EVIDENCE IN CHIEF OF MORGAN TROTTER
18 MARCH 2016

1. My name is Morgan Trotter. I am a Fish and Game Officer employed by the Otago Fish and Game Council and I hold a Bachelor of Science degree with a double major in Zoology and Ecology and a Postgraduate Diploma in Environmental Science (awarded with distinction) from the University of Otago. I am currently completing a Master of Science thesis at the University of Otago studying juvenile trout movement and survival in the Lindis River. I have been trout fishing since I was a child and I have fished most rivers (including the Lindis) and lakes in Otago, and extensively throughout New Zealand.

2. I first became familiar with the Lindis River when conducting electrofishing surveys of fish populations as an Otago Regional Council Field Advisor approximately 12 years ago. I have been employed as a Fish and Game Officer with Otago Fish and Game Council for the last eleven years. For the first four years of my Fish and Game career I was based in Cromwell and during that time I conducted survey work on the Lindis including:

   - electrofishing surveys
   - bank surveys of fish numbers (in the mainstem river and irrigation channels)
   - a helicopter spawning survey of the lower Lindis and Upper Clutha Rivers.

   I also undertook several attempts to salvage stranded fish from the lower Lindis River when that river reach dried up in summer. In 2005 I conducted an assessment considering the ecological benefits of purchasing the Beggs Stackpoole mining privilege and returning the flow to the river. I concluded that there was not enough water (the take was 278 l/s, or 10 heads at that time) to provide a meaningful connecting flow, or ecological improvement.

3. Over the last two years I have spent a large amount of time (approximately 75 days) in the field studying the effects of low flows on the ecology of the lower Lindis River, (mostly downstream of the Ardgour Road Bridge) as part of my Master of Science research. This has included co-ordinating and conducting:

   - Tracking surveys to study the movements and survival of >1000 juvenile trout marked implanted passive integrated transponder (PIT) tags
   - Juvenile trout habitat preference surveys
   - Electrofishing surveys of fish populations
   - Habitat monitoring surveys (wetted area, depth, temperature monitoring and algae coverage)
   - Aquatic invertebrate inspections
   - Spotlight surveys observing night time movement of fish and habitat use

- Monitoring and measuring surface water connection patterns during low flow conditions
- Observations of native fish impacts during low flow events
- Investigations of fish predation and scavenging during low flow events
- Surveys of river birds

4. I confirm I have read and agree to apply with the Code of Conduct of Expert Witnesses (December 2014). This evidence is within my area of expertise, except where I state where I am relying on what I have been told by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Summary of evidence

5. I have been asked to assess the fishery values of the Lindis River and the anticipated impacts of various flow regimes on the ecological health of the river

6. In summary, my evidence will address:

    a. The fishery value of the Lindis River

    b. The effect of the current flow regime on the ecology of the river

    c. The anticipated impacts of a minimum flow of 450 l/s on the ecology of the river

    d. The anticipated impacts of a minimum flow of 750 l/s

    e. The anticipated impacts of a minimum flow of 1000 l/s

    f. The anticipated impacts of a minimum flow of approximately 1500 l/s

Executive Summary

- The lower Lindis River is presently being subjected to severe drought-like events on an annual basis due to high levels of abstraction. This is resulting in extremely high rates of juvenile trout mortality (approximately 70 %) during the low flow abstraction period. This mortality is primarily due to high levels of predation because of a lack of effective cover at very low flow levels.

- The idea that trout populations may avoid significant mortality during severe low flow events the by seeking refuge in residual pools simply does not work. At very low flow levels fish cover is compromised and they are subjected to high levels of predation. Fish that do die from heat stress and oxygen depletion in drying pools are quickly removed by scavengers. Because of this any dead fish observed during prolonged low flow conditions are likely to represent a small proportion of the total mortality experienced.

- A minimum flow of 450 l/s would not provide a significant improvement in fish survival due to a lack of effective cover from predation

- A minimum flow of 750 l/s would provide improved fish habitat and survival in gaining reaches, but the improvement would be reduced in losing reaches. The measuring point for the future minimum flow (Ardgour Flow recorder) is located in a gaining reach, and 750 l/s at the recorder means a lower flow for losing reaches, particularly around the Lindis Crossing, and the Ardgour Road bridge. In these areas high levels of fish predation and algal blooms could be expected.

- A minimum flow of 1000 l/s is far from ideal from an ecological point of view but it would see further improvement of fish habitat and survival. Flows at this level would be expected to provide fish passage along the lenght of the river.

Fishery values

Sport fish populations

1. The Lindis River is a major spawning and juvenile trout rearing stream that is important for juvenile trout recruitment to the nationally important Clutha River system and Lake Dunstan fisheries (Jellyman 1990, Jellyman & Bonnett 1992, ORC 2006, Otago Fish and Game Council 2015). The spawning and juvenile rearing value of the Lindis River is limited by abstraction, which can result in the drying of approximately 9 -10 km of the lower 25 km of riverbed. This results in fish strandings, and mortalities during the summer low flow period (ORC 2006, Jellyman & Bonnett 1992). The current flow regime is limiting the rivers potential for juvenile rearing and recruitment to the Upper Clutha and Lake Dunstan fisheries.

2. The lower Lindis contains predominately 0+ (young of the year) and 1+ (yearling) brown trout and rainbow trout. Brown trout are most common with rainbows representing <10% of the population. At present the river sustains a population of adult brown trout. These can reach sizes of 50 - 55 cm and approximately 2kg. The occasional fish obtains 2.5 - 3 kg. Brown trout spawning generally occurs from April to July. Adult brown trout are commonly found in areas of adult

habitat such as pools or deeper runs and especially upstream from the Lindis Crossing. Adult rainbow trout are rarely seen during the angling season but utilise the river and tributaries for spawning (Jellyman and Bonnett, 1992) which mostly occurs from May to November.

3. Generally trout fisheries with a diversity of spawning and rearing habitat across a wide geographical area have a reduced vulnerability to environmental events. Events such as flooding can adversely impact cohort (year class) recruitment success (Hayes, 1995).

4. Protection of a range of spawning and rearing habitats is therefore important for ensuring the resilience of the Upper Clutha and Lake Dunstan trout fisheries by providing recruitment despite adverse natural events.

5. Some spawning and rearing habitats in the Upper Clutha area already compromised to a degree. Significant blooms of the algae didymo (*Didymosphenia geminata*) in the Upper Clutha and Hawea River, as well as fluctuating rivers flows as a result of hydro electricity generation have degraded juvenile trout habitat. Although the Clutha River is extensive, very little of it is considered suitable habitat for rearing juvenile 0+ trout (Jellyman and Bonnett, 1992). In the Cardrona River and the Low Burn juvenile trout habitat is limited by significant water abstraction for irrigation. The compromised state of potential juvenile trout habitat across the system gives further weight to the need to protect and enhance the Lindis River in order to maintain fishery resilience and recruitment to the nationally important Upper Clutha and Lake Dunstan fisheries.

Recreational angling values

6. The Upper Clutha River and Lake Dunstan fisheries are both recognised as nationally important fisheries in their own right attracting 22,030 and 26,140 angler days respectively. (Unwin 2009a). The Upper Clutha was first identified as nationally important for angling in 1982 (Teirney LD, 1982). The national importance of Lake Dunstan and the Upper Clutha is also recognised by inclusion as a “Potential Water Bodies of National Importance for Recreation Value” (MFE, 2004), which was prepared as part of government’s ‘Water Programme of Action’.
7. These nationally important fisheries are wild and self sustaining by natural spawning and rearing in suitable locations including the Lindis River. Thus the Lindis is an integral component of the nationally important Lake Dunstan and Upper Clutha River fisheries.

8. The Lindis is also a locally important trout fishery in its own right. Even in its current state which is heavily impacted by abstraction the Lindis River has some significance as a small stream trout fishery (Figure 1 and Figure 2) accounting for some 330 angler visits during the seven month angling season (NIWA, 2009). From an angling pressure viewpoint it sustains similar levels of use to other small streams such as Dunstan Creek (360), Ida Burn (200), Kaiwera Stream (260), Waitahuna River (260), Deep Stream (210), Lee Stream (150) and Kye Burn (140) (NIWA, 2009). Small streams are an important component of the recreational opportunity spectrum in Otago (OFGC, 2015) and provide a peaceful and more secluded angling experience, which should not be underestimated through comparison with much larger waters such as the Clutha or Lake Dunstan which can accommodate many more anglers.

9. NIWA's attributes survey (Unwin 2009b) assessed eight specific attributes for 63 named rivers and streams in Otago and assessed overall importance on a 1 to 5 scale. In the Lindis River the key attributes that stood out were its proximity to holiday homes, its ease of access and its scenic values. Anticipated catch rate and fishable area were both low. This most likely reflects the impact of over allocation. Angling values can be expected to increase with the restoration of reasonable summer flows in the river.

Figure 1. Trout like this one captured in October 2015 sustain a locally significant fishery

Figure 2. A junior learning to fish on the Lindis River (December 2014) – small rivers like the Lindis can be ideal for novice anglers and are an important part of the angling spectrum.

10. The estimated naturalised (without abstraction) 7-day Mean Annual Low Flow (MALF) of the lower Lindis is approximately 1.860 m^3/s (Horrell, 2014). However, after abstraction for irrigation the actual MALF is 0.177 m^3/s (Horrell, 2014; Dale, 2008). Abstraction results in the complete drying of approximately 10 km of lower river reaches most summers (Jellyman and Bonnett, 1992), and a fragmented river corridor.

11. Surface flow reductions caused by abstraction are compounded by groundwater losses in affected reaches (ORC, 2008).

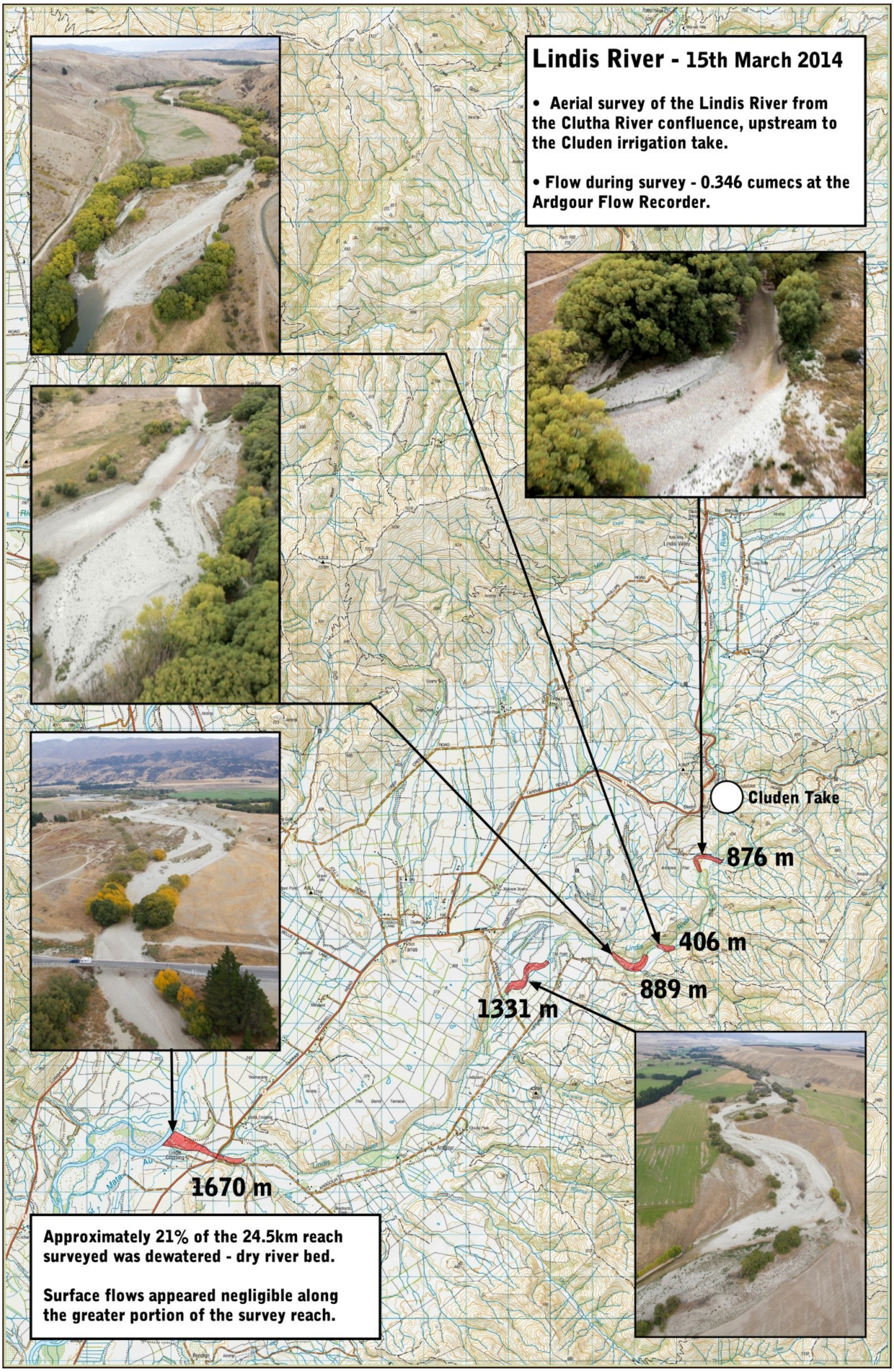

Figure 3. Clutha Fisheries Trust Aerial Survey of surface connection along the lower Lindis River, 15 March 2014

12. The hydrology of the Lower Lindis is complex with groundwatrer and surface water interactions as well as abstractions and irrigation returns. . However, the aerial observations of Clutha Fisheries Trust (CFT) on 15th March 2015 (Figure 3, above) reveal two major losing reaches, one is located around the Lindis Crossing, and one around Ardgour Road. The flow at the Ardgour Recorder on that day initially read as 346 l/s but was subsequently corrected by ORC to 278 l/s.

13. When flows at the Ardgour Recorder dropped to their lowest point during my study, which occurred around early to mid March both study years (and was approximately 220 l/s on the amended dataset) the drying reach (dry riverbed with occasional drying, stagnant pools) near the Crossing extended approxamately 2.5 km. The drying reach (dry riverbed with occasional drying, stagnant pools) downstream near Ardgour Road extended for approximately 2.4 km.

14. Mr Rekker and Mr Gabrielsson will give further evidence on the hydrology of the river.

15. The over abstraction and dewatering of habitat in the Lindis is a limiting factor for both juvenile trout production, and the adult trout fishery (see sections 54 - 56 for discussion on mortality rates).

16. From an ecological point of view it is important to set a minimum flow at a level that provides for both fish movement along the river corridor and migration to the Clutha River, and a functioning river ecosystem. A minimal surface connection in drying streams does not ensure fish passage (Magoulick and Kobza, 2003), which can be affected by shallow riffle length and predator presence (Schaefer, 2001). Meaningful flow restoration and surface connection will improve both juvenile and adult trout habitat. This would likely see a significant increase in juvenile trout recruitment, adult trout numbers, and angler participation.

Effects of current flow regime

17. To assess the effects of low flows on the aquatic ecosystem in the Lindis River I have conducted spotlighting and electrofishing surveys, habitat assessment, and have undertaken a tracking study of juvenile trout utilising PIT (passive integrated transponder) tags.

18. Since the early 1990s passive integrated transponders (PIT tags) have been used to understand the biology of fish species (Zydlewski et al., 2006). They consist of a coil of wire which generates electricity when it passes through the

electromagnetic field of a matched antenna. Each tag contains a microchip programmed with a unique number. When PIT-tagged fish swim through or in the vicinity of an antenna the date and time of passage, along with each fish's unique tag number is detected by the antenna receiver, recorded, and stored (Ombredane et al 1998, Zydlewski et al 2006).

19. PIT tag technology was employed in my study because tags are easily applied, well retained and have a minimal effect of growth and survival (Gries and Letcher, 2002, Zydlewski et al., 2006, Ombredane et al., 1998). Most importantly this technology allow the identification of individual fish and their mark/recapture in an unobtrusive manner that results in less disturbance and potential stress than repeat electrofishing (Sloat et al., 2011). To ensure the well being of sample fish, prospective PIT taggers undertook training on live fish at the Otago University, and a Professor supervised all tagging operations in the field.

20. PIT tag research was undertaken over the summer-autumn months of 2013/2014 and 2014/2015 and involved one of the most intensive field programmes conducted by Otago Fish and Game in the last 20 years. This was in order to observe changes in habitat condition and document the effects of the current flow regime on fish populations.

21. Based on field observations flows during the irrigation season may be generally divided into three ecologically relevant flow periods:
    - Spring (September to November)
    - Summer/early autumn (December to March)
    - Late autumn (April to May).

Spring (usually September to November)

22. In the spring period flows can be characterized as boisterous and variable. Residual snow melt clears, water levels trend down. There is generally significant flow variability provided by small freshes. Fish habitat is provided throughout the river in pools, runs and riffles. Water temperatures are generally cool, oxygen levels high, and algal cover levels low.

Summer/Early Autumn (usually December to March)

23. As flows drop both the area and quality of aquatic habitat decline. As water levels drop instream cover provided by turbulent water, woody debris and water

depth and or bank cover, provided by shading or draping vegetation or undercut backs is reduced and it becomes easier for predators such as shags and herons to target fish. During daylight hours juvenile 0+ trout prefer riffle habitat where turbulence provides somewhere to hide. This is most likely due to predation avoidance (from larger trout, eels, shags and herons). Water temperatures begin to rise and algal biomass begins to increase.

24. As the summer progresses flows decrease to very low levels and the river experiences increasingly adverse ecological impacts. The summer/early autumn period may be characterised by extreme low flows and lack of flow variability; flows ‘flat-line’ for several weeks or even months. Remaining surface water can diminish very quickly (Figure 4). Significant reaches of river dry up below, and near the Lindis Crossing, and upstream of the Ardgour Road Bridge (see appendix one).

Figure 4. (Above) Lindis River approximately 200 m upstream from Lindis Crossing Bridge, early March 2014; (Below) the same reach on the next morning (6 March 2014) completely dewatered.

25. Aquatic habitat becomes non-existent in many reaches and is severely degraded elsewhere. Where surface water remains flows are often negligible and in shallow open runs and pools there is little to no effective cover for fish life from predation and scavengers (shags, herons, cats etc) (Figure 4 above). Where flow continues the water depth diminishes, runs become shallow and draw away from bank vegetation, turbulence in riffles diminishes to the point where there is no

broken water. Life supporting capacity is degraded or lost due to reduced habitat area, high water temperatures in disconnected pools and in certain reaches excessive periphyton growth (Figure 6).

Late Autumn (usually April/May)

26. Reconnection of the river generally occurs in mid-late autumn when increased rainfall and reduced abstraction pressure result in increased and more variable river flows and groundwater replenishes. River depth is restored along with riffle turbulence, and in many reaches water reconnects with bankside vegetation.

27. Fish habitat is once again found along the length of river throughout pools, runs and riffles. Flushing flows capable of clearing periphyton accumulations will occur. Water temperatures cool and surviving trout can be found in riffles runs and pools.

Summary of low flow effects

Fish passage

28. To maintain a functional ecosystem for migratory salmonids longitudinal (upstream and downstream) connectivity is required to allow movement between juvenile rearing streams and adult habitats (Greenberg and Calles, 2010).

29. Fish passage and outmigration is prevented not only when complete dewatering results in a loss of surface flow connectivity, but also where flow decreased to low levels. A bare minimum of surface connection in a drying river does not provide fish passage (Magoulick and Kobza, 2003).

30. Restrictions of fish passage as a result of extreme low flows, flow diversion or complete lack of flow can delay or interfere with the timing of movement at different stages of life history and impede the ability for fish to seek refuge or alternative habitat in response to unfavourable environmental conditions (Elliott et al., 1997, Greenberg and Calles, 2010).

31. In the Lindis high levels of abstraction resulted in loss of longitudinal connection and fragmentation of the river due to dewatering of reaches during both years of my study. This prevented possible movement to refuge water such as the Clutha River, or the Upper Lindis River where there is limited abstraction.

32. The fragmentation of the river corridor resulted in fish becoming stranded in stressful habitat which was a contributing factor to the very low survival of the sample population.

33. A proportion of tagged fish moved along the remaining fragmented river corridor, presumably in an attempt to leave stressful habitat, and/or migrate to the Clutha River (Appendix 1). However, by the time they tried to move it was not possible for them to access larger potential refuge water (Clutha River or Upper Lindis) due to the drying of river reaches. A possible reason for lack of pre-emptive migration to refuge habitat is that fish fail to recognize the disturbance early enough, and become stranded in stressful habitat (Davey and Kelly, 2007).

34. During both years of my study fish were not able to access potential refuge water such as the Upper Clutha River, or the Upper Lindis River due to areas of dry river bed. In one river reach that dried soon after tagged fish were released into it, approximately 10% of the fish moved upstream before the drying event. This left the majority of tagged fish stranded in areas that eventually dried up resulting in mortality.

35. During January 2014 yearling trout that were thought to be attempting to migrate to the Clutha River were documented congregated in the mouth of the Beggs Stackpoole race. It is not known if this was a natural out-migration pattern, or if the fish were responding to stressful conditions. Approximately half of these fish (48) were PIT tagged and tracked. A small number of these fish were able to migrate downstream to the Lindis Crossing (SH 8 bridge) but could not continue further downstream as the riverbed was dry. Most of these became stranded with other trout near the SH 8 bridge, and all stranded fish perished (Figure 8). I would estimate that at least 350 yearling fish perished in the pools around the Lindis Crossing during the summer of 2014.

Irrigation raceway

36. The Beggs Stackpole diversion bund, which diverts surface water into the irrigation channel, acts as a barrier to upstream movement of fish under low flow conditions. The diversion arm also entrains downstream moving fish in the irrigation channel.

37. Jellyman and Bonnett (1992) undertook extensive electrofishing studies throughout the Lindis River catchment from 1989 – 1992. This was in order to study juvenile trout population dynamics. They extrapolated their results to estimate that up to 59 % of all juvenile recruitment could be lost each year,

primarily due to entrainment in unscreened irrigation races. To the best of my knowledge most, if not all irrigation raceways in the Lindis Catchment remain un-screened.

38. During the low flow period in year one of my study only a small number of sample fish descended past the first culvert in the Beggs Stackpoole raceway (n=7). This culvert is located approximately 350 m down the channel.

39. Upstream of the Beggs Stackpoole bund schools of yearlings accumulated in the mouth of the raceway during low flow conditions. When the fish migration is blocked, or delayed at this point, they become very exposed to predation from birds, as there is not much cover in the open channel.

Habitat

Temperature

40. Hay et al. (2006) conclude that the productivity of a trout population (especially brown trout) will be negatively impacted as water temperature approaches and exceeds 19°C. Growth limits for brown trout are 4-19.5°C; upper limits for survival are between 25-30°C depending upon acclimation temperature (Elliot 1994). Trout deaths have been reported in New Zealand rivers when temperatures have reached or exceeded 26°C (Jowett 1997). Sub-lethal high temperatures may affect fish behaviour, growth rates, survival rates and population production (Hay et al., 2006).

41. Fish kills from heat stress in Otago streams primarily occur when fish become stranded in pools disconnected from the main flow (Caruso, 2001).

42. Water temperatures taken from flowing water in my PIT tag study area remained below the incipient lethal temperature of 25 °C (Elliott, 1981, Matthews, 1997). The maximum recorded in flowing water was 21 °C. The highest temperature recorded (24 °C) was in shallow standing water prior to a logger becoming dewatered. In my experience fish kills from thermal stress occur in disconnected and drying pools (Figure 5). I have frequently seen fish gasping at the surface when stranded in drying pools, and expect that under these conditions oxygen levels drop to lethal levels. When monitoring water temperature I have not found high temperatures where there is surface flow. I have not seen and would not expect fish kills from thermal stress to occur in the Lindis River where there is meaningful surface flow.

Figure 5. Several year classes of brown trout stranded in a disconnected residual pool below Lindis Crossing bridge, summer 2007; some already perished from temperature and oxygen stress.

Periphyton

43. Excessive periphyton growth is aesthetically unappealing and impacts general recreational amenity values and natural character values (Figure 6). Blooms of the toxin producing cyanobacteria *Phormidium* were observed in the Lindis River under prolonged low flow conditions.

44. As periphyton biomass increases benthic habitat is degraded and the abundance of mayflies, stoneflies and caddisflies decreases, while the relative abundance of midges, worms and snails increases. Such changes to the invertebrate community composition often results in smaller prey items which are energetically more costly as a food source for trout. When very high biomass is built up, algae respiration at night, and the decomposition of the lower layers can reduce oxygen levels. Periphyton build up can also clog up the interstitial spaces in cobble substrate commonly used as cover by juvenile trout and small fish. Thick blooms can impact fish passage in shallow riffles.

45. During the 2015 low flow period, periphyton cover exceeding 90 % was observed in reaches of the lower Lindis (Figure 5). The proliferation of periphyton in reaches of the lower river during the summer of 2015 is likely to be related to the extent of the low flow period (the river flat lined without a fresh/flushing flow for several months). Staff familiar with the river noted that the algae blooms present in the lower river during the summer of 2015 were the worst they had seen in terms of area covered and biomass (Figure 5).

46. Other factors such as increased nutrient concentrations in the river may have also influenced periphyton growth. The most recent SOE monitoring report identified a 'meaningful' increasing trend for total nitrogen for Lindis River at Ardgour over the 2006-2011 period (Ozanne, 2012). The 2015 water quality and ecosystem health summary reported nitrate-nitrite nitrogen levels occasionally exceeded the Schedule 15 targets for the catchment (ORC, 2015).

47. Fish and Game and Clutha Fisheries Trust staff undertook habitat surveys in the upper Lindis at Elliotts Bridge during January 2015. At this site flows had not receded below approximately 1000 l/s. The upper site appeared to be relatively healthy when compared to the lower river. Algae biomass was relatively low, instream and bankside cover was available, and juvenile trout numbers were considered to be moderate to common. During the same period, I considered juvenile trout numbers in the lower river (subjected to significant abstraction) to be low to very low.

Figure 5. Algae bloom (brown and green filamentous and didymo) observed in the lower Lindis January 2015; in some reaches algae coverage exceeded 90%. This is in breach of ANZECC periphyton guidelines.

Cover and habitat use

48. Cover is an important component of trout habitat; features such as deep water, surface turbulence, overhanging vegetation, undercut banks and instream woody debris provide refuge from predators. Overhanging riparian vegetation can also reduce temperatures through shading.

49. As flows decrease to low levels cover provided by deep water and areas of surface turbulence are lost. The wetted area of the river narrows and contracts from the banks so that cover from overhanging vegetation and undercut banks is reduced and in some reaches lost entirely.

50. Under these conditions juvenile trout are vulnerable to very high levels of predation pressure. Herons are able to wade the shallow water and easily spot small fish on which to feed. In open pool habitat with limited cover juvenile trout may also be predated by larger trout, eels, shags, and herons.

51. During low flow events in the Lindis River the majority (63 %) of PIT tagged juvenile trout fish were found within relatively shallow water riffle habitat. When conducting mobile antenna surveys it was apparent that juvenile 0+ fish preferred bubbly riffle habitat if any remained available. Fish found in disconnected pools were unable to access this habitat. In my opinion this is likely to be because riffle habitat provides better oxygenation and cover from predators. Research elsewhere noted that riffle habitat may provide cover from predation (Henderson and Letcher, 2003). The presence of larger fish in pools, can exclude smaller fish from deep water refuge habitat during drought (Magoulick and Kobza, 2003). During summer low flow conditions smaller fish may also find higher oxygen levels in bubbly riffle habitat.

52. When riffles in open river bed areas dry up any surviving trout including 0+ (young of the year) drop into pools as a last resort. ORC's report on management flows for the Lindis (ORC 2006) proposed that residual pools within the lower river provided refuge for trout so that they might survive times of low and discontinuous flow. My observations including monitoring using motion activated cameras show that the refuge pool hypothesis postulated in ORC's management flows report does not work in practice. Fish confined to pools with little cover during extended low flow events are subjected to very high levels of predation, from which they cannot escape. Any fish stranded in isolated pools that are not predated eventually die from high water temperature and/or low dissolved oxygen levels.

Figure 6. A white faced heron feeding one of the few remaining trout stranded within a residual pool January 2015.

Figure 7. Remnants of a school of 150 plus (mostly yearling) trout that were stranded in a pool by the Lindis Crossing bridge summer 2014. Almost all of these fish exhibited predator strike markings indicating that they were attacked by predators (probably shags or herons) before they died from stress. By the following day the fish shown above, which had been left on the river bank had been taken by scavengers (probably cats and ferrets etc).

Figure 8. Scavenger species such as this ferret were documented removing dead trout from residual pools at Lindis Crossing.

53. Investigation of scavenging using motion activated trail cameras found that fish which died in residual pools were quickly removed, by a number of scavenger species such as ferrets, cats and rats. A trial with 16 dead trout (size range 65 – 520 mm) recovered from a residual pool, tagged and returned to the pool in the evening, found no sign of fish or tags by the following morning. Similarly upland bullies which suffered a mass kill (up to 50 per m^2) in a dewatered reach upstream of Lindis Crossing (Figure 10), as observed on the morning of 6 March 2014, were almost completely removed by scavengers within 24 hours.

54. Due to the activity of predators (Figure 7) and scavengers (Figure 9) it cannot be assumed that significant fish kills have not occurred if no dead fish are observed (Caruso, 2001). It is highly likely that wherever a dry riverbed is observed, a significant mortality event has occurred. Any observed mortalities are likely to represent only a small proportion the number of fish killed when a river is subject to extreme low flows and dewatering. The initial population may be first reduced by increased predation pressure, while the scale of any eventual fish kills are likely masked by scavengers quickly removing dead fish.

Figure 9. Upland bullies (seven in total) observed under a single cobble within a dewatered reach early morning 6 March 2014. The embedded substrate prevented them from burrowing. Up to 50 stranded bullies per square metre were found in this reach.

55. Electrofishing surveys found very low numbers of bullies following reconnection of flows at Lindis Crossing in March 2014, where previous surveys prior to dewatering had found they were so abundant it was difficult to count them all.

Juvenile trout survival estimate

56. Research shows juvenile trout experience high mortality rates after emerging from gravels. This life stage is known as the critical period and can last for approximately 30-70 days (Elliott, 1994, Jonsson and Jonsson, 2011). During the critical period the majority of alevins rarely feed, drift downstream and die, while the remainder compete for and establish feeding territories (Elliott, 1993, Elliott, 1994). At this stage the young alevins are also highly vulnerable to predation (Jonsson and Jonsson, 2011). Mortality levels during the critical period can be as high as 80-90% (Elliott, 1994, Jonsson and Jonsson, 2011, Elliott, 1993).

57. Following the critical period juvenile salmonids generally experience a period of lower mortality that is fairly consistent unless the population is impacted by major floods or extreme low flow events (Elliott, 1994, Jonsson and Jonsson, 2011). Juvenile trout that survive the critical period and increase in size are much more likely to survive and recruit to adult trout populations (Rosenau, 1991) and juvenile trout in the Lindis increase in potential recruitment value with age.

58. The survival rates of juvenile trout in the Lindis are much lower than would be expected for post-critical period juvenile trout. For the Linids River post-crtical period juvenile trout survival was estimated at 29 and 34% for two consectutive summer low flow periods (no more than 3 months each). By comparison with a similar study in the Rainy River where survival was estimated at 71 % over a nine month period (Holmes et al., 2013). That population was subjected to a significant flood event which was thought to be the primary cause of their mortality.

59. In year one of my study, flows reduced to approximately 25% of MALF (measured at Ardgour Road) or less, for 70 days and the population experienced an estimated survival rate of 34 % (95 % CI[1]: 0.21-0.50). In year two flows were reduced to approximately 25 % of MALF or less for the entire period of 59 days, and the population experienced an estimated survival rate of 29 % (95 % CI: 0.18-0.39).

60. The effects of extreme low flow events can result in long term impacts on salmonid population structure (Elliott et al., 1997 Jonsson and Jonsson, 2011, Elliott, 1993). Streams that are dried to isolated pools and dewatered riverbed are likely to act as populations sinks, where breeding effort and recrutiment potential is lost (Magoulick and Kobza, 2003). The high mortality of juvenile trout in the Lindis River (which has an extreme low flow event annually) will therefore reduce the recruitment potential of this population to other waters such as the Upper Clutha River.

[1] CI – confidence interval

Anticipated impacts of various minimum flow regimes

<u>Dealing with uncertainty in hydrological estimates</u>

61. There is uncertainty regarding the accuracy of surface flow records, and surface to ground water interactions along the lower 25 km of the Lindis River. This needs to be taken into account when considering potential minimum flow regime. Making correlations between flow levels and available habitat is complicated by changes in abstraction levels, irrigation recharge, and points of take depending on the season.

62. The potential flow regimes mentioned below are based around flows at the ORC Ardgour flow recorder, which will be the measuring point for the future minimum flow. I understand that there have been problems with this recorder, and the dataset has been amended. I am not a hydrological expert, and am relying on the others to provide the best estimate possible given the circumstances.

63. The following predictions regarding available habitat and fish population dynamics at various flows are based on my first hand observations of surface water connection along the lower river, and measurements of available fish habitat and fish population response over the past two summers. I consider that levels of habitat and population response to extreme low flow events are so high, that some variability around extreme low flow levels would have a negligible impact on fish population response over time. For example, predation levels when the river is at 350 l/s for an extended period (months on end) are so high due to a lack of effective cover, that it doesn't matter if the river was at 350 or 450 l/s a similar population response would be likely to eventuate.

64. My predictions regarding fish passage and population response to various flows do not take into account the Beggs Stackpole raceway or diversion bund. During low flows the diversion bund prevents upstream fish movement, and entrains downstream moving fish into the mouth of raceway during low flow periods.

Anticipated impacts of a minimum flow of 450 l/s

65. There is considerable variation in surface water levels in the lower 25 km of Lindis River when the Ardgour flow recorder is at or near 450 l/s. In many open riverbed areas the riverbed is dry, or surface water levels are so low they provide little to no effective habitat for fish life, or connection for fish passage. This is particularly apparent adjacent to and below the Lindis Crossing and the Ardgour Road Bridge (Figure 11 and 12). While in other reaches that are willow lined and have ground water upwelling pool habitat remains.

Figure 11: 05/02/2014. Lindis River downstream of Lindis Crossing. Most of the river bed below the Lindis Crossing was dry or drying. Flow at ORC Ardgour recorder 435 l/s

Figure 12: 05/02/2014. Lindis River downstream of Lindis Crossing. The pool was becoming disconnected from surface flows and drying quickly. It contained no effective cover for juvenile trout. Estimated flow at ORC Ardgour recorder 435 l/s

66. Mark recapture model analysis (Holmes et al., 2013) indicates that >60 % of the juvenile trout population died within the first six weeks of the low flow event in both study years. The lowest fish survival probability occurred between 7/02/2014 and 20/02/2014, the average flow at the Ardgour flow recorder during this time was approximately 380 l/s.

67. During this time frame the river was drying around the Lindis Crossing. The survival probability of fish in reaches where there was flowing water, such as upstream of the Beggs Stackpole raceway, and upstream of the Ardgour flow recorder was not significantly better than fish in reaches subject to ground water losses and drying (around the Lindis Crossing). This research indicates that flows around 380 l/s for extended periods are insufficient to prevent very high mortality due to predation, which was shown to a major cause of mortality. I do not think there is a meaningful difference in available predation cover for fish at or about 380 l/s as opposed to 450 l/s and am sure that if flows were held at 450 l/s for prolonged periods (months on end) the fish population in the Lindis River would be subject to very high levels of predation.

68. My observations of juvenile trout movements indicate that they were unable to move to effective refuge habitat during my study period because of dry river reaches, low surface flows and an irrigation diversion bund. Jellyman (1992)

conducted extensive electrofishing studies throughout the Lindis catchment over four years. He noted that congregations of 1+ fish near the Lindis Crossing were associated with reduced numbers of 1+ fish further upstream, and concluded that some fish were attempting to leave the Lindis. He also noted that during summer there is a constant trickle of downstream migrants.

69. During my study some 1+ fish exhibited considerable movement along the fragmented river corridor, and schooling behaviour which can be associated with fish migration. My interpretation of these movements and behaviour is that some 1+ fish were attempting to leave the Lindis River as flows reduced but simply could not due to dry reaches. I do not know if this was a natural migration event, or a response to low flow stress. Meaningful surface connection is required along the length of the river to allow fish migration to larger water such as the Clutha; 450 l/s at the flow recorder does not provide that.

70. Algae blooms (brown and green filamentous and didymo) in some reaches of the lower Lindis during the summer of 2015 were the worst that I have seen, other than in low land streams suffering nutrient enrichment (Figure 6). It is likely that the prolonged low flow without flushing events, and potentially increasing levels of nitrogen (Ozanne, 2012), caused these blooms. I think that flat lining the river at this level would also result in major algae bloom problems due to lack of flushing flows. Algal bloom problems could be compounded by higher levels of nutrients.

Anticipated impacts of a minimum flow of 750 l/s

71. IFIM analysis has indicated that approximately 750 l/s is the point of inflection for juvenile brown trout habitat in the Lindis River. I consider that a continuous flow of 750 l/s throughout the lower Lindis River would provide fish passage and a significant improvement of habitat values, particularly in maintaining shallows and riffle habitat which is crucial in sustaining small fish populations.

72. The problem is that the measuring point (Ardgour Flow recorder) is located in a gaining reach, and 750 l/s at the recorder means a lower flow for losing reaches, particularly around the Lindis Crossing, and the Ardgour Road bridge (Figure 3). The amount of surface water lost to ground downstream of the Lindis Crossing when the river decouples from groundwater, and upstream of the Ardgour Road has been estimated to vary between 400-500 l/s. This means that a minimum flow of 750 l/s set at the flow recorder would result in significantly lower flows than the recorder value for much of the lower 25 km of river, particularly in the reaches below Lindis Crossing, and upstream of Ardgour Road.

73. The arid nature of the catchment and demand for abstraction means that during the summer abstraction season the lower river is flat lined for several weeks or even months on end. If flows of 750 l/s are held at the Ardgour Flow recorder for an extended period, problems with algae blooms and high levels of fish predation may occur in losing reaches. In these reaches flows could be around 300 l/s or less (Mr Gabrielson and Mr Rekker discuss this). If flows were held at this level for extended periods fish in losing reaches would be under significant predation stress due to lack of effective cover.

74. It is uncertain if fish passage along the length of the river would be provided for at 750 l/s at the flow recorder (Mr Gabrielson discusses this). A bare surface connection is maybe too shallow for fish to move through. Fish that were attempting to move along the main stem of the river (either due to natural migratory behaviour, or to avoid habitat stress) and encountered surface water loosing reaches could be subjected to very high levels of predation due to lack of cover.

75. Algae bloom problems can be expected in losing reaches held at low flows for prolonged periods, due to insufficient flows and higher nutrient concentrations. Shallow riffles above the Clutha confluence may be expected to provide the biggest impediment to migrating fish during summer low flow. Fish movement restrictions in this area maybe expected to be compounded by excessive algae growth during prolonged low flow periods. Thick blooms would also be expected to degrade invertebrate populations in affected reaches.

Anticipated impacts of a minimum flow of 1000 l/s

76. A minimum flow of 1000 l/s measured at the Ardgour flow recorder would mean that significantly more of the lower river would be at or about 750 l/s. While this is far from optimum it would provide a meaningful improvement in riffle and run habitat to sustain small fish (juvenile trout, upland bullies) populations. I consider that sustaining bubbly water riffles which are the preferred habitat of young of the year trout in the Lindis River, and providing water depth for migration to the Clutha are the most effective improvements that could be made.

77. A proportion of the lower river would be at or about 500-600 l/s, but I consider that fish should be able to move along the river corridor at these levels if they experienced stressful habitat conditions. The main reaches of compromised habitat would be the open bed areas that experience surface water losses near the Lindis Crossing, and above and below the Ardgour Road bridge. The final connection to the Clutha would likely be shallow; however fish would at least have a reasonable chance of longitudinal movement along the river corridor.

78. Migration of juvenile brown trout from their natal rearing streams to adult habitat is often downstream and at night (Elliott, 1994, Jonsson and Jonsson, 2011). Fish movement at night would be expected to reduce predation risk, and thermal stress, and increase the chances of fish moving through a short section of shallow water successfully.

79. With longitudinal connection and habitat provided along the length of the lower river a significant improvement of juvenile trout recruitment to the Upper Clutha and Lake Dunstan Fisheries would be expected.

80. I would expect that adult trout fishery values would be improved, as the amount of deep water pools and runs connected to cover such as undercut banks and overhanging willows would be increased. I would expect that improvement of this type of habitat would also be beneficial to long fin eel populations as well.

Anticipated impacts of a minimum flow of approximately 1500 l/s

81. The draft National Environmental Standard on minimum flows for rivers the size of the Lindis River (Ministry for the Environment 2008) recommended ninety percent of MALF as a precautionary approach to abstraction from streams with a median flow of less than 5 cumecs. These interim limits were recommended for water bodies not already covered by environmental flows, or environmental flow investigations. Mr Wilson has discussed this in his evidence. Ninety percent of MALF would equate to a minimum flow of approximately 1500 cumecs (Horrell, 2014).

82. IFIM analysis suggests that available habitat for adult brown trout continues to increase with flows up to approximately 4000 l/s, and juvenile habitat is maximised around 1400 l/s.

83. Mr Gabrielsson has suggested that bioenergetics approaches to modelling habitat in the Lindis would generally suggest that more water is better for fish.

84. If summer flows remained at approximately 1500 l/s juvenile trout riffle and run habitat would be provided throughout the length of the river. Longitudinal connection would be provided, and juvenile recruitment to the Upper Clutha and Lake Dunstan Fisheries would be significantly improved.

85. I would also anticipate that there would be a quick response in the productivity of the adult trout fishery. This would mostly be due to an increase in habitat in

the form of deep runs and pools with nearby cover such as undercut banks. Migratory movement would be provided along the river corridor. The associated increased survival and contribution of juvenile fish would also be expected to result in an increased returning adult (spawning run) population and a higher adult resident population.

86. With flows restored the Lindis would become a very desirable stream for recreational activities. It would contain clear water and deep pools with cover for fish life and increased numbers of medium to large brown trout. I would anticipate that the numbers of early season adult rainbows in the stream should increase, and become an important part of the fishery. Small streams with clear water which present sight fishing opportunities for medium to large trout are highly desirable to fly anglers. It is likely the Lindis would become well known for providing a high quality trout fishing experience for resident and non-resident anglers alike.

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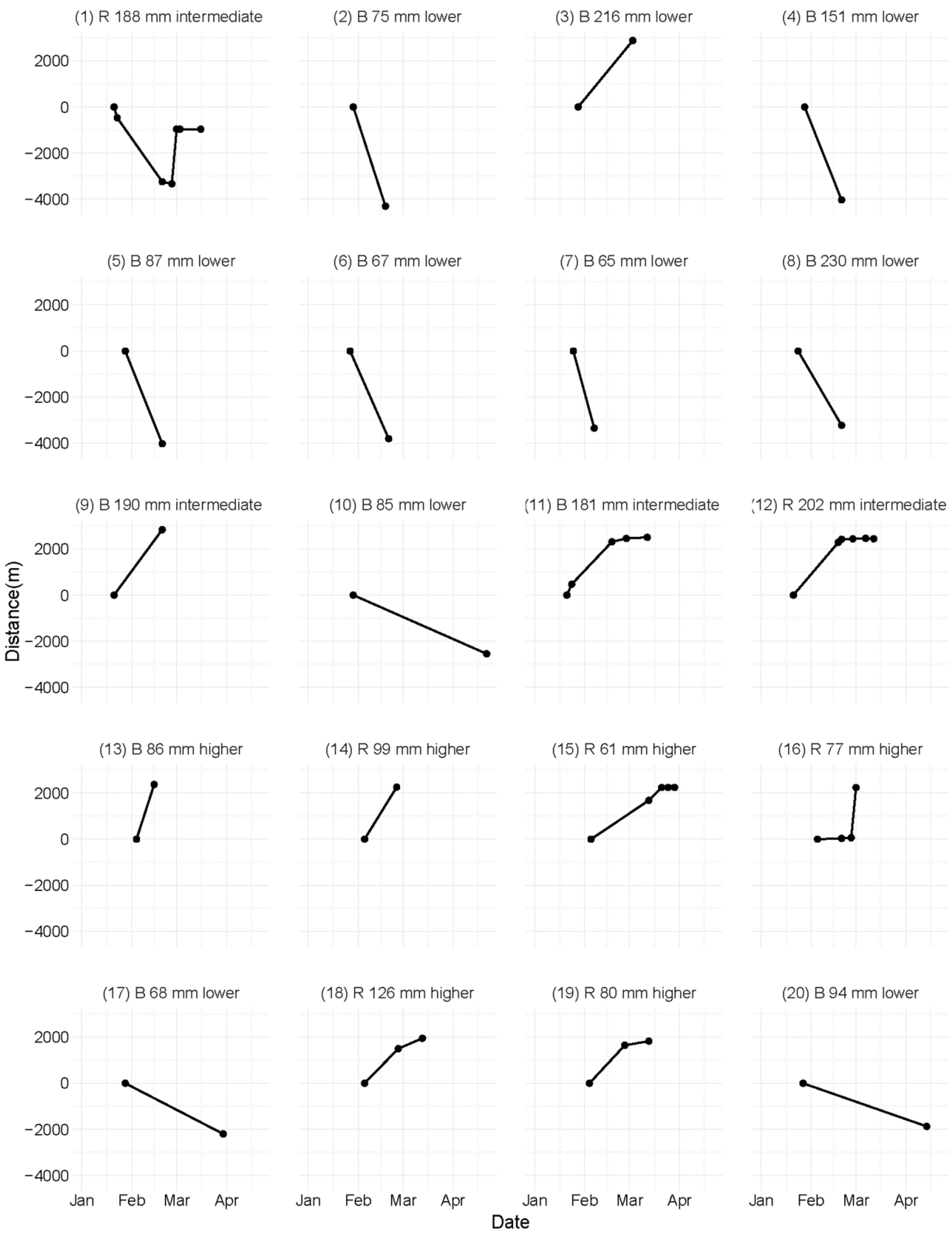
Appendix 1



Straight line distance moved from release point (0 m) by 20 mobile fish. Negative numbers indicate downstream movement, positive numbers upstream movement. The species (brown B, rainbow R), fork length in mm at time of release, and release segment are described for each fish.