ASSESSING THE BIOLOGICAL QUALITY OF FRESH WATERS:

RIVPACS AND OTHER TECHNIQUES

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CHAPTER 7

The potential of RIVPACS for predicting the effects of environmental change

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Summary

RIVPACS has been used successfully for biological assessment of river water quality but its potential in forecasting the effects of environmental change has not been investigated. This study has shown that it is possible to simulate faunal changes in response to environmental disturbance, provided that the disturbance directly involves the environmental variables used in RIVPACS predictions. These variables relate to channel shape, discharge and substratum. Many impacts, particularly those associated with pollution, will not affect these variables and therefore RIVPACS cannot simulate the effects of pollution. RIVPACS was sensitive only to major changes in substratum. It was concluded that, because of the static nature of RIVPACS, it cannot respond to the dynamic effects and processes associated with environmental disturbance. Thus RIVPACS, while showing direction of change and indicating sensitive taxa, cannot be used to predict or forecast the effects of environmental impacts.

Introduction

The "Rivers (Prevention of Pollution) Act 1951" set the scene for the beginning of the current monitoring and planning systems of the UK water industry. Since that time the assessment of environmental impacts on streams and rivers has been a prime concern of water resource managers. All national assessments of water quality before 1970 were based on chemical data, despite the existence of several biotic score systems. In part, this was due to the inability of these scores to be applied nationwide. However, even after the Biological Monitoring Working Party (BMWP) developed a nationally acceptable score system, there were difficulties associated with the high variability in achievable score in unpolluted sites over a wide range of physical conditions (Armitage *et al.* 1983). Other problems of score systems are dependency on sampling effort and the fact that they set the same target for all sites. The need to define a target community was the necessary precursor to the development of the River InVertebrate Prediction And Classification System (RIVPACS).

This system is founded on a large database of taxa lists and associated environmental features from unpolluted or best available quality sites throughout Great Britain. Selected environmental variables at a site are used to predict the probability of occurrence and relative abundance of taxa, and from this information, estimates of faunal parameters such as BMWP score, number of taxa, and average score per taxon (ASPT), are computed. The expected values of the faunal parameters are compared with those observed to provide an Ecological Quality Index (EQI) for the site (Chapter 4, p. 57). This is the most commonly used feature of

RIVPACS employed by the Environment Agency in its routine monitoring and Biological General Quality Assessment (Environment Agency 1996).

RIVPACS has other applications which make use of its ability to predict species. These predictions can be used to indicate baseline conditions before implementation of necessary management procedures. The predictions will indicate whether the site meets expectations or shows some form of stress. In "before and after" studies, RIVPACS can be used to monitor changing conditions. Close examination of predicted species/families occurrence and predicted abundance (for single season samples) can provide insights into the causative agents of change.

These applications have proved to be useful in assessing biological quality at the time of sampling (Armitage & Gunn 1996; Wright *et al.* 1994) but do not involve forecasting the future. However, it would be of considerable benefit for water managers to know what the precise effects of a given disturbance would be on the instream biota. Can RIVPACS be used in this way and if so under what circumstances? It is the objective of this chapter to examine the potential of RIVPACS to predict the effects of environmental stress.

Impacts

The main activities associated with river management are flow regulation, engineering works, and water treatment and disposal of effluents. However, disturbances in the catchment area due to agricultural practices, forestry work, quarrying, mining, construction activity and urbanisation, will also have a major influence on instream biota. These disturbances will have a variety of effects depending on their intensity, the type of river, and whether they are acting alone or with other impacting agents. Major disturbances and their primary effects are listed in Table 7.1, which shows that the disturbances relate to three main areas: flow regime, habitat and water chemistry. These in turn will have specific effects on the instream biota. For illustrative purposes, Table 7.2 presents a list of the families of macroinvertebrates found at East Stoke on the River Frome in Dorset, south-west England, together with the probable effects of specific disturbances on the occurrence of taxa, derived from published work.

Application of pesticides for agricultural purposes is often directed at insects. In this hypothetical example the effects of permethrin are shown to remove crustaceans and insects, and leave molluscs and annelids unaffected (Kingsbury 1986). Heavy metal pollution has a deleterious effect on molluscs and annelids (Hellawell 1986). Organic pollution results in the increasing loss of taxa as its severity is increased. Reduced flows favour deposit feeders at the expense of grazers, and increased flows have the reverse effect (Armitage 1987). Weed-cutting, depending on timing and extent, has little effect on the occurrence of any taxa although it may reduce abundance (Armitage, Blackburn *et al.* 1994). Construction work will generate silt and is likely to cause a reduction in taxa that require coarse substrata (Armitage & Gunn 1996).

As noted above, it is possible to theorise on the likely effects of particular impacts, based on information in the literature, but it would be preferable to simulate any given disturbance by altering environmental variables and observing the intensity and direction of the response of the instream community. Can RIVPACS be used for this purpose? Before this question can be answered it is necessary to consider which of the environmental variables used in RIVPACS will be affected by each of the possible impacts.

RIVPACS uses the following site descriptors to predict the faunal assemblages present at a site: national grid reference; altitude; distance from source; slope; alkalinity; discharge category; mean water width; mean water depth; substratum characteristics as percentage cover of boulders/cobbles, pebbles/gravel, sand, and silt/clay.

Of these descriptors, the first three cannot change (except in the most catastrophic of circumstances!). Slope could be affected by local channelisation activity but the RIVPACS

Table 7.1. *Major disturbances on rivers and their primary effects.*

Main activity	Impacts	Primary effects
Flow regulation	Increased flow	Substratum instability
	Reduced flow	Siltation
	Constant flow	Substratum stability
	Altered flow regime	Severe fluctuations in velocity
	Flood relief channel	No high flows
Engineering	Bridge construction	Substratum disturbance
	Channelisation	Channel shape
	Dredging	Substratum disturbance
	Dam construction	Flow regime
	Channel diversions	Flow regime
Water supply and disposal	Abstraction	Wetted area
	Transfer	Flow patterns
	Pollution from effluents	Increased nutrient load
Catchment activities	Agriculture	Nutrients/Pesticides
	Land clearance	Siltation
	Forestry	Siltation
	Quarrying and mining	Siltation/Pollution
	Construction work	Siltation
	Urbanisation	Pollution/Siltation
	Industry	Pollution

measure of slope is probably too crude to register change. Alkalinity is also unlikely to change unless there is a major pollution incident or the river is in receipt of transferred water with a different chemical composition. This leaves four variables that relate to channel shape, discharge and the substratum. Listed below are the likely effects of each impact (from Table 7.2) on the instream environment.

(1). Pollution. Five impacts are considered.
  (a). Pesticide: no RIVPACS variables will be affected.
  (b). Zinc: no obvious effects on variables recorded for RIVPACS.
  (c). Mild organic pollution: little effect on variables except possible algal growth on the substratum.
  (d). Severe organic pollution: increasing algal growth; no change to remaining variables.
  (e). Very severe organic pollution: growth of sewage fungus over the entire river bottom.

(2). Flow. Two impacts are considered.
  (a). Reduced flow: reduced width, depth, and discharge; increased siltation.
  (b). Increased flow: increased width, depth and discharge; removal of fines; concretion and formation of armoured layer.

(3). Weed-cutting. Reduced depth and width; increased velocity; redistribution of fines.

(4). Construction. Dredging and channelisation – engineering works. Increased sediment loads, altered slope, width, depth and substratum characteristics.

From the list above it is clear that RIVPACS could be used only to test those disturbances which are likely to affect wetted area and substratum characteristics. Organic and heavy metal

Table 7.2. *The possible effects of environmental disturbance on the occurrence of families of macroinvertebrates from an unstressed site on the River Frome, Dorset, south-west England, based on published work. Also shown are summary faunal parameters (number of taxa, BMWP score(1) and ASPT(2)) for pre-disturbance (natural, unstressed conditions) and post-disturbance at the site.*

(1) Total BMWP score for the site; (2) Average score per taxon = BMWP score ÷ number of taxa.

Score = BMWP score for individual sites; N = natural (unstressed); P = pesticide; HM = heavy metals; MO = mild organic; SO = severe organic, VSO = very severe organic pollution; Red = reduced flow; Inc = increased flow; Constr = construction (engineering works).

		Pollution						River flow		Weed cutting	
Taxa	Score	N	P	HM	MO	SO	VSO	Red	Inc		Constr
Neritidae	3	1	1	–	1	–	–	–	–	1	–
Valvatidae	3	1	1	–	1	–	–	–	–	1	–
Lymnaeidae	3	1	1	–	1	1	–	–	–	1	1
Physidae	3	1	1	–	1	–	–	–	–	1	–
Ancylidae	6	1	1	–	–	–	–	–	1	1	–
Sphaeriidae	3	1	1	–	1	–	–	1	–	1	–
Oligochaeta	1	1	1	–	1	1	1	1	1	1	–
Piscicolidae	4	1	1	–	–	–	–	–	–	1	–
Glossiphoniidae	3	1	1	1	1	1	–	–	1	1	1
Asellidae	3	1	–	1	1	1	–	1	–	1	1
Gammaridae	6	1	–	–	1	–	–	–	1	1	1
Baetidae	4	1	–	1	1	1	–	1	1	1	1
Heptageniidae	10	1	–	–	–	–	–	–	1	1	–
Ephemeridae	10	1	–	–	–	–	–	1	–	1	–
Leuctridae	10	1	–	1	–	–	–	–	1	1	–
Calopterygidae	8	1	–	–	1	–	–	1	–	1	–
Aphelocheiridae	10	1	–	–	–	–	–	–	–	1	–
Corixidae	5	1	–	–	1	–	–	1	–	1	1
Elmidae	5	1	–	–	1	–	–	–	1	1	–
Gyrinidae	5	1	–	1	1	1	–	1	–	1	–
Rhyacophilidae	7	1	–	1	–	–	–	–	1	1	–
Hydropsychidae	5	1	–	1	1	–	–	–	1	1	–
Leptoceridae	10	1	–	–	–	–	–	1	–	1	–
Hydroptilidae	6	1	–	–	1	–	–	–	–	1	–
Brachycentridae	10	1	–	–	–	–	–	–	–	1	–
Tipuliidae	5	1	–	1	1	1	–	1	1	1	1
Chironomidae	2	1	–	1	1	1	1	1	1	1	1
Simuliidae	5	1	–	1	1	–	–	–	1	1	–
Number of taxa:		28	9	10	19	8	2	11	13	28	8
Total BMWP score(1):		155	29	49	78	26	3	56	69	155	31
ASPT(2):		5.54	3.22	4.90	4.11	3.25	1.50	5.09	5.31	5.54	3.88

pollution will not affect the variables used in RIVPACS. Thus, although RIVPACS can be used to assess sites that are impacted by these factors, by comparing the observed faunal community with that predicted for a site with similar environmental conditions, it cannot be used to simulate the impacts of pollution. In contrast, disturbances which result in changes in channel characteristics and substratum composition may be amenable to simulation. These aspects will be addressed below.

Simulation of disturbance

An attempt to simulate disturbance with an early version of RIVPACS is reported by Armitage (1989). The substratum of a hypothetical upland site was changed from boulder/cobbles to silt, with all other variables kept constant, in order to examine the response of selected families and species (Fig. 7.1). Baetidae and Hydropsychidae are relatively insensitive to change, up to a mean phi value of 0 (sandy gravel), but as the substratum becomes finer these taxa (i.e. families) show a steep decrease in abundance. Nemouridae show an immediate reduction in response to decreasing particle size, in contrast to Sphaeriidae whose abundance increases. The species show similar fluctuations, but two, the stonefly *Leuctra geniculata* and the mayfly *Centroptilum luteolum*, are most abundant at mean phi values of 1 to 2. Knowledge of the habitat requirements of these taxa indicates that the predictions of abundance and occurrence make "ecological sense", and shows that there may be some potential in this technique for anticipating those organisms which are most likely to respond to increased siltation.

In a recent study (Armitage *et al.* 1997), attempts were made to simulate the effects of low flow by altering the environmental variables used in RIVPACS III predictions at three sites. Predictions were run for the summer season. Two of the sites, 200 m apart, are situated on the Mill Stream (a side channel of the River Frome, Dorset) and differ in channel shape and substratum (sites MH and MS). The third site (R) has physical features based on those of a typical chalk stream in its middle reaches. In all three sites the proportion of fine substratum was increased and width and depth decreased, to simulate the effects of reduced discharge (see Table 7.3). The results for these three sites are presented in Table 7.3, together with data from another two sites: an additional chalk stream middle reach (F), and an upland coarse-bottomed stretch of the South Tyne (ST) in Cumbria, northern England. Chalk stream sites dominate this selection because they show the most pronounced reaction to low flow stress (Armitage & Petts 1992). The upland site is included for comparative purposes. A further four sites on two small lowland streams, (Wool Stream and Swan Brook), where known substratum changes had taken place, were used to test the sensitivity of RIVPACS in detecting or highlighting change in the faunal assemblages (Table 7.3).

The full output from RIVPACS is voluminous and the results are presented in summary form only. For each site, observed environmental data were used to predict abundance and occurrence of invertebrate families. This was then considered as the control against which to measure the effects of simulation. The results are expressed as the difference between the control values and those derived from the most extreme simulation for each site. In most cases the combination of environmental variables used in the extreme simulation generated a warning notice from the RIVPACS program, indicating that a site with these physical characteristics had a low probability of belonging to any group in the dataset (Table 7.3). Only those families showing the greatest response are considered.

The effects of the simulations on occurrence are illustrated in Figures 7.2, 7.3 and 7.4, where positive values of percent difference indicate a reduction in the probability of occurrence of a taxon from the control to the simulated state. For example, if the probability of Ephemerellidae occurring at the control site is 50%, but this reduces to 30% for the extreme simulation, then the percent difference for control minus simulation gives a positive value of 20% for Ephemerellidae. The main points to note are the relatively small response in the Mill Stream sites (maximum difference <20% in Fig. 7.2) compared to a massive response in the South Tyne (over 90% in Fig. 7.4). Similar trends were observed for abundance (Fig. 7.5) but responses of individual families differed; for example, at site F, Rhyacophilidae showed the greatest response in occurrence (Fig. 7.3) but Ephemerellidae showed the largest change in abundance (Fig. 7.5). Similar results are seen at site R (cf. Figs 7.3 and 7.5).

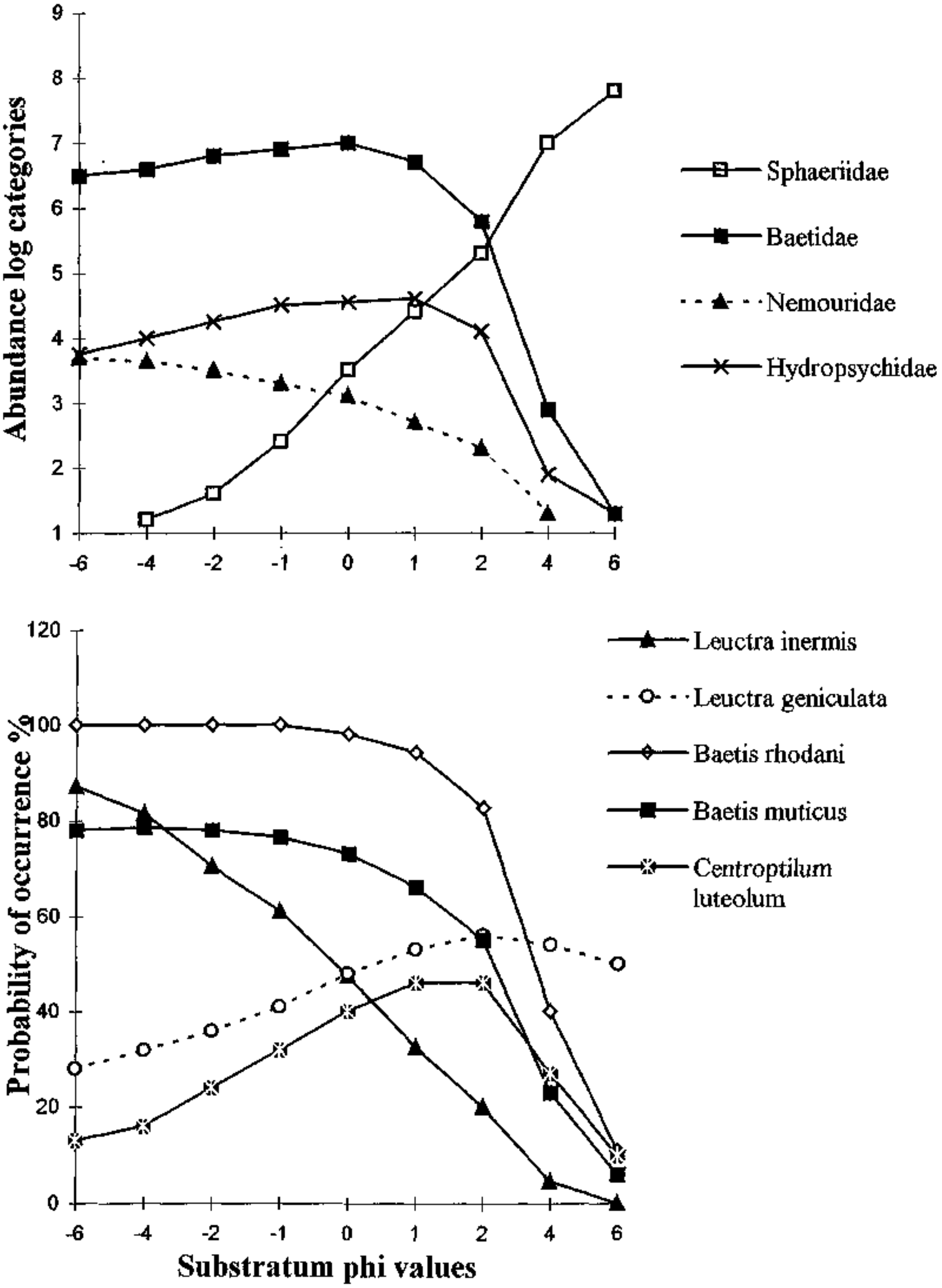


Figure 7.1. The effect of simulated change in mean substratum particle size on the predicted abundance of four macroinvertebrate families and the probability of occurrence of five species. (Predictions are based on three seasons).

Table 7.3. *The environmental parameters used in simulations for the Mill Stream sites (MH and MS), the middle reaches of a chalkstream (R and F), the South Tyne (ST), the Wool Stream (W3, W5) and Swan Brook (S4, S5).*

Discharge ($m^3 s^{-1}$) is based on categories used in RIVPACS whereby <0.31 $m^3 s^{-1}$ = 1, <0.62 = 2 etc.

Stream width is given in metres and stream depth in cm.

Values for substratum (bc = boulders and cobbles; pg = pebbles and gravel; sa = sand; sc = silt and clay) are percent cover, together with mean substratum particle size for each site in phi units.

Fit (final column) indicates the probability (%) of the site belonging to any group in the RIVPACS classification.

				Substratum (% cover)				Mean	
Site	Discharge	Width	Depth	bc	pg	sa	sc	size	Fit
MH Control	1.25	4.6	65	0	23	50	27	2.41	100
MH Test 1	0.62	4.3	50	0	10	60	30	3.28	100
MH Test 2	0.31	4	35	0	1	54	45	4.65	<5
MS Control	0.62	5	32	0	70	20	10	–1.08	100
MS Test 1	0.31	5	20	0	30	40	30	2.23	100
MS Test 2	0.31	5	15	0	5	35	60	5.34	<1
R Control	1.25	10	30	15	70	10	5	–2.84	100
R Test 1	0.62	5	15	1	10	29	60	4.98	100
R Test 2	0.31	5	5	1	4	10	85	6.79	<0.1
F Control	2.50	12	41	27	62	9	2	–3.77	100
F Test 1	1.25	9	30	15	40	30	15	–0.66	100
F Test 2	0.62	7	20	5	20	25	50	3.46	100
F Test 3	0.31	2	10	0	10	20	70	5.68	<5
ST Control	1.25	6	17	98	2	0	0	–7.66	100
ST Test 1	0.62	4	10	40	1	40	19	–0.81	100
ST Test 2	0.31	2	5	5	1	44	50	4.46	<0.1
ST Test 3	0.31	1	4	2	0	20	78	6.49	<0.1
W3 Control	0.31	2.6	16	2	55	37	6	–0.72	100
W3 Test 1	0.31	2.4	16	0	30	40	30	2.23	100
W3 Test 2	0.31	2.2	15	0	6	44	50	4.69	100
W3 Test 3	0.31	2	14	0	0	30	70	6.20	100
W5 Control	0.31	2.1	17	0	6	44	50	4.69	100
W5 Test 1	0.31	2.1	17	0	30	40	30	2.23	100
W5 Test 2	0.31	2.2	17	0	40	45	15	0.80	100
W5 Test 3	0.31	2.3	17	2	55	37	6	–0.72	100
S4 Control	0.31	3.3	21.6	25	60	10	5	–3.29	100
S4 Test 1	0.31	2.5	15	15	40	25	20	–0.36	100
S4 Test 2	0.31	1.5	10	10	20	20	50	2.98	100
S4 Test 3	0.31	1	5	5	5	15	75	5.75	<1
S5 Control	0.31	3.6	30.3	5	5	15	75	5.75	100
S5 Test 1	0.31	3.6	35	10	20	20	50	2.98	100
S5 Test 2	0.62	3.6	40	15	40	35	10	–0.96	100
S5 Test 3	0.62	3.6	50	25	60	10	5	–3.29	<5

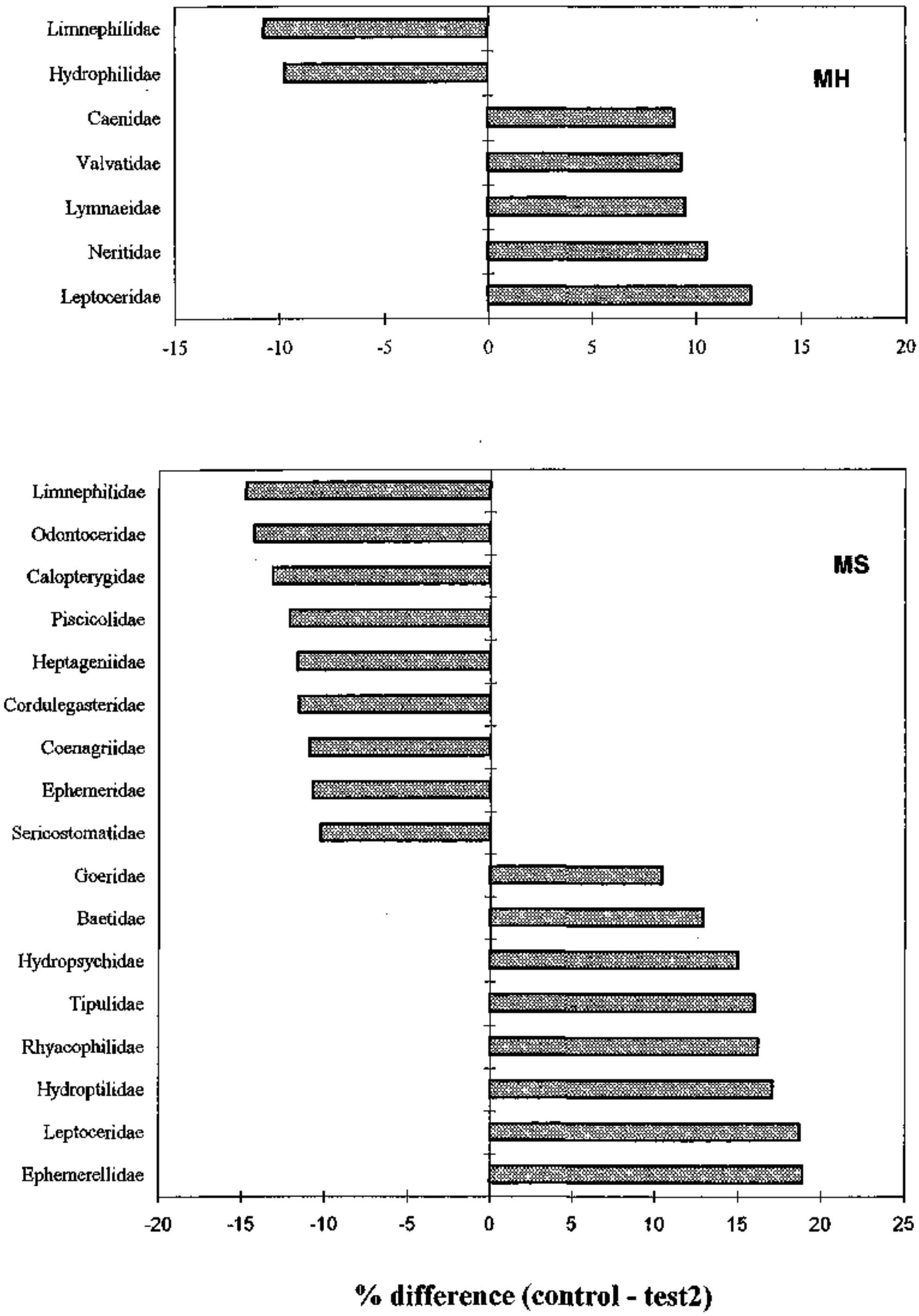
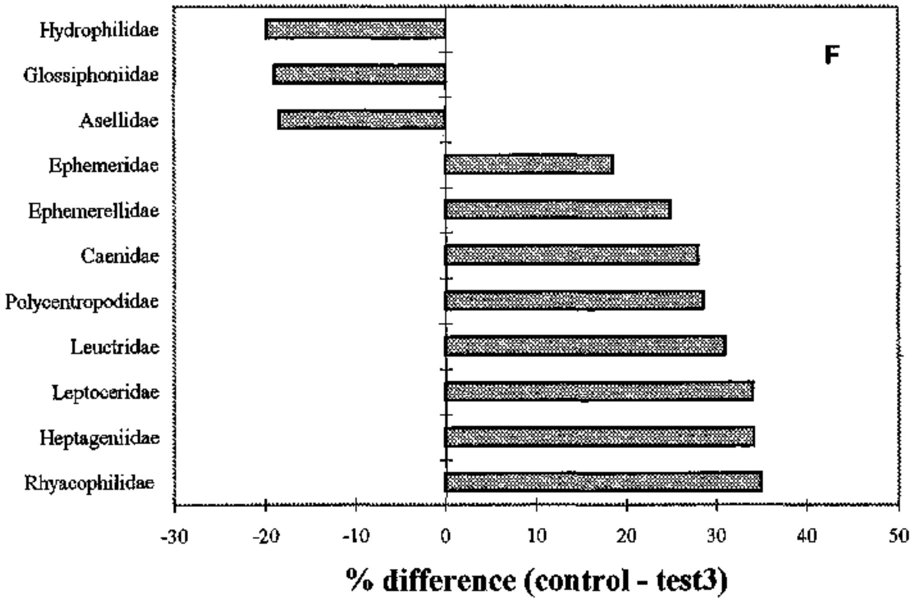


Figure 7.2. The difference between the probability of occurrence derived from control and extreme simulations for those families showing the greatest response at the Mill Head (MH) and Mill Stream (MS) sites, in lowland streams, Dorset, south-west England. Positive values of percent difference indicate a reduction in the predicted probability of occurrence of a taxon.



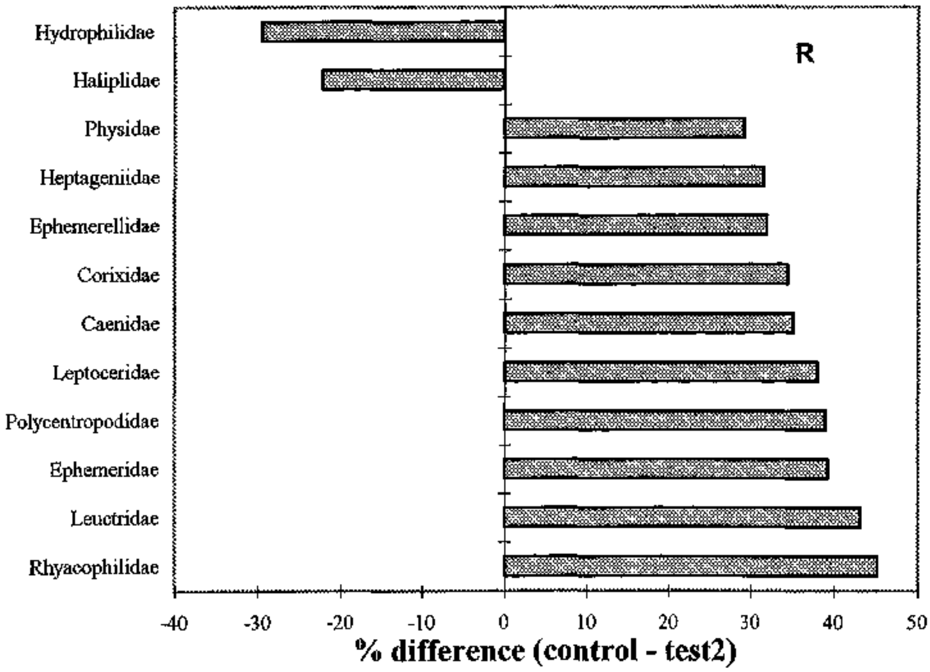


Figure 7.3. The difference between the probability of occurrence derived from control and extreme simulations for those families showing the greatest response at two chalk stream sites, F and R, in Dorset. Positive values of percent difference indicate a reduction in the predicted probability of occurrence of a taxon.

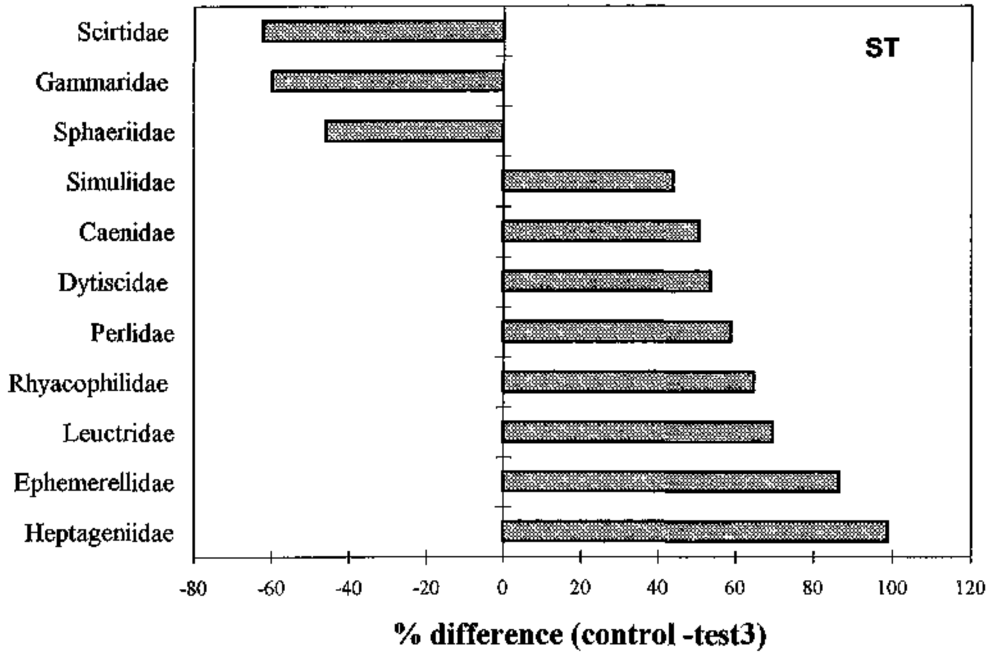


Figure 7.4. The difference between the probability of occurrence derived from control and extreme simulations for those families showing the greatest response at the South Tyne site near Alston in Cumbria, northern England. Positive values of percent difference indicate a reduction in the predicted probability of occurrence of a taxon.

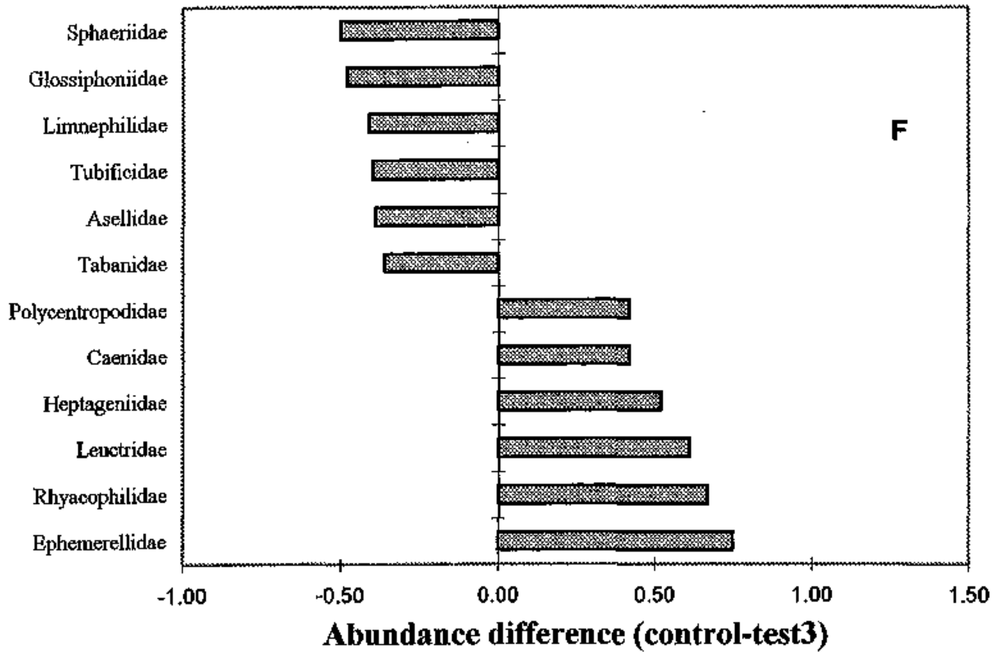
Validation of prediction

The examples shown in Figures 7.2 to 7.5 illustrate how RIVPACS predictions respond to the effects of siltation in streams, but there is no validation of the prediction. In order to examine the "accuracy" of the RIVPACS simulation, two lowland streams are considered where known siltation has taken place.

The Wool Stream is a small spring-fed watercourse. In its lower reaches at site W5 it flows through pasture. It has been severely channelised and the banks have been poached by cattle. This, together with some constriction of flow through a culvert, has resulted in an increase in siltation. About 200 m upstream at site W3 there is no channelisation and the bottom is a sandy gravel. The question posed was: if the substratum of the upstream site (W3) is changed to that of the silted site (W5), will the predictions simulate the observed differences between sites?

The Swan Brook is a small lowland stream draining a hilly catchment and entering the sea at the town of Swanage, in Dorset. The town has been subject to severe floods and recently a relief channel has been constructed to divert all extreme flows. This has resulted in the siltation of the old channel downstream of the diversion (S5), since it no longer experiences flushing flows. A site above the diversion (S4) has a coarse substratum and reflects the pre-regulation situation. A similar question was posed: if S4 is silted-up to the level observed at S5, will the RIVPACS predictions simulate the observed differences between sites? Similarly, if silt is removed from S5, will the reverse hold true?

The results, based on predictions of occurrence, are shown in Figure 7.6. At the Wool Stream site (W3) it is clear that increase in the proportion of silt in the simulation had little effect on



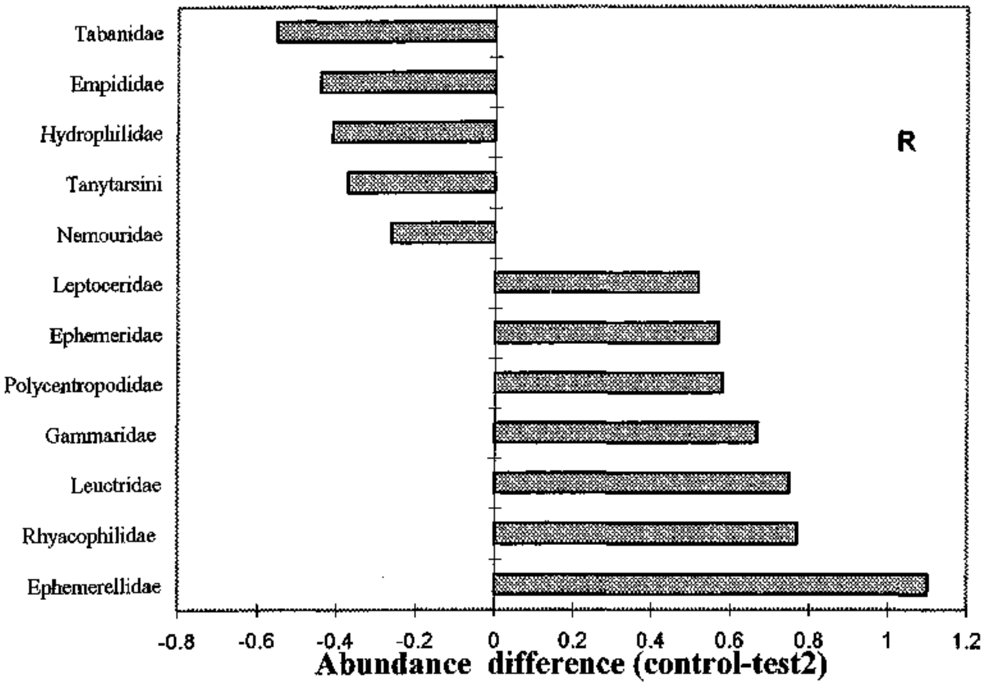


Figure 7.5. The difference between the predicted $\log_{10}$ abundance values derived from control and extreme simulations for those families showing the greatest response at two chalk stream sites, F and R, in Dorset. Positive values of percent difference indicate a reduction in the predicted abundance of a taxon.

the predictions of faunal occurrence (percent difference <2.0%). In the Swan Brook, differences were greater (up to 30%) at both sites. At S4 the probability of occurrence of three families, Lymnaeidae, Nemouridae and Leptophlebiidae, increased with siltation, but a larger number (15) showed a reduced probability of occurrence. At S5 where the mean particle size was increased, the Leuctridae, Perlodidae, Hydropsychidae and Gammaridae showed an increase in their probability of occurrence.

In the Swan Brook, the tests are set up so that the most extreme simulation at S4 mimics the observed substratum at S5 and *vice versa*. Similarly, in the Wool Stream at W3 the most extreme simulation corresponds to the observed substratum at W5. The relationship between pairs of comparisons of observed and predicted abundances, and predicted probability of occurrence, was examined using the Spearman rank test. For probability of occurrence only predicted values could be compared, as observed values were either 100 or 0. The results from the matrix of comparisons are presented in Table 7.4. Values of the coefficients >0.359 and >0.329 are significant at the $p = 0.05$ level for the Swan Brook and Wool Stream respectively. The main conclusion from this analysis was that despite the changes in environmental parameters, the faunal characteristics of control and simulated predictions remained similar. Thus in the Swan Brook, the faunal abundances of the 24 test families predicted using the actual substratum variables, were close to those predicted when using the altered substratum variables (S4C/S4T, $r_s = 0.976$). The equivalent value for occurrence is 0.930. In the Wool Stream, similar relationships were noted between comparisons.

The particular comparisons that relate to the questions posed above are S4T/S5O, S5T/S4O, and W3T/W5O. The r_s values associated with these comparisons for abundances are respectively 0.515, 0.586 and 0.548. This indicates that a simulated reduction in mean substratum particle size at S4O results in predicted abundances similar to those observed at S5. Furthermore, the increase in the mean particle size of the substratum of S5O results in a fauna resembling that of S4O, and simulated reduction of particle size at W3O results in a fauna similar to that observed at W5O. However, association between other pairs of comparisons, as noted above, is much higher, and it is difficult to interpret these data. It appears that in streams of this type, simulations of environmental change do not result in major shifts in community composition.

Using faunal parameters

So far, the analyses have focused on family occurrence and abundance, but a more common treatment of survey data is to use faunal parameters to summarise the results. The observed and expected values of BMWP score, number of taxa and ASPT are listed in Table 7.5, for sites where simulations were tested. The effect of simulated change on the expected faunal parameters is presented in Figure 7.7, where the sites are ordered according to the amount of simulated substratum change (substratum difference). Thus the South Tyne (ST) ranged from a mean substratum of –7.66 (observed state) to 6.49 (extreme simulation) and the Mill Stream (MS) ranged from –1.08 to 5.34. In general there was a positive association between faunal difference and substratum difference but some sites, for example those on the Mill Stream, MS and MH, and at Wool 3, showed little response to changes in substratum.

The overall lack of response is shown in Figure 7.8, which depicts the situation in a hypothetical coarse-bottomed stream where the mean substratum particle size is reduced to 1.5 from a start value of –7.7. (This extreme change did not generate a warning notice from the RIVPACS program). It is clear that despite this reduction in mean substratum there is little change in the faunal parameter values. At present this is unexplained, but it may be related to the fact that changes in faunal composition are not always reflected by single parameter values.

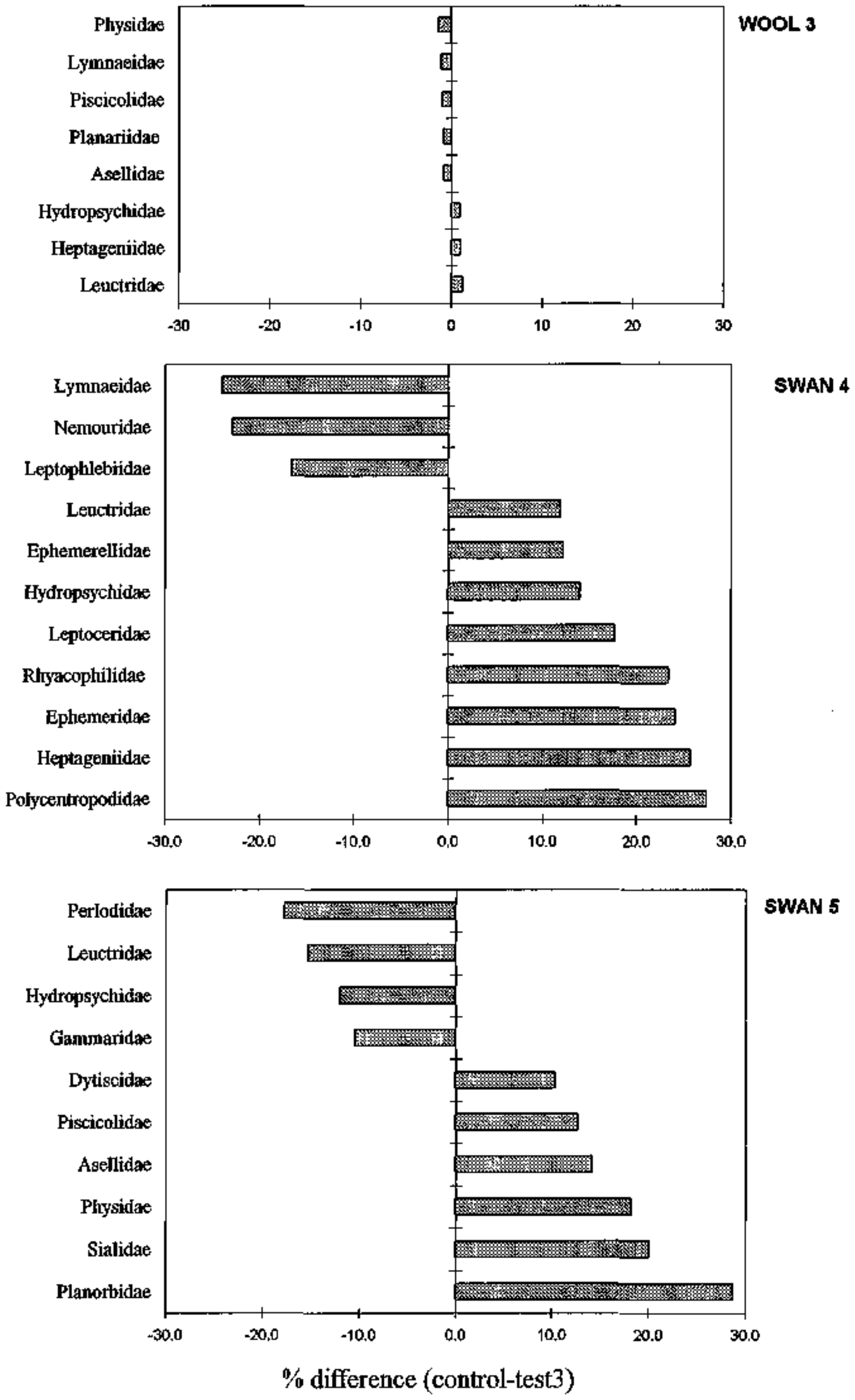


Figure 7.6. The difference between the probability of occurrence derived from control and extreme simulations for those families showing the greatest response at the Wool Stream site (W3) and at sites S4 and S5 on the Swan Brook, in Dorset. Positive values of percent difference indicate a reduction in the predicted probability of occurrence of a taxon.

Table 7.4. *Correlation (Spearmans, calculated from ranked values) between pairs of comparisons for Swan Brook sites S4 and S5, and Wool Stream sites W3 and W5, for observed (O), predicted control (C), and extreme simulations (T), based on predicted probability of occurrence and abundance.*

N = 24 for the Swan Brook and 28 for Wool Stream; * indicates invalid comparisons.

Further details are given in the text.

Swan Brook:	S4O	S4C	S4T	S5O	S5C
Abundance					
S4C	0.588				
S4T	0.546	0.976			
S5O	0.043	0.425	0.515		
S5C	0.511	0.927	0.966	0.591	
S5T	0.586	0.990	0.987	0.477	0.955
Occurrence					
S4C	*				
S4T	*	0.930			
S5O	*	*	*		
S5C	*	0.896	0.869	*	
S5T	*	0.992	0.936	*	0.907

Wool Stream:–	W3O	W3C	W3T	W5O	W5C
Abundance					
W3C	0.826				
W3T	0.827	0.997			
W5O	0.391	0.538	0.548		
W5C	0.824	0.998	0.999	0.547	
W5T	0.815	0.997	0.995	0.538	0.997
Occurrence					
W3C	*				
W3T	*	0.981			
W5O	*	*	*		
W5C	*	0.986	0.983	*	
W5T	*	0.997	0.980	*	0.991

That is to say, different combinations of environmental variables can result in the same BMWP score, ASPT or number of taxa. Another possibility is the starting point of the simulation. For instance a change from small cobble (phi –6) to fine gravel (phi –1), a difference of five substratum units, may generate greater differences in faunal parameters than a similar five units change, from coarse gravel (phi –3) to medium sand (phi 2). This requires testing on a wide range of examples.

Discussion

There is sometimes an expectation that RIVPACS has the ability to predict the effects of environmental change. However, this was never the objective and its main role has been in assessing environmental quality, by comparing observed faunal occurrence and abundance at a site with that predicted from environmental variables recorded at the same site. The ability to predict the effects of future impacts on a river system would be a valuable tool, and given the comprehensive database associated with RIVPACS, its potential as a predictor of the effects of

Table 7.5. *Observed values of three faunal parameters: BMWP score, number of taxa (N-Taxa) and average score per taxon (ASPT), with expected values from RIVPACS predictions for all control and test simulations.*

Site	Observed Score	N-Taxa	ASPT	Expected Score	N-Taxa	ASPT
MH Control	165	31	5.32	131.9	26.1	5.04
MH Test 1	165	31	5.32	129.4	25.7	5.03
MH Test 2	165	31	5.32	130.8	25.7	5.08
MS Control	190	33	5.76	139.2	26.4	5.25
MS Test 1	190	33	5.76	143.3	26.7	5.35
MS Test 2	190	33	5.76	140.2	26.4	5.29
R Control	122	23	5.3	147.2	26.8	5.48
R Test 1	122	23	5.3	140.9	26.2	5.36
R Test 2	122	23	5.3	105.5	21.8	4.81
F Control	137	25	5.48	144	25.7	5.6
F Test 1	137	25	5.48	144.6	26.3	5.49
F Test 2	137	25	5.48	146.8	26.7	5.48
F Test 3	137	25	5.48	119.6	23.4	5.08
ST Control	91	14	6.5	102.5	16.3	6.27
ST Test 1	91	14	6.5	109.3	17.7	6.17
ST Test 2	91	14	6.5	71.9	13.4	5.33
ST Test 3	91	14	6.5	64.5	12.4	5.16
W3 Control	133	26	5.12	112.8	23.5	4.79
W3 Test 1	133	26	5.12	112.6	23.5	4.78
W3 Test 2	133	26	5.12	112.5	23.5	4.78
W3 Test 3	133	26	5.12	112.5	23.5	4.78
W5 Control	56	14	4.0	112.7	23.5	4.78
W5 Test 1	56	14	4.0	112.9	23.5	4.79
W5 Test 2	56	14	4.0	113.2	23.5	4.8
W5 Test 3	56	14	4.0	113.7	23.5	4.83
S4 Control	100	19	5.26	136.3	24.6	5.53
S4 Test 1	100	19	5.26	136.4	24.8	5.48
S4 Test 2	100	19	5.26	131.5	24.3	5.41
S4 Test 3	100	19	5.26	111.8	21.6	5.15
S5 Control	63	17	3.71	139.9	26	5.37
S5 Test 1	63	17	3.71	145.3	26.5	5.48
S5 Test 2	63	17	3.71	140.9	25.6	5.5
S5 Test 3	63	17	3.71	137.1	24.9	5.5

environmental change required investigation. This preliminary study has shown that only those disturbances which involve changes to the variables currently used in RIVPACS can be considered. This restricts its possible use to changes involving channel characteristics, discharge and alkalinity (a surrogate for parent rock-type in the catchment).

The results indicate that it is possible to record faunal change by altering environmental variables to simulate potential impacts. However, the responses are relatively small and although the two validation tests carried out in this study indicate the possibility of simulating a real change, the process shows a lack of sensitivity except in the most extreme cases. The situation in the Wool Stream provides a good example of this insensitivity. Despite a change from a gravel substratum to one dominated by silt, the predicted family occurrence and

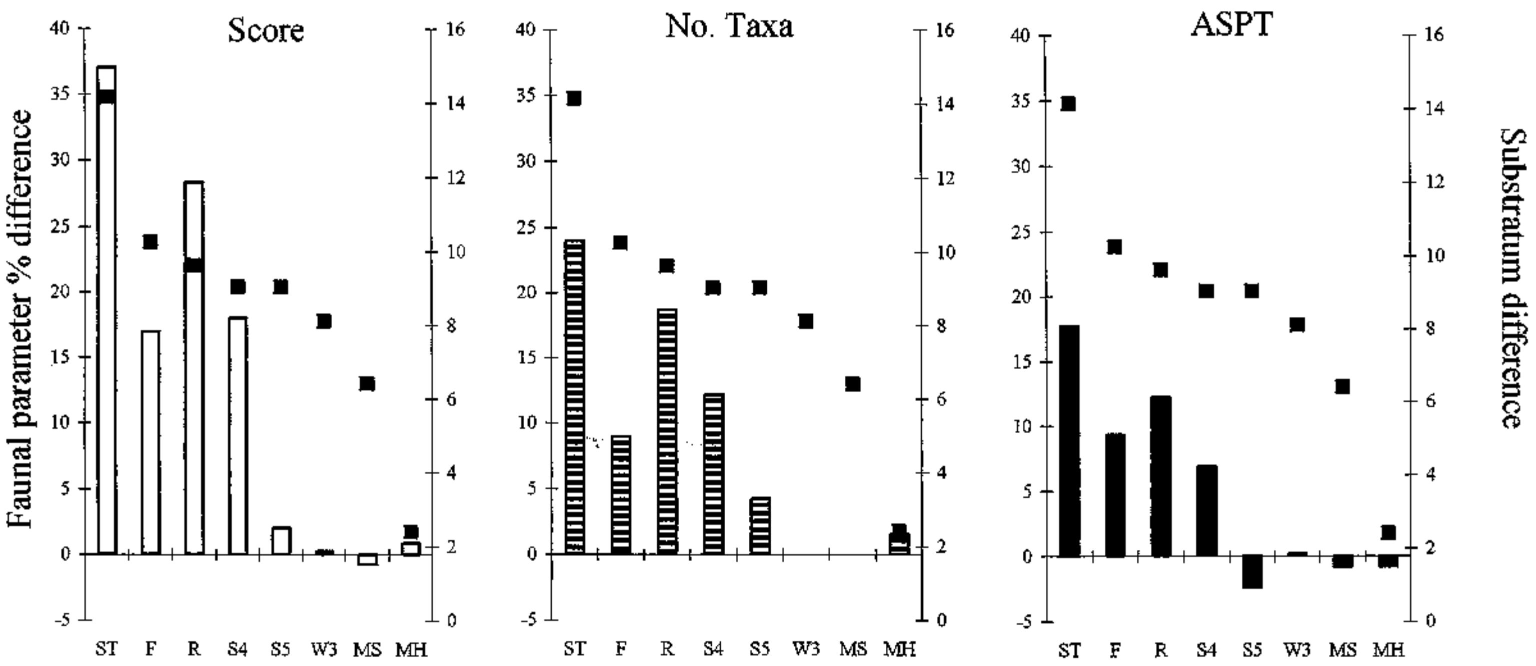


Figure 7.7. The effect of simulated substratum change (squares) on the prediction of three faunal parameters (columns): BMWP score, number of taxa and ASPT. The results are expressed as the percent difference between the control (unstressed) and most extreme test for each river. (ST = South Tyne; F and R = chalk stream middle section; S4 and S5 = Swan Brook; W3 = Wool Stream; MH = Mill Head, MS = Mill Stream). Also shown is the difference between substratum values of control and extreme tests – thus a simulated change from a mean substratum value of phi –4 to phi +5 represents a change of 9 units.

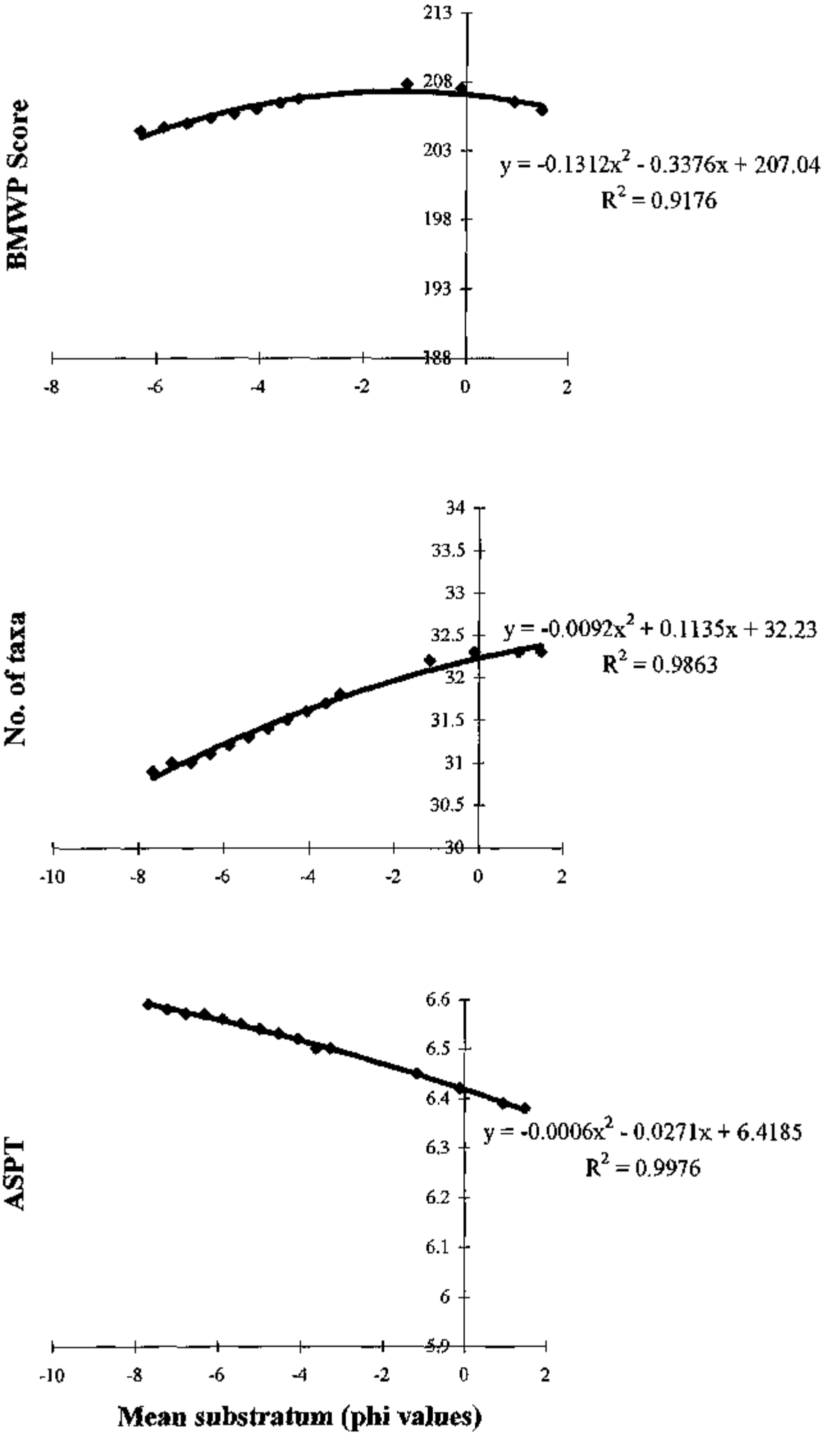


Figure 7.8. The effect of simulated increase in siltation on predictions of three faunal parameters: BMWP score, number of taxa and ASPT. Points represent the mean substratum values entered in the simulations, and their distribution is described by the fitted polynomial.

abundance did not alter. Even the most extreme simulation did not generate a warning notice from the program, and the predicted group membership did not change. The observed environmental conditions placed the site in RIVPACS III group 31 with a probability of 97.8%, and the most extreme simulation placed it in the same group with a probability of 99.9%. This group contains small lowland streams with a high alkalinity, and it is these properties which define the group, despite a wide range of substratum conditions. This feature makes RIVPACS insensitive to substratum changes in streams of this type. In addition, extreme simulations are frequently unsuitable for RIVPACS, and the program provides a warning when the particular combination of environmental variables has a low probability of occurrence in the dataset. These reasons alone show that RIVPACS probably does not have much potential to predict the possible effects of environmental disturbance or stress.

Another possible reason for the lack of sensitivity may be the RIVPACS sample itself, which includes all available habitats. This means that if some prime habitat is much reduced it will still be sampled, and it is highly likely that the species will occur in the sample. The use of abundance data will improve matters but there will be cases where animals are concentrated into a small area, and when this is sampled, abundance will seem to be relatively high. An example is seen when chalk stream systems are subject to low flow, where Rhyacophilidae will be concentrated in areas of fast flow channelled between weed-beds.

It is clear that most stresses/disturbances on the lotic system involve changes, either directly or indirectly, to instream habitat. For example, dredging and channel engineering will affect the distribution of substratum particles and alter channel dimensions (Brooks 1994). Flow regulation below reservoirs may result in modifications to the substratum (Simons 1979; Gore 1994) and the removal or addition of water (transfers and abstractions) may radically alter the wetted area in a stream and hence the availability and quality of habitat (Armitage & Petts 1992). The patchwork of habitats or mesohabitats, observed from the bank of a river, possess characteristic faunal assemblages (Armitage *et al.* 1995; Pardo & Armitage 1997) and disturbances will affect their distribution and extent. In RIVPACS, all available habitats are sampled roughly in proportion to their occurrence but are combined, so there is no habitat-specific data. An ideal system for forecasting the effects of environmental change on macroinvertebrate assemblages will require habitat-specific sampling, and knowledge of the area or percentage cover of the habitat patches constituting the area of investigation. The effects of particular disturbances and management regimes on instream habitat will provide a necessary first step towards modelling and forecasting the effects of changes and disturbances to the environment.

RIVPACS is a static model and cannot validly be used as a forecasting system. Such a system will need separate development and will require different types of data. Predictive models are particularly well developed with respect to the effects of nutrient enrichment in lake ecosystems (Vollenweider 1975; Aldenberg & Peters 1990; Reynolds 1996; Reynolds & Irish 1997) and in rivers (Dauta 1986; Reynolds & Glaister 1993), and are frequently based on detailed information on the response of algal populations to changing environmental conditions. Alternatively, historical data may be used to forecast ecological succession (Bravard *et al.* 1986). Such information is not a part of RIVPACS.

Where next? The modification of RIVPACS to include polluted sites may offer the possibility of classifying pollution responses in a wide range of river types. However, prediction of change would still be impossible because of several complicating factors, such as synergistic effects of variables, differing rates of recovery from pollution, and recolonisation processes. An alternative approach would be to build on knowledge of the processes involved in environmental disturbance. To forecast or predict the effects of environmental change we need to know what happens when disturbances take place, how long the effects will take to develop, and their duration. A series of case-histories in different river types may provide suitable data on the physical changes that accompany disturbance. This, in conjunction with more detailed information on geomorphology, hydraulics and siltation relationships, will contribute to the development of a system which could predict future impacts. When this is linked to information on the effects of a suite of pollutants under different flow conditions, at different concentrations and in different seasons, we would have the ingredients for an expert system. Such a system should enable the manager of a river to forecast the likely effects of an environmental disturbance. This is a long way in the future, and depends on the investment of the water resource organisations in acquiring knowledge of the processes associated with specific disturbances. At present it must be concluded that RIVPACS, while showing direction of change and indicating sensitive taxa, cannot be used to predict or forecast the effects of environmental impacts.

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