivers experienced an extended period of natural low flow during the first three months of the year. It is likely that the steady low flows during this period would have affected both the upstream migration of adult salmon and the downstream migration of eels in both rivers. The effect of water allocation under the future scenarios would be to greatly increase the duration of flat-lining in low flow years (Figures 5 and 6).

36 To evaluate the different scenarios, I used a semi-quantitative assessment, being the sum of subjective scores (from 0 to 5, where 0 = no biologically significant difference to the natural situation, and 5 = substantial difference), for the following criteria (a) the hydrograph of the typical year, (b) the hydrograph for the low flow year, (c) the flood/fresh frequency, (d) the duration of the period between floods. I then summed these scores, and normalized the results to give a probability (0-1) for that scenario achieving the associated objective from the HWRRP.

37 Based on the above assessments, I then used the 'scenario evaluation tables' that are described in the evidence of Mr Norton, to provide a simple, colour-coded, visual summary of the extent that I would expect the relevant HWRRP objectives and policies will be achieved under each scenario. For this exercise, I nominally assigned scores of < 0.1 as "almost certainly", scores from 0.1 – 0.4 as "probably", scores from 0.4 – 0.7 as "possibly" and scores > 0.7 as "unlikely".

38 To assess the impact of mouth closures, I have relied upon the evidence of Dr. Hicks. Although his analysis of the likelihood of mouth closure does not include any seasonal differences, the annualized likelihood is a relevant criterion as there is some movement of fish through the mouth during all months. Accordingly, I have adopted Dr Hicks' scenario evaluation table for mouth

closure as also being an appropriate for describing impacts of potential mouth closure on fish movements at the river mouth. As explained by Dr. Hicks, the Hurunui mouth can close when flows fall below 15 m^3/s, and this situation will increase, compared to the natural flow regime, under all scenarios. In contrast, his analysis showed no potential closure of the Waiau mouth under any scenario.

In summary,

- Mid-range flows are important to fish for maintaining suitable physical and chemical conditions (ecosystem health) and stimulating fish migrations. Conversely, extended periods of without flow variation may produce adverse effects for fish and fish communities. With our current state of knowledge, it is not possible to determine particular threshold flows that will trigger fish movements. Consequently, any evaluation of the effect of different flow scenarios on fish migrations will be partly subjective.

- With increasing allocation in the Hurunui River, there is increasing likelihood of not achieving the natural level of fish migrations - hence my assessment of the scenarios reflects that progression (Tables 3 and 4). I believe scenario 1 will almost certainly achieve the goal, and scenario 2 will probably achieve it, but scenarios 3 and 4 are unlikely to. For the Waiau the likelihood of achieving this objective is greater for scenarios 2 and 4, than for scenarios 3 and 5.

- I consider that the opportunities for fish movements through the respective river mouths are directly related to the probability of mouth closures. As the Waiau mouth is not expected to close under any of the flow scenarios there are no associated implications for fish movements. For the Hurunui River, the likelihood of mouth closure and associated interruptions to fish migrations is greater for scenarios1 and 2 than for 3 and 4 as the latter 2 scenarios assume increased minimum flows (Table 3).

Table 3 . Likelihood of achieving HWRRP freshwater fish outcomes in the Hurunui River at two sites (Mandamus and State Highway 1) under the natural flow regime, status quo and flour flow allocation scenarios. Note that this assessment and summary is based on the assumption that water quality remains as for the status quo. For an analysis of this assumption, and assessment of water quality, see the evidence of Mr Norton.

ACHIEVES…	Scenarios…					
	Natural	**Status Quo**	**Scenario1**	**Scenario2**	**Scenario3**	**Scenario4**
Provision for the upstream and downstream of native fish and salmonids	Almost Certainly	Almost Certainly	Almost Certainly	Probably	Unlikely	Unlikely
Mouth openings: Provision for the migration of native fish and salmonids	Almost Certainly	Possibly	Unlikely	Unlikely	Possibly	Possibly

Table 4. Likelihood of achieving HWRRP freshwater fish outcomes in the Waiau River at Marble Point under the natural flow regime and five flow allocation scenarios. Note that this assessment and summary is based on the assumption that water quality remains as for the status quo. For an analysis of this assumption, and assessment of water quality see the evidence of Mr Norton.

ACHIEVES…	Scenarios…					
	Natural	**Scenario1**	**Scenario2**	**Scenario3**	**Scenario4**	**Scenario5**
Provision for the upstream and downstream of native fish and salmonids	Almost Certainly	Probably	Possibly	Unlikely	Possibly	Unlikely
Mouth openings: Provision for the migration of native fish and salmonids	Almost Certainly	Almost Certainly	Probably	Probably	Probably	Probably

D Jellyman

24 September 2012

References

Crow, S. K., Booker, D.J., Snelder, T.H. (in review). Contrasting influence of flow regime on freshwater fishes displaying diadromous and non-diadromous life-histories. Ecology of Freshwater Fish

Glova GJ, Docherty C, Washbourne TJ (1988) Radio-tracking Rakaia salmon. Freshwater Catch 36:11

Jellyman, D.J., Glova., Sykes, J.R.E. 2002. Movements and habitats of adult lamprey (Geotria australis) in two New Zealand waterways. New Zealand Journal of Marine and Freshwater Research 36: 53-65.

Jowett, I.G.; Richardson, J.R.; Bonnett, M.L 2005. Relationship between flow regime and fish abundances in a gravel-bed river, New Zealand. Journal of Fish Biology 66: 1419–1436

McDowall, R.M. 1995. Seasonal pulses in migrations of New Zealand diadromous fishand the potential impacts of river mouth closure. New Zealand Journal of Marine and Freshwater Research 29: 517-526

Snelder, T., Booker, D., Jellyman, D., Bonnett, M.,Duncan, M. 2011. Waiau River mid-range flows evaluation. NIWA Client Report CHC2011-084. 77 p