CAWTHRON

30 June 2023

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Dear Peter

INVERTEBRATE DRIFT–FLOW RELATIONSHIPS: COMPARISON BETWEEN THE MANUHEREKIA AND OTHER RIVERS

This advice letter responds to a 2 June 2023 request from Otago Regional Council for further analysis of invertebrate drift–flow data, specifically to compare drift rate–flow relationships from other rivers with those established from the Manuherekia River. The additional information is to assist the Manuherekia Technical Advisory Group (TAG) to better understand the expected form of the response of invertebrate passive drift rate to flow reduction. We hope that this will decrease uncertainty associated with the empirical drift–flow data collected from the Manuherekia and reported in previous Cawthron reports and advice letters (Shearer & Hayes 2021;[1] Hayes et al. 2021;[2] Hayes & Shearer 2021;[3] Hayes & Shearer 2023[4]). The drift–flow information is contributing to the TAG's assessment of minimum flow and flow allocation options for the river.

Invertebrate drift–flow relationships from the Manuherekia River

Figures 1 and 2 show the total aquatic invertebrate community drift–flow relationships that have been established from the lower Manuherekia River from sampling natural flow recessions (presented in Appendix 3.1 of Hayes & Shearer 2023). These figures plot

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1 Shearer K, Hayes J. 2020. The relationship between invertebrate drift and flow in the Manuherikia River. Nelson: Cawthron Institute. Cawthron Report 3574. Prepared for Otago Regional Council, Aukaha, and Otago Fish & Game.

2 Hayes J, Shearer K, Casanovas P. 2021. The relationship between invertebrate drift and flow in the Manuherikia River: revised analysis and implications for setting minimum flow and allocation limits. Nelson: Cawthron Institute. Cawthron Report 3574A. Prepared for Otago Regional Council, Aukaha, and Otago Fish & Game Council..

3 Hayes J, Shearer K. 2021. Response to review of Cawthron reports presenting invertebrate drift relationships for the Lower Manuherekia River. Nelson: Cawthron Institute. Cawthron Advice Letter 2179.

4 Hayes J, Shearer K. 2023. Response to review of Cawthron reports presenting invertebrate drift–flow relationships for the lower Manuherekia River. Nelson: Cawthron Institute. Cawthron Advice Letter 2319.

standardised drift rate versus flow, the standardisation being necessary to account for the following:

1. differences in benthic invertebrate density between the two flow recessions over which sampling occurred
2. the inability to calculate drift concentration due to water velocities at the drift sampler locations being below the calibrated range of the sampler current meters during the periods of very low flow sampled during the second flow recession.

The standardised drift rates calculated for the Manuherekia River apply at the scale of the samplers (i.e. they represent changes in the rate of invertebrates drifting through the 0.150 m-diameter [0.018 m^2 cross-sectional area] opening of the drift samplers with respect to flow).

As described in Hayes et al. (2021) the standardisation of drift rate was achieved by first multiplying the drift rates for the second (January) flow recession by the ratio of benthic density measured on 2 December 2019 (first flow recession) over benthic density estimated for each drift sampling occasion in the second recession. After standardisation by benthic density, the drift rates at each location were comparable within and between recessions but not between location, owing to water velocities and related volumes sampled being specific to each location. To average the trends between drift rate and flow among locations, we further standardised drift rates, calculating the drift rate for each occasion at a location as a proportion of the total drift rate summed over all occasions for that location. Standardised drift rate for each occasion could then be averaged over all locations.

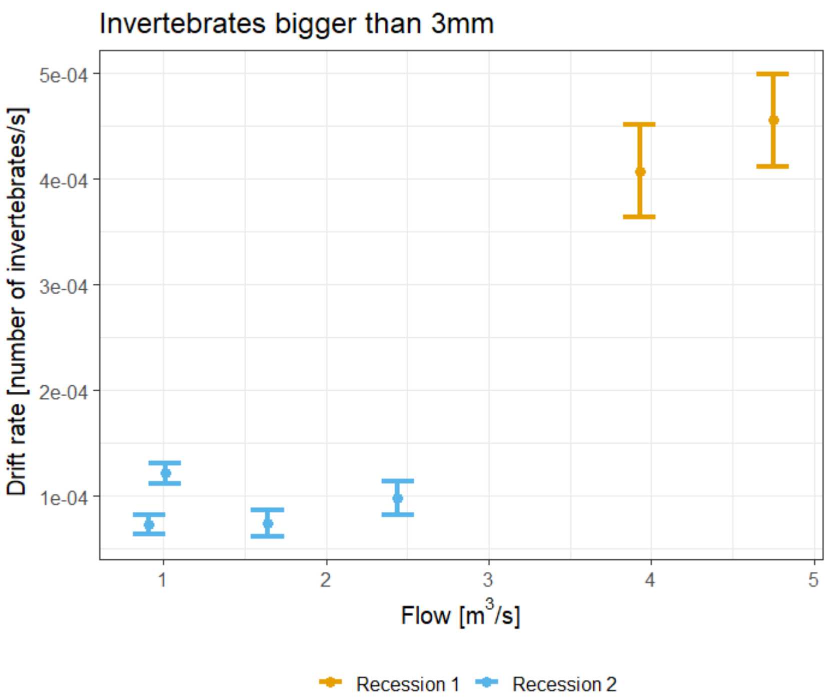

Figure 1. Relationship between flow and standardised total community drift rate (± SE) of invertebrates bigger than 3 mm for the lower Manuherekia River. Drift rate applies to the scale of the drift samplers.

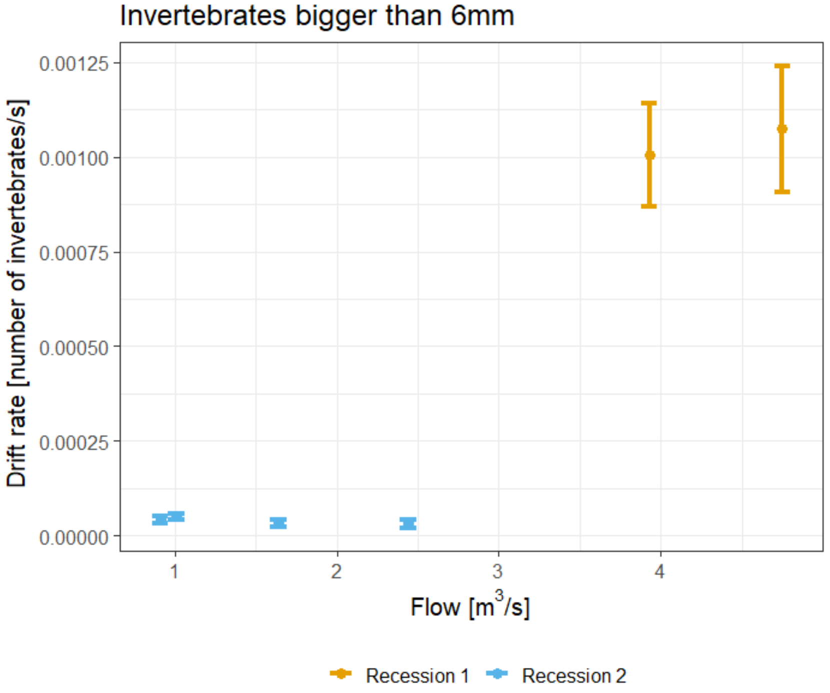

Figure 2 Relationship between flow and standardised community drift rate (± SE) of invertebrates bigger than 6 mm for the lower Manuherekia River. Drift rate applies to the scale of the drift samplers.

Our conclusion from Figures 1 and 2 was that drift rate declined with flow reduction in the Manuherekia study reach from about the mean annual low flow (MALF; ~ 4 m^3/s) to about 2 m^3/s. However, drift rate appeared to be insensitive to further flow reduction. The insensitivity of drift rate to flow reduction through the lower flow range sampled is inconsistent with theory on the expected response of passive drift with flow reduction. For passively drifting invertebrates, drift concentration and rate ought to decline with flow reduction (Hayes & Shearer 2023). Even if drift concentration remained constant with flow reduction, drift rate would decline because of the flow, and related water velocity effect, on drift rate. This rational indicates that the insensitivity of standardised drift rate to flow reduction over the low-flow range sampled in the Manuherekia River may have been due to invertebrates actively drifting as the flow declined.

Aquatic invertebrates actively drift to avoid predators and competitors, to vacate unsuitable habitat and food supply, and to emerge from the water to complete their life histories. While flow reduction may contribute to active drift, through its effects on suitable benthic habitat conditions, it has a pervasive effect on passive drift – hence the attention this flow-related process has received in instream flow investigations in the Manuherekia and other rivers in Southland and Otago in recent years.

Invertebrate drift–flow relationships from other New Zealand rivers

In this section we present empirical total community invertebrate drift rate–flow relationships for four rivers: the Mataura, Ōreti and Aparima in Southland, and the Lindis River in Otago. These data were collected over natural flow recessions. We also present a drift rate–flow relationship for the Mataura River predicted by a numerical drift transport model based on sediment transport theory and launched from a hydraulic model developed in RHYHABSIM (Jowett et al. 2015[5]). The model was described and tested by Hayes et al. (2018).[6] The predictions of the drift transport model complement the empirical drift–flow relationships by confirming the expected shape of the empirical relationships and allowing extrapolation beyond the limited flow range over which the drift data were collected. Importantly, the drift transport model can predict a drift rate–flow relationship through the mid- and low-flow range down to zero flow.

The empirical drift–flow relationships are based on datasets we have collected for instream flow investigations, three of which (Mataura, Ōreti and Aparima) included drift-feeding trout bioenergetics modelling, which required drift concentration–flow relationships for data input (Hayes et al. 2012;[7] Hayes et al. 2016;[8] Hayes et al. 2019;[9] Hayes et al. 2020[10]). The drift transport model for the Mataura was also calibrated on the empirical drift concentration–flow and benthic invertebrate density data collected on that river. Moreover, the quality of the Lindis drift–flow dataset was sufficient to calculate drift concentration, as well as drift rate, for its original presentation by Rasmus Gabrielsson in the 2018 Lindis River water consents appeal hearing.

Figures 3 to 6 present drift rate–flow relationships for the four rivers. Drift rate in these figures is actual drift rate (no./s) for the entire cross-sectional area of the river. This differs from the standardised drift rates for the Manuherekia River presented in Figures 1 and 2, which apply to the scale of the drift samplers. Drift rate for the average river cross section can be calculated as the product of average drift concentration (no.m^3) and river flow (m^3/s). Drift rates at the scale of the average sampler and at the scale of the average river cross

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5 Jowett IG, Payne T, Milhous R, Hernández JMD. 2015. System for Environmental Flow Analysis (SEFA), software package. http://sefa.co.nz

6 Hayes JW, Goodwin EO, Shearer KA, Hicks DM. 2018. Relationship between background invertebrate drift concentration and flow over natural flow recession, and prediction with a drift transport model. Canadian Journal of Fisheries and Aquatic Sciences. 76(6):871–885.

7 Hayes J, Goodwin E, Hay J, Shearer K, Kelly L. 2012. Minimum flow requirements of trout in the Mataura River: comparison of traditional habitat and net rate of energy intake modelling. Nelson: Cawthron Institute. Cawthron Report 1957. Envirolink MAG.

8 Hayes JW, Goodwin E, Shearer KA, Hay J, Kelly L. 2016. Can WUA correctly predict the flow requirements of drift-feeding trout? Comparison of a hydraulic-habitat model and a drift-net rate of energy intake model. Transactions of the American Fisheries Society. 145(3):589–609.

9 Hayes J, Goodwin E, Shearer K, Hay J, Hicks M, Willsman A, Bind J, Haddadchi A, Walsh J, Measures R. 2019. Ecological flow regime assessment for the Oreti River at Wallacetown: complementing hydraulic-habitat modelling with drift-feeding trout net energy intake modelling. Nelson: Cawthron Institute. Cawthron Report 2948. Prepared for Environment Southland and Envirolink.

10 Hayes J, Goodwin E, Shearer K, Bind J, Hoyle J, Stecca G, Measures R, Haddadchi A, Walsh J, Willsman A. 2020. Ecological flow regime assessment for the Aparima River at Anderson's Beach: Complementing hydraulic-habitat modelling with drift-feeding trout net energy intake modelling. Nelson: Cawthron Institute. Cawthron Report 3457. Prepared for Environment Southland.

section exhibit similar relationships with flow. Furthermore, the drift rate data also exhibit similar patterns with flow as the drift concentration data, but with the former declining more steeply with flow reduction (results not shown here).

With one exception (invertebrates bigger than 3 mm in the Ōreti), the drift rate–flow relationships for the rivers shown in Figures 3 to 6 exhibit positive relationships with flow, consistent with passive drift response. The flat to slightly negative drift rate–flow relationship for invertebrates bigger than 3 mm invertebrates in the Ōreti (Figures 3 and 4) indicates that active drift was compensating for passive drift over decreasing flow, but the plot was included in this investigation of passive drift–flow relationships for transparency.

The empirical relationships that are consistent with passive drift fit reasonably well to log power functions (as reported in Hayes & Shearer 2023[11]), with drift rate smoothly curving downward with flow reduction.

The TAG was interested in whether there might be an inflection point in the passive drift rate–flow relationship for the Manuherekia River, which would make identification of a minimum flow easier. An inflection point would indicate a flow above which positive effects on drift increase disproportionately. This question was raised in relation to the flow gap in the Manuherekia drift data between the two flow recessions sampled, and the relatively flat response to flow over the low-flow recession. However, the empirical data from the other rivers confirm that the passive drift rate–flow pattern to be expected is a smooth curvilinear reduction in drift rate from mid-range flows down through the low-flow range (i.e. with no inflection point).

The drift transport model's predictions for the Mataura River provide corroborating evidence for this view. The model predicts a smooth curvilinear reduction in drift rate from mid-range flows through to zero flow, with no inflection point. This is unlike relationships between flow and hydraulic variables (depth and velocity), wetted width and instream habitat, predicted by hydraulic-habitat models, which often exhibit inflection points due to interactions with channel shape. However, because the drift transport model is launched from a reach-scale hydraulic model, it is informed by water depths and velocities, and related near-bed shear stresses, influenced by the interaction of flow with the channel shape, roughness and slope.

Conclusion

The drift rate–flow relationship results from other rivers confirm the observed relationship of drift rate declining with flow reduction in the lower Manuherekia River.

The empirical relationships from the other rivers, and drift transport model predictions, help resolve the uncertainties in the Manuherekia drift rate–flow dataset and indicate that the relationship between passive drift rate and flow in the Manuherekia should decline in a smooth curvilinear fashion down through the MALF (~ 4 m^3/s) towards zero at zero flow.

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[11] Hayes J, Shearer K. 2023. Response to review of Cawthron reports presenting invertebrate drift–flow relationships for the lower Manuherekia River. Nelson: Cawthron Institute. Cawthron Advice Letter 2319.

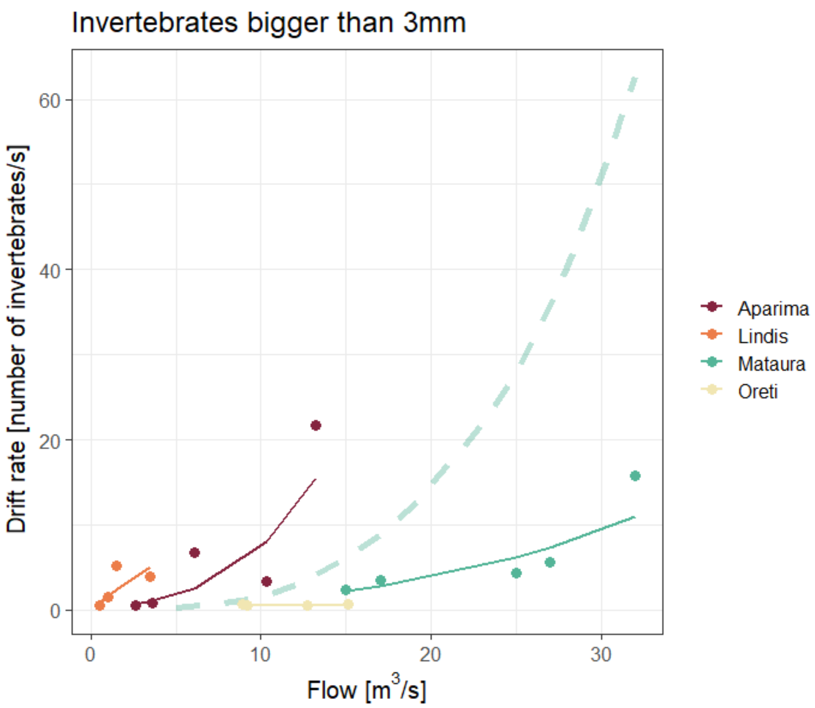

Figure 3. Relationships between flow and community drift rate (± SE) of invertebrates bigger than 3 mm for four Southland and Otago rivers. Drift rate applies to the scale of the average river cross section.

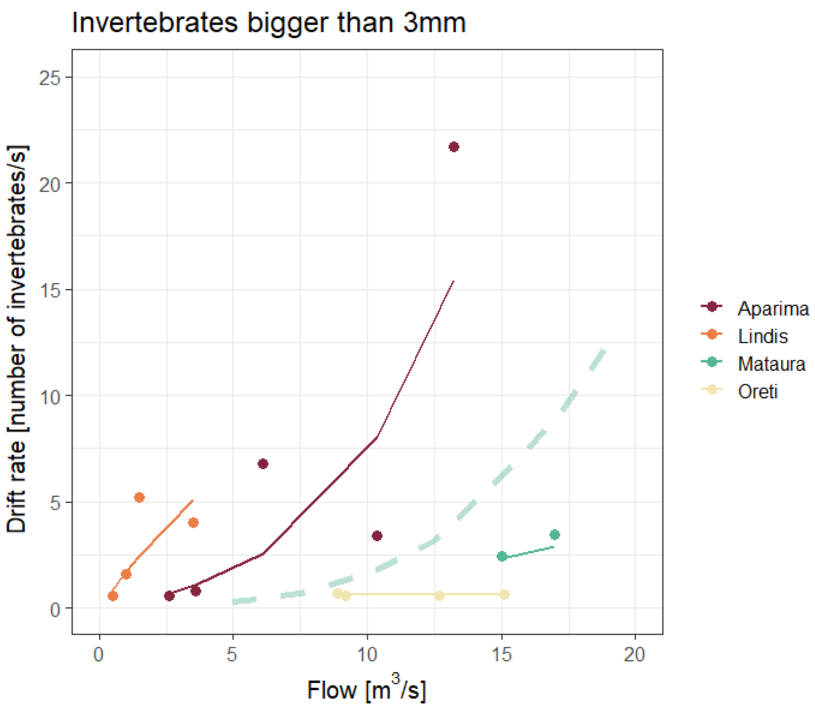

Figure 4. Same plots as Figure 3 but with a reduced flow scale to provide finer resolution over the low-flow range.

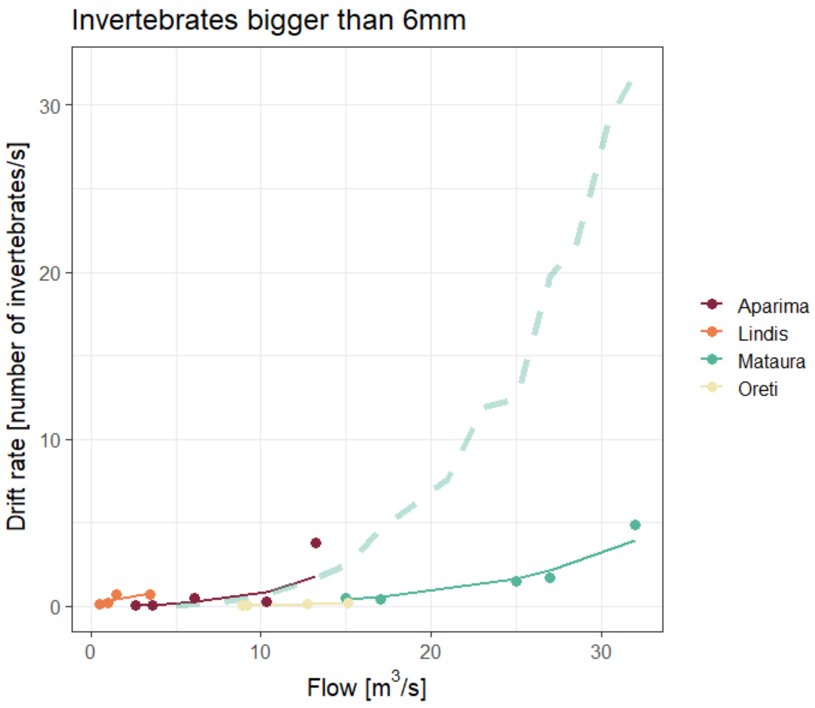

Figure 5. Relationships between flow and community drift rate (± SE) of invertebrates bigger than 6 mm for four Southland and Otago rivers. Drift rate applies to the scale of average river cross section.

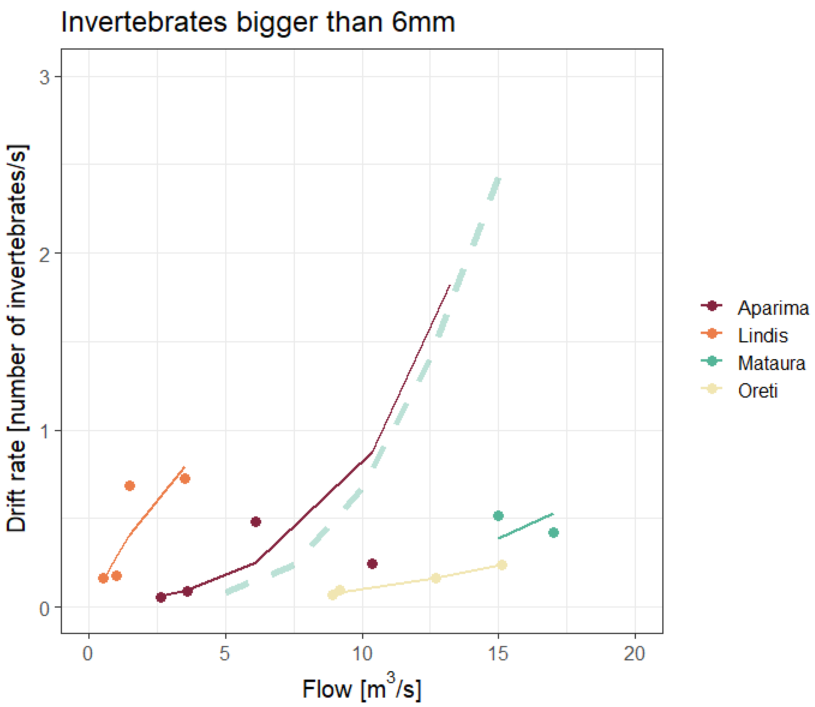

Figure 6. Same plots as Figure 5 but with a reduced flow scale to provide finer resolution over the low-flow range.

Yours sincerely

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