Hydrology, water quality and ecology of the lower Clutha

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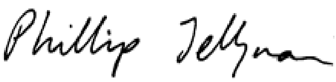	Approved for release by:	Phillip Jellyman

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Executive summary

This report presents a literature review and monitoring data stock-take of previous research relating to the hydrology, water quality, and ecology of the Clutha River (Mata-Au) downstream of Roxburgh Dam (referred to as the lower Clutha).

The flow regime of the lower Clutha River is relatively well recorded and documented. There are four river flow monitoring locations on the Clutha River between Roxburgh Dam and Balclutha (below Roxburgh Dam, Roxburgh turbidity gauge, Tuapeka Mouth and Balclutha). There are several NIWA reports relating to the river's flood and drought regime, the impact of hydropower on managed flows, and tidal influences on the hydrology of the lower reaches.

The lower Clutha has a mean flow of 516 m^3/s (2000–2020) just downstream of Roxburgh Dam with highest flows generally occurring in summer (December and January) and late autumn (May). From 2000 to 2020, flow varied between 100 and 1965 m^3/s and can typically range between 400 and 600 m^3/s in a single day.

The water quality in the lower Clutha is described as excellent (Land Air Water Aotearoa), based on monthly monitoring at Millers Flat and at Balclutha. The 5-year median values of ammoniacal nitrogen, nitrate nitrogen, and dissolved reactive phosphorus for both sites fall into the NPS-FM A band, while the 5-year medians for water clarity and *E. coli* at Balclutha fall into the NPS-FM D band (below the national bottom line).

Periphyton used to be dominated by diatoms, until the invasive species *Didymosphenia geminata* was discovered in the lower Clutha in 2006 and has since become established in the entire river. Macroinvertebrate monitoring data from Millers Flat indicate low MCI scores (NPS-FM D band, below the national bottom line), which may be a result of the establishment of *Didymosphenia* and/or natural turbidity.

The lower Clutha has a native fish assemblage typical of many South Island east coast rivers. Based on sampling to date, the abundance of fish is relatively low, mainly due to the lack of suitable habitat due to the varying flow regime from Roxburgh Dam (but also loss of wetlands and bank instability in the lower reaches of the river). The lower river supports an important recreational trout and salmon fishery, but upstream distribution of salmon is curtailed by Roxburgh Dam. The whitebait fishery is considered the most important recreational and commercial whitebait fishery in the Otago region. Longfin eels support an important commercial fishery and probably a small customary fishery, but recruitment to the catchment is low, resulting in limited upstream transfers of juvenile eels past Roxburgh Dam.

1 Introduction

NIWA was asked to conduct a literature review and monitoring data stock-take of previous research relating to the hydrology, water quality, and ecology of the Clutha River (Mata-Au) downstream of Roxburgh Dam (referred to as the lower Clutha). This review was to include consideration of the fish species present in the lower Clutha and in Lake Roxburgh, and interpretation of water quality data collected in the lower Clutha. The aim of the work was to facilitate a future wide-ranging assessment of potential environmental impacts of a pumped hydro scheme at Lake Onslow.

2 Hydrology

The Clutha River is the longest in the South Island (338 km) and has the highest mean flow in the country (614 m^3/s). The three lakes in the upper Clutha catchment (Wakatipu, Wānaka and Hāwea) provide approximately 75% of the flow seen 140 km downstream at Balclutha (Hicks 1975) and thus lake outflows exert considerable influence on the downstream flow regime. The Clutha is a predominantly single thread river, and downstream of the Clyde and Roxburgh Dams the river channel is vulnerable to erosion as sand and gravels that make up the bedload of the river are depleted by up to 95% (from 0.9 to less than 0.06 million tonnes per year; Mager and Horton 2018).

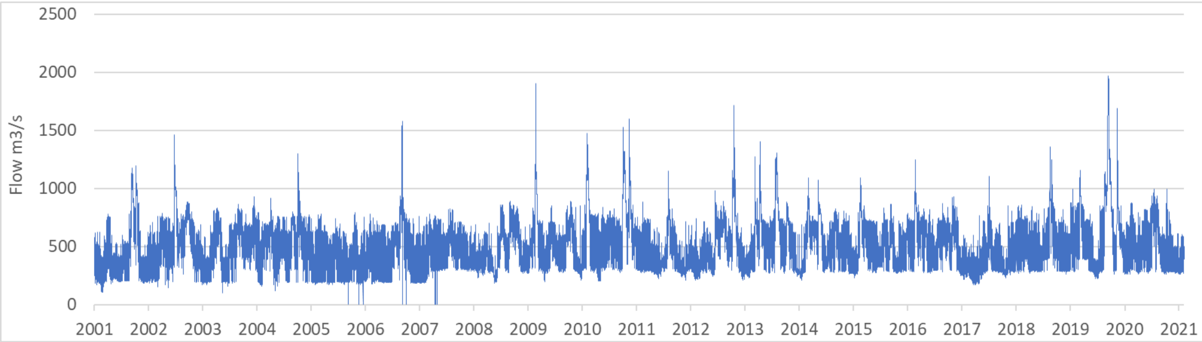
The Teviot River (into which Lake Onslow flows) is the only significant tributary between Roxburgh Dam and Beaumont. Other smaller tributaries include the Tima Burn, Talla Burn and Beaumont River that drain from the north, and Benger Burn that drains from the south. From Beaumont, the Tuapeka River, the Pomahaka River, the Kuriwao Creek, the Waiwera River and the Waituahuna River are the prominent tributaries (see Figure 2-1). As the gradient of the river decreases downstream of Balclutha, sediment deposition increases, and the river divides into two branches. The southwestern branch, the Koau, is the larger and carries approximately 70% of flow to the coast (18 km downstream of the divide). The northern branch (approximately 30% of flow), the Matau, is more sinuous and is 29 km in length to the sea.

River flow data for the lower Clutha are available for the time periods indicated in Table 2-1 and the locations illustrated in Figure 2-1. The long-term variability of the Clutha River downstream of Roxburgh Dam from 2001 to 2021 is illustrated in Figure 2-2 (top panel). Flows vary between 100 and 1965 m^3/s. With high flows being sustained for up to 50 days above 790 m^3/s, as in the summer 2019 floods Figure 2-2 (bottom panel). Figure 2-3 illustrates that mean monthly flows are greatest in summer (December and January) and late autumn (May). Sub-daily flow data (Table 2-1) illustrates the impact of flow management on daily variability, which typically varies between 400 and 600 m^3/s, also depending on seasonal variability. Flow data are available at sub-hourly intervals and can be sourced direct from the Otago Regional Council website (orc.govt.nz).

Figure 2-1: Location of river flow gauges in the lower Clutha catchment.

Table 2-1: River level gauges in the lower Clutha River.

Name	Station Number	Start	End
Clutha at Below Roxburgh Dam	75220	28-Mar-01	-
Clutha at Roxburgh Tailrace D/S	75246	13-Jan-95	30-Oct-96
Clutha at Roxburgh turbidity	575240	13-Sep-95	1-Jan-18
Clutha at Tuapeka Mouth	75222	5-Nov-92	21-Feb-13
Clutha at Balclutha	75207	7-Jul-54	-
Clutha at Thompsons Pump	75204	18-Sep-95	19-Jun-12
Clutha Koau at Inchclutha Pumps	75201	30-May-88	-
Clutha Matau at Kaitangata Locks	75205	29-Mar-88	25-Oct-01
Clutha Matau at Rutherford Locks	75202	29-Mar-88	-
Inchclutha Pump at Rutherfords	75203	9-Dec-92	-



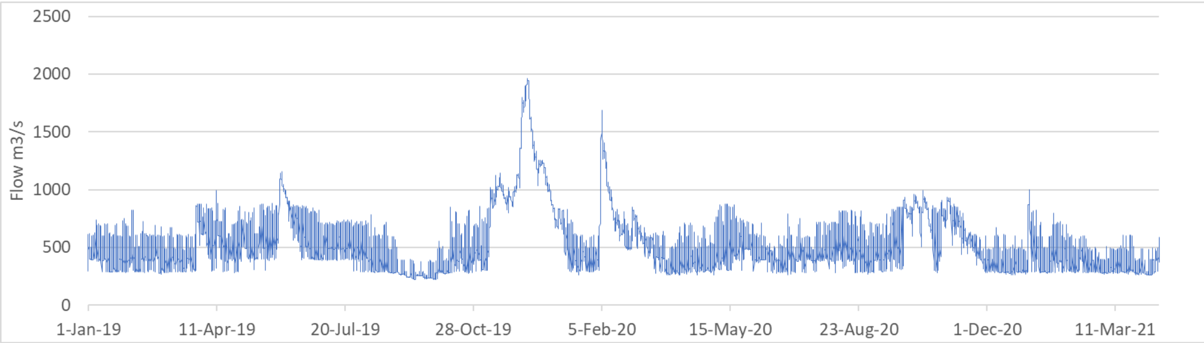


Figure 2-2: River flows measured in the lower Clutha River (Below Roxburgh Dam) from 2001 to 2021 (top) and from January 2019 to March 2021 (bottom).

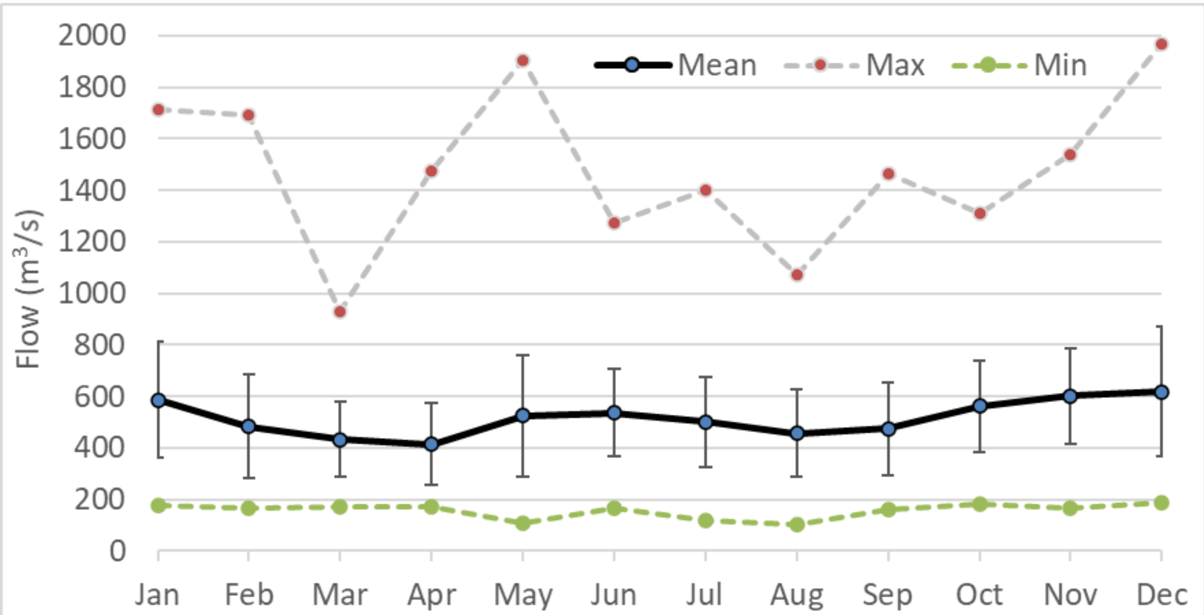


Figure 2-3: Monthly mean, maximum and minimum flows in the lower Clutha River. Data are from the flow gauge 'Below Roxburgh Dam' from 2001 to 2021 (standard deviation shown as error bars around the mean).

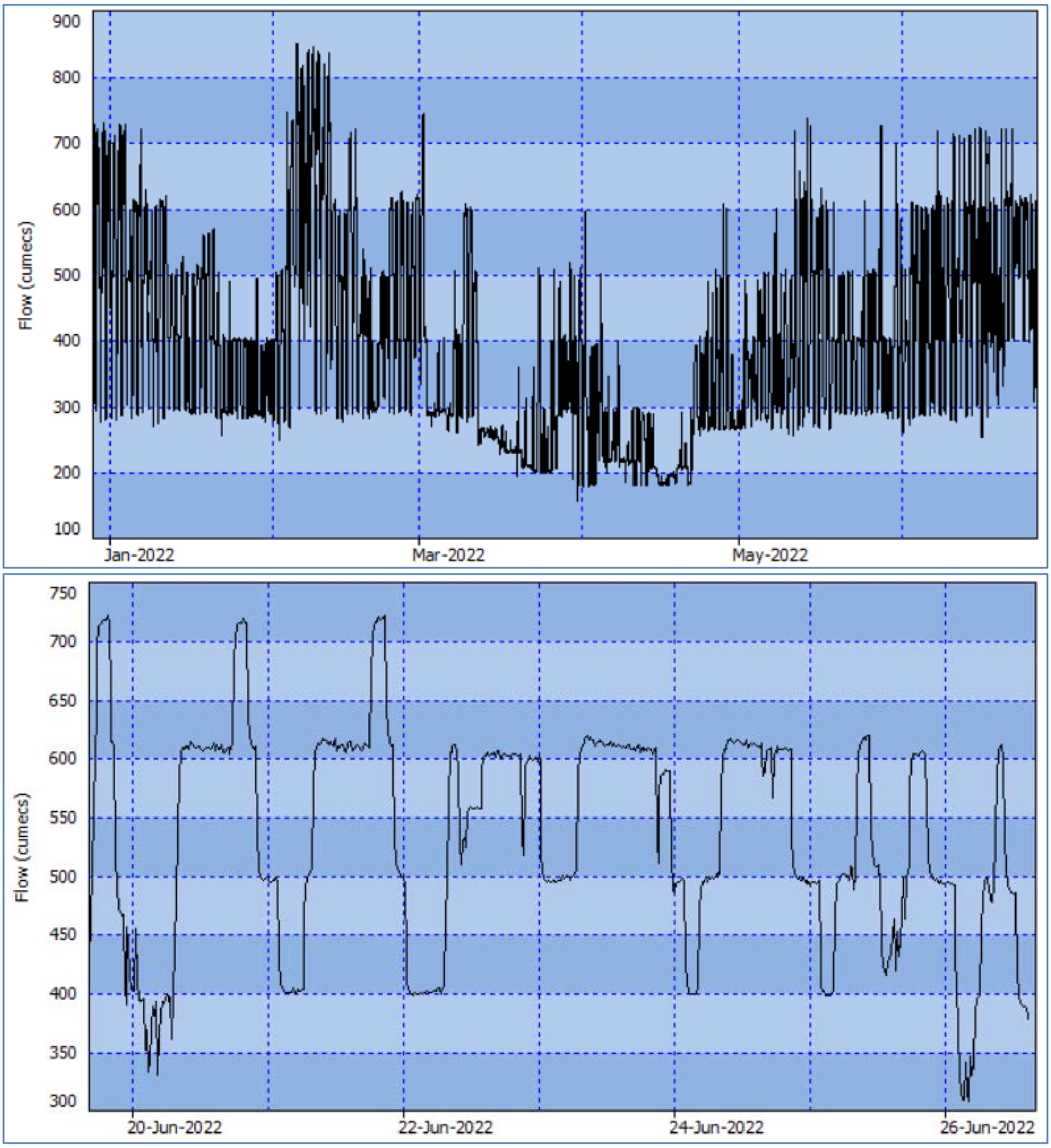


Figure 2-4: River flows measured in the lower Clutha River. The flow data are from gauge 'Below Roxburgh Dam' in 180 days to 26 June 2022 (top) and 7 days to 26 June 2022 (bottom).

There are several previous NIWA reports relating to the flow regime of the lower Clutha. Many of these were commissioned by Contact Energy (e.g., Butler et al. 2011), the Electricity Corporation of New Zealand (ECNZ), such as Goring (1993) and Jowett (1995), or Otago Regional Council (e.g., Henderson 1999). In addition, several reports have been commissioned during feasibility studies for dams at Beaumont and Tuapeka (e.g., Mackay 1995). Many of these reports, however, are marked as confidential and require permission for use of the information contained therein. Lower in the catchment, several reports focus on the intertidal regime and hydrological interactions (Smart 2005 and 2006).

WSP-OPUS (2018) showed that flows at Roxburgh Dam and Balclutha (25% larger catchment area) exhibited similar variability (albeit 10–15% larger at Balclutha). The 1000-year event was estimated to be 5850 m^3/s at Balclutha (based on observed data and a generalised extreme value distribution). It was also noted that flows as low as 37 m^3/s have been observed at Balclutha (lower quartile 398.8 m^3/s).

River flow variability in the Clutha is relatively large due to its size, shape and location relative to the rain shadow of the Southern Alps. Flows may be sustained by rainfall in the upper catchment for example even when there is a relative drought in the middle catchment. Conversely, weather fronts from the east may result in rainfall in the lower catchment but no rainfall in the upper and middle catchment. As a result of the frequent 'disconnect' between upper and lower catchment flows, it can be difficult to characterise the drought risk condition of the river at any one time. Taylor and Bardsley (2019) addressed this issue by derivation of a drought index based on flows from Hāwea and flows observed downstream of Roxburgh Dam which allowed consideration of the impact of lower spring and summer flows from Hāwea after the damming of Lake Hāwea.

3 Water quality

Publications and grey literature with assessments of water quality in the Clutha downstream of Roxburgh Dam are very scarce. However, river water quality has been monitored since 1989 at two National River Water Quality Network (NRWQN) sites: Clutha River at Millers Flat and Clutha River at Balclutha. Data from these sites, up to December 2020, are summarised (Table 3-1) and time series are presented in Figure 3-1.

Table 3-1: NIWA National River Water Quality Network monitoring data for the Clutha River up to 16 December 2020.

Council site ID	Measurement	Unit	Mean	Median	Minimum	Maximum	n	Start date	End date
Clutha @ Millers Flat	Clarity	m	1.99	1.80	0.05	5.95	377	2/02/1989	14/12/2020
Clutha @ Millers Flat	Dissolved reactive phosphorus	mg/L	0.001	0.001	0.000	0.016	377	2/02/1989	14/12/2020
Clutha @ Millers Flat	*E. coli*	/100 mL	39	12	0	2419	187	15/02/2005	14/12/2020
Clutha @ Millers Flat	Ammoniacal nitrogen	mg/L	0.004	0.003	0.000	0.026	365	2/02/1989	14/12/2020
Clutha @ Millers Flat	Nitrate and nitrite nitrogen	mg/L	0.037	0.034	0.007	0.203	377	2/02/1989	14/12/2020
Clutha @ Millers Flat	Total nitrogen	mg/L	0.096	0.089	0.040	0.483	360	2/02/1989	14/12/2020
Clutha @ Millers Flat	Total phosphorus	mg/L	0.010	0.006	0.002	0.213	374	2/02/1989	17/11/2020
Clutha @ Millers Flat	Turbidity	NTU	4.25	1.90	0.28	120.00	377	2/02/1989	14/12/2020
Clutha @ Balclutha	Clarity	m	1.46	1.26	0.03	5.93	386	25/01/1989	16/12/2020
Clutha @ Balclutha	Dissolved reactive phosphorus	mg/L	0.002	0.001	0.000	0.032	386	25/01/1989	16/12/2020
Clutha @ Balclutha	*E. coli*	/100 mL	196	39	2	2613	188	9/02/2005	16/12/2020
Clutha @ Balclutha	Ammoniacal nitrogen	mg/L	0.005	0.004	0.000	0.034	373	25/01/1989	16/12/2020
Clutha @ Balclutha	Nitrate and nitrite nitrogen	mg/L	0.092	0.053	0.002	0.748	386	25/01/1989	16/12/2020
Clutha @ Balclutha	Total nitrogen	mg/L	0.184	0.134	0.045	1.255	373	25/01/1989	16/12/2020
Clutha @ Balclutha	Total phosphorus	mg/L	0.017	0.009	0.002	0.558	386	25/01/1989	16/12/2020
Clutha @ Balclutha	Turbidity	NTU	5.90	2.85	0.30	135.00	386	25/01/1989	11/11/2020

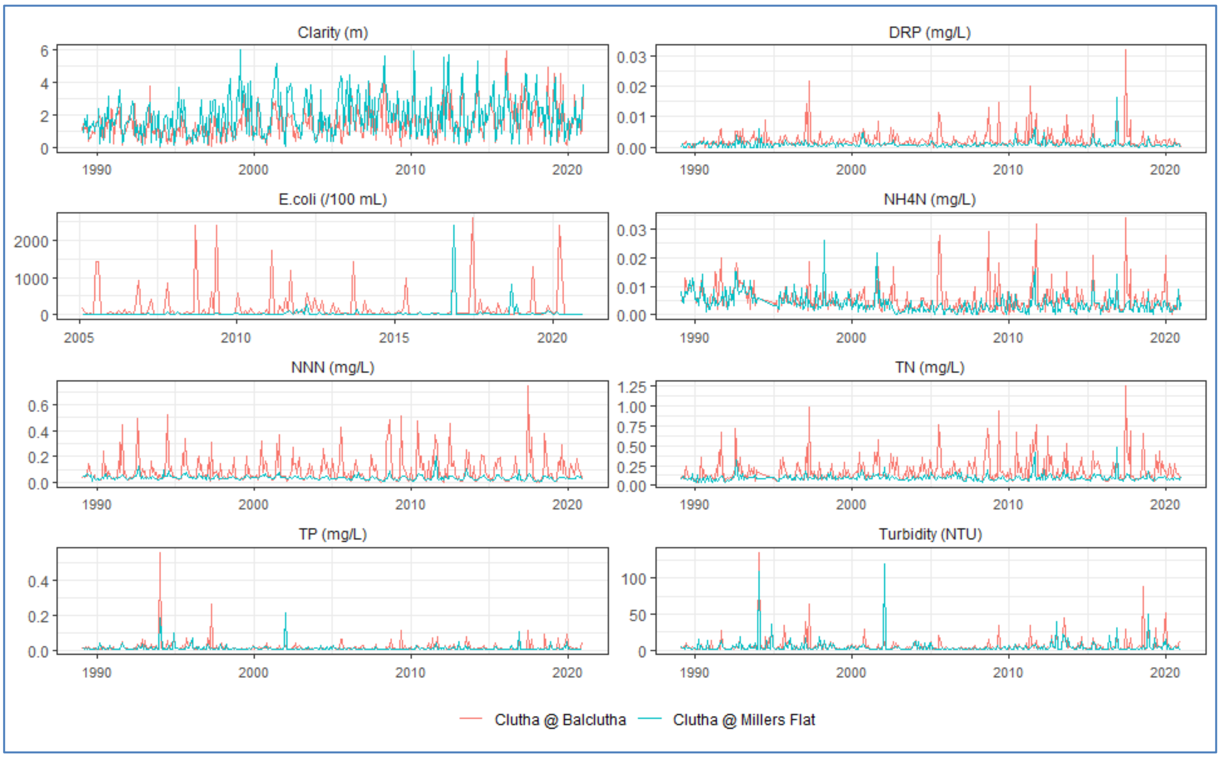


Figure 3-1: Time series of water quality monitoring data at two sites on the Clutha River from 1989 through 2020. Measurements include water clarity, dissolved reactive phosphorus (DRP), E. coli, ammoniacal nitrogen (NH4N), nitrate and nitrite nitrogen (NNN), total nitrogen (TN), total phosphorus (TP), and turbidity.

Table 3-1 summarises monitoring results published by Land Air Water Aotearoa (LAWA, lawa.org.nz), also within the context of attribute bands in the National Policy Statement for Freshwater Management (NPS-FM 2020).

Table 3-2: LAWA water quality monitoring results, NPS-FM attribute bands and 5-year trends for two sites on the lower Clutha River. There are no NPS-FM attribute bands for turbidity, total nitrogen, total oxidised nitrogen, total phosphorus in rivers (marked as n/a).

Council site ID	Measurement	5-year median	State	Attribute band	5-year trend
Clutha @ Millers Flat	*E. coli*	10/100 mL	In the best 25% of sites	A	Likely degrading
Clutha @ Millers Flat	Clarity	2.19 m	In the best 25% of all sites	D	Very likely degrading
Clutha @ Millers Flat	Turbidity	1.805 NTU	In the beset 50% of all sites	n/a	Very likely degrading
Clutha @ Millers Flat	Total nitrogen	0.085 mg/L	In the best 25% of all sites	n/a	Likely improving
Clutha @ Millers Flat	Total oxidised nitrogen	0.0315 mg/L	In the best 25% of all sites	n/a	Likely degrading

Council site ID	Measurement	5-year median	State	Attribute band	Trend
Clutha @ Millers Flat	Ammoniacal nitrogen	0.003 mg/L	In the best 25% of all sites	A (toxicity)	Indeterminate
Clutha @ Millers Flat	Nitrate nitrogen	Not assessed	Not assessed	Not assessed	Not assessed
Clutha @ Millers Flat	Dissolved reactive phosphorus	0.0005 mg/L	In the best 25% of all sites	A	Very likely improving
Clutha @ Millers Flat	Total phosphorus	5 mg/L	In the worst 25% of all sites	n/a	Likely degrading
Clutha @ Balclutha	*E. coli*	31.45/100 mL	In the best 25% of all sites	D	Indeterminate
Clutha @ Balclutha	Clarity	1.74 m	In the best 50% of all sites	D	Very likely degrading
Clutha @ Balclutha	Turbidity	3.515 NTU	In the worst 50% of all sites	n/a	Very likely degrading
Clutha @ Balclutha	Total nitrogen	0.12 mg/L	In the best 25% of all sites	n/a	Very likely degrading
Clutha @ Balclutha	Total oxidised nitrogen	0.056 mg/L	In the best 25% of all sites	n/a	Very likely degrading
Clutha @ Balclutha	Ammoniacal nitrogen	0.003 mg/L	In the best 25% of all sites	A (toxicity)	Likely degrading
Clutha @ Balclutha	Nitrate nitrogen	Not assessed	Not assessed	Not assessed	Not assessed
Clutha @ Balclutha	Dissolved reactive phosphorus	0.0011 mg/L	In the best 25% of all sites	A	Likely improving
Clutha @ Balclutha	Total phosphorus	0.007 mg/L	In the best 25% of all sites	n/a	Very likely degrading

The data collected from the Clutha at Millers Flat, a lowland forest site, indicate excellent water quality. The data collected from the Clutha at Balclutha, a lowland rural site at the bottom of the Clutha catchment, also indicate overall excellent water quality, except for water clarity and *E. coli* concentrations at Balclutha. Five-year trends of several attributes at both sites indicate that water quality is degrading but that conditions are improving with respect to dissolved reactive phosphorus.

Apart from the NRWQN data summarised above, we only found one report focused on water quality in the lower Clutha River. Davies-Colley (1985) stated that lower Clutha water was of “moderately high turbidity (low clarity) associated with fine-grained suspended sediment.” The author postulated that, since there are no sizable inflows below Roxburgh Dam, water quality in the lower Clutha is largely determined by the generally high water quality in Lake Roxburgh. Davies-Colley (1985) cited a report by the Otago Catchment Board (1981), which described the lower Clutha as having high water quality (with near-saturation dissolved oxygen, very low biochemical oxygen demand and low nutrient levels, low faecal coliform concentrations). Note that *E. coli* concentrations are currently elevated at Balclutha (NPS-FM D band). The water was described as soft calcium-bicarbonate water due to low conductivity, low calcium, and low magnesium concentrations. pH was always acceptable (ranging 6–9).

Water quality in the lower Clutha highly depends on water quality in its main water source, Lake Roxburgh. Davies-Colley (1985) cited Biggs and McBride (1981), who identified phytoplankton growth in the lake as phosphorus-limited, based on N:P ratios. The lower Clutha water has been described as milky bluish-green and not ideal for swimming and contact recreation because clarity is often lower than the commonly adopted criterion of 1.2 m (Hart 1974, cited in Davies-Colley 1985). Relatively high turbidity has been attributed to fine suspended solids (consistent with lower Secchi depth in Lake Roxburgh) and is partly natural due to glacial sediments and partly due to legacy sediments from gold mining and other anthropogenic activities (Hicks et al. 2000). The nutrient status of the lower Clutha was oligotrophic according to Davies-Colley (1985) and Biggs and McBride (1981).

4 Periphyton and macroinvertebrates

Davies-Colley (1985) stated that there was not much algal growth in the lower Clutha and that the algal assemblage was dominated by diatoms (*Melosira* spp., *Fragilaria* spp.). Periphyton cover has been visually assessed approximately monthly at the two lower Clutha sites (Millers Flat and Balclutha) as part of NRWQN monitoring since 1990. Cover estimates have increased since the invasion of the diatom *Didymosphenia geminata* (didymo, discovered in the lower Clutha in 2006). Didymo has since become established in the entire river (ORC 2007). We are not aware of any periphyton biomass time series (chlorophyll *a* per unit area).

Macroinvertebrates have been sampled annually (usually in February or March) in the Clutha River at Millers Flat as part of NRWQN monitoring since 1990. The macroinvertebrate community index (MCI) is an attribute included in the NPS-FM to assess ecosystem health in wadeable rivers. Based on records spanning 1990 to 2019, the mean MCI for the Clutha at Millers Flat is 84.3, the median is 86.0, the minimum is 50.0 (March 1995) and the maximum is 99.3 (April 2007). Based on the 5-year period spanning 2015–2019, the minimum (77.6), median (80.0), mean (81.4), and maximum (86.0) MCI values all fall below the national bottom line (90), classifying the site in the D band: “Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.” High turbidity due to fine suspended sediments has been suspected to impair some water uses and this may limit periphyton and macroinvertebrate presence and diversity. In addition, the establishment of didymo often results in degraded macroinvertebrate communities and thus lower MCI scores.

5 Fish and fisheries

5.1 Character and flow of the mainstem river

The extent of the tidal influence on the Clutha is not well understood but based on changes in the observed ecosystems within the Koau and Matau Branches, the saltwater wedge is thought to extend to just downstream of Kaitangata in the Matau Branch and approximately the equivalent distance in the Koau Branch (~5–6 km). However, the tidally influenced reach, where fresh water is held back by tidal water levels, is thought to extend potentially as far as 20–25 km upstream, although further investigations are required to confirm the tidal influence (ORC 2016).

From Roxburgh to Balclutha, the river is relatively deep and swift, with limited marginal littoral zones. Banks are often colonised by willows, making access difficult. Consequently, the mainstem river has received relatively little attention from fisheries researchers, and most records of freshwater fish are from the tributaries. A report on the native fish of the lower river (Glova et al. 2000) concluded "In general, the mainstem of the Clutha River provided relatively little suitable habitat for native fish. More favourable habitat for this fauna tended to occur in the cobble/boulder-bedded confluences of the tributaries with the Clutha River". Further, the survey found that "with exception of common smelt, there is not much suitable habitat and relatively little change in the amount of habitat for native fish in the Clutha River with flows between 100 and 500 m^3/s". For common smelt, there was considerable habitat at low flows (say, 100–300 m^3/s), but this decreased rapidly with increasing flow (note that common smelt are almost entirely confined to the tidally influenced reach of the river).

5.2 Fish species recorded

5.2.1 Native species

There are several reports of freshwater fish present below Roxburgh. An initial report by Jellyman (1984) was compiled from the Freshwater Fish Database, supplemented by local knowledge and records; Pack and Jellyman (1988) carried out field studies from Roxburgh to Tuapeka mouth, while Glova et al. (2000) used a combination of previous studies supplemented by field sampling. A summary of results (Table 5-1) indicates that 12 species of native fish have been recorded from the mainstem river, and an additional two species from tributaries. With the exception of upland bully, common river galaxias[1], and roundhead galaxias, all native species are diadromous (require access to the sea to complete their life history), meaning that those diadromous species recorded from tributaries but not the mainstem river (e.g., kōaro, giant kōkopu) must have passed through the mainstem while en route to tributaries. Thus, while the mainstem river has a more limited assemblage of native species, it does provide a thoroughfare for the many diadromous species. While common bully is normally a diadromous species, and newly hatched larvae get swept out to sea before returning as juveniles some months later, examination of otolith (ear bone) microchemistry has shown that a proportion of this species is able to carry out the whole of its life history within the Clutha River, with larvae remaining in the tidally affected reach (Closs et al. 2003). This species, together with common smelt and kōaro, has also formed lake-limited populations in the natural and hydro lakes of the Clutha catchment.

[1] Common river galaxias was a species name used >20 years ago to describe what is now known to be a suite of genetically distinct species.

Table 5-1: Freshwater fish recorded from the mainstem Clutha River below Roxburgh, and tributaries. The italicised term reflects a species name that is now known to represent a suite of genetically distinct species. The species 'roundhead galaxias' did not exist in 1988 and a roundhead galaxias would have been recorded as common river galaxias.

Species	Jellyman 1984			Pack and Jellyman 1988			Glova et al. 2000	Freshwater Fish Database		
	Main river	Tributaries	Lake Roxburgh	Main river	Tributaries	Lake Roxburgh		Main river	Tributaries	Lake Roxburgh
Native species										
Lamprey	Y	Y		Y	Y				Y	
Shortfin eel	Y	Y		Y	Y				Y	
Longfin eel	Y	Y	Y	Y	Y	Y		Y	Y	Y
Common smelt	Y							Y		
Īnanga	Y	Y						Y		
Kōaro		Y			Y	Y	Y		Y	Y
Giant kōkopu		Y							Y	
Common river galaxias					*Y*					
Roundhead galaxias							Y			
Torrentfish		Y			Y		Y		Y	
Common bully	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Redfin bully							Y			
Upland bully		Y	Y	Y	Y	Y			Y	Y
Black flounder	Y									
Introduced species										
Brown trout	Y	Y	Y	Y		Y	Y	Y	Y	Y
Rainbow trout	Y	Y	Y	Y		Y		Y	Y	Y
Chinook salmon	Y	Y	y	Y		y		Y	Y	y
Perch		Y	y	Y		Y		Y	Y	y

The assemblage is not quite as diverse as that of nearby rivers, with an absence of fish like bluegill bullies, giant bullies, banded kōkopu. While this will in part reflect the difficulty of sampling the mainstem, it will also be due to unsuitable habitat – many native species are cryptic, edge-dwelling, and adapted to shallow marginal (often slow-flowing) habitats, and these are largely absent in the lower river. So, while a reasonable variety of native species has been recorded in the lower river, there is general agreement that the density of these fish is low (e.g., Jellyman 1984; Mitchell and Davis-Te Maire 1996, Glova et al. 2000). Of zoogeographic interest is the limited distribution of roundhead galaxias, being confined to the Clutha and Taieri catchments.

5.2.2 Introduced species

Four species of introduced fish have been recorded from the lower Clutha River: brown and rainbow trout, Chinook salmon, and perch. The latter are largely confined to small ponds (e.g., Pinders Pond near Roxburgh) and the lower reaches of the mainstem (above saline influence) and are relatively unimportant as a sports fish. Rainbow trout are not common, being a species more associated with the inland lakes and tributaries. In contrast, brown trout are ubiquitous, occurring throughout the lower river. Diadromous ("searun") brown trout are known from the lower reaches of the river, especially below the confluence with the Pomahaka, and constitute an important seasonal fishery.

Although there are landlocked stocks of Chinook salmon in the hydro and upper Clutha lakes, the salmon below Roxburgh are all diadromous, i.e., moving to the ocean as juveniles before returning as adults. Generally, returning adult salmon are 2 or 3-year-old fish, but fish as old as 6 years have been recorded in the Clutha, as these fish have spent their 2 or 3 years in the Clutha lakes before going to sea (Pack and Jellyman 1998).

5.3 Fisheries

5.3.1 Whitebait

The Clutha River has been regarded as the most important recreational and commercial whitebait fishery in the Otago region, with catch rates being consistently higher than those from other rivers in the district (Kelly 1988). Like other east coast South Island rivers, the catch is dominated by īnanga (McDowall 1965). Catches can be significant with some fishers reporting up to 70 kg on a good day (Glova et al. 2000). Īnanga tend to spawn in the less flood-prone, lowland tributaries, than along the banks of major rivers like the Clutha, and Taylor et al. (1992) noted that the main stem of the lower Clutha River appeared to have relatively little suitable habitat for īnanga spawning. Īnanga do not "home" to the river they were born in (Hickford and Schiel 2016), so the Clutha benefits from īnanga spawning in nearby rivers.

5.3.2 Eels

The Clutha River is an important commercial and customary fishery for both native eel species (Beentjes 2000). "The mean length of commercial catches of longfins are smaller than shortfins, reflecting heavy fishing pressure on longfins" (Beentjes 2000). Shortfins are mainly distributed near the coast and are relatively unaffected by hydro development but are affected by loss of wetland habitat in the lower reaches. In contrast, longfins are distributed throughout the Clutha River catchment and are significantly affected by hydro development. "Roxburgh Dam has restricted elver and juvenile upstream migration since it was built in 1958, and only a small remnant population of longfin females remain in the headwater lakes (Lakes Wānaka, Hāwea and Wakatipu). The fishery in these lakes (commercial and customary) is therefore a diminishing resource" (Beentjes 2000).

A mahinga kai survey of the Clutha catchment (Mitchell and Davis-Te Maire 1996) focused mainly on longfin eels, and the negative impacts of hydro and river control works.

5.3.3 Trout

The Clutha catchment is the most popular angling catchment in the Otago Fish and Game region, accounting for almost 76% of the total fishing effort (Unwin 2016). The effort expended in the mainstem below Roxburgh is comparable to that on the lower Waitaki River (Table 5-2).

Fish and Game describe the river as a "very large river, predominately single-channelled with gravel and cobble beaches. Some sections are fast-flowing, lined with bedrock and quite gorgy, particularly between Millers Flat and Tuapeka Mouth. The section between Tuapeka Mouth and Balclutha is quite attractive to the angler with a medium gradient, wide open riffles and runs and well-defined pools, especially when the river flows are low (less than 400 m^3/s)". "Small brown trout (0.5 kg) are plentiful throughout the lower river and tend to make up the bulk of the angler's catch. There are larger resident fish present (1–2 kg) [...] and seasonal migrations of searun brown trout which average 2–3 kg […] returning Chinook salmon average 2–6 kg."[2]

The results of a survey of experienced anglers of their perceptions of change in lowland river fisheries indicated a perceived decline in angling quality and numbers and size of fish in the lower Clutha, but these changes were less than those for the Clutha catchment as a whole (Jellyman et al. 2002).

Table 5-2: The estimated number of angler-days per year spent fishing for salmon and trout in the lower Clutha catchment. Recorded in the 2014/15 National Angling Survey (Unwin 2016). Comparative data given for some Clutha lakes and lower Waitaki River.

Catchment	Target species	Angler days/year
Mainstem lower Clutha	Salmon	6760
	Trout	16760
Lower Clutha tributaries and lakes	Not specified	5930
Mainstem river above Roxburgh	Not specified	8030
Lake Wanaka	Not specified	23740
Lake Dunstan	Not specified	17290
Lake Roxburgh	Not specified	1420
Lower Waitaki River	Salmon	9560
	Trout	16680

5.3.4 Chinook salmon

Prior to the building of Roxburgh Dam, salmon traversed the length of the Clutha River and could be found spawning as far upstream as the tributaries of Lakes Wānaka and Hāwea (Jellyman 1984). The Clutha is the most southerly of the recognised salmon rivers, and salmon continue to arrive each spring and summer, albeit in much smaller numbers than before construction of Roxburgh Dam. Today, salmon fishing is concentrated near the mouth, but also in the reach immediately below Roxburgh Dam. Surveys have found little suitable spawning gravel in this area (James 1995), and any

[2] https://fishandgame.org.nz/otago/freshwater-fishing-in-new-zealand/fishing-locations-and-access

spawning in this area has limited success, especially when redds (salmon "nests") are laid in areas subject to daily dewatering.

5.4 Factors impacting fish distributions and fisheries

5.4.1 Bed configuration and flow

The lower Clutha River is a rather hostile environment for native fish. There is limited stable and shallow littoral habitat, partly due to the confinement of the river into a single incised channel, and the water is swift and subject to daily level variations resulting from hydro operations. Marginal willows provide good cover for longfin eels but poor cover for other species. There is general agreement that the absence of suitable instream cover is a primary reason for the low densities of native fish in the lower river (Jellyman 1984, Glova et al. 2000). In addition, the invasive diatom *Didymosphenia geminata* discovered in the lower Clutha in 2006 now infests the entire river and has a negative impact on fish communities (Jellyman et al. 2016).

5.4.2 Hydro impacts

Prevention of upstream fish passage

Roxburgh Dam is an impassable barrier to all fish seeking to migrate upriver past this point. Among the native fish are juvenile eels and adult lampreys, and possibly minor numbers of juvenile kōaro, although landlocked populations of kōaro do exist above the dams. Migrating elvers appear at the Roxburgh Dam generally between January and February (Jellyman 1977), whereas lampreys arrive earlier and have been noted to be abundant by late October (Jellyman and Robinson 1997). To facilitate upstream passage of juvenile eels, an elver pass was installed in 1996, but numbers of elvers caught annually are small (average 4,100, range 100–13,800; Martin and Bowman 2016; and range 0–8,710 in 2015–2018; Crow et al. 2020) – such numbers are very low in comparison with the annual catch of 2–4 m elvers at Karapiro dam on the Waikato River (Karapiro is a comparable distance upstream, i.e., 152 km upstream compared with 132 km for Roxburgh). There is evidence of declining recruitment of glass eels to New Zealand as a whole (Jellyman et al. 2009), so small numbers of elvers at Roxburgh Dam are more likely to reflect this trend, rather than a result of hydro operations on the river.

Flow fluctuations

Roxburgh Dam is operated as a peak load station, and daily flow fluctuations are typically 300–650 m^3/s but can range from 200 to 850 m^3/s over longer time periods (as shown **Error! Reference source not found.**). While such variation is attenuated with distance downstream, there are reports of daily level fluctuations at Millers Flat of 2 m (Young and Foster 1986). Not only do such diel flow variations dewater much of the bankside littoral zone, but they also promote bank erosion. Conclusions from a study of fluctuating flow effects on aquatic life (Jowett and Dungey 2000) were "that there is reason for concern over hydro-peaking flow regimes. They have the potential to impair benthic invertebrate production, the supply of invertebrate drift, fish habitat, fish feeding opportunities, and spawning". Within the operating consents for Roxburgh, some provision has been made to prevent dewatering of salmon redds and to enhance īnanga spawning in the lower river.

Being a large and versatile fish, brown trout are somewhat less impacted by flow fluctuations, although their general small size probably reflects the overall paucity of suitable food in the lower river. Searun brown trout that enter the river to spawn, are an exception, as most of their life is spent at sea where food is more plentiful. Migrating adult salmon are the least affected species, as they are powerful upstream swimmers and do not feed in fresh water; however, like trout, their spawning success in the mainstem is limited due to possible dewatering of redds and suitable spawning substrate.

Turbine mortality

Downstream migrating fish in the upper catchment need to negotiate Clyde and Roxburgh dams. There have been no studies of the impact of this, but of most concern is the annual seaward migration of maturing longfin female eels as passage through the turbines is generally fatal (Mitchell and Davis-Te Maire 1996). At present, Contact Energy maintains a catch-and-carry system to catch as many silver (migrant) eels as possible from the source lakes and liberate them below Roxburgh Dam (Egan and Rose 2022).

6 Summary

The hydrology of the lower Clutha is predominantly controlled by inflows from the upper lakes (Wakatipu, Wānaka and Hāwea) which provide approximately 75% of the flow seen downstream and Balclutha. However, the flow regime is heavily influenced by the hydro-power stations at Clyde and Roxburgh Dams. The flow regime is well documented with flow records at four locations between Roxburgh Dam and Balclutha dating back to 1954. The flow regime downstream of Roxburgh Dam can range from 100 to 1965 m^3/s, with flows often varying between 400 and 600 m^3/s within a single day.

The water quality in the lower Clutha is described as excellent (Land Air Water Aotearoa, lawa.org.nz), based on approximately monthly monitoring at two sites (Clutha River at Millers Flat and Clutha River at Balclutha) since 1989 (National River Water Quality Network). The 5-year median values of ammoniacal nitrogen, nitrate nitrogen, and dissolved reactive phosphorus for both sites fall into the NPS-FM A band (highest grade), while the 5-year medians for water clarity and *E. coli* (*E. coli* at Balclutha) fall into the NPS-FM D band (lowest grade, below the national bottom line).

Periphyton used to be dominated by diatoms, until the invasive species *Didymosphenia geminata* was discovered in the lower Clutha in 2006 and has since become established in the entire river. Macroinvertebrate monitoring data from Millers Flat indicate low MCI scores (NPS-FM D band, below the national bottom line). Fine suspended sediments and low water clarity (milky bluish-green water colour) may be a reason for limited periphyton and didymo biomass is often associated with having a negative impact on macroinvertebrate diversity.

The lower Clutha has a native fish assemblage typical of that of an East Coast (South Island) river. The present list of species recorded may be incomplete due to limited sampling within the main river. However, the abundance of fish is relatively low, mainly due to the lack of suitable habitat resulting from the varying flow regime from Roxburgh Dam, but also loss of wetlands and bank instability in the lower reaches of the river. Despite these limitations, the lower river supports an important recreational trout and salmon fishery, although the upstream distribution of salmon is curtailed by Roxburgh Dam. The whitebait fishery is considered the most important recreational and commercial whitebait fishery in the Otago region. Longfin eels support an important commercial fishery and probably a small customary fishery, but recruitment to the catchment is low, resulting in limited upstream transfers of juvenile eels past Roxburgh Dam.

7 References

Beentjes, M.P. (2000) Clutha River eel fishery and the effects of hydro activity. NIWA Client Report CHC00-48.

Biggs, B.J., McBride, G.B. (1981) An assessment of the possible effects on the proposed Luggate and Queensberry Hydro-electric impoundments on the water quality of the Upper Clutha River. Water Quality Technical Summary Report No. 2, Clutha Valley Development Environmental Impact Report. April 1980. NZE, MWD. 10 p.

Butler, M.J., Lodge, S., Walter, K.M. (2009) Contact Energy hydrological stations quarterly report:1 July - 30 September 2009. NIWA Client Report CHC2009-195.

Closs, G.P., Smith, M., Barry, B., Markwitz, A. (2003) Non-diadromous recruitment in coastal populations of common bully (*Gobiomorphus cotidianus*). *New Zealand Journal of Marine and Freshwater Research, 37:* 301-313.

Crow SK, Jellyman PG, Martin ML, Bowman E 2020. Recruitment of freshwater eels, 1995–2018. New Zealand Fisheries Assessment Report Prepared for the Ministry for Primary Industries 120 p.

Davies-Colley, R.J. (1985) Water quality of the lower Clutha River - Assessment of the potential water quality impact of proposed hydro-electric development: 42.

Egan, E., Rose, A. (2022) Migrant eel trap-and-transfer in the Clutha Mata-au Catchment Memo of data for the 2020/21 season. NIWA Client Report 2022052CH. 19 p.

Glova, G., Jowett, I., Taylor, M., Sykes, J. (2000) A report on native fish stocks and the whitebait fishery in the Clutha River catchment below the Roxburgh Power Station. NIWA Client Report: CHC00/44

Goring, D.G. (1993) Estimate for Upper Clutha Flow Forecasting System, New Zealand Freshwater Miscellaneous Report No. 133, prepared for ECNZ.

Henderson, R.D. (1999) Inflows to Clutha Lakes October/November 1999, NIWA Consultancy Report CHC00/16, prepared for Otago Regional Council.

Hickford, M.J.H., Schiel, D.R. (2016) Otolith microchemistry of the amphidromous *Galaxias maculatus* shows recruitment to coastal rivers from unstructured larval pools. *Marine Ecology Progress Series 548*:197-207.

Jellyman PG, Harding JS 2016. Disentangling the community-wide impacts of didymo (*Didymosphenia geminata*): how are higher trophic levels affected? Biological Invasions 18: 3419-3435.

Jellyman, D.J., Booker, D.J., Watene, E. (2009) Recruitment of glass eels (*Anguilla* spp.) in the Waikato River, New Zealand. Evidence of declining migrations? Journal of Fish Biology 74: 2014 – 2033.

Jellyman, D.J., Unwin, M.J., James, G.D. (2002) Anglers perceptions of the status of lowland rivers and their trout fisheries throughout New Zealand. NIWA Technical Report 122, 61p.

Jellyman, D.J., Robinson, M. (1997) Lampreys on the move. NIWA Water and Atmosphere 5(4): 5.

Jellyman, D.J. (1984) Distribution and biology of freshwater fish in the Clutha River. MAF Fisheries Environmental Report No. 46.

Jellyman, D.J. (1977) Summer upstream migration of juvenile freshwater eels in New Zealand. *New Zealand Journal of Marine and Freshwater Research 11*: 61-71.

Jowett, I.G. (1995) Assessment of Flow Requirements for the Clutha River, NIWA Consultancy Report ELE60209, prepared for ECNZ.

Jowett, I.G., Dungey, R.G. (2000) Effect of varying flows on benthic invertebrate and salmonid habitat in the Clutha River below Roxburgh Power Station. NIWA Client Report COE00224.

Kelly, G.R. (1988) An inventory of whitebaiting rivers in the South Island. Freshwater Fisheries Centre. New Zealand Freshwater Fisheries Report No. 101.

McDowall, R.M. (1965) The composition of the New Zealand whitebait catch, 1964. New Zealand Journal of Science 8: 285-300.

McDowall, R.M., Eldon, G.A. (1980) The Ecology of Whitebait Migrations (Galaxiidae: *Galaxias* spp.). New Zealand. Fisheries Research Bulletin No. 20.

McDowall, R.M. (1990) New Zealand Freshwater Fishes: A natural history and guide. Heinemann Reed Wellington.553 p.

Mackay, (1995) Downstream effects of a proposed Hydro-electric Dam at Tuapeka, Clutha River, NIWA Consultancy Report WOR505, prepared for ECNZ.

Mager, S., Horton, S. (2018) The Hydrology of Southern New Zealand in Strack et al. (eds), Riverscapes - Research essays on the social context of southern catchments of Aotearoa New Zealand, University of Otago, Dunedin.

Martin, M.L., Bowman, E. (2016) Recruitment of freshwater eels 1995–2015 New Zealand Fisheries Assessment Report 2016/46. 102 p.

Mitchell, C.P., Davis-Te Maire, K.T.A. (1996) Mahinga kai survey of the Clutha River system. Report to Contact Energy. 124 p.

Hicks, D.M., Walsh, J.M., Duncan, M.J. (2000) Clutha River sediment budget. NIWA Client Report COE00501, prepared for Contact Energy.

Otago Regional Council (2007) Didymo in Otago: A Summary. Otago Regional Council 1-877265-53-5

Otago Regional Council (2016) Natural Hazards on the Clutha Delta, Otago. Otago Regional Council May 2016. 137 pp.

Pack, Y.M., Jellyman, D.J. (1988) Fish stocks and fisheries of the lower Clutha River. New Zealand Freshwater Fisheries Report No. 98.

Smart, G., Duncan, M., Bind, J. (2005) Clutha Delta flood hazard study, NIWA Consultancy Report CHC05/14, prepared for Otago Regional Council.

Smart, G., Bind, J. (2006) Clutha Delta flood protection, NIWA Consultancy Report CHC06/21, prepared for Otago Regional Council.

Taylor, M., Bardsley, E. (2019) A hydrological drought index for the Clutha catchment, New Zealand. Journal of Hydrology (New Zealand), 58(1), 47-56.

Taylor, M.J., Buckland, A.R.; Kelly, G.R. (1992) South Island inanga spawning surveys. 1988-1990. New Zealand Freshwater Fisheries Report No. 133. 69 p

Unwin, M.J. (2016) Angler usage of New Zealand lake and river fisheries. Results from the 2014/15 National Angling Survey. NIWA Client Report 2016021CH. 143 p.

WSP-OPUS (2018) SH8 Beaumont Bridge replacement – Hydrological Assessment (www.wsp-opus.co.nz).