AN ABSTRACT OF THE THESIS OF

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N. H. Anderson

The importance of active-entry drift at a community-scale was evaluated by testing whether the placement of wood in streams affected the abundance of *Baetis* spp. mayflies in drift. *Baetis* were chosen because they use drift as a behavioral strategy and are important in salmonid diets. The density of woody debris was manipulated in a divided concrete diversion channel by building a debris jam on one side and leaving the other side free flowing. Although the drift density (as measured by *Baetis*/unit volume) was almost equal between the two channels, more *Baetis* were retained in the channel with woody debris due to the slower flow rate. While possibly an important behavioral strategy, active-entry by the insects does not appear to be a factor in community-scale macroinvertebrate drift dynamics. The diversion channel results were tested against samples from Badger, Hoffman and Trout Creeks in the Ochoco National Forest. The results of these field tests were inconclusive because of a depression in the number of *Baetis* in the system apparently as a result of the presence of grazing

cattle. *Baetis* exhibited a complex relationship to wood. Nonmetric Multidimensional Scaling (NMS) ordinations of samples taken from wood and from gravel benthos showed little difference in *Baetis* response to substrate type. The possible changes in macroinvertebrate assemblages resulting from the presence of cattle in the stream were explored using survey data from Badger Creek as well as benthic samples taken from two comparable reaches of stream, one with cattle and one without. Ordinations of these data indicate dramatic differences in community composition which suggest that the cattle have a greater effect on macroinvertebrate drift than does the presence or absence of wood in the system.

Drift, Wood, and Grazing Cattle:
Macroinvertebrates in Managed Streams

by

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APPROVED:

Redacted for Privacy

Major Professor, representing Entomology

Redacted for Privacy

Chair of Department of Entomology

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Dean of Graduate School

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Chapter 1
Introduction

The theoretical ideal of the Scientific Method describes a linear sequence of questions asked and answered which lead inevitably from one to the next. In contrast, the path of questions which drove this study followed a convoluted trail marked by real-world disruptions. It began with my attempt to carve an answerable question out of macroinvertebrate drift response to wood in streams and ended with the use of a multivariate analysis of survey data to assess the possible effects of cattle grazing on the macroinvertebrate community of Badger Creek.

In the spring of 1994 I received a small grant from the Ochoco National Forest to survey the macroinvertebrates of Badger Creek. This entailed monthly sampling of the creek using a Surber sampler, as well as drift samples and beating of riparian vegetation.

I became interested in a phenomena which I call active-entry behavioral drift. This behavior has been described for certain mayflies which appear to drift/swim in order to find forage or escape predation. This has been reported in a wide range of organism-scale studies but has not been addressed on a population- or community-scale. I was interested in discovering to what extent this use of drift as transportation affects overall drift densities for these taxa. I hypothesized that if there was a community-scale effect then the drift densities would vary between areas with different habitat features.

One habitat difference that seemed ubiquitous, likely to be affecting these organisms, and easily manipulated was coarse woody debris in the stream channel. I therefore designed a study to examine population-level response of an active-entry drifter, larval *Baetis* spp. mayflies, to the presence or absence of wood in streams.

My first goal was to see if there was an effect on the drift densities of the mayflies within an artificial system, where the primary difference between control and treatment channels was the presence of wood. Although I wanted the system to be as free from confounding factors as possible, I was determined to retain as much connection to a real system as possible. In order to do this I reclaimed a diversion channel on Oak Creek in MacDonald-Dunn Forest, Corvallis, OR. This entailed clearing blackberry bushes, cleaning debris out of the channel and rebuilding the diversion dam on Oak Creek.

I wanted to sample the drift in this limited system and then check my results against field samples which could be taken in the Ochoco National Forest as part of the Badger Creek survey. However, when I traveled to Badger Creek, the path of my study took a sharp turn. On the same day that I arrived at Badger to start a week-long regime of drift sampling approximately 150 cattle also arrived to start a week-long regime of intensive grazing. At its widest point the valley through which Badger runs is no more than 1/4 mile wide. Because of this, and the reported warm-weather preference of cattle for grazing in riparian zones (Larsen, 1989), the cattle spent a great deal of time in the stream.

The number of *Baetis* in drift samples during this time was extremely low. I hypothesized a connection between this paucity of Baetis and the presence of the cattle. However, when I went to the literature I found very little reference to the effects of cattle on stream insects. I have therefore used as much information as I had available, from sampling done later in July and also from the eight month survey data which I collected for the Forest Service, to ascertain if there was a link between increased grazing pressure and decreased *Baetis* abundance or a change in overall stream macroinvertebrate community composition.

This thesis is therefore divided into two parts. The first is my exploration and analysis of the input of active-entry drift to stream drift densities. For this I have relied on drift samples taken in the Oak Creek diversion channel, in Badger and Hoffman (a tributary of Badger) Creeks as well as Trout Creek, also in the Ochoco National Forest, from which cattle have been excluded for the past two years. In the second part I took a number of different approaches to assessing grazing pressure and macroinvertebrate communities. These approaches include reanalysis of previously published data and a multivariate analysis of the macroinvertebrate community in Badger Creek, from three months before the arrival of the cattle to three months after they had gone. I also took samples from an area on Badger Creek where cattle were currently grazing and an area where there had been no cattle for a month in order to assess community differences between the two areas.

The prevalence of anthropogenic disturbance is perhaps the one unifying characteristic of managed streams. Theoretically, management-based perturbations should be more predictable than natural disturbances, but in practice, agencies tend to function from a Biblical paradigm in which one hand knows not what the other has planned. Within this framework of reactive rather than proactive management, the plasticity required throughout this study seems appropriate.

The logical, linear march from one question to the next may work well in laboratory studies where the researcher is able to exert total control over her experimental environment. A field scientist on the other hand, must be adaptable, even opportunistic. While the arrival of cattle at Badger Creek confounded my original research question, it also opened up an entirely different field of inquiry, the effect of grazing cattle on macroinvertebrate community composition.

Chapter 2
Active-entry drift response of *Baetis spp* larvae to wood in streams

Introduction and Literature Review

Drift

Macroinvertebrate drift, or the downstream flow of insects and other arthropods, was observed and reported by P. R. Needham (1928). Since then it has been extensively studied (Muller 1954, Elliott 1967, Waters 1972). Drift has been classified into three categories: constant, catastrophic and behavioral (Waters 1965). Classification is based on the method by which drifting insects entered the water column.

Constant drift is a function of the continual current to which aquatic insects are subjected. Although stream organisms are adapted to some level of current, when they move around they sometimes are dislodged and become a component of the constant drift. There is evidence that the constant drift contains a large proportion of animals which are infested with parasites and pathogens (Wilzbach and Cummins 1989) or missing limbs (Williams and Levens 1988). In one of the classic studies, Bishop and Hynes (1969) found that almost all benthic species were represented in the drift, but the benthos/drift proportions varied between different taxa.

Catastrophic drift is related to elevated flow events that dislodge benthic invertebrates and transport them downstream. Drift density (insects per liter of flow) increases dramatically during high flow (Poff and Ward 1991), and drift density appears to be greatest in areas with low spatial heterogeneity (Scarsbrook and Townsend 1993). Often the insects enter drift when their habitat (e.g. a leaf pack or stick of wood) is displaced (Anderson and Lehmkuhl 1968). In flume experiments, Borchardt (1993) found that woody debris reduced the number of organisms lost to catastrophic drift. Retention of drifting macroinvertebrates was correlated with the filtering effect of the dam, as measured by the quantity of organic matter retained.

Abiotic factors often influence the quantity of drifting animals. Behavioral drift increases at night (Waters 1962), decreases with amount of visible light (Anderson 1966) and also increases with lowered flows (Minshall and Winger 1968). The slackening current at the beginning of pools often results in organisms being lost from drift. They may encounter lower dissolved oxygen levels and attempt to swim up into the water column. Their success may depend on the length of the pool (Kovalak 1978) and their ability to swim (Martin and Knight 1989). Dead organisms drift through pools, but if they drop to the bottom they tend to stay there. Live animals are more likely to either swim/drift or crawl out, implying an active behavioral response to the change in water velocity (Walton 1978).

Brittain and Eikeland (1988) revised Water's definition of behavioral drift to include two distinct subgroups. The first encompasses the original concept of animals drifting as an indirect result of increased activity. The second subcategory is termed "active drift" which the authors define as the drift of animals which "actively enter the water column, for example to escape from a predator" (Brittain and Eikeland 1988, p.78).

Although a number of hypotheses regarding these various components of drift have been studied, questions regarding drift response to habitat or stream restoration have rarely been addressed. This study set out to explore the possible effect on swimming species of the presence of woody debris, using their response to stream restoration projects as an indicator of the magnitude of the "active-entry" drift component.

Active-entry drift

There is no practical way to ascertain the method by which an insect captured in a drift net entered drift. Therefore, to estimate active-entry drift it was crucial to choose a study organism for which this type of behavior is well documented. This estimate was made by measuring the entire drift density of a population of known active-entry drift organisms and assuming that a relatively consistent proportion of that drift density could be attributed to active-entry. Comparisons were then be made to organisms, such as terrestrial insects like ants which, because they do not normally inhabit the stream, could only have entered drift by accident. Although the pitfalls of generalizing behavior at the generic level were acknowledged, the response of larvae of the mayfly genus, *Baetis*, was used as the test of the community scale dynamics of active-entry drift.

In a lab study *Baetis vagans* proved to be an active and continual swimmer in standing water (Corkum 1978). This was consistent with earlier field observations of *Baetis rhodani* (Elliott 1968). Wiley and Kohler (1980) reported that several species of mayflies swam up into the water column when dissolved oxygen fell below a species-specific threshold. *Baetis tricaudatus* exhibited the highest oxygen threshold. Ciborowski (1983) observed that when released in midchannel *Baetis tricaudatus* larvae exhibit a tendency toward lateral dispersal beyond what would be expected if they passively settled out of the current. In an artificial stream setting, Kohler (1985) demonstrated a strong relationship between foraging behavior and active entry into the water column for *Baetis* spp. larvae which actively abandoned habitats when food became scarce.

One of the most fruitful avenues for exploring active-entry drift has been examining predator-prey interactions (Peckarsky 1980, Walton 1980, Malmqvist and Sjostrom 1987, Malmqvist 1992). A recent study of drifting response of *Baetis tricaudatus* found that in the presence of a predator, the likelihood of drifting increased (Scrimgeour et al 1994). From all of these studies one constant has emerged, *Baetis* larvae appear to actively enter stream drift.

In order to assess the importance of this response to population-scale dynamics,the hypothesis was tested that there is a difference in the drift response of *Baetis* between channels with woody debris dams and channels without because the insects will respond to the difference in habitat. This was first done in an artificial system in which the primary variable was presence or absence of wood. The results were then tested against field samples from naturally flowing streams. The artificial system was developed in a diversion channel off Oak Creek in the MacDonald Dunn Forest. Field samples were taken from Badger Creek, south of Mitchell, Oregon, in the Ochoco National Forest.

Study Sites

Oak Creek

The manipulative components of this study were done in a concrete diversion channel adjacent to Oak Creek, MacDonald Forest, approximately 10 km. northwest of Corvallis, Oregon. Oak Creek is a third-order stream with extensive riparian vegetation which drains the eastern foothills of the Oregon Coast Range.

The diversion channel is 90 cm wide with an approximate gradient of 2% and connects with the creek at either end (Fig. 2.1). The sides are concrete with a certain amount of moss overgrowth and the bottom is gravel. A temporary dam was used to partially block the creek and flood the channel. The area surrounding the channel is fenced to keep out large animals.

The natural composition of macroinvertebrate drift was retained by diverting stream-flow from Oak Creek into the channel. The concrete sides and gravel substrate of the artificial channel reduced the number of variables affecting *Baetis* drift densities. It is important to note, however, that research in artificial streams has been compared to that done at the laboratory bench, implying that while the results should not be dismissed out of hand, they must be validated in the field in order to draw conclusions with a wider application than the laboratory setting (McCormick

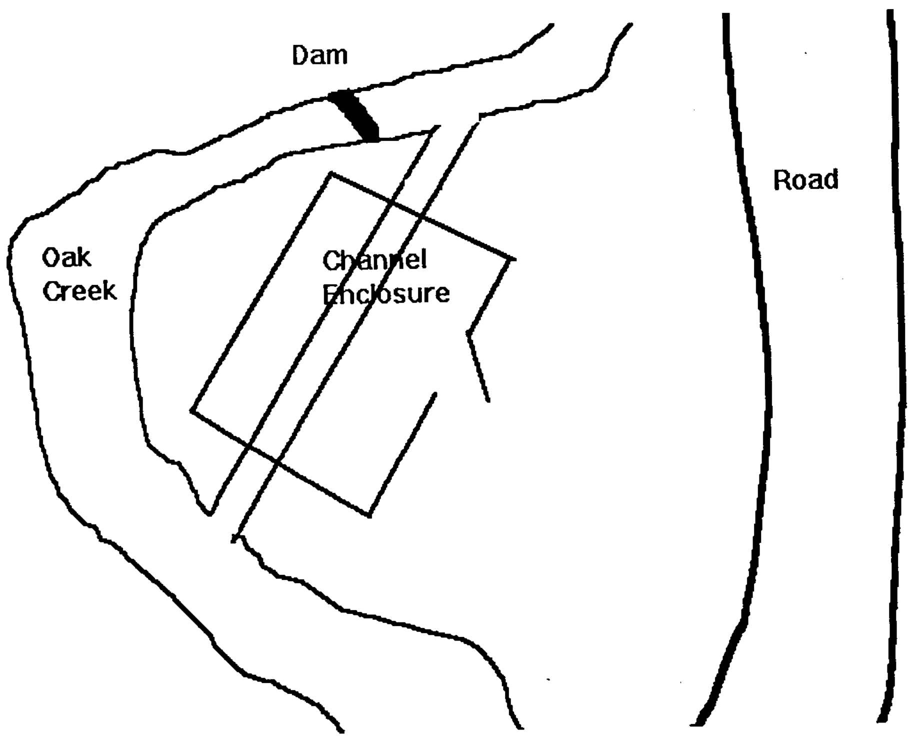

Fig. 2.1 Diagram of the Oak Creek diversion channel.

1993). And, of course, the availability of a single concrete channel and the use of temporal replicates from this one treatment must necessarily limit the scope of inference drawn from this study.

Badger and Hoffman Creeks

Badger Creek is a third-order creek in the Ochoco National Forest approximately 12 km south of Mitchell, Wheeler County, Oregon. The headwaters are within Forest Service boundaries and are subject to rotational cattle grazing. The lower reaches are privately owned and heavily grazed. Because of this grazing activity, the stream has very little riparian cover and, for the most part, flows though meadows. The exception to this is a very constrained reach, approximately one mile long, between sites 1 and 2 of this study, that had substantial deciduous riparian growth.

Forest Service personnel initiated a stream restoration project along Badger Creek in 1991 which involved placing wood in some sections of the stream. Logs were placed so that they spanned the width of the creek. Debris jams have formed around these logs.

Drift was sampled at three pairs of sites along Badger Creek (Fig. 2.2). Each pair was composed of a "treatment" site with a debris jam and a "control" site with no wood for at least 30 meters upstream. The pair were separated by enough distance that they functioned as separate entities with separate drifting assemblages. In each case the control site was upstream of the treatment site because the danger of a site without wood somehow confounding the data collected from a site with wood was far less than the reverse. It was hoped this would minimize any effect of misjudgment by insuring that the more benign site lay upstream.

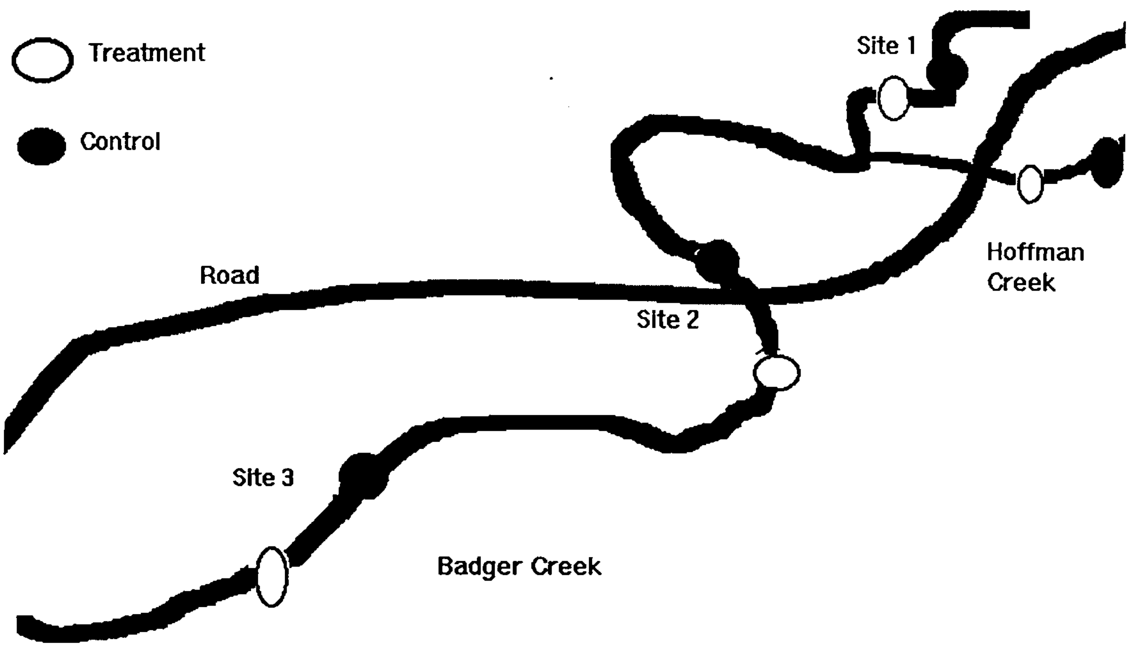

Fig. 2.2 Diagram of the control and treatment sites on Badger and Hoffman Creeks, Ochoco National Forest.

Site selection was arbitrary but without preconceived bias. The three site pairs were separated from each other by a minimum of 100 meters. One pair of sites on Hoffman Creek was also chosen. This is a small, somewhat more pristine, tributary of Badger Creek which has naturally occurring debris jams. Because the drift nets were to be recovered after sundown the safety of researchers traveling over uneven ground in the dark was a factor in site selection.

Materials and Methods

Oak Creek diversion channel

The channel had not been used for several years and the first task was to cut down the abundant vegetation and clean the channel of debris. The channel was divided in two by placing 4 1′ x 8′ plywood sheets down the center (Fig. 2.3). The resulting "streams" were 44 cm wide. Next the partial dam on Oak Creek was rebuilt to divert water into the channel. In this way a 5-9 cm depth of flow was provided in the diversion channel. The dam built on April 6, 1994 lasted only a week. On May 1 the dam was reconstructed so that it lasted through the rest of the study.

Food coloring was added above the diversion channel to monitor flow pattern along both sides of the central barrier. While equal amounts of dyed water appeared to flow through both channels, the colored water entered the right channel first. This may have indicated some slight discrepancy between the channels which was controlled by sequential use of both channel halves as treatment and control. Once the dam was in place and the channel flooded it was left undisturbed for two weeks during which colonization occurred. During that time periodic drift samples were taken using a block net to filter incoming drift and sampling drift at the downstream end of both channels. The difference between what was drifting through the channels and what had become resident was gauged by comparing catches in the two nets. Nets were set at 7 pm and picked up at 7 am the next day. Initially the blocked channel primarily had terrestrial insects in the drift but gradually the drift samples included more and more of an aquatic component. After 13 days the insects collected were primarily aquatic.

The nets used throughout this study were 44 cm wide and 28 cm high, made with a 333 μm mesh (Fig. 2.4), and constructed to collect the total flow coming out of these channels. Concrete blocks with plastic nipples embedded in them were used to hold stakes securing the nets. The blocks were buried so that the tops were level with the substrate. Therefore, setting and removing nets did not disturb the substrate.

Fig. 2.3 Divided Oak Creek diversion channel.

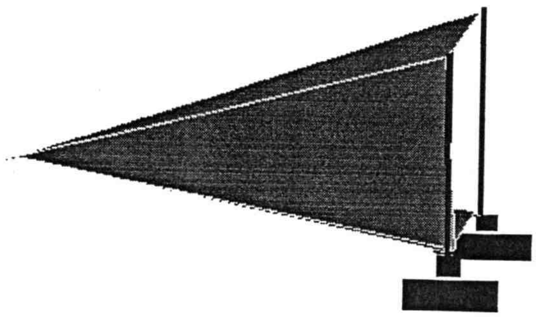

Fig. 2.4 Diagram of the nets used in the Oak Creek diversion channel.

Once the channel was substantially colonized by aquatic organisms, a 3-night trial was initiated to ensure that equal amounts of drift were passing through both untreated channels. The drift entering the channels was also sampled by placing nets at the top of both channels. Table 1.1 gives the results of these initial measurements. Although the data are slightly skewed, with more *Baetis* appearing to drift out of the right channel, this difference was not statistically significant ($p \le 0.33$). The mean number of drifting *Baetis* coming out of the left channel was estimated to be between 41 fewer and 17 more than that of the right channel (95% confidence interval).

At the upper nets 29 *Baetis* entered the right side of the channel during the same time period that 21 *Baetis* entered the left. Again, the sequential use of first one and then the other channel side as treatment units was used to control differences between the drift density through the two channels.

Table 2.1 Numbers of *Baetis* collected in 3 hour drift net catches during channel tests.

Date	# *Baetis*: left channel	# *Baetis*: right channel
5/23	17	19
5/24	30	25
5/25	9	47

Because the initial overnight sampling had captured a large amount of organic material, making the samples overwhelming to process, subsequent sampling was limited to 3-hour intervals. The strong diel periodicity of drift made it logical to time the sampling to include sunset.

The first "debris jam" in the right channel (Fig. 2.5) was built using wood from an actual debris jam just downstream of the channel outlet. The wood was washed to minimize transport of organisms into the system. The wood was also measured, individual pieces photographed and relative amount of microbial conditioning noted. In this way the original debris jam could be replicated in the left channel.

The jam was constructed approximately 70 cm upstream of the net holders. One large, curved stick was wedged between the channel divider and the concrete wall. This piece formed a brace against which the other pieces were placed to form a lattice of wood which spanned the small channel.

A spate washed out the debris jam after six days. Much of the wood was recovered, including the large curved stick which was used to construct a new debris jam, this time in the left channel. The earlier structure was duplicated as closely as possible. Where the original wood was not available it was replaced with a stick of equivalent size, length and age. The second jam was also 70 cm upstream of the net holders.

The velocity of the water as it passed through the nets was substantially slower in the blocked channel. In order to estimate the difference young blackberry leaves were dropped into the channel and their speed clocked with a stop watch. Depth measurements were also taken to estimate of the amount of water flowing through each net.

Fig. 2.5 The debris jam built in right channel of the Oak Creek diversion channel.

Liquid food coloring was used to periodically test for leakage between the channels. There was a consistent seepage which flowed through the gravel, under the channel divider and penetrated approximately 10 cm into the non-blocked channel. The amount of seepage was comparable between the left and right channel dams.

Drift material was washed from the nets into a pan using a backpack sprayer. Excess water was removed by filtering through a 333 μm mesh screen. The material was preserved in 95% ethyl alcohol and taken back to the lab for further processing.

Badger and Hoffman Creeks

The drift was collected from the four pairs of sites for five consecutive nights between June 18 and 22, 1994. To minimize the repeated disturbance of the sites, nets were constructed which could be set in the stream with minimal effect on the substrate (Fig. 2.6). These nets were set in place between 7:15 and 7:45 and picked up 3 hours later. Samples were processed in the same manner as described for those taken from the Oak Creek diversion channel. Depth measurements were taken every night and water velocity was measured on June 21.

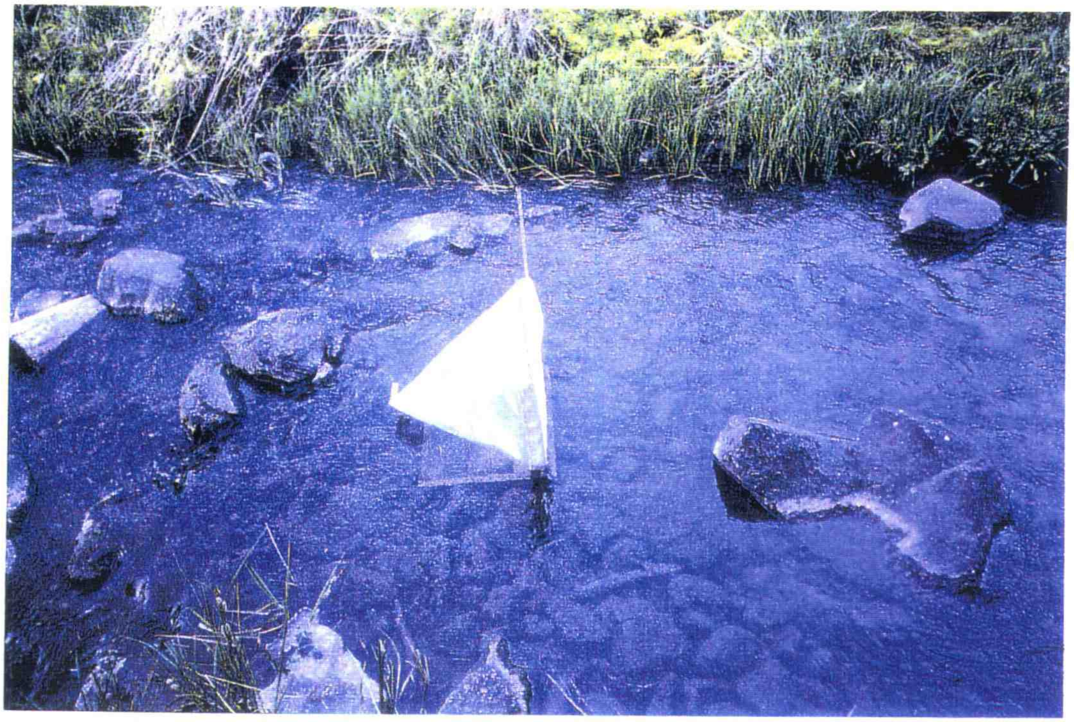

Fig. 2.6 Nets used for field sampling of drift.

As one component of the Badger Creek macroinvertebrate survey conducted for the Ochoco National Forest, "washed wood samples" were taken. Five samples were taken using of a bucket of water in which well conditioned wood was scrubbed to remove the resident macroinvertebrates. The water was then filtered through a fine mesh and the resulting organic matter preserved in 95% ethyl alcohol. These samples were paired for comparison with randomly chosen benthic samples (also from the Badger Creek survey).

Trout Creek

In collaboration with a fish-movement study conducted by Christine Hirsch, Department of Fish and Wildlife, Oregon State University, a pair of sites on Trout Creek was sampled in the same manner as the drift-sample sites on Badger and Hoffman Creeks. In this case the sites were both outflows of pools. In one of the sites a large rootwad spanned the outflow, creating a debris jam. The other site lacked large woody debris.

Taxonomy

Three sets of samples were used from each collection point. From these the number of *Baetis spp.* were counted. The current taxonomic revision of Baetidae (McCafferty and Waltz 1990) leaves *B. bicaudatus* as the only species of *Baetis* larva that can be positively identified. Although a few *B. bicaudatus* specimens were noted at Badger and Hoffman Creeks, they comprised less than 10% of the total *Baetis* examined and were not treated separately. No *B. bicaudatus* were found in the Oak Creek samples. In this paper, for convenience, all species of the genus are referred to as *Baetis*. Other insects were identified as either aquatic or terrestrial (adult mayflies, stoneflies and caddisflies were included as terrestrial).

Data Analysis

Statistical analysis was done using STATGRAPHICS (STSC Inc. 1985-1991). The number of individuals in each group (*Baetis*, aquatic or terrestrial) was compared between sites with wood and those without using a two-sampled t-test with a null hypothesis of no difference in the numbers of individuals collected from the paired sites. In addition rough estimates of the volume of water (liters) filtered for both treatments were also subjected to the same test. A two-sample t-test was also used to compare *Baetis* abundances between washed wood and benthic samples.

Analysis and ordination of data from the washed wood and benthic samples was done using PCORD (McCune and Melford 1995), a software program designed for multivariate community analysis. To assess the difference in community composition between the two sets of samples the 37 taxa found in 10 samples were put into a 37 X 10 matrix. The matrix was then subjected to two data transformations designed to increase the information to noise ratio. The first of these was a log transformation, necessary because there was a difference of two orders of magnitude between the highest and lowest values within the matrix. A general relativization of the samples was performed in order to minimize the effects of different sampling techniques. These manipulations reduced the coefficient of variation (which should ideally be under 100%) from 314% to 128% within taxa, and from 91% to 0% within samples. PCORD row and column analysis following the transformations showed that skew was reduced within samples from 3.9 to 1.5. Between sample skew was also somewhat reduced, from 1.6 to 1.1.

The specific ordination technique used was Non-metric Multidimensional Scaling (NMS) which is based on ranked distances. The PCORD version of NMS uses algorithms developed by Kruskal (1964) and Mather (1976). In order to diminish the zero truncation problem and insure that the importance of each gradient was proportional to the number of species responding to it, distance was measured using the Sorenson coefficient (2W/(A+B)) (Beals 1984). The Sorenson distance measure was also used for a Multi-response Permutation Procedure (MRPP) run on PCORD to test the hypothesis of no difference between overall community composition of the washed wood and benthic samples. MRPP is a non-parametric method by which weighted mean within-group distances are compared to produce a test statistic and p-value. A more thorough description as well as the weighting formula are given in Mielke (1984).

Ordinations both in this section and the next are used as a technique for describing community changes along biotic and abiotic gradients. The specific ordinational technique used (NMS) is less common in the literature than many other techniques. Therefore, a discussion of general ordination of samples in species space and a description of this method in more detail follows.

Imagine a line representing a single species along which samples could be placed according to the abundance of that species. A two dimensional graph could be made by joining two of these species lines and samples could then be graphed relative to each other. In this way adding more species adds more dimensions until, in the case of the matrix used in this section, 10 samples were graphed in 37 dimensions. This is the raw data of the ordination.

NMS is an iterative, step-wise technique which seeks to relieve the stress between the placement of samples in the original 37 dimension space and their placement in the reduced ordinational space. It does this by recalculating stress after every "step" until a minimum value is achieved. To insure that this is a global rather than local minimum NMS must be rerun a number of times until a stable and consistent final stress value is achieved.

Unlike other methods in which ordinal dimensions are fixed, in NMS the configuration of the dimensions shifts as more dimensions are added to the solution. To find the appropriate number of dimensions a plot of final stress vs dimensions is examined. The steeper the drop in stress between dimensions, the greater the amount of variance in community structure explained by that axis.

Some advantages of using NMS on community data are that the it is robust for non-normal data and can be used with data sets containing a great many zeros. Neither of the data sets used in this study were normally distributed and, with the exception of extremely abundant taxa like Chironomidae, Elmidae and *Baetis*, species distributions were patchy.

Results

Oak Creek Artificial Channel

The total number of *Baetis* collected was significantly higher in the channel without wood (control) than in the channel with wood (treatment) (Table 2.2). This was also true of the other aquatic insects (both active and non-active drifters) and the floating terrestrial insects (which generally cannot swim and are floating with the current). The level of certainty of a significant difference decreases substantially when drift density (*Baetis*/liter) is calculated to control for the lower flow rate caused by the increase in roughness elements introduced by the wood.

It is interesting to note that the estimate of a difference between the mean *Baetis* drift density (95% CI) suggests a higher drift density in the treatment channel, a reversal of the trend expected from the number of *Baetis* drifting out of each channel. This may indicate that *Baetis* are using the wood as a habitat and are therefore more likely to be available to drift from the wood. An attempt has been made to address this habitat question using data collected from Badger Creek. Results from that analysis are presented in the field studies section.

Table 2.2 Mean number of organisms in 3-hour drift collections from channels with (treatment) and without (control) a debris jam, Oak Creek diversion channel.

Oak Creek	Treatment (X_1)	Control (X_2)	SD	p-value	95% CI (X_1-X_2)
Baetis	93	167	52	0.035	(-141, -6.4)
Other Aquatic Insects	55.5	93.2	28	0.045	(-74.4, -0.96)
Terrest. Insects	37.5	137	25	0.00048	(-132, -66.9)
Baetis drift density	1.13	0.71	0.55	0.21	(-0.28, 1.13)

Field Studies

General Analysis

The following is a general analysis of field data using averages from the three sites on Badger Creek and those on Hoffman and Trout creeks. The average number of *Baetis* in drift net collections during a 3-hour period in the sites with (treatment) and without wood (control) varied between sites (Fig. 2.7). *Baetis* drift density at the same sites

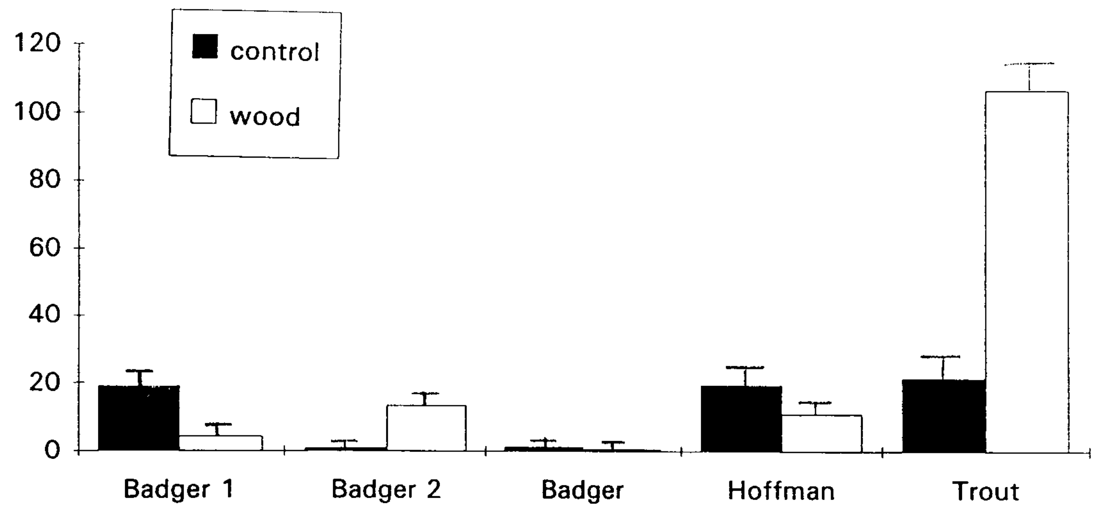

Fig. 2.7 Average number of Baetis in 3-hour drift net collections on Badger, Hoffman and Trout Creeks, Ochoco National Forest, summer 1994.

was also compared. A third analysis sorted the same site pairs according to flow velocity rather than wood. Table 2.3 gives the results of all three data tests.

Table 2.3 Mean number of organisms in 3-hour drift collections from reaches with (treatment) and without (control) a debris jam on Badger, Hoffman and Trout Creeks.

Field data	Treatment (X_1)	Control (X_2)	SD	p-value	CI 95% (X_1 - X_2)
Baetis	27.1	12.4	32.3	0.49	(-32.4, 61.9)
Baetis drift density	0.62	0.29	0.73	0.56	(-0.92, 1.6)
Baetis (faster-slower*)	30.1	9.5	31.3	0.33	(-25.1, 66.3)

*"faster" and "slower" are used here as terms defining one channel relative to the other. With the exception of one site on Trout Creek, all drift samples were taken from reaches where the surface water velocity exceeded 0.22 m/s.

At the majority of field sites - Trout, Hoffman and site 2 on Badger - the water velocity was higher through the site with wood. In all of the sites the wood amounted to a debris jam, much like the jam built in the artificial channel. However, in the artificial channel the wood constituted the most substantial roughness element in the system and based on water velocity this was not true in the field. When the sites were chosen the substrates at the sites without wood appeared very similar to those with wood and there was no discernable difference in slope. However, differences in the velocities point to the possibility that there were substrate and or slope differences which were not apparent.

Although it was disappointing, it was not surprising that the field data lacked the clarity exhibited by the data collected from the artificial channel. What was surprising was the lack of a clear trend across the field data. To try to find out why the numbers were so different between sites, the data from the three streams were analyzed separately.

Badger Creek

Due to the high variance, the results are much less clear-cut in the field than in the Oak Creek diversion channel. On Badger Creek, the number of *Baetis* collected in drift samples was very similar between control and treatment sites (Table 2.4). However, for other aquatic and terrestrial insects there was a slight suggestion that more insects were drifting through the control than through the treatment sites. This is consistent with the results from the Oak Creek diversion channel and probably indicates that a greater amount of water was filtered through the control site net due to higher water velocity. Also in agreement with the diversion channel results, the *Baetis* drift density values suggested a higher drift rate of *Baetis* in treatment sites than in the control.

The number of *Baetis* collected in the drift nets was too low to provide any conclusions about the effects of wood on active-entry drifters. The total collection of *Baetis* on Badger Creek from 3 sites for 3 nights was 55 in the treatment reach and 64 in the control. An average of 7 *Baetis* per night were collected in the Badger Creek control site samples, compared to an average nightly sample size of 164 *Baetis* per night in the corresponding Oak Creek samples.

Table 2.4 Mean number of organisms in 3-hour drift collections from reaches with (treatment) and without (control) a debris jam on Badger Creek.

Badger Creek	Treatment (X_1)	Control (X_2)	SD	p-value	CI 95% (X_1 - X_2)
Baetis	6.1	7.1	8.2	0.8	(-9.2, 7.2)
Other Aquatic Insects	19.1	40	30	0.16	(-51, 9.1)
Terrest. Insects	24	49	38	0.18	(-63, 12.7)
Baetis drift density	0.08	0.03	0.07	0.14	(-0.02, 0.16)

This paucity of *Baetis* may have been due to the presence of cattle at this site. On June 19th a cow was observed standing in the stream at Badger Creek site 2 approximately 20 minutes before the nets were placed. The possible effects on *Baetis* of the presence of cattle in the streams will be dealt with in another section.

Hoffman

The data show some slight evidence that fewer *Baetis* may have drifted from the area with wood than from the area without wood. Compared with the control, there also were significantly fewer other aquatic and terrestrial insects collected in the treatment channel. Contrary to the results from both the Oak Creek diversion channel and Badger Creek, drift density tended to be slightly higher in the control than in the treatment channel (Table 2.5)

The Hoffman Creek samples contained more *Baetis* than did the Badger Creek samples, but this drift rate was only 10% of that in the Oak Creek channels. Although cattle were present, there did not appear to be as many hoof prints or manure piles in and near the creek. However, a number of fresh-water clams, which would not normally be expected to drift, were collected in the drift nets which is good evidence of recent disturbance of the substrate. This recent disturbance may account for the low drift densities relative to the Oak Creek samples. However, it may be that the somewhat lighter grazing pressure left a higher population density of *Baetis* available for drift on Hoffman than on Badger Creek.

Table 2.5 Mean number of organisms in 3-hour drift collections from reaches with (treatment) and without (control) a debris jam on Hoffman Creek.

Hoffman Creek	Treatment (X_1)	Control (X_2)	SD	p value	CI 95% (X_1 - X_2)
Baetis	11	19.3	8.16	0.28	(-26.8, 10.2)
Other Aquatic Insects	51.3	103	16	0.015	(-87, -16.3)
Terrest. Insects	24.3	78.3	37	0.15	(-137, 29.4)
Baetis drift density	0.2	0.43	0.19	0.22	(-0.66, 0.21)

In Hoffman Creek the water velocity was 0.47 m/s through the treatment site and only 0.33 m/s through the control. However, the control site tended to be slightly deeper so there was no discernable difference in the amounts of water filtered between the two treatments ($p \leq 0.5$). It is unlikely that the almost equal flows at the two sites contributed to the reversal of the trend toward higher *Baetis* drift densities noted in the diversion channel and at

Badger Creek because on Trout Creek, where depths were equivalent between the two sites and the water velocity at the control site was slower than at the treatment, there again was evidence of more *Baetis* drifting out of the treatment than from the control channel.

Trout Creek

Significantly more *Baetis* were collected from the treatment site than the control site on Trout Creek (Table 2.6). This may have been due to the difference in flow rates between the two sites. At 0.06 m/s, the control site

Table 2.6 Mean number of organisms in 3-hour drift collections from reaches with (treatment) and without (control) a debris jam on Trout Creek.

Trout Creek	Treatment (X_1)	Control (X_2)	SD	p-value	CI 95% (X_1 - X_2)
Baetis	106.3	21.3	12	0.0009	(58.3, 111.7)
Other Aquatic Insects	23.3	15.7	5.3	0.12	(-3.4, 20.7)
Terrest. Insects	3	3.7	1.6	0.64	(-4.4, 3.0)
Baetis drift density	2.6	0.94	0.38	0.005	(0.86, 2.57)

had the slowest flow of any in this study. Mean water velocity at the treatment site (0.11 m/s) was also slower than at sites on Badger and Hoffman. This is the only study site at which more water was filtered at the treatment site than at the control. Even so, the trend toward great *Baetis* drift densities coming out of the treatment site observed on Badger Creek and in the Oak Creek diversion channel was substantiated at these sites.

Cattle had been excluded from the Trout Creek watershed for over two years and as a result, substantial riparian vegetation shades the stream. This may, in part, account for the greater abundance of *Baetis* taken in Trout Creek drift samples. However, more riparian vegetation alone would not account for this difference since *Baetis* typically increase following clearcutting of riparian zones (Wallace and Gurtz 1986). The other difference between the sites on Trout Creek and other field sites was that rather than sampling from a riffle, these sites were at the outflow of a pool.

Wood

The hypothesis that active-entry drift will differ between these treatment and control sites was predicated on *Baetis* larva responding differently in the presence of wood than they do on a bare gravel substrate. Although this is not an unreasonable assumption, it was not borne out in the two sample t-test of data from washed wood and benthic samples ($p \leq 0.86$). It is not clear, however, if this was a fair test of *Baetis* resource use since there was so much variance in gross abundances among the 10 samples. These numbers are graphed in Fig. 2.8. It is interesting to note that the larvae collected in the September samples were primarily early instars (mean length 1.75 mm). It may be that wood serves as a more stable substrate than the gravel and is more likely to retain very early instars.

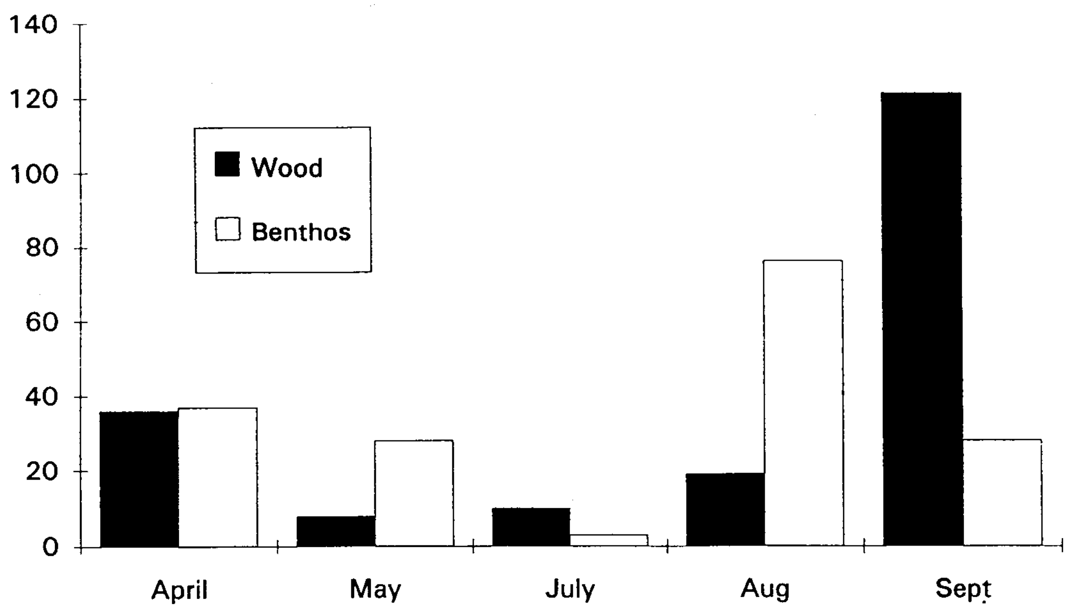

Fig. 2.8 Gross abundances of Baetis in washed wood and benthic samples, Badger Creek.

Tables 2.7 and 2.8 list the insects found in these samples. Alpha diversity, or the average number of taxa per sample, was 16 for the combined washed wood and benthic data. As noted before, the total number of taxa present (Gamma diversity) was 37. As a measure of the heterogeneity of the samples, beta diversity (gamma over alpha) was 2.3, indicating a relatively homogeneous data set.

A Multi-response Permutation Procedure (MRPP) run on these samples showed a difference in the macroinvertebrate assemblages within the washed wood and benthic samples ($T = -2.6$, $p = 0.014$). Although the samples were taken over a period of six months, an MRPP using date as the grouping variable did not find the same evidence of tighter within-group than between-group connection ($T = -0.92$, $p = 0.18$).

In order to create a graphic image of this sample grouping, the matrix was subjected to a Non-metric Multidimensional Scaling (NMS) ordination. A plot of the final stress vs number of dimensions from a six dimensional solution with 100 iterations revealed that most of the information was contained on the first three axis (Fig. 2.9). The graphs from a three dimensional NMS are given in Fig. 2.10 - 2.12. An analysis of these graphs, along with additional overlay information will follow in the next section.

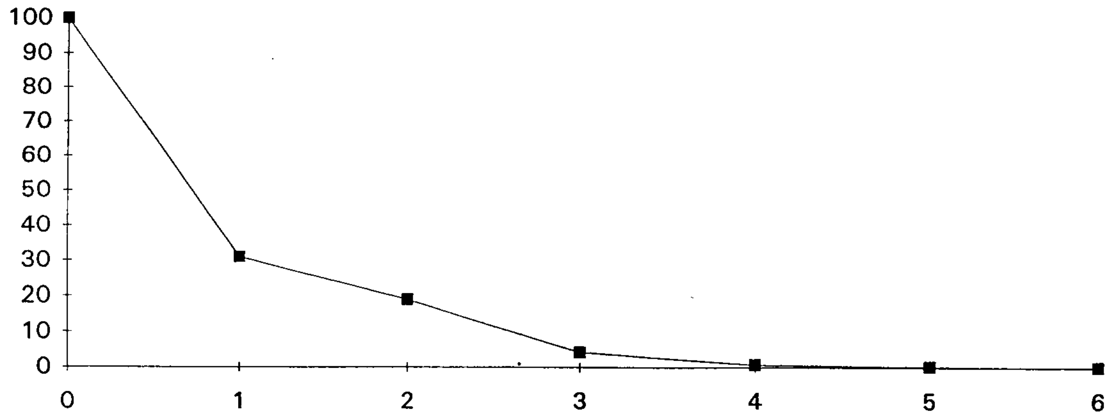

Fig. 2.9 Plot of stress vs iterations, NMS of washed wood and benthic samples, Badger Creek.

Table 2.7 List of taxa collected in washed wood samples, Badger Creek, summer 1994.

TAXA	1	3	5	7	9
Coenagrionidae				8	
Baetis	36	8	10	19	121
Cinygmula	7		2	3	5
Epeorus	1	1			
Ironodes	4				
Drunella	1				2
Serratella	4	9	2	56	9
Paraleptophlebia	1		2	12	
Misc. Ephemeroptera	28			1	
Capnia	6				
Zapada					5
Misc. Nemouridae			1		
Yoraperla	1				1
Calineuria	1				
Brachycentrus	4				3
Micrasema	46		6	33	82
Hydropsyche	2		1	1	27
Hydroptila					4
Lepidostoma	1			4	2
Neophylax					
Misc. Limnephilidae	1			1	2
Rhyacophila	13	1		1	10
Dytiscidae		1		1	
Elmidae	20	2	10	85	28
Staphylinidae	3	1			
Ceratopogonidae				3	
Chironomidae	300	20	11	828	340
Dixa				1	
Tabanidae					
Tipulidae	1	2		3	22
Simuliidae	252	1	4		16
Diptera Pupae	1	1		5	26
Hydrachnida			2	2	1
Annelida	1				
Sphaeridae				2	

Table 2.8 List of taxa collected in benthic samples, Badger Creek, summer 1994.

TAXA	2	4	6	8	10
Coenagrionidae				61	
Baetis	37	28	3	76	28
Cinygmula	14	15		3	13
Epeorus	5	9			
Ironodes					
Drunella					
Serratella	1	27	9	50	9
Paraleptophlebia	3	4	13	12	6
Misc. Ephemeroptera	55			1	3
Capnia	1				
Zapada					
Misc. Nemouridae					
Yoraperla	2				
Calineuria	1				
Brachycentrus					
Micrasema	1			4	2
Hydropsyche	19				
Hydroptila					
Lepidostoma	2	2			8
Neophylax	1				
Misc. Limnephilidae	2				
Rhyacophila	1		7		
Dytiscidae				3	1
Elmidae	19	35	6	61	21
Staphylinidae					
Ceratopogonidae	1				
Chironomidae	156	10	38	256	72
Dixa					
Tabanidae				1	
Tipulidae		2	1	3	5
Simuliidae	10	1		1	
Diptera pupae				12	6
Hydrachnida	1	1		3	2
Annelida	2		2	21	4
Sphaeridae	19		7	53	17

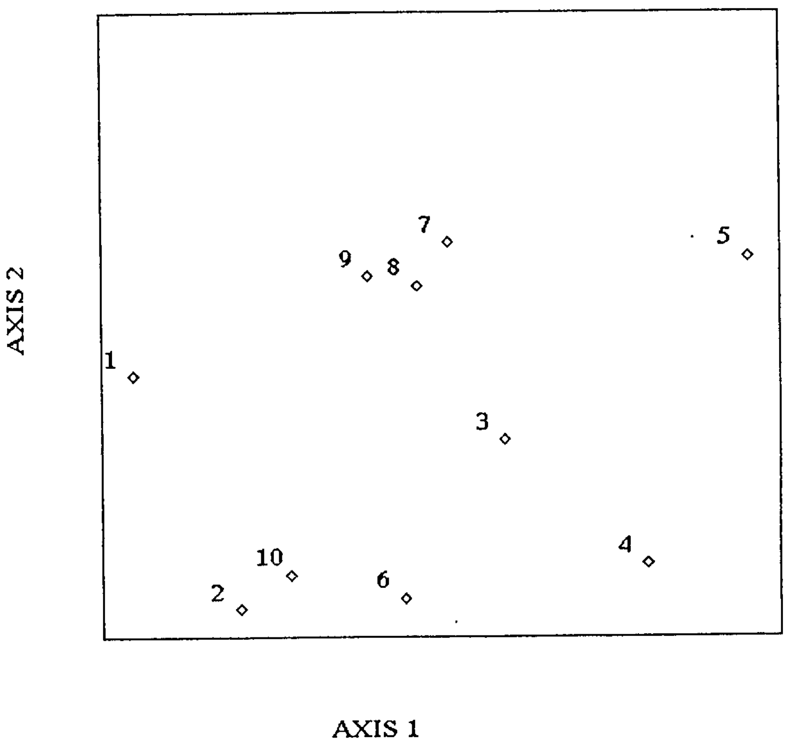

Fig. 2.10 Axis 1 & 2, NMS washed wood and benthic samples.

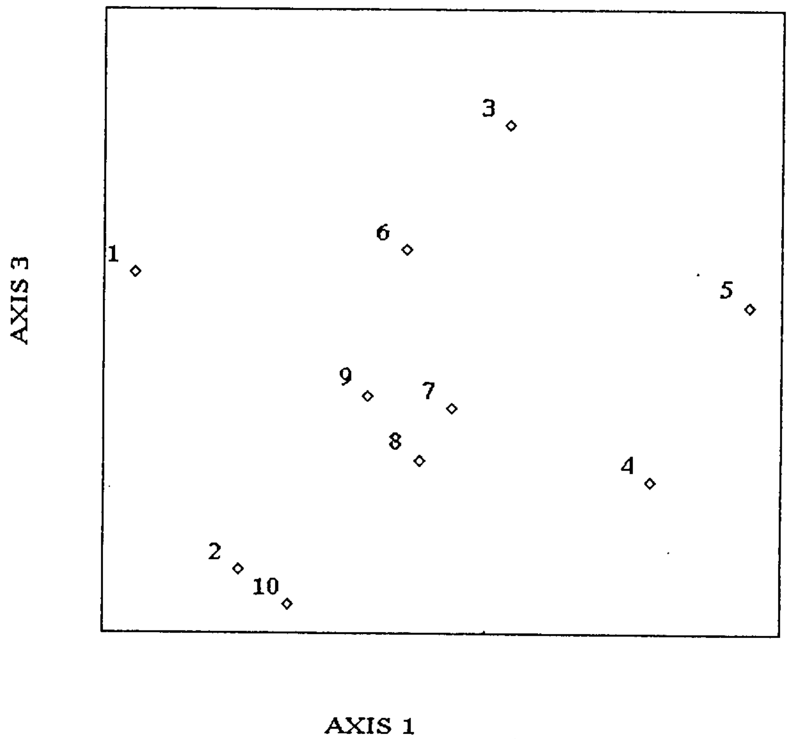

Fig. 2.11 Axis 1 & 3, NMS washed wood and benthic samples.

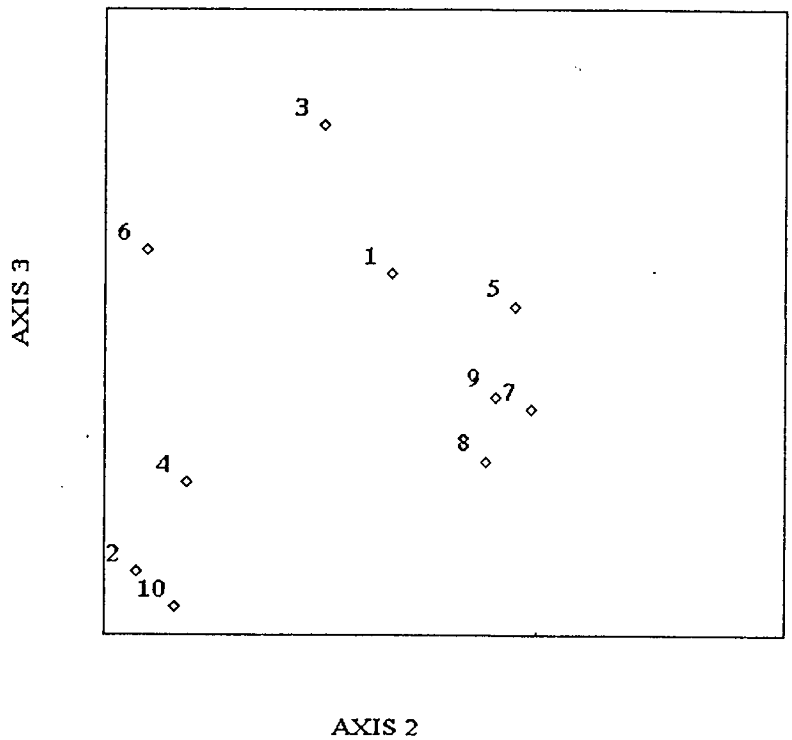

Fig. 2.12 Axis 2 & 3, NMS washed wood and benthic sample.

Discussion

The original hypothesis was that if active-entry was a functional component of community-scale drift then drift densities of an active-entry species would differ between reaches with and without wood because the insects were likely to respond to a difference in habitat. In the Oak Creek diversion channel more *Baetis* were collected in nets below control channels than in nets below the debris jam in treatment channels.

However, in the Oak Creek channels not only were there more *Baetis* drifting out of the control channels, there were also more of the other aquatic organisms and terrestrial "floaters." This result implies that while *Baetis* may use drifting as a behavioral strategy, the relative numbers of drifting organisms is unaffected by active-entry drift and that some other factor was responsible for these between treatment differences.

Even in the relatively controlled experimental unit of the diversion channel, the variance in numbers of *Baetis* collected between samples was very high. Within the control channel, the number sampled ranged from 84 on May 30 to 226 on June 15. The majority of these were early instars. While the between-channel differences were dramatic enough to overcome this variation, it is important to note that the 226 count appeared to represent early instars following the hatch of eggs laid in the right channel at some point after the channels were divided. Since the treatment was switched from right to left channel prior to this catch, it is impossible to report the condition of the right channel at the time of oviposition. However, it is likely that with an average stream temperature of approximately 10° C oviposition occurred during the colonization, pretreatment period.

Once the greater volume of water flowing through the net in the control channel was accounted for, it appeared that more *Baetis* were drifting out of the treatment channel on a per unit volume basis than from the control channel. The channels were allowed to become fully colonized before sampling began, therefore if the number of *Baetis* drifting out of each channel was proportional to the number present, then more *Baetis* were utilizing this wood substrate. Although the coarse gravel substrate of the channels should have been the preferred habitat (Phillips and Kilambi 1994), *Baetis* will facultatively use a wood substrate (Dudley and Anderson 1982). There may have been additional factors which, in combination with the wood, made the treatment channel more attractive to the colonizing *Baetis*.

Although there was no apparent difference in the number of *Baetis* collected from Badger Creek on washed wood and benthic samples, there appeared to be more early instars collected from the wood than from the benthos. This was particularly evident in September when the washed wood sample contained well over three times as many early instar *Baetis* as the benthic sample.

That the relationship between *Baetis* and wood is complex was borne out in the NMS ordination of these washed wood and benthic samples. Figure 2.13 shows axes 2 and 3 of the ordination with samples identified by sampling method (0 = benthic, 1 = washed wood). This ordination has been rotated 45° for ease of interpretation. The grouping of like samples in species space is clear.

A graph of the correlation of *Baetis* along axis 2 and 3 (Fig. 2.14) shows that while the washed wood and benthic samples clearly separated out along axis 2, *Baetis* showed no correlation that axis. Contrast this with a similar graph for *Micrasema*, caddisflies which feed on moss and can be expected to require a more solid substrate than the gravel benthos (Fig. 2.15). One would expect this insect to be more abundant in the washed wood samples (N. H. Anderson, personal communication) and indeed it exhibits strong negative correlations along axes 2.

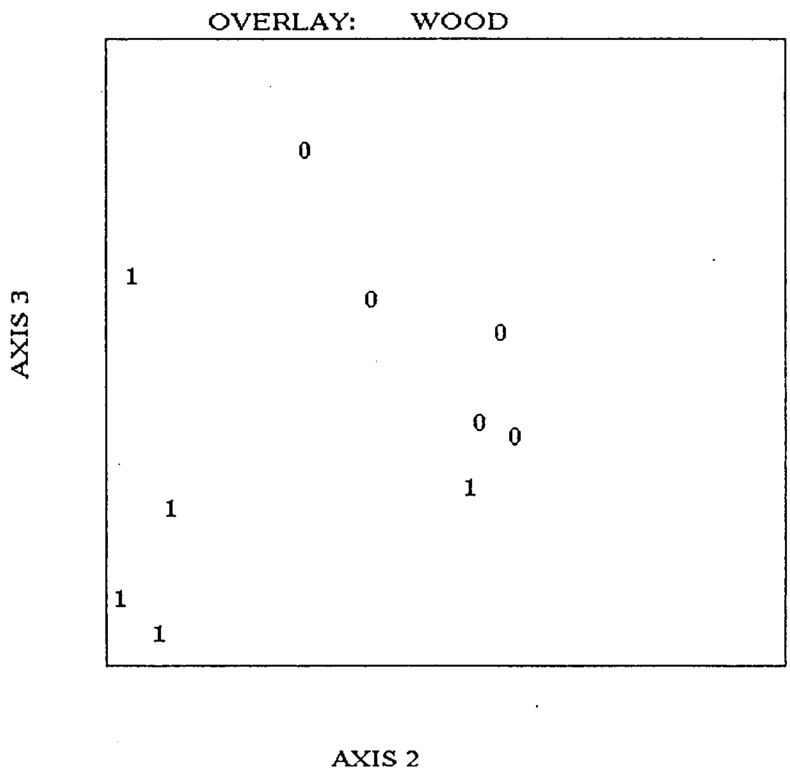

Fig. 2.13 Axes 2 & 3 of the NMS ordination of washed wood and benthic samples. Washed wood samples are identified with a 1, benthic with a 0.

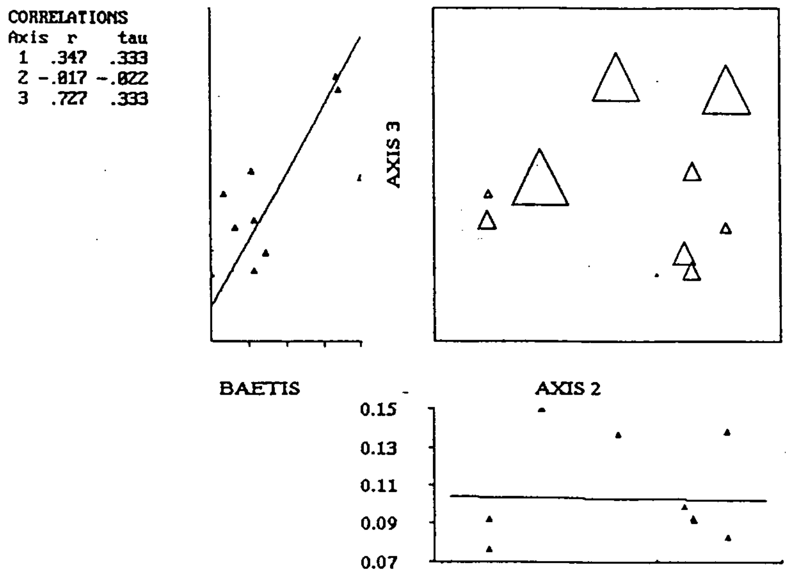

Fig. 2.14 Correlations of *Baetis* with axes 2 & 3 of the NMS ordination of washed wood and benthic samples.

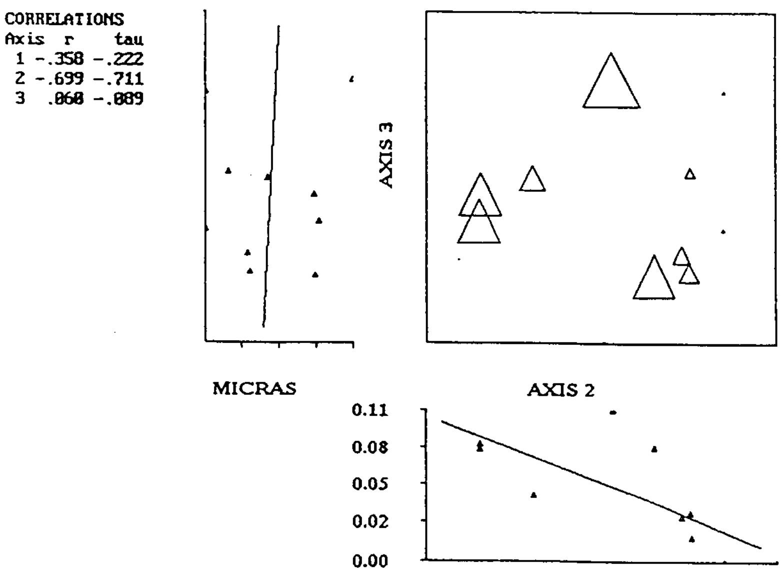

Fig. 2.15 Correlations of *Micrasema* with axes 2 & 3 of the NMS ordination of washed wood and benthic samples.

In an early investigation of drift as a colonization strategy, Bishop and Hynes (1969) concluded that drift was not a directed behavior but rather a function of the availability of insects to current. More recent investigators such as Peckarsky (1980) have shown that under a given set of circumstances certain insects actively enter the drift to avoid predation or to forage.

The active-entry drift occurring during the Oak Creek diversion channel manipulations was not happening on a scale large enough to affect population densities. This does not invalidate the importance of these behavioral strategies in the life histories of active-entry drifters. *Baetis* drift distance in response to predation may be as short as 4 cm (Scrimgeour et al 1994). This distance may be adequate to escape the approaching stonefly but have no effect on abundances in a drift net 70 cm below a debris jam. Active-entry drift has been primarily studied in lab streams rather than the field. The disparity in scale between the drift events of individuals and the overall drifting assemblage may be too great for active-entry drift to be addressed using techniques which measure total drift density.

Whatever the mechanisms, the results of this study showed that, within the controlled setting of the Oak Creek diversion channel, wood acted as a retention device, keeping the insects from drifting out of the system. Since drift is an important component of salmonid diets (Elliott 1973), retention of drifting organisms may be a valid consideration for stream managers contemplating the addition of coarse woody debris to streams.

Although there was a great deal of discrepancy between field streams, as well as considerable within-site variance, a trend toward a difference between the treatments appears to be supported by the field data. The direction of this difference, whether more *Baetis* drifted out of the treatment or out of the control sites, was not consistent between streams. This is not surprising given that the streams varied in water velocity between the two treatments.

One partial validation of the idea that active-entry may not be a serious factor in large-scale drift dynamics is that, while variance in the number of *Baetis* was high, this degree of variability is evident in the non-*Baetis* drifting aquatic insects collected as well as in the terrestrial "floaters." There is also no consistency in the *Baetis* drift density between sites. Nor is there a trend evident when the "fast" and "slow" sites are compared. Clearly, the natural systems are more complex than was controlled for in this test.

The single factor contributing most to a lack of drift data in the field that would corroborate the results from the Oak Creek diversion channel was the extremely low numbers of *Baetis* captured in the field. Given the high numbers in the Oak Creek drift samples of the month before, this was an unexpected occurrence. There are several factors that may have contributed to the difference in *Baetis* density between Oak Creek and Badger Creek.

Abiotic differences between Oak Creek and Badger Creek include altitude and the temperature at the time of sampling. The Oak Creek diversion channel is on a section of stream which drains the low foothills around Corvallis. The sites sampled on Badger Creek are at an altitude of approximately 5000 ft. Because of this difference in altitude and the consequent spring temperature differences, larval development of *Baetis* could be expected to be somewhat delayed on Badger Creek. However, most *Baetis* retrieved in Badger Creek and Hoffman Creek were between 2 and 4 mm in length. In contrast, most *Baetis* collected in the Oak Creek diversion channel nets were less than 2 mm long. This could account, in part, for the lower abundances in the Badger Creek and Hoffman Creek samples since size of the larval cohort diminishes with increasing age/size.

However, in the Badger Creek survey samples, *Baetis* mean length was not substantially different between May and June. The graph in Figure 2.16 shows the mean length of *Baetis* sampled on Badger across eight months. Across the bottom of this graph are written the total numbers collected in 3 benthic samples for each sampling period. Mean length did not go up until July, yet the numbers collected dropped in June.

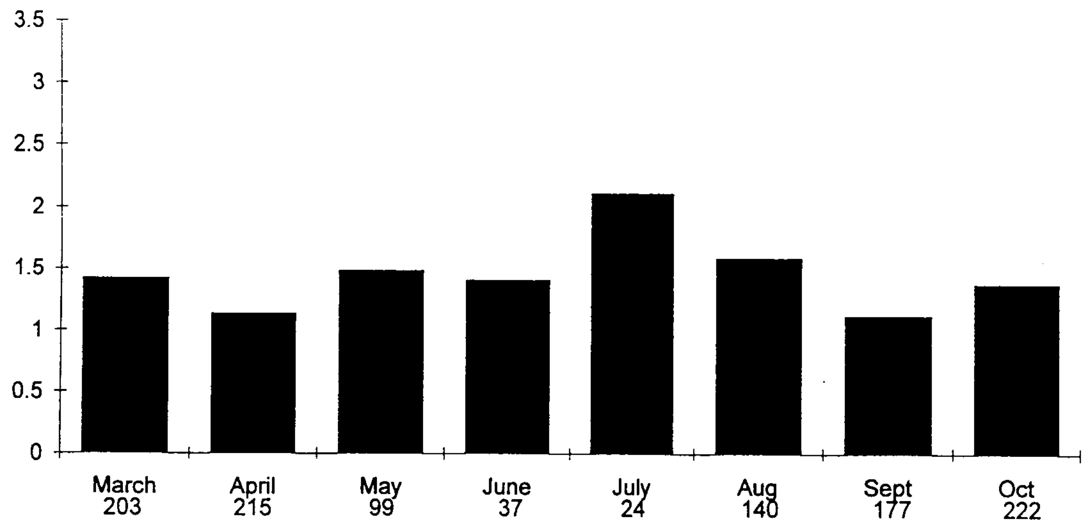

Fig. 2.16 Mean lengths of *Baetis* from Badger Creek survey data (n = 15). Abundance data for 3 benthic samples is given below each date.

A second consideration is the lack of riparian vegetation on Badger and Hoffman Creeks as opposed to the lush growth shading the reach of Oak Creek from which the sampled population came. Although the literature does not directly address the presence of *Baetis* relative to riparian vegetation, there is a certain amount of information available concerning *Baetis* populations relative to clear-cuts. *Baetis* has been reported as a weedy species which quickly colonizes the reaches of stream which run through new clearcuts where riparian vegetation has been substantially reduced (Wallace and Gurtz 1986). As an example of this, the following data was culled from Carlson's (1989) study in Oregon. She compared the macroinvertebrate density and diversity in five pairs of streams (logged and unlogged). Table 2.9 shows the mean number of *Baetis* per kick sample.

Although the variance was too high to get a significant difference ($p = .13$), there is a clear trend toward more Baetis being found in the streams running through logged areas. Thus, it is unlikely that the lack of riparian vegetation along Badger Creek resulted in the near absence of *Baetis* in the Ochoco National Forest field sites.

Table 2.9 Mean number of *Baetis* per kick sample in logged and unlogged streams of eastern Oregon (data from Carlson, 1989).

Pair	Logged	Unlogged
1	13.5	12.8
2	43.2	12.0
3	13.0	8.4
4	31.4	26.4
5	21.2	4.0

Also investigated was the possibility that the dearth *Baetis* in the drift samples was the result of natural population cycles. To analyze this, data from Oregon Department of Environmental Quality surveys in eastern Oregon (Caton 1993) was examined. In 1991 three streams in the South John Day; Basin, Utley Creek (Grant County), Pine Creek (Wheeler County) and Corral Creek (Grant/ Harney County), were sampled on April 15-18 and again on June 17-21. Six of the eight sample sets taken from the three creeks had substantially more *Baetis* during June than during April (Table 2.10). Utley Creek and site 1 on Corral Creek had lower numbers in June but, in both cases, the number of *Baetis* was under 10 for both dates.

Table 2.10, Mean number of *Baetis* per sample from eastern Oregon streams, spring and summer 1991 (DEQ data).

Sample Site	April	June
Pine Creek #4	89	103
Pine Creek #6	72	106
Pine Creek #7	21	13
Pine Creek #2	16	30
Utley Creek	8	2
Corral Creek #2	5	11
Corral Creek #1	4	1
Pine Creek #5	2	95

Given the patterns shown in the above data, it is unlikely that the low number of *Baetis* in the Badger Creek drift samples was entirely due to life-stage driven population dynamics.

The final large scale difference between Oak Creek and Badger and Hoffman Creeks at the times of sampling was the presence of cattle in the Badger Creek watershed during the entire sampling period. The cattle arrived on June 18, the night of which was our first drift sampling. As noted earlier, drift samples from Hoffman Creek, a tributary of Badger Creek, contained a number of clams which would only be expected to drift following mechanical disturbance. It was postulated that the combination of being dislodged by cattle hoofs and the subsequent organic contamination from manure and urine may have accounted for the rarity of *Baetis* in Badger and Hoffman Creek drift samples. The next chapter will explore some of the possible effects of cattle grazing on the macroinvertebrate community of Badger Creek.

Chapter 3
Macroinvertebrate communities in the wake of grazing cattle on Badger Creek

Introduction

Few studies have examined the effect on aquatic macroinvertebrate communities of cattle grazing in the riparian zones. Rinne (1986) found that within-site differences in test plots in northwestern New Mexico were too large to afford robust conclusions about the effects of cattle grazing pressure on aquatic insect communities. A Texas study of streams adjacent to dairy farms (Rushin 1993) proported to find no effect of cattle effluent on macroinvertebrate communities. However this study is unconvincing due to the lack of a control stream in which no cattle effluent was present. Rushin compared streams with 9 and 21 dairy farms within their drainages, and using the Shannon-Weaver (1949) Diversity Index found no differences in community health between the two streams. When analyzed using the Hilsenhoff Family Biotic Index (1988), it was found that both streams in Rushin's study showed evidence of fairly substantial organic pollution (see Appendix I).

Badger Creek sampling site #2, which yielded the least *Baetis* was also characterized by the steepest slopes adjacent to the stream. Cattle spend a large percentage of their grazing time in the riparian zone (Larson 1989), especially during the first few weeks in a new pasture (Johnstone-Wallace and Kennedy 1944), and when the alternative is grazing on steep slopes (Roath and Krueger 1982). Cattle will continue to use the riparian zone even when forage plants are more dense in non-riparian areas. (Gillen et al 1985).

Organic contamination is one possible effect of cattle grazing in riparian zones. At least one study found no apparent risks to water quality from fecal coliform deposited by cattle (Buckhouse and Gillford 1976). However, the finding that direct fecal deposits into the stream by grazing cattle were highest during the summer months (Larson 1989) indicates that contamination may have contributed to the depressant effect of mechanical disturbance on *Baetis* drift populations.

Data collected during the course of the Badger Creek survey as well as two sets of samples collected especially for this analysis to assess the impact of the presence of cattle on the Badger Creek *Baetis* population and the macroinvertebrate community composition of the stream. In this way longer term data are combined with a "snap-shot" view of the stream on a particular day.

Methods

The data used in this analysis were collected as part of a survey of macroinvertebrates on Badger Creek conducted for the Ochoco National Forest. Six samples were taken from Badger Creek each month from March to October 1994. One of the May samples was subsequently lost. All samples were taken by disturbing the substrate for ten seconds upstream of a modified Surber sampler.

On July 31, 1994 a small test of the effects of cattle on the macroinvertebrate community was conducted by taking 5 samples from a reach of the stream on which approximately 50 head of cattle were grazing (Fig. 3.1) and 5 from a site upstream in an area where there had been no cattle present for at least a month (Fig. 3.2). The first site was the only reach of stream where cattle were still present. The consideration used to choose the second site was that it mirror as closely as possible the geomorphology of the first. Within these sites 10-second Surber samples were taken from randomly chosen areas of the benthos.

The data were analyzed using NMS ordinations as well as a number of other descriptive techniques that, while they do not imply cause-effect relationships, do assess the differences in community composition between the two sample sets. All three matrices used were subjected to a log transformation before performing NMS on the data. This was

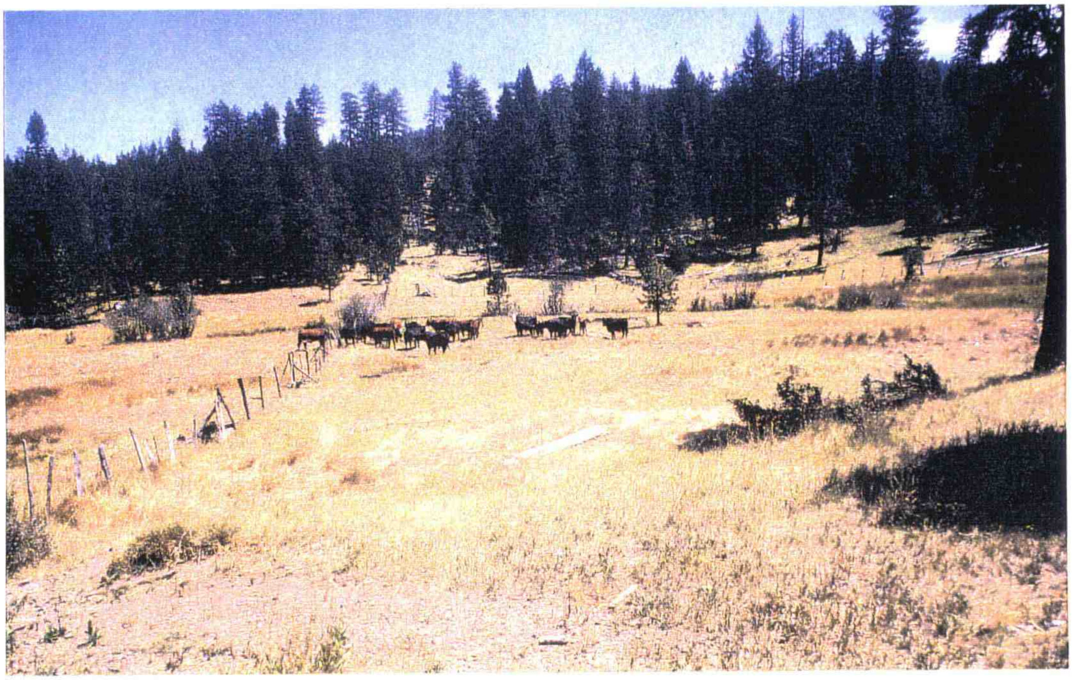

Fig. 3.1 July 31 site on Badger Creek where cattle were present.

Fig. 3.2 July 31 site on Badger Creek where no cattle were present.

necessary because there was a difference of two orders of magnitude between the highest and lowest values within the matrix. These ordinations were done looking for large scale changes across time and disturbance. Therefore, taxa which were found in fewer than 5% of the samples were deleted from the matrices to insure that the gradients of community compositional change defined by the final ordinations would be descriptive of general trends and not skewed by the presence or absence of rare species. This resulted in a 35 taxa by 41 sample matrix for the 7 month survey data, a 41 taxa X 15 sample matrix for the 3 month NMS (because of a lost May sample only 5 samples from each month were used for this ordination) and a 19 taxa X 10 sample matrix for the ordination of sites with and without cattle. Table 3.1 gives the coefficient of variance and skew of the data for rows (samples) and columns (taxa) before and after transformation for all three matrices.

Table 3.1 Skew and coefficient of variance values for data in the matrices used for the ordinations in this chapter, before and after data transformations. Data from Badger Creek.

Data set		Skew	CV	Skew	CV
7 month	row	4.4	87%	1.5	38%
	column	3.9	297%	1.6	118%
3 month	row	3.0	60%	1.0	33%
	column	5.9	188%	0.6	97%
July 31	row	3.8	50%	1.4	25%
	column	1.5	272%	0.7	113%

Figure 3.3 shows plots of final stress vs number of dimensions for six dimensional solutions with 100 iterations for the matrices. In all three ordinations 2 axes appeared to provide sufficient information. For both the seven months of survey data and the samples from sites with and without cattle, the final ordinations were rotated clockwise by 45° in order to increase interpretability. Whether or not rotation occurred, all correlations used in this paper are against the ordinations as they appear in the text. In this way, the meaning of the picture presented is not obscured.

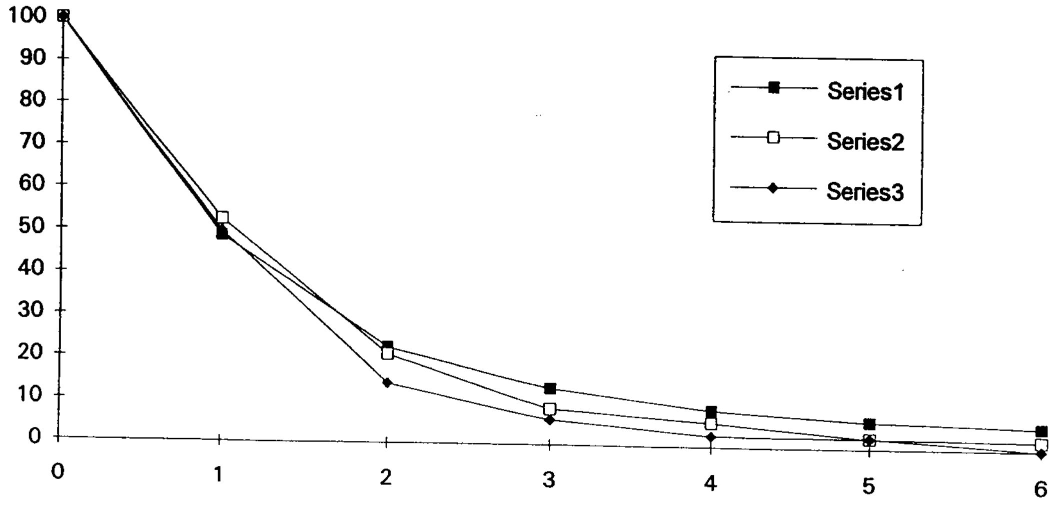

Fig. 3.3 Final stress vs number of dimensions for 3 matrices.

Results and Discussion

An ordination of the community composition of Badger Creek over seven months revealed little in terms of effects due to cattle. This ordination (Fig. 3.4) primarily reflects the strong influence of temperature and seasonality on aquatic insect communities. The temperature vector (as well as all other "overlays" on the ordination) is derived from a comparison of the original ordination with a second matrix of environmental variables. That temperature was the driving variable of the ordination is not surprising given that the data span seven months.

Axis 1 in this rotated ordination may have some relationship to seasonality or emergence patterns. The total numbers of insects collected was low in June and July (Table 3.2). The samples which fall on the left side of the matrix tend to come from these months when the number of insects collected in the Surber samplers was low. Sample #2, a sample from March with an unusually small total count, is also on that side of the ordination.

While the general trend toward fewer insects collected in the July samples may be related to emergence, this may also be reflective of some unaccounted for difference since the number of beetles (Coleoptera) was also quite low in the July sample. The majority of beetles found in the benthic samples were Elmidae, or riffle beetles, which are aquatic over the entire life-cycle and therefore do not leave the water at emergence. Full detail on the taxa found in the Badger Creek survey is given in Appendix II.

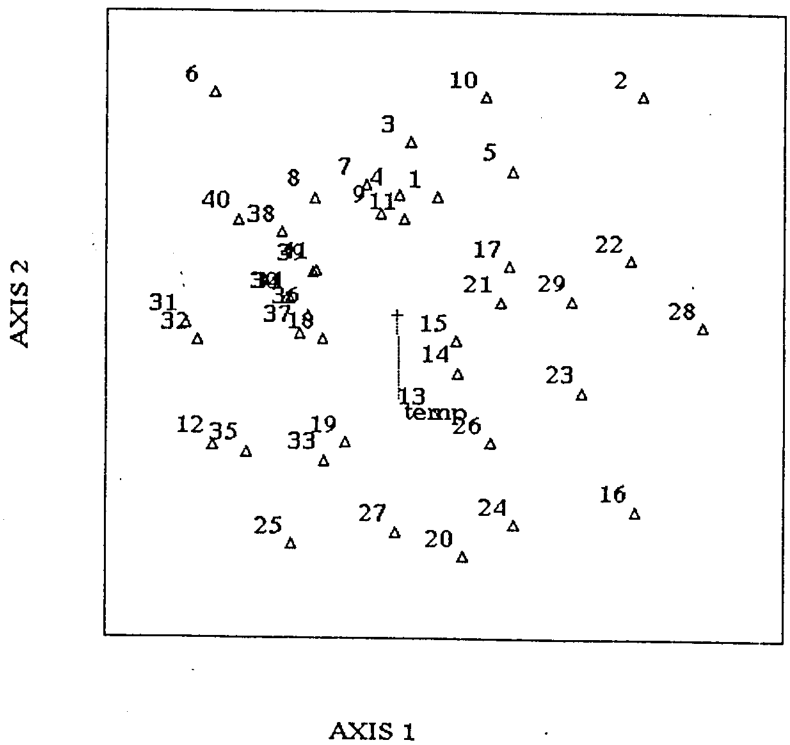

Fig. 3.4 NMS ordination of 7 months of survey data from Badger Creek. Note the temperature vector (TEMP) coming down axis 2 from the centroid. (Samples numbers start with the March samples and continue on through September with approximately 6 samples per sampling date.)

Table 3.2 Number of insects (by Order) collected each month in 3 benthic samples as part of the Badger Creek macroinvertebrate survey in 1994.

Order	Mar	Apr	May	Jun	Jul	Aug	Sep
Ephemeroptera	478	630	232	156	75	395	331
Odonata	4	0	0	0	1	133[1]	0
Plecoptera	9	10	1	4	1	0	4
Trichoptera	35	29	24	34	1	16	63
Coleoptera	23	104	106	206	75	164	134
Diptera	503	450	43	226	62	697	264
Total insects	1052	1223	406	626	215	1405	796

It is possible that the low numbers in the July samples are connected to the effects of cattle on the Badger Creek macroinvertebrate community. They may represent a lack of full recovery by stream communities following the June grazing disturbances.

The survey data from the months of May, June and July was analyzed separately to more closely assess the change in community composition for the period surrounding the arrival of the cattle on Badger Creek. An NMS of these three months is given in Figure 3.5. with the clusters circled to indicate those samples taken during the same sampling period. That these clusters are distinct is clear.

[1]The majority of these were very early instar Coenagrionidae (probably *Argia*, of which larger specimens also were collected).

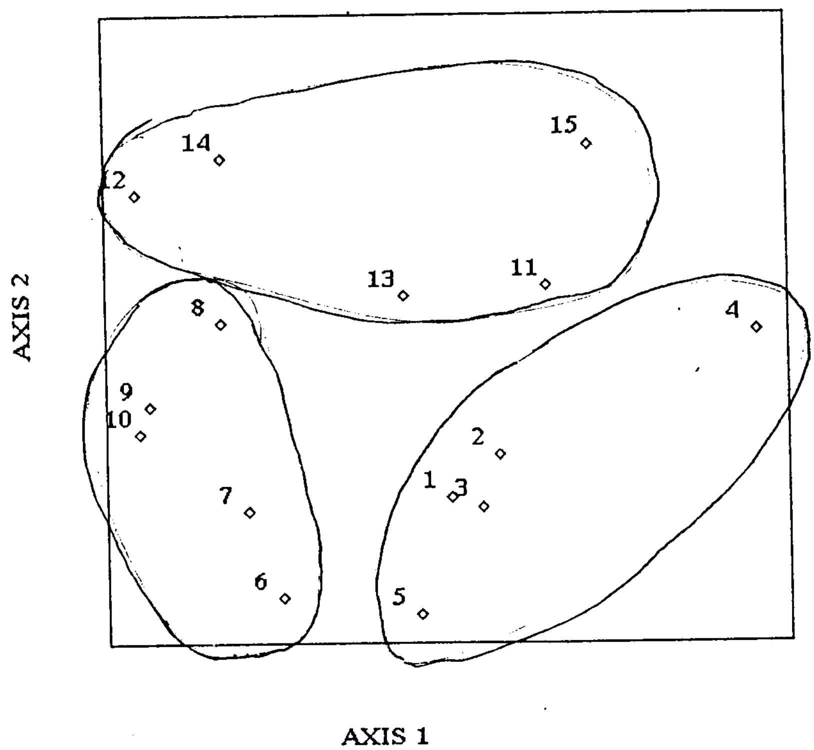

Fig. 3.5 NMS of 3 months of data from the Badger Creek survey. Samples 1 - 5 are from May, 6 - 10 are from June, and 11 - 15 are July samples.

Axis 2 appears to be a reflection of the same emergence, seasonality, or sampling difference demonstrated in the ordination of the entire survey data. Samples 5 and 6 contained a large number of insects (235 and 354 respectively). On the other hand samples 4 and 8, the uppermost points of the May and June clusters, contained far fewer insects (44 and 94 respectively). As mentioned above, the July samples had the fewest insects of any group in the entire survey.

The change in species across axis 1 is a reflection of disturbance in the stream. As evidence of this, examine the correlation of two taxa along axis 1. Figure 3.6 shows the correlation data for Chironomidae. With an r value of almost -0.9, chironomid abundances are shown to have a strong association with the samples which fall on the left side of axis 1. These are the samples taken in June when the cattle were present when organic input would increase and silt load could also be expected to increase from the breakdown of stream banks by cattle hooves (Platt 1991).

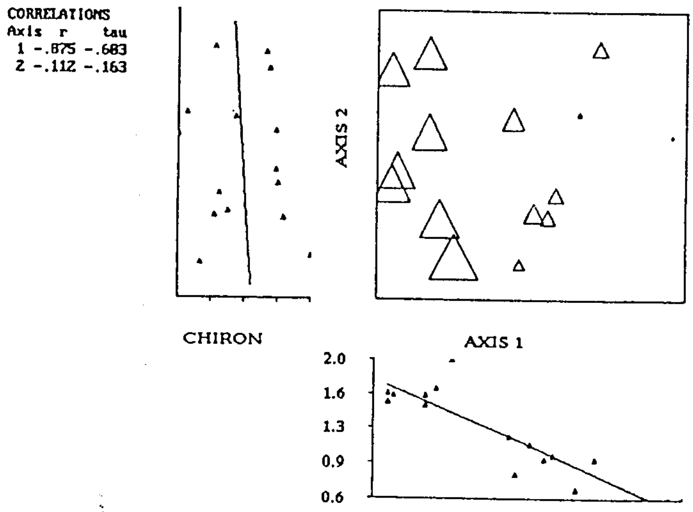

Fig. 3.6 Correlation of Chironomidae in 3 month NMS.

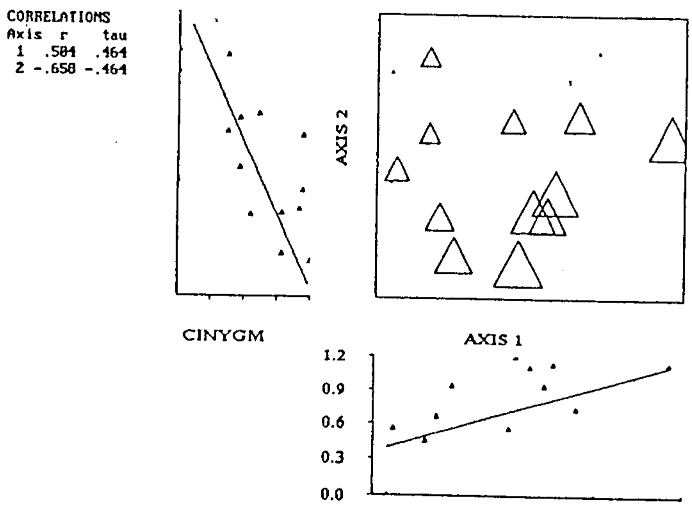

Fig. 3.7 Correlation of *Cinygmula* in 3 month NMS

With a Hilsenhoff FBI[2] value of 6 on a scale of 10, chironomids are relatively tolerant of organic pollution (Hilsenhoff 1988). They are also not as subject of immediate catastrophic drift due to point source pollution as *Baetis* (DuBois and Plaster 1993).

On the other side of axis 1, *Cinygmula* mayflies (Fig. 3.7) show a strong correlation (r = .5). *Cinygmula* nymphs are scrapers, feeding off the periphyton which builds up on rocks and are much less likely to tolerate a heavy silt load in the stream. Their Hilsenhoff FBI rating of 4 (the same as *Baetis*) shows they are also less tolerant of organic pollution.

Baetis also exhibit a strong correlation with the May sample side of axis 1 (Fig. 3.8). This is hardly surprising given that the paucity of *Baetis* in June was the impetus for this analysis.

By the time the July samples were taken the cattle had been gone for at least three weeks. That these samples span the entire length of this disturbance gradient makes sense

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[2]The Hilsenhoff Family Biotic Index (Hilsenhoff 1988) is designed to test water quality by calculating the overall tolerance to organic pollutants of an aquatic insect assemblage. On a scale of 0 (intolerant) to 10 (extremely tolerant), a tolerance value is given to the aquatic insect families. To obtain a value for a site, the number of insects in each family collected is multiplied by the family tolerance valuer and the total for the assemblage is summed. This is divided by the total number of insects to produce an Family Biotic Index (FBI) value for the site. Index values range from excellent (0-3.75) to very poor (7.26-10).

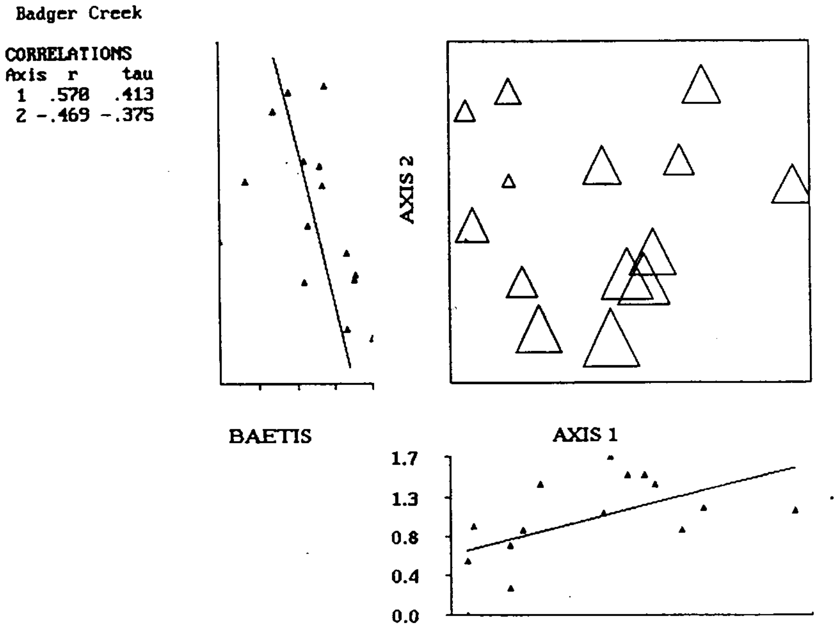

Fig. 3.8 Correlation of *Baetis* in 3 month NMS

if one assumes that the microhabitats sampled show differential rates of rebound.

Before discussing the NMS results for the July 31 "snap-shot" sampling of Badger Creek with and without cattle, it is important to get an idea of the community composition at the two sites used for this study. An analysis of the pooled contents of the five random samples taken at each site is included (Table 3.3). A complete list of taxa is given in Appendix III.

The number of *Baetis* collected was greater at the site where cattle were present. However, the *Baetis* sample size was very small at both sites. It is quite possible that the numbers obtained in this experiment reflect a continued reduction after the cattle were present in June. Figure 3.9 shows the number of *Baetis* found in three sets of benthos samples taken on May 28, June 21 and Aug 1 of 1994 as part of the Badger Creek survey. The density in June and August was less than %50 of that in May, before the cattle were present.

Table 3.3 Numbers of *Baetis*, percent community dominance, Family Biotic Index and EPT/Chironomidae metrics for samples taken from Badger Creek sites with and without cattle.

TEST	Site w/ cattle	Site w/o cattle
Baetis (no/.09$^{m^2}$) % *Baetis*	36 5.5	21 2.5
Dominance	69.8% Chironomid 13.2% Elmidae 17.0% Other	44.4% Elmidae 38.6% Chironomid 17.0% Other
Hilsenhoff FBI	5.19 Fair	4.91 Good
EPT/ Chironomidae[3]	0.195	0.238

The difference in community composition between these two sites is most apparent in the change in percent dominance. The Elmidae and Chironomidae had similar densities in the site without cattle (Fig. 3.10), but in the site where cattle were grazing there was a shift to a

[3]This metric is a ratio between the abundance of Ephemeroptera, Plecoptera and Trichoptera (EPT) and the abundance of Chironomidae.

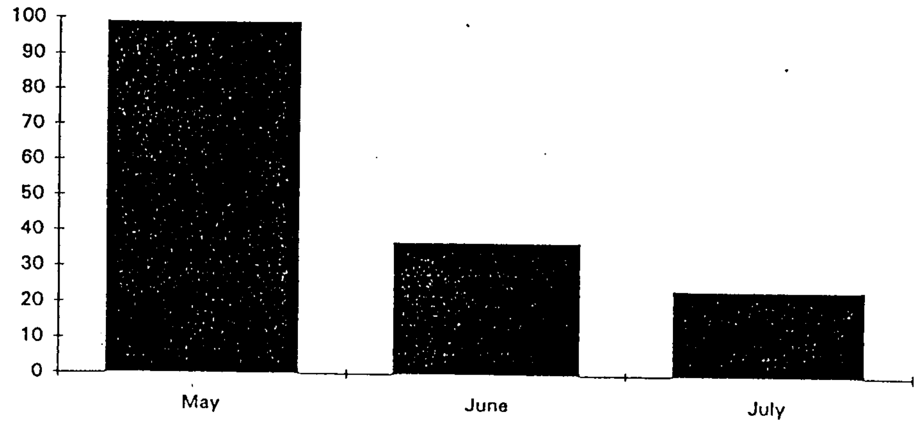

Fig. 3.9 Total number of *Baetis* collected over 3 months in 3 benthic samples each month.

community in which Chironomidae were strongly dominant (Fig. 3.11).

A Hilsenhoff FBI of 5.1 gives some indication that at the site with cattle there was some organic contamination. Some residual organic contamination may have been present at the site without cattle (FBI = 4.9). The index gives 5.0 as the arbitrary cut-off between "good" and "fair" water quality, but ecosystems are rarely that discrete. Another sign of possible organic contamination is given by the EPT/Chironomidae index. In this index the higher the number the more pristine the system is likely to be. Again the

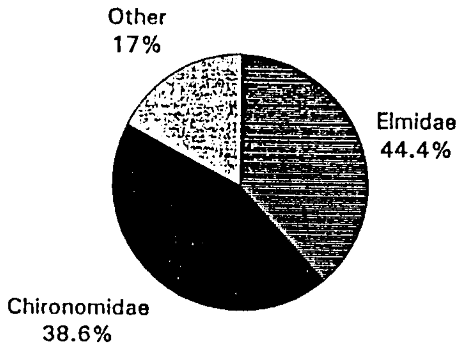

Fig. 3.10 Community dominance at the site with no cattle, July 31, 1994, Badger Creek.

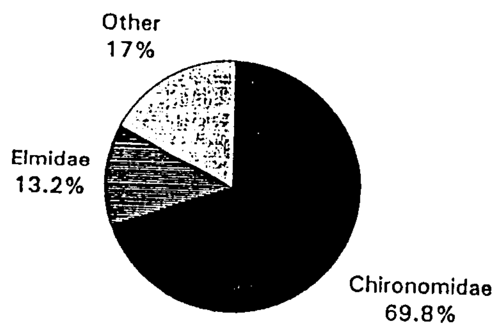

Fig. 3.11 Community dominance at the site with cattle, July 31, 1994, Badger Creek.

difference between the two sites is small (0.195 to 0.238) with the site without cattle having the highest EPT/Chironomidae value.

In Figure 3.12 an NMS ordination of this data is given with the samples from the site with cattle present labeled with a 1 and the samples from the upstream site labeled with a 0. Interestingly the same two taxa discussed earlier in the 3-month NMS (chironomid midges and *Cinygmula* mayflies) define the edges of the axis along which the two sets of samples taken on July 31, 1994 are delineated.

There is a clear separation along axis 2 between the sites with and without cattle present. Figures 3.13 and 3.14 show the correlations for Chironomidae and *Cinygmula*. That these taxa show up on opposing axes-sides on two independent ordinations, created from entirely different sample sets used to examine the same question, is evidence of a robust underlying environmental gradient. Since samples from both sites span the length of axis 1, that gradient shall not be analyzed here.

The shift in community dominance shown earlier by the pie charts also is evident in a comparison of the ordinational correlations of chironomids and elmids which show the two taxa opposing along both axes (Fig. 3.15). This strong differentiation is evidence that the ordination is reflective of the large scale community changes.

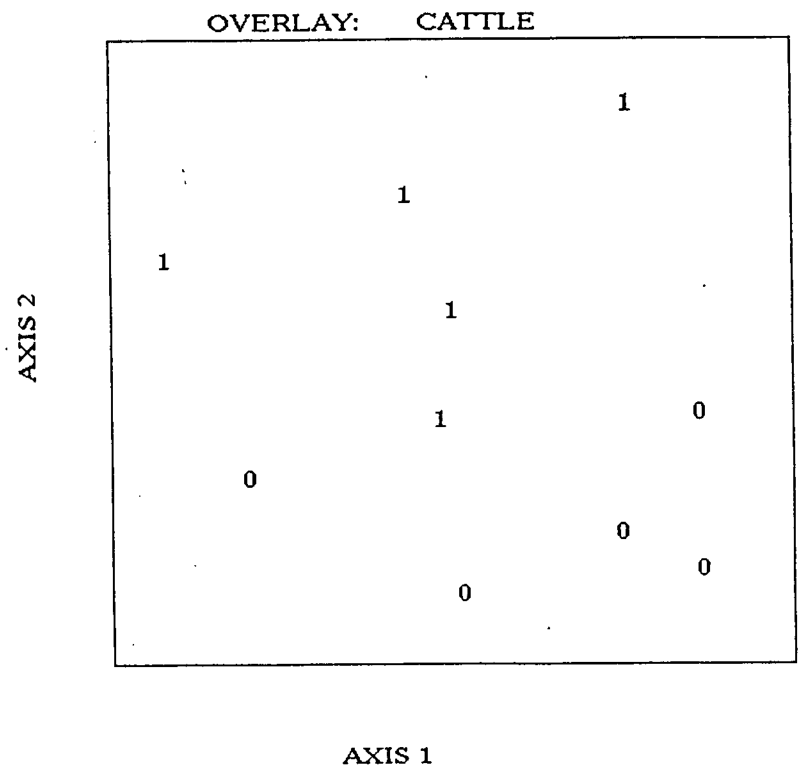

Fig. 3.12 NMS of samples from the site with cattle (1) and the site without cattle (0), July 31, 1994, Badger Creek

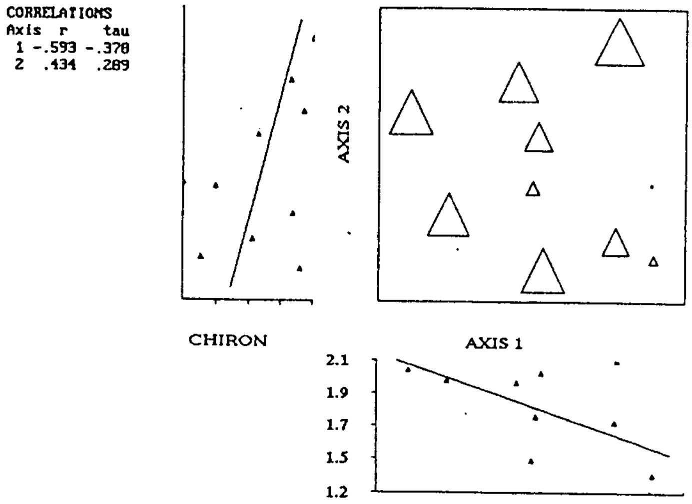

Fig. 3.13 Correlation of Chironomidae in NMS of samples from the site with and the site without cattle.

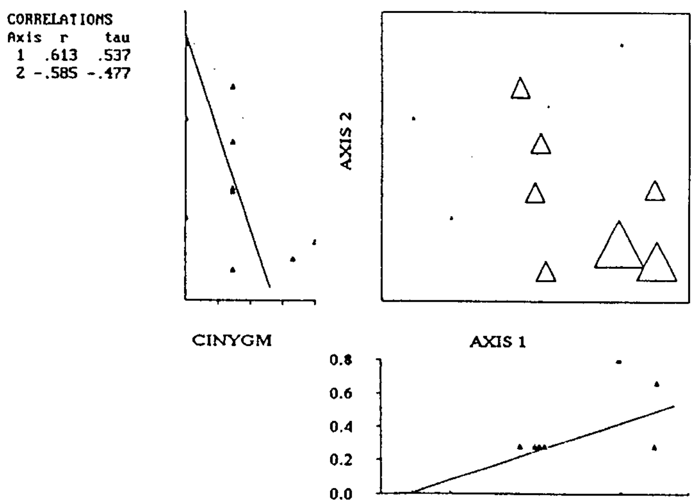

Fig. 3.14 Correlation of *Cinygmula* in the NMS of samples from the site with and the site without cattle.

a)

b)

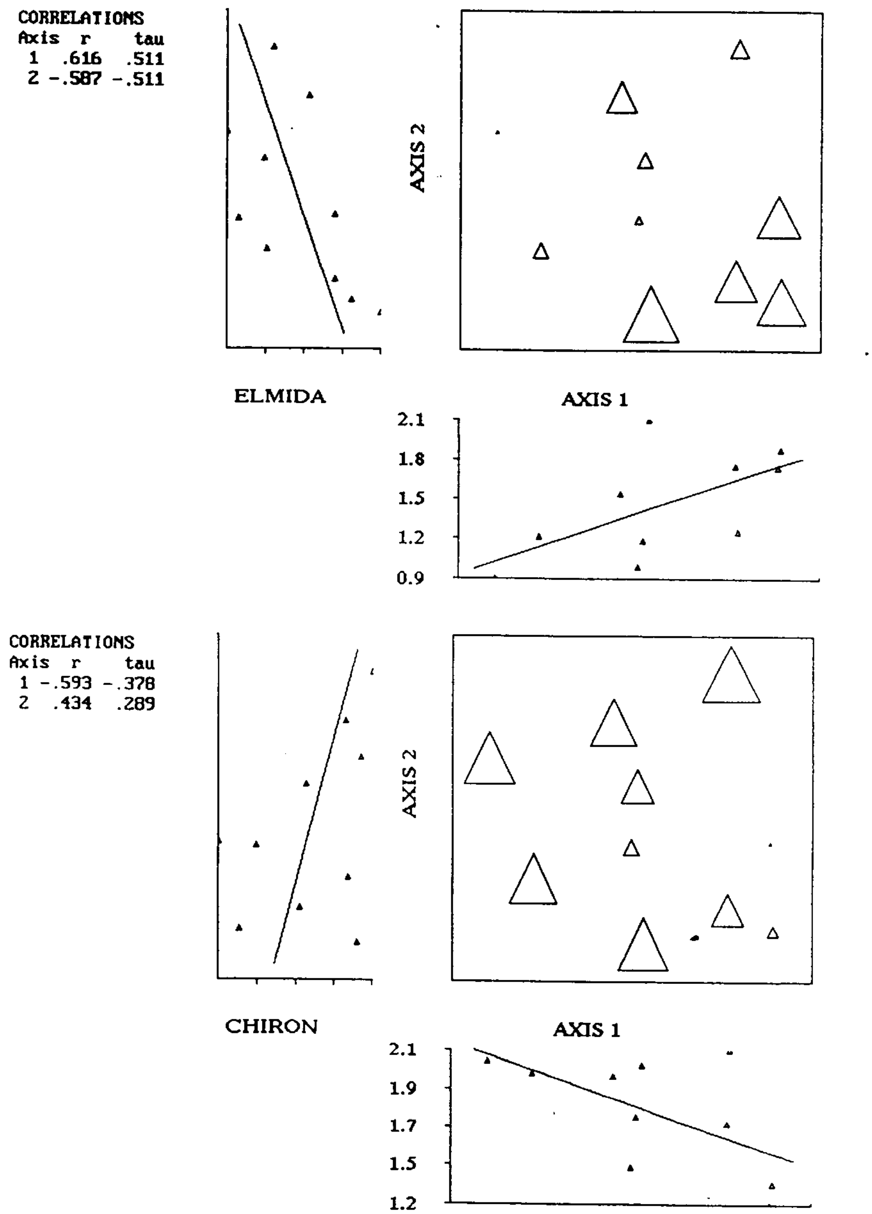

Fig. 3.15 Correlations of chironomids (a) and elmids (b) in the NMS of samples from the site with and the site without cattle.

As a reference the correlation chart for *Zapada* stonefly larvae has also been included (Fig. 3.16). As a taxon which is intolerant of both silt and organic enrichment, these insects would not be expected at sites where cattle were present. This is reflected in the very strong negative correlation of *Zapada* along axis 2 (r = -0.735).

As an aside, one of the criticisms often leveled at ordinational techniques such as NMS is that because they rely on the analyst's prior knowledge of the system and the

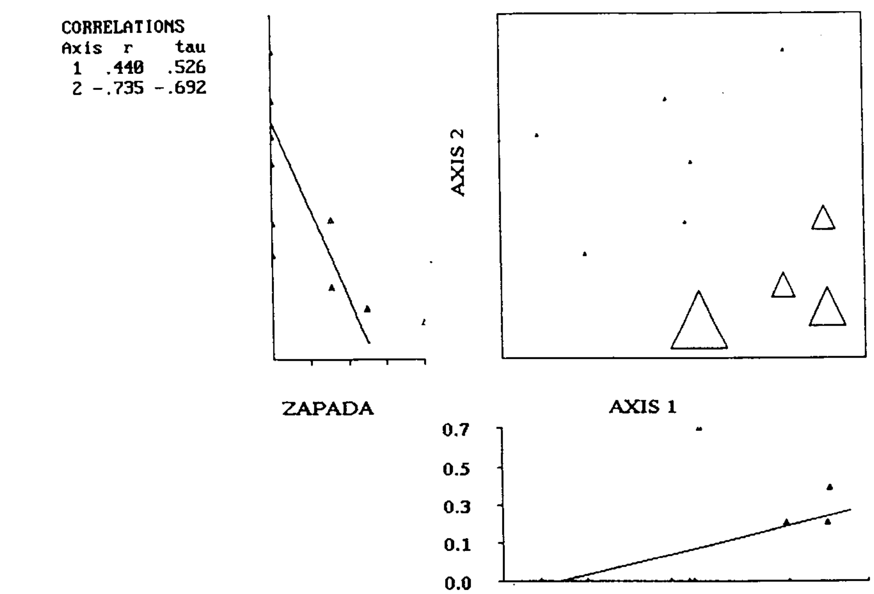

Fig. 3.16 Correlations of *Zapada* in the NMS of samples from the site with and the site without cattle.

organisms within it, that no new information is actually gleaned from their use. However, there was at least one unexpected result from the ordinations included in this chapter, and that was the correlation data for *Argia*. These damselflies are silt tolerant and have a Hilsenhoff FBI value of 9, indicating virtually no sensitivity to organic pollution. *Argia* did not show up in the three-month NMS because it was only recorded from one insect in August and therefore was deleted before the ordination. However, in the July 31 samples, there were 20 larvae in the samples from the site without cattle and none from the site with cattle. Furthermore, those 20 were distributed through 4 of the 5 benthic samples. *Argia*, therefore, displays a very strong negative correlation ($r = -0.8$) along axis 2 of this ordination (Fig. 3.17). This may represent a coincidence since only two sites along the stream were sampled. However, it shows that an ordination can produce an unexpected observation.

Baetis shows a positive correlation along axis 2 of the ordination of July 31 samples (Fig. 3.18). However, as mentioned earlier, this may reflect the continued depression of the number of *Baetis*, the population of which (as reflected in the survey samples) did not rebound until September.

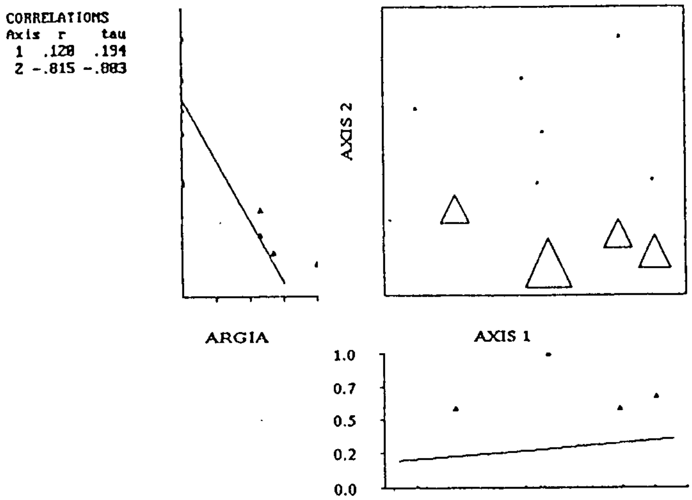

Fig. 3.17 Correlations of *Argia* in the NMS of samples from the site with and the site without cattle.

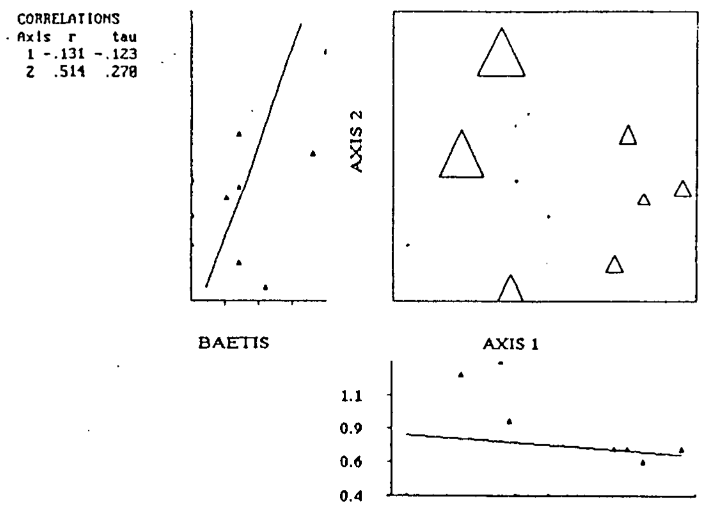

Fig. 3.18 Correlations of *Baetis* in the NMS of samples from the site with and the site without cattle.

Although the data are inconclusive regarding the effects of cattle on the *Baetis* population of Badger Creek, the general shift in community composition reflected in both the 3-month and July 31 ordinations point to the likelihood that the cattle serve as an agent of disturbance in the stream.

The question of how cattle grazing in riparian zones affects macroinvertebrate communities deserves further study. It has been suggested that only through long-term monitoring of sensitive populations will we be able to distinguish natural and anthropogenic stress (Shindler 1987). However, with a large enough sample size, rigorous statistical procedures and the use of such "natural experiments" as stream restoration projects which have excluded cattle from riparian zones for a substantial length of time, it may be possible to decrease the high degree of variance and be able to infer some causality.

One way to assess the possible effects of cattle on aquatic insect assemblages across a range of streams would be to design a study in which available Forest Service and Bureau of Land Management records were used to develop a list of streams on which cattle were grazing and a list of comparable streams from which cattle had been excluded. Several streams could then be randomly selected, as many as funding permitted, from this list of forest areas and sample sites chosen from each at equivalent altitudes and with similar geomorphology. The macroinvertebrate assemblages of these sites could then be sampled by pooling the contents of 3 Surber samplers (for which 0.09 m^2 of upstream substrate was disturbed to a depth of 10 cm). This amount of sampling should be sufficient to insure a comparably accurate estimate of community composition between the streams (Chutter 1972). Both parametric and non-parametric analysis techniques could then be used to assess the differences between the stream assemblages. With a large enough, randomly selected, sample size the high variability of field data would have less effect and general conclusions about the effects of cattle presence in the riparian zones and streams on macroinvertebrate communities could be inferred.

The usual approach taken by management agencies when attempting to protect riparian areas from grazing pressure, while at the same not offending cattle interests, is to limit the amount of time that the cattle are present along any one reach of stream (Elmore and Beschta 1987). To assess this strategy, a follow-up study could be designed in which sites were chosen where disturbance intensity from cattle grazing varied across four treatments: light, intermediate, catastrophic, and no disturbance. These are defined in terms of duration, i.e. grazed for one week or less each year (light disturbance), grazed from three to six weeks a year (intermediate disturbance), constantly grazed (catastrophic disturbance) and exclosure from grazing (no disturbance). Seasonality of disturbance would also be a consideration in site selection. For example, if the cattle were present at the light disturbance sites in early spring then sites where the cattle arrived in spring would also be chosen for the intermediate disturbance treatments. Likewise sampling at all sites would be done over the course of one or two weeks.

Insects are crucial components of stream ecosystem functioning. They are important as food for fish and other wildlife, filter water and are integral to the mechanical breakdown of organic material necessary for nutrient cycling within the stream. In order to protect this valuable biotic resource, more study is needed to define the relationship between macroinvertebrate populations and grazing cattle.

Chapter 4
Conclusion

Stream restoration projects such as that begun at Badger Creek are based on an understanding of the importance of coarse woody debris (CWD) in streams for use as habitat and refugia for fish. While prey selection differs between species, both terrestrial and aquatic components of drift have been reported in fish gut analyses (Hubert and Rhodes 1989, Needham 1929). *Baetis* larvae may constitute a substantial percentage of trout diets (Aho 1976), so retention by wood debris of a large standing crop of *Baetis* is potentially quite beneficial.

Within the controlled setting of the Oak Creek diversion channel, more *Baetis*, other drifting aquatic insects and terrestrial "floaters" were retained by the addition of CWD. This is in keeping with studies which have shown that the filtering effectiveness of a dam is an important factor in macroinvertebrate drift retention (Smock et al 1989). Wood can act as a retention device, keeping aquatic insects from drifting out of the system.

This study found no validation of the hypothesis that active-entry by drifting insects has any significant effect on overall drift density. While the behavioral strategies involved in the active-entry into drift by various species may be important in individual population dynamics (Peckarsky 1980), they do not appear to be functioning on a large enough scale for the drift density to be affected by behavioral changes in the presence or absence of wood.

The *Baetis* mayflies showed no correlation (positive or negative) to wood as opposed to mineral substrate for habitat. A different choice of variables, something to which the mayflies showed a strong reaction, might produce a large enough response from the active-entry drifters to be seen in a population-scale experiment. However, it is also very possible that the difference in scale between the behavior of an individual *Baetis* larva and the population at large may make such measurement unfeasible.

There were a number of factors confounding the field validation of results from the artificial channel. In at least one reach of stream where cattle were present, the macroinvertebrate community composition appeared different from a comparable reach of stream where cattle had not been present for some time. Possible causes of a shift to a system dominated by chironomids include increased organic input. Also bank breakdown can lead to silt loading of the stream. There is a need for more study of the effects of cattle grazing on aquatic communities, especially in areas where salmonid production is of concern to stream managers.

Managing agencies need to consider the entire ecosystem when designing stream restoration projects. Reintroducing wood into impoverished streams is not likely to have the desired positive effect on salmonid populations as long as these same streams are subjected to serious disturbance by cattle.

The presence of uncontrolled cattle in the riparian areas of a stream which is at the same time being "restored" for increased salmonid production indicates a high level of cognitive dissonance within the Forest Service. Whatever conclusions can be drawn from this study regarding the response of drifting *Baetis* (fish food) to increased large woody debris (fish habitat) in streams, is far overshadowed by the likely effects of cattle breaking down stream banks, disturbing habitats and urinating and defecating in the stream. Ecosystem Management means considering not only the physical habitat structures in the stream but also considering the wider floodplain and watershed to insure that the overall habitat quality is maintained.

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APPENDICES

Appendix I
FBI calculations for Birch and Running Creeks, Hopkins County, Texas[1]

Table I.1 FBI calculations for Running Creek, a stream with 21 dairy farms in the watershed.

Family	Quantity	FBI value	FBI sum
Caenidae	696	7	4872
Ephemerellidae	71	1	71
Heptageniidae	195	4	780
Calopterygidae	154	5	770
Coeragrionidae	64	9	576
Gomphidae	597	1	597
Aeshnidae	6	3	18
Macromiidae	15	3	45
Hydropsychidae	13	4	52
Ceratopoginidae	86	6	516
Simuliidae	57	6	342
Tabanidae	35	6	210
Tipulidae	65	3	195
Chironomidae	4865	6	29190
Corydalidae	5	0	0
Grammaridae	442	4	1768
Totals	7366		40002
FBI = 5.44	**Fair**		

[1]Data taken from Rushin (1993).

Table I.2 FBI calculations for Birch Creek, a stream with 9 dairy farms in the watershed.

Family	Quantity	FBI value	FBI sum
Caenidae	2605	7	18235
Ephemerellidae	281	1	281
Heptageniidae	4	4	16
Perlidae	94	1	94
Calopterygidae	200	5	1000
Coenagrionidae	9	9	81
Gomphidae	122	1	122
Aeshnidae	3	3	9
Macromiidae	40	3	120
Hydropsychidae	137	4	548
Ceratopogonidae	129	6	774
Simuliidae	5	6	30
Tabanidae	15	6	90
Tipulidae	577	3	1731
Chironomidae	4223	6	25338
Psephenidae	1	4	4
Corydalidae	6	0	0
Grammaridae	2533	4	10132
Totals	10984		58605
FBI = 5.34	**Fair**		

Appendix II
Lists of taxa collected in a seven month survey of the macroinvertebrates of Badger Creek, Ochoco National Forest

Table II.1 List of taxa collected in March 1994.

TAXA	1	2	3	4	5	6
Argia		3	1	1	1	
Baetis	95	35	73	38	40	263
Cinygmula	94	19	33	29	17	103
Epeorus	7	1	8	2	9	2
Ironodes						1
Drunella	2	5				5
Serratella	3	1	5	1	1	
Paraleptophlebia	6	7	4	7	2	22
Misc. Ephemeroptera	18	22	30	44	42	
Alloperla	1					
Misc Chloroperlidae						15
Zapada			1	5		11
Misc. Nemouridae	2		3		2	
Calineuria		2				
Classenia						2
Yoraperla				1		2
Brachycentrus						3
Micrasema	5		3			37
Glossosoma	1					
Hydropsyche	2		1	3		1
Lepidostoma				2		24
Neophylax	2		2			3
Misc. Limnephilidae		1	17			
Rhyacophila				1	2	13
Elmidae	21	1	1	5	5	20
Ceratopogonidae						2
Chironomidae	239	1	159	138	114	302
Tipulidae	1		3	3		9
Simuliidae	62		36	10	28	169
Diptera Pupae						1
Annelida	1			3		11
Sphaeridae				3		10

Table II.2 List of taxa collected in April 1994.

TAXA	1	2	3	4	5	6
Baetis	27	151	37	43	31	12
Cinygmula	32	62	14	18	26	8
Epeorus		16	5	8	5	
Drunella		1				
Serratella		16	1			1
Paraleptophlebia	1	12	3			1
Misc. Ephemeroptera	72	125	54	45	43	
Capnia			2			
Alloperla		2				
Zapada		2				
Yoraperla			2			
Calineuria		1				
Misc. Plecoptera			1			
Micrasema	2	7	1			1
Hydropsyche	2	1				2
Lepidostoma	1		2			2
Neophylax	2	7	1			1
Misc. Limnephilidae			2			
Rhyacophila			1			
Elmidae	4	80	19		13	1
Staphylinidae	1					
Ceratopogonidae		3	1			
Chironomidae	77	174	156	86	167	117
Tipulidae		4				
Simuliidae	1	23	10	13	6	
Diptera pupae		1				
Hydrachnida		1	1		1	
Annelida	1	4	2	3	18	
Sphaeridae	7	14	19	1	16	13

Table II.3 List of taxa collected in May 1994.

TAXA	1	2	3	4	5
Baetis	36	28	35	14	57
Cinygmula	14	15	9	15	18
Epeorus	2	9	4	2	3
Ironodes			1	2	6
Drunella	1		1		3
Serratella	29	16	27	2	45
Paraleptophlebia		4	2	1	4
Zapada				1	
Yoraperla	1				
Calineuria				1	
Micrasema	6		2		3
Hydropsyche			7		1
Lepidostoma	1	2	2		1
Neophylax		1			
Rhyacophila			3		1
Dytiscidae			1		
Elmidae	47	35	24	3	56
Chironomidae	13	10	9	3	6
Tipulidae	3	2		1	
Simuliidae		1	4		26
Diptera Pupae			1		
Hydrachnida		1		1	
Annelida				1	
Sphaeridae			2		

Table II.4 List of taxa collected in June 1994.

TAXA	1	2	3	4	5	6
Baetis	28	8	1	9		
Cinygmula	9	4	2	3		1
Epeorus	4		2	7	5	1
Drunella	2		2	2	2	
Serratella	42	38	8	20	11	7
Paraleptophlebia	5		1	1	1	
Ephemeroptera				26	6	7
Alloperla	1					
Chloroperlidae					3	
Zapada					1	
Yoraperla	2	1				
Brachycentrus					2	1
Micrasema	26	1		1	2	1
Hydropsyche	1	2		2	3	1
Hydroptila	1					
Lepidostoma	1					
Onocosmoecus		1				
Rhyacophila		1		1	2	
Dytiscidae	1					
Elmidae	94	80	31	17	38	7
Gyrinidae						1
Chironomidae	110	54	45	45	48	34
Tipulidae	2			1		
Simuliidae	3	1		44	42	17
Diptera Pupae	5	4	2	2		1
Hydrachnida					1	1
Annelida	2	1			2	
Sphaeridae	15	3				4

Table II.5 List of taxa collected in July 1994.

TAXA	1	2	3	4	5	6
Argia					1	
Baetis	8	3	13	5	15	30
Cinygmula	5		3	2		3
Epeorus	2				1	
Drunella			3			
Serratella	1	9	4	1		5
Paraleptophlebia	3	13		4	2	3
Ephemeroptera			8		3	17
Chloroperlidae						4
Zapada			1			
Nemouridae					1	
Calineuria					2	
Micrasema			1		1	1
Hydropsyche					1	7
Psycoglypha				1		
Rhyacophila						3
Dytiscidae			1	1		1
Elmidae	26	6	41	8	7	23
Gyrinidae			1			
Chironomidae	4	38	16	35	9	5
Tipulidae	2	1	1			
Simuliidae				2	4	5
Hydrachnida				1		
Annelida		2				
Sphaeridae	1	7	1	4		

Table II.6 List of taxa collected in August 1994.

TAXA	1	2	3	4	5	6
Argia			3			
Coenagrionidae	23	61	46	1	7	2
Baetis	64	77	61	7	27	7
Cinygmula	22	3	1	2	46	2
Drunella	1				1	
Serratella	22	50	39	5	6	9
Paraleptophlebia	20	12	7		11	
Ephemeroptera	13	1	2	2	5	
Zapada				1		
Isoperla					1	
Micrasema	2	4	1	10	18	1
Hydropsyche	1		1	1	1	1
Lepidostoma	2		1		3	
Psychoglypha					1	
Limnephilidae	4			1		
Rhyacophila					1	
Dytiscidae		3	1			
Elmidae	75	61	24	11	55	12
Staphylinidae					2	
Chironomidae	130	256	275	64	74	118
Empididae			1			
Psychodidae				1		
Tabanidae		1	1			
Tipulidae	2	3	2	2	5	
Simuliidae		1				
Diptera Pupae	4	12	9	5	3	10
Hydrachnida	1	3	3			1
Annelida	2	21	1		1	4
Sphaeridae	21	53	59	1	15	29

Table II.7 List of taxa collected in September 1994.

TAXA	1	2	3	4	5	6
Baetis	29	28	120	109	181	81
Cinygmula	15	13	51	29	53	38
Ironodes				1		
Drunella			1			
Serratella	18	9	4	4	11	1
Paraleptophlebia	8	6	10	6	23	6
Ephemeroptera	4	3	12	5	32	8
Zapada			3	1		
Calineuria					1	
Plecoptera			1	1	1	
Sialis			1			
Brachycentrus	1					
Micrasema	3	2	11	9	25	4
Hydropsyche	3		19	8		8
Hydroptila	1				1	
Lepidostoma	6	8	4	6	25	8
Limnephilidae			1			
Rhyacophila	1		3		1	
Dytiscidae		1			1	
Elmidae	10	21	100	18	35	22
Staphylinidae			1			
Ceratopogonidae					1	
Chironomidae	101	72	60	120	69	78
Dixa					1	
Tipulidae	3	5	12	5	6	2
Simuliidae				2	2	1
Diptera Pupae	5	6		5	2	3
Hydrachnida	2	2	2	1	4	6
Annelida	5	4		4	6	2
Sphaeridae	7	17	4	6	104	4

Appendix III
Lists of taxa collected at two sites on Badger Creek, July 31, 1994.

Table III.1 List of taxa collected in 5 benthic samples on July 31, 1994 at a site on Badger Creek where cattle were present.

TAXA	1	2	3	4	5
Baetis	2	17	2	21	2
Cinygmula	2	1			1
Epeorus	2				
Drunella		1			
Serratella	1	1	2	2	
Paraleptophlebia	1			3	3
Ephemeroptera	3				
Yoraperla	1				
Calineuria					1
Micrasema		6		6	2
Hydropsyche		1			
Hydroptila				3	
Neophylax			1	1	
Dytiscidae		3	1	5	7
Elmidae	9	37	7	18	15
Gyrinidae					1
Chironomidae	30	101	124	145	59
Tipulidae		1			
Simuliidae				6	
Diptera Pupae	6	1		3	5
Gerridae				1	
Hydrachnida		1		3	
Annelida	2	2	1		5

Table III.2 List of taxa collected in 5 benthic samples on July 31, 1994 at a site on Badger Creek with no cattle present.

TAXA	1	2	3	4	5
Argia	10	3	3		4
Baetis	5	8	4	5	5
Cinygmula	1		6	1	4
Drunella		1			1
Serratella	1			1	
Paraleptophlebia	3		1	1	2
Zapada	5		1	1	2
Micrasema	1				
Hydropsyche	13				
Hydroptila		1			
Neophylax		1	1		
Dytiscidae		1			
Elmidae	146	105	61	60	84
Chironomidae	118	135	54	18	24
Tabanidae		11			
Tipulidae	1				
Simuliidae			7	6	15
Diptera Pupae	3	5	2	3	2
Corixidae		3			
Annelida	7		2		1