9 INDIRECT EFFECTS ON AQUATIC AND TERRESTRIAL ECOLOGY

9.1 Effects on macro-invertebrates

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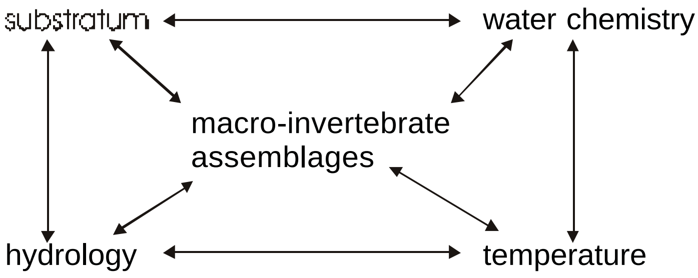
9.1.1 Introduction

Changes in climate have always occurred. Biological communities endured these changes and either adapted or went extinct. The speed with which changes occurred differed as well as the evolutionary adaptations. Just the last hunderd years man introduced a new mechanism causing a relatively quick change of the climate. Both the rate of change as well as the potential capacity of biological systems to get adapted are yet unknown.

About the relationship between discharge pattern and macro-invertebrate communities in lowland streams little is known. Even less known are the effects of changes in hydrology of the catchment on the lowland stream ecosystem. The most important and most indicative organism group in lowland streams are the macro-invertebrates. In a natural stream they compose the larger part of the ecosystem and generalists as well as specialists occur. A high number of taxa inhabit the streams and all differ in sensitivity to different ecosystem components (Figure 9.1). This makes the macro-invertebrates well suited to be used as indicators for quality, in this respect as indicators of hydrological quality or in other words discharge regime.

Figure 9.1 The simplified relationship between macro-invertebrates and the stream environment (adjusted after Cummins & Lauff 1969).



In our study the streams did not differ in water chemistry. The substrate relationships are discussed in Chapter 6. From that it appeared that substrate and hydrology could be exchanged as explanatory variables though both could not explain the other. In this chapter the interactions between macro-invertebrates and hydrology is elaborated. This means an acceptance of a strong relation between substratum and hydrology which is not yet further unravelled.

The objective of this study is to establish a robust relationship between discharge regime and macro-invertebrate communities. A relationship which can be used as a tool to assess the effect of changes in the climate through changes in hydrology on the natural lowland stream community.

9.1.2 Materials and methods

Metrics

Constrained ordination analysis resulted in a major gradient between small 'high and low discharge average ranges' at one side of the gradient versus wide 'high and low discharge average ranges', in other words high peaks at one side and constant discharge on the other. This gradient runs almost along the first ordination axis which indicates the high importance of this factor. Thus 'high and low average discharge ranges' are strongely related to the distribution patterns of macro-invertebrates in our studied streams. To refine this relationship the macro-invertebrate samples of our ten studied streams were translated into the following more general metrics:

- <u>stream velocity index</u> (v-index; Tolkamp & Gardeniers 1977)

  description: This index represents the rate of rheophily of the macro-invertebrate taxa per sample. The rate of rheophily is expressed in five classes, running from class one referring to stagnant water taxa (limnetic taxa) up to class five referring to taxa solely occurring in (fast) running water (rheobionts).

  rationale: The more natural a stream is, the more rheophilic taxa will be present, thus the index score will be higher.

- <u>diversity index</u> (H'-index; Shannon & Weaver 1949)

  description: This index represents the diversity in taxon composition of a sample.

rationale: The more natural a stream is, the higher the diversity score will be until an optimum in a near-natural stream is reached. A slight disturbance in a pristine stream leads to an increase in diversity, while a further disturbance will result in a drop in diversity. From the optimum diversity (under slightly disturbed conditions) on, the diversity index will decrease towards a pristine condition. As in this research only natural and near-natural streams were sampled the index will decrease along a gradient towards the most natural conditions studied.

- rarity-index (r-index)

  description: This index represents the rate of rare taxa present in a sample. The rarity-index is expressed in five classes from class one referring to very common taxa up to class six referring to very rare taxa.

  rationale: The more natural a stream is, the more rare taxa will occur, thus the index score will be higher.

- saprobity index (s-index; Sladecek 1973)

  description: The saprobity index represents the saprobity rate indicated by the macro-invertebrate taxa per sample. The saprobity rate is expressed in five classes from class five referring to oligosaprobic taxa up to class one referring to taxa solely occurring in polysaprobic waters (saprobionts).

  rationale: The more natural a stream is, the more taxa indicating oligosaprobic conditions will be present, thus the index score will be higher.

To calculate an index-score all taxa were as much as possible classified into the respective classes that compose the specific index. All indices, except for the diversity, are calculated according to the formula:

$$index\ score = sum\ (t_i * n_i) / sum\ (n_i)$$

in which:

- t_i : indicative weight of taxon *i* in the sample
- n_i : total number of individuals of taxon *i* in the sample

All but one index increases in score when streams become more natural.

Of special interest for this study is the discharge dynamics index (DDI). In a natural lowland stream the retention capacity of the catchment is capable of 'absorbing' the rain water deposition and then releasing this water slowly to the stream. Thus a natural stream will show a stable discharge pattern without high peaks or low drops in discharge. With this rationale on natural discharge regime, discharge dynamics were translated into the discharge metric DDI. It represents the rate in discharge dynamics indicated by continuously measured discharge data over one year in a stream. Discharge dynamics were translated into five classes ranging from class one for the most extreme discharge events to class five for the most constant discharge periods. In formula it is given by:

$$DDI = sum\ (R_i * s_i) / sum\ (R_i)$$

in which

- s_i : indicative weight per discharge dynamic class (i=1…5)
- R_i : total number of scores in the repective discharge dynamics class R

The index runs from 5 for a very constantly discharging stream towards one for a very dynamic stream.

Statistical testing

To test whether the assumptions about biological and hydrological metrics and their mutual relationships are correct, the data for the ten studied streams were used. Each of the biological indices is plotted against the DDI, the trendline is indicated in the plot and the R-square is calculated (linear regression analysis).

Scenarios

The different scenarios - listed in Table 2.7 - were tested. The current climate condition is taken as the reference.

9.1.3 Results

All four biological metrics were calculated for each of the studied streams and plotted against the discharge dynamics index (DDI). Trends between stream velocity (Figure 9.2), saprobity (Figure 9.3), rarity (Figure 9.4) and diversity (Figure 9.5) were indicated in the respective plots.

Figure 9.2 Trend between stream velocity index (v-index) and discharge dynamics index (DDI).

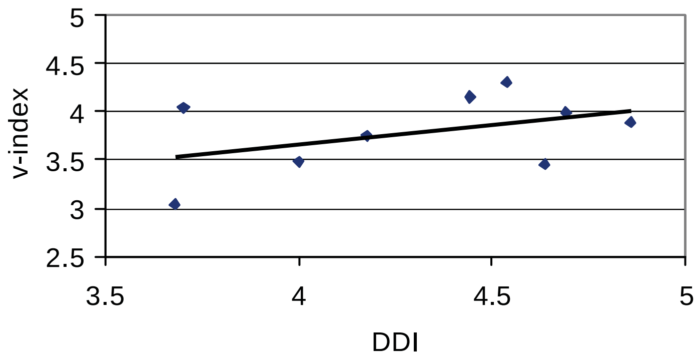


Figure 9.3 Trend between saprobity index (s-index) and discharge dynamics index (DDI).

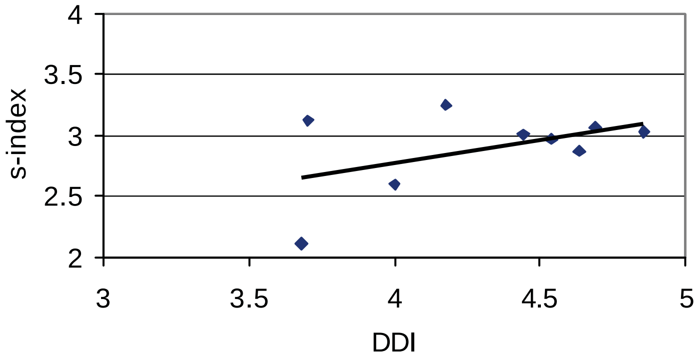


Figure 9.4 Trend between rarity index (r-index) and discharge dynamics index (DDI).

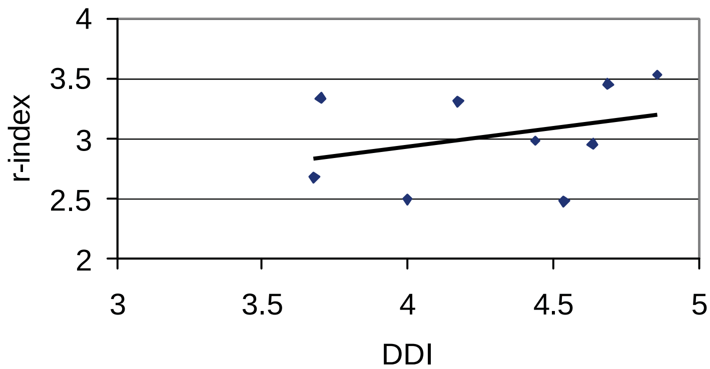


Figure 9.5 Trend between diversity (H-index) and discharge dynamics index (DDI).

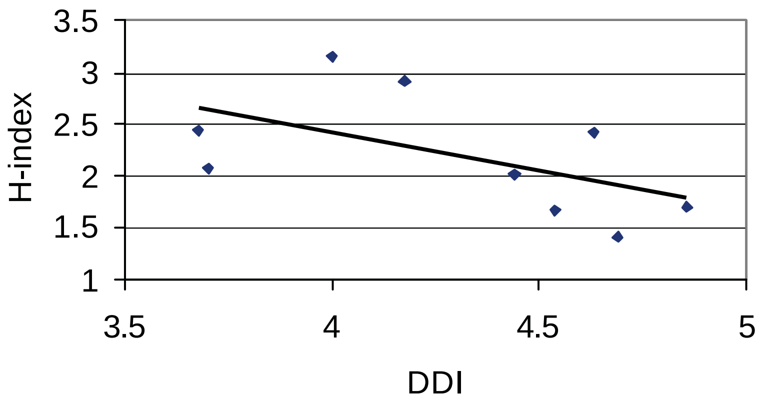


Table 9.1 R-square values for each the biological metrics.

DDI tested against:	R-square	R-square minus Springendal stream South
stream velocity index	0.19	0.45
saprobity index	0.22	0.54
diversity index	0.31	0.49
r-index	0.10	0.32

Using all data the plots showed a clear trendline but the R-square values were very low (Table 9.1). It turned out that one of the streams, Springendal stream South, had a high DDI but still was inhabited by a reasonably well developed natural stream community. This extraordinary condition can be explained by two possible causes:

1. The Springendal stream South is fed by deep groundwater and despite occasional discharge peaks, caused by drainage of part of the upper catchment, a very constant base flow is guaranteed. Furthermore, though the main channel receives drainage water from small agricultural enclaves in the upper catchment, the channel is also accompanied by a number of side springs and small side tributaries (short, small upper courses), both ensuring a constant input of sensitive and characteristic taxa.
2. The Springendal stream South is a smal tributary in a network of two main tributaries (the other is the Springendal stream North) and another three less important ones. Except for Springendal stream South all these tributaries are near-natural. These tributaries guarantee a constant input of biological material (eggs, larvae, etc.) into another tributary.

Therefore, Springendal stream South was left out of the statistical testing series (Table 9.1). This shows a raise of the R-square value to about 50%, except for the rarity index. The r-index does not seem to be suitable and should be investigated further. A R-squared value of around 50% is not high but for the limited number of eight streams and with the knowledge that also other parameters like substratum influence the macro-invertebrate distribution, a percentage of 50% nevertheless indicates a positive correlation. Therefore, it is concluded that the biological metrics support the DDI as a measure of hydrological quality in the studied streams. The higher the DDI score is, the more natural a stream will become.

9.1.4 Scenario Testing

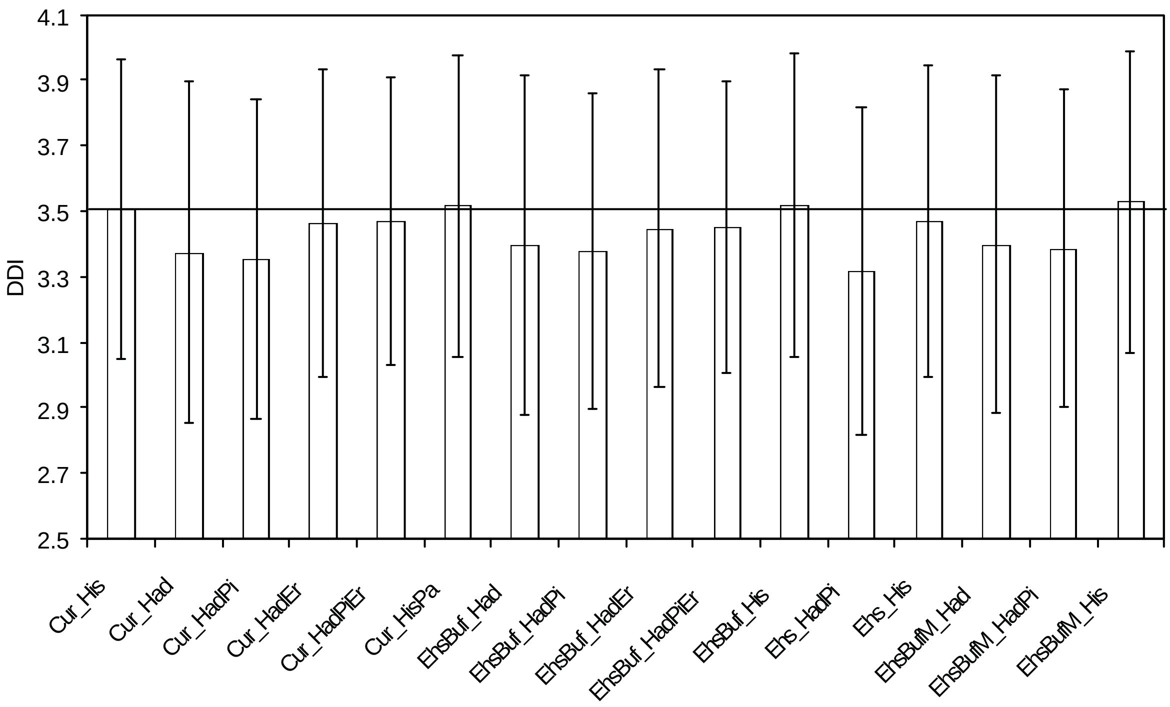
The DDI was used as a measure for the naturalness of (small) upper to middle courses of lowland streams. For each of the scenarios the DDI was calculated for the years 1998 and 2100. About 1400 sites within the test area, the catchment of Beerze-Reusel, were suited to be included in the scenario study. In total 16 scenarios were tested (Table 9.2). The results for the catchment under study were summarized by calculating the average and standard deviation of DDI-scores over all the sites (Figure 9.6). The differences in average index score were tested (Table 9.2).

The average discharge dynamics score differs for most of the scenarios significantly from the reference (current condition), even though the value of the average index only differs slightly.

Table 9.2 Significance of differences between scenarios (for scenario codes see Table 2.7).

scenario	average DDI	sd DDI	number of dry sites		P-value	significance
Cur_His	3.47	0.44	417			reference
Cur_HisPa	3.52	0.46	515	+98	0.703	ns
Cur_Had	3.51	0.46	508	+91	0.000	***
Cur_HadPi	3.37	0.52	605	+188	0.000	***
Cur_HadEr	3.35	0.49	493	+76	0.045	*
Cur_HadPiEr	3.46	0.47	509	+92	0.061	ns
Ehs_His	3.52	0.46	495	+78	0.642	ns
Ehs_HadPi	3.40	0.52	595	+178	0.000	***
EhsBuf_His	3.38	0.48	480	+63	0.000	***
EhsBuf_Had	3.45	0.48	520	+103	0.006	**
EhsBuf_HadPi	3.45	0.44	426	+9	0.009	**
EhsBuf_HadEr	3.47	0.48	511	+94	0.096	ns
EhsBuf_HadPiEr	3.32	0.50	488	+71	0.000	***
EhsBufM_His	3.53	0.46	487	+70	0.361	ns
EhsBufM_Had	3.40	0.51	580	+163	0.000	***
EhsBufM_HadPi	3.39	0.48	477	+60	0.000	***

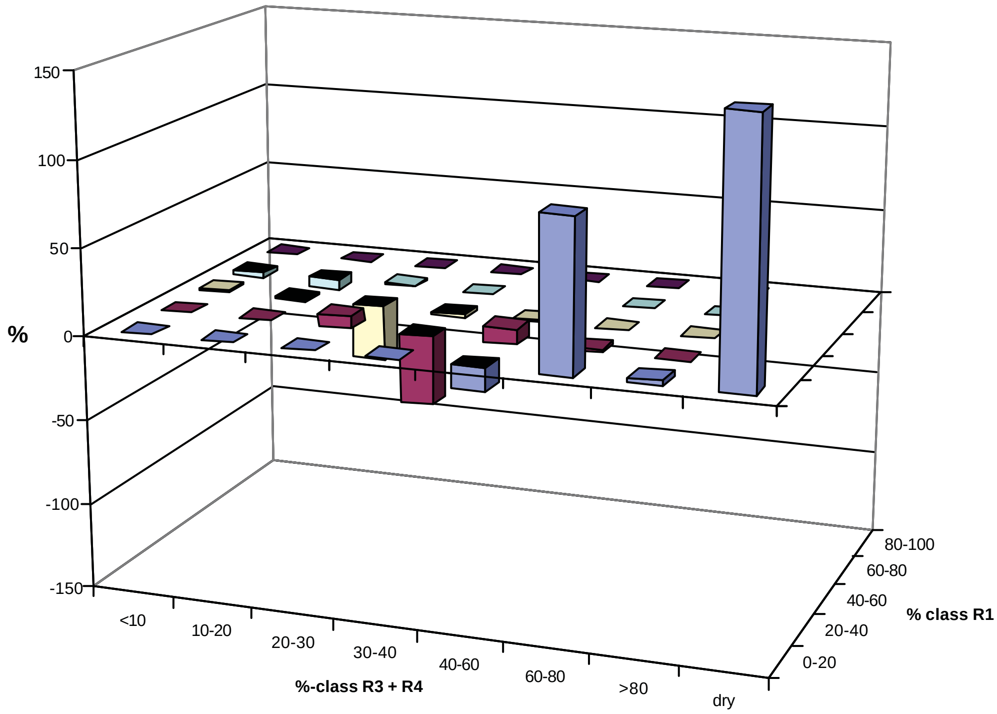
Figure 9.6 Average and standard deviation of DDI score per scenario (for codes see Table 9.2).



The scenarios which resulted in a significantly different score all show a decrease in the index. Under all these scenarios the climate change shows a significantly negative effect on the stream community. Also looking at the sites which dry up for a longer period of time (Table 9.2) it appears that all scenarios show an extended number of desiccated sites. Desiccation is fatal for most stream communities. All scenarios show an extended drought effect in the catchment.

Comparing the current condition with the implemented ecological infrastructure (*Ehs*), the EHS and buffer zone of extensive grassland (*EhsBuf*) and the EHS and buffer zone and free meandering main streams (*EhsBufM*), it is concluded that nor the ecological infrastructure, nor the buffer zone nor the meandering main stream affect the discharge dynamics index. This does not mean that especially the latter will not affect the macro-invertebrate community. On the contrary it will have a major effect but this parameter is not included in the hydrological quality assessment.

Figure 9.7 Differences between the current climate condition (*Cur_His*) and the most dynamic climate condition (*Cur_HadPi*) in percentage of sites which change of discharge dynamics class between both scenarios.



Looking in more detail at the most dynamic scenario (*Cur_HadPi*) the scores for this scenario for discharge dynamics class R_1 were classified in percentages and plotted against the sum of scores for classes with the sum of R_3 and R_4. In this plot results show the percentage changes of sites in comparison to the current climate condition (*Cur_His*) (Figure 9.7). The percentage of sites which are classified into a more extreme discharge class (R_3R_4 %-class 60-80) increase strongely, indicating the increase in dynamics under this scenario. Also the number of sites with an extended period of drought strongely increases (Figure 9.7).

9.1.5 Discussion

The response of the macro-invertebrates to extreme flow events and their ability to recover are shown to be related to the discharge dynamics index. Using stream velocity, saprobity, rarity and diversity as measures for the degree of development of the stream community, they all – except for rarity – show a correlation with discharge dynamics. These trends support the importance of discharge regime on community development. With this tool changes in climate resulting in changes in hydrology could be used to predict ecological effects. Climate change leads, in most scenarios, towards a worsening of the ecological circumstances in (small), soft-bottomed lowland streams.