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Hydrology and Earth System Sciences Discussions

Interactive comment on "Variability in stream discharge and temperatures during ecologically sensitive time periods: a preliminary assessment of the implications for Atlantic salmon" *by* D. Tetzlaff et al.

D. Tetzlaff et al.

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General comments:

1) We have re-written and restructured the paper in many sections as recommended and have been more precise in our use of scientific terms and treatment on numerical data. We recognise that the abstract and introduction in the original manuscript gave the misleading impression that the paper was going to comparatively analyse flow and temperature variability at different temporal scales. The objectives of the paper are now clearer and more sharply focused and link much more directly to the results presented.

2) We clarify in the text that in spite of a number of background studies on flows and temperatures in the Girnock, these have rarely linked inter- and intra-annual variability

to ecological receptors in the way that this paper does.

3) Regarding the definition of four ecologically “sensitive” time periods; we now make clear that these refer to periods during the freshwater, post-emergence life stages of Atlantic salmon, as these are particularly susceptible to flow and temperature influences. Of course we recognise that the precise timing of these periods varies inter-annually. Salmon are selected to use intrinsic “calendars” and modify timings of certain activities according to the prevailing environmental conditions. However, the time periods specified are based on almost 40 years of empirical observations in the Girnock to identify the time “windows” that best encapsulate these periods.

4) The abstract and introduction have now been modified and the potential utility of the CDV approach in integrating flow and temperature influences has been emphasized. The paper aims to present a preliminary analyses of how empirical data on stream temperature and discharge can be integrated using the concept of Critical Displacement Velocity (CDV) for juvenile fish based on the published approach of Graham et al., 1996. The study provides an insight into how differences in annual flow and thermal regimes might influence foraging opportunities for juvenile salmon. As we note in the introduction, temperature-driven growth models can explain around 85 % of observed fish growth at his site. The CDV approach is intended to provide an additional parameter in such models that may help account for the unexplained variance. Indeed colleagues are currently working towards this goal. However, this is a major task and clearly outwith the objectives of this paper. We have now modified the introduction, to make clearer the objectives and state that additional modelling work is underway. However, we still feel that the development of the approach provides as reported in the paper has sufficient research novelty in the potential for deriving hydraulic data from flow records and insight into potential influences on juvenile salmon.

The reviewer expresses his doubt that the approach used may not reflect either spatial variability in velocities around the catchment, nor may measures based on velocities at 0.6 x depth be representative of those experienced by juvenile fish. We recognise that calculation of velocity based on readily available discharge data is very much a first approximation and a relatively simplistic representation of the complex velocity fields that will occur in a river such as the Girnock. But the objective of the present study was to capture temporal variability in velocity conditions in different hydrological year. In this sense, we view the Littlemill data as being a useful indicator of temporal variability of conditions in the rest of the river system. Of course we recognise that hydraulic conditions will differ in different channel types as the reviewer comments. Also, as we acknowledge (and demonstrate in Figure 2), that there will be variability along a cross-section of the channel and at different depths in the water column. There is now a much clearer evaluation of the assumptions behind the modelling approach in the methods section. To represent the range in spatial variability within a whole catchment, high spatial resolution data would need to be collected which would be a major undertaking. Moreover, at most sites even moderately high flows could not be gauged safely. An alternative would be hydraulic modelling, which previous work that we have carried out (cf Gibbins et al, 2004) has shown is difficult and potentially erroneous in a hydraulically rough, montane river channel. Thus, the authors are convinced that the approach presented is a valuable method in deriving ecologically meaningful insights from hydrological data sets particularly by focussing at this stage on temporal variability in ten hydrologically contrasting years. We believe that in understanding short-term hydroecological associations we must use existing (especially long-term) data sets where available and try and ensure that useful insights help inform river management strategies. Although the approach has limitations, it has helped in the formulation of hypotheses that can be later tested and we fail to see which alternative approaches would be free of other limitations or assumptions.

5) Spring salmon return to the Dee system from December in the year prior to spawning. They migrate slowly upstream in response to hydrological conditions throughout the year. Thus the hydrological conditions within the Dee system throughout the year (as at least generally indexed by flows in the Girnock) influence the distribution of fish within the Dee system. We know from radio tracking studies that Girnock fish gradually

move towards pools in the Dee a short distance downstream from the Girnock in the final months prior to spawning. The final entry of salmon into the Girnock is generally triggered by high flow events as shown in Figure 10. Our point is that extreme hydrological years (i.e. when flow conditions are highly variable in 1995/96, or not variable (1997/98)) have the most marked influences on spawning access. In other words, high, variable flows prior to spawning allow unhindered access which permits large numbers of females to enter the burn. In contrast, low unvarying flows ($<$ 0.3 m3 s-1) hinder access, both physically, or in terms of absence of a physical cue, result in low female entry. In more “typical” years, the relationship with flow is less clear. The complex temporal variation in flow is indexed by the coefficient of variation each year. Thus, the hydrological extremes are of particular importance and analysing the data without them seems to be of limited value. However, we have now included fuller statistical information in Table 4.

Specific comments: (sequentially dealing with each point raised)

Title:

1. Changed as requested

Abstract:

2. Terminology hydrological/ hydraulic: It is widely acknowledged that aquatic organisms experience hydraulic forces. Hence, discharge as a hydrological variable influences indirectly biota. Therefore, hydrological and hydraulic are not meant to be used as synonyms and the text was modified where necessary to clarify the differences. 3. Abstract text is modified and results are provided. 4. Text is now changed 5. Text has been modified.

Introduction:

6./7/8. The introduction has been largely re-written and the suggestions and remarks of all 3 referees considered. 9. Please see response to general comments 1). Objectives are now clearer. 10. Sentences are modified.

Study site:

11. Changed 12. Text was modified.

Data and Methods

13. See above (point 2) 14. Text was modified. 15. Text is now more precise. Please see also response to General Comments 3. 16. Section title was changed. 17. Please see modified text. 7% of the data was filled with the method which is now hopefully explaind much more clearly. As written, the methods in the original m/s implied that monthly data were used to infil the gaps. In fact hourly data were used, but air-stream temperature relationships were established for individual months. The text is more precise now. 18. We now make clear that high CDVs do not preclude feeding but speculate - reasonably - that CDV exceedence is likely to reduce scope for movement which is a probable constraint on food acquision, particularly as high flows in Scottish rivers will increase turbidity and water colour inhibiting prey capture futher. Testing this would be a separate exercise calling for hypothesis tests on feeding and growth which is beyond the scope of this study. 19. Methodology of estimated growth estimates is fully explained and growth curves are given in given reference, Tetzlaff et al, 2005, Hydrobiologia. The different fish length information (for 2002: 504 individual 0+ salmon and 1008 individual 1+ salmon; in 2003: 183 individual 0+ salmon and 167 individual 1+ salmon) were measured at six different monitoring sites (please see details in Tetzlaff et al., 2005, in press). There were no significant differences in lengths at different monitoring sites. Given this similarity, spatially averaged fish length data for all sites were used to characterise fish sizes in the stream and these data were used to calculate CDVs at the gauging site, where the corresponding flow data are available. 20. The opinion of the authors is that these numbers are important to put the numbers of this study into the broader context (for readers which are less familiar with longer-term adult spawner numbers).

Results:

21. Text is modified. 22. Mean and Standard deviation were also calculated for the whole hydrological year and each of the sensitive periods. Coefficient of variation is an index of variability of streamflow for a given period. As spawners migrate into the river in relation to spates, it indexes the opportunity for access. 23. The paragraph is clarified now and more precise. 24. Text (section title) was modified 25. Cumulative temperature was and is still described in methodology section. 26. Section title is changed 27. Graham et al. developed CDV for 0+ and 1+ (see Graham et al., 1996). In addition, for 2+ fish much coarser fish length information was available, hence for a "time series" of daily fish length assumptions would have been even greater for those for 0+ and 1+ fish. For details please see Tetzlaff et al., Hydrobiologia ("in press"). 28. We think this sentence paragraph is required as an introduction and explanation. 29. Please see general comment 5. 30. In Table 4 (where P values are given now) the relationship between flow variability and spawning returners is indexed by the CoV of flow and the correlations are provided.

Discussion:

31. Discussion is now restructured. 32. / 33. Text is modified. 34. This point is mistaken since we refer only to the final phase of upstream migration - we make this clear in the revised text. 35. See general comments. Numerically full juvenile recruitment means that spawning salmon are distributed throughout the burn, thus allowing juvenile habitat to be fully occupied. This is now clarified in the text. 36. Text is modified 37. Whole MS is modified. We don't understand the point re. validation of the periods chosen for study, we have chosen them based on long-term experiences and knowledge. However, we make the rationale, and basis for it, much clearer in the revised text.

Tables: Combination of Table 1 and 2 would result in a huge, complex table that would lose clarity. Terminology modified as requested.

Table 3: Please, see point 27.

Table 4: Correlations are now expressed as coefficients of correlations (r), p-values are listed, Standard deviation is listed.

Figures: Figure 1 Modified as requested

Figure 2: Modified. The relatively low velocities reflect the relatively high hydraulic roughness of the stream channel.

Figure 3: Caption is modified

Figure 4: This shows flow duration curves and the axes are conventionally log-scale axes.

Figure 5: The cumulative curves allow a direct comparison of intra-and inner annual variability, again, conventionally used in the hydrological literature. The curves start on 1st October, as the hydrological year starts conventionally at 1st October (until 30th September).

Figure 6: Now just optimum temperature after Elliot and Hurley (2003) is given as orientation (for biologically less informed readers). Figure caption is clarified.

Figure 8: Modified to make cleaered. Fry are given included.

Figure 9: Statistics are provided as requested.

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 691, 2005.