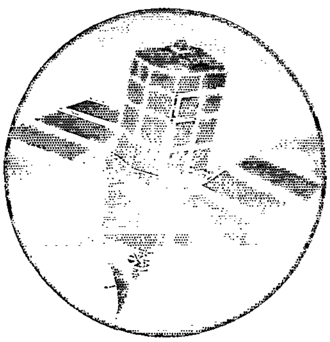
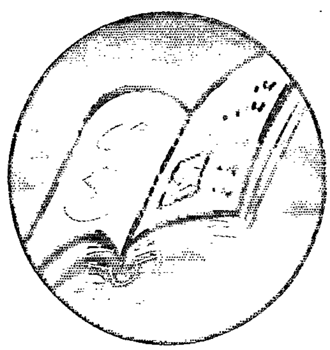
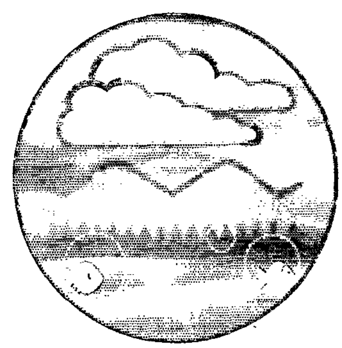
The Role of Bankside Habitat in River Ecology

The Importance of Riparian and Marginal Vegetation on the Distribution and Abundance of Aquatic Invertebrates

Research and Development

Technical Report
W198

ENVIRONMENT AGENCY

The Role of Bankside Habitat in River Ecology

The Importance of Riparian and Marginal Vegetation on the Distribution and Abundance of Aquatic Invertebrates

R&D Technical Report W198

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Research Contractor:

(NERC/Environment Agency Research Fellowship)

Institute of Freshwater Ecology

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Publishing Organisation:
Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol BS32 4UD

Tel: 01454 624400 Fax: 01454 624409

ISBN: 1 85705 080 0

Dissemination status
Internal: Released to Regions
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This R&D Technical Report summarises the findings of R&D Project Record W1/F01/1. It describes the ecology of aquatic invertebrates with respect to the bankside vegetation of chalk rivers and streams, and recommends guidelines for the management of riparian and marginal habitats.

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ACKNOWLEDGEMENTS

This study was co-funded by The Natural Environment Research Council and The Environment Agency as a post-doctoral research fellowship, held by the senior author, at the Institute of Freshwater Ecology, Dorset, UK. We are grateful to Judith Crompton (Environment Agency, Blandford) and Jonathan Newman (Centre for Aquatic Plant Management) for guidance throughout the project, and to Nigel Holmes (Alconbury Environmental Consultants) for later comments. We are also grateful John Blackburn, John Wright and other staff at the River Laboratory for technical assistance and advice during the study. We would also like to thank the landowners that allowed us access to their land during the course of the study, in particular Dr. and Mrs. Gorley, and Mr. and Mrs. Holland.

1. The Role of Bankside Habitat in River Ecology

1.1 Introduction

A number of recently completed, or ongoing projects, funded by English Nature and the Environment Agency (Mainstone *et al.*, 1998; Raven *et al.*, 1998; Ward *et al.*; 1998) have addressed problems associated with low flows, invertebrate association with habitat types, and various aspects of river corridor management and river habitat surveys. However none of these studies have addressed, in a holistic sense, the marginal zone of rivers. The interactions between plants, their effects on flow hydraulics and the associated fauna of invertebrates, fish, birds and mammals, are highly developed in the bankside habitat. In certain rivers this may provide most of the faunal diversity and furnish cover for both adult and juvenile fish.

This area requires basic research to support, underpin and enable development of optimal management procedures. Knowledge of this habitat is essential in order to sustain faunal and floral diversity, encourage the continuance of 'natural' habitats, and follow the succession and evolution of bankside development.

The work reported here focuses on chalk streams which represent perhaps the most important European river habitat type in terms of conservation; these rivers are routinely managed for flood defence and fisheries and are under pressure from water abstraction and agricultural land-use practices. Chalk streams have been identified as a key habitat by the UK Biodiversity Steering Group (1995), and are the only UK River systems for which Biodiversity/Habitat Action Plans are being developed. The three broad objectives of the project were:

1) To describe quantitatively and qualitatively the fauna and flora of bankside and permanent instream marginal habitats of rivers.
2) To examine and analyse the functional dynamics of this habitat in response to natural seasonal effects and different management regimes.
3) To develop best practice guidelines to optimise management procedures with respect to both functional and ecological aspects.

These objectives were met by asking six specific questions:

- **Is there any significant difference between the abundance and community composition of aquatic invertebrates in stream reaches that differed with respect to the types and extent of terrestrial riparian vegetation?**

- **Is there any difference between the individual species abundance and community composition of aquatic invertebrates in the three main instream habitats: main channel gravel, *Ranunculus* (water crow-foot) and vegetated margins?**

- **Is there any difference between the abundance and community composition of aquatic invertebrates in different types of marginal vegetation?**

- **Do bankside trees play a specific role in the ecology of stream invertebrates, via their effect on terrestrial adult distribution and abundance (with specific reference to the glossosomatid caddis *Agapetus fuscipes*)?**

- **Do different riparian vegetation regimes have an influence on the distribution of the emergent adults of aquatic invertebrates?**

- **What is role of vegetated margins in 'buffering' the interactions between fish (*Cottus gobio*, the bullhead) and stream invertebrates such as *Gammarus pulex*?**

1.2 The Study Area

Ten streams were chosen from across the Frome/Piddle catchment, in Dorset, UK. It was apparent that there were several distinct types of riparian management that directly affected the quality and quantity of bankside and instream habitat, and therefore potentially influenced invertebrates in the stream. These management types were:

• **Ungrazed**. (Plate 1.1). Stretches were fenced from grazing stock (for at least three years, prior to sampling). The abundant tall vegetation along the bank was dominated by:
The semi aquatic grasses *Glyceria maxima* (*Hartm.*) Holmb. and *Catabrosa aquatica* L.,

Hogweed (*Heracleum sphondylium*),	Sedges (*Carex* spp.),
Willowherb (*Epilobium* spp.),	Rushes (*Juncus* spp.),
Comfrey (*Symphytum officinale*),	Nettle (*Urtica dioica*),
Meadow-sweet (*Filipendula ulmaria*),	Elder (*Sambucus nigra*),
Black Nightshade (*Solanum nigrum*),	Bramble (*Rubus fruticosus*),
Bittersweet (*Solanum dulcamara*),	Thistles (*Cirsium* spp.),
Water-dropwort (*Oenanthe crocata*),	Occasional riparian trees.

• **Grazed**. (Plate 1.2). Stretches were fully accessible to grazing stock (sheep or cattle) on both sides. Bankside vegetation was characterised by a closely grazed short sward of grass, right up to the water's edge, and *Apium*, both of which were grazed by cattle. Cattle grazing and drinking at the water's edge caused the banks to slope more gradually into the water, creating a series of silty, marginal berms and 'pondlets'. Grazing by cattle prevented the grasses and *Apium* from growing into the main channel to any great extent.

• **Woodland**. (Plate 1.3). Stretches were fenced from grazing stock. Riparian trees were present for at least 10m away from each bank and formed a closed canopy over the stream. Trees were predominantly Alder (*Alnus glutinosa*) and Willow (*Salix* spp.). The dominant wet marginal habitat was the stems and leaves of some of these terrestrial plants, largely ivy, bramble and water-dropwort, which were overhanging the bank and trailing in the water. The often sparse terrestrial vegetation under trees along the bank consisted largely of:

Nettle (*Urtica dioica*),	Bramble (*Rubus fruticosus*),
Water-dropwort (*Oenanthe crocata*),	Ivy (*Hedera helix*),
Elder (*Sambucus nigra*)	Other young trees.

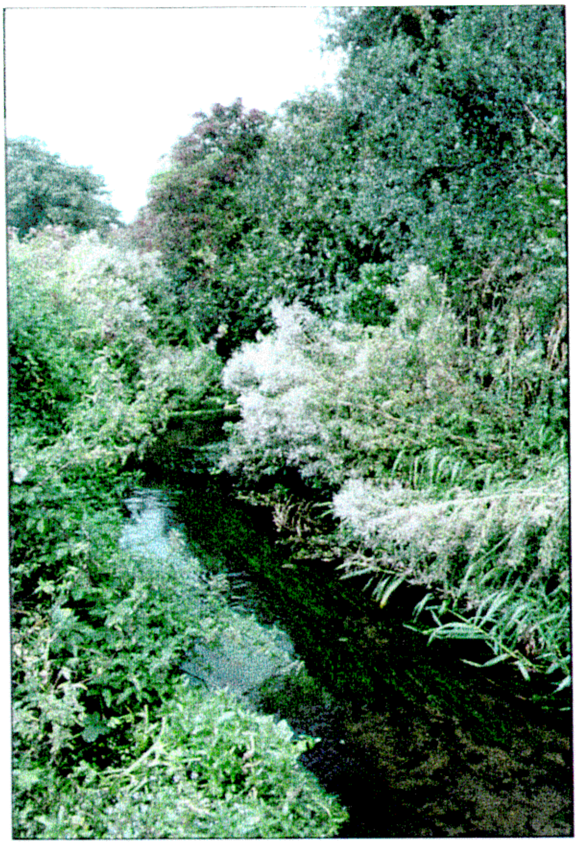

Plate 1.1: 'Ungrazed'
(Tadnoll Brook, September 1996)

Plate 1.2: 'Grazed'
(Hooke River, July 1996)

Plate 1.3: 'Woodland'
(Bere Stream, September 1996)

1.3 Sampling

1.3.1 Aquatic habitats

Kick Samples: (Mid-channel gravel). Samples were taken using a standard 15-second 'kick' with a 0.9mm-mesh long-handled pond net. The invertebrates were preserved in 70% alcohol, and counted and identified to the highest possible taxonomic level.

Sweep samples: (*Ranunculus* and marginal vegetation). The same 0.9mm-mesh pond-net was 'poked' into the vegetation for 15 seconds, working upstream. No attempt was made to avoid sampling the mineral substrate underneath marginal vegetation. No *Ranunculus* was sampled in woodland habitats, due to its rarity. Marginal vegetation that was sampled included:

- reeds and other monocotyledonous plants
- overhanging vegetation (*Urtica dioica, Rubus fruticosus* etc.)
- grass, at the edge of grazed margins
- *Apium* and *Rorippa*

Bullhead cages and tiles: The role of marginal vegetation in invertebrate predation by fish was assessed. Small cages were constructed from tough plastic 5mm-pore mesh, and one of a variety of different types of substrate (washed gravel, cress and *Apium* stems, and strips of green plastic tarpaulin) was introduced into each cage. Cages were placed in mid-stream and the vegetated margins, after a single large bullhead had been introduced into half of the cages. Benthic tiles were placed on the bed gravel in shallow and deep areas, across a range of flow conditions. Invertebrates and fish were sampled 10 days later using a Surber net.

1.3.2 Terrestrial habitats

Sweeps: Using a standard sweep-net, terrestrial vegetation was swept for 30 seconds. In grazed stretches this was short grass. In woodland stretches, the lower branches, twigs and leaves of trees and the tall herbs underneath the trees. In ungrazed stretches, the lower branches of any trees present, the terrestrial portion of marginal vegetation and terrestrial tall herbs were all sampled

Malaise traps: These large 'tent' traps were erected approximately 2-3 metres from the edge of the individual watercourses, and left for an average of 3-4 days before the collecting bottle was emptied. Woodland and a variety of more open areas were sampled.

Sticky traps: A4-size acetate sheets were coated with a specialist, non-toxic, non-drying insect adhesive (Oecotak) and wrapped around sections of 7cm-diameter drainpipe. These drainpipe sections were fastened to wooden stakes, which held them approximately 1.5 – 2 feet off the ground. Sheets were collected after several days. The trapped animals were preserved with alcohol, identified and counted without removal from the sheets.

24-Hour sweep samples: Using the sweep procedure described above, samples were taken at 8.30-9.00 a.m., 1.30-2.30 p.m., and 10.00-10.30 p.m., on two occasions (06/07/98 and 13/08/98) from terrestrial vegetation in woodland, an adjacent ungrazed/fenced area, and a grazed field downstream.

1.4 Nomenclature

In order to avoid excessively long terminology in the text of this report, abbreviations have been used, such as 'grazed gravel', 'ungrazed *Ranunculus*' and 'woodland margin' (for example). These abbreviations refer to the stretch type and specific habitat sampled within that stretch, respectively. The above examples therefore denote a main-channel gravel sample taken from a grazed regime, a *Ranunculus* sample taken in an ungrazed (fenced) stretch, and a vegetated margin sample taken from a woodland stretch.

2. The Impact of Riparian Management, and the Ecology of Aquatic Margins

2.1 Introduction

2.1.1 Riparian Characteristics: Marginal vegetation is abundant in spring-fed chalk streams, due to extremely stable flows and low stream power. Banks experience little erosion and are typically shallow. Riparian vegetation characteristics in any location are thus determined largely by local agricultural practices, rather than by interactions between fluvial hydraulics and local topography/geology.

In the headwaters, the low bank profile allows ready access for cattle and sheep to almost all parts of the stream. Grazing animals can therefore have very strong impacts on riparian vegetation along chalk streams, both due to trampling of the water's edge when they drink from the stream and the high palatability of emergent vegetation. Concern is growing over the effect of cattle grazing along the banks of these streams, particularly in the effect this can have on brown trout (*Salmo trutta*) populations, via the removal of the extensive marginal vegetation and overhanging cover (Giles & Summers, 1996). Fencing streams from stock is now being canvassed as a means of restoring the conservation and fishing potential of chalk streams (Giles & Summers, 1996). Little is known of the effects this may have on invertebrate communities.

Where fences prevent cattle from reaching the stream banks, riparian and marginal vegetation grows luxuriantly. If kept from the stream for long enough, small blocks of woodland can develop. The stable flow regimes and similarity of aquatic habitat across different vegetation types also makes it easier to assess the influence of terrestrial adult distribution and behaviour on larval distribution and abundance.

2.1.2 The functional ecology of marginal vegetation: There is a growing awareness that the 'conservation value' of marginal habitat can be high relative to other habitats in the stream. This is due in part to the apparent high macroinvertebrate diversity associated with emergent marginal macrophytes and to the 'functional' importance of margins for invertebrates (Ormerod, 1988; Wright *et al.*, 1994; Cogerino *et al.*, 1995; Armitage & Cannan, 1998; Harper & Everard, 1998). Recent concern about agricultural management practices along chalk streams has focused attention on the functional role that marginal macrophytes play, particularly in the ecology of brown trout (*Salmo trutta*) (Giles & Summers, 1996). Grazing by cattle at the water's edge can have large impacts on chalk stream marginal vegetation, due to the shallow, accessible nature of the banks. Little is known about the functional role such marginal vegetation plays in the ecology of aquatic invertebrates, despite its abundance and ubiquity.

2.2 Results

2.2.1 Differences in the three main instream habitats (gravel, *Ranunculus* and vegetated margins)

There were strong differences between invertebrate communities in marginal vegetation habitats compared to mid-channel gravel and *Ranunculus* habitats. Both ordination and cluster analysis showed that invertebrate communities from the three habitats were consistently distinct from each other over all four sampling occasions, as noted in previous studies (Armitage *et al.*, 1995; Pardo & Armitage, 1997). The slight overlap between marginal macrophytes and *Ranunculus* invertebrate communities in July and particularly September indicated that physical conditions in the two habitats resembled each other. In the summer, during conditions of low flow and high macrophyte abundance, some marginal macrophyte and *Ranunculus* stands tended to merge together at the edges of the channel. Flow rates in such *Ranunculus* habitats were typically low, such that they approached those typical of marginal vegetation. During periods of higher flow and lower macrophyte abundance, the two habitats were physically separated and had very different flow regimes.

Overall, each habitat was characterised by a distinctive 'suites' of invertebrates, although many numerically dominant groups or taxa, such as chironomids, *Gammarus pulex* and mayfly nymphs were abundant in all three habitats. The gravel habitat contained a characteristic group of invertebrates that included cased and case-less caddis and mayflies associated with stony substrata, the elmid riffle beetles and gravel-dwelling Dipteran larvae. *Ranunculus* had a very distinct group of invertebrates, principally the mayfly nymphs *Baetis* spp. and *Ephemerella ignita* and the blackfly larva *Simulium* spp. Two caddis larvae were also characteristic of this habitat – *Ylodes conspersa* and *Ithytrichia* sp. The caddis *Brachycentrus subnubilus* that is very common in *Ranunculus* beds in lower stretches of chalk streams (Gunn, 1984) was less common in this study of small chalk streams. Interestingly, *Ranunculus* is listed as a natural habitat type with special Conservation status under Annex 1 of the Habitats Directive (92/43/EEC). **However, marginal vegetation had a larger group of characteristic invertebrates than either gravel or *Ranunculus*.** There were particularly high numbers of snails (excluding the small hydrobiid snail *Potamopyrgus jenkinsi*), true bugs, large beetles, fly larvae, small fish and damselfly nymphs. The high numbers of small instar limnephilid caddis in the margins in January probably reflected oviposition in the margins by winged adults, rather than intrinsic choice for this habitat by the larvae, which occurred abundantly in gravel as later instars. The marginal vegetation itself will provide both food, directly for those species that can consume live and decaying plant material, (Jacobsen & Sand-Jensen, 1992; Newman *et al.* 1996) and indirectly, through the high abundance of periphyton on leaves and stems of plants.

A key factor of marginal vegetation is the variability of the habitat. Not only is the habitat structurally complex, but margins possess elements of the other two mid-channel habitats. Where marginal vegetation is entrained in high flows at the interface between margins and flowing water, the habitat will resemble that of the trailing stems and leaves of mid-channel *Ranunculus*. For taxa that live on the surface of stones and gravel, rather than burrowing between or underneath them, the large, relatively fixed stems of marginal vegetation may provide a similar physical habitat and may also have similar resource levels, such as periphytic algae.

Table 2.1: Summary of habitat preferences of **taxa showing significant differences** (P<0.05) in abundance per sample between habitats. * = habitat preference and (-) = habitat avoidance. M J S J = May, June, September and January, respectively.

Gravel	M	J	S	J
Agapetus fuscipes	*	*		*
Drusus annulatus	*	*		
Hydropsyche siltalai	*			
Hydropsyche pellucidula			*	
Odontocerum albicorne	*		*	*
Sericostoma personatum	*	*		*
Rhyacophila dorsalis		*		*
Athripsodes albifrons		*		
Athripsodes sp.		*		
Silo nigra		*		*
Elmis aenea	*	*		*
Limnius volckmari	*	*	*	*
Oreodytes sanmarkii	*	*		
Ancylus fluviatilis	*		*	*
Ephemera danica	*	*		*
Caenis rivulorum	*			
Heptagenia sulphurea			*	*
Dicranota sp.	*	*	*	*
Empididae	*			
Ceratopogonidae				*
Tabanus sp.		*	*	*
Tipula sp.				*
Tanypodinae		(-)		
Leuctra geniculata	*			
Erpobdella octoculata	*			
Glossiphonia complanata		*		
Piscicola geometra			(-)	
Gammarus pulex				*
Oligochaeta		*	*	
Physa fontinalis		(-)	(-)	
Planorbis vortex			(-)	
Mites	*			
Total (*)	15	15	8	15

Ranunculus	M	J	S	J
Ylodes conspersus	*			
Ithytrichia sp.			*	
Lepidostoma hirtum			*	
Sphaeriidae	(-)			(-)
Potamopyrgus jenkinsi	*			
Planorbis planorbis			*	
Baetis spp.	*	*	*	
Ceratopogonidae	(-)			
Ephemerella ignita	*	*	*	
Simulium sp.	*		*	*
Asellus aquaticus				(-)
Total (*)	5	2	6	1

Margins	M	J	S	J
Halesus radiatus				*
Halesus / Potamophylax sp. (small instars)				*
Limnephilus lunatus	*	*		*
Mystacides azurea	*			*
Oecetis sp.	*			*
Potamophylax cingulatus/latipennis				*
Lasiocephala basalis	*			
Agabus paludosus	*			
Agabus sp.	*			
Anacaena sp.	*	*	*	
Elodes sp.	*		*	
Helophorus brevipalpis	*	*		*
Ilybius fuliginosus	*			
Brychius elevatus		*		
Ochthebius sp.		*		
Potamonectes depressus		*		
Haliplus lineatocollis			*	
Lymnaea peregra	*	*		
Lymnaea palustris		*	*	*
Succinia sp.	*	*	*	
Planorbis vortex				*
Valvata piscinalis				*
Micronecta poweri	*	*		*
Sigara dorsalis	*	*	*	*
Sigara venusta	*		*	*
Velia caprai	*	*	*	
Corixidae (immature)		*		
Hydrometra stagnalis		*		
Nepa cinerea		*		
Stratiomyiidae	*			*
Tanypodinae	*			*
Dixa sp.	*	*	*	*
Psychodidae		*		*
Tipula sp.		*		
Limnophora sp.			*	
Chironomidae (excl. Tanypodinae)				*
Ptychopteridae				*
Baetis spp.				*
Paraleptophlebia sp.				*
Asellus aquaticus	*			
Calopteryx splendens	*		*	
Ostracoda	*			*
Crangonyx pseudogracilis		*		
Phoxinus phoxinus		*		
Gasterosteus aculeatus		*	*	
Total (*)	22	21	12	22

Many taxa avoided gravel and *Ranunculus* altogether, over the course of the investigation, whereas only very few taxa were never found in margins (which in this respect acted as 'generalist reservoirs'). *Ranunculus* and, to a lesser extent the mid-channel gravel, can thus be thought of as relatively extreme habitats, poor in taxa and dominated by a few characteristic taxa. Although margins possess many 'specialists' such as the true bugs and many beetles and snails, many other taxa were present in high proportions in the margins, even if they were more abundant in other habitats. **The margins were thus strongly favoured by a few taxa, suitable for many taxa and only disfavoured by a few taxa. *Ranunculus*, on the other hand, was strongly favoured by only a very few taxa, suitable for only a few and strongly disfavoured by many.** Gravel was intermediate between the two. Margins can thus be thought of as the most critical habitat for the whole invertebrate community in a small chalk stream ecosystem, although the high invertebrate abundance per sample in *Ranunculus* beds demonstrates the importance of this habitat for stream secondary production. In addition, the surface area covered by gravel and *Ranunculus* in many streams may well exceed that of marginal vegetation. The relative contribution of these habitats to the chalk stream invertebrate community as a whole may well exceed that of marginal vegetation, as a result.

2.2.2 'Rare' taxa: A much greater number of 'rare' taxa were found in marginal vegetation, including many beetles and bugs. In other studies, stream margins have been found to contain taxa otherwise rare in the stream (Jenkins *et al.,* 1984). Rare taxa in this study were arbitrarily defined as those taxa found in less than 5% of all samples. Many more such taxa were found in marginal vegetation than in the other two habitats.

Table 2.2. Taxa found solely in one habitat (from six streams and four sampling occasions)

Mid-channel gravel	*Ranunculus*	Margins
Hydatophylax infumatus	*Psychomyia pusilla*	*Beraeodes minutus*
Rhithrogena semicolorata	*Dryops* sp.	*Limnephilus politus*
Cordulegaster boltonii	*Leuctra hippopus*	*Lype reducta*
Atherix sp.		*Oxyethira* sp.
		Agabus didymus
		Dytiscidae sp.
		Haliplus obliquus
		Helophorus grandis
		Hydrobius fuscipes
		Hydroporus tesselatus
		Laccobius bipunctatus
		Laccophilus hyalinus
		Laccophilus minutus
		Ochthebius pusillus
		Brachycercus harrisella
		Curculionidae
		Ephydridae
		Sciomyzidae
		Hesperocorixa sahlbergi
		Notonecta glauca
		Plea leachi
		Corixidae indet.
		Coenagrion puella
		Austropotamobius pallipes
Total = 4	Total = 3	Total = 24

Marginal vegetation can also be vital for the reproduction of many stream invertebrates, including those normally found in other habitats. **The significantly higher abundance of egg masses and adults in the margins indicated that this habitat was used as a site of oviposition by many taxa.** The presence of adults in samples also indicated either that adults were entering the water along the margins to lay eggs, or were emerging from the water. Margins thus acted as a 'conduit' for many taxa with terrestrial adults and aquatic larvae. Stream sections without well-developed margins may have poorer recruitment of some aquatic insects as a result. Many beetle taxa are reported to pupate on dry land, usually only a few centimetres from the waters edge (Fitter & Manuel, 1986). The physical nature of margins may thus not only be important for beetles as they move onto dry land, but may itself reflect terrestrial conditions. Well-consolidated, vegetated margins may be more suitable for beetle pupation than silty, unstable grazed banks dominated by grasses. Three native crayfish (*Austropotamobius pallipes*) were observed during the sampling programme. All three were found in marginal vegetation, in ungrazed reaches.

2.2.3 Differences in invertebrate abundance and community composition between different types of marginal vegetation.

The types of marginal vegetation examined and compared were:

- The *Apium* and short grass dominated margins (grazed reaches)
- Emergent *Apium* and reeds (ungrazed reaches)
- Trailing terrestrial vegetation (ungrazed reaches)
- Trailing terrestrial vegetation (woodland reaches)

An ordination and cluster analysis of invertebrate communities showed that there was little overall difference between aquatic communities from the different types of marginal vegetation, although individual families were more abundant in certain kinds of margin. Seasonal differences (governed by changes in macrophyte architecture and invertebrate life histories, for example) were apparently much greater than differences between individual marginal vegetation types.

Bugs, some snails and small fish (minnows and sticklebacks) were more abundant, in spring and summer, in the grassy margins of stream sections running through grazed meadows. These margins were characterised by the abundance of small shallow 'pondlets', which were created by the poaching action of cattle grazing or drinking at the water's edge. Bugs and snails may have favoured low current velocities and high periphyton density or plant debris on the silty substrate in these margins. They may also have favoured locally high temperatures in the silty pondlets in spring and summer. Minnows have been shown to use shallow marginal habitats of chalk streams for energetic reasons, where the warmer temperatures in shallow, silty margins allow greater growth of fish (Garner *et al.*, 1998). The other groups of invertebrates that were less common in grassy margins may have preferred habitats with greater current velocities, or greater physical habitat structure. Adult oviposition may also have been less in grassy margins, where there was little terrestrial bank vegetation structure to facilitate adult reproduction.

A significant finding of this study is the relative importance of terrestrial vegetation trailing in the water at stream margins. This habitat had as abundant and diverse an invertebrate community as semi-emergent marginal macrophytes, such as stands of *Apium* or reeds. In woodland sections, the invertebrate community in the sparse marginal vegetation (consisting of occasional trailing stems and leaves of terrestrial plants, such as ivy and water-dropwort) was almost as abundant and diverse as that in much more abundant marginal emergent vegetation in open sections. Despite confirmation of the importance of vegetation that provides a physical transition between water and land (Ward *et al.*, 1998), this kind of marginal habitat is virtually ignored in stream invertebrate studies. Management of the riverbanks will greatly influence the degree to which vegetation trails in the water. In streams with little marginal semi-emergent vegetation (for example, due to high erosive force on the banks), trailing terrestrial vegetation may be the only 'soft' (sensu Rutt *et al.*, 1989), structurally complex vegetated habitat in the stream. Trailing vegetation was also found to persist over winter, when it is likely to assume even more importance as in-stream macrophytes die back. This has clear implications for autumn bankside-clearance programs.

2.2.4 Difference in abundance of individual families between grazed, ungrazed and woodland stretches

Although only small differences were seen between the **total** invertebrate communities between stretches, there were significant differences in the abundance of individual families. Families with significant differences in abundance between stretches of different management type are shown in Tables 2.3 and 2.4. Family abundance was compared between ungrazed and woodland stretches (3 streams) and between ungrazed and grazed stretches (5 streams).

Table 2.3. Families showing **significant differences** (not presence/absence) in mean invertebrate abundance between 'ungrazed' and 'woodland' stretches in each of two habitats, gravel and marginal vegetation. (*Ranunculus* was not compared due to its rarity in woodland). * = P<0.05, + = P<0.1, M J S J = May, June, September, January (respectively).

Families	UNGRAZED STRETCHES								WOODLAND STRETCHES							
	Gravel				Margin				Gravel				Margin			
	M	J	S	J	M	J	S	J	M	J	S	J	M	J	S	J
Glossosomatidae										*						
Limnephilidae															+	
Rhyacophilidae		+														
Ephemerellidae		+				+										
Caenidae	*					+										
Heptageniidae									*							
Ancylidae					+											
Lymnaeidae		*												*		
Physidae							*									
Planorbidae							*									
Elmidae									*	*		+				
Helodidae																+
Gyrinidae								+								
Veliidae														*		
Asellidae								+								
Stratiomyiidae													+			
Tanypodinae						+	*									
Hydracarina						*										
Total abundance	+					+										
Numbers of families Showing significant differences (P<0.05)	2				4				3				2			
Numbers of families Showing significant differences (P<0.1)	4				9				3				5			

Table 2.4. Families showing **significant differences** (not presence/absence) in mean invertebrate abundance per sample between 'ungrazed' and 'grazed' stretches in each of three habitats, Gravel, *Ranunculus* and Vegetated margins. * = P<0.05, + = P<0.1, M J S J = May, June, September, January (respectively)

Families	UNGRAZED STRETCHES												GRAZED STRETCHES											
	Gravel				*Ranunculus*				Margin				Gravel				*Ranunculus*				Margin			
	M	J	S	J	M	J	S	J	M	J	S	J	M	J	S	J	M	J	S	J	M	J	S	J
Brachycentridae									+															
Hydroptilidae	+	*							*			+												
Hydropsychidae		+						+			+	+												
Leptoceridae							*		+															
Lepidostomatidae											*													
Odontoceridae			*																					
Sericostomatidae		*										+												
Rhyacophilidae										+							*							
Elmidae		*	*		*		*		+		+	+												
Dytiscidae			*			*																		
Hydraenidae											+													
Caenidae	+		*	+																				
Baetidae												*										+		
Heptageniidae			*	*					+			+												
Leptophlebiidae																								*
Leuctridae											+													
Calopterygidae									*	*	*	*												
Ancylidae				*				+																
Bithyniidae																							*	
Lymnaeidae				*																				*
Hydrobiidae								*																
Valvatidae																			+					
Planorbidae																								*
Erpobdellidae																*								
Glossiphoniidae													+		+									
Asellidae							*				*													
Gammaridae					*																			
Ostracoda	*																							
Nepidae																						*		
Veliidae																					*			
Ceratopogonidae																					*			
Tipulidae											*												+	
Simuliidae										*	*													
Tanypodinae								+																
Empididae																								+
Sialidae										+														
Hydracarina				*																				+
Tricladida			*						+															
Gasterosteidae																							*	
Cottidae																					+			
Total abundance																						+		
Numbers of families Showing significant differences (P<0.05)	12				6				7				1				1				8			
Numbers of families Showing significant differences (P<0.1)	15				9				20				2				2				13			

2.3 Summary of difference between the three main instream habitats (gravel, *Ranunculus* and margins)

- In comparison to seasonal effects, little difference was found between invertebrate communities in different types of marginal vegetation. The characteristic features of most marginal vegetation included high structure, abundant detritus, periphyton and other plant-derived food and low flow. The aquatic invertebrate assemblages found in the trailing stems and leaves of overhanging terrestrial vegetation were as abundant and taxon-rich as those found in semi-emergent marginal macrophytes.

- The invertebrate assemblages in marginal vegetation, *Ranunculus* beds and in mid-channel gravel could be distinguished from each other over most of the year, particularly in spring and winter. Taxon richness was generally higher in the margins, although invertebrate abundance per sample was highest in *Ranunculus*, due to the high numbers of mayfly (Ephemeroptera) and blackfly (Simuliidae) larvae.

- Over half of all taxa identified on each sampling occasion showed significant difference in abundance between habitats. Of these taxa, many more were found in the marginal vegetation compared to gravel or *Ranunculus*. Significantly greater numbers of egg masses and adult insects (either emerging from the water or ovipositing in water) were found in marginal vegetation, also demonstrating the value of this habitat for reproduction and recruitment of aquatic insects.

- For each taxon, the mean proportion of its population in each of the three habitats was calculated. The overall mean proportion per taxon in each habitat was greatest for marginal vegetation, and least for *Ranunculus*, with gravel intermediate. This indicated that for the invertebrate community as a whole, margins were relatively more important for taxa than either gravel or *Ranunculus*. In addition, many more taxa avoided gravel and *Ranunculus* than avoided margins, over all four sampling occasions.

- The physical diversity within marginal vegetation, including elements of other habitats, allowed different invertebrate groups to live there. These included:
  a) taxa normally restricted to lotic margins,
  b) taxa typical of other stream habitats but occasionally found in margins,
  c) taxa using margins as a temporary habitat or refuge,
  d) taxa normally found in still-water habitats, such as ditches and small ponds,
  e) taxa spending only part of their life cycle in aquatic habitats.

In contrast, gravel and *Ranunculus*, which experienced high flow, comparatively low structural diversity, and potentially high predation pressure, were colonised by specialist taxa.

2.4 Summary of differences between woodland, ungrazed and grazed regimes

- Little difference was found in overall invertebrate community between habitats (gravel, *Ranunculus* and margin) from different regimes, reflecting the similar physical conditions in each habitat across stretches. However, there were significant differences in the abundance of certain families between the three types of regime.

- A greater number of invertebrate families were more abundant in habitats in ungrazed stretches compared to the same habitats in grazed stretches. This was particularly the case for caddis families, elmid and dytiscid beetles, caenid and heptageniid mayflies and calopterygid damselflies.

- Taxon diversity was higher in ungrazed habitats, compared to grazed habitats. Differences between the two stretch types could be explained by the more abundant and diverse marginal vegetation in ungrazed stretches, which may have acted as a possible 'source' of invertebrates to other habitats.

- A similar number of families were more abundant (as larvae) in habitats in ungrazed compared to woodland stretches, despite the lower abundance of marginal macrophytes in woodland. There was greater taxon diversity within certain orders of invertebrate in ungrazed, compared to woodland stretches. Two families were, however, particularly more abundant in woodland gravel, compared to gravel in ungrazed stretches – glossosomatid caddis and elmid riffle beetles. Elmid beetles may also favour wooded banksides as sites of pupation.

- Management of riparian corridors along chalk streams should aim for diversity of bankside vegetation. Extensive stretches of heavily grazed banks should be avoided and stretches with abundant 'untidy' marginal and terrestrial vegetation encouraged. Short stretches of woodland bankside, although reducing primary and secondary production and lowering in-stream diversity, may act as vital areas of adult habitat, thus increasing reproduction and recruitment in streams.

3. The Influence of Riparian Vegetation on Adult and Aquatic Insects

3.1 Introduction

The ecology of aquatic insects is widely assumed to be determined solely by aquatic factors, both biotic and abiotic. Recent research, however, has demonstrated the importance of terrestrial adults in the distribution, abundance and population dynamics of aquatic larvae. Riparian vegetation is known to be an important factor in the ecology of adult insects. Very few studies have looked at the link between terrestrial vegetation, adults and larvae, although adult swarming and oviposition near to bankside trees and reeds has been shown to be a major determinant of the distribution of larvae of lotic caddis flies (Statzner, 1977).

This study was undertaken in three parts:

- An initial survey of aquatic invertebrates from the mid-channel gravel of short (50-200m) stream sections, which differed in their riparian vegetation characteristics.

Subsequently, the distribution of the common and very abundant cased caddis *Agapetus fuscipes* Curtis (Glossosomatidae) larvae was found to be strongly influenced by riparian trees.

- Thus, a detailed, single-species investigation of the factors affecting the distribution and abundance of *Agapetus* adults and larvae with respect to bankside trees was carried out. The distribution and abundance of other adult caddis were also considered at this time, but not in as much detail.

- A third investigation examined the distribution of adult invertebrate stages using sticky traps, and a 24-hour sweep-sampling regime.

Work with Malaise traps showed a link between terrestrial vegetation and invertebrate distribution. This was indicated by *Agapetus*' apparent requirement for woodland (in the first instance) and in particular the interface between woodland and open-areas. However, Malaise traps were identified as a possible source of bias to the data, given that they had the potential to function as surrogate bushes. Accordingly the sticky traps were designed to be considerably less intrusive in nature.

The investigations aimed not only to assess the requirement of adult insects for distinct vegetation types, but also to go some way towards demonstrating the relative importance and dependence that various adult taxa place upon each riparian zone. Some of the work was preliminary in nature and time constraints largely determined the extent of data collection and analysis.

3.2 Results

3.2.1 Difference in abundance and diversity of adult (emergent) insects in terrestrial vegetation between grazed, ungrazed and woodland stretches – initial survey

Initially, differences in both the abundance and species richness of adult insects were assessed between grazed and ungrazed stretches, and between ungrazed and woodland stretches, by taking sweeps of terrestrial vegetation. Subsequently, Malaise- and sticky-traps were used. Due to the lack of sites that possessed adjacent woodland and grazed stretches it was not possible to compare these two stretch types directly.

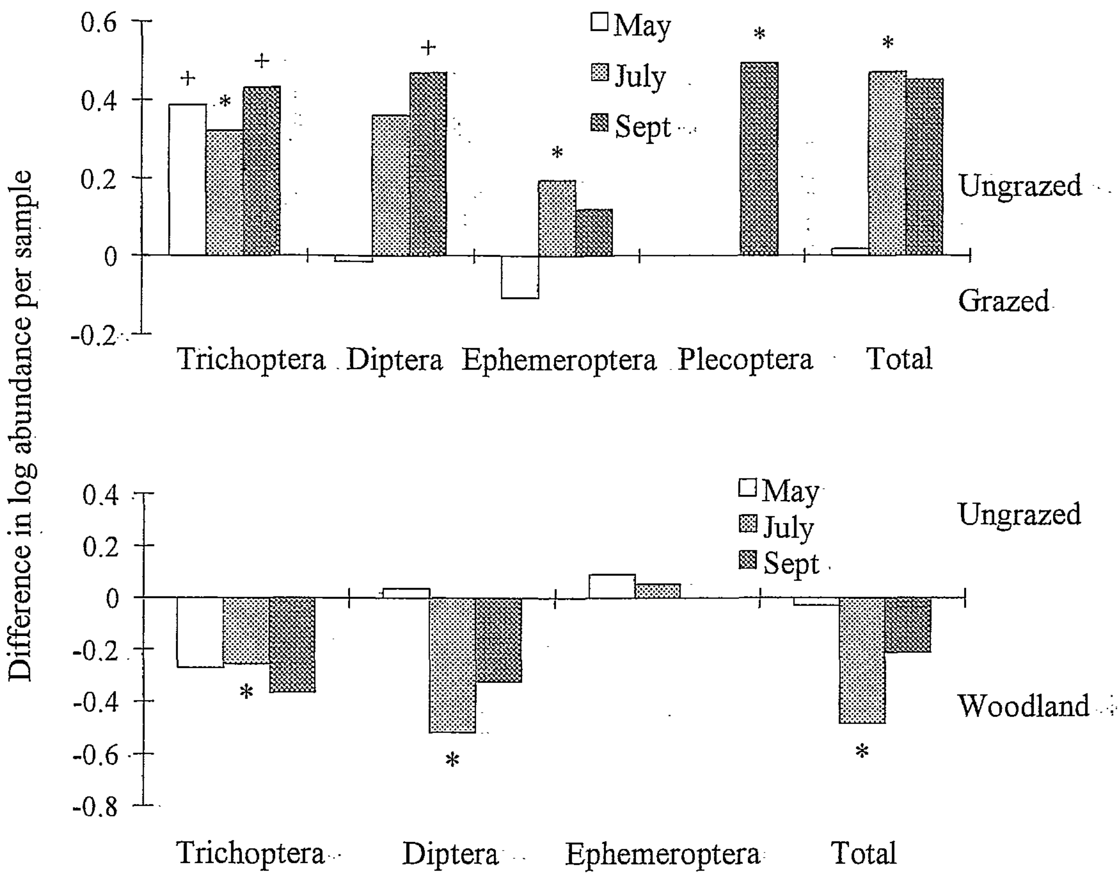

Figure 3.1. Mean difference in total abundance per sample (log-transformed) of adults of the major groups of aquatic insects caught in sweeps of 'grazed' and 'ungrazed' bankside vegetation (top panel), and 'ungrazed' and 'woodland' bankside vegetation (bottom panel). * = $P<0.05$, + = $P<0.1$

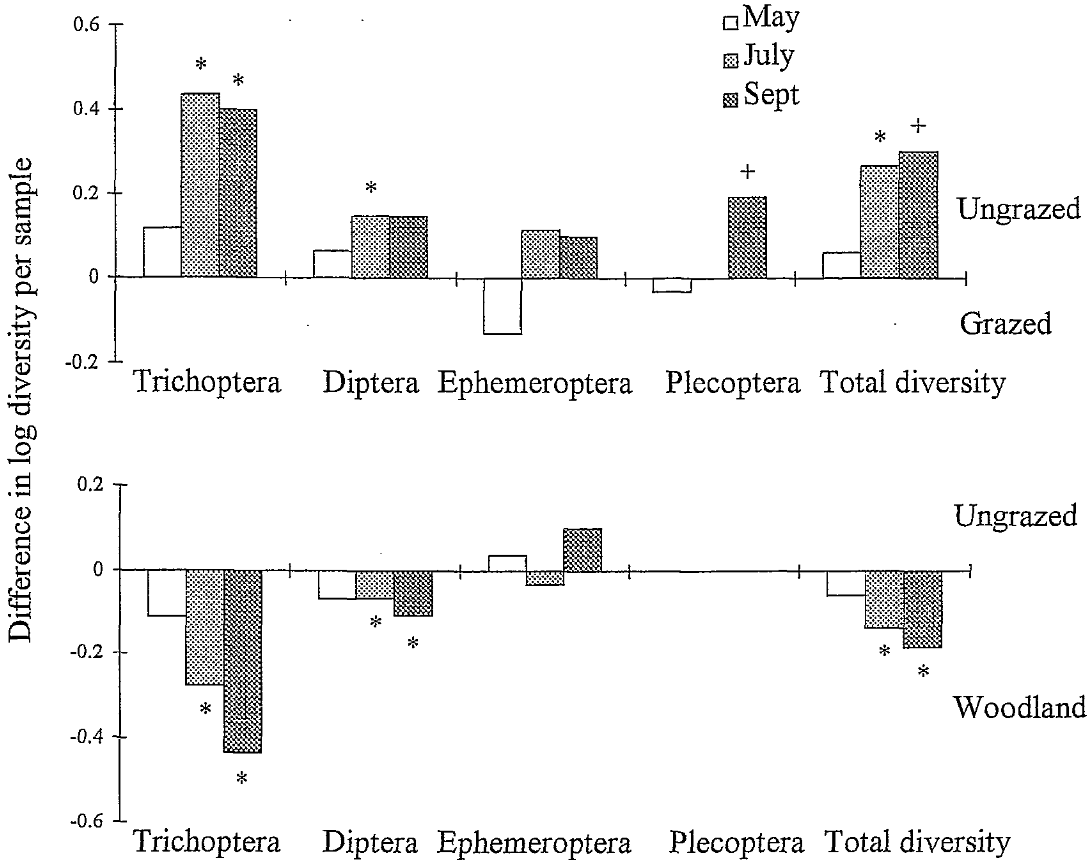

Figure 3.2. Mean difference in diversity/richness per sample (log-transformed) of adults of the major groups of aquatic insect caught in sweeps of 'grazed' and 'ungrazed' bankside vegetation (top panel), and 'ungrazed' and 'woodland' vegetation (bottom panel). * = P<0.05, + = P<0.1.

a) Differences between grazed and ungrazed stretches

There were significant differences in the abundance of adult insects caught in terrestrial vegetation between the two management types (Fig. 3.1 Top panel). Adults of all the major orders were found in greater abundance in ungrazed vegetation. Trichoptera in particular were more abundant in ungrazed vegetation, differences being significant for each month. The total abundance of adult insects was significantly greater in ungrazed stretches in July. The diversity of adult families of the major orders was also greater in ungrazed stretches. Again, this was true particularly of caddis adults, which were significantly more diverse in both July and September (Fig. 3.2 Top panel).

b) Differences between Ungrazed and Woodland stretches

Adult Trichoptera and Diptera were significantly more abundant in woodland vegetation, though only on one of the three sampling occasions (Fig. 3.1 Lower panel). Abundance of adult Ephemeroptera showed little difference between stretches. The total abundance of adults was significantly greater in woodland stretches, in July. The diversity of Trichoptera and Diptera families was greater in woodland stretches compared to ungrazed stretches, in both July and September. Total family diversity was also greater in July and September (Fig. 3.2 Lower panel) .

3.2.2 The distribution of Trichoptera

a) *Agapetus fuscipes*

Initial investigation showed that *Agapetus* larvae were very much more abundant in woodland sections than either grazed or ungrazed sections, particularly in July. Here, numbers of larvae declined rapidly, such that there was little difference between sections in January. There were significant differences between sections in the abundance of adults, with particularly large numbers of adult *Agapetus* in woodland in May. Very few adults were found in the short vegetation characteristic of grazed regimes.

Study of the distribution of *Agapetus fuscipes* adults between three habitat regimes (within woodland, adjacent to trees, and away from trees), using Malaise traps, showed that significantly more adults were always caught in Malaise traps near trees compared to away from trees. This pattern was demonstrated consistently between May and August, 1997.

b) The distribution and abundance of adult caddis other than *Agapetus*

Some caddis were clearly influenced by various types of terrestrial vegetation, and for others terrestrial vegetation seemed to make little or no difference to their distribution. *Beraea maurus*, *Glyphotaelius pellucidus* (a limnephilid) and *Sericostoma personatum* are examples of the former group, whilst *Rhyacophila dorsalis*, Hydroptilidae and Psychomyiidae belong to the latter. Caddis such as *Limnephilus extricatus*, *Silo nigricornis* and Leptoceridae showed distinct preferences for certain habitats, but low abundances elsewhere meant overall distribution could not be statistically linked to any particular area. Caddis diversity between the three different regimes (wood, near trees, away from trees) was very similar, as a mean of the three study streams. In each case, the samples from either the woodland or 'near-trees' traps generally recorded greater species richness than the 'away from trees' traps, although this was not statistically significant on any occasion.

3.2.3 Sticky-trap results.

The sticky-traps revealed important differences in the distribution of several taxa between the woodland and open areas. Notably, Baetidae, *Drusus,* Simuliidae and Sialidae were all more abundant in the open stretch. Several other taxa showed consistent differences between the two management regimes but not at a significant level, these were Tipulidae (more common in the open), Caenidae and Nemouridae (both more common in woodland). Many taxa showed no difference in their abundance on sticky traps between the two regimes despite contrary evidence from Malaise traps (e.g. Chironomidae and *Agapetus*). No significant difference in total adult abundance between management regimes was recorded on any of the four sampling occasions throughout the summer. The numbers of insects caught in both the woodland and the open sections matched each other very closely during this period, with peak abundances occurring in June (over 1000 flies/A4 acetate-sheet). Total adult diversity was, however, significantly greater in the open section in May and September, largely due to small numbers of Diptera (Tipulidae, Simuliidae), caddis (Sericostomatidae, Rhyacophilidae) and Sialidae.

3.2.4 24-Hour Sweep-samples.

These samples showed a strong diel movement of chironomids and psychodids between the woodland area and the open reaches (open and 'field'). Psychodid abundance increased dramatically in the woodland reach in the evening, from a near zero level during the daytime to a mean of over fifty flies per sample in the evening. Chironomid abundance in woodland showed a similar increase in the evening, albeit not so striking. This evening increase was mirrored by a decrease in chironomid numbers in the grazed field – a regime that demonstrated very high numbers of chironomids at all times.

Other patterns were also observed. *Drusus* increased in abundance in the evening in both the open and the woodland reach, suggesting a general preference for activity at this time irrespective of vegetation. Conversely, *Agapetus* numbers peaked at noon in similar numbers in all three reaches, wood, open and field. Culicidae abundance during the daylight hours remained low in all three reaches, then showed a large increase in the field in the evening. (This accords well with the adult dispersal described by Cranston *et al.,* 1985). Tipulidae abundance remained at similar levels for all three reaches throughout the morning to evening period, with greatest abundance recorded from the wooded reach.

3.3 Summary of riparian influences on adult invertebrates

- A greater abundance and variety of terrestrial adult insects were caught in bankside vegetation along ungrazed stretches, compared to grazed stretches. However, the terrestrial adult abundance and species-richness was greater in woodland compared to ungrazed stretches, indicating that dense riparian trees also provide a valuable habitat, or refuge, to adults of many aquatic insect species, and possibly provide a superior adult habitat compared to more open banksides.

- The greater abundance of *Agapetus fuscipes* egg masses, small size-class larvae and adults found under trees and particularly in open sites near trees, indicates that larvae were recruited in these areas following adult oviposition. Very low persistence of *Agapetus* larvae in woodland sections, despite the high recruitment, suggests that adults may have maximised their own survival at the expense of their larvae.

- *Agapetus* evidently needs both suitable aquatic habitat for larvae and terrestrial habitat for adults in order to flourish in any particular water body. Potentially, therefore, changes to the riparian landscape could have important consequences for invertebrate abundance and diversity in streams, via its effect on terrestrial adults.

- Results from malaise-traps and sticky-traps suggested:
  1. that many emergent caddis-adults distribute widely with no significant preference for wooded or open areas, and
  2. several caddis species were particularly distinct and consistent in their site of capture.

  The reality is likely to be much more complex than this, with diversity of taxa and distribution of invertebrates being a function of all the locally available habitats.

- 24-hour sweep sampling revealed that many caddis and other adult invertebrates displayed patterns of diel movement between different vegetation types. Woodland, open (tall herbs) and open (grazed field) were all important (to greater or lesser extents, depending on the specific taxa) in the dispersal of adult invertebrates.

- It is probable that the abundance of a particular habitat may not be as important as its proximity to other, different, habitats. Despite the relatively distinct appearance of riparian stretches such as woodland or grazed fields, regimes such as these are unlikely to function independently of each other for many invertebrate species and families.

- The extreme mobility of adult-invertebrates compared to their larvae means that even regular monitoring may miss a transitory visit to a certain area. On an individual stream basis, identification of bankside areas that may play separate roles in adult invertebrate distribution is therefore essential. Maintenance of distinct areas of diverse vegetation structure must be a paramount objective. Together with contrasting management regimes, (such as woodland, herbaceous strips and short grazed sward) this includes the need to encourage structurally different plants within the regimes.

4. Distribution of the freshwater shrimp *Gammarus pulex* and the Bullhead *Cottus gobio* with respect to Marginal Vegetation

4.1 Introduction

Gammarus pulex are among the most abundant invertebrates in chalk streams and account for a high proportion of the total invertebrate biomass. They are able to tolerate a wide range of environmental conditions, and are associated with many different kinds of habitat. They are also omnivorous and thus able to exploit many different kinds of food. Not only are they are major processors of plant detritus in streams (thus providing a quantitatively important link between trophic levels) but they are also voracious predators and can, potentially, strongly influence other invertebrate populations. *Gammarus* are also an important food item of many fish, particularly benthic feeding species. Bullheads can be the most abundant fish in chalk streams, in terms of numbers and biomass. Not only are they important predators of benthic invertebrates, they are a favoured food item of brown trout. They thus act as an important trophic link between food levels, as do *Gammarus*.

Gammarus pulex and the bullhead may therefore be highly important species in terms of trophic functioning and animal biomass. Despite their importance, relatively little is known about either their habitat use or interactions. Both species can be found in abundance in main channel gravel, *Ranunculus* and vegetated margins. Neither showed any strong preference for any one habitat for much of the year, in the first year's investigation, although *Gammarus* appeared to prefer gravel in January. Bullheads are said to prefer gravel habitats, where they hide under large stones during the day. However, many were found in margins and *Ranunculus* during this study.

One of the many functions of margins may be to provide invertebrates with refugia from predators. Many of the larger, predatory invertebrate species (e.g. damselfly larvae, true bugs and beetles) are found in the vegetated margins. This may not only be related to their foraging ecology but also to the need to escape predatory fish, which tend to favour large-bodied active species. *Gammarus* are particularly active and are also one of the larger species of invertebrates, when fully grown. They may therefore potentially use the margins as refugia from fish, particularly benthic feeders such as bullheads.

Predator-prey relationships in lakes have been shown to be stabilised by the presence of spatial refugia for zooplankton, such as macrophyte beds. These refugia prevent fish from consuming all the available prey, thus preventing large oscillations in both fish and zooplankton populations. This also stabilises zooplankton–phytoplankton interactions and prevents lakes becoming dominated by phytoplankton over time. One of the dominant features of chalk streams is both the high abundance and diversity of fish and invertebrates, but also the stability of populations of both groups. Hydraulic factors are undoubtedly responsible for much of this stability, but the high abundance of marginal vegetation may play a role, by 'buffering' the interactions between fish and invertebrates.

This investigation concerns the interaction between *Gammarus pulex* and bullhead, and the role marginal vegetation plays in this interaction.

4.2 Results

Gammarus and Bullhead distribution.

In summer the majority of bullheads were found in gravel and *Ranunculus*. Very few fish were found in margins. Small *Gammarus* were however found largely in *Ranunculus* and *Apium* margins. Larger *Gammarus* were found predominantly in the margins. Very few *Gammarus* of any size were found in the gravel and only small individuals were found in *Ranunculus*. In direct contrast to the distribution of bullheads in summer, winter distribution showed most fish in the margins, particularly the 4-5cm size class. Similarly, in contrast to the summer distribution, *Gammarus* were found in greatest abundance in the gravel, compared to either *Ranunculus* or margins. There thus appeared to have been a switch in the distributions of both *Gammarus* and bullheads, from summer to winter.

Habitat preference of *Gammarus* across deep and shallow areas.

A greater number of large *Gammarus* were found in shallow margins, compared to shallow gravel, although they were still abundant in the latter habitat. Very many more large *Gammarus* were found in the shallow gravel compared to deep gravel. Large *Gammarus* were almost absent from this habitat, whereas smaller *Gammarus* showed little difference between shallow and deep gravel.

Using experimental cages, the distribution of the two size classes of *Gammarus* showed strong differences. In shallow water, *Gammarus* preferred cages containing *Apium*, rather than gravel, but this effect was more marked in small individuals. Large *Gammarus* showed little obvious preference. Very few *Gammarus* were found in cages of either type (*Apium* or gravel contents) that were placed in deep-water areas.

Unglazed tiles (placed in the stream) and invertebrates were categorized into depth classes: 0.5-3cm, 3.5-6cm, 6.5-10cm and 10cm+. There were two patterns of distribution seen in invertebrates and fish. *Gammarus* were abundant under shallow tiles but numbers declined dramatically under tiles at a depth greater than 6cm. Bullheads were rare under shallow tiles but increasingly more abundant under deeper tiles. Mayflies, chiefly *Ephemerella ignita*, were rarer under deeper tiles. *Asellus aquaticus* were more common under deeper tiles.

The effect of Bullhead upon *Gammarus*, using experimental cages

In August, large *Gammarus* in particular were found more abundantly in cages without fish. More *Gammarus* of all sizes were found in the middle compared to margins. Although substrate appeared to have little effect with fish, *Gammarus* preferred gravel in the absence of fish. Thus, in the absence of fish more *Gammarus* were found in cages in the middle channel containing gravel – the habitat where they were rarest in investigations of the natural habitat.

In February, *Gammarus* are again found in greater abundance in fishless treatments and again more were found in cages placed in the middle of the stream. In winter, *Gammarus* (particularly large individuals) preferred *Apium* rather than gravel, in contrast to their summer distribution. Despite the switch in habitat selection from summer to winter, *Gammarus* still demonstrated a similar preference for fishless cages placed in the middle, although there appears to be a preference in winter for *Apium*, rather than gravel.

4.3 Summary of *Gammarus*/Bullhead interactions, with respect to marginal vegetation

- One of the important functions of margins in streams may be to provide refugia for invertebrates such as *Gammarus* from fish such as bullhead. These two species are dominant species in chalk streams. Bullhead are also protected under Annex 2 of the EU Habitats Directive.

- Experiments with artificial exclosures and substrata showed that fish presence/absence was the dominant factor in the distribution of *Gammarus* in the streams investigated. In the absence of fish, *Gammarus* showed little preference for either vegetation or gravel as a microhabitat.

- Bullheads exert a strong effect on *Gammarus* distribution, both across the stream from mid-channel to marginal habitats, and longitudinally from shallow to deep areas. Bullhead avoided shallow areas presumably because of the risk of stranding, *Gammarus* on the other hand strongly favoured shallow habitats.

- In natural habitats in summer, *Gammarus* (particularly large individuals) was very much more abundant in margins and rare in gravel. Fish showed the opposite distribution, being common in gravel and rare in the margins, suggesting a strong negative correlation in the distribution of the two species.

- In winter, bullhead were found to be abundant in margins and somewhat less so in gravel. *Gammarus* showed the opposite distribution, being abundant in gravel and rarer in margins. This demonstrated a habitat shift by the two species, the distribution of bullhead possibly driving that of *Gammarus*.

- The spatial separation of the two strongly interacting species in summer (with *Gammarus* using the margins as a predation 'refuge') is likely to contribute to population stability for both species. This feature of margins – the buffering of fish/invertebrate interactions - may also have important implications for other species and contribute to high diversity and abundance of invertebrates in chalk streams, particularly for groups vulnerable to fish predation, such as large-bodied beetles, bugs and molluscs.

- Continuous stretches of marginal vegetation such as *Apium* should be permitted to grow in summer to provide refugia for invertebrates from fish predation. Removal of vegetation from one bank may mitigate against a resulting increase in water depth (should this be deemed undesirable), but complete removal of marginal vegetation should be avoided.

5. Seasonal Changes in Marginal Habitats in the River Frome

5.1 Introduction

The bankside habitat is a dynamic zone where large seasonal changes in physical appearance occur. Optimal management of this area to balance conservation issues with those of flood-control and other physical disturbances requires basic information on the year round functional aspects of this habitat. It is crucial to know the relative importance of time of year, bank profile and riparian characteristics in determining the faunal assemblages that inhabit this marginal zone.

The main objectives of this study were:

- To carry out an **intensive survey** of seasonal variation in the faunal assemblages of bankside habitat.
- To examine the observed changes with respect to bank profiles and riparian vegetation
- To analyse and identify the stability and sensitivity to change of physically different bank types

The link between seasonal changes in bankside vegetation and associated faunal assemblages at the bank/water interface was examined between January 1998 and February 1999 along both banks of a 250m long stretch of the River Frome at East Stoke. Twenty-three sites, incorporating a wide range of flow-types, bank profiles and riparian characteristics were sampled every three weeks. This work is still in progress and the faunal data have not been analysed fully. The account below outlines the scope of the work and reports on progress based on samples collected in February, June and October.

5.2 Results and Discussion

Preliminary results show that the bankside zone is a highly dynamic environment with individual sites experiencing a very broad range of conditions. The early part of the year up to May is characterised by relatively little change in total abundance, with a few noted exceptions such as Simuliidae and *Brachycentrus subnubilus* which emerge early. Most "activity" would appear to take place in the second half of the year and October values for abundance and richness were generally the highest of the three months data examined.

An illustration of the variability of the environment is provided by the three sites situated on the iron pilings of the revetted section. The sites were close together and the substratum of each was exactly the same and covered by a dense growth of moss, so one might expect that they would support similar faunal densities. However the October abundances at site 23 were six times greater than at the other two sites, 21 and 22, mainly due to high abundances of oligochaetes, *Gammarus pulex* and Orthocladiinae larvae. An explanation will have to await further analysis but there may well be a random element following egg-laying and dispersal of first instar larvae. The direction of water currents carrying juveniles will fluctuate possibly resulting in settlement over a wide range of sites.

The data on the distribution of individual species will when all the analysis is complete provide information which can be used to optimize environmental management. If a specific bank type is proved to support particular species in high abundances then the river manager could avoid disturbance to this area. Similarly in order to maintain a high diversity or species richness along the bank, knowledge of the association of bank type with specific faunal assemblages is a necessary prerequisite.

This account is based on sample sets collected in February, June and October and summarises the state of the study so far. We hope to have information on life-histories of some of the main taxa and a complete record of velocity fluctuations over the whole year. It is too early to draw any firm conclusions from this work since, as pointed out above, the most active part of the year appears to be after June. However, there are indications that certain types of site are more favourable than others for maintaining both abundance and faunal richness and that a site which is suitable at one time of the year may be unsuitable at another for a given species. At the end of the study we hope to be able to quantify these findings in more detail.

6. Management Implications

6.1 Background

Stream and river management has, in the past, typically addressed problems such as flood relief, recreational conflicts and water quality. In addition, wildlife enhancement often comes some way down the list of reasons for river management, whose other considerations include improvement of land drainage, maintenance of conditions suitable for navigation and improved geomorphic stability (RSPB, NRA & RSNC, 1994). It is also the case that bankside vegetation in the form of tall herbs, scrub and trees, whilst having conservation value, is often secondary to the need for flood prevention and is considered as a hindrance to bank access. Marginal vegetation is nevertheless recognised as highly important for wildlife in general, and many specialised plants and animals occur only in the marginal zone. It is possible in this respect to denote merit or worth to almost every type of riparian margin in terms of particular organisms. However, this says nothing about the 'value' of one management regime in comparison to others, or of the consequences of changing the land-use along a particular stretch of river. This project has shown that different land-management and land-uses in the areas adjacent to streams can have considerable implications for the invertebrate fauna within those streams.

6.2 Management definitions

A point to note is the definition of the term 'grazed'. Drake (1995) refers to 'lightly cattle-trampled margins' and suggests that they act as a superior habitat to fenced margins. (Evidence of light trampling substantiated by the fact that only one of his sampling points was damaged by cattle). Most of the banksides sampled as 'grazed' for this project could arbitrarily then be defined as severely grazed, or overgrazed, as in most cases poaching sometimes running the entire length of field sections had occurred. Extensive foraging by dairy herds had left the banksides with mono-specific, cropped grass-swards, and direct pollution by the cows into the watercourses was evident. This project would not recommend that large lengths of watercourses be grazed in this fashion, but would instead place a contradictory emphasis on either much more lightly grazed regimes, or ungrazed and woodland banks as areas of preferred conservation.

Thus, disagreement over the value of grazed sections could arise as a result of misinterpreting the term 'grazed'. It is acknowledged that sections of river to which cattle are allowed access in moderate numbers may be useful to the river as a whole, as this would help provide a diverse linear mosaic of habitats which would maximise invertebrate taxonomic variety. Confusion with the other terms (ungrazed and woodland) are less likely. Where fencing has been erected, floristic successional changes are much more prone to following a set-pattern. Anthropogenic influences in such sections are generally very low and thus the basic features of ungrazed and wooded areas are similar from site to site.

6.3 The impact of riparian management

The study has shown that the nature of the terrestrial bankside environment clearly influenced the abundance of some aquatic invertebrate families. Invertebrate diversity was generally greater in ungrazed stretches with abundant marginal vegetation. Heavy cattle-grazing in summer tramples both invertebrates and habitat, and reduces the sites available for oviposition. Despite this however, some animals were more abundant in grazed reaches, particularly bugs, snails, leeches and small fish.

Comparing woodland to ungrazed stretches, most invertebrate groups were less abundant in woodland, and the overall abundance was generally lower in woodland habitats. The lack of *Ranunculus* in woodland will depress abundance, since high numbers of *Simulium* spp. and baetid mayflies favour this habitat. However, some taxa were much more abundant in woodland than in the other regimes, particularly the caddis larva *Agapetus fuscipes* and elmid riffle beetles. Preliminary observations and discussions suggest that many if not all aquatic beetles pupate on the bank. They are unlikely to favour the unstable, silty, excessively wet or desiccated soils that are typical of the margins of streams where cattle graze. Well-structured, stable, porous soils with firm root structure are likely to provide beetles with a stable, humid and undisturbed site for pupation. These types of habitats are more likely to be found on banks with a well-developed vegetation structure, including trees. Determination of beetle pupation sites represents an important area of future investigation. The high numbers of adult insects found in woodland terrestrial habitats indicates a different aspect of the woodland environment which may be vital for many invertebrates – that of oviposition.

In the light of this information, best management of bankside habitats would seem to be to discourage heavy grazing along the banks of streams and rivers. This would prove advantageous to most invertebrate taxa in the stream and disadvantageous to only a very few. In reality however, fenced and wooded areas interspersed with stretches of lightly-grazed field would be acceptable and even recommended in order to achieve maximum diversity of invertebrate and fish populations.

6.4 Adult (emergent) invertebrates & woodland

Patches of woodland were found to be of definite benefit to streams, even though these habitats were generally less productive. Reduced light levels under the tree canopies decreases both the productivity of macrophytes and algae, and hence the availability of refuge-areas and food for many invertebrates. Beneficially though, wooded areas can stabilise and strengthen stream banks, moderate stream temperatures, reduce sediment inputs, and provide important sources of organic matter (Osbourne & Kovacic, 1993).

Woodland areas may also provide a favoured habitat for many adult insects that lay their eggs in or near woodland, as was found to be the case with *Agapetus fuscipes*. The presence of adults in woodlands indicates that this is a favoured habitat, without which they would presumably suffer greater mortality or have lower reproductive success. It is unlikely though that many (or indeed any) adults spend their time exclusively in this environment, but rather use it, for example, as shelter when conditions in other habitats become less than favourable. It is likely therefore that part of the value of woodland to adult invertebrates is in its proximity to different neighbouring habitats. Thus it could be concluded that best management practice would encourage a patchwork of distinct riparian regimes, with blocks of woodland (perhaps no greater than 30 or 40 metres in length) adjacent to open areas, with a clear interface between the two. This diversity of habitat would cater for the habitat preferences and behavioural patterns in the great majority of emergent adults.

Thus, understanding how vegetation 'works' with respect to invertebrate life-histories can enable managers to prescribe best practices for banksides. In practice this is reasonably simple to achieve, compared to more intractable problems of abstraction or flow management.

Simply fencing streams from stock will ameliorate streams for invertebrates and for fish, such as trout. Few invertebrates would suffer from a policy of fencing, although poached grazed margins may support semi-aquatic species not studied during this investigation. Where streams exceed a certain size, flood risk would perhaps need to be assessed to ensure that excessive vegetation on the banks did not impede floodwaters. Trees, however, will eventually shade out marginal vegetation, producing a 'cleaner' more open stream channel.

6.5 The function of aquatic margins

Vegetated margins are functionally extremely important for chalk stream invertebrates. Not only are they habitats of high biodiversity, they are also vital for the reproduction and recruitment of invertebrates, and are likely to be important refugia for invertebrates during spates and from fish.

There appeared to be little functional difference for invertebrates between different types of vegetated margin. One important finding is that margins consisting of the trailing stems and leaves of terrestrial vegetation can be as valuable a habitat for most invertebrates as semi-emergent aquatic vegetation. Dead bankside vegetation, left trailing in the water from the previous year, can support diverse and abundant invertebrate assemblages. It is also persistent. This overhanging vegetation is particularly important in reaches where it is dominant due to the rarity of aquatic macrophytes, such as in woodlands.

Trailing stems may function as a direct pathway from the water to the land and vice versa, and thus be a particularly valuable habitat for those species that travel between the two 'biotopes' at some point of their lives. Such vegetation is also able to ameliorate the effects of high winter flow conditions for invertebrates by providing areas of structural stability and reduced water velocities. Additionally, this vegetation may well confer substantial protection from scour erosion upon the bank itself, especially where woody stems are involved (Morgan *et al.*, 1999). Its clearance may thus be potentially damaging to bank structure, as well as invertebrate biodiversity. In addition, the benefit of leaving such vegetation has important resource-saving implications for bankside managers, particularly on smaller streams where banks and margins are managed needlessly via routine mowing, annual clearance programs and weed control.

Marginal habitat would therefore appear to function as well with dead vegetation as with live. It is thus likely that the presence/absence of marginal vegetation may be more important than its extent. The caddis and beetles, in particular, were as abundant in the sparse woodland margins as they were in the wider grazed and ungrazed margins. This may be due to the fact that the margins 'function' is provided by only a small quantity of that habitat, for example that needed for oviposition or refuge from flow.

Marginal areas are also likely to provide a generally discrete area for predation avoidance. Work with *Gammarus* and Bullhead demonstrated the value of *Apium* as an invertebrate refuge, a feature which is highly likely to stabilise population fluctuations for both sets of animals by reducing the invertebrate vulnerability. Therefore, wetted marginal vegetation should be seen as an essential component of all watercourses, in the form of fresh emergent macrophytes such as *Apium* and/or 'fallen-in' riparian plants like dead reeds and *Oenanthe*. The extent of this vegetation need not reach such levels where flood defence measures are jeopardised, but neither should these latter considerations be allowed to prescribe complete removal of marginal vegetation, especially at vulnerable times of year like winter.

This study, and others (Armitage & Cannan, 1998), has demonstrated the high importance of stream margins relative to the mid-channel habitats of coarse gravel and *Ranunculus* beds. Chalk-stream conservation management should perhaps focus on marginal areas as centres of biodiversity, rarity and reproduction. Projects that aim to improve mid-channel substrate at the expense of well-developed marginal vegetation may reduce, rather than improve, the conservation value of the stretch. Creating conditions under which marginal vegetation can flourish should thus assume significant importance in stream restoration projects.

6.6 Vertebrate wildlife

Included within the project's original proposal was the discretionary examination of the effect that various bankside management regimes have upon mammals, bird-life, and fish. The main body of work was however concentrated on aquatic invertebrates - larger river fish, riverine mammals and associated birds were not studied, there is however a wealth of information on these subjects (e.g. RSPB, NRA & RSNC, 1994).

Mammals are generally sensitive in their requirements, not only in terms of suitable habitat but also with regard to disturbance and pollution. In addition, the large areas of 'quality' riverbank required to attract animals such as otters means management must often be species-specific. However, a common requirement in mammal habitat management is the necessity of bankside vegetation. Although water shrews and voles prefer certain bank profiles and flow regimes, the presence of tall herbs, thickets and scrub etc. is essential to provide cover, and thus protection from predation. Particular species of marginal trees also appear highly important – the root systems of oak, ash and sycamore spread horizontally, rather than downwards in a mesh as with alder and some willows.

For many of the birds that use rivers as breeding and feeding grounds, marginal vegetation in the form of aquatic macrophytes, terrestrial herbs, scrub and trees is a fundamental component – providing cover, food (insects and seeds etc.) and nesting sites. Although limited livestock access along certain reaches can produce muddy margins beneficial for wading birds, removal of woodland, bankside scrub and overwintered vegetation through grazing or agricultural cultivation will dramatically reduce the suitability of a river stretch for many bird species.

Fish requirements are often summarised in terms of water quality, hydraulics and substrate for spawning. From personal observation and recent research by the Game Conservancy Trust, however, it is clear that trout and salmon are considerably more abundant in ungrazed (fenced) sections of stream than in adjacent grazed areas. Pinder (1997) states that cutting of marginal macrophytes should be avoided to provide shelter [for fish] from high current velocities, spawning habitat and enhanced feeding conditions for young fish generally. Trees are also important bankside features for fish, providing flow diversity where branches or trees fall in, invertebrate input and shade. Terrestrial input of invertebrates from trees alone has been estimated to possibly exceed within-stream production of benthic invertebrates at certain times of year (Mason & Macdonald, 1982).

Bats have also received attention from river managers. Requirements for Daubenton's Bat have been described in detail with respect to riparian vegetation: 'Riverside woodland corridors and woodland areas close to rivers should be maintained or created to encourage a diversity of insect species' (British Wildlife, Vol.10, No.1). The necessity for long stretches of bankside vegetation appears common for the species associated with watercourses, mainly because vegetation of this nature yields an abundance of diverse insect prey.

6.7 Links with River Habitat Survey (RHS)

The RHS is able to provide baseline data on the current state of over 5,600 river and stream sites across the UK. Besides reporting specific statistics on riverine features it is capable of identifying areas (e.g. individual sites, catchments and regions) of particular habitat value for wildlife. Rare features within a region, or rare combinations of features for a particular river type can be identified.

In this respect RHS is able to highlight and monitor areas requiring conservation management, by providing a huge range of detail on the physical aspects of river corridors, including riparian (bankside) land-use. RHS information can thus be used as a benchmark for management policy, perhaps indicating areas where rehabilitation would, or would not, enhance an existing combination of characteristics and allow the potential introduction of absent species. Detailed ecological information on marginal biota, which identifies quantitative relationships between 'animal and habitat', would thus provide the necessary link between RHS and instream surveys.

In addition, RHS would doubtless prove to be a powerful tool in locating regions of the country where further assessment of the importance of bankside and marginal vegetation should be carried out – for example, locations with many impacted watercourses such as East Anglia.

6.8 Non chalk-stream systems

In general terms, the conclusions relating to the value of certain margins and bankside management regimes are relevant to all watercourses. However, greater national coverage and assessment of the value of riparian and marginal vegetation countrywide would be a logical and practical step forward - clay catchments, upland areas, plus sites which have been heavily impacted and/or degraded are examples of systems which might be considered. Additionally, there is a need to extend this work to larger watercourses (width >10m) where the effect of riparian changes, and the amount of marginal vegetation, may have different influences on the aquatic invertebrate fauna. In larger rivers, compared to small streams, areas of marginal vegetation may be more important for invertebrates relative to benthic habitats. Deep rivers can prevent sufficient sunlight penetrating to the mid-channel substrata, and they therefore often lack aquatic macrophytes except at the margins.

Permeable geology and aquifer-fed water supplies tend to ensure that catastrophic (*sensu* Borchardt, 1993) spates do not occur in chalk-streams. However, many small streams running over largely impermeable geology record spate-flows in synchrony with rainfalls. This can hinder or prevent marginal vegetation and invertebrate communities establishing themselves to any great extent, and sweep out emergent vegetation that has grown - leading to a situation where small channels act primarily as water-conduits rather than wildlife corridors. The value of riparian vegetation management thus becomes subordinate to the flow characteristics, which are dictated by the underlying catchment geology. The feasibility of directed bankside management on such streams again requires assessment.

7. Conclusions and Recommendations

It is clear that good management of stream and river banksides is a major contributing factor in the achievement of a diverse and abundant aquatic invertebrate community. This work on chalk-streams has highlighted the fundamental nature of aquatic marginal vegetation, and described the importance of different bankside environments. Further recognition of the importance of these areas would aid considerably in meeting specific Environment Agency (EA) goals related to rivers, such as those laid out in EA Functional Action Plans and the UK Biodiversity Action Plan, for example:

- Conservation and enhancement of biodiversity
- Improvement of river landscapes
- Promotion of wildlife habitats
- Provision of conservation benefits through natural processes

On smaller rivers and streams in particular where severe flooding is rare (and where past practices to alleviate flood risk have led to degraded bankside habitat and vegetation structure) encouraging botanical communities to re-establish would enable the statutory obligations listed above to be met whilst maintaining awareness of potentially conflicting interests. The monitoring of invertebrate community changes in response to a realistic bankside management program that satisfies both Conservation and Flood Defence interests and Action Plan aims would seem an obvious future study.

In degraded river systems, bankside vegetation (both aquatic and terrestrial) is likely to be of even greater importance. Chalk streams support exceedingly rich and diverse communities of plants and animals (Mainstone *et al.*, 1998), unique recognition of which, in terms of rivers, has been denoted by preparation of Biodiversity (Habitat) Action Plans. Yet even so, habitats can be prioritised, and the presence of a natural riparian and marginal environment has emerged as paramount. In less productive watercourses, and those that have been insensitively managed in the past, such physical habitat is often largely absent. This is likely to render any remaining areas of bankside/marginal vegetation of vital significance. In order that objectives concerning the conservation of natural resources, animals and plants etc. can be met, this work would urge that such areas are -

- Monitored, to assess their importance with regard to associated invertebrate communities
- Protected from detrimental practices or events
- Encouraged, by sympathetic management

The project findings relate to the streams and rivers on which the work was carried out, and practical assessment of their applicability, at this stage, to other types of watercourse is required. Ecologically damaging practices such as bank-toe mowing, severe grazing and annual macrophyte clearance have been similarly recognised by wider studies (Ward *et al.*, 1998) as detrimental. It is therefore expected that best environmental practice for river habitat protection and restoration, as revealed by this study, would be similar nation-wide. Accordingly, it is suggested that attention be focused on the following Best Practice Guidelines:

- **Reduction of severe bankside damage by cattle, thereby**
  - improving bank integrity, with morphological and ecological implications
  - producing intermittent reaches where light-grazing leads to characteristic poached margins, which are beneficial to snails, bugs and fly-larvae

- **Enhancement of the instream marginal environment**
  - by encouraging a heterogeneous aquatic macrophyte community
  - by allowing dead or senescent trailing ('fallen-in') terrestrial vegetation to overwinter, particularly where other refugia cover is absent

- **Encouraging the return of marginal vegetation where it is absent**
  - by reducing cattle access, by restructuring steep banks to a more favourable profile and/or by minimising unnecessary human disturbance e.g. frequent mowing, thus creating structural diversity of water-edge habitat of benefit to fish and invertebrates.

- **The promotion of 'complex' riparian habitat**
  - creating floristically diverse areas of mixed structure and height etc. advantageous to adult invertebrates, birds and riverine animals such as voles
  - allowing patches of scrub and woodland to develop for similar faunal benefit

This project has determined recommendations for bankside management (for invertebrates) based on sound scientific investigation. It has also revealed the amount of research still required, at the specific level of topics such as the location of beetle pupation sites, to assessment of the 'critical amount' of particular vegetation types that are required to sustain an ecologically dynamic riparian system. In addition, further work in alternative catchment areas is essential to determine, for example, whether in-situ management practices for plants, birds and fish etc. concur with invertebrate requirements, and to assess the importance of 'habitat-islands' in watercourses with impoverished bankside vegetation. An understanding of the functional ecology of riparian margins would seem to be an essential ingredient in the link between invertebrate and bankside management. It is hoped that the main findings, summarised below, will contribute to decision-making processes and stimulate further investigation and research.

- *Areas of wetted marginal vegetation are extremely important components of the riverine environment in all chalk-stream riparian management regimes in terms of aquatic invertebrate biodiversity, abundance, rare species and reproduction.*

- *The emergent adult life-stage of many aquatic invertebrates may require as much attention as the larval stage. Best management should aim at maximising the variety of bankside vegetation structure, and recognise the significance of ungrazed and wooded sections.*

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