Before the Hearings Commissioners
at Christchurch

---

in the matter of:	a submission on the proposed Hurunui and Waiau River Regional Plan and Plan Change 3 to the Natural Resources Regional Plan under the Resource Management Act 1991
to:	**Environment Canterbury**
submitter:	**Meridian Energy Limited**

Statement of evidence of Ian George Jowett

Dated: 12 October 2012

REFERENCE: JM Appleyard (jo.appleyard@chapmantripp.com)
TA Lowe (tania.lowe@chapmantripp.com)

Chapman Tripp
T: +64 3 353 4130
F: +64 3 365 4587

245 Blenheim Road
PO Box 2510, Christchurch 8140
New Zealand

www.chapmantripp.com
Auckland, Wellington,
Christchurch

CHAPMAN TRIPP

1. QUALIFICATIONS AND EXPERIENCE

1.1 My full name is Ian George Jowett.

1.2 I have a Bachelor of Engineering degree from Canterbury University in 1968 and became a registered engineer in 1970. I am a member of the New Zealand Hydrological Society and the New Zealand Freshwater Sciences Society.

1.3 I am a scientist/engineer and was employed by the National Institute of Water and Atmospheric Research until my retirement on 31 October 2007. I have been engaged by Meridian Energy Limited as a private consultant to prepare this evidence.

1.4 Between 1969 and 1984, I worked on the investigation, operation and environmental impact of hydroelectric schemes. In 1984, I was employed by MAF Fisheries, now part of NIWA, and began research into the factors influencing the abundance and distribution of native fish, trout, and benthic invertebrates and relationships between aquatic communities and flow.

1.5 For the past 26 years, I have carried out research to determine factors that influence the distribution and abundance of trout and native fish. I have authored or co-authored over 40 scientific publications on effects of flow on aquatic organisms, methods of assessing flow requirements, and habitat requirements of benthic invertebrates, brown trout and native fish. Results of this work have been incorporated into the Ministry for the Environment's "Flow guidelines for in-stream values" (MFE 1998) and into Environment Southland’s Regional Fresh Water Plan, following a review (Jowett & Hayes 2004) which I co-authored with Dr Hayes, Cawthron Institute. I have also been involved in the preparation of a proposed National Environmental Standard on methods for use in assessing flow regime requirements.

1.6 I have carried out instream habitat surveys of more than 250 reaches, including two surveys of the Hurunui River, and carried out detailed assessments of minimum flow requirements for more than 50 rivers. For many of these studies, I have prepared reports and presented evidence to Regional Council and Environment Court hearings on the effects of flow on stream invertebrates, native fish and trout.

1.7 In preparing this evidence, I have carried out the following work in relation to Meridian Energy Limited's (Meridian's) Balmoral Hydro Project (BHP);

a. Re-analysis of an instream habitat survey carried out in 2004.

b. Reviews of the report on Hurunui River flow requirements by Mr Duncan (Duncan & Shankar 2004) and the assessment of environmental effects prepared by Boffa Miskell Limited for Meridian.

1.8 In preparing this evidence, I have reviewed the statements of evidence of other experts giving evidence on behalf of Meridian relevant to my area of expertise, namely:

i. Mr Steven Woods

ii. Dr Mark Mabin

iii. Dr Mark Sanders

1.9 The evidence I present is within my area of expertise, except where I state that I am relying on information provided by another party.

1.10 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted material facts known to me that might alter or detract from the opinions expressed.

2. SCOPE OF EVIDENCE

2.1 I have been asked by the applicant to prepare evidence in relation to:

- an assessment of the ecologically relevant hydrological changes of the flow regime in the Proposed Hurunui and Waiau River Regional Plan ("the Proposed Plan"), and
- an assessment of ecological instream values and effects on instream habitat, fish, benthic invertebrates, periphyton and passage for fish and jet boats.

2.2 Under the Proposed Plan, which was notified on 1 October 2011, the present hydro proposal (BHP) is to take up to 15 m^3/s from Blocks "A", "B" and "C" water, with consented uses for irrigation having priority at all times for "A" water, and the Hurunui Water Project (HWP), if consented, having priority for "B" and "C" block water. In my analyses, I have used the flow regimes, as described in the evidence of Mr Woods.

2.3 I understand that the Proposed Plan makes mention of the need to consider flow variability, invertebrate food production, fish passage, and jet boat passage when making decisions on water allocation. I cover all these matters in my evidence.

2.4 Throughout this evidence, I have compared the effects of the BHP on the existing flow regime and flow regimes with full and partial proposed irrigation development. These have been modelled for the period 1 June 1972 to 31 May 2011. The existing flow regime includes current irrigation and other water takes as described by Mr Woods in his evidence.

3. SUMMARY OF EVIDENCE

3.1 The BHP will take up to 15 m^3/s water from at or near the existing Balmoral Irrigation Scheme intake on the north bank of the Hurunui River downstream of the Mandamus River confluence. This water will be discharged back into the river 28 km downstream from the intake, and about 8.2 km downstream of the SH7 bridge. In this evidence this is called the Amuri Reach. As the scheme is essentially a run of the river scheme, all water taken will be discharged back to the river, and there are few effects on flow downstream of the discharge.

3.2 Instream values in the Amuri Reach of the Hurunui River do not appear to be high, although instream values in other parts of the river are high, particularly for scenic values and trout and salmon angling. The Amuri Reach contains fish and invertebrate species that are typical of gravel bed rivers at mid-elevations. Compared to other New Zealand rivers, fish and benthic invertebrate densities are less than average, but river bird values are higher than average because of the braided nature of the river (see the evidence of Dr Sanders). The river is ranked as the fifth most important salmon river in New Zealand, but most salmon angling takes place downstream of the Amuri Reach and spawning takes place upstream.

3.3 In general, braided rivers do not provide good habitat for benthic invertebrates and fish. The morphology is unsuited to providing suitable habitat for adult salmon and trout, and the unstable nature of the substrate limits benthic species, such as native fish and invertebrates. In this regard, densities of aquatic biota in the Amuri Reach of the Hurunui River will be higher than in other braided rivers, because of the less variable flow regime resulting from attenuation of floods as they pass through Lake Sumner.

3.4 I carried out a 1D instream habitat survey of the Hurunui River on 8 March 2004, in conjunction with the 2D survey of Mr Duncan (Duncan & Shankar 2004). The survey was carried out at a flow of 45 m^3/s. Measurements were made at 25 transects spaced at roughly equal intervals along the 1.3 km survey reach a short way downstream of the SH7 bridge. Calibration measurements were carried out at flows of 19.7 and 12.8 m^3/s. Mr Duncan and I have published a paper which shows that the depth and velocity predictions of the 1D survey were slightly more accurate than those of the 2D survey, but the habitat/flow relationships were similar (Jowett & Duncan 2012). I used this survey for additional habitat analyses using the most recent (Jowett & Richardson 2008) habitat suitability criteria.

3.5 Compared with the existing flow regime, the BHP would reduce the mean annual flow from 56.5 m^3/s to 45.5 m^3/s, and the median flow from 41.9 m^3/s to 26.9 m^3/s. The frequency and duration of flushing flows of 130 m^3/s or higher will not be affected significantly because the BHP proposal is to shut the intake for 48 hours if the flow at Mandamus exceeds 130 m^3/s.

3.6 I calculated ecologically relevant annual flow statistics for water years beginning 1 June and examined the ecologically important characteristics of the various flow regimes, with particular reference to native fish and salmonid habitat and benthic invertebrate production (*Deleatidium* and food producing habitat).

3.7 The Proposed Plan specifies a post-storage seasonally varying minimum flow of 12-15 m^3/s, with a winter minimum of 12 m^3/s from May to August and a summer minimum of 15 m^3/s in other months. A flow regime with low winter and higher summer minimum flows is ecologically appropriate because metabolic demands and temperature stresses are higher in summer. In my opinion, summer flows are more likely to affect fish and benthic invertebrates than winter minimum flows. The summer minimum of 15 m^3/s provides 87% of torrentfish habitat available at the natural MALF and at least 95% of habitat available for other fish species. The summer minimum provides 97% of habitat for *Deleatidium* and 95% of habitat for food production. The minimum flow provides a high level of protection and any change in habitat is unlikely to have any effect on fish populations.

3.8 The minimum flow requirements of the Proposed Plan provide a high level of environmental protection and can be expected to maintain aquatic species with life cycles of more than a year. Provided the frequency of floods and flushing flows is not altered significantly, there will be no significant change to state of the river with regard to channel morphology and the accumulation of silt and periphyton. The BHP will not take flows above 130 m^3/s for at least 48 hours, and there is also opportunity to pass freshes down the river. The BHP take plus the various irrigation take scenarios can be managed to not alter the frequency or duration of flushing flows and channel maintenance flows significantly.

3.9 Although the various scenarios will reduce flows when they are above the minimum flows, the changes in the length of time between flushing events (from 20 days to 30 days with full irrigation) are not sufficient to result in significant changes to invertebrate production. The BHP will reduce flows in winter. However, the median length of time between flushing events for all BHP flow scenarios will be less than 30 days, so the effect on invertebrate production will be minimal, especially and the greatest changes will occur in winter.

3.10 The BHP will increase the frequency of low flow events (< 20 m^3/s) by about 4 events and about 40 days per year. The BHP increases the average duration of low flow events (<= 20 m^3/s) by about 1 day. These changes will have no effect on fish or invertebrate populations because the additional low flow events will occur in winter or spring. Fish populations are controlled by annual minima rather than occasional short duration flow reductions, and the duration of events is too short for total food production to be affected.

3.11 Any habitat reduction in winter or spring is likely to have less effect on ecology than a reduction in summer flow, because growth rates and energetic demands increase with water temperature.

3.12 Compared with the existing and future irrigation flow regimes, the additional flow changes resulting from the BHP will have minimal effects on habitat for most fish species (c. 10% reduction) in winter and spring months. Benthic invertebrate habitat will be affected by less than 10% in winter and spring. Invertebrates are an important source of food for birds and fish. The slight reduction in invertebrate habitat will have no effect on birds and fish, especially as the reduction is in winter and spring.

3.13 The minimum flow of 12-15 m^3/s in the Proposed Plan should not affect the passage of salmon and migratory native fish species, but jet boating in the vicinity of SH7 might be marginal at a flow of 12 m^3/s according to Duncan and Shankar (2004).

4. DESCRIPTION OF RIVER

4.1 The braided Amuri Reach of the Hurunui River is about 35 km long and comprises alternating runs and riffles. The proposed hydro-electric development will affect up to 28 km of this reach. The number of channels in the Amuri Reach varies from about 2 to 7 (see the evidence of Dr Mabin).

4.2 The substrate is comprised of gravel and cobbles; 52% cobble, 24% gravel plus small amounts of boulder, fine gravel and sand.

5. HYDROLOGY

5.1 The hydrology of the Hurunui River is discussed in detail in the evidence of Mr Woods. Flow scenarios were modelled to assess the effect of the proposed BHP take on flow regimes resulting from existing irrigation, partial future irrigation and full future irrigation. The future scenarios include all existing takes.

5.2 The Proposed Plan includes two sets of seasonally varying minimum flows for the Amuri Reach of the Hurunui River, depending on whether or not storage greater than 20 million cubic metres is developed in the catchment (Table 1). The existing and full future irrigation scenarios used the future post-storage minimum flows. The partial future irrigation scenarios used pre-storage minimum flows.

5.3 The flow and allocation regime in the Proposed Plan will alter the hydrology of the Hurunui River, with the degree of alteration dependent upon the extent of irrigation development. Irrigation will reduce the mean flow by 2 to 11 m^3/s, and the median flow by 2 to 16 m^3/s (Table 2). Flow variability will increase, with an increase in the coefficient of variation and frequency of floods above 3 times the median (FRE3). The number of days that the flow is less than 20 m^3/s will increase by between 20 and 41 days. There will be more low flow events, but the duration of these will be relatively short so that the duration does not increase significantly.

5.4 Implementation of the flow and allocation regime in the Proposed Plan will not alter the frequency of flushing flows greater than 130 m^3/s significantly regardless of irrigation or hydroelectric development. There would be between 6 and 7 flushing events per year on average and the duration would be about 3 days (Table 3).

5.5 The BHP would reduce the mean annual flow by about 10 m^3/s and the median flow by 15 m^3/s compared to existing and partial future irrigation scenarios (Table 2). The estimated natural mean annual 7-day low flow (MALF) in the Amuri Reach (Hurunui plus Mandamus rivers) is 18 m^3/s. The MALF does not alter significantly between flow regime scenarios. The flow reductions are less when compared to the full irrigation scenario. The frequency and duration of flushing flows of 130 m^3/s or higher will not be affected significantly because the BHP proposal is to shut the intake for 48 hours following a flow greater than 130 m^3/s.

5.6 The BHP take increases the number of low flow events (<= 20 m^3/s) by about 4 per year and the number of days with flows <= 20 m^3/s by about 40 days per year (Table 2). Because irrigation has priority, these low flows are mostly in the winter and early spring months (Fig. 1). The BHP only increases the average duration of low flow events (<= 20 m^3/s) by about 1 day. The increase in duration of events is relatively small because the frequency of freshes limits the duration of events.

6. Instream values

6.1 The Amuri Reach is at an elevation of about 180-300 m asl and is about 40-70 km from the sea. The elevation and distance from the sea limits the number of native fish species present. The New Zealand Freshwater Fish Database records the presence of six native species and two introduced species along the Amuri Reach and tributaries feeding into it. The fish species are: longfin eel, shortfin eel, torrentfish, upland bullies, Canterbury galaxias, koaro, brown trout, and Chinook salmon.

6.2 Glova et al. (1985) measured an average fish density (total number in three electric fishing passes) of 60 per 100 m^2 in 20 riffles in the Hurunui River at the SH7 bridge. Jowett & Richardson (1996) measured fish densities in runs and riffles in a range of smaller gravel bed rivers in the North and South Islands and found an average density of 53 fish per 100 m^2 by single pass electric fishing. Typically, single pass electric fishing densities will be about 50% of the total number in three passes and densities in riffles will be 2-3 times higher than in runs (Jowett & Richardson 1996), so the density of fish in the Amuri Reach is probably slightly below average for its elevation and distance inland.

6.3 Periphyton and benthic invertebrates have been monitored at Mandamus and at SH1 by NIWA as part of the national water quality network. The Mandamus sampling site is not braided, and the SH1 is well downstream of the Amuri Reach. Comparative analyses of periphyton (Quinn, 2010) show relatively low periphyton biomass at both sites (i.e., 97-98% of observations with less than 15% cover). The median benthic invertebrate density (1989-2010) at Mandamus was 1083 per m^2, which is slightly higher than found in New Zealand braided rivers, but less than the national median for all rivers of 2784 per m^2 (Scarsbrook et al. 2000). The invertebrate densities at SH1 were higher, with a median density 3767 of per m^2. Invertebrate densities have not been sampled in the Amuri Reach, but I would expect them to be similar to those at Mandamus, i.e., a slightly higher density than those in most braided rivers because of the more stable flows of the lake-influenced flow regime. The dominant benthic invertebrate species were chironomid larvae, mayfly larvae *Deleatidium* spp., caddisfly larvae *Aoteapsyche* spp. and *Pycnocentrodes*, elmid beetles and snails (*Potamopyrgus*). This group of species is typically found in gravel bed rivers. Trout and river birds feed on macroinvertebrates so the production of food (macroinvertebrates) will be important, at least for trout abundance (Jowett 1992; Jowett et al. 1996).

6.4 Adult trout probably reside in the Amuri Reach of the river, but numbers will be limited by a lack of cover. Although there is no information on the popularity of the Amuri Reach for trout angling, other areas of the river, such as the North Branch downstream of Lake Sumner, provide far better trout habitat and angling opportunity.

6.5 The Hurunui River is ranked as the fifth most important salmon river after the Waimakariri, Rakaia, Waitaki and Rangitata (Martin Unwin pers. comm.). Salmon move through the Amuri Reach between January and April on their way to their spawning grounds upstream. There may be some salmon angling in the Amuri Reach, but most salmon angling takes place further downstream.

6.6 The Amuri Reach provides habitat for significant numbers of braided river birds, including black-fronted terns, black-billed gull, banded dotterels, pied oystercatchers, and pied stilts. Some species of river birds require an open river bed for nesting and feeding, so the maintenance of an open gravel river bed is critical to their successful breeding. Dr Sanders in his evidence describes how the variation in benthic invertebrate production probably has little effect on river bird populations because most bird species have other sources of food available. He considers predation to be main factor in any decline of river bird populations. Islands in braided river systems provide potentially safer nesting places from predation than river edges but probably not from flooding, which is another factor influencing river bird populations.

6.7 In general, braided rivers do not provide good habitat for benthic invertebrates and fish. The morphology is unsuited to providing suitable habitat for adult salmon and trout, and the unstable nature of the substrate limits benthic species, such as native fish and invertebrates. In this regard, densities of aquatic biota in the Amuri Reach will be higher than in other comparable braided rivers, because of the less variable flow regime resulting from attenuation of floods as they pass through Lake Sumner.

7. Habitat suitability curves

7.1 Duncan and Shankar (2004) used native fish habitat suitability curves based on data presented in Jowett and Richardson (1995). More recent curves are now available. These are developed curves using more data from 124 different rivers with 5000 sampling locations and 21,000 fish (Jowett & Richardson 2008). I re-calculated habitat-flow relationships using these revised suitability curves.

7.2 Adult salmon rest or hold in deep water ("lies") and these are the areas targeted by salmon anglers. I use salmon angling habitat suitability curves developed for the Waimakariri River (Jowett et al. 2008) because of the similarity between the flow regimes and morphology of the two rivers.

7.3 Young salmon travel down the river to the sea over the spring and summer. A long river-residence time enhances their chances of survival and subsequent return to the river as adults. Most fry leave their natal streams in September and travel directly to the sea. Habitat used by juvenile salmon (< 55 mm) is described by the habitat suitability curves of Glova & Duncan (1985). The Washington Fish and Wildlife habitat suitability curves (Washington Fish and Wildlife 1987) describe the slower, deeper water habitat used by larger fingerlings (> 55 mm). The habitat described by the Washington Fish and Wildlife curves is the same as the habitat used by larger juvenile salmon in the Rakaia River as described by Davis et al. (1983). Most juvenile salmon have migrated to the sea by April of the year following hatching.

7.4 The benthic invertebrate habitat suitability curves that I use are based on data reported in Jowett et al. (1991). As in many New Zealand rivers, *Deleatidium* (mayflies) are one of the most common invertebrate species in the Hurunui River. I also use suitability curves for food producing habitat (Waters 1976), which generally describe habitat suitability for benthic invertebrates. I showed (Jowett 1992) that the amount of food producing habitat at median flow was one of the factors related to brown trout abundance.

7.5 I use curves for long filamentous algae, short filamentous algae and diatoms that were based on the experience of Dr Barry Biggs of NIWA.

8. INSTREAM HABITAT SURVEY

8.1 I carried out a 1D instream habitat survey of the Hurunui River on 8 March 2004, in conjunction with the 2D survey of Mr Duncan (Duncan & Shankar 2004). The survey reach was a short distance downstream of the SH7 bridge and was carried out at a flow of 45 m^3/s. Measurements were made at 25 transects spaced at roughly equal intervals along the 1.3 km survey reach. Calibration measurements were carried out at flows of 19.7 and 12.8 m^3/s. Mr Duncan and I have published a paper which shows that the depth and velocity predictions of the 1D survey were slightly more accurate than those of the 2D survey, but the habitat/flow relationships were similar (Jowett & Duncan 2012). The 1D model was used to calculate habitat/flow relationships for periphyton, benthic invertebrates and fish for flows of 5 to 40 m^3/s using the habitat suitability curves described above and the methods described in my evidence for the Waiau River.

Instream habitat

8.2 The habitat/flow relationships for native fish, salmonids, and benthic invertebrates in the Hurunui River generally show a common trend, with the amount of habitat increasing sharply with flow up to about 10-15 m^3/s and then levelling off (Fig. 2). Habitat/flow relationships for upland bullies, juvenile shortfin eels and juvenile salmon showed little variation with flow. A reduction in flow favoured species that prefer pool habitat, such as adult eels, salmon smolts and adult trout. The amount of habitat that provides suitable “lies” for adult salmon, according to the Waimakariri suitability criteria, increased linearly with flow up to 40 m^3/s.

8.3 A flow regime with low winter and higher summer minimum flows is ecologically appropriate because metabolic demands and temperature stresses are higher in summer than in winter. The Proposed Plan post-storage minimum flow of 15 m^3/s in summer provides 87-113% (average 96%) of the amount of habitat available at the natural mean annual 7-day low flow (MALF) (18 m^3/s) for juvenile trout, salmon, eels, torrentfish, upland bullies and Canterbury galaxias (Table 4). The minimum flow of 12m^3/s in winter provides 72-126% (average 94%) of the amount of habitat available at MALF for these fish species (Table 4). These minimum flows provide 95-97% of habitat at MALF, respectively for food production and *Deleatidium* in summer and 87-94% in winter. The minimum flows provide high levels of habitat retention.

8.4 The proportion of the river bed suitable for the growth of long filamentous algae increased as flow and water velocity decreased (Fig. 3). The reverse pattern occurred for diatoms, with the proportion of river suitable for diatoms increasing with flow. This pattern is typical of that modelled in rivers, with long filamentous algae favouring shallow low velocity conditions and diatoms swift deep water. However the amount of algal growth will be controlled by the frequency of floods and freshes and the area of suitable habitat only defines the area of potential growth under constant flows.

Salmon and jet boat passage

8.5 The ability of a jet boat to traverse a river depends on the type of jet boat, the skill of the driver, and knowledge of the river. Duncan and Shankar (2004) report that they travelled by jet boat through the Amuri Reach for 17 km from the SH 7 bridge when the flow was 13.5 m^3/s. They found that the deepest part of the shallowest riffle was 0.25 m.

8.6 Duncan and Shankar (2004) considered that it would be difficult to traverse the region around the SH7 bridge at flows less than 13.5 m^3/s. Their jet boat had a relatively deep draft and the driver had no prior knowledge of the river. Mosley (1982) describes how a jet boat in the Rakaia River traversed a riffle with a maximum depth of 0.1 m, but suggests a more generous allowance of 0.25 m passage depth should be made for less expert jet boaters. Jet Boating NZ assert that a flow of 20 m^3/s is “adequate” in the reach between SH1 and SH7, whereas in the braided section from SH7 to the Mandamus confluence a flow of 35 m^3/s is adequate, but that this reach will not generally be used by recreational boaters at flows below 40 m^3/s.

8.7 Adult Chinook salmon will migrate upstream through the Amuri Reach between January and April, when the minimum flow in the river is 12-15 m^3/s. Salmon passage depth for adult salmon is usually assumed to be 0.24 m with a velocity less than 2 m/s (Everest et al. 1985). According to these criteria, salmon could pass through the shallowest riffle at these minimum flows.

9. Effects of the Proposed Plan Flow and Allocation regime

Cumulative effects of irrigation and BHP and flow variation

9.1 Aquatic life in rivers and rivers has developed under a natural flow regime. If the river aquatic environment under natural flows is unsuitable for a particular species then that species will not be well established in a river. The biota present in a river have survived series of floods and droughts and, presumably, will continue to survive provided that the frequency of these disturbances does not change. If the abundance of an aquatic species in a particular river is limited by the naturally occurring low flows in that river then further reduction in flow at such times could have a detrimental effect on that species, but if the species is not limited by low flows then further reduction in low flows will have no effect. Given that the typical life of river fish is between 3 and 15 years, fish will have survived droughts that occur about once every two years and the status quo, in terms of river biology, is likely to be retained if flow abstraction ceases when the minimum flow falls below the mean annual minimum flow. Biologically, the mean annual minimum flow in river systems where low flow limits the amount of available habitat, or some other necessary biological function, may be a "bottleneck" for aquatic species that have life cycles in the order of 3 to 15 years.

9.2 While trout, native fish, invertebrates, and periphyton are all affected by flow variability to some extent it appears that they are mostly affected at the extremes of intensity and frequency of events (i.e., low flows and floods). The ratio of mean to median flow is an index of flow variability that has been shown to be an excellent indicator of biotic condition (Jowett and Duncan, 1990; Clausen and Biggs, 1997). For benthic communities, many taxa such as the common mayfly *Deleatidium* spp. are able to survive and prosper under a variety of regimes – from spring-fed streams with almost no flow variability to the flashiest of mountain rivers (Quinn and Hickey, 1990). Most New Zealand stream invertebrates have flexible life-histories with non-seasonal or weakly seasonal patterns of development (Scarsbrook, 2000), and patterns in invertebrate species richness and diversity as a function of flow variability are not strong across a very wide spectrum of New Zealand rivers (Jowett and Duncan, 1990; Clausen and Biggs, 1997).

9.3 While Clausen and Biggs (1997) found that average periphyton species richness decreased as a function of flood frequency among 22 streams from around New Zealand, a subsequent study by Biggs and Smith (2002) with more intensive regional sampling found no significant pattern in mean monthly periphyton taxonomic richness in relation to flow variability among 12 hydrologically-contrasting central South Island streams. This indicates that periphyton are probably well adapted to tolerate a range of flow conditions within a region, either through resistance traits or rapid immigration. Indeed, it appears that New Zealand aquatic systems (at least for invertebrates and periphyton) are characterised by populations that have evolved to be resilient and opportunistic, with flexible poorly synchronised life-histories with non-seasonal or weakly seasonal patterns of development (Biggs et al., 1990; Winterbourn et al., 1981; Scarsbrook, 2000; Thompson and Townsend, 2000). This is not surprising given the lack of strong seasonality in flow regimes.

9.4 Trout, native fish, aquatic invertebrates, macrophytes and periphyton are all affected detrimentally by floods to some extent (Jowett and Richardson, 1989; Quinn and Hickey, 1990; Scrimgeour and Winterbourn, 1989; Clausen and Biggs, 1997; Biggs et al., 1999; Riis and Biggs, 2003), and significant macrophyte development and high species richness only occur where bed moving floods are rare or absent (Riis and Biggs, 2003). The effects of floods can be both positive and negative – i.e., the effect of "flushing" and "refreshing" the river on the one hand, and disturbance to parts of the ecosystem on the other. During floods, the stability and movement of sediment accumulation, as well as the physical stress of high water velocities, influences aquatic organisms.

9.5 Channel-forming floods that maintain the character and morphology of the river significantly can only be influenced by large scale storage developments, such as hydro-electric and main-stem irrigation dams. However the abstraction of water without main-stem dams, such as provided for in the Proposed Plan, can be managed to have little effect on the frequency of floods and freshes, even cumulatively, but can reduce flows during periods of low flow.

9.6 The minimum flow requirements of the Proposed Plan provide a high level of environmental protection, as I show in Table 4, and can be expected to maintain aquatic species with life cycles of more than a year. The frequency of floods and flushing flows can be retained to the extent that there will be no significant change to channel morphology and the accumulation of silt and periphyton.

9.7 The main effect of the flow and allocation regime in the Proposed Plan is to reduce flows when they are above the minimum flows. This will not affect longer lived species, such as fish which will already be limited by frequently occurring low flows. However it can affect total benthic invertebrate production if the length of time between high flow events, such as flushing flows (> 130 m^3/s), allows invertebrate densities to increase significantly between high flow events. The median length of time between flushing flows is 23-24 days with natural, existing and partial irrigation flow regimes and increases to 30 days with full irrigation. These changes in duration are not sufficient to result in significant changes to invertebrate production.

9.8 The BHP plus the various irrigation scenarios can be managed to not alter the frequency or duration of flushing flows and channel maintenance flows significantly. However, the BHP will reduce flows in winter and spring and increase the frequency and duration of low flows. As the median length of time between flushing events will be less than 28 days, the effect on invertebrate production will be minimal, especially as the greatest changes will occur in winter.

Instream habitat

9.9 The lack of strong variation in habitat with flow (Fig. 2) and the relatively small changes in low flow suggest that the BHP will have relatively little effect on habitat, other than in the winter months. To demonstrate the seasonal variation in habitat retention, I compared habitat for dry (flow exceeded 90% of time), typical (50%), and wet (10%) months of the existing plus BHP flow regime with habitat for dry, typical and wet months for the existing flow regime, calculating the percent of habitat retained each month as:

$$Habitat\ retention\ (existing + BHP) = 100 \times \frac{WUA[i] with\ existing + BHP}{WUA[i] at\ existing}$$

where *WUA*[*i*] is the weighted usable area for each month *i* (i.e., January to December). Table 5 shows the monthly flows that were compared. Comparisons were not made with other flow regime scenarios because the flow changes are similar or less than those with the existing flow regime, as shown in Table 6.

9.10 I assumed that there would be no habitat loss or gain when flows were above the natural median (44 m^3/s).This was because high flows do not persist for long enough for there to be an ecological effect on parts of the river that are only inundated by flows greater than median. High flows also create a degree of sediment movement which can have supplementary, and possibly opposite, effects to habitat change. In wet months, monthly median flows are often greater than the long-term median flow for the flow regime scenarios, so that although there may be changes in flow, habitat retention is effectively 100%.

9.11 Changes in habitat retention reflect changes in monthly flows. In dry months, there is little hydrological change because of irrigation and minimum flow requirements, whereas in typical months the BHP can reduce flow by up to 15 m^3/s (Table 6).

9.12 Tables 7 to 20 show how the BHP flow regimes will usually reduce habitat retention during the winter for riffle-dwelling species but increase it for pool dwelling species.

9.13 The greatest changes were in typical months because flows in wet months for the BHP flow regimes were greater than the natural median flow (44 m^3/s). With the BHP flow regime, the average loss in habitat, compared to the existing flow regime, over typical winter months was less than 10% for *Deleatidium* and food production, 10% or more for torrentfish, brown trout < 100mm, Canterbury galaxias, upland bully, and juvenile eels, with an average gain of 20% or more for adult brown trout, adult eels and salmon > 55 mm.

Periphyton

9.14 The growth of long filamentous algae on substrate in the river is considered to be detrimental to the invertebrate community and river users, so that any increase in the amount of habitat suitable for its growth is regarded as a detrimental effect.

9.15 The growth of short filamentous algae on substrate in the river is not considered to be detrimental as it provides food for many species in the invertebrate community. It makes the substrate slippery for river users, but is not considered to be visually undesirable.

9.16 The growth of diatoms algae on substrate in the river is generally considered to be sign of a healthy and stable river. Diatoms make the substrate slightly slippery for river users, and native species are not considered to be visually undesirable.

9.17 The BHP flow regimes are expected to have relatively minor effects on habitat on long and short filamentous algae and diatoms (Tables 7, 8 & 9), with a winter loss of up about 30% diatoms in dry months and increases of up to 20% for short and long filamentous algae.

Deleatidium

9.18 *Deleatidium* are a common invertebrate species in the Hurunui River, because of their ability to re-colonise quickly after floods. These mayflies are one of the most important aquatic invertebrate food sources for native fish, salmonids and birds.

9.19 Under the BHP flow regimes, there is less than a 10% decrease in *Deleatidium* habitat in a few months when flows are typical or lower (Table 10).

Food production

9.20 Food producing habitat has been shown to be related to the abundance of adult brown trout (Jowett 1992), and is probably a good indicator of suitable habitat for benthic invertebrates in rivers like the Hurunui.

9.21 Under the BHP flow regimes, there are minimal changes to food producing habitat (Table 11).

Longfin and Shortfin eel (> 300 mm)

9.22 Large eels are found in association with cover, such as boulders, large woody debris and undercut banks. There is relatively little cover for adult eels in the Hurunui River, and this would be expected to limit the number of eels rather than water depth and velocity.

9.23 In terms of physical habitat created by water depth and velocity, the BHP flow regimes would increase the amount of habitat; for longfin eels the increase was about 20% in dry and typical winter months (Table 12).

Longfin and shortfin eel (< 300 mm)

9.24 Juvenile eels are found in association with cover, usually substrate of cobbles and gravel or vegetation along stream edges. In the Hurunui River, the main habitat would be cobble riffles.

9.25 The BHP flow regimes have relatively little effect on the amount of suitable habitat for juvenile eels, decreasing the amount of habitat by about 10% in typical winter months for both species (Table 13).

Torrentfish

9.26 Torrentfish are found in swift riffles in relatively shallow water. This type of habitat can be affected by flow reductions and result in reduced abundance of torrentfish (Jowett et al. 2005).

9.27 Flow abstraction decreases the amount of suitable habitat for torrentfish, with the BHP flow regimes decreasing the amount of habitat by up to 10-25% in winter months when flows are typical or lower (Table 14).

Canterbury galaxias

9.28 Canterbury galaxias are found in riffles, usually in moderate velocities towards the edges. This type of habitat can be affected by severe flow reductions and result in reduced abundance of Canterbury galaxias (Jowett et al. 2005).

9.29 The BHP flow regimes reduce the amount of suitable habitat for Canterbury galaxias by up to 10% in typical winter months (Table 15).

Upland bully

9.30 Upland bullies are found along the margins of runs and riffle, in shallow low velocity water. This type of habitat is increased by flow reductions and result in unchanged or increased abundance of upland bullies (Jowett et al. 2005).

9.31 Abstraction decreases the amount of suitable habitat for upland bullies by about 10% in typical winter months (Table 16).

Adult brown trout

9.32 The preferred feeding location of adult brown trout is in runs or at the heads of pools in depths greater than 0.5 m and in moderate velocities (0.5 m/s). Because velocity is high in most of the deep water, a reduction in flow will favour adult brown trout. Cover is also important for brown trout and there is relatively little cover in this section of river, and this will limit trout numbers.

9.33 BHP flow regimes will increase the amount of suitable habitat for adult brown trout by 20-50% in typical and dry winter months (Table 17).

Juvenile brown trout

9.34 Juvenile brown trout (< 100 mm) are often found in runs and riffles in shallower water but similar velocities to adult brown trout. Cobbles or boulders provide shelter from the current and predators.

9.35 BHP flow regimes will have little effect on juvenile brown trout habitat, with a decrease of about 10% in typical winter months (Table 18).

Juvenile salmon

9.36 Juvenile salmon (< 55 mm) are often found in runs and riffles in similar habitat to juvenile brown trout. Cobbles or boulders provide shelter from the current and predators.

9.37 BHP flow regimes will have little effect on juvenile salmon habitat, with a decrease of about 10% in typical winter months (Table 19).

9.38 When salmon grow larger than about 55 mm, their habitat use changes and they begin to live in pools with moderately low water velocities. This change in habitat use is described by habitat suitability curves for juvenile salmon > 55 mm. Because these salmon live in low velocity water, a reduction in flow favours them. Although there is little deep, low velocity habitat in the braided section of river, BHP flow regimes would increase the amount of habitat for juvenile salmon > 55 mm by about 25% in typical and dry winter and spring months (Table 20).

Ecological effects

9.39 Theoretically, a change in available habitat will only result in a population change when all available habitat is in use (Orth 1987). In most cases, populations are probably at less than maximum levels because flows and available habitat are varying all the time. That being the case, a habitat retention level of, say 90%, would maintain existing population levels, whereas retention levels of 50% might result in some effect on populations, especially where densities were high.

9.40 The minimum flows of 12-15 m^3/s, provided in the Proposed Plan, maintain a high percentage of the habitat available at the natural MALF (Table 4). Consequently, if as is commonly assumed, fish populations are limited by annual low flows that occur every year or so, the minimum flows will result in no or very little effect on fish populations, regardless of irrigation or hydro development.

9.41 The BHP will increase the frequency of low flow events (< 20 m^3/s) by about 4 events and by about 40 days per year. This will have no effect on fish or invertebrate populations because the additional low flow events will occur in winter or spring. Fish populations are controlled by annual minima rather than occasional short duration flow reductions and the duration of events is too short for total food production to be affected.

9.42 Compared with the existing and future irrigation flow regimes, the additional flow changes resulting from the BHP will have minimal effects on habitat for most fish species (c. 10% reduction) in winter and spring months. Benthic invertebrate habitat will be affected by less than 10% in winter and spring. Although invertebrates are an important source of food for birds and fish, the slight reduction habitat will have no effect on birds and fish, especially as the reduction is in winter and spring.

9.43 The BHP will have little effect on salmon angling because salmon angling takes place January-April when there is little change in monthly flows in dry and average years (Table 6).

9.44 Any habitat reduction in winter or spring is likely to have less effect on ecology than a reduction in summer flow, because growth rates and energetic demands increase with water temperature.

9.45 The minimum flows of 12-15 m^3/s provided in the Proposed Plan should not affect the passage of salmon and migratory native fish species, but jet boating in the vicinity of SH7 may be restricted when natural flows are less than 12 m^3/s.

Ian Jowett

12 October 2012

References

Biggs, B.J.F.; Smith, R.A. (2002). Taxonomic richness of stream benthic algae: effects of flood disturbance and nutrients. Limnology and Oceanography 47: 1175-1186.

Biggs, B.J.F.; Duncan, M.J.; Jowett, I.G.; Quinn, J.M.; Hickey, C. .; Davies-Colley, R.J.; Close, M.E. (1990). Ecological characterisation, classification, and modelling of New Zealand rivers: an introduction and synthesis. New Zealand Journal of Marine and Freshwater Research 24: 277-304.

Clausen, B.; Biggs, B.J.F. (1997). Relationships between benthic biota and hydrological indices in New Zealand streams. Freshwater Biology 38: 327-342.

Davis, S.F.; Eldon, G.A.; Glova, G.J.; Sagar, P.M. (1983). Fish populations in the lower Rakaia River. New Zealand Ministry of Agriculture and Fisheries, Fisheries Environmental Report 33.

Duncan, M.; Shankar, J. (2004). Hurunui River habitat 2-D modelling. NIWA Client Report CHC2004-011., NIWA, Christchurch.

Everest, F. H.; Sedell, J. R.; Armantrout, N. B.; Nickerson, T. E.; Keller, S. M.; Johnson, J. M.; Parante, W. D.; Haugen, G. N. (1985). Salmonids. In Brown E.R., Ed, "Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington - Part 1”, U.S.D.A. Forest Service, pp 199-230.

Glova, G.J.; Bonnett, M.L.; Docherty, C.R. (1985). Comparison of fish populations in riffles of three braided rivers of Canterbury, New Zealand. New Zealand Journal of Marine and Freshwater Research 19: 157-165.

Glova, G.J.; Duncan, M.J. (1985). Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. Transactions of the American Fisheries Society 114: 165-181.

Jowett, I.G. (1992). Models of the abundance of large brown trout in New Zealand rivers. North American Journal of Fisheries Management 12(3): 417-432.

Jowett, I.G.; Duncan, M.; Hayes, J. (2008). Flow requirements for fish habitat and salmon angling in the Waimakariri River. NIWA Client Report: HAM2006-026.

Jowett, I.G.; Duncan M.J. (1990). Flow variability in New Zealand rivers and its relationship to instream habitat and biota. New Zealand Journal of Marine and Freshwater Research 24: 305-317.

Jowett, I.G.; Duncan M.J. (2012). Effectiveness of 1D and 2D hydraulic models for instream habitat analysis in a braided river. Ecological Engineering 48: 92– 100.

Jowett, I.G.; Hayes, J.W. (2004). Review of methods for setting water quantity conditions in the Environment Southland draft Regional Water Plan. NIWA Client Report: HAM2004-018. 86 p.

Jowett, I.G.; Richardson, J. (1989). Effects of a severe flood on instream habitat and trout populations in seven New Zealand rivers. New Zealand Journal of Marine and Freshwater Research 23: 11-17.

Jowett, I.G.; Richardson, J. (1995). Habitat preferences of common, riverine New Zealand native fishes and implications for flow management. New Zealand Journal of Marine and Freshwater Research 29: 13-23.Jowett, I.G.; Richardson, J. (1996). Distribution and abundance of freshwater fish in New Zealand rivers. New Zealand Journal of Marine and Freshwater Research 30: 239-255.

Jowett, I.G.; Richardson, J. (2008). Habitat use by New Zealand fish and habitat suitability models. NIWA Science and Technology Series No. 55.

Jowett, I.G.; Richardson, J.; Biggs, B.J.F.; Hickey, C.W.; Quinn, J.M. (1991). Microhabitat preferences of benthic invertebrates and the development of generalised *Deleatidium* spp. habitat suitability curves, applied to four New Zealand rivers. New Zealand Journal of Marine and Freshwater Research 25: 187-199.

Jowett, I.G.; Richardson, J.; Bonnett, M.L. (2005). Relationship between flow regime and fish abundances in a gravel-bed river, New Zealand. Journal of Fish Biology 66: 1-18.

Jowett, I.G.; Richardson, J.; McDowall, R.M. (1996). Relative effects of in-stream habitat and land use on fish distribution and abundance in tributaries of the Grey River, New Zealand. New Zealand Journal of Marine and Freshwater Research 30: 463-475.

Ministry for the Environment (1998). Flow guidelines for instream values (2 volumes). Ministry for the Environment, Wellington.

Mosley, M.P. (1982). Critical depths for passage in braided rivers, Canterbury, New Zealand. New Zealand Journal of Marine and Freshwater Research 16: 351-357.

Orth, D.J. (1987). Ecological considerations in the development and application of instream flow-habitat models. Regulated Rivers: Research and Management 1:171-181.

Quinn, J. (2010). 21 years of Hurunui mainstem environmental monitoring: what does it tell us? Land and Water Quality Project Catchment Workshop 3, Environment Canterbury.

Quinn J.M.; Hickey, C.W. (1990). Characterisation and classification of benthic invertebrates in 88 New Zealand rivers in relation to environmental factors. New Zealand Journal of Marine and Freshwater Research 24: 387-406.

Riis, T.; Biggs B.J.F. (2003). Hydrologic and hydraulic control of macrophyte establishment and performance in streams. Limnology and Oceanography 48(4): 1488–1497.

Scarsbrook, M.R. (2000). Life-histories. In: Collier, K. J.; Winterbourn, M. J. eds New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, Christchurch. Pp. 76-99.

Scarsbrook, M.R.; Boothroyd, I.K.G. ;Quinn, J.M. (2000). New Zealand's National River Water Quality Network: long-term trends in macroinvertebrate communities. New Zealand Journal of Freshwater Research 39: 284-302.

Scrimgeour, G. J.; Winterbourn, M. J. (1989). Effects of floods on epilithon and benthic macroinvertebrate populations in an unstable New Zealand river. Hydrobiologia 171: 33-44.

Thompson, R.M.; Townsend, C.R. (2000). Is resolution the solution?: the effect of taxonomic resolution on the calculated properties of three stream food webs. Freshwater Biology 44 (3): 413–422.

Washington Department of Fish and Wildlife, (1987). Curve file data. Department of Ecology, Olympia, Washington.

Waters, B.F. (1976). A methodology for evaluating the effects of different streamflows on salmonid habitat. In Orsborn, J. F. and Allman, C. H. (Eds), Proceedings of the Symposium and Speciality Conference on Instream Flow Needs II. American Fisheries Society, Bethesda, Maryland. pp. 224-234.

Winterbourn, M.J.; Rounick, J.S.; Cowie, B. (1981). Are New Zealand stream ecosystems really different? New Zealand Journal of Marine and Freshwater Research 15: 321-328.

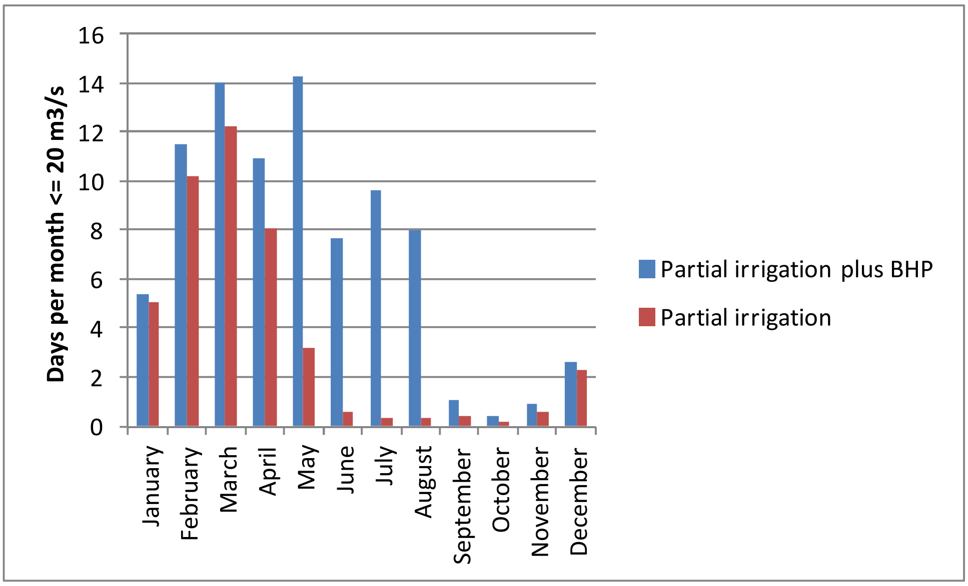

Figure 1: Number of days per month with flows <= 20 m^3/s for partial irrigation and partial irrigation with BHP flow regimes.

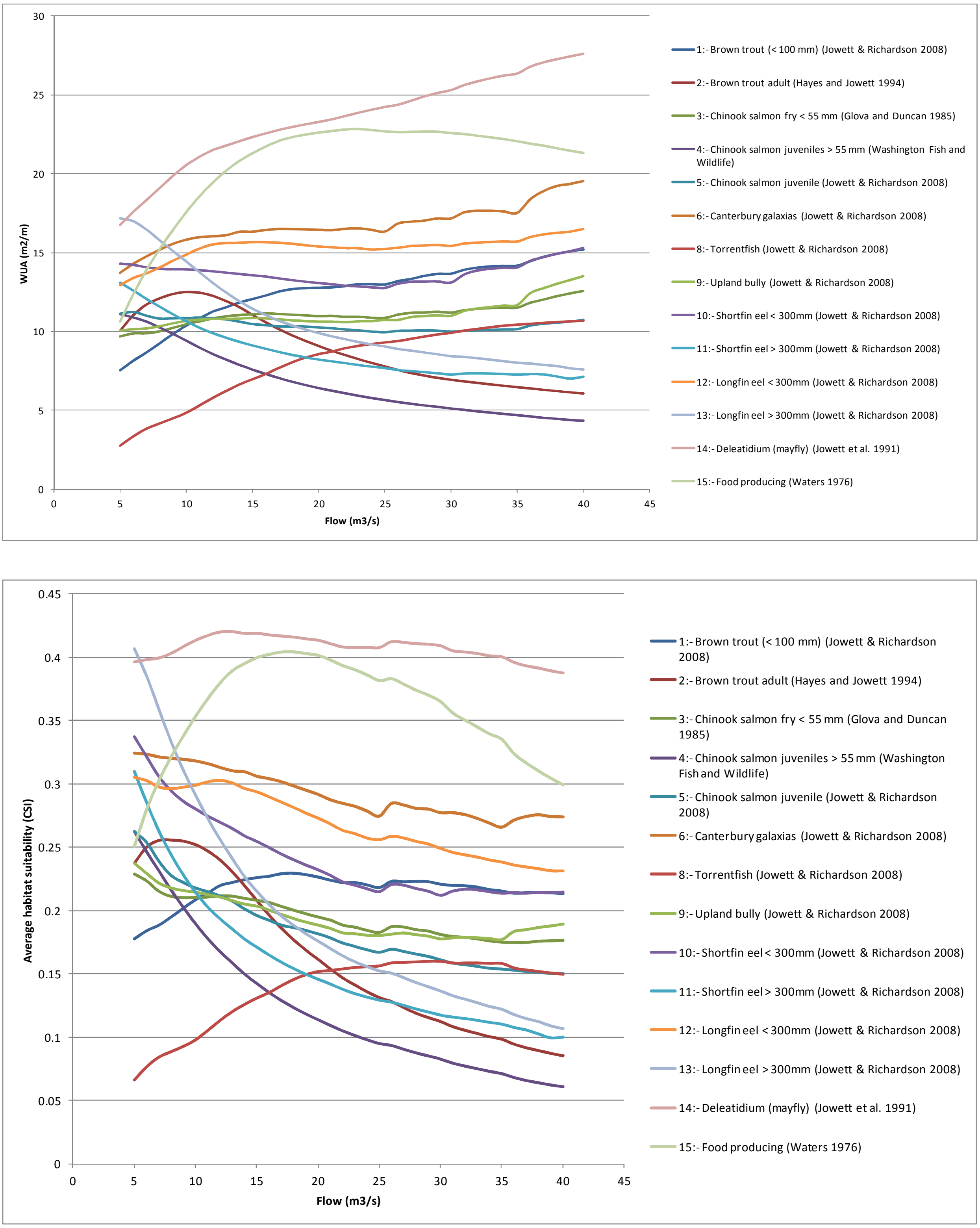

Figure 2: Habitat (WUA above CSI below) flow relationships for fish and benthic invertebrates in the Amuri reach of the Hurunui River.

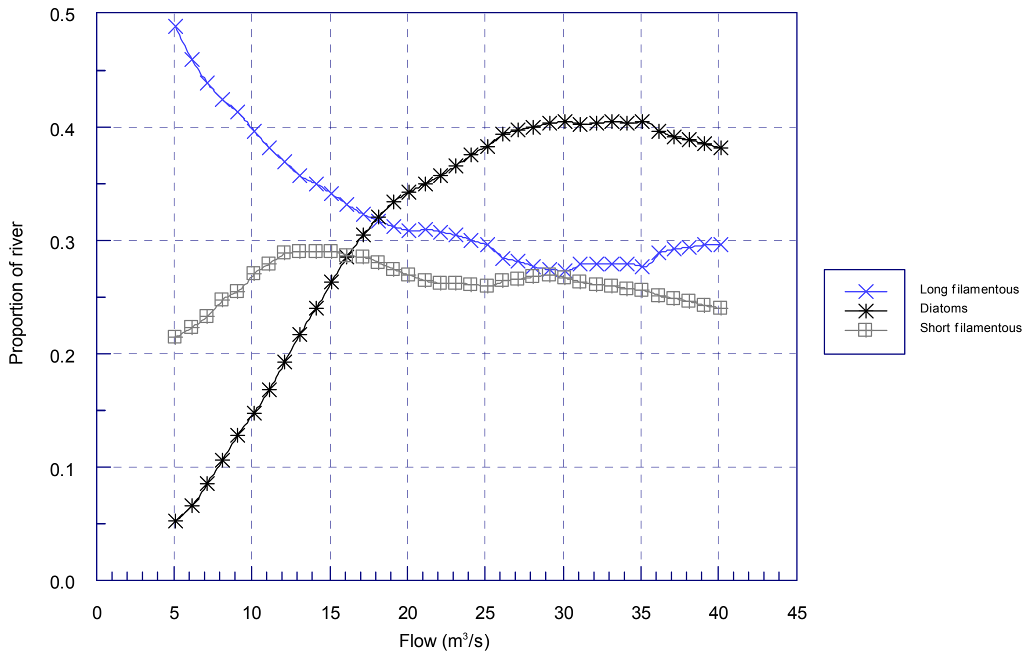

Figure 3: Proportion of river area suitable for long filamentous algae, short filamentous algae and diatoms in the Amuri reach of the Hurunui River.

Table 1: Hurunui River monthly minimum flows for existing and future users in the Proposed Plan. The minimum flow is measured at the Mandamus recorder site.

9.1 Month	**Existing**		**Future**	
	Existing AIC Irrigation	Existing Other irrigation (1.2 m^3/s allocation)[1]	"Pre-storage"[2]	"Post-storage"[2]
Jan	12	10	15	15
Feb	12	10	12	15
Mar	12	10	12	15
Apr	12	10	12	15
May	12	10	12	12
Jun	12	10	12	12 (10)[3]
Jul	12	10	12	12 (10)[3]
Aug	13	11	13	12 (10)[3]
Sep	15	13	15	15
Oct	19	17	15	15
Nov	18	16	15	15
Dec	13.5	11.5	15	15

[1] Minimum flow regime is subject to 1:1 flow sharing.

[2] As in the 'Proposed Hurunui and Waiau River Regional Plan October 2011'.

[3] Values in () are for non-consumptive takes provided the point of take and discharge are less than 250m apart.

Table 2: Ecologically relevant hydrological statistics for flow scenarios for the Amuri Reach of the Hurunui River. **FRE3** = frequency of flows > 3 x median per year, **N <= 20** is Number of days with flow <= 20 m^3/s per year, **Nevents <= 20** is number of contiguous events <= 20 m^3/s per year, **Duration <= 20** is the 25%-75% percentiles of duration (days) of events < =20 m^3/s.

Statistic	Natural	Existing	Existing+ BHP	Partial irrigation	Partial irrigation +BHP	Full irrigation	Full irrigation +BHP
Mean flow	58.6	56.5	45.5	55.5	44.9	47.3	39.9
Median flow	43.8	41.9	26.9	40.8	25.8	28.2	23.9
Coefficient of Variation	0.86	0.90	1.10	0.91	1.11	1.03	1.18
FRE3	5.5	5.8	7.9	5.9	8.1	7.6	7.5
MALF	17.9	14.8	13.4	14.8	13.6	15.3	13.8
N <= 20	22.1	39.8	86.2	43.3	86.3	62.9	101.6
Nevents <= 20	2.2	4.3	8.7	4.6	8.8	6.1	9.3
Duration <= 20	3-12	2-11	3-13	2-12	3-13	3-13	3-14

Table 3: Frequency and duration of flushing flows > 130 m^3/s in the Amuri Reach of the Hurunui River.

Statistic	Natural	Existing irrigation	Partial irrigation	Full irrigation	Existing+ BHP	Partial irrigation +BHP	Full irrigation +BHP
Average number of contiguous events per year	6.9	6.8	6.7	5.8	7	7	5.9
Maximum duration	22	21	21	19	17	17	15
Duration exceeded by 25% of events	4	4	4	4	3	3	3
Mean duration	3.5	3.4	3.4	3.2	3	2.9	2.9
Median duration	3	3	2	2	2	2	2
Duration exceeded by 75% of events	1	1	1	1	1	1	1

Table 4: Habitat retention of the minimum flows (10-15 m^3/s) compared to the natural MALF (18 m^3/s).

Species life stage	**Habitat retention of minimum flows (10-15 m^3/s) compared to the natural MALF**		
	10 m^3/s	**12 m^3/s**	**15 m^3/s**
Brown trout (< 100 mm)	82	89	95
Brown trout adult	128	126	113
Chinook salmon fry < 55 mm	95	98	100
Chinook salmon juveniles > 55 mm	138	126	111
Chinook salmon juvenile	105	105	101
Canterbury galaxias	96	97	99
Torrentfish	60	72	87
Upland bully	100	101	101
Shortfin eel < 300mm	105	104	102
Shortfin eel > 300mm	125	116	107
Longfin eel < 300mm	96	100	101
Longfin eel > 300mm	139	126	110
Deleatidium	89	94	97
Food producing	79	87	95

Table 5: Monthly flow (m^3/s) statistics used to calculate monthly habitat retention for the existing flow regime and the existing + BHP flow regime for dry (90% exceedence) and average (50% exceedence) and wet (10% exceedence) months.

Month	Dry		Typical		Wet	
	Existing flow exceeded 90% of time	Existing + BHP flow exceeded 90% of time	Existing median	Existing + BHP median	Existing exceeded 10% of time	Existing + BHP flow exceeded 10% of time
January	17.9	17.1	34.9	23.6	88.8	73.8
February	12.5	12.5	25.6	22.9	63.1	48.1
March	12.5	12.5	24.9	21.8	62.0	47.0
April	14.8	14.8	32.0	23.1	79.7	64.7
May	19.6	14.3	37.2	22.2	99.4	84.4
June	27.2	14.7	47.5	32.5	103.5	88.5
July	26.5	14.7	43.3	28.3	97.0	82.0
August	27.5	14.7	49.0	34.0	106.5	91.5
September	29.1	22.9	55.5	40.5	128.6	116.0
October	33.1	23.3	68.4	53.4	163.1	154.1
November	29.2	23.2	52.1	37.1	127.2	112.4
December	23.3	21.5	43.8	28.8	107.4	92.4

Table 6: Change in dry, typical and wet monthly flows resulting from the BHP with existing, partial and full irrigation flow regimes.

Month	**Flow change (m^3/s) from existing**			**Flow change (m^3/s) from partial irrigation**			**Flow change (m^3/s) from full irrigation**		
	Dry	Typical	Wet	Dry	Typical	Wet	Dry	Typical	Wet
Jan.	0.8	11.4	15.0	0.2	7.9	15.0	1.5	1.5	10.7
Feb.	0.0	2.7	15.0	0.0	0.2	15.0	0.8	0.3	11.2
Mar.	0.0	3.1	15.0	0.0	1.3	15.0	0.1	0.7	11.7
Apr.	0.0	8.8	15.0	0.0	7.4	14.6	0.2	0.4	14.5
May	5.3	15.0	15.0	5.7	15.0	15.0	0.1	7.4	14.7
Jun.	12.5	15.0	15.0	12.5	15.0	15.0	4.9	15.0	15.0
Jul.	11.8	15.0	15.0	11.8	15.0	15.0	6.1	15.0	15.0
Aug.	12.8	15.0	15.0	12.8	15.0	15.0	8.5	15.0	15.0
Sep.	6.1	15.0	12.6	4.7	15.0	13.1	0.7	14.4	13.0
Oct.	9.8	15.0	9.0	9.0	15.0	7.4	1.4	14.7	7.9
Nov.	6.1	15.0	14.8	3.6	15.0	14.3	0.8	5.6	9.3
Dec.	1.7	15.0	15.0	0.8	15.0	15.0	0.9	2.1	14.0

Table 7: Retention of habitat for long filamentous algae with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	102	108	100
Feb.	100	103	100
Mar.	100	104	100
Apr.	100	108	100
May	109	107	100
Jun.	117	97	100
Jul.	117	98	100
Aug.	118	96	100
Sep.	107	104	100
Oct.	109	100	100
Nov.	107	99	100
Dec.	102	98	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 8: Retention of habitat for short filamentous algae with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	101	107	100
Feb.	100	102	100
Mar.	100	103	100
Apr.	100	103	100
May	115	112	100
Jun.	123	117	100
Jul.	123	119	100
Aug.	123	115	100
Sep.	101	104	100
Oct.	104	100	100
Nov.	101	110	100
Dec.	102	120	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 9: Retention of habitat for diatoms with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	96	93	100
Feb.	100	95	100
Mar.	100	94	100
Apr.	100	92	100
May	74	93	100
Jun.	66	110	100
Jul.	66	108	100
Aug.	66	110	100
Sep.	92	103	100
Oct.	92	100	100
Nov.	92	107	100
Dec.	96	109	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 10: Retention of *Deleatidium* habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	99	91	100
Feb.	100	98	100
Mar.	100	98	100
Apr.	100	93	100
May	97	88	100
Jun.	92	92	100
Jul.	93	89	100
Aug.	92	93	100
Sep.	95	98	100
Oct.	92	100	100
Nov.	95	95	100
Dec.	99	89	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 11: Retention of food producing habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	99	103	100
Feb.	100	100	100
Mar.	100	100	100
Apr.	100	101	100
May	96	104	100
Jun.	97	106	100
Jul.	97	107	100
Aug.	97	105	100
Sep.	100	101	100
Oct.	102	100	100
Nov.	100	103	100
Dec.	100	107	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 12: Retention of adult (> 300 mm) longfin eel habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	102	116	100
Feb.	100	105	100
Mar.	100	106	100
Apr.	100	113	100
May	116	122	100
Jun.	128	114	100
Jul.	128	118	100
Aug.	129	112	100
Sep.	110	104	100
Oct.	114	100	100
Nov.	110	108	100
Dec.	103	118	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 13: Retention of juvenile (< 300 mm) longfin eel habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	100	97	100
Feb.	100	100	100
Mar.	100	101	100
Apr.	100	98	100
May	105	96	100
Jun.	107	92	100
Jul.	107	91	100
Aug.	107	93	100
Sep.	99	98	100
Oct.	98	100	100
Nov.	99	95	100
Dec.	100	91	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 14: Retention of torrentfish habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	97	87	100
Feb.	100	96	100
Mar.	100	95	100
Apr.	100	89	100
May	81	84	100
Jun.	74	93	100
Jul.	74	89	100
Aug.	73	94	100
Sep.	92	98	100
Oct.	88	100	100
Nov.	92	96	100
Dec.	97	89	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 15: Retention of Canterbury galaxias habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	100	94	100
Feb.	100	100	100
Mar.	100	100	100
Apr.	100	95	100
May	99	89	100
Jun.	98	89	100
Jul.	98	86	100
Aug.	97	89	100
Sep.	96	100	100
Oct.	94	100	100
Nov.	96	94	100
Dec.	100	87	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 16: Retention of upland bully habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	100	92	100
Feb.	100	99	100
Mar.	100	99	100
Apr.	100	95	100
May	103	86	100
Jun.	101	81	100
Jul.	101	79	100
Aug.	101	83	100
Sep.	98	97	100
Oct.	94	100	100
Nov.	98	89	100
Dec.	100	79	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 17: Retention of adult brown trout habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	103	126	100
Feb.	100	108	100
Mar.	100	110	100
Apr.	100	123	100
May	129	136	100
Jun.	161	117	100
Jul.	158	125	100
Aug.	162	114	100
Sep.	117	105	100
Oct.	124	100	100
Nov.	117	110	100
Dec.	105	124	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 18: Retention of juvenile brown trout habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	99	91	100
Feb.	100	99	100
Mar.	100	99	100
Apr.	100	93	100
May	96	88	100
Jun.	94	89	100
Jul.	94	86	100
Aug.	93	90	100
Sep.	95	98	100
Oct.	92	100	100
Nov.	95	93	100
Dec.	99	87	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 19: Retention of juvenile salmon habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Chinook salmon fry < 55 mm			
Month	Dry	Typical	Wet
Jan.	100	95	100
Feb.	100	100	100
Mar.	100	101	100
Apr.	100	96	100
May	102	91	100
Jun.	103	88	100
Jul.	103	86	100
Aug.	103	89	100
Sep.	98	98	100
Oct.	96	100	100
Nov.	98	93	100
Dec.	100	86	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention

Table 20: Retention of juvenile salmon (> 55 mm) habitat with existing + BHP flow regime as a percentage of habitat available with the existing flow regime for wet, dry and typical months.

% retention with existing + BHP flow regime compared to existing			
Month	Dry	Typical	Wet
Jan.	103	125	100
Feb.	100	107	100
Mar.	100	108	100
Apr.	100	120	100
May	117	134	100
Jun.	137	119	100
Jul.	136	128	100
Aug.	138	116	100
Sep.	114	105	100
Oct.	122	100	100
Nov.	114	111	100
Dec.	104	127	100

Key:

Habitat loss	<70% retention	70-79% retention	80-89% retention	90-110% retention
Habitat gain	90-110% retention	111-120% retention	121-130% retention	>130% retention