Ecological Effects of Discharges from Watercress Farms on the Chalk-Streams of the NRA Wessex Region.

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November 1992

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SUMMARY

Discharges from watercress farms are of considerable concern to the Wessex Region of the NRA, relating principally to excessive siltation and an absence of the freshwater shrimp (*Gammarus pulex*) below effluent discharge points. This investigation was carried out in order to assess the severity and extent of these problems, and to identify any further impacts from watercress cultivation.

Fifteen working watercress farms were identified in the Wessex Region; all were located in the Avon and Dorset Area. Macroinvertebrate samples were taken and macrophyte surveys undertaken, at points above and below each watercress farm. Where watercress farms were located at the source or perennial head of a stream, control samples were taken on an adjacent tributary, if one existed. The resulting data were analysed using biotic indices, the RIVPACS predictive model, and the multivariate statistical technique TWINSPAN.

In most cases, observed biotic scores exceeded RIVPACS predictions and indicated high environmental quality. ASPT and EQI (ASPT) values were, however, lower downstream of watercress farm discharges. This generally corresponded with an increase in the number of scoring taxa, BMWP score and their EQI's. These changes were attributed to the effects of siltation downstream of watercress farm discharges.

There was evidence of organic pollution below watercress farms located at Hill Deverill, Waddock Cross and Broad Chalke. Nearby fish farms were implicated as the most likely pollution source in these cases.

Comparison of the observed macroinvertebrate fauna with that predicted by RIVPACS revealed more differences at sites below watercress farm discharges than at control sites. This was attributed to a shift in the fauna from one characteristic of an eroding substratum to one characteristic of a depositing substratum. Siltation processes downstream of watercress farm discharges were again implicated.

Abundances of *Gammarus pulex* were generally much lower below watercress farm discharges than above. In the cases of Bishopstone, Waddock Cross and Spetisbury, *G. pulex* was absent from the macroinvertebrate fauna. This may be attributed to the release of zinc-contaminated sediments during bed cleaning operations. *G. pulex* densities were generally lower in the autumn than in the spring, possibly due to the seasonality of these operations.

TWINSPAN analysis of the macroinvertebrate data clearly differentiated between sites immediately downstream of watercress farms and control sites. A number of sites further downstream also fell into the impacted site groupings, indicating more far-reaching effects in these cases. Separation of site groups appeared to be related to the degree of siltation. Impacted sites were characterised by species of depositing substrata, whilst non-impacted sites were characterised by species typical of eroding substrata.

Macrophyte surveys proved less successful in differentiating between impacted and non-impacted sites. Sites downstream of watercress farm discharges were characterised by either emergent plants or aquatic grasses. Emergent species formed extensive bands of marginal vegetation. At other sites, grasses grew out from the margins and formed floating rafts of vegetation. Since these were not rooted to the stream bed, they were largely unaffected by siltation processes which might otherwise have buried the plants.

The current investigation has clearly demonstrated the impact that watercress farms are having on receiving watercourses in Wessex. At present there are a number of changes occurring in the watercress industry. Many farms are building effluent treatment facilities, and discharges to streams are to be consented and regularly monitored by the NRA. It is suggested that similar biological investigations would be an effective way of assessing any improvement resulting from these changes.

ACKNOWLEDGEMENTS

I am very grateful to a number of colleagues at the NRA Biology Laboratory at Blandford, for their assistance with this project. I would especially like to thank Debbie Snook, who carried out a significant proportion of the field and laboratory work, and Dave Cooling, Mitch Perkins and Sarah White for help with data analysis. Thanks are also due to Dave Cooling, George Green, Jon Ponting and Debbie Snook for comments on various drafts of the manuscript.

1. INTRODUCTION

Concern has been expressed for some time over the impact of discharges from certain watercress farms on receiving watercourses in the Wessex Region of the National Rivers Authority. Excessive siltation and the absence of the freshwater shrimp (*Gammarus pulex*) have given rise to particular concern. Previous investigations carried out by staff at the Regional Biology Unit have confirmed such effects in a number of watercourses receiving discharges from watercress farms (Smith and Snook, 1990; Smith, 1991).

Under the Water Resources Act (1991), the NRA has a statutory responsibility to protect the fauna and flora in the waters under its control. At present there is a lack of information on the impact of discharges from watercress farms on the ecology of receiving streams and rivers in Wessex.

At present there are a number of changes occurring in the watercress industry. Many watercress growers are building, or have recently built, effluent treatment facilities, and discharges to streams are to be consented and regularly monitored by the NRA. The current investigation had the broad objective of assessing the ecological effects of watercress cultivation in Wessex, by reference to aquatic macroinvertebrate and macrophyte communities.

The use of aquatic macroinvertebrates for biological monitoring of streams and rivers is well established. Biotic indices derived from macroinvertebrate data are widely used in water quality management. Aquatic macrophytes have been much less widely used in water quality assessment in the UK, but are used for assessing overall environmental quality and conservation value.

The specific aims of this investigation were:

i. To assess the impact of watercress cultivation on the environmental quality of streams and rivers
ii. To identify any component of the aquatic fauna or flora that is eliminated by, or is characteristic of watercourses receiving discharges from watercress farms, and to assess how widespread the absence of *G. pulex* is
iii. To identify and measure the extent of any other effects on the fauna and flora that are common to watercourses impacted by watercress farms

2. THE WATERCRESS INDUSTRY

2.1 Current Status

At present the watercress farming industry in the UK is relatively small, with an annual turnover of approximately £9 million. Most farms are located on the southern chalk streams of Dorset, Wiltshire (NRA Wessex Region), Hampshire and Sussex (NRA Southern Region), with the remainder located in the Thames and Yorkshire Regions.

2.2 Regulation

The watercress industry is regulated by the National Farmers' Union Watercress Growers Association, who have produced a Code of Practice for watercress cultivation. This outlines standards for the construction of cressbeds, the application of additives to crops and general hygiene, which registered growers must conform to. In collaboration with the NRA this code of practice is currently being updated, and will incorporate consents for discharges from watercress farms. These consents are designed to ensure that Environmental Quality Standards assigned to receiving watercourses are met.

2.3 Production

Watercress farms may be defined as either 'traditional' or 'intensive', based on their management practices. In all cases, farms manipulate the growth of the endemic watercress, *Rorippa nasturtium aquatica*. Seeds are planted on to either a peat or agar base in a covered propagation unit. When seedlings reach a certain size (usually about 1 inch), they are planted out on to cropping beds. These are typically rectangular beds of very fine gravel and sand overlaying an impermeable base, and enclosed by a low concrete wall (Plates 1 to 4).

At the time of planting the gravel bed is kept moist by abstractions of groundwater from boreholes drilled into the chalk aquifer, which are fed into one end of the bed. Once the seedlings have rooted the water flow is increased. The cropping beds have a gently sloping base, which ensures a constant steady flow of water of about 3 inches depth along the bed. The outflow from a cropping bed may connect directly to an adjacent stream, or enter a series of carriers collecting water from a number of different cropping beds. Water in such carriers may or may not be treated prior to discharge to an adjacent stream.

During the main growing period (April to October), the crop is ready to harvest within a further 3 weeks. This is achieved by hand-cutting of the watercress plants. On 'intensive' farms the cropping beds are cleared of silt and plant debris by mechanical methods, between successive harvests. During winter, however, successive crops are allowed to regrow without being cleaned out. On 'traditional' farms, only one or two crops are produced in the course of a year and the cropping beds are cleaned annually.

2.4 Potential Effects on Receiving Streams

A review of the available literature, combined with discussions with other NRA staff and watercress growers, revealed a number of potential impacts from watercress cultivation.

Discharges from watercress farms may provide a significant proportion of the summer and autumn flow of headwater chalk-streams, and this may prevent streams drying-up in years of low rainfall. Groundwater abstractions to supply watercress beds may, however, create a cone of depression in the vicinity of watercress farms resulting in reduced river flows.

Fertilizers are added to crops to increase growth rates. Elevated levels of phosphate and potassium have been detected in effluents. Iron may also be added as a growth supplement.

Zinc is added to crops continuously between October and the end of March to control Crook Root Disease. Elevated levels have been recorded in receiving streams, particularly in association with fine sediments.

When watercress beds are planted, harvested and in particular when they are cleaned out, large quantities of silt may be discharged to receiving streams. Plant debris, labels and rubber bands also find their way into adjacent watercourses.

The watercress industry has recently been granted off-label approval for the use of a number of pesticides and fungicides. Those most commonly used have been Malathion, Dimethonate, Benomyl and Mancozeb with Metalaxyl (Anon., 1991). Molluscicides are also used on some watercress farms.

Chlorinated water is frequently used on site for washing watercress prior to its sale. This may be discharged to sewer or may be disposed of into an adjacent stream.

In some instances weed-cutting and silt removal are carried out in streams adjacent to watercress farms to ensure the free flow of water from the cropping beds.

2.5 Watercress Cultivation in Wessex

Fifteen working watercress farms were identified in the Wessex Region. All of these farms are located adjacent to chalk streams in the Avon and Dorset Area of Wessex NRA (see Figure 1 and Table 1).

Of these watercress farms, Donhead, Lower Magiston, Ilsington, Tincleton and Waddock Cross are farmed in a 'traditional' manner; all of the other farms can be classed as 'intensive'.

All fifteen farms are thought to be using zinc, in one form or another, for disease control. In the case of Hill Deverill, a request has been made to the Ministry of Agriculture, Fisheries and Food, for permission to use Derris (a crude form of the fish toxicant Rotenone) for this purpose. It is known that liquid nutrient and Malathion are added to watercress at Spetisbury, Roke Farm, Bere Regis and Dodding's Farm. Hand-applied fertilizer and pesticide are applied at Ilsington, Tincleton and Waddock Cross. Iron is added as a growth supplement at Bishopstone watercress farm.

Effluent is treated in settlement tanks at Hill Deverill (Plate 1) and Spetisbury. A settlement lagoon has been constructed at Cranborne (Plate 5), and a stilling pond is currently being built at Dodding's Farm. At present, there is no effluent treatment at any other watercress farm in Wessex, although 10% of the outflow from Cecily Bridge passes through a fish farm and receives some settlement.

Processing of harvested watercress takes place at Bere Regis (for crops from Spetisbury, Roke Farm, Bere Regis and Dodding's Farm), Waddock Cross (for Ilsington, Tincleton and Waddock Cross), Warmwell (for Cecily Bridge and Warmwell), Hill Deverill, Donhead, Broad Chalke, Bishopstone, Lower Magiston and Cranborne. All processing plants use chlorinated water, which is discharged to the adjacent watercourse.

Hill Deverill, Cecily Bridge and Lower Magiston share sites with fish farms, although in the case of Lower Magiston the fish farm is at present not in use. Fish farms also exist downstream of Donhead (closed very recently) and upstream of Waddock Cross and Broad Chalke.

3. SAMPLING PROGRAMME

3.1 Site Selection

At each of the fifteen watercress farms identified, biological samples were taken at three sites on the watercourse receiving the effluent discharge:

i. Immediately upstream of effluent discharge point (A sites);
ii. Immediately downstream of effluent discharge point (B sites);
iii. Approximately 3km downstream of effluent discharge point (C sites).

This strategy gave a control site (i), a site to monitor any localised effect (ii), and a further site to assess the extent of any effect (iii).

Where watercress farms were located at the source or perennial head of a watercourse (Donhead, Broad Chalke, Spetisbury, Roke Farm and Ilsington) control samples were taken on an adjacent tributary, where available (Donhead, Broad Chalke and Spetisbury).

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Where more than one watercress farm discharged to the same watercourse, (River Ebble and Bere Stream), sites upstream of farms lower down the watercourse were downstream of other watercress farms. These could not be regarded as true control sites for the lower farms.

An additional downstream site was sampled below Bishopstone watercress farm on the River Ebble to coincide with a previous survey.

In the case of Waddock Cross watercress farm only one downstream site was sampled because of the short distance between the discharge point and the confluence with the River Frome.

The selected sites are listed in Table 2.

3.2 Macroinvertebrate Samples

As a result of the seasonality of the flora and fauna and the likely intermittent nature of any effects from watercress farm discharges, two samples were taken from each of the sites in Table 2 during the course of the year. The first set of samples were taken in the spring (16th March to 21st May) and the second in late summer and autumn (24th August to 15th October). No spring sample was obtained from the site downstream of Lower Magiston.

The sampling objective was to obtain as complete a species list as possible at each site. For this purpose a standard FBA pond-net was used with the kick and sweep technique, to sample the major habitat types present for a total of approximately three minutes. The methodology employed was in accordance with nationally agreed procedures (Anon., 1991b).

Physical variables (depth, width and substrate composition) were recorded in the field. Water samples were taken in 0.5l plastic bottles for alkalinity determination at the NRA's Exeter laboratory.

Macroinvertebrate samples were returned to the biology laboratory at Blandford Forum in 1.3l wide-necked plastic containers. Samples were sorted 'live' in white trays, within 36hrs. of collection. Relatively large numbers of specimens were removed for subsequent identification and estimation of relative abundance. In most cases identification was to species level. The major exceptions to this were:

Heptageniidae - genus	Chironomidae - family
Leptophlebiidae - genus	Oligochaeta - class
Simuliidae - family	Sphaeriidae - genus
Tipulidae - sub-family	Hydroptilidae - genus

Non BMWP scoring taxa were not generally identified beyond family level.

The relative abundance of each taxon was estimated using a logarithmic scale of abundance:

Category	Estimated numbers
1	1-9
2	10-99
3	100-999
4	1000-9999
5	>=10000.

3.3 Macrophyte Surveys

Macrophyte surveys were carried out simultaneously to macroinvertebrate sampling. No Spring survey was carried out at the site downstream of Lower Magiston.

The objective of the macrophyte surveys was to assess the overall diversity of the aquatic flora and the abundance of each plant species. At each site, 50m stretches of the channel were mapped on 0.5cm squared paper. The field biologist then walked up the centre of the channel, where possible, in an upstream direction, sketching in the extent of plant growth within the channel outline. Species codes were used to indicate which species provided the cover. Where a species occured in different growth forms (e.g. submerged and emergent *Berula erecta*) each form was recorded separately. Individual occurences of plants were marked by an 'X'.

In the laboratory these maps were used to produce species lists and estimates of percentage cover of each plant species and growth form. Percentage cover was recorded on the following scale:

Category	Estimated percentage cover
1	<1
2	1-10
3	11-50
4	>50.

This method has been used successfully in a previous investigation into the impact of watercress and fish farm effluent discharges into the River Wylye (Smith and Snook, 1990).

4. DATA ANALYSIS

4.1 Biotic Indices and RIVPACS

Biotic indices provide a means of condensing the large quantities of data resulting from biological surveys into a form that can be more readily comprehended. This process reduces ecological information, but makes the results more accessible to non-biologists involved in the management of the water environment. The nationally recognised system for the assessment of the biological quality of rivers is the Biological Monitoring Working Party (BMWP) score (Chesters, 1980), and the closely related Average Score Per Taxon (ASPT) (Armitage *et al.*, 1983).

A recent advance in the interpretation of macroinvertebrate data has been the development of RIVPACS (River InVertebrate Prediction And Classification System) by the Freshwater Biological Association (Cox *et al.*, 1991). RIVPACS is a computer model that, given certain physical and chemical variables, can predict the probability of capture of invertebrate taxa at a site, assuming that the site is unpolluted. The model can therefore be used to generate a target community and target biotic scores for comparison with survey data.

In the current investigation the IBM PC version of RIVPACS II was used to predict the target community for each site. The site environmental variables used in the predictions are listed below:

Mean water depth	Distance from source
Mean water width	Channel gradient
Mean substratum particle size†	Discharge category
Altitude	Mean annual air temperature*
Longitude*	Mean annual air temperature range*
Latitude*	Alkalinity

(* values obtained by RIVPACS from grid reference)
(† values obtained from % cover of different substratum types)

The macroinvertebrate taxa observed in the two surveys were compared to those predicted by RIVPACS in an attempt to identify particular 'indicator taxa', which responded to the effects of watercress farming activities in a consistent manner. Following the criteria used by Petts and Armitage (1991) any taxa that were predicted by RIVPACS to occur with greater than 70% probability, but were absent from a sample were regarded as 'significant absences'. Any taxa present in a sample, but not predicted at greater than 1% probability, were regarded as 'significant presences'.

4.2 Multivariate Analysis

The macroinvertebrate and macrophyte data were also analysed using TWINSPAN (TWo-way INdicator SPecies ANalysis), which classifies sites on the basis of the pattern of distribution of different taxa (Hill, 1979a). In this way, sites supporting a similar fauna or flora are grouped together. TWINSPAN also classifies taxa on the basis of their occurrence in different site groupings. The analysis was carried out using the VESPAN II computer package (Malloch, 1988) on an IBM PC. The 'pseudospecies' concept was employed using the abundance categories defined in sections 3.2. and 3.3. The program also constructs a key to the classification by defining one or more 'differential' or diagnostic taxa at each level. Taxa showing a preference for one or other group are listed at each level of the classification. Separate analyses were performed on data from the spring and autumn surveys.

5. RESULTS

5.1 Site Characteristics

Physico-chemical parameters for the sampling sites are given in Table 3. The selected sites covered a wide range of chalk-stream types, varying from near the source to 33km from it. Altitude ranged from 17m, at the bottom site on the R. Piddle, to 125m near the source of the R. Nadder. Stream gradient ranged from 0.9m/km on the Spetisbury Stream to 20.0m/km on the R. Crane and R. Nadder tributary. The sites also covered a range of flow categories, from small streams to the more major R. Piddle, R. Wylye and R. Ebble. Channel width varied from 1.9 to 8.8m (mean 4.6m) and the average depth from 8-50cm (mean 28cm). Alkalinity showed little variation (mean 222; range 194-261mg/l $CaCO_3$), except for the low result on the R. Nadder tributary, which drains off of a belt of Greensand.

At control sites the dominant substrate in the spring was gravel, except at sites 3A and 6A where silt predominated. In contrast, at sites downstream of cressbeds silt was generally the dominant substrate. In many cases siltation was very severe. At sites 1C, 2B, 5B, 6C, 8B and 14B silt occupied over 75% of the channel bed, and at sites 2C, 13B and 15B silt cover was 100%. In the autumn survey siltation was greater at virtually all sites. A further three sites (5A, 6A and 13C) had 100% silt cover, and sites 1C, 2B, 5B, 6B, 7B, 9B, 9C, 11C and 14B had over 75% silt cover. B sites generally had greater amounts of silt than C sites, although at Hill Deverill, Ludwell, Broad Chalke and Dodding's Farm the reverse was true. In the case of Cecily Bridge and Ilsington there was no major increase in silt immediately below the watercress farm discharge.

Plate 6 shows a typical small chalk-stream, and Plate 7 a severely silted stretch below a watercress farm discharge.

5.2 Assessment of Site Performance

BMWP scores and ASPTs, together with RIVPACS predictions and ratios of observed to predicted biotic indices (EQIs), are presented in Table 4 for the spring survey and Table 5 for the autumn survey.

The vast majority of sites exceeded their RIVPACS prediction for number of taxa, BMWP score and ASPT in both surveys, although this was generally less pronounced for ASPT. The resultant EQIs of over 100% are indicative of high environmental quality.

The major exception to this was site 2C, 3km downstream of Donhead watercress farm (and a fish farm discharge), which supported a very limited fauna. Those groups which were present were, however, largely pollution-sensitive forms resulting in high ASPTs in both seasons.

The control site for Spetisbury watercress farm (6A), similarly supported a limited, but relatively pollution-sensitive fauna.

Although most sites recorded high environmental quality, ASPT and EQI (ASPT) values were generally lower at sites immediately downstream of watercress farms than at control sites. This was true in the case of Hill Deverill (autumn), Broad Chalke (spring), Bishopstone (spring), Spetisbury (autumn), Cecily Bridge, Bere Regis, Dodding's Farm, Lower Magiston (autumn), Waddock Cross (spring) and Warmwell. There was also strong evidence of depressed ASPTs below Roke Farm (Figure 2), although there was no upstream control sample for comparison.

In the cases of Hill Deverill, Broad Chalke, Lower Magiston, Cecily Bridge (autumn) and Waddock Cross the decrease in ASPT and EQI (ASPT) were also associated with decreases in the number of taxa, BMWP score and their corresponding EQIs. In contrast, the results for Bishopstone, Spetisbury, Cecily Bridge (spring) and Dodding's Farm, show an increase in the diversity of the fauna below watercress farm discharges.

In most cases where there was no decline in ASPT or EQI (ASPT) below a watercress farm discharge, this may be attributed to the poor performance of the corresponding control site. On the R. Nadder and R. Crane the control sites (2A and 5A respectively) recorded EQI (ASPT) values of less than 100% in both surveys. The control site on the Spetisbury Stream also recorded low EQIs, especially for number of taxa and BMWP score. Ilsington and Tincleton lacked control sites, and the results at downstream sites are therefore more difficult to interpret. EQI values may also be unreliable, since the combination of physico-chemical features for these sites were outside of the scope of RIVPACS II. There is evidence of reduced environmental quality below watercress farm discharges in all of these cases, when performance is compared with that recorded at other control sites.

In virtually every case there was an improvement in environmental quality between sites immediately downstream of watercress farm discharges (B sites) and those further downstream (C and D sites). This was not, however, true of the R. Nadder where there was a decline in BMWP score and number of taxa between sites 2B and 2C, although ASPT and EQI (ASPT) did increase. In the case of the River Ebble the downstream improvement was only apparent in the spring survey (Figure 3), with site 3C showing a large deterioration later in the year. On the Tincleton Middle Carrier there was a further deterioration in environmental quality between sites 13B and 13C. This may have been due to the fact that site 13C is downstream of both Ilsington and Tincleton watercress farms.

Environmental quality at sites downstream of watercress farms showed the greatest seasonal variation, although there was no consistent pattern to the observed variation. EQI (ASPT) was less variable than either EQI (Taxa) or EQI (BMWP).

Sites 3B, 4B, 5C, 13B, 14B, 15B and 15C all showed signs of improvement between the two surveys, recording higher EQIs in autumn than in spring. In contrast, sites 2C, 3C, 4D, 5A, 6C, 10C, 12B and 13C showed overall signs of a deterioration during the year. EQI (BMWP) and EQI (Taxa) were also lower in autumn than in spring at sites 7B and 7C, but EQI (ASPT) showed a slight increase. At site 15C, EQI (BMWP) and EQI (Taxa) were higher in autumn than in the spring, whilst EQI (ASPT) remained unchanged. At all other sites there was little apparent change in environmental quality between the two surveys.

5.3 Comparison of Predicted and Observed Taxa

A total of 67 'significant absences' were recorded in the current investigation. Of these, 24 were at B sites, 23 were at C sites, 18 at A sites, and 2 were at site 4D. Of the 14 taxa which made up these absences, 6 were more frequently absent from downstream sites.

Gammarus pulex was absent at site 4C below Bishopstone in both surveys, and below Waddock Cross in spring and both sites below Spetisbury in the autumn survey.

Elmis aenea was absent below Roke Farm, Bere Regis, Dodding's Farm (all located on the Bere Stream) and Tincleton in spring, and below Cranborne and Spetisbury in the autumn survey. In addition, *E. aenea* was not recorded at the control site for Spetisbury in either season, and above Cranborne in the autumn.

Baetis rhodani failed to occur in samples below Warmwell watercress beds in the spring, and below Spetisbury and Tincleton in the autumn. This species was also absent from the spring sample taken above Waddock Cross.

Polycelis felina was absent from samples below Broad Chalke, Spetisbury (both sites), Ilsington and Tincleton (both sites) in the autumn survey.

Pisidium spp.were absent from sites below Spetisbury and Bere Regis watercress farms in the spring. In the autumn these taxa were not recorded in samples taken from up and downstream of Hill Deverill, the control site for Spetisbury and site 8C at Bere Regis.

A total of 200 'significant presences' were recorded in the current investigation. Of these, 89 were at B sites, 60 were at C sites, 47 were at A sites, and 4 were at site 4D. These 200 presences comprised 90 different taxa, of which only 9 occurred on more than 5 occasions, a further 15 occurred on 3 or more occasions, and 44 occurred just once.

Sericostoma personatum, *Tropidiscus planorbis* *Oxyethira* sp. and *Sigara venusta* all occured as significant presences on more than 5 occasions and only at sites downstream of watercress farm discharges. *Lymnaea palustris*, *Agabus didymus*, *Chaetopteryx villosa*, *Sympetrum striolatum/sanguineum* and *Nemurella picteti* similarly occurred on more than 5 occasions, primarily downstream of watercress farms but also upstream at lower frequencies.

Of the taxa which occured as significant presences on 3 or more occasions, *Cordulegaster boltonii, Sigara dorsalis* and Tipulidae (excluding *Dicranota* spp.) only occurred at downstream sites. In addition, *Bathyomphalus contortus* and *Physa acuta* occurred primarily at sites downstream of watercress farms.

The following taxa occurred as significant presences only at sites downstream of watercress farms, but did so at low frequencies:

(a) Significant presences on 2 occasions:

Dendrocoelum lacteum	*Dugesia polychroa/lugubris*	*Centroptilum luteolum*
Centroptilum pennulatum	*Nepa cinerea*	*Gyrinus* sp.
Laccobius bipunctatus	*Hydrobius fuscipes*	

(b) Significant presences on 1 occasion:

Polycelis nigra/tenuis	*Helobdella stagnalis*	*Anisus vortex*
Succinea sp.	*Niphargus* sp.	*Ephemera danica*
Ecdyonurus sp.	*Caenis rivulorum*	*Ephemerella ignita*
Cloeon dipterum	*Ischnura elegans*	*Pyrrhosoma nymphula*
Leuctra sp.	*Rhyacophila dorsalis*	*Hydropsyche siltalai*
Hydroptila sp.	*Tinodes waeneri*	*Limnephilus lunatus*
Potamophylax latipennis	*Mystacides azurea*	*Ylodes conspersus*
Beraea Pullata	*Haliplus lineatocollis*	*Haliplus wehnckei*
Gyrinus substriatus	*Gyrinus urinator*	*Hygrotus inaequalis*
Hydroporus marginatus	*Hydroporus palustris*	*Ilybius fuliginosus*
Laccophilus minutus	*Helophorus grandis*	*Laccobius sinuatus*
Laccobius striatulus	*Anacaena limbata*	*Elodes* sp.

5.4 TWINSPAN Site Classification

Each TWINSPAN classification was concluded at level 2 after the the production of four site groups; further divisions did not produce ecologically meaningful results. The resulting site classifications are shown in Figure 4 for the spring invertebrate survey, Figure 5 for the autumn invertebrate survey, Figure 6 for the spring macrophyte survey and Figure 7 for the autumn macrophyte survey.

In both invertebrate classifications sites immediately downstream of watercress farm discharges (B sites) tended to group together. The major exception was site 7B, downstream of Cecily Bridge, which fell into site groups comprising largely A and C sites. This was also true of site 15B, downstream of Warmwell, in the autumn site classification.

In the spring invertebrate classification site group A1 comprised largely B sites, which supported between 28 and 41 taxa (mean 37). Characteristic taxa included species of Gastropoda and Coleoptera (Dytiscidae and Haliplidae). Sites in group A2, which also included a significant number of downstream sites, supported between 28 and 52 taxa (mean 38). Taxa characteristic of group A1 were also characteristic of group A2, as were Glossiphonidae (Hirudinea), Ostracoda, *Crangonyx pseudogracilis, Asellus aquaticus* (Crustacea) and Hydracarina. In contrast, sites in groups A3 and A4 were characterised by Trichoptera, Ephemeroptera and Coleoptera (Elmidae and Gyrinidae). Group A3 sites supported a diverse fauna (mean 47 taxa; range 34-56), whilst sites in group A4 were less diverse (mean 33 taxa; range 22-41). These groups were composed almost exclusively of control and downstream C (and D) sites.

The autumn invertebrate site classification was broadly similar to that produced from the spring data. In this case, however, the sites immediately downstream of watercress farms fell largely into one group (group B2). Sites in this group generally supported a diverse fauna (mean 39 taxa; range 26-53) and were characterised by Gastropoda (e.g. *Bathyomphalus contortus, Valvata cristata* and *Physa acuta*), certain Ephemeroptera (*Cloeon dipterum* and *Centroptilum pennulatum*), *Sympetrum striolatum/sanguineum, Limnephilus lunatus,* Hydroporinae and Culicidae. Site group B1 contained just three sites. The fauna at these sites was similar to that at sites in group B2, although the Gastropod fauna was less diverse. *C. pseudogracilis* was diagnostic of this site grouping. Site groups B3 and B4 were composed largely of A and C sites. The fauna was characterised by Trichoptera, Coleoptera (Elmidae), Ephemeroptera (*Heptagenia* sp.) and Plecoptera.

In both site classifications based on macrophyte data, downstream sites showed less tendency to group together. In the Spring classification most B sites did, however, fall into one of two groups (C2 and C3). Group C2 sites supported low macrophyte diversity (mean 8 taxa; range 2-12). This group was characterised by Poacea and *Cladophora* sp.. Group C3 supported a more diverse flora (mean 10 taxa; range 5-14), and was characterised by tall emergent plants (especially *Glyceria* sp.). Site group C1 contained three C sites, supported low macrophyte diversity (mean 8 taxa; range 8-9) and was characterised by *Berula erecta* (submerged and emergent forms). Group C4 contained sites with the most diverse flora (mean 12 taxa; range 8-17). The emergent species *Mentha aquatica, Iris pseudacorus* and *Phalaris arudinacea* were all characteristic. This group was composed largely of C sites.

The autumn macrophyte classification separated three sites from all others into site groups D3 and D4. These were characterised by tall emergent species (*Phalaris arudinacea* and *Glyceria* sp.) and a lack of submerged species. The remaining sites were split into two groups. Group D1 contained sites with lower macrophyte diversity (mean 8 taxa; range 2-14) than group D2 (mean 12 taxa; range 6-20). Both groups were characterised by the submerged taxa *Ranunculus* sp., *Callitriche* sp. and *Cladophora* sp.. Group D2 sites were also characterised by the broad-leaved emergent forms (*Myosotis* sp. and *Mentha aquatica*), and group D1 by Poacea. Most A and B sites were in group D1, whilst group D2 contained mainly C sites.

6. DISCUSSION

6.1 Environmental Quality Assessment

Indices based on the macroinvertebrate fauna indicated relatively high environmental quality at virtually all sites. The one major exception to this was the site 3km downstream of Donhead watercress farm and a fish farm discharge, where EQI (BMWP) and EQI (Taxa) fell well below 100%. The effect would appear to be one of severe siltation, since the high EQI (ASPT) indicates there is no organic pollution problem. The bed of the R. Nadder at this site was completely smothered with deep silt deposits on both sampling occasions.

Although the results indicated high environmental quality at all other sites, there was strong evidence that ASPT and EQI (ASPT) were slightly lower downstream of watercress farm discharges. In some cases this was evident from a comparison of upstream and downstream sites, whilst at others the effect was masked by a lack of, or the poor performance of, control sites.

In general, lower ASPT and EQI (ASPT) values were associated with higher BMWP, EQI (BMWP), Taxa and EQI (Taxa). This pattern of indices is almost certainly due to siltation, as opposed to a change in water quality. Siltation results in an increase in taxa characteristic of depositing substrata without the loss, except possibly in very severe cases, of the fauna characteristic of eroding substrata. This is because in all but the most severe cases of siltation, some areas of unsilted stream bed will remain. Since macroinvertebrates characteristic of depositing substrata also tend to be tolerant of pollution, and *vice versa,* siltation will result in an increase in BMWP and Taxa and their corresponding EQIs, and a reduction in ASPT and EQI (ASPT). In contrast, deteriorations in water quality will eliminate pollution-sensitive taxa and therefore lead to decreases in the diversity of the fauna, both BMWP and ASPT, and EQIs.

The RIVPACS model takes differences in substratum into account, when generating the target fauna and target indices. In theory therefore RIVPACS predictions may underestimate the potential ASPT of sites which have become heavily silted due to watercress farm discharges. This in turn would lead to increased EQI (ASPT) values, and could mask the effects of discharges of silt from watercress farms. In practice, however, the RIVPACS predictions at downstream sites were generally comparable to those at similar, but less silty, upstream sites.

The EQI and biotic score results indicate siltation problems below the following watercress farms:

Donhead	Bishopstone	Cranborne	Spetisbury
Roke Farm	Bere Regis	Dodding' s Farm	Lower Magiston
Tincleton	Warmwell		

Reduced environmental quality was also indicated below Hill Deverill (autumn only) and Waddock Cross (spring only). In these two cases there was evidence of a decline in water quality. The sites in this latter category are associated with fish farms, which are likely to be a significant source of organic pollution. Organic pollution was also indicated below Broad Chalke, but this is likely to be due to the fish farm discharge upstream of the control site, where organic pollution could also be detected.

There was no detectable effect below Ilsington watercress farm in the spring survey, but ASPT and EQI (ASPT) values were much lower in the autumn. In the case of Cecily Bridge, there would appear to be little effect on the quality of the R. Piddle, although ASPT and EQI (ASPT) did decrease slightly downstream of the watercress farm in both surveys.

In most cases siltation effects appeared to be restricted to sites immediately downstream of watercress farms. Generally faunal diversity, biotic scores and EQIs increased between sites immediately downstream and those further downstream. The major exceptions to this were Donhead (discussed previously), Tincleton and Ilsington. In the case of of Tincleton and Ilsington the site was still only 0.3km downstream of Tincleton watercress farm, and received silt inputs from two watercress farms. A deterioration was also detected between sites downstream of Broad Chalke in the autumn survey; this may or may not have been related to the watercress farm.

Although environmental quality changed between the spring and autumn at a number of downstream sites, there was no consistent pattern to this change.

6.2 Significant Absences and Presences of Invertebrate Taxa

Five taxa predicted to occur by RIVPACS were absent below watercress farm discharges in a number of cases. Of these *G. pulex*, *E. aenea*, *B. rhodani* and *Pisidium* spp. can be regarded as being virtually ubiquitous in chalk-stream communities. *Polycelis felina* is characteristic of smaller chalk-streams only.

The absence of *G. pulex* below watercress farms has been a previous cause of much concern. It is regarded as being one of the most important invertebrate species, in chalk-streams, in terms of biomass and food for fish (Welton, 1979). In the current investigation *G. pulex* was absent from one site on the R. Ebble (in both surveys), below Waddock Cross (spring survey), and both sites below Spetisbury (autumn survey). Previous surveys have recorded an absence of *G. pulex* below Spetisbury (Green, 1989b; Hall, 1991) and Hill Deverill watercress farms (Green, 1985), and on the Bere Stream and R. Ebble (Green, 1989a; Smith, 1991). In the case of Spetisbury and Hill Deverill, the effect has been shown to be intermittent in nature. The R. Ebble was sampled on a monthly basis throughout 1991, and the results indicated a year-round absence of *G. pulex* for approximately 5km of the river below Bishopstone watercress farm (Smith, Unpublished Data). Upstream of Bishopstone the river supported a healthy freshwater shrimp population, although Green (1989a) detected a lack of *G. pulex* at one site downstream of Broad Chalke watercress farm.

Although *G. pulex* was recorded below the vast majority of watercress farms in the current survey, there was a significant reduction in abundance between up and downstream sites in most cases. Densities were also generally lower in the autumn than in the spring survey. Low densities were recorded in the following instances:

i. 1-10 individuals per sample:

Hill Deverill (autumn)	Donhead (spring)	Broad Chalke (autumn)
Spetisbury (spring)	Bere Regis (autumn)	Dodding's Farm (autumn)
Ilsington	Tincleton	Waddock Cross (autumn)

ii. 11-100 individuals per sample:

Donhead (autumn)	Cranbourne (spring)	Roke Farm (spring)
Bere Regis (spring)	Dodding's Farm (spring)	Lower Magiston (autumn)
Warmwell		

In the case of Hill Deverill and Broad Chalke, the number of *G. pulex* dropped from 101-1000 in the spring, to 1-10 in the autumn survey.

Research carried out by Roddie *et al.* (1990) has linked the absence of *G. pulex* to the use of zinc at upstream watercress farms. There is no evidence of direct toxicity, but zinc-contaminated silt has been shown to be only marginally capable of supporting *G. pulex* populations. It is as yet unclear whether this is due to sub-lethal toxicity or to behavioural avoidance of zinc-contaminated sediments. Even where silt is not the predominant substratum, available food sources (i.e. leaf litter) will still be contaminated. Zinc is generally added to crops between October and the end of March. The lower autumn densities of *G. pulex* observed in the current investigation may be attributable to the release of zinc-contaminated silt during bed cleaning operations from late spring onwards.

E. aenea, B. rhodani and *P. felina* are all species characteristic of eroding substrata. Their absence at a number of sites is likely therefore to be a result of siltation. This is supported by the fact that all three taxa were absent below Spetisbury and Tincleton, where siltation was severe (see section 5.1) in at least one survey. *E. aenea* was also absent from the fauna above Cranborne in the autumn survey, when this site silted-up, and was absent at the control site for Spetisbury, which was also silty. The bivalve *Pisidium* spp. are more characteristic of depositing substrata. Their absence may, however, be due to the excessive quantities of silt found below watercress farms, or the nature and instability of the silt deposits.

The use of pesticides cannot be ruled out as a cause for the absence of specific taxa. Experiments carried out by NRA Southern Region, however, found no detectable effect on the macroinvertebrate fauna of two Hampshire streams, downstream of watercress farms where pesticides were applied (Anon., 1991a). Chlorinated water is also discharged at some watercress farms, but its usage does not coincide with the observed absences.

Of the taxa which occured as 'significant presences', the majority were recorded at sites downstream of watercress farm discharges. The taxa involved were from a wide range of taxonomic groups, but the vast majority were those associated with depositing substrata. The presence of these taxa would therefore appear to be related to siltation and increases in the extent of the channel margins (see section 6.4), below watercress farms.

The 'significant presences' recorded included those such as the Odonata, which are very uncharacteristic of the chalk-stream fauna. *Lymnaen palustris* has been recorded below watercress farms previously, and it may be that individuals were washed out of the watercress beds. The same may also be true of *P. acuta*.

The occurrence of *S. personatum*, a species associated with eroding substrata, as a 'significant presence', would appear to be due to an anomoly in the RIVPACS model. This species was recorded at virtually every site in the current investigation, and in fact was more frequently absent from samples taken below watercress farms than at control sites. It was, however, predicted to occur at all control sites, but not at all downstream sites.

6.3 Analysis of TWINSPAN Site Groups for Macroinvertebrates

TWINSPAN analysis, using macroinvertebrate data, clearly differentiated between sites immediately downstream of watercress farms and control sites. In the spring, impacted sites fell into one of two groups (A1 and A2), whilst in the autumn survey one group of impacted sites was identified (B2). The major exception to this was the site downstream of Cecily Bridge, where, as discussed previously (section 6.1), there was little if any impact. The site downstream of Warmwell also failed to conform to this pattern in the autumn survey. This site had similarly shown less of an impact in terms of biotic indices and EQIs than other downstream sites, especially in the autumn survey (see Table 5).

Control sites for Hill Deverill, Broad Chalke, Cranbourne, Spetisbury and Waddock Cross fell into impacted site groupings in one or both surveys. The poor performance of these control sites was also noted in terms of biotic indices and EQIs (see sections 5.2 and 6.1).

A number of sites further downstream of watercress farms (C sites) also fell into the groups of impacted sites. This was true of sites below Hill Deverill, Broad Chalke and Bere Regis, in both surveys; Spetisbury and Tincleton/Ilsington in the spring survey, and Dodding's Farm in the autumn. This indicates a greater extent of impact on watercourses receiving effluents from these watercress farms. In the cases of Bere Regis, Spetisbury, Tincleton and Ilsington, the greater extent of effect may be due partly to the lack of dilution received by effluent discharges.

Site classification at TWINSPAN level 1 (i.e. separation of groups 1 and 2 from Groups 3 and 4), was based on similar taxa in both seasons. Impacted sites were characterised by taxa characteristic of depositing substrata:

Gastropoda
Coleoptera (Dytiscidae and Haliplidae)
Crustacea (Ostracoda, Hydracarina, *C. pseudogracilis* and *A. aquaticus*)
Ephemeroptera (*Centroptilum* sp. and *Cloeon* sp.)

Non-impacted sites were characterised by taxa associated with eroding substrata:

Ephemeroptera (*Heptagenia* sp., *Ecdyonurus* sp.)
Trichoptera (Lepidostomatidae, *Silo* spp., *Odontocerum albicorne, Potamophylax* spp.)
Coleoptera (Elmidae and Gyrinidae)
Plecoptera (Leuctridae, *Isoperla* sp.)

The separation of impacted from non-impacted sites would therefore appear to be based primarily on the effects of siltation at impacted sites. The impacted sites identified by TWINSPAN, including control and C sites, were those where siltation effects have already been implicated (see sections 6.1 and Table 3). In the case of the control site upstream of Broad Chalke, organic pollution from a fish farm is implicated.

At level 2, further separation of impacted sites appears to bear no obvious relation to the impact of discharges from watercress farms. In the spring, the separation appears to be based on sub-catchment characteristics. For example, impacted sites on the Bere Stream all fell in group A1, whilst those on the R. Wylye fell into group A2. Separation of TWINSPAN groups 3 and 4 resulted in sites 2A, 2C, 5C (and 11A in the spring) forming a separate group. These sites supported a fauna rather uncharacteristic of chalk-streams (e.g. *Rhithrogena* sp.). The rather different nature of the fauna at these sites masked any intra-group differences. That is, although site 2C was clearly suffering from severe siltation and supported a very restricted fauna (see section 6.1), those groups which were present were not those characteristic of impacted chalk-stream sites. As discussed previously (section 5.1) the control site for Donhead on a stream draining off of Greensand, and site 2C immediately downstream of the confluence with the R. Nadder may have been influenced by the rather different physico-chemical nature of this stream.

6.4 Analysis of TWINSPAN Site Groups for Macrophytes

TWINSPAN analysis, using the macrophyte data, was less successful in separating impacted from non-impacted sites. Site classifications from the spring and autumn survey data were also rather different. Two types of impacted site could, however, be identified.

Most group C2 and D1 sites, which included many of the most heavily silted sites, were characterised by Poacea. Poacea grew out from the margins, forming floating rafts across the channel. The plants were not rooted in the stream bed, and were largely unaffected by the heavily silted and unstable nature of the substratum. Growths of Poacea were particularly apparent below Cranborne, Spetisbury and Roke Farm.

A number of other impacted sites were characterised by broad-leaved and tall emergent plants. These sites fell largely into groups C3, C4 and D2, and included those downstream of Donhead, Bishopstone, Bere Regis, Ilsington, Tincleton and Waddock Cross. Control sites for Hill Deverill, Cranborne and Spetisbury were also characterised by broad-leaved emergent plants. Species such as *Nasturtium rorippa aquatica, Mentha aquatica, Myosotis* sp., *Glyceria* sp., *Sparganium erectum* and *Phalaris arudinacea,* formed extensive margins at these sites, which encrouched well into the main channel in many cases. These growths of marginal plants entrapped large quantities of silt, and consequently these sites were characterised by margins of deep silt.

7. CONCLUSIONS

Discharges from watercress farms have a deleterious effect on the flora and fauna of receiving chalk-streams.

These deleterious effects are apparent using nationally recognised biotic indices (ASPT), predictive modelling techniques (RIVPACS) and multivariate statistics (TWINSPAN).

The main effect is one of excessive siltation below discharge points. This results in a shift from a fauna characteristic of eroding substrata to one characteristic of depositing substrata. Certain species characteristic of the chalk-stream fauna are eliminated by this siltation; other less characteristic species are favoured by the modified environment. The fauna below watercress farm discharges remains diverse and abundant.

Below discharges from Bishopstone, Waddock Cross and Spetisbury, *Gammarus pulex* was absent from the macroinvertebrate fauna. In the former case this was a year round absence; below Waddock Cross and Spetisbury an intermittent effect was apparent. Numbers of *G. pulex* were also low below a number of watercress farm discharges, especially in the autumn survey.

The use of macrophyte surveys proved less successful in differentiating between impacted and non-impacted sites. Two types of effect, however, were detected and these were again attributed to increased silt deposition. In some cases floating mats of Poacea grew out from the channel margins, whilst at others the aquatic flora was characterised by emergent species, which formed extensive bands of marginal vegetation.

Similar biological investigations would be an effective way of assessing any ecological improvement, resulting from the current changes in the regulation of watercress farms.

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Plate 1 Aerial photograph of watercress farm at Hill Deverill, alongside the R. Wylye. The large settlement tank is visible at the top of the photograph.

Plate 2 Watercress beds at Hill Deverill.

Plate 3 Watercress beds at Broad Chalke alongside a perennial section of the R. Ebble.

Plate 4 Watercress beds at Hill Deverill.

Plate 5 Settlement lagoon at Cranborne watercress farm, seen soon after excavation. Following settlement effluent is discharged to the adjacent R. Crane.

Plate 6 'Classic' small chalk-stream with gravel being the dominant substrate.

Plate 7 Heavily silted stretch of the Spetisbury Stream below cress farm at Spetisbury.

Figure 1 Location of Watercress Farms in N.R.A. Wessex Region (Avon & Dorset Area)

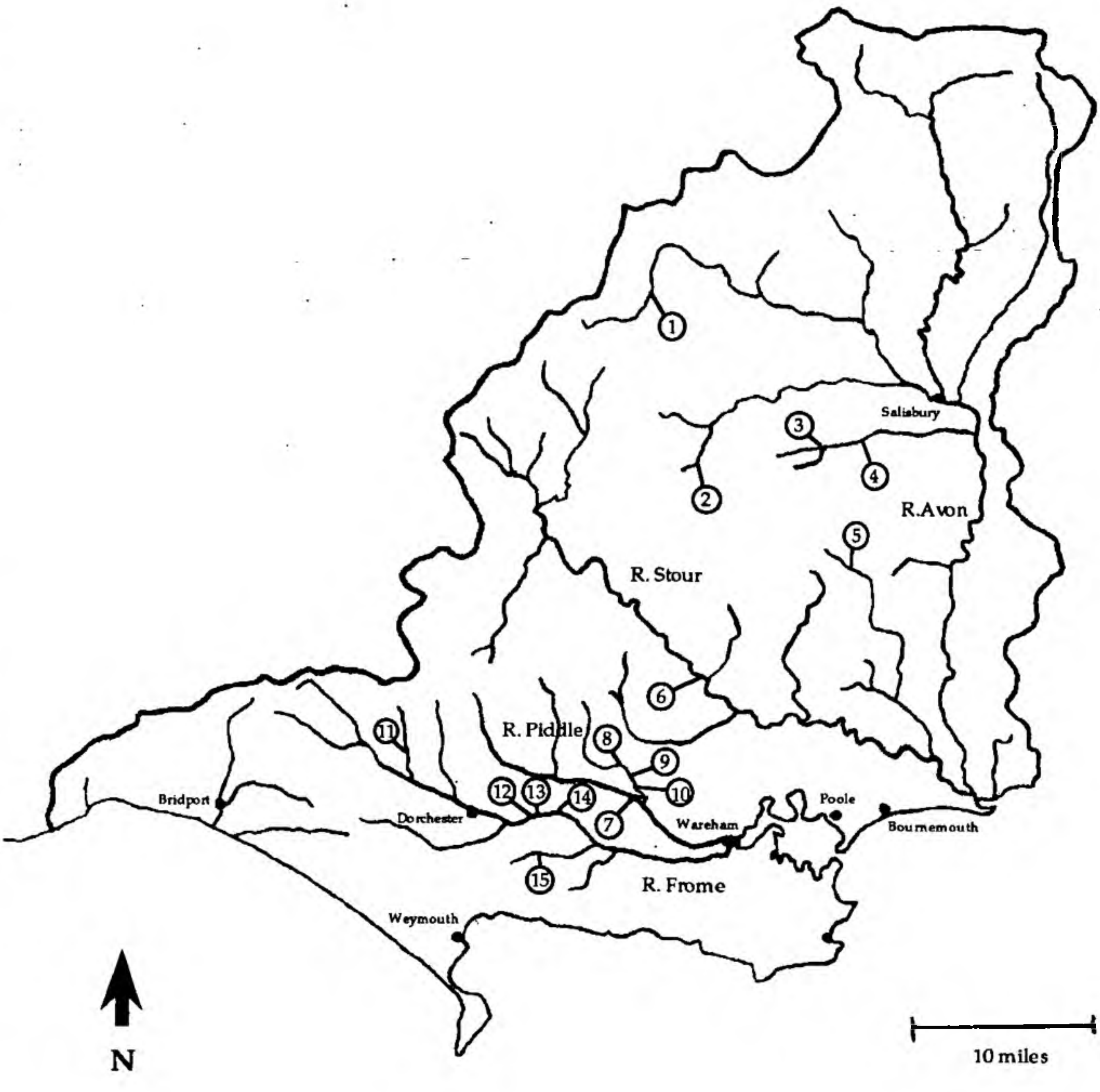

Table 1 Location of Watercress Farms in N.R.A. Wessex Region

Site No. (see Fig. 1)	Site Name	N.G.R.	Watercourse
1	Hill Deverill	ST869404	River Wylye
2	Donhead	ST907223	River Nadder
3	Broad Chalke	SU029251	River Ebble
4	Bishopstone	SU067256	River Ebble
5	Cranborne	SU071127	River Crane
6	Spetisbury	ST904029	Spetisbury Stream
7	Cecily Bridge	SY835929	River Piddle
8	Roke Farm	SY837958	Bere Stream
9	Bere Regis	SY849945	Bere Stream
10	Dodding's Farm	SY852933	Bere Stream
11	Lower Magiston	SY635963	Sydling Water
12	Ilsington	SY755918	Tincleton Middle Carrier
13	Tincleton	SY766917	Tincleton Middle Carrier
14	Waddock Cross	SY797909	River Frome Carrier
15	Warmwell	SY748873	Tadnoll Brook

Table 2 Location of Sampling Sites

Site No.	Watercourse	Site Name	N.G.R.	Comments
1A	R. Wylye	Hill Deverill Manor	ST869402	Immed. u/s Hill Deverill
1B	R. Wylye	A350 Hill Deverill	ST871407	Immed. d/s Hill Deverill
1C	R. Wylye	Longbridge Deverill Church	ST868413	1.0km d/s Hill Deverill
2A	trib. R. Nadder	Donhead Hall	ST904240	Control site for Donhead
2B	R. Nadder	Ludwell Bridge	ST908226	Immed. d/s Donhead
2C	R. Nadder	Donhead Lodge	ST914246	3.0km d/s Donhead
3A	The Chalke	Mount Sorrel Farm	SU035250	Immed. u/s Broad Chalke
3B	R. Ebble	D/s Broad Chalke	SU032253	Immed. d/s Broad Chalke
3C	R. Ebble	Croucheston Mill	SU063255	3.2km d/s Broad Chalke, u/s Bishopstone
4B	R. Ebble	Bishopstone	SU071266	Immed. d/s Bishopstone
4C	R. Ebble	Cranborne Cottage	SU104265	3.5km d/s Bishopstone
4D	R. Ebble	Homington	SU126263	6.2km d/s Bishopstone
5A	R.Crane	U/s Cress Beds	SU070128	Immed. u/s Cranborne
5B	R.Crane	D/s Cress Beds	SU073125	Immed. d/s Cranborne
5C	R.Crane	Heavy Horse Centre	SU078111	1.7km d/s Cranborne
6A	trib. Spetisbury Str.	U/s Mill House	ST911031	Control site for Spetisbury
6B	Spetisbury Str.	D/s Railway Bridge	ST908031	Immed. d/s Spetisbury
6C	Spetisbury Str.	D/s John's House	ST911029	0.3km d/s Spetisbury
7A	R.Piddle	Throop	SY827933	1.0 km u/s Cecily Bridge
7B	R.Piddle	D/s Cecily Bridge	SY838928	Immed. d/s Cecily Bridge
7C	R.Piddle	Hyde	SY865906	4.0 km d/s Cecily Bridge
8B	Bere Stream	D/s Roke Farm	SY839956	Immed. d/s Roke Farm
8C	Bere Strea	Bere Regis	SY845947	1.3km d/s Roke Farm, u/s Bere Regis
9B	Bere Stream	D/s Bere Regis	SY849946	Immed. d/s Bere Regis
9C	Bere Stream	U/s Dodding's Farm	SY851939	0.7km d/s Bere Regis, u/s Dodding's Farm
10B	Bere Stream	D/s Dodding's Farm	SY855931	Immed. d/s Dodding's Fm.
10C	Bere Stream	Stockley Farm	SY859919	1.2km d/s Dodding's Farm
11A	Sydling Water	U/s Cress Beds	SY636963	Immed. u/s Lwr. Magiston
11B	Sydling Water	D/s Cress Beds	SY630960	Immed. d/s Lwr. Magiston
11C	Sydling Water	Grimstone	SY640947	1.8km d/s Lwr. Magiston
12B	Tincleton M.C.	D/s Ilsington	SY756917	Immed. d/s Ilsington
13B	Tincleton M.C.	D/s Tincleton	SY769917	Immed. d/s Tincleton
13C	Tincleton M.C.	Ewerleaze Farm	SY772916	1.9km d/s Ilsington, 0.3km d/s Tincleton
14A	R.Frome Carrier	U/s Waddock Cross	SY790909	0.3km u/s Waddock Cross
14B	R.Frome Carrier	D/s Waddock Cross	SY798907	Immed. d/s Waddock Cross
15A	Tadnoll Brook	U/s Warmwell	SY745875	Immed. u/s Warmwell
15B	Tadnoll Brook	D/s Warmwell	SY753873	Immed. d/s Warmwell
15C	Tadnoll Brook	Moigne Combe	SY775872	3.0km d/s Warmwell

Table 3 Physico-Chemical Features of Sampling Sites

Site No.	Altitude (m)	Source Distance (Km)	Gradient (m/Km)	Discharge Category **	Width (m) *	Mean Depth (cm) *	Dominant Substrate ***	Alkalinity (mg/l $CaCO_3$) *
1A	119	8.0	2.5	3	5.4	24	G-S	259
1B	118	9.0	2.5	3	5.6	38	G-G	251
1C	115	10.0	2.5	3	8.0	44	S-S	241
2A	120	2.0	20.0	1	1.3	13	G-G	82
2B	125	0.5	10.0	1	2.6	15	S-S	247
2C	108	3.5	4.4	1	3.6	24	S-S	194
3A	87	1.5	5.0	1	2.7	30	S-S	228
3B	86	1.8	5.0	3	3.6	34	G-G	229
3C	73	5.0	3.3	3	4.2	26	Sa-Sa	213
4B	70	6.3	3.3	3	5.5	36	Sa-S	217
4C	60	9.8	2.9	3	5.2	20	G-G	223
4D	54	12.5	2.9	3	5.8	23	G-G	216
5A	46	5.8	20.0	1	3.3	25	G-S	231
5B	44	6.3	20.0	1	4.5	35	S-S	225
5C	38	8.0	2.9	1	3.4	25	G-G	226
6A	30	1.0	0.9	1	2.2	36	S-S	252
6B	30	0.5	0.9	1	2.8	17	S-S	226
6C	30	0.8	0.9	1	4.1	20	S-S	226
7A	33	18.8	2.4	4	6.8	28	G-G	231
7B	28	20.5	2.4	4	8.8	30	G-G	242
7C	17	24.5	2.5	4	8.0	28	G-Sa	231
8B	39	10.5	4.0	1	4.1	25	S-S	232
8C	35	11.8	4.0	2	4.6	23	S-G	235
9B	32	12.3	4.0	2	6.0	30	S-S	234
9C	30	13.0	4.4	2	5.0	29	S-S	238
10B	27	13.8	4.4	2	7.3	21	G-G	237
10C	21	15.0	4.4	2	5.8	50	S-S	236
11A	88	5.5	6.7	1	3.9	16	G-G	228
11B	86	5.7	6.7	1	4.0	17	-S	218
11C	77	7.5	5.0	1	4.8	38	Sa-S	214
12B	40	0.1	2.9	1	2.3	8	G-G	206
13B	40	0.2	2.9	1	3.8	39	S-S	223
13C	40	2.0	2.9	1	4.3	44	S-S	196
14A	30	32.5	2.5	1	4.3	42	G-G/S	227
14B	30	33.0	2.5	1	1.9	34	S-S	234
15A	45	1.5	5.0	1	4.2	18	G-G/Sa	231
15B	40	2.0	3.3	1	5.3	31	G-Sa	230
15C	35	5.0	3.3	1	4.9	26	G-G	209

* Average of spring and autumn survey results.
** Measured as average daily flow. 1<=0.31 cumecs; 2<=0.62; 3<=1.25; 4<=2.50.
*** Dominant substrate for spring survey followed by autumn survey. S=Silt: Sa=Sand; G=Gravel.

Table 4 Biotic Scores and Site Performance for Spring Survey

Site No.	Obs. Taxa	Pred. Taxa	EQI Taxa	Obs. BMWP	Pred. BMWP	EQI BMWP	Obs. ASPT	Pred. ASPT	EQI ASPT
1A	28	21.1	133	139	104.7	133	4.96	4.9	101
1B	30	21.8	138	151	109.7	138	5.03	5.0	101
1C	24	21.4	112	122	106.3	115	5.08	4.9	104
2A	26	24.0	108	157	154.4	102	6.04	6.4	94
2B	27	20.2	134	124	91.1	136	4.59	4.5	102
2C	15	21.4	70	97	104.4	93	6.47	4.9	132
3A	25	20.4	123	121	93.2	130	4.84	4.6	105
3B	22	21.0	105	107	100.3	107	4.86	4.8	101
3C	27	23.3	116	152	123.0	124	5.63	5.3	106
4B	30	23.6	127	160	125.5	127	5.33	5.3	101
4C	33	23.1	143	193	120.9	160	5.85	5.2	113
4D	36	22.8	158	206	117.1	176	5.72	5.1	112
5A	30	23.3	129	158	123.8	128	5.27	5.3	99
5B*	25	20.8	120	128	99.9	128	5.12	4.8	107
5C	30	22.3	135	180	114.5	157	6.00	5.1	118
6A	18	20.2	89	85	91.0	93	4.72	4.5	105
6B	21	20.2	104	102	90.8	112	4.86	4.5	108
6C	21	20.2	104	114	90.8	126	5.43	4.5	121
7A	34	24.9	137	207	132.1	157	6.09	5.3	115
7B	39	23.5	166	231	122.0	189	5.92	5.2	114
7C	38	24.2	157	228	127.2	179	6.00	5.2	115
8B	25	21.2	118	130	104.6	124	5.20	4.9	106
8C	28	22.2	126	158	112.1	141	5.64	5.0	113
9B	27	21.9	123	138	109.6	126	5.15	5.0	103
9C	26	21.7	120	144	107.9	133	5.54	4.9	113
10B	30	22.7	132	153	117.0	131	5.10	5.1	100
10C	32	22.4	143	202	113.0	179	6.31	5.0	126
11A	26	23.5	111	156	126.3	124	6.00	5.3	113
11C	27	23.1	117	154	120.7	128	5.70	5.2	110
12B*	27	20.0	135	148	91.7	161	5.48	4.6	119
13B*	24	20.1	119	108	90.5	119	4.50	4.5	100
13C*	25	21.3	117	133	103.1	129	5.32	4.8	111
14A	31	21.7	143	167	107.8	155	5.39	5.0	108
14B*	22	21.6	102	107	107.5	100	4.86	4.9	99
15A	28	21.0	133	160	99.8	160	5.71	4.7	121
15B	28	21.8	128	146	108.9	134	5.21	5.0	104
15C	30	23.3	129	183	123.5	148	6.10	5.3	115

* Sites fall outside of the operational scope of RIVPACS II and predictions and EQIs should therefore be treated with caution.

Table 5 Biotic Scores and Site Performance for Autumn Survey

Site No.	Obs. Taxa	Pred. Taxa	EQI Taxa	Obs. BMWP	Pred. BMWP	EQI BMWP	Obs. ASPT	Pred. ASPT	EQI ASPT
1A	28	20.9	134	136	96.3	141	4.86	4.6	106
1B	25	21.6	116	120	102.3	117	4.80	4.7	102
1C	25	21.7	115	128	101.8	126	5.12	4.7	109
2A	22	22.0	100	131	131.8	99	5.95	6.0	99
2B	28	19.2	146	133	88.3	151	4.75	4.6	103
2C	13	22.4	58	71	111.5	64	5.46	5.0	109
3A	26	19.3	135	122	90.9	134	4.69	4.7	100
3B	26	19.3	135	132	92.8	142	5.08	4.8	106
3C	26	22.5	116	122	112.2	109	4.69	5.0	94
4B	33	21.8	151	175	104.9	167	5.30	4.8	110
4C	31	23.2	134	176	117.0	150	5.68	5.0	114
4D	27	23.1	117	148	115.1	129	5.48	5.0	110
5A*	21	20.7	101	94	96.3	98	4.48	4.6	97
5B	27	21.4	126	135	102.2	132	5.00	4.7	106
5C	28	22.0	127	180	106.2	169	6.43	4.8	134
6A	17	19.2	89	89	90.2	99	5.24	4.7	111
6B	20	19.2	104	99	90.3	110	4.95	4.7	105
6C	21	19.2	111	102	90.4	113	4.86	4.7	103
7A	33	23.1	143	194	112.8	172	5.88	4.9	120
7B	34	23.9	142	194	118.1	164	5.71	4.9	117
7C	33	24.7	134	194	123.7	157	5.88	5.0	118
8B	24	21.1	114	122	98.9	123	5.08	4.7	108
8C	27	22.5	120	145	109.6	132	5.37	4.9	110
9B	26	21.7	120	122	103.4	118	4.69	4.7	100
9C	29	21.9	132	150	104.6	143	5.17	4.8	108
10B	30	22.3	135	153	107.7	142	5.10	4.8	106
10C	32	22.5	142	170	108.6	157	5.31	4.8	111
11A	27	22.1	122	155	109.0	142	5.74	4.9	117
11B	26	21.9	119	124	106.3	117	4.77	4.8	99
11C	24	21.5	112	133	102.3	130	5.54	4.7	118
12B*	27	19.0	142	128	90.2	142	4.74	4.7	101
13B*	30	19.1	157	149	89.6	166	4.97	4.7	106
13C*	23	20.1	114	111	97.2	114	4.83	4.8	101
14A	33	22.3	148	174	106.8	163	5.27	4.8	110
14B*	31	21.9	142	167	104.1	160	5.39	4.7	115
15A	27	19.4	139	148	92.1	161	5.48	4.7	117
15B	28	19.7	142	149	93.2	160	5.32	4.7	113
15C	38	23.4	162	223	119.3	187	5.87	5.1	115

*Sites fall outside of the operational scope of RIVPACS II and predictions and EQIs should therefore be treated with caution.

Figure 2 EQI (ASPT) Values for the Bere Stream

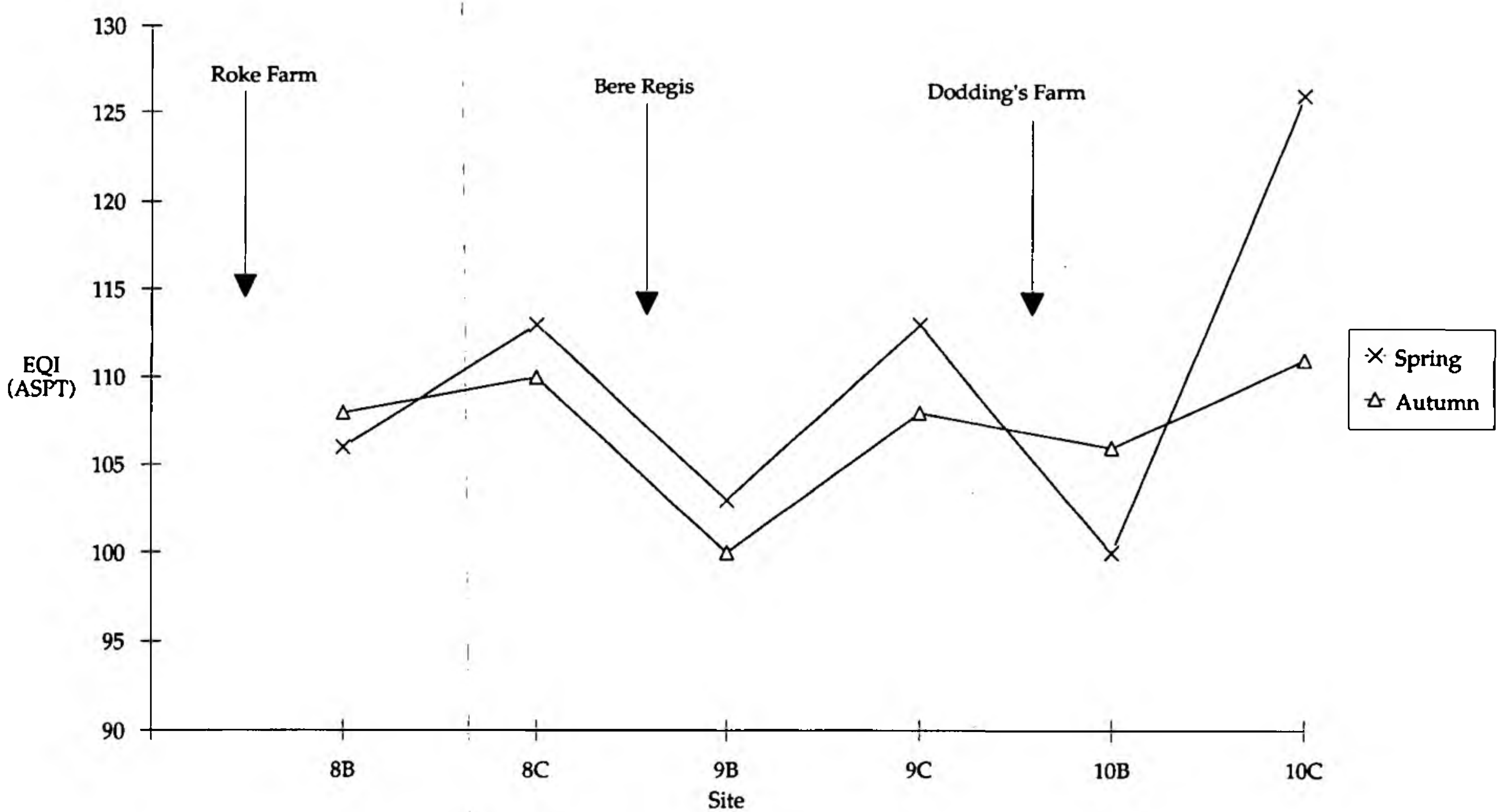

Figure 3 EQI (ASPT) Values for the River Ebble

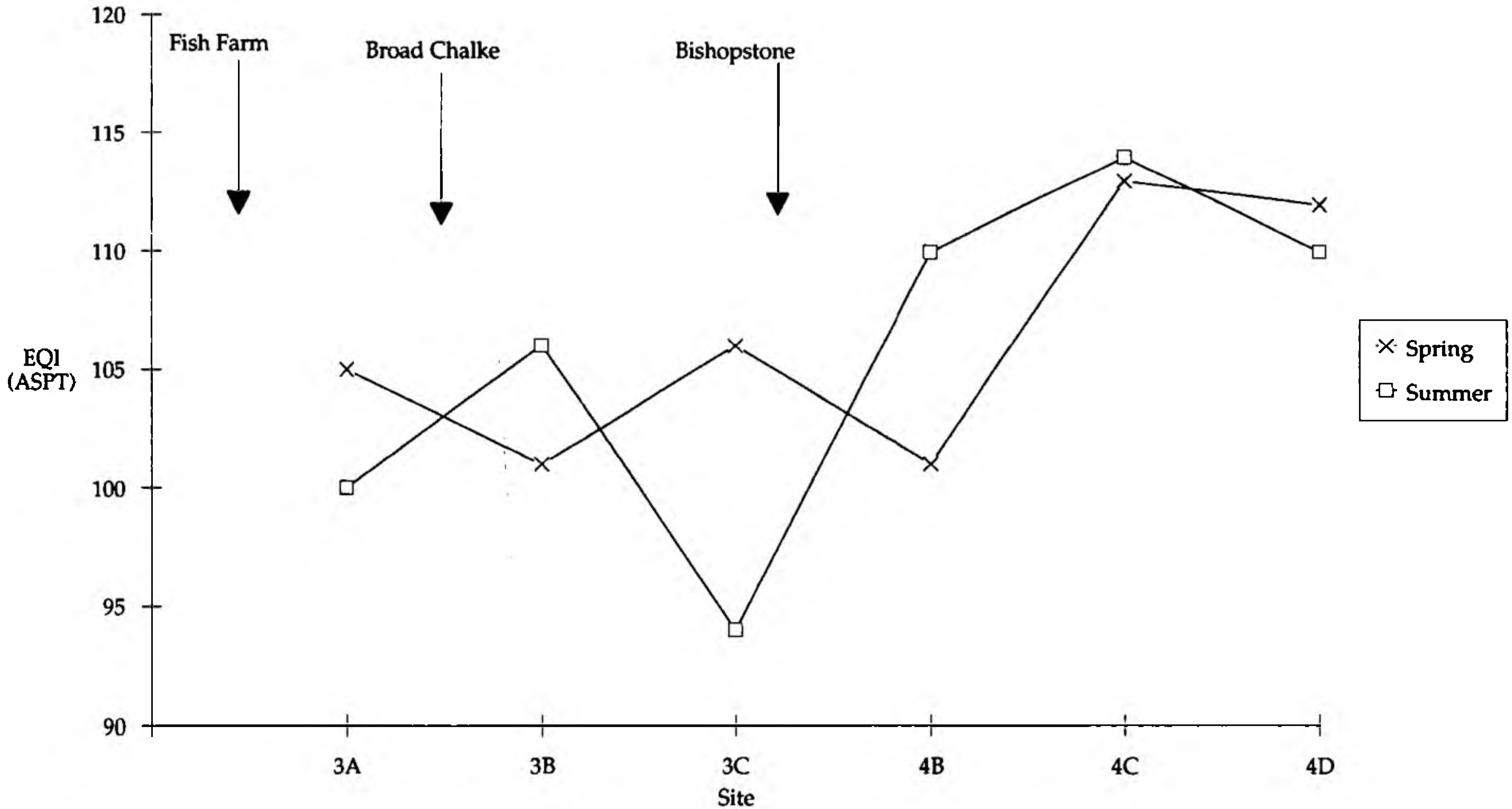

Figure 4 TWINSPAN Site Classification of Macroinvertebrate Samples - Spring Survey

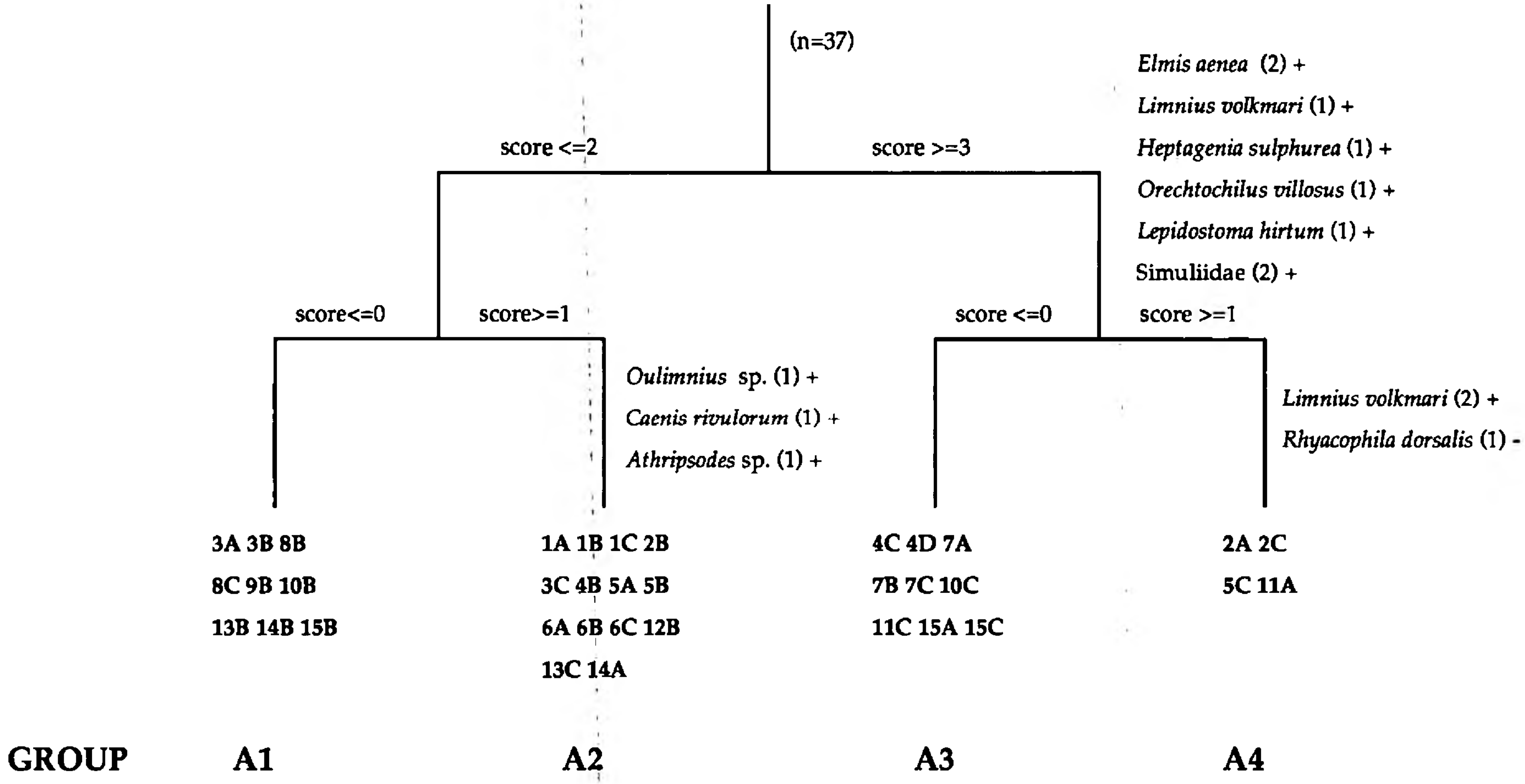

Figure 5 TWINSPAN Site Classification of Macroinvertebrate Samples - Autumn Survey

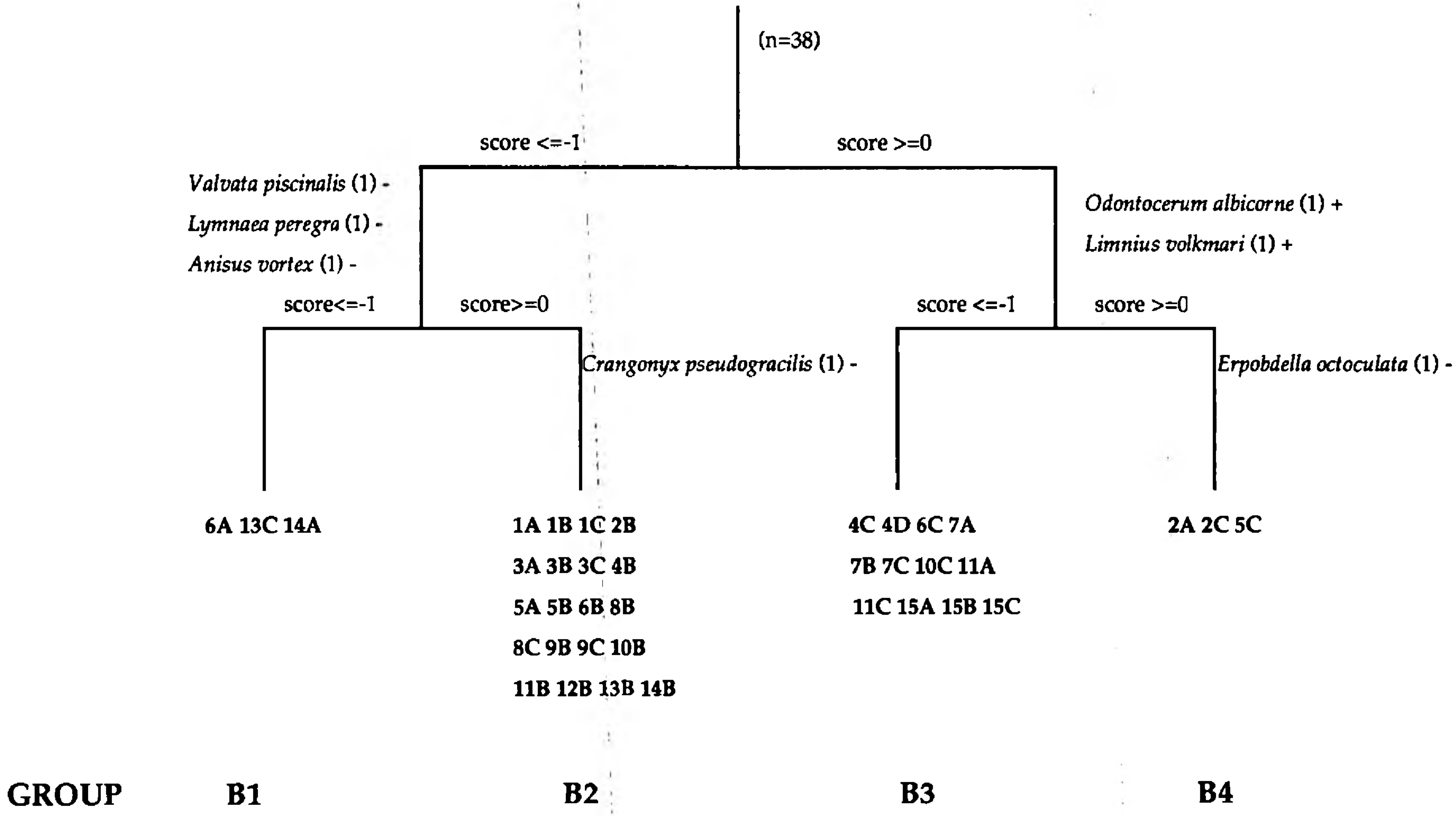

Figure 6 TWINSPAN Site Classification for Spring Macrophyte Survey

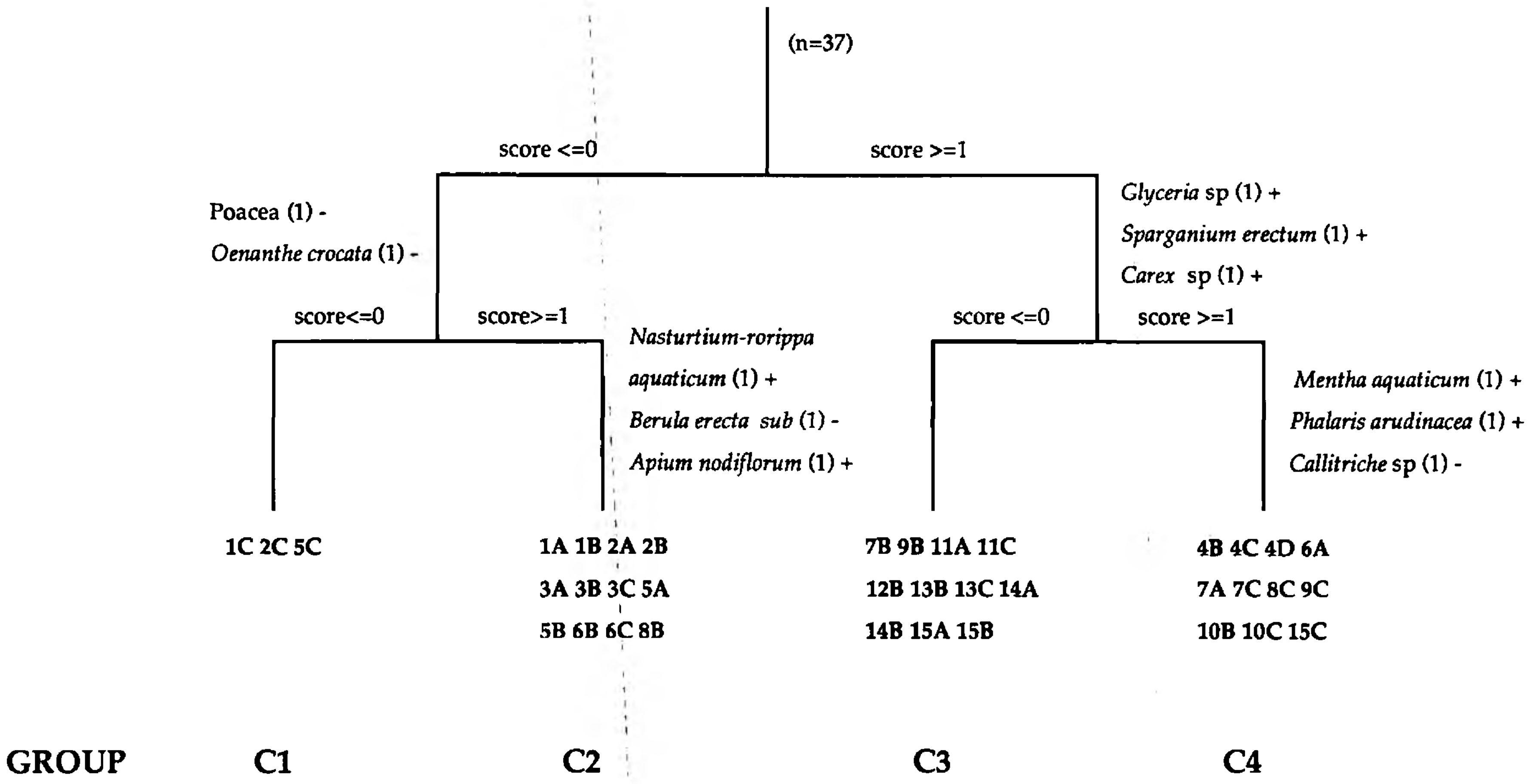

Figure 7 TWINSPAN Site Classification for Autumn Macrophyte Survey